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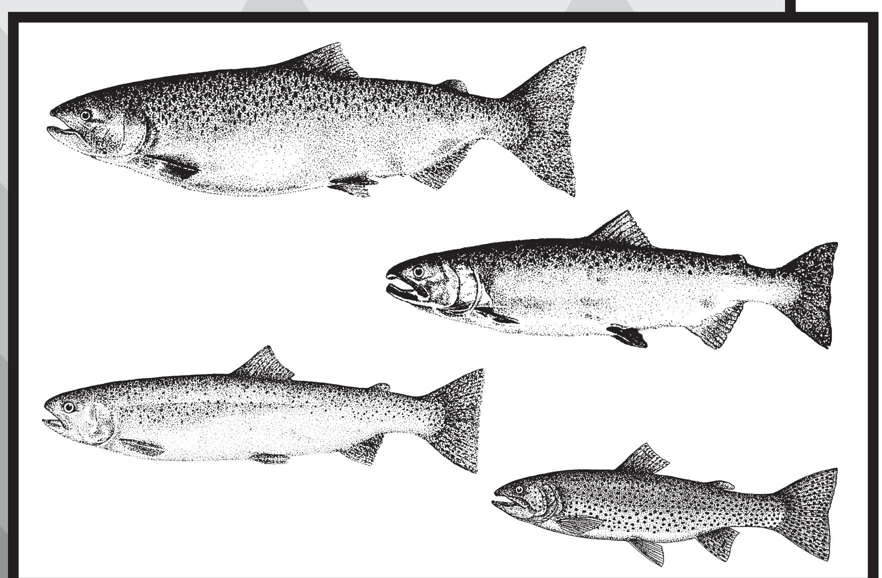
2000 Green River Juvenile Salmonid Production Evaluation



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Washington Department of
FISH AND WILDLIFE
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Acknowledgments

Measuring juvenile salmon production from large river systems like the Green River involves a tremendous amount of work. Key to developing these estimates are the long hours of trap operation provided by our dedicated scientific technicians: Sam Gibbons, John Thompson, Roy Morse, and their field supervisor, Paul Lorenz. Logistical support and map development was provided by Wild Salmon Production Evaluation Unit biologists, Mike Ackley and Laurie Peterson, respectively.

A number of other individuals and agencies contributed to this project. For providing access to the trap site, we thank landowners Bill Mosby and King County Parks Department. We also thank WDFW Habitat Construction foreman Jack Smith who enabled access by constructing and installing a bridge across a slough on the King County Parks Department land. We are also grateful to Jack for constructing the smolt trap. We also acknowledge the contribution provided by Mike Wilson, Manager of the Soos Creek Hatchery, for providing logistical support, office space, and a secure staging site near the trap. And finally, we thank Fred Goetz of the United States Army Corps of Engineers for providing funding and coordination for this project.

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Executive Summary

The National Marine Fisheries Service (NMFS) listed Puget Sound chinook as threatened under the Endangered Species Act (ESA) in March 1999. This listing triggered action on the part of state and local governments to develop plans and implement actions designed to restore Puget Sound chinook runs to healthy levels. An important, but often missing, component of the plans is accurate information on wild chinook abundances and the factors that limit or impact production and productivity in key wild chinook stocks. One such key stock, Green River chinook, represents one of the largest populations of chinook within the Puget Sound Evolutionary Significant Unit (ESU). Since quantifying juvenile anadromous salmonid populations as they migrate seaward is the most direct assessment of stock performance in freshwater, a long-term wild juvenile salmon production study was initiated in the Green River to estimate and monitor the production of chinook and coho salmon, steelhead, and cutthroat trout.

Beyond monitoring for ESA considerations, this study provides important information for run-size forecasting and enables assessment of recovery actions in terms of change in wild salmon production. The study will also be used to evaluate a large water storage and diversion project on the Green River (Howard Hansen Dam [HHD] Additional Water Storage [AWS] Project). This report documents our investigations during 2000, the first year of this project and the first year of pre-construction baseline monitoring for the AWS project. Study objectives in 2000 include estimating Green River wild chinook freshwater production, migrant size, and migration timing to evaluate the condition of the stock and to help develop a better understanding of factors influencing their production and life history.

In addition to the work in the Green River, this report also describes the results from our one-year juvenile chinook trapping project in Big Soos Creek. This project assessed the level of natural production resulting from hatchery parents spawning in the wild.

To accomplish these objectives, two floating screw traps were operated, one on the mainstem Green River (river mile 34.5) and one just upstream of the Soos Creek Hatchery on Big Soos Creek. A portion of all downstream migrating juvenile salmonids were captured in these traps. To estimate the capture efficiency, over the season groups of dye-marked or fin-marked fish were released upstream of the traps. Nightly migration was estimated by dividing the nightly catch by the flow-based estimate of trap efficiency.

Over the 154-day February 10 to July 13 trapping period, over 12,000 juvenile chinook were captured in the mainstem trap. From this catch and our estimates of trap efficiency, we estimated a total of 536,000 age 0+ wild chinook migrated past our trap in 2000. This estimate assumes that 76,000 age 0+ chinook migrated between an assumed January 1 migration starting date and the date that trapping began (February 10).

The trap on Big Soos Creek was operated over a 147-day period (February 1 to June 26). During this period over 90,000 juvenile chinook were captured. Based on our estimates of trap efficiency, we estimate total age 0+ chinook natural production from Big Soos Creek at 275,000.

