Annual Report- 2009

Stillaguamish River Smolt Trapping Project

Jason Griffith, Rick Van Arman

December 2010

Stillaguamish Tribe of Indians
Natural Resource Department
Arlington, Washington 98223

Table of Contents

Index of Tables & Figures

Acknowledgments

Funding to build the Stillaguamish smolt trap was provided through a Salmon Recovery Funding Board Early Action Grant. Funding to operate the trap during the 2009 season was provided through a combination of Hatchery Reform and Pacific Coastal Salmon grants.

The Tribe also wishes to thank the landowners at our field site: Stanwood Redi-Mix and the Orr family for allowing us to anchor the trap from their property. Mr. Ken Christoferson and all the employees at Stanwood Redi-Mix were especially helpful in providing Ecology blocks, equipment, and access to the concrete plant 24 hours a day, seven days a week.

The 2009 trapping season was the result of much hard work by Stillaguamish Tribe Natural Resources Staff including Kevin Graybill, Kate Konoski, Jody Pope, Claire Atkins-Davis, Robbie Hutton, Jen Sevigny, Jody Brown, Rick Rogers, Charlotte Scofield, Kip Killebrew, and Kevin Gladsjo. Since the project's inception, helpful advice on study design, and modifications to trapping equipment were provided by Marianna Alexsandersdottir of the Northwest Indian Fisheries Commission (NWIFC), Mike MacKay of the Lummi Tribe, and Dave Seiler (retired) of WDFW.

Introduction

Chinook returns to the Stillaguamish today are much reduced from the historic escapements of the mid to late 19th century. It is estimated that before European settlement of the watershed, the Chinook population ranged from 9,700-13,321 returning adults as compared with average of 1080 seen within recent years (includes hatchery fish, 1996-2003, SIRC 2005). In the last few decades, the 12-year moving average for adult returns has been below the 900 wild fish upper management threshold agreed to by Washington Department of Fish and Wildlife, the Tulalip Tribes and the Stillaguamish Tribe (PSIT & WDFW 2010). During years when escapements are predicted to fall below this threshold, directed fisheries are not allowed on Stillaguamish Chinook.

Stillaguamish Chinook populations are part of the greater Puget Sound evolutionary significant unit (ESU) and were listed as threatened by the National Marine Fisheries Service (NMFS) in March 1999 under the Endangered Species Act (ESA). However, even before the listing (and especially since), researchers in the Stillaguamish basin have focused on documenting the status of the Chinook stocks and have attempted to identify the factors contributing to their low abundance. Past and ongoing research/monitoring projects include: redd mapping, adult carcass surveys, adult and juvenile snorkel surveys, estuary mapping, and analysis of the effects of scour and fine sediment on survival to emergence.

A key project in these ongoing research/monitoring efforts has been the operation of a rotary screw smolt trap in the lower mainstem Stillaguamish River by the Stillaguamish Tribe Natural Resource Department. Two thousand and nine marked the completion of the ninth year of a long term monitoring project directed at measuring trends in the year-to-year production of Chinook smolts in the Stillaguamish. This is not the first time a smolt trap has operated on the Stillaguamish; the Washington Department of Fisheries operated an inclined plane trap near Haller Park in Arlington 1981-1983. However, no smolt data was collected between 1983 and the start of this effort in 2001. Measuring and understanding the interannual variation in run size of these various species is critical for managing harvest and prioritizing habitat restoration. Quantifying the number of smolts leaving the watershed is one of the few methods available that provides a direct measure of the year-to-year changes in freshwater survival and growth, free from the confounding influences of marine conditions. Smolt production data from this project can also be combined with adult escapement numbers to develop natural production potential estimates for the watershed, stock/ recruit functions for each species of interest, and to better understand the major density-independent sources of interannual variation in freshwater survival.

The smolt trapping program is also used to evaluate the effectiveness of the Stillaguamish Tribe's hatchery program in meeting its goals. The tribal hatchery has undertaken a wild stock supplementation program since 1980, with the intent of rebuilding the North Fork Chinook population. This broodstocking program captures Chinook from the spawning grounds, spawns and rears the progeny, and releases the sub yearling smolts back into the upper North Fork

Stillaguamish. One of the goals of the Stillaguamish hatchery is to produce juvenile Chinook that are indistinguishable from their wild spawned cousins in both timing and size at migration. Before release, all of the hatchery produced Chinook smolts are Coded Wire Tagged (CWT), and adipose fin-clipped, meaning hatchery and wild spawned Chinook can be differentiated and compared in a variety of ways.

One of the concerns raised by NMFS after the Chinook salmon listing, was the potential long-term genetic impact of the Stillaguamish hatchery program on the wild Chinook populations in the Stillaguamish. Staff at the NMFS questioned whether taking a small percentage of the Chinook escapement and producing two hundred thousand hatchery smolts could affect the survival rates of wild smolts through competition and genetic drift. The data collected by the Stillaguamish Smolt Trapping Project generates yearly estimates of the hatchery contribution to the Chinook smolt out-migration, along with monitoring timing and size at migration. Combining this monitoring with adult escapement estimates (broken into hatchery and wild components), differences in marine survival may become apparent, perhaps indicative of competition in the river, estuary, or nearshore.

Previous genetic analysis has determined that the Stillaguamish watershed supports two genetically distinct stocks: a summer and fall run. The fall population has hovered near 200 fish in recent years (WDFW, Peter Verhey, unpublished data), and the Stillaguamish tribe is in the process of developing an integrated recovery hatchery program similar to the one focused on the summer population, described earlier. As the fall stock spawns later, when survey conditions are often difficult, the tribe is looking for a more reliable way of measuring the health of this stock. Using microstatellite GAPS analysis (Small et al. 2010), we are now able to differentiate the smolts intercepted on the smolt trap each spring.

The primary purpose of the Stillaguamish smolt trapping project is to develop a yearly production estimate for the Chinook salmon populations in the watershed and use this estimate to track egg-migrant survival. Two thousand and nine marked the seventh year where the trap fished seven days a week and, consequently, the seventh season that provided sufficient data to estimate the total annual Chinook smolt production. While the primary purpose of the Stillaguamish smolt trapping project won't change, the newly added (2008) genetic analyses will allow the co-managers to monitor the populations separately.

Study Site

The Stillaguamish Smolt Trap is located in the lower mainstem at approximately river mile 6, just downstream I-5 where the South Slough rejoins the main channel (Figure 1). This is an ideal location for a number of reasons: both sides of the river at the anchor locations are privately owned and limit public access (i.e. vandalism), the river constricts and increases velocity (the cone spins quickly enough at most flows), there is a wide sandbar on the left bank to facilitate easy set up and tear down of the trap, and the location is low enough in the watershed to intercept most of the salmon emigrating from the various tributaries. The channel at this location is approximately 45 meters wide and 6.5 meters (maximum) deep under average flow conditions. As this site is located at a large bend in the river, the thalweg (area of fastest current) flows tight against the right bank. From work on other river systems (D. Seiler, WDFW retired, pers.

comm.) catch per unit effort (CPUE, fish/hour) is maximized when the trap in positioned directly in the thalweg. As the area of fastest current varies with flow, we position the trap accordingly, depending on river stage.

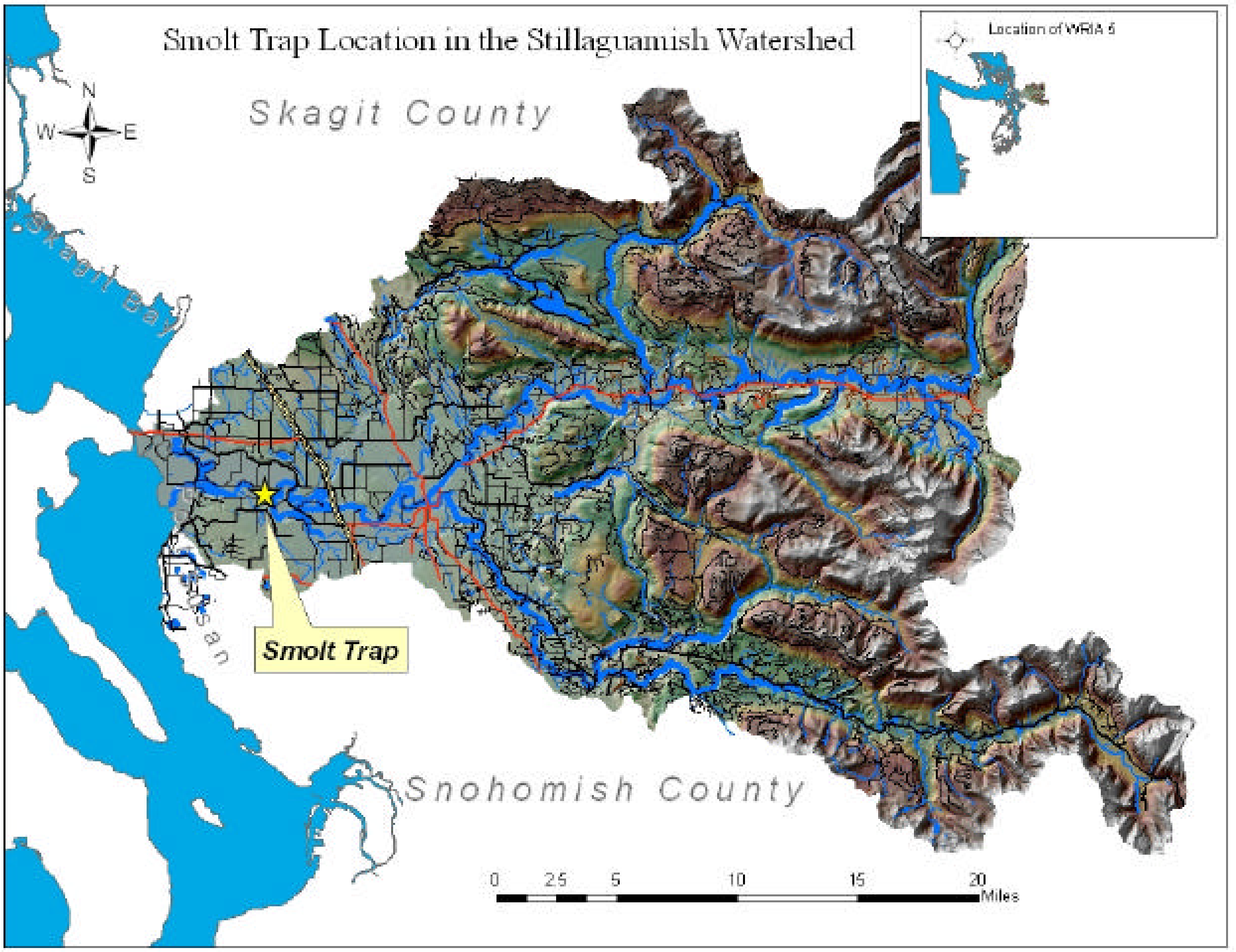

Figure 1. Location of the Stillaguamish Smolt Trap. T. 32N R 6E, Sect. 2

Smolt Trap Description

The Tribe purchased the smolt trap used in this project in 1999 (Figure 2). The cone and live box are manufactured by E.G. Solutions and are largely unmodified from the manufacturer, while the pontoons, walkways, and overhead supports are built from a design used by the Lummi Tribe Natural Resources Program Smolt Trapping project (Conrad and MacKay 2000). We have made minor changes to the design in order to strengthen the trap and add some features for comfort. These include: lights and a table on the stern of the trap, strengthening the winch platform channels with 1 cm steel plates, strengthening welds, along with many other small changes. All told, approximately $8000 has been spent in after-market additions.

Figure 2. Photo of the Stillaguamish smolt trap.

At the sampling location, a 1.6 cm Spectra line (hereafter referred to as the highline) is strung across the width of the channel (~130 m). On the right bank, it is anchored to a large western red cedar approximately 4-5 meters off the ground, and is backed up to two large cottonwoods located further from the river. On the left bank, the highline is attached to four concrete ecology blocks. The trap is positioned in the river using hand winches (spooled with 1 cm Spectra Line) located on either side of the trap. The Spectra line used on the winches and on the highline have an advantage over steel cable in that while having a similar working load per diameter, it is significantly lighter. This reduces the amount of sag in the span over the river and decreases the likelihood of injuring unsuspecting boaters. A small shed/cabin is located on site to serve as a crew base when the trap is fishing, and a skiff (3 m) is used for accessing the trap once it is positioned in the thalweg.

The opening of the cone is 2.43 m (8 ft.) in diameter giving a sampling depth of 1.2 meters when lowered into the water for fishing. The cone and live box are connected together by a steel frame that allows the entire assembly to be winched easily into and out of the water. This steel frame is suspended from overhead supports that span the two pontoons and is raised and lowered using two hand winches mounted on the supports. The cone works like an Archimedes screw, with vanes in the interior of the trap forcing the cone to spin in the current, funneling fish to the live box located aft of the cone. The live box has a trash rack mounted on the stern on the box that removes a portion of the small debris that enters the live box.

Methods

Sampling Design

The sampling design utilized in 2009 was the same one used since the 2003 season; the primary objective is to fish seven days a week through the entire season (February to July). Each day the trap was fished for a six-hour shift (0000-0600, 0600-1200, 1200-1800, 1800-2400), with the shift rotating based on the day of the week. Thursday through Monday, the shifts were varied but the same week to week (i.e., every Friday was 0000-0600, every Saturday 0600-1200, etc.), with Tuesday and Wednesday's shifts rotated to evenly distribute the effort over the four different time slots (this is an artifact of attempting to fish 4 shifts twice during a seven-day week). Traps operated on less turbid systems (Skagit, Snohomish) fish mostly at night, as catches of Chinook during daylight hours are sparse. In the Stillaguamish however, data collected over the last six years indicates Chinook CPUE does not differ significantly between day and night periods (Figures 12 & 13). Outmigration appears mostly influenced by flow and water clarity, variables randomized by nature (Griffith et al. 2001, 2005).

Our season of operation is based on the estimated timing of the Chinook out-migration in the Stillaguamish watershed. During the last nine years, we have installed the trap in the river in mid to late February, began fishing in late February/early March, and ceased fishing in late June/early July. From the number and timing of the Chinook catches, this seems to be an adequate window of operation to intercept a large majority of the Chinook out-migration. In 2009, we started fishing on February 9th and finished for the season on June 14th. Since Chinook emigrate over such a broad time frame, this trapping season is also sufficient to capture the entire coho out-migration along with a significant portion of the chum and pink salmon smolt emigration. There were rare deviations from this sampling schedule, mainly for efficiency trials (more about these in following sections), and sometimes when the river was too high or full of debris to fish safely.

Trap Operation

Each sampling shift is termed a "set" and is the sum of all the time the cone is in the water fishing. Before the start of each set, the smolt trap is positioned in the thalweg of the river using the hand winches mounted to each pontoon. The live box assembly is lowered into the river and when the cone shaft touches the water, the "start time" is noted on our data sheets. Similarly, the "stop time" is noted on the data sheet when the cone shaft leaves the surface of the water. The cone and live box are raised from the water, and the frame is raised in such a way as to lift the cone out of the water while still leaving a small amount of water in the live box. The live box is completely raised from the water after the last of the fish are cleared from the box.

After getting the trap fishing and recording this starting data, typically the crew will leave the trap and check in on it on a regular basis (usually every 1-2 hours) throughout the set. However, when catches are large or debris abundant, the crew might have to stay on the trap for the duration of the set and work continuously. Occasionally a log or stick will stop the cone from rotating and it will have to be raised for cleaning. During these instances, the time lost from fishing is noted on the data sheet.

Environmental Variables

At the start of every set, a visibility measurement is taken off the bow of the trap using a secchi disc attached to a long steel pole. This involves lowering the 21cm black and white disc into the water until it is no longer visible, and recording the depth. During the hours of darkness, the measurement is taken with the aid of a powerful flashlight. In addition, a water sample is collected to measure the turbidity of the waters passing through the trap. Further data collected at the start of the set included: the rotational speed of the cone (how many seconds per rotation), water color, water temperature, type and amount of river and live box debris, and weather conditions (cloud cover, wind speed and direction, and any precipitation). At the end of the set, another secchi measurement is taken along with weather observations and a turbidity sample.

Catch Processing

Fish are dip netted out of the live box, and transferred to a small anesthetizing tank set into the table on the stern of the trap. Instead of the common anesthetizing agent, tricane methanesulfonate (MS-222), we use clove oil to sedate the fish. Clove oil has several advantages over MS-222 including much lower cost (1/40th the cost per dose) and no toxicity for humans. From research on coho and Chinook salmon, the optimal dosage is 25 mg/l, resulting in fast knockout and recovery times and no mortalities (Taylor and Roberts 1999).

Once the fish are anesthetized, they are identified to species, individually counted, and a sub sample measured. The first twenty of all salmonid species (other than Chinook) are measured (for length, nearest mm), and the rest enumerated. Every fifth Chinook is measured, wanded with a coded wire tag detector (since the tribal hatchery reared Chinook are not adipose fin-clipped, this is the only way of detecting them), and a small tissues sample is taken from the caudal fin of wild smolts for later genetic analysis.

Processed fish are allowed to fully recover in a tank of clean river water for 5-10 minutes before they are released back into the river to resume their seaward journey.

Estimation of Smolt Trap Capture Efficiency

Capture efficiency is defined at the instantaneous percentage of smolts passing the trap that are captured by the gear. The capture efficiency of the smolt trap is the most important variable to quantify because it is needed to expand the catches at the smolt trap and estimate of Chinook outmigration for the entire river on a given day. It is also important to be able to relate capture efficiency to some environmental parameter in order to create a relationship that predicts efficiency over the broad range of conditions experienced over the course of the trapping season. Other trapping operations around the state have shown that capture efficiency can be affected by: water velocity, time of day (daylight or nighttime), species and life stage, river stage, origin of fish (hatchery or wild), trap placement within the channel, and water clarity (Conrad and MacKay

2000, Seiler et al. 2001). For a turbid river system (the Nooksack), the Lummi trapping operation has found Secchi depth to be the best predictor of trap efficiency (Conrad and MacKay 2000).

Capture efficiency experiments were performed by releasing a known number of marked, hatchery reared Chinook smolts upstream of the trap and then enumerating the number of marked fish recaptured on the trap. In 2009, the two groups were released about 2.5 kilometers upstream of the smolt trap, one group into each fork of the Stillaguamish below the I-5 bridge (Figure 3). Both release groups were marked with Bismark Brown dye and ad-clipped.. These are the same release locations used since 2002; releases above where the river forks (2001) did not produce efficiencies in line with what has been reported from others using similar gear in neighboring rivers (Seiler et. al. 2002, Nelson et. al 2003). It is not known what percentage of juvenile salmonids travel down each of the channels immediately above the smolt trap, however previous calibration experiments (where the fish released into each fork were marked differently) did not find significantly different recapture rates (Figure 4).

All fish used in our capture efficiency trials were from the Stillaguamish Tribal hatchery. Catches of wild Chinook were not high enough to create an adequate sample size for paired releases (less than 1600 wild Chinook were captured during the entire season). The hatchery fish used in the efficiency trials were clipped a few weeks prior to the first release and portioned into raceways by their mark. Just before release, two groups of approximately (the exact numbers varied from trial to trial, see Table 1.) 3000-4000 fish were loaded into both tanks of a large hatchery truck. Bismark brown dye was added to the tanks at the manufactures recommendation of one gram for every 57 liters of water and was kept oxygenated using bottled O_2 and an air stone. From the time the fish were loaded into the tote to release was usually one hour. In our experience, this was a sufficient amount of time for the stain to take effect and dye the Chinook an obvious gold color.

The fish were driven to the two bridges indicated in Figure 3 and given a quick release. A 10cm hose was attached to the drain of the tank and all dyed fish were spread across the thalweg in the span of about a minute. The fish reached terminal velocity quickly, splashed into the river and swam away immediately, appearing unharmed. This release procedure was repeated soon after at the other fork of the river so both groups were always released within one half hour of each other.

During the release process the smolt trap was either in operation, or in the process of being deployed. The release site was far enough upstream so that fish never reached the trap until it had been fishing for close to one hour. During the efficiency trials, secchi measurements were taken every 2-3 hours and a water sample was taken for turbidity every 6 hours. The trap was fished continuously for at least 24 hours after marked fish were released, and usually until three hours elapsed without catching any marked fish.