Like other wild juvenile chinook migrations that we have monitored, the chinook migration from the mainstem Green River followed a bi-modal timing distribution. An earlier-timed "fry" component, comprised of newly emerged fry, that migrated between February and early April was followed by a later-timed "smolt" component, comprised of larger chinook smolts, that migrated from May through June. On Big Soos Creek, nearly all age 0+ chinook migrated as fry which, we believe, indicates nearly all parent-brood spawning occurred just upstream of the trap.

Relating our estimates of age 0+ chinook production to the number of eggs estimated to have been deposited above the traps in the mainstem Green River and in Big Soos Creek results in egg-to-migrant survival estimates of 7.3% and 3.8%, respectively. We believe differences in survival between these two streams are primarily related to the delayed release of spawners upstream of the Soos Creek Hatchery rack in 1999 which concentrated the spawning activity in Big Soos Creek to a small area and resulted in redd superimposition. There may also be differences in the quality of spawning habitat given differences in basin morphology and stream power between the Green River and Big Soos Creek, as well as differences in the genetic fitness of the Soos Creek stock.

By summing the estimated chinook production from the mainstem Green River above the trap with that from Big Soos Creek, and accounting for mainstem production below the trap, we estimate total 2000 Green River age 0+ chinook natural production at 1.08-million.

In addition to age 0+ chinook, we also estimated 33,000 wild and 203,000 hatchery coho smolts, 36,000 to 41,000 wild and 46,000 to 52,000 hatchery steelhead smolts, and 400 to 500 wild cutthroat smolts migrated past the mainstem Green River trap in 2000. We also estimate that 64,000 coho smolts were produced in Big Soos Creek.

Introduction and Background

The National Marine Fisheries Service (NMFS) listed Puget Sound chinook as threatened under the Endangered Species Act (ESA) in March 1999. Out of the 28 chinook stocks included in the Puget Sound Evolutionary Significant Unit (ESU), Green River chinook is one of the largest. In recent years, this stock has comprised approximately 21% of the total natural escapement for the ESU. Although an unknown level of the natural escapement has been attributed to hatchery strays from Big Soos Creek (WDFW et al. 1993), recent (1996 to present) escapement levels have exceeded natural escapement goals for the Green River. Consequently, Duwamish-Green River chinook are considered a healthy stock.

Under the Governor's Salmon Plan to restore salmon populations, one major objective is to determine the limiting factors for chinook salmon in priority watersheds. Necessary data for this purpose include habitat inventory, annual adult escapement estimates, and wild juvenile chinook assessment. The juvenile production evaluation is a vital link in this process because it provides a direct measure of freshwater survival.

Quantifying juvenile anadromous salmonid populations as they migrate seaward is the most direct assessment of stock performance in freshwater. It is preferred over other approaches such as run reconstruction because the error associated with partitioning brood losses into freshwater and marine environmental effects and harvest effects is excluded. Relating smolt production to parent spawners over a number of brood cycles provides an understanding of key variables for the recovery and management of the stock. For example, if adequate escapements occur, smolt production monitoring provides an empirically-derived measure of the watershed's natural production potential. Smolt production measured over a range of escapements can also be used to develop the spawner/recruit function for the stock. Finally, this information enables identification of the major density-independent source(s) of inter-annual variation in freshwater survival which is critical to improving harvest, habitat and endangered species management.

To accomplish these and other fish management objectives, beginning in 1976 the WDFW implemented a long-term research program directed at measuring wild salmon production (smolt and adult populations) in selected watersheds. Recently, the state legislature provided additional funding to expand downstream migrant assessments throughout the state (JNRC 2000). During the scoping phase of this expansion, chinook streams throughout the Puget Sound ESU were evaluated for selection based on considerations such as feasibility and the importance of the stock to fisheries. Another important consideration was the selection of streams or sites that precluded the capture of large numbers of hatchery fish which would make wild stock monitoring difficult. Based on these criteria, the Green River was considered a desirable candidate for monitoring.

Most of the larger chinook-bearing rivers entering Puget Sound have salmon rearing facilities on them. In the Green River system, a large salmon hatchery is located on Big Soos Creek, a large right-bank tributary located at river mile 33.7. Smaller facilities located further upstream on the Green River include the Keta Creek Hatchery on Crisp Creek, the Icy Creek Hatchery, and the Palmer Ponds. Site selection was given careful consideration in order to avoid capturing large numbers of hatchery fish, achieve adequate flow velocities to optimize capture rates, and to capture fish low enough in the Green River system to measure most of the wild production. Two trapping sites were established, one on the Green River mainstem approximately 0.5-miles upstream of the mouth of Big Soos Creek, and another on Big Soos Creek just upstream of the hatchery. The mainstem site was established for long-term monitoring of wild juvenile chinook production. The Keta Creek, Icy Creek, and Palmer Ponds facilities were located upstream from this site; but, unlike the Soos Creek Hatchery, these facilities posed less of a problem for estimating wild salmon production since they produced fewer fish, released very few age 0+ chinook, and were located well upstream of the trap site. The Big Soos trap site was selected to evaluate the level of natural chinook production that resulted from hatchery-origin parents and to compare these production levels to those in the Green River itself. The Big Soos Creek effort was designed as a one year study and trapping at this site only occurred in 2000.