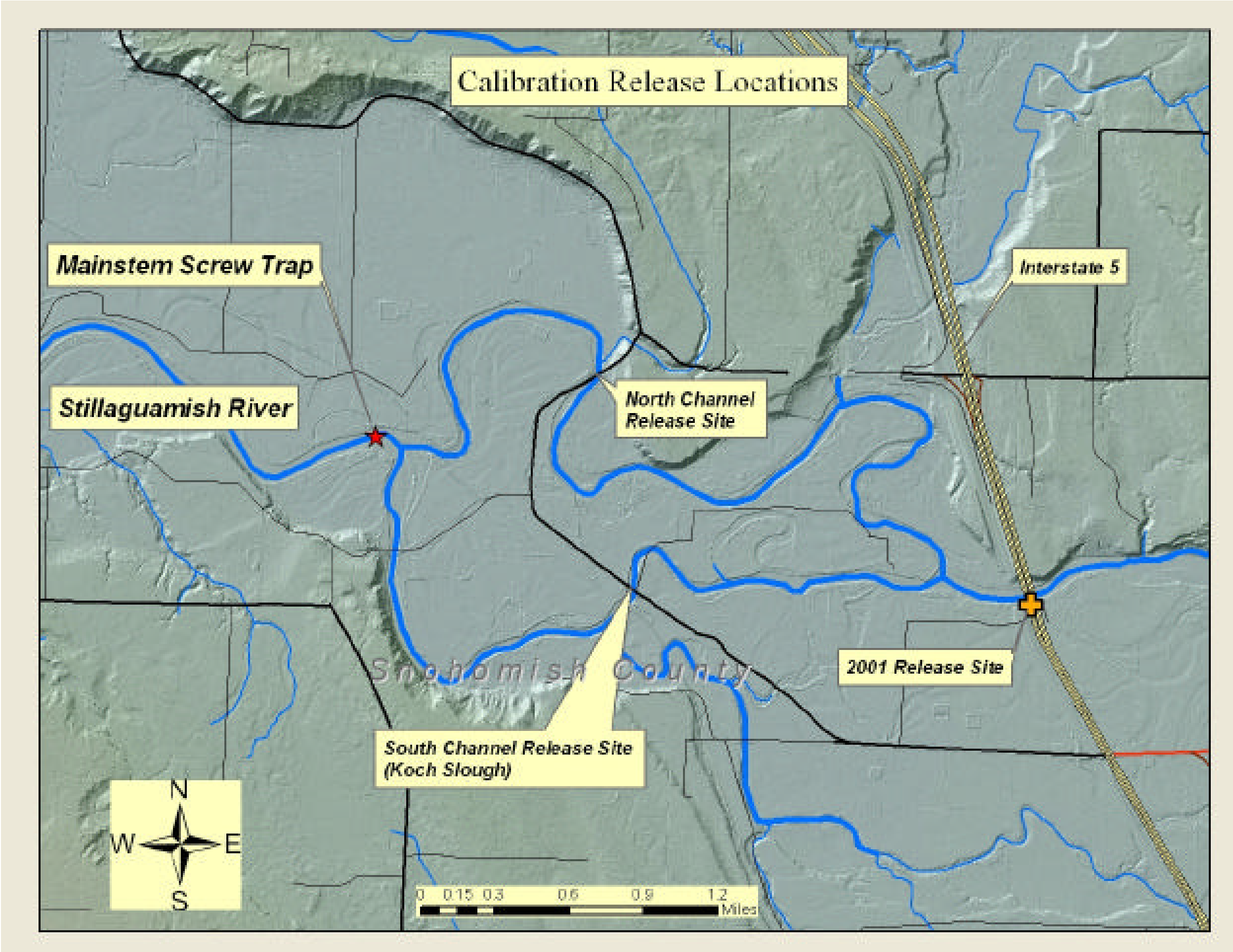

Figure 3. Map of the lower mainstem Stillaguamish, with locations of calibration releases.

Estimation of Chinook Smolt Outmigration.

There are several steps in the estimation of the annual Chinook smolt outmigration from the Stillaguamish:

1. Run trap efficiency trials and estimate percent efficiency for each trial.
2. Estimate relationship between environmental variables and percent efficiency using data for all years from 2002 onward.
3. Sample 6-hour period each day, chosen in a systematic random manner.
4. Estimate catch per hour fished for natural origin and hatchery origin smolts from sampling data.
5. If a day's sampling is missing, estimate the day's CPUE from surrounding fishing dates.
6. Use trap efficiency relationship to expand to total out migration per hour for the period.
7. Expand 6-hour period to total day
8. Sum up days out migration for total production migrating past the trap site.

The Efficiency Trials.

Smolts are marked and released above the trap in two channels, the north and the south (the channels rejoin a couple of hundred meters above the smolt trap). Trap efficiency is estimated as the number recaptured in the trap over the number released above the trap. At the same time, several environmental variables are measured and are available for analysis: secchi disk reading, turbidity and flow.

Four releases were made in 2009, adding to the 27 trials run between 2002 and 2008. During 2009, estimates of efficiency ranged from 0.13%-1.4% (Figure 4). While there were individual trials (in 2004, 2006, 2008) where recapture rates have been significantly different between the forks, there has not been a consistent significant difference (a=0.05, p>0.05) in recapture rates or timing between the forks when looking at an entire season or combining seasons (Figure 4). Therefore, differential marks were not used in 2009 , and the efficiency data has been pooled for both forks in generating a regression relating capture efficiency to an environmental variable. For further discussion of our methods of testing differences in timing and rate of recovery for efficiency groups please see the 2004 Stillaguamish River Smolt Trapping Project Report (Griffith et al. 2005).

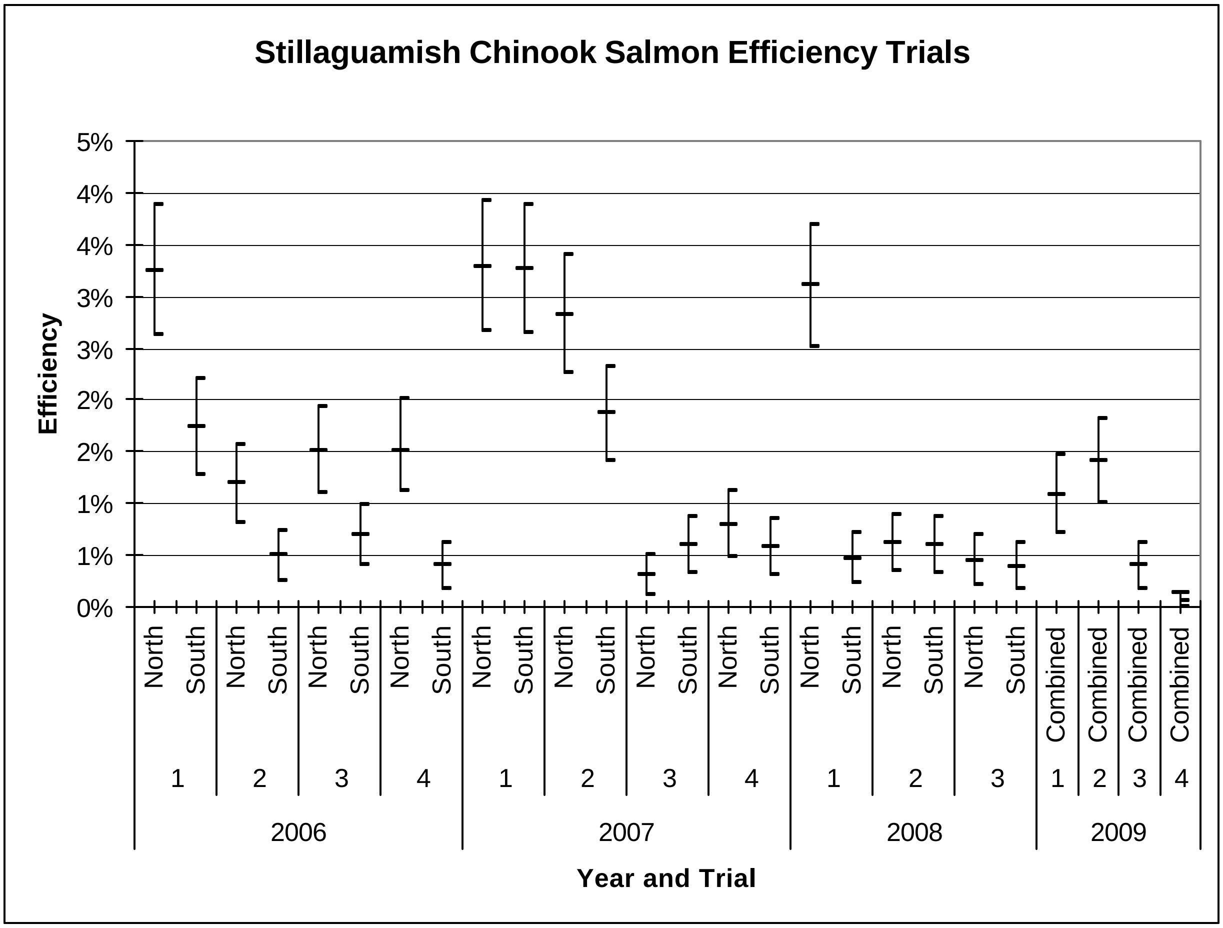

Figure 4. Estimates of trap efficiency as a percentage of release (recovered/released * 100) by trial, year, and channel of release for Stillaguamish Chinook salmon. Error bars represent 95% confidence intervals surrounding the estimate.

There are several choices for using the efficiency estimates for expanding catch per hour at the trap to total out migration per hour past the trap for any single day. These would include, estimating a mean efficiency over all trials, or estimating a relationship between the efficiencies and environmental variables that can be measured on a daily basis. The average secchi disk reading has been the best predictor of trapping efficiency for all of the years the Stillaguamish Trap has operated (Figure 5); an exponential function provides an estimate of the relationship:

$$E_i = ae^{b \cdot SDR_i} \quad \text{Equation 1}$$

where $\boldsymbol{E_i}$ is the efficiency for period i and $\boldsymbol{SDR_i}$ is the average secchi disk reading for period i.

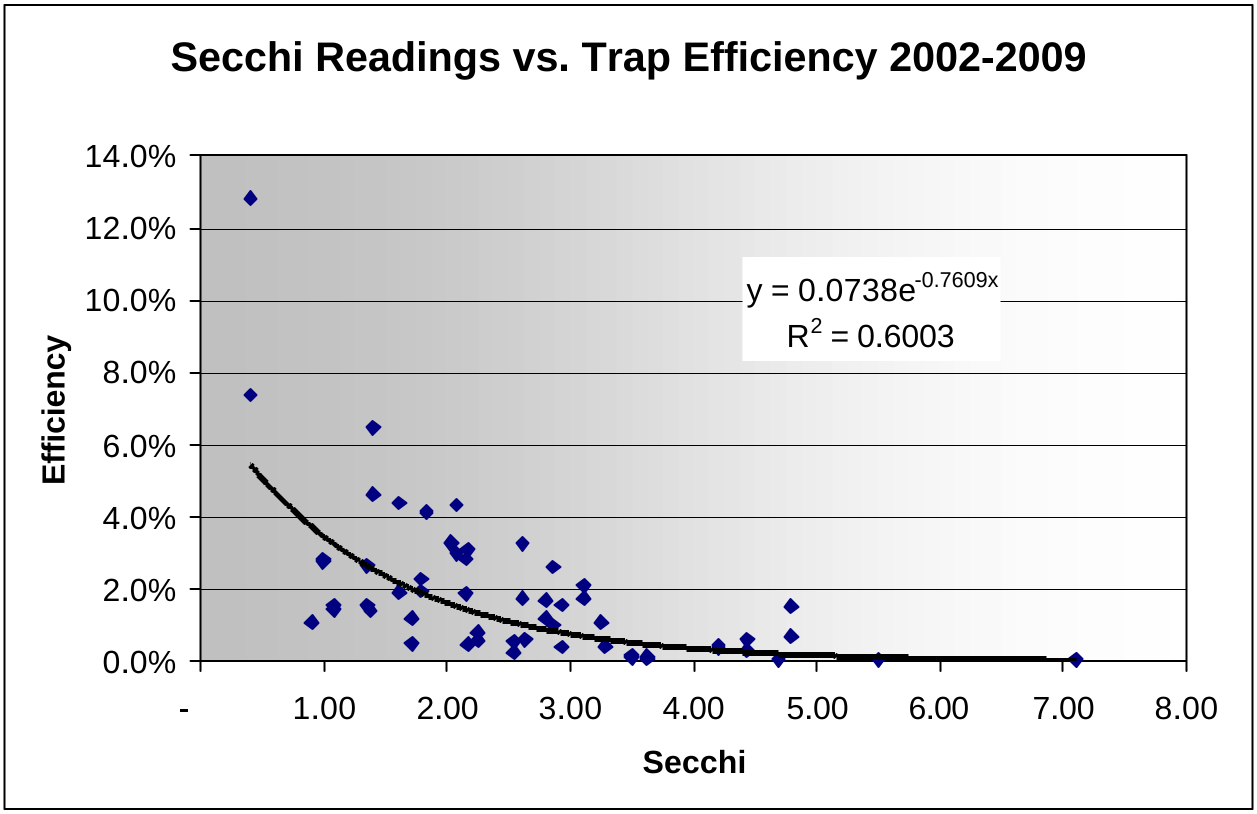

Figure 5. Regression relating capture efficiency of the Stillaguamish Smolt Trap to secchi depth measurements taken off the trap itself. Data depicted were collected in the 2002-2009 trapping seasons.

There is quite a bit of variability surrounding the relationship in Figure 5, and the production estimates derived using it, in some years, do not appear to be realistic. For example, if the estimated hatchery production greatly exceeds the known number that were released upstream of the trap, it is certain that the trap was more efficient at capturing smolts than the secchi-efficiency relationship indicates (Figure 5). During these anomalous years, the number of hatchery fish counted out of the release site is multiplied by the average survival to the smolt trapping location (67% as averaged from 2003, 2004, & 2006 hatchery production estimates, similar to the 1% mortality rate per river mile observed on the Skagit- D. Seiler pers. comm.). This corrected production number is divided into the raw hatchery production produced by equations 2-10 below. That factor is then added into the a constant detailed above (Equation 1) to "correct" the efficiency equation to bring it in line with what could be considered a reasonable estimate, based on a given visibility (secchi). In 2009, this technique was used, as the "raw" hatchery production estimate was more than three times the number that was released upstream.

Estimation of out migrations of smolts.

The trap samples a single period each day and the total catch per hour by type (natural or hatchery origin) for each period is c_i. The migration per hour for period i is estimated as;

$$\hat{n}_i = \frac{c_i}{\hat{E}_i} \qquad \text{Equation 2}$$

and the variance is;

$$Var(\hat{n}_i) = \hat{n}_i^2 \frac{Var(\hat{E}_i)}{\hat{E}_i^2} \qquad \text{Equation 3}$$

The out migration per hour averaged over multiple sample periods within a day is;

$$\bar{n}_d = \frac{\sum_{j=1}^{p} \hat{n}_j}{p} \qquad \text{Equation 4}$$

and the variance among the periods is,

$$Var(\bar{n}_d) = \frac{\sum_{j=1}^{p} (\hat{n}_j - \bar{n}_d)^2}{(p-1)} \qquad \text{Equation 5}$$

where p is the number of periods in a 24 hour day. As the migration for each period is an estimate, a variance within periods must also be accounted for, by:

$$V(\hat{\bar{n}}_d) = (1 - \frac{p}{P})\frac{Var(\bar{n}_d)}{p} + \frac{\sum_{j=1}^{p} Var(\hat{n}_j)}{p} \qquad \text{Equation 6}$$

A total out migration (N_d) is estimated for the 24-hour day by expanding the mean out migration per hour by 24,

$$\hat{N}_d = H \hat{\bar{n}}_d \qquad \text{Equation 7}$$

and the variance by,

$$V(\hat{N}_d) = H^2 Var(\bar{n}_d) \qquad \text{Equation 8}$$

The variance equation in equation 6 has two variance components, variance among periods ($Var(\bar{n}_d)$) and variance within periods, ($Var(\hat{n}_i)$). The single sample period per day does provide an estimate of the variance within period, but does not allow an estimate of the variance among periods. Although the regular sampling schedule was to sample a single period, full 24-

hour days were sampled when trap efficiency tests were being carried out. These data can be used to estimate a coefficient of variation among periods, which can then be used to estimate the first variance component in equation 6. The coefficient of variation is,

$$CV(\bar{n}_d) = \frac{\sqrt{Var(\bar{n}_d)}}{\bar{n}_d} \qquad \text{Equation 9}$$

and so the variance of the average out migration per hour for day d can be estimated by,

$$Var(\bar{n}_d) = CV^2(\bar{n}_d)\ \bar{n}_d^2 \qquad \text{Equation 10}$$

In order to get a daily migration estimate for those days not fished, we needed to estimate what CPUE (numbers of Chinook per hour) would have been had the trap actually collected data (Equation 2). It was also necessary to estimate what the secchi measurement would have been if the trap would have been fishing (Equation 1). In such instances of non-fishable flows, the only environmental data available are flow measurements from the USGS gauge site on the North Fork Stillaguamish. Plotting CPUE values (two weeks surrounding a missed day) as a function of flow produced a regression that could be used to interpolate CPUE for those days not fished (Figures 6 & 7). The relationships are quite weak (especially for wild fish), underscoring the difficulty of estimating migration on days without sampling effort.

Similarly, a regression relating flow to Secchi measurements (Figure 8) was used to estimate what the secchi measurement would have been, had the trap actually been fishing. The interpolated values for both efficiency and CPUE were subsequently used in Equation 2 to estimate daily migration for Chinook.

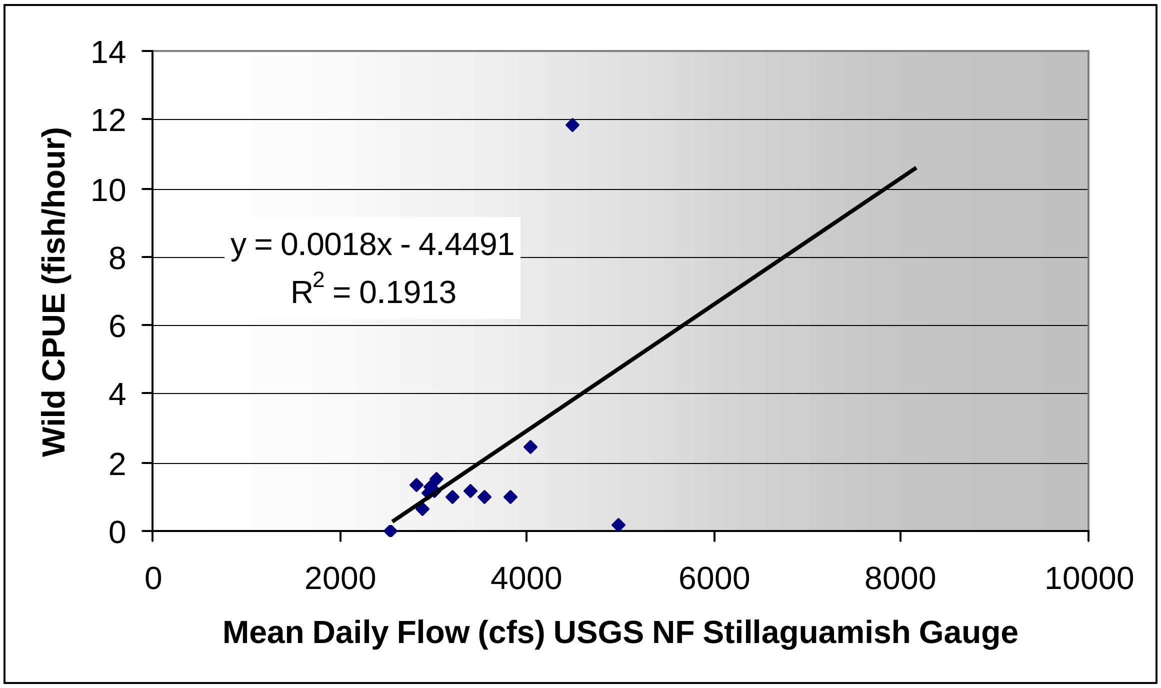

Figure 6. Regression relating CPUE to flow surrounding the April missed fishing day.

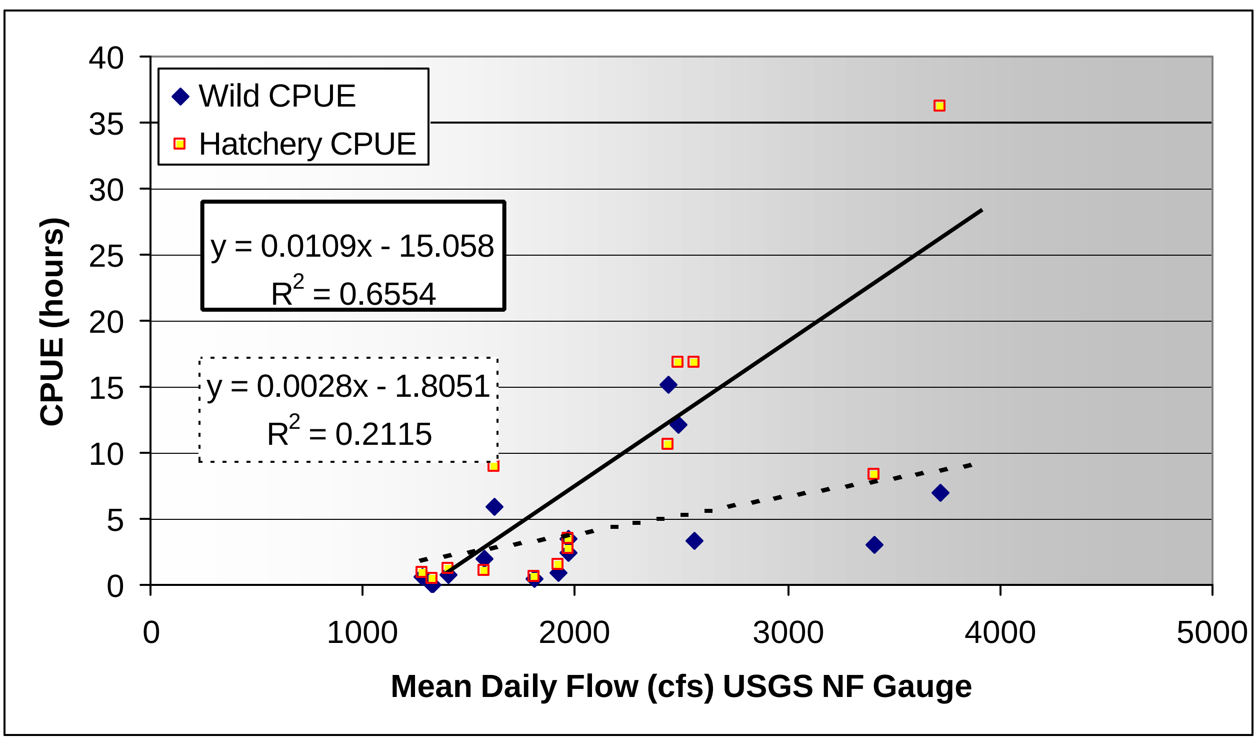

Figure 7. Regression relating CPUE to flow surrounding the May missed fishing day. Solid line is regression for hatchery fish, dashed is for wild Chinook.