In addition to monitoring for ESA and fisheries management considerations, juvenile salmon production and migration monitoring was also needed on the Green River to evaluate the effects of a large-scale water project that was recently approved, as well as its mitigation elements. Over the past eight years, the U.S. Army Corps of Engineers (USACE) and Tacoma Public Utilities (TPU) have worked with the U.S. Fish and Wildlife Service (USFWS), NMFS, WDFW, Washington Department of Ecology (WDOE), and the Muckleshoot Indian Tribe (MIT) to scope, conduct, and evaluate the feasibility studies for the Howard Hansen Dam (HHD) Additional Water Storage (AWS) Project. The project would include raising the reservoir surface elevation to 1,167 feet to increase water storage for domestic use. To accommodate this project, a wide variety of mitigation and monitoring activities were planned including a full-height fish passage facility, right abutment drainage remedies, Phase I fish and wildlife habitat restoration and mitigation, and monitoring and evaluation studies (USACE 1998). Tacoma's Second Supply Water Right (20,000 ac-ft of storage) would be stored in the spring for water supply use in the summer and fall. The final design for the project would be developed between 1999 and 2001, while construction would begin in 2001 and continue through 2005. The project is scheduled to begin operation, storing water, and operating the fish passage facility in 2005.

Monitoring activities required for this project include the study of the instream migration of juvenile salmon and steelhead during the water storage and release operations at HHD. The objective of this monitoring component is to evaluate strategies designed to minimize the impact of existing and future planned operation of the AWS Project on the survival of emigrating (naturally-reared and hatchery) juvenile salmon and steelhead. Juvenile salmon emigration monitoring for the AWS project includes a two-year pre-construction baseline phase (2000 to 2001) and a five-year post-construction monitoring phase (2005 to 2009). This before and after

AWS project monitoring will provide important feedback which may result in adjustment to storage and release regimes in response to observed results through an adaptive management process. This report describes our activities and findings relative to the first year of baseline monitoring.

Goals and Objectives

As part of our wild salmon monitoring activities under the State Agencies' Action Plan for the Statewide Strategy to Recover Salmon (JNRC 2000), Green River wild chinook freshwater production, migrant size, and migration timing are measured or estimated to evaluate and monitor the condition of the stock. This information will also be used to develop a better understanding of factors influencing their production and life history, and to provide direction for habitat protection. In addition, monitoring on the Green River will provide an opportunity for hatchery programs to test strategies for improving in-river survival of their releases.

Data collected during our one-year trapping project in Big Soos Creek will assess the level of natural production resulting from hatchery parents spawning in the wild. This information will be useful for designing hatchery operations to optimize the production and survival of these offspring.

Attaining these goals and objectives will contribute to better understanding the continued production of wild chinook salmon in the Green River and the actions needed to maintain the productivity of this stock. As part of the baseline monitoring for the AWS project, the monitoring completed in 2000 documents existing characteristics of juvenile instream migration, such as seasonal and diel timing. In addition, it begins to document the response of different salmonid species at various life-stages to environmental changes (e.g., flow, turbidity, day length, and temperature) and their response to HHD refill and release. This information will be evaluated and used to refine an adaptive refill and release schedule for the planned AWS Project. As this is the first year of the project, this report will also develop recommendations to guide future juvenile salmonid production and migration monitoring activities in the Green River.

Trap Operations

A floating screw trap (Busack *et al.* 1991) was used on the Green River to capture downstream migrant chinook, coho, chum, and steelhead. The mainstem trap was located at river mile 34.5; approximately 3,200-ft upstream of the Highway 18 bridge, on the left bank (Figure 1). The trap consisted of two, four-foot wide tapered flights, wrapped 360 degrees around a nine-foot long shaft. These flights were housed inside a five-foot diameter cone-shaped frame covered with perforated plating. The shaft was aligned parallel with the flow and was lowered to the water's surface via davits and winches mounted on two 30-ft steel pontoons. The trap fished half of a five-foot circle with a cross sectional area of 9.8-ft^2. Water current acting on the flights caused the trap to rotate, and with every 180 degrees of rotation, a flight entered the water while the other emerged. As the leading edge of a flight emerged from the water it prevented the escape of trapped fish. The fish were gently augured into a solid sided, baffled live box.

The trap on the Green River was operated continuously between February 10 and July 13, except for periods when river flow and debris loads made trap operations unsafe. Trapping was also occasionally suspended early and late in the trapping season, primarily during daytime periods, when catches were low. Fish were usually removed from the trap and counted at dawn and at dusk to evaluate differences in daytime and nighttime catch rates. In addition to these periods, the trap was checked at other times, as needed, based on debris loads and capture rates. At the end of most trapping periods, all fish captured in the trap were identified to species and enumerated. Occasionally, catch estimation was used in lieu of a count when high catch rates of hatchery chum salmon necessitated using a volumetric approach to estimate the chum catch. When this occurred, dip net loads of fish were removed from the trap. Every third dip net load was retained and the loads were combined and counted. The chum catch was estimated by applying the average number of chum fry per dip net load to the total number of dip net loads of chum fry removed from the trap.

A second trap was installed and operated in Big Soos Creek, upstream of the hatchery (Figure 1). This trap was identical to the Green River trap, but was mounted onto a smaller set of pontoons. It operated continuously between February 1 and June 26, except during periods when debris, maintenance, or other occurrences forced temporary suspension of trapping. Trap operation and data collection was conducted as described for the Green River trap except on multiple occasions between mid-February and mid-March, sub-sampling of the catch was used to estimate large catches of either age 0+ chinook or both age 0+ chinook and age 0+ coho.

When only the chinook catch was estimated, we applied the same approach that was used to estimate the chum catch in the Green River trap. Where a combined catch of chinook 0+ and coho 0+ required estimation, species composition was estimated along with the total catch. Three approaches were used in this situation. Each approach used a 33% sampling rate by

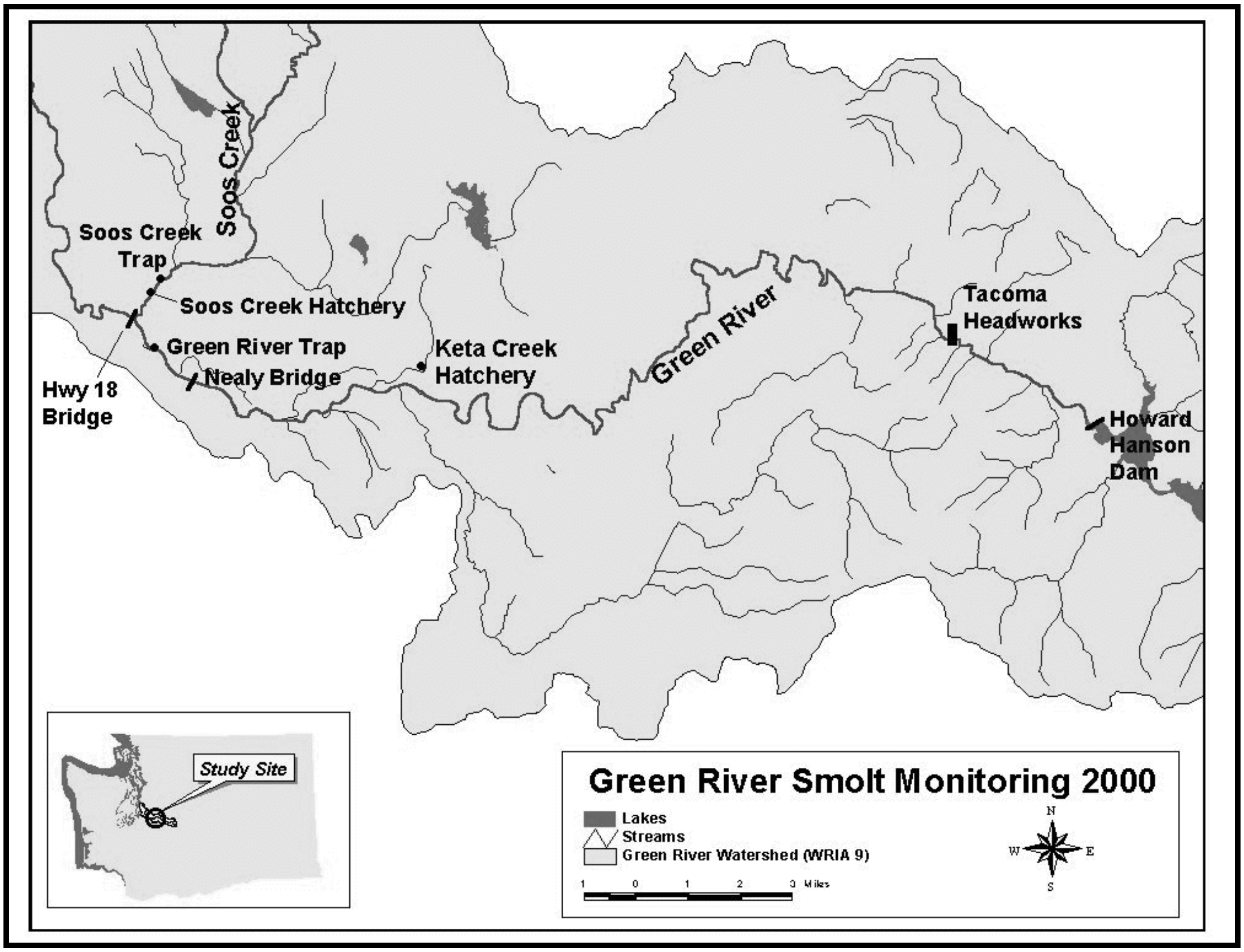

Figure 1. Location map of the Green River and Big Soos Creek screw traps relative to hatcheries and hydro-projects, Middle Green River 2000.

retaining one out of every three dip-net loads of fish for estimating the catch and species composition, or the species composition alone. Using the first method, every third dip-net load of fish was retained and the retained loads were then combined and counted to estimate the number of chinook and coho per dip-net load. The resulting catch and composition rates were applied to the total number of dip-net loads removed from the trap to estimate the chinook 0+ and coho 0+ catch. Technicians noted that as fish were removed from the trap, they had an increasingly difficult time maintaining a consistent dip-net load level. Therefore, a second approach was developed in which fish from each retained dip-net load were counted separately. The number of chinook and coho in each retained dip-net load was applied to the next two uncounted dip-net loads that it represented. To further reduce the bias associated with our inability to remove consistently loaded dip-net loads from the trap, a third approach was developed that estimated the composition, but not the number caught. As with the first approach, every third dip-net load was retained and all retained dip-net loads were combined. The retained catch was counted to develop the proportions of chinook 0+ and coho 0+ in the catch. The remaining (un-retained) catch was counted, but not identified to species. The proportions of chinook 0+ and coho 0+ found in the retained catch was applied to the total count to estimate the catch of each species. None of these approaches enabled an estimation of the variance of the catch estimates, therefore, estimates were treated as counts in all subsequent calculations.