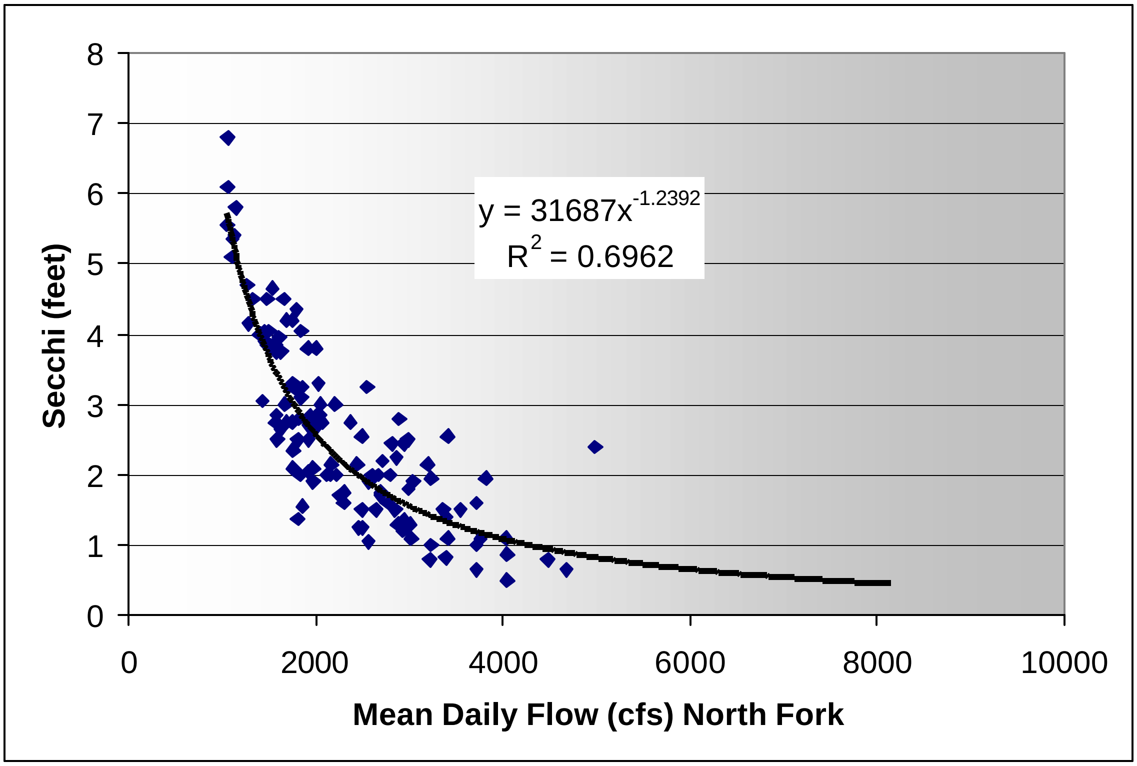

Figure 8. Regression relating Secchi measurements at the trap to flow measurements at the USGS North Fork Gauge during the 2009 fishing season.

Egg to Migrant Survival

Once total Chinook production is estimated for a particular brood year, it is straightforward to estimate survival from egg deposition to smolt outmigration. Following from Seiler et al. (2002):

Egg-to-migrant survival for brood year i, S_i is estimated by:

$$S_i = \frac{M_{i+1}}{R_{si} F_i} \qquad \text{Equation 11}$$

Where: M_{i+1} = *estimated age 0+ Chinook migration in year i+1*

R_{si} = Numbers of Females estimated to have spawned in year i.

F_i = estimated Chinook fecundity in year i.

R_{si} is estimated from the yearly WDFW Chinook redd counts on the Stillaguamish (assuming one female/redd). F_i is estimated using fecundity data from the Stillaguamish Tribe's Chinook broodstocking program.

Genetic Analysis

Tissue samples collected from smolts were classified into either summer or fall Stillaguamish populations by genotyping samples at the 13 GAPS microsatellite loci and one additional locus, Ssa197 (Small et al. 2010). The genetic processing was performed by the WDFW's genetics lab in Olympia, while genetic data analysis was performed by Adrian Spidle of the NW Indian Fisheries Commission, and Maureen Small at WDFW. For more details, a report summarizing the genetics sampling and analysis is available (Small et al. 2010).

Results

Smolt trap effort and trapping season

In 2009, the Stillaguamish Smolt Trap fished on 126 days for a total of 799 hours. The trap was fished on a systematic random sampling design, seven days a week, from February 9th to June 14th. Most sets were six hours, except during the four efficiency trials. During efficiency trials, the trap was fished varying amounts depending on the number of recaptures of marked fish (times ranged from 23-28 hours). Two thousand and nine was fairly benign year, flow wise, with only two days lost to high flows. During flood events, the speed of the river and the volume of debris (logs, sticks, car tires, etc.) make trap operation unsafe for both crew and fish. There were no days lost to mechanical or staffing problems.

Wild Chinook Catches

Over the entire season, 1524 wild smolts were captured and released (Figure 9), including 21 mortalities (1.4%). Most wild Chinook captured were in the 40-70 mm range, most likely 0+ smolts. Most years, a few large (>90 mm, presumable 1+ smolts) Chinook are captured early in the year, however only 4 fish fitting this life history profile were captured during the 2009 sampling season. The trap is capable of catching fish in this size range, however; more than 5500 coho (averaging >90 mm) were captured during the season, in addition to over 1200 larger (>150mm) steelhead and cutthroat trout. Wild Chinook were captured a few weeks after the trap started fishing (2/9), with a 50% migration date of May 10 for wild Chinook (Figures 9 & 11). Catch per unit effort (CPUE, hours) for wild Chinook exhibited a weak bi-modal distribution with the peaks in April and May-early June. The mean daily discharge at the USGS North Fork gauge has been added on a second axis (log scale), illustrating that most peaks in CPUE are related to spikes in the hydrograph (Figure 9).

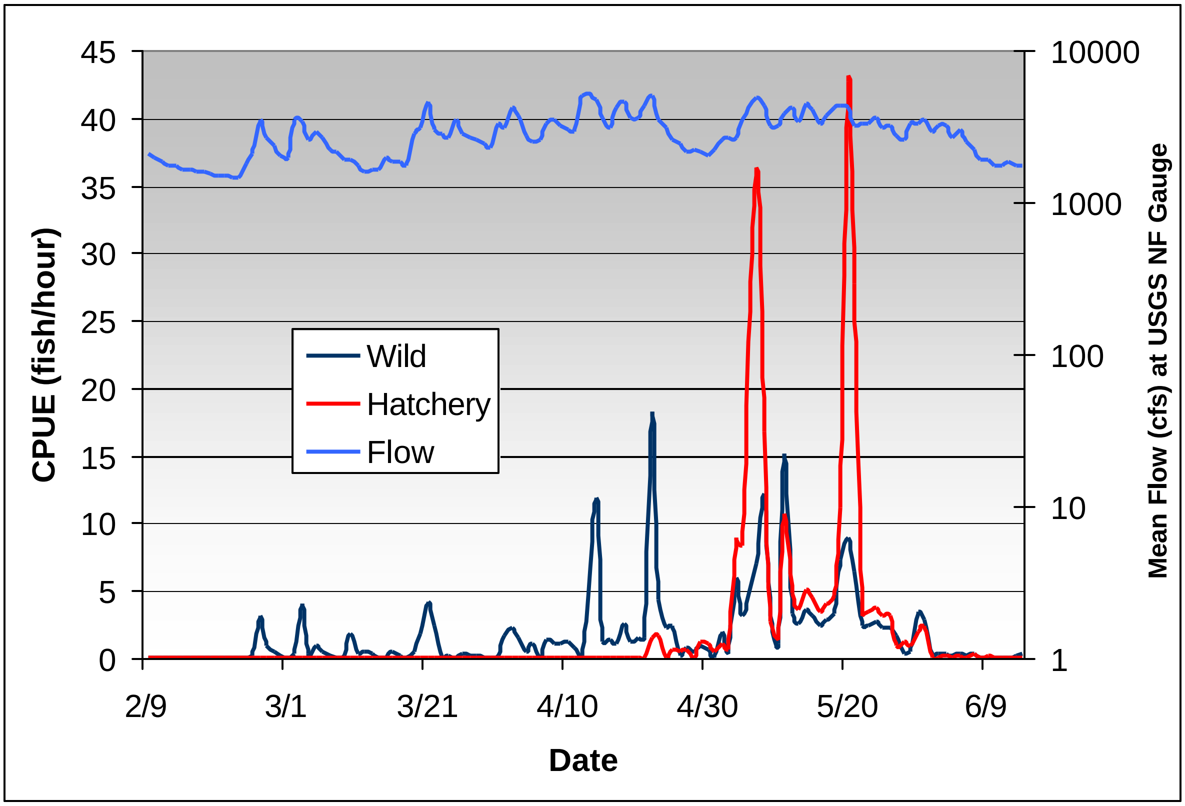

Figure 9. Wild and Hatchery Chinook CPUE over the 2009 trapping season along with mean daily discharge (cfs).

Hatchery & Wild Chinook- Migration Timing and Size

During the 2009 season, 2027 (including 4 mortalities- 0.2%) hatchery Chinook were captured and released from the trap. All of the hatchery Chinook are doubly marked with coded wire tags (CWTs) and adipose clips, allowing hatchery fish to be differentiated from wild spawned smolts. Hatchery fish were significantly ($p<.01$) larger during all weeks sampled (usually ~15-20 mm) as compared with wild Chinook (Figure 10). While exhibiting similar timing of migration in relation to rain events (Figure 9), hatchery fish migrated predominately during the latter half of the wild outmigration.