A subsample of chinook, coho, steelhead, and cutthroat from both traps were measured for fork length and transferred to individual buckets prior to being released downstream. At the Green River trap, chinook and chum salmon used for trap efficiency testing were anesthetized with tricaine methanesulfonate (MS 222), identified to species, and marked with a unique partial fin clip or with Bismark Brown dye. Marked fish were allowed to recover in fresh water before being placed in buckets, transported upstream, and released at the Nealy Bridge, approximately 0.5-miles upstream of the trap. Fish used for trap efficiency calibration were released in the morning or evening to evaluate daytime and nighttime capture rates. At the Big Soos Creek trap, chinook and coho used for efficiency testing were treated in a similar manner to the Green River efficiency test fish. The marked Big Soos Creek fish were released approximately 0.2-miles above the trap.

At the Green River trap, the gut contents were removed from a subsample of sculpin, cutthroat, steelhead, coho, and other piscivorous species to determine the rate of predation on emigrating salmonid fry. Besides providing an evaluation of predation timing and characteristics, stomach sampling also indicated the predation levels occurring in the live box. Excessive predation would indicate a need to check the trap more frequently. Each sampled fish was identified and the fork length was recorded. A syringe without a needle was used to inject water into the stomach of the sampled fish in order to flush out the gut contents. Fish prey items were sorted, counted, and their identification was attempted. All fish data and duration of fishing were recorded on field data sheets.

In addition to the fish data, mean daily flow data for the Green River and Big Soos Creek were provided by the USGS gauges at Auburn and Big Soos Creek, respectively.

Production Estimation

Chinook

Estimating chinook production from the Green River and Big Soos Creek was done in two steps. Since the trap did not operate continuously over the entire trapping period, the first step involved estimating or interpolating catch for periods when the trap did not fish. The second step involved estimating the capture rate or trap efficiency.

To interpolate catch for periods when the trap was not fishing, diel differences in migration rates were evaluated. Salmonids often migrate at different rates between day and night periods (Seiler *et al.* 1981), therefore, fishing periods were stratified into daytime, nighttime, and combined periods. The stratification was simplified by performing the trap checks near day break and twilight periods. Catch rates were estimated by;

$$\hat{R}_{fj} = \frac{C_{fj}}{T_{fj}} \quad \textbf{(1)}$$

Where:

$\hat{R}_{fj}$ = *The catch rate during fishing period f in diel stratum j*,

C_{fj} = *Catch during fishing period f in diel stratum j, and*

T_{fj} = *The duration of fishing period f in diel stratum j.*

When part of a daytime or nighttime period was fished, catch for the remaining un-fished period was estimated by;

$$\hat{C}_{ij} = \hat{R}_{fj} \times T_{ij} \quad \textbf{(2)}$$

Where:

$\hat{C}_{ij}$ = *The estimated catch during unfished period i in diel stratum j, and*

T_{ij} = *The duration of unfished period i in diel stratum j.*

Catch rates would be expected to vary within and between fishing periods. Since we have no way of measuring the variance within a fishing period, the variance in catch rates between fishing periods was used to approximate the variance within a fishing period. Therefore, the variance of the catch rate, R_{fj}, was approximated by;

$$\hat{V}(\hat{R}_{fj}) \cong (\hat{R}_{fj} \times CV(\overline{R}_{jk}))^2 \quad \textbf{(3)}$$

Where:

$CV(\overline{R}_{jk})$ = *The coefficient of variation of the mean capture rate for fishing periods within diel stratum j in statistical week k.*

The variance for the estimated catch was found using;

$$\hat{V}(\hat{C}_{ij}) = V(\hat{R}_{fj}) \times T_{ij}^2 \quad \textbf{(4)}$$

To facilitate the estimation of catch where entire daytime periods were not fished, catch was interpolated using daytime period catch rates from adjacent days. Where this information was not available, weekly average daytime/nighttime catch rate ratios were calculated by,

$$\overline{Q}_k = \frac{\overline{R}_{fdk}}{\overline{R}_{fnk}} \quad \textbf{(5)}$$

Day catch rates were then estimated by;

$$\hat{R}_{idk} = R_{fnk} \times \overline{Q}_k \quad \textbf{(6)}$$

Where:

$\overline{Q}_k$ = *The ratio of average day catch rates over average night catch rates during statistical week k,*

R_{fdk} = *The catch rate during fishing period f for daytime stratum d in statistical week k,*

R_{fnk} = *The catch rate during fishing period f for nighttime stratum n in statistical week k, and*

$\hat{R}_{idk}$ = *The estimated catch rate during unfished period i for daytime stratum d in statistical week k.*

The variance of the average day/night catch rate ratio was approximated using the variance of products with the delta method (Goodman 1960):

$$\hat{V}\left(\overline{Q}_k\right) = \left(\overline{Q}_k\right)^2 \times \left(\frac{\hat{V}(\overline{R}_{dk})}{\overline{R}_{dk}^{\,2}} + \frac{\hat{V}(\overline{R}_{nk})}{\overline{R}_{nk}^{\,2}}\right) - \hat{V}(\overline{R}_{dk})\frac{\hat{V}(\overline{R}_{nk})}{\overline{R}_{nk}^{\,4}} \qquad \textbf{(7)}$$

Since this equation sometimes resulted in negative variances, the final term (-*V(R_{dk})*...) was removed from the equation. The resulting approximation of variance was, therefore, considered conservative.

The variance of the estimated day catch rate was similarly approximated, with the final term removed, by;

$$\hat{V}(\hat{R}_{id}) \cong \hat{V}(R_{fn})\overline{Q}_k^{\,2} + \hat{V}\left(\overline{Q}_k\right)R_{fn}^{\,2} \qquad \textbf{(8)}$$

With the estimated daytime catch rate, day catch was then estimated by,

$$\hat{C}_{idk} = \hat{R}_{idk} \times T_{idk} \qquad \textbf{(9)}$$

and the variance of the day catch by,

$$\hat{V}(\hat{C}_{idk}) = \hat{V}(\hat{R}_{idk}) \times T_{idk}^{\,2} \qquad \textbf{(10)}$$

Finally, to estimate catch where the trap was not fished for one to several days, catches from adjacent days were used to interpolate catch(es) for the unfished day(s). The variances of the daily catch estimates, $V(C_z)$, were estimated by:

$$V(\hat{C}_z) = \left(\hat{C}_z \times CV\left(\overline{C}_p\right)\right)^2 \qquad \textbf{(11)}$$

Where:

$\hat{C}_z$ = *The estimated catch for day z, and*

$CV(\overline{C}_p)$ = *The coefficient of variation for the average catch from the preceding and following complete days fished over the adjacent period p.*

Catches from nighttime fishing periods that spanned midnight were partitioned into before and after midnight catches. Actual and estimated catches were then summed over each 24-hour period to estimate the total daily chinook catch. Variances for the interpolated values were also summed to estimate the variance of these daily catch estimates. These methods were also used to estimate the adipose-marked (ad-marked) and unmarked components of the daily chinook catch.

Daily chinook migration was estimated using the following;

$$\hat{N}_z = \frac{\hat{C}_z}{\hat{e}_z} \qquad \textbf{(12)}$$

The variance was approximated using the variance of products with the delta method (Goodman 1960) by;

$$V(\hat{N}_z) = \hat{N}_z^2\left(\frac{V(\hat{C}_z)}{\hat{C}_z^2} + \frac{V(\hat{e}_z)}{\hat{e}_z^2}\right) - V(\hat{C}_z)\frac{V(\hat{e}_z)}{\hat{e}_z^4} \qquad \textbf{(13)}$$

Where:

$\hat{N}_z$ ' *The estimated migration on day z,*
$\hat{e}_z$ ' *The estimated capture rate on day z, and*
$V(\hat{e}_z)$ ' *Is the variance of the estimated capture rate on day z.*

Again, since this equation sometimes resulted in a negative variance, the final term (-*V(Cz)...*) was removed. The resulting variance was, therefore, considered a conservative approximation.

In order to estimate the capture rate, small groups of marked age 0+ chinook migrants were released at the Nealy Bridge on the Green River, located approximately 0.5-miles upstream of the trap, and at a release point 0.2-miles upstream of the trap on Big Soos Creek. The groups consisted of chinook that were captured the previous night and marked with partial fin-clips or Bismark brown dye. Partial upper and lower caudal clips and left and right ventral clips were used to mark the fish. Fish dyed in Bismark brown dye were held in a dye concentration of 14-ppm for 1.5 hours. The marked fish were transported in five-gallon buckets and distributed across the channel at the two release sites. The capture rate was calculated for individual tests using;

$$\hat{e}_i = \frac{r_i}{m_i} \qquad \textbf{(14)}$$

Where:

$\hat{e}_i$ = *The capture rate estimated for trap efficiency test i,*
r_i = *The number of marked or dyed migrants captured in trap efficiency test i, and*
m_i = *The number of marked or dyed migrants released in trap efficiency test i.*

The variance of each trap efficiency estimate was calculated by;

$$V(\hat{e}_i) = \frac{\hat{e}_i(1-\hat{e}_1)}{m_i - 1} \qquad \textbf{(15)}$$

On the Green River, tests were conducted during morning and evening periods to ascertain whether trap efficiencies responded differently between day and nighttime fishing periods. On

Big Soos Creek, each test entailed releasing groups of fish with the same mark during both day and night over a three-day test period, and recording the recoveries.

Since chinook migrants were not always available in large numbers during the trapping period, a number of additional tests on the Green River were made using chum fry. These fry were usually similar in size or slightly smaller than chinook at the time they were used for testing. Capture rates resulting from the tests were stratified by species and tested for differences at a 95% significance level using a Wilcoxin two-sample test. Where capture efficiencies using chum fry were not found to be significantly different from those using chinook migrants, the chum fry test results were pooled with the chinook migrant test results to provide more robust set of efficiency data.

Linear regression analysis was used to test the effect of mean daily flow on capture rate in the Green River. Where the regression was found to be significant ($p<0.05$), mean daily flow, f_z, was used to estimate daily trap efficiency as predicted by the regression equation;

$$\hat{e}_z = \alpha + \beta f_z \qquad \textbf{(16)}$$

The variance of the predicted efficiency on any day z was;

$$V(\hat{e}_z | f_z) = MSE\left(1 + \frac{1}{n} + \frac{(f_z - \bar{f})^2}{(n-1)s_f^{\,2}}\right) \qquad \textbf{(17)}$$

Where:

MSE ' *the mean square error for the regression*,
n ' *the number of observations in the regression*,
s_f^2 ' *the sample variance of the observed flows*, *and*
$\bar{f}$ ' *the mean of observed flows*.

Since efficiency tests were conducted over three days in Big Soos Creek, the average mean daily flow over the test period was correlated with capture efficiency. Although use of the mean of means can be problematic if unequal sample sizes are used, we were comfortable with its use in this case since the daily means were calculated using continuous stage data which provided a large number of data points.