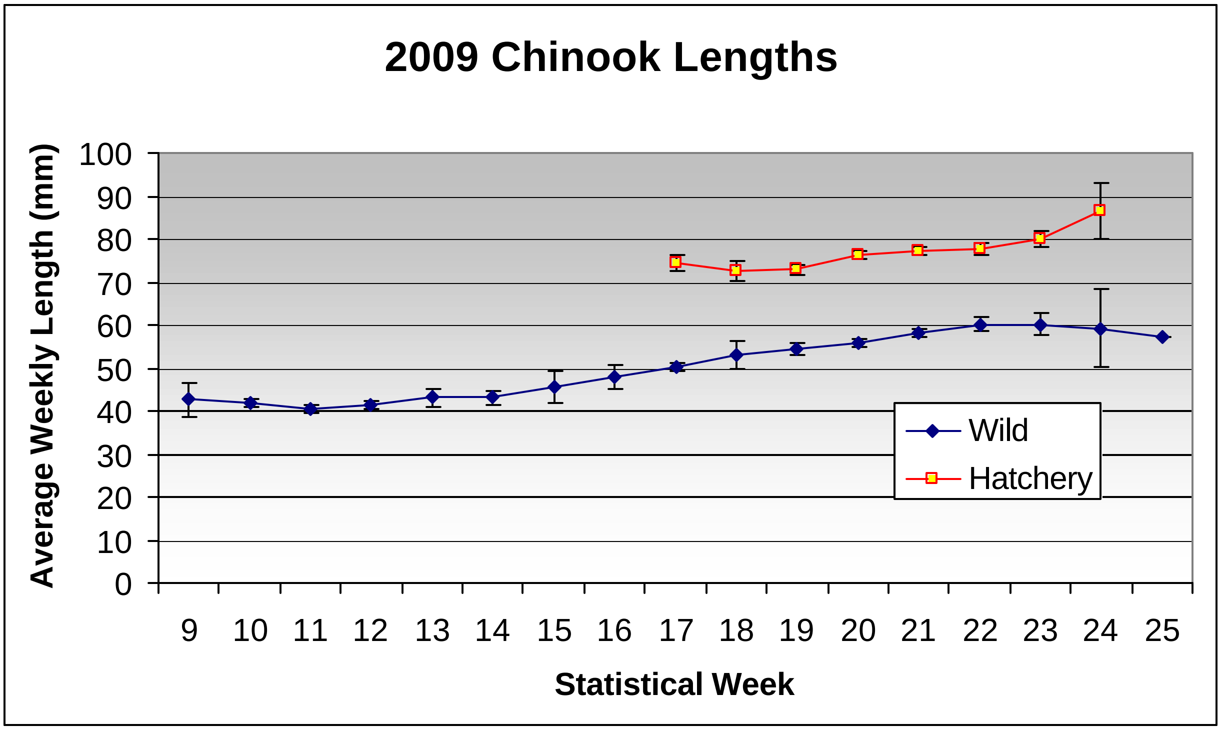

Figure 10. Weekly mean size (mm) of hatchery and wild fish. Error bars depict the 95% confidence interval surrounding the mean; some are small and difficult to see.

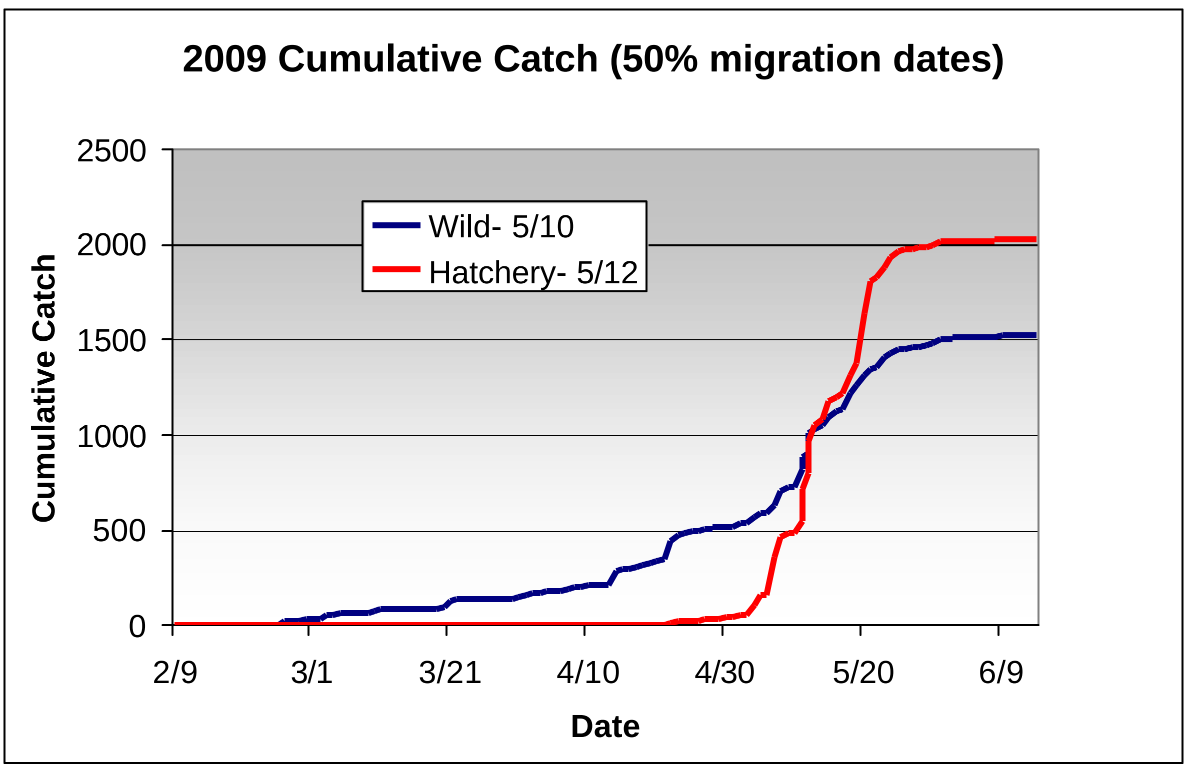

Figure 11. Hatchery and wild cumulative catches of Chinook salmon on the smolt trap 2009. 50% migration dates were 5/12 for hatchery and 5/10 for wild Chinook smolts.

Outmigration Estimates for NOR and HOR smolts

Utilizing the equations detailed in the Methods section, and a hatchery release derived correction factor, a total of 92,871 natural origin smolts and 108,645 hatchery origin smolts were estimated to have passed the trap location over the sampling period. The outmigration is summarized below in Table 1. May was the peak month of outmigration for wild and hatchery Chinook smolts (Table 1, Figure 12). Combining the wild smolt production estimate with adult escapement estimates and fecundity for the 2008 brood (Equation 11) yields an egg-migrant survival estimate of 3.2%.

Table 1. Estimated average daily out migration of smolts from Stillaguamish for 2009 and total out migration for the season. Pooled Standard Error: PSE = $\frac{\sqrt{Variance}}{Estimate}100$

Average Out Migration Per Day-2009				
	Natural Origin		Hatchery Origin	
Month	**Estimate**	**PSE**	**Estimate**	**PSE**
February	52	22%	0	0%
March	222	59%	0	0%
April	748	82%	174	16%
May	1635	71%	2146	76%
June	645	52%	147	24%
Total Out Migration for 2009				
Total	**92,871**	57%	**108,645**	39%
Lower 95% CI	72,224		72,814	
Upper 95% CI	113,517		144,476	

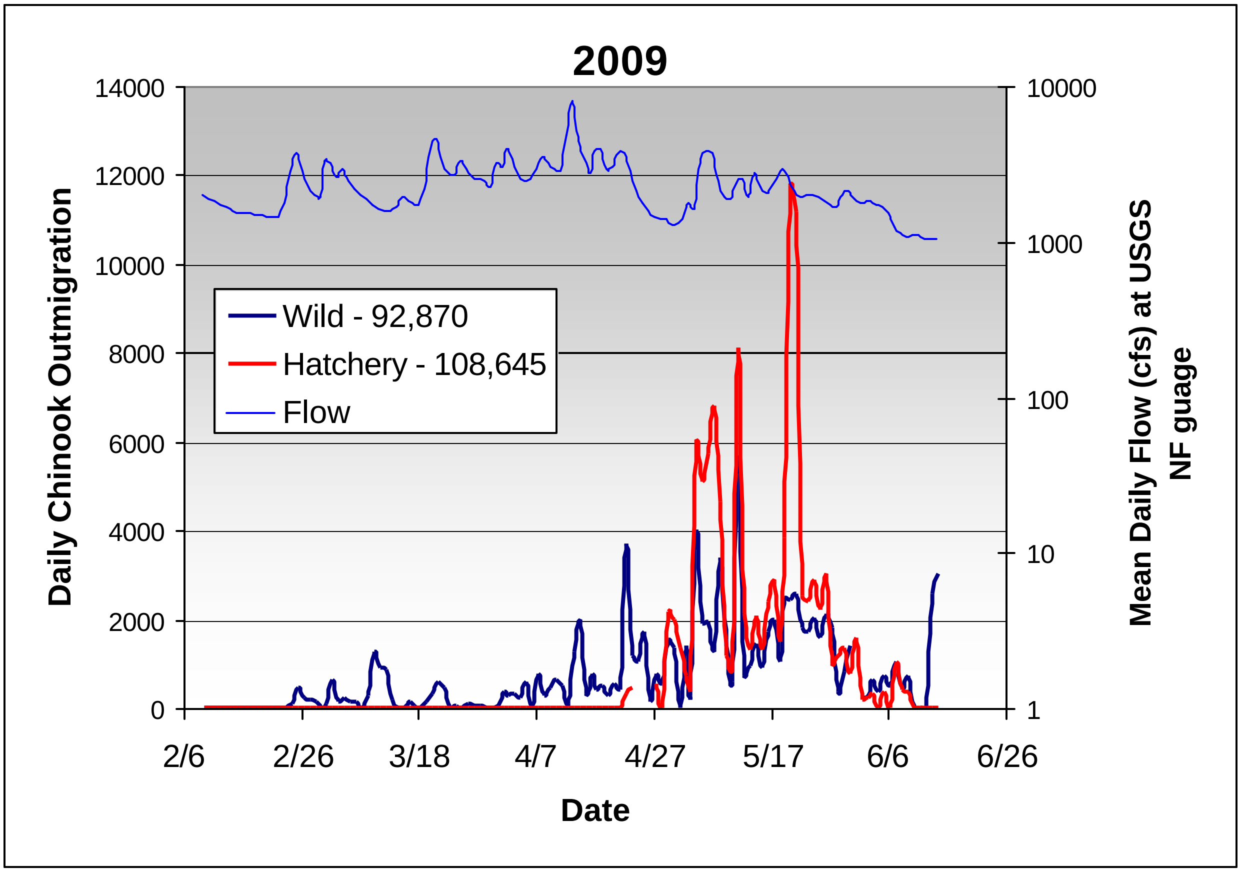

Figure 12. Estimated daily migration for wild and hatchery origin Chinook smolts. Flow (cfs) as measured at the USGS North Fork Gauge is added on a secondary axis.

The sample design required that the trap be fished daily, however we were not able to fish on two days, one in April and one in May. The total out migration for the missed days was estimated to be 3200 wild and 5700 hatchery origin Chinook smolts, representing 3.5% and 5.2% of the total natural and hatchery origin Chinook outmigration, respectively.

During efficiency trials the trap is fished continuously for 24 hours or more. During these experiments, the data is collected using the same six hour time periods (0000-0600, 0600-1200, 1200-1800, 1800-2400) as a normal fishing day. This allows the variability among periods to be estimated for a given fishing season. For the 2009 data, the average CV measuring variability among periods was estimated as 81%, and the running average (across all years) was 74.6%. This CV estimate was used in Equations 9 and 10 to estimate the variance component in Equation 6.