Where regression derived relationships were not found to be significant on the Green River, trap efficiency tests were stratified by morning tests and evening tests. Normally, the strata would be tested to determine if differences existed between capture rates derived from them. However, since few evening tests were conducted, we verified that they were within the range of capture rates observed for the morning releases and pooled the strata. Mean trap efficiency for chinook was calculated by;

$$\bar{e} = \frac{\sum_{i=1}^{n} e_i}{n} \qquad \textbf{(18)}$$

The variance of the capture rate was;

$$V(\bar{e}) = \frac{\sum(\hat{e}_i - \bar{e})^2}{n(n-1)} + \frac{\sum V(\hat{e}_i)}{n} \qquad \textbf{(19)}$$

Daily estimates of the ad-marked, unmarked, and total (ad-marked and unmarked) chinook migrations were summed across the season to estimate migration for each group over the trapping period. Daily variance estimates for these groups were also summed across the trapping period to estimate variances for the seasonal totals.

When trapping began on February 10 in the Green River and on February 1 in Big Soos Creek, the chinook migrations were already underway. Based on work done in other systems, we chose January 1 as the date that the wild chinook migration began (Seiler *et al.* in press). Linear extrapolation was used to estimate migration between January 1 and the start trapping date for both sites. The extrapolation was based on the estimate of average migration from the first three days trapped in February. The variance of the extrapolated daily migration estimates was approximated using:

$$\hat{V}(\hat{N}_{zi}) - \left(\hat{N}_{zi} \times CV(\bar{N}_{1,2,3})\right)^2 \qquad \textbf{(20)}$$

Where:

$\hat{N}_{zi}$ ' *Migration estimate for day z during unfished period i, and*

$CV(\bar{N}_{1,2,3})$ ' *The coefficient of variation for the mean daily migration from the first, second, and third day of trapping.*

The ad-marked, unmarked, and total 1999 brood chinook migrations past the traps were estimated by summing the daily migration estimates from the trapped and extrapolated periods, January 1 to July 13 on the Green River and January 1 to June 26 on Big Soos Creek. The variances of these estimates were generated by summing the variance estimates for the daily migrations over the same periods.

Coho

The methods used to estimate the Big Soos Creek coho smolt migration in 2000 were identical to the approach used to estimate the chinook migration. On the Green River, however, a different approach was used. Coho catches from the Green River were expanded to estimate catch that would have occurred had the trap operated continuously between February 10 and July 13 using Equations 1-11, as was done with the chinook data. Similarities between the analysis of chinook and coho data ceased at that point. Trap efficiency tests were not performed using coho smolts in 2000. Instead, the number of ad-marked hatchery coho smolts caught in the trap was related to the number released to estimate capture efficiency.

Beginning on May 2, 50,973 ad-marked coho salmon were released from Keta Creek Hatchery, located approximately six miles upstream of the Green River trap. Ad-marked coho smolts captured in the trap after that date were assumed to be from that release. The capture rate for coho was estimated by dividing the number of ad-marked coho captured in the trap after May 2 by the total ad-marked Keta Creek Hatchery release. Total 1998 brood coho migration was then calculated using Equation 12, except the season total coho catch was substituted for daily catch (C_z) and the capture rate described above was substituted for the daily trap efficiency (e_z) in the equation to estimate total migration for the year. The trapping period encompassed the total coho migration, therefore, no extrapolation of the data beyond the trapping period was required for the coho migration estimate. Also, because we did not know the precision of the estimate of ad-marked coho that were released from the hatchery, no attempts were made to estimate the variance for the trap efficiency estimate or for the total migration estimate.

The migration of hatchery coho salmon was estimated by expanding the estimated migration of ad-marked coho by the unmarked proportion in the hatchery releases. Wild migration was then estimated by subtracting the hatchery migration estimate from the total migration estimate. Confidence intervals for these estimates were not developed.

Steelhead and Cutthroat

Production estimates were not made for steelhead smolts and juvenile cutthroat in Big Soos Creek. The remainder of this section, therefore, describes procedures to estimate production from the Green River only. Steelhead and cutthroat catches from the Green River were expanded to account for periods not fished, as was done for chinook and coho migrants using Equations 1-11. No efficiency tests were conducted on the Green River for these species, therefore another method was used to estimate production at that site. Smolt trapping data collected over the last 20 years has shown that trap efficiency is inversely related to fish size (Seiler *et al.* in press). Steelhead smolts and cutthroat migrants are similarly sized and substantially larger than coho smolts; therefore we expect trap efficiency for these species to be similar to each other and lower than that for coho smolts. We estimated steelhead and cutthroat trap efficiency on the Green River by multiplying the coho capture rate by the ratios between steelhead and coho capture rates from other sites. Because of the uncertainty reflected in the coho capture rate and with using this approach, no attempt was made to estimate the precision of the steelhead and cutthroat rates, or of the resulting migration estimates.

Daily steelhead and cutthroat migrations were estimated for the Green River using Equation 12. Daily estimates were summed to estimate total migrations of ad-marked and unmarked steelhead and cutthroat. No extrapolations of migration beyond the trapping period were performed for these species.

Results

Green River

Estimating the production of naturally-produced chinook, coho, steelhead, and cutthroat migrants was complicated by the large numbers of hatchery salmonids planted into the river. Table 1 provides a summary of hatchery releases that could have been captured in the screw trap in 2000.

Table 1. Hatchery releases of year 2000 migrants that occurred upstream or near the Green River screw trap.