All periods within the day had a chance of being sampled, although for most days only one period was sampled. The mean CPUE for wild Chinook by fishing shift is plotted in Figure 13 along with the 95% confidence intervals for the means; there was not a significant difference between the four shifts (ANOVA, $\propto$ 0.05, p= 0.66). There also were no significant differences in hatchery Chinook CPUE among the four fishing shifts (ANOVA, $\propto$ 0.05, p= 0.08, Figure 14).

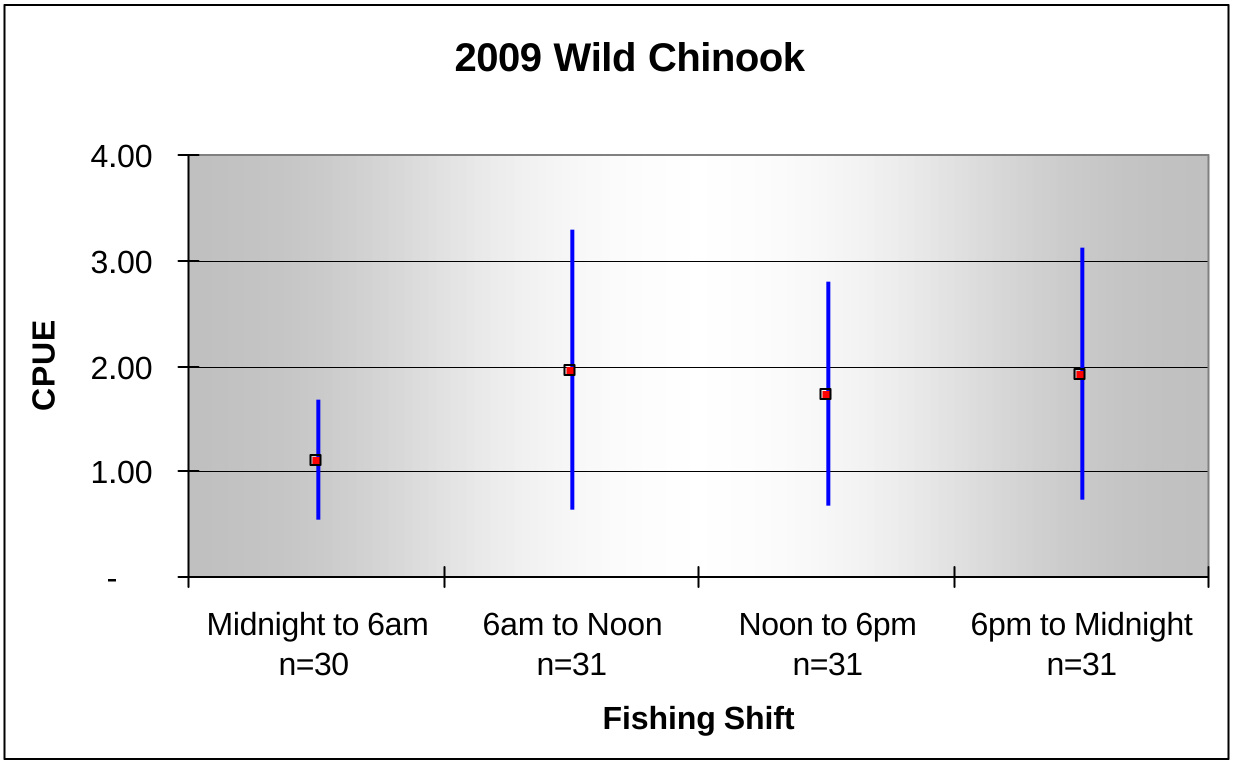

Figure 13. Mean wild Chinook CPUE (boxes) along with 95% confidence intervals (bars) by fishing shift for the Stillaguamish smolt trap in 2009.

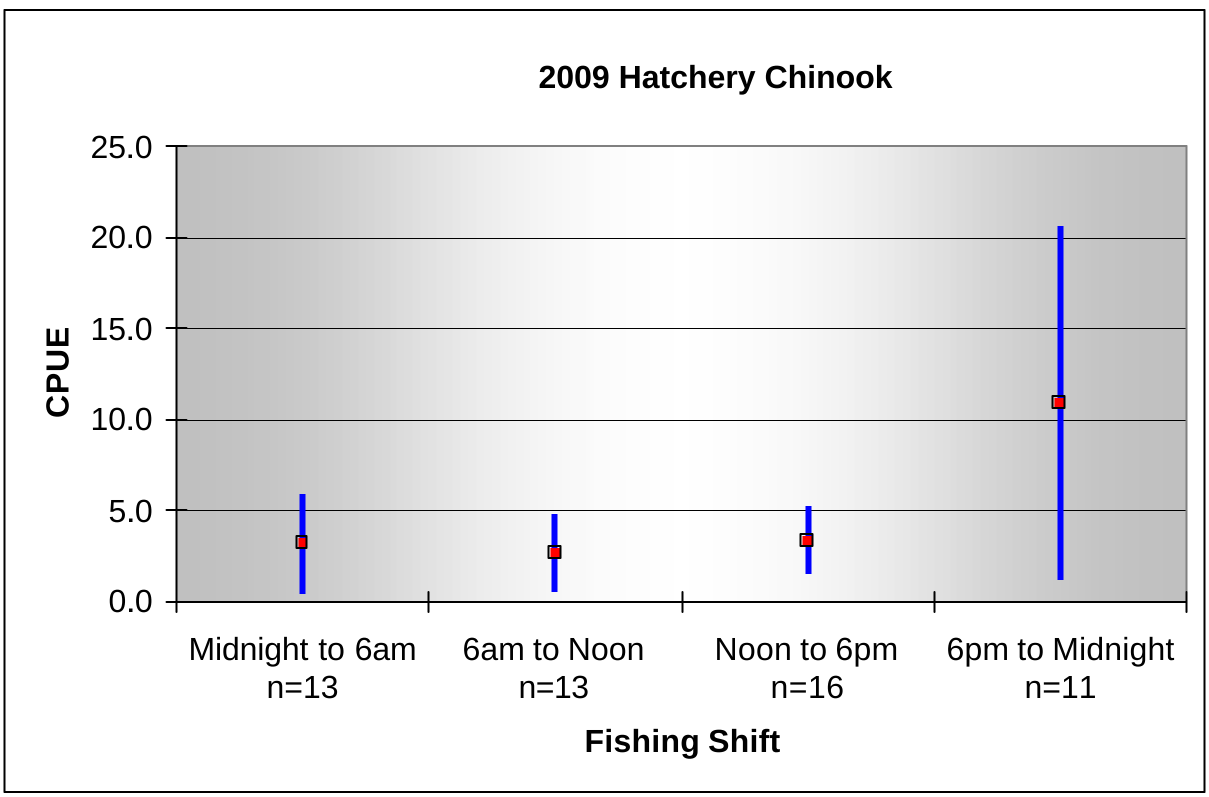

Figure 14. Mean hatchery Chinook CPUE (boxes) along with 95% confidence intervals (bars) by fishing shift for the Stillaguamish smolt trap in 2009.

Genetic Analysis of Smolt Tissue Samples

In 2009, 752 smolts were sampled for genetic material. All smolts were assigned (when possible) to the genetic baseline developed from adult collections, which included the contemporary and GAPS data from the Stillaguamish River (Small et al. 2010). Results of the genetic analysis concluded approximately 20.2% of the assigned samples (24% of the samples failed to amplify) aligned with the fall population, with the remainder aligning with the summer population (Table 2).

Table 2. Summary of results of Genetics results- 2009

	highest likelihood		> 90 relative likelihood			
	Summer	Fall	Summer	Fall	unassigned	Total
2009	600	152	492	77	183	752
percentage						
2009	79.79	20.21	65.43	10.24	24.34	

Discussion

The primary goal of the Stillaguamish smolt trapping operation is to estimate the number of Chinook smolts produced by the system each year; this is the sixth year where production estimates have been made. We estimated that 92,871 (PSE=57%) natural origin smolts and 108,645 (PSE=39%) hatchery origin Chinook migrated past the trap from mid February to early July. While there is evidence that some fish migrated after the trap fished, we did not attempt to determine numbers in the post fishing season tail.

Relatively moderate flows allowed the trap to operate most days, except for a day in each of April and May. During these missed fishing days, a relatively small percentage (<6%) of the hatchery and wild production was estimated to have passed the trap. This is fortunate, as the relationship relating flow and CPUE is weak (Figures 6 & 7), thus there is limited confidence in the estimates for missed fishing days.

However, the secchi-efficiency relationship (Eq. 1, Figure 5) certainly underestimated the efficiency of the trap in capturing HORs. The uncorrected estimate was several times larger than the known number of fish released upstream, and the constant in Eq. 1 needed to be altered to bring the production estimate in line with what could be expected given the observed average survival to the smolt trap from the release location. Given the high flows experienced during incubation for the 2008 brood, it is also likely that the uncorrected production number for NORs was also high. The original estimate produced an egg-to-migrant survival number very far off the peak flow/migration relationship (Figure 15). This is not the first year where a correction to the constant had to be made in the analysis and indicates that there are issues, in some years, with the calibration experiments. This is puzzling, as the methods of transport, dye, and release do not change from year to year. We will continue to monitor our methods and adjust in coming years to better measure the true efficiency of the smolt trap.

Combining the 2009 wild smolt production estimate with 2008 adult escapement estimates yields an estimate of the egg-migrant survival rate of 3.2%. This estimate is lowest yet observed in the nine years of trapping (but still falls near the regression line) and is a reflection of the incubation conditions experienced during the fall and harsh winter of 2008. Peak flows typically result in gravel scour and sediment deposition, processes that (depending on the severity of event-Figure 15) can kill a large number of the eggs deposited, either by suffocation or displacement from the gravel (Healy 1991). After a prolonged cold spell with record low temperatures and snow, the watershed experienced a near flood of record on 1/8/2009 (49,000cfs on the North Fork) that severely impacted juvenile chinook as they were still in the gravel. Refining the relationship between egg-migrant survival and environmental variables continues to be an important component in understanding the limiting factors affecting Chinook populations. A clear understanding of the limiting factors is important for prioritizing limited restoration funds, and implementing the Stillaguamish chapter of the Puget Sound Chinook Recovery Plan (SIRC 2005).

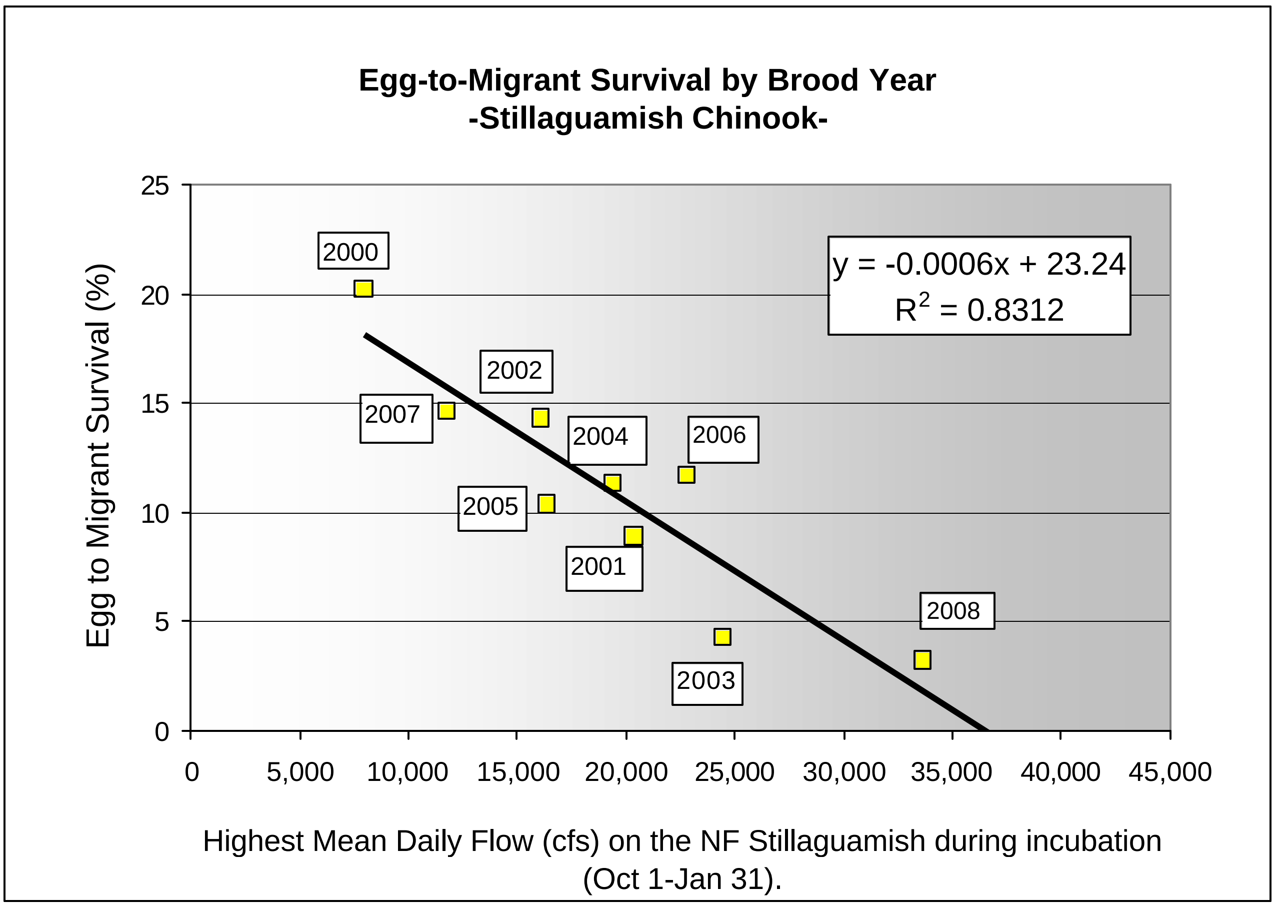

Figure 15. Egg-Migrant Survival by Brood Year for Stillaguamish Chinook.

Two thousand and nine was the second year where genetic material was collected from smolts. By analyzing genetic material collected from smolts, we aim to track the contributions of the summer and fall Chinook populations to the total smolt outmigration. While some of the samples were too small to amplify (field methods are being modified to prevent this from occuring again), the majority could be assigned to either population. This was an important development, as survey conditions are often problematic during peak spawning of the fall stock, and it is difficult to determine the status of the population. According to the probabilistic model, in a mixture of summer and fall Chinook salmon from the Stillaguamish River, when the true percentage of fall Chinook salmon is around 20% the detected proportion is predicted to be most similar to the true proportion. Although the sample size for 2009 is smaller than the sample in the model, the assignment results (~20%) suggests that fall Chinook salmon produced roughly 20% of the wild smolts collected in the mainstem (Table 1, ~18,500 smolts). As the fall stock is returning at low numbers, it is important to determine which direction the population is trending. Adult counts are incomplete in most years, thus further sampling will determine if it is feasible to track the status of the fall population via smolt production estimates.

One of the advantages of this project is that the catches can be used to compare migration timing and size at migration between hatchery and wild spawned Chinook. In all the years of trapping thus far (including 2009), wild origin Chinook were smaller and migrated earlier than hatchery origin Chinook smolts (Figures 10 & 11). Because the Stillaguamish Hatchery program is an Integrated Recovery type operation (designed to help recover the endangered Chinook populations on the Stillaguamish), it is important that hatchery releases, as closely as possible, mimic their wild counterparts in size and timing of migration. The goal is to produce hatchery fish that are subject to the same selective pressures as their wild cousins, thereby minimizing genetic differences over generations. In response to data collected on the smolt trap over the past several years, hatchery feeding rates/release timing has been adjusted to better produce smolts that more closely resemble their wild spawned cousins (one of the goals of the Stillaguamish Hatchery Genetic Management Plan). As is evidence by the 2009 data, however, there is still more work to do to match the timing and size of the wild Chinook. The Stillaguamish Tribal hatchery is on stream water that is significantly warmer than the water experienced by the wild Chinook in the upriver spawning gravels. Since water temperature regulates growth rates, we have found it difficult to match the wild fishes' size without starving the hatchery fish. In addition, the hatchery Chinook have to be a certain size before they can be coded wire tagged and adipose clipped. This means that the earliest the hatchery fish are ready for release is usually early/mid-April, approximately one month after the wild fish have already begun their seaward migration. We are investigating the feasibility of chilling the hatchery water supply to more closely match the rearing environment experienced in the wild.

In order to make inferences about migration timing and to estimate daily and total migration, the efficiency of the trap has to be estimated over a range of flows and environmental conditions. Efficiency is the key variable that allows for catch expansion and production estimation. As is evidenced by the last six years of capture efficiency trials, trap efficiency is not a constant; it varies with respect to flow, turbidity, and perhaps most importantly, visibility. Since the smolt trapping program's inception, variation in capture efficiency has been best explained by the visibility at the trapping site (Figure 5; Griffith et al. 2001, 2003, 2005). Visibility likely influences the ability of the fish to avoid the trap but perhaps also the depth at which the fish migrate. The cone of the trap only strains the top 1.25 meters of the water column, while the river underneath is more than 4 meters deep, allowing ample room to migrate at a deeper depth then the trap can fish. The accuracy and precision of our yearly Chinook production estimate leans heavily on our ability to estimate the instantaneous efficiency of the trap. As is evidenced by the need to correct the hatchery and wild production estimate in 2009, the equations that estimate efficiencies are not perfect and have room for improvement. The efficiencies measured (0.05 – 1.4%) are much lower than to those observed before on the Stillaguamish and lower than those reported from other river systems (Conrad and MacKay 2000; Seiler et al. 2000).

On relatively clear river systems like the Skykomish and Skagit, there is evidence that daylight has a negative influence on migration or capture by rotary type screw traps. In these systems, catch rates are reported to decrease during daylight hours (Seiler et al. 2001, Nelson et al. 2003.). On more turbid systems such as the Nooksack, catch rates during the night and day are not significantly different (Conrad and MacKay 2000). During the 2009 season, as in the previous seven years, catch rates of wild Chinook did not vary significantly between "day" and "night" time periods (Figure 12). The Stillaguamish is so turbid during much of the migration period that, from a predation perspective, it may not matter if Chinook migrate during the day or night, but rather when the flows are most conducive for a rapid move down into the estuary. Future years of trapping will continue to test for differences between time periods, so that the fishing schedule and data analysis can be adjusted accordingly

References

Conrad, R. H., and M.T. MacKay. 2000. Use of a Rotary Screwtrap to Monitor the Out-migration of Chinook Salmon Smolts from the Nooksack River 1994-1998. Northwest Fishery Resource Bulletin. Project Report Series No. 10. May 2000.

Griffith, J., R. Rogers, J. Drotts, and P. Stevenson. December 2001. Annual Report 2001, Stillaguamish River Smolt Trapping Project. Stillaguamish Tribe of Indians. Arlington, WA.

Griffith, J., R. Rogers, J. Drotts, and P. Stevenson. March 2003. Annual Report 2002, Stillaguamish River Smolt Trapping Project. Stillaguamish Tribe of Indians. Arlington, WA.

Griffith, J., M. Alexsanderdottir, R. VanArman, and J. Drotts. June 2005. Annual Report 2004, Stillaguamish River Smolt Trapping Project. Stillaguamish Tribe of Indians. Arlington, WA.

Healy, M.C. 1991. Life history of Chinook salmon, (Oncorhynchus tshawytscha). Pages 313-393 *in* C. Groot and L. Margolis, (eds). Pacific Salmon Life Histories. UBC Press, University of British Columbia, Vancouver, Canada.

Nelson, K., B. Kelder, and K. Rawson. 2003. 2001 Skykomish River Chinook and Coho Out-migration Study. Tulalip Tribes, Tulalip Natural Resources Division. Tulalip, WA.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife. April 12, 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. http://wdfw.wa.gov/publications/pub.php?id=00854

Seiler, D., S. Neuhauser, and L. Kishimoto. 2002. 2001 Skagit River Wild 0+ Chinook Production Evaluation Annual Report. Washington State Department of Fish and Wildlife. May 2002.

Seiler, D., S. Neuhauser, and L. Kishimoto. 2001. Annual Project Report. 2000 Skagit River Wild 0+ Chinook Production Evaluation. Washington State Department of Fish and Wildlife. April 2001.

Seiler, D., S. Neuhauser, and L. Kishimoto. 2000. Annual Report. 1999 Skagit River Wild 0+ Chinook Production Evaluation. Washington State Department of Fish and Wildlife. April 2000.

Small, M. P., A. Spidle, J. Griffith, and J. Von Bargen. 2010. Genetic differentiation between summer and fall run Chinook salmon in the North and South Fork Stillaguamish River: Can Chinook salmon in the mainstem be identified to run group? April 2010.

Stillaguamish Implementation Review Committee (SIRC). 2005. Stillaguamish Watershed Chinook Recovery Plan. Published by Snohomish County Department of Public Works, Surface Water Management Division. Everett, WA.

Stillaguamish Tribe 2009. Stillaguamish Estuary Use by Juvenile Chinook Final Report. FY 2005 Pacific Coastal Salmon Recovery Funding. Stillaguamish Tribe of Indians. Arlington, WA. www.stillaguamish.nsn.us

Taylor, P.W., and S.D. Roberts. 1999. Clove Oil: An Alternative Anesthetic for Aquaculture. North American Journal of Aquaculture. 61: 150-155.