	Species	Hatchery	BY	Ad-CWT	CWT Only	Ad-Only	Unmarked
1999 releases upstream of the Green River trap							
	Coho	Soos Creek	98	0	0	0	94,944
	Coho	Keta Creek	98	0	0	0	470,986
	Fall Chinook[a]	Keta Creek	98	0	0	557,033	0
1999 releases into Big Soos Creek[b]							
	Coho	Soos Creek	98	0	0	0	59,400
1999 releases where there is uncertainty whether they were released upstream of trap							
	Coho[c]	Soos Creek	98	0	0	0	89,600
2000 releases upstream of the Green River trap							
	Fall Chinook	Icy Creek	98	0	0	146,610	0
	Fall Chinook	Keta Creek	99	0	0	289,594	0
	Coho	Keta Creek	98	47,864	0	3,109	143,207
	Fall Chum	Keta Creek	99	0	0	0	1,160,851
	Winter Steelhead	Flaming Geyser	99	0	0	4,500	0
	Winter Steelhead	Keta Creek	99	0	0	50,000	0
	Winter Steelhead	Palmer	99	0	0	305,565	0
2000 releases into Big Soos Creek							
	Coho	Soos Creek	98	66,895	36,757	0	572,153
	Fall Chinook[d]	Soos Creek	99	193,356	201,589	2,581,854	534,415
2000 releases where there is uncertainty whether they were released upstream of trap							
	Fall Chinook[c]	Keta Creek	99	0		0	23,760

[a] Released above HHD, some may have been retained during fill period to migrate as 1+ smolts in 2000
[b] Although Big Soos Creek is located 0.5-miles downstream of trap, some Soos Creek fish were caught.
[c] Released into "Green River". We were unsure of the exact location. Assumed "Duwamish" releases were downstream of the trap and are not included herein.
[d] 414,800 unmarked chinook averaged less than two grams each. The rest averaged 5.89-g each.

Chinook

Catch

We caught 67 juvenile chinook on the first night of trapping, February 10, indicating the migration was underway when trapping began. Over the entire 155 day season, we captured 12,356 unmarked and 355 ad-marked age 0+ chinook migrants (Appendix A). Daily unmarked wild age 0+ chinook catch averaged 117 migrants over the first two complete days of trapping (February 11 and 12). Daily catch of unmarked migrants increased to 584 on March 3[1]. After March 3, daily catches then declined to less than 20 migrants by mid-April. Daily catches of wild age 0+ chinook migrants began to increase again in early May, peaking on May 8 at 868 migrants and again on June 12 at 515 migrants, before declining to less than 20 migrants by the last week in June.

The only confirmed hatchery chinook releases of age 0+ fry above the trap were experimental releases above Howard Hansen Dam. All of these were ad-marked. Ad-marked age 0+ chinook first entered catches on March 29, a day or two after their release on March 27 and 28. The last was caught on July 8.

Over the season, we also caught 36 unmarked and 2,218 ad-marked age 1+ chinook migrants. Ad-marked age 1+ chinook were caught from February 27 to June 14. After several weeks of not catching any ad-marked age 1+ chinook migrants, 225 ad-marked migrants were captured on April 20 and catches of greater than 20 age 1+ chinook per day continued for three weeks. A release of nearly 147,000 ad-marked age 1+ chinook from the Icy Creek Hatchery was reported to have occurred on April 24; but the catches beginning on April 20 indicated the release began a few days earlier than reported. Ad-marked age 1+ chinook catches could also have resulted from releases of 0+ chinook made above HHD in 1999 that failed to migrate prior to the water storage period and held-over to migrate in 2000. It is likely that few of these fish survived, however, since only one ad-marked age 1+ chinook was caught prior to the April 20 release from Icy Creek Hatchery.

Size

Wild chinook 0+ averaged less than 40-mm through the second week in March. They grew rapidly afterwards, averaging nearly 80-mm by June (Table 2, Figure 2). Migrants measuring around 35-mm were found through the first week in April, after which, the minimum size increased steadily to over 60-mm at the end of the trapping period. We speculate that 40-mm

[1]Catch on this date would have been higher had high debris loading during a freshet not resulted in the suspension of trap operation between an estimated 2140 hrs on March 3 to 1800 hrs on March 5. Trapping was suspended on March 3 due to debris jamming the trap screw.

Table 2. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of wild age 0+ chinook measured by statistical week, Green River, 2000.

STAT WEEK					RANGE				Percent
No.	Begin	End	Avg	s.d.	Min	Max	n	Captured	Sampled
7	02/07	02/13	38.55	1.20	35	41	40	347	11.53%
8	02/14	02/20	37.8	1.88	34	43	146	815	17.91%
9	02/21	02/27	39.26	1.62	36	44	88	1,063	8.28%
10	02/28	03/05	38.86	2.18	35	45	76	1,359	5.59%
11	03/06	03/12	38.83	2.28	34	46	71	973	7.30%
12	03/13	03/19	43.74	7.58	34	60	86	1,299	6.62%
13	03/20	03/26	57	n/a	57	57	1	646	0.15%
14	03/27	04/02	45.83	9.84	36	68	40	167	23.95%
15	04/03	04/09	52.03	12.58	34	73	36	118	30.51%
16	04/10	04/16	52.19	7.78	41	73	26	74	35.14%
17	04/17	04/23	57.22	6.55	47	65	9	46	19.57%
18	04/24	04/30	59.61	7.75	40	78	28	43	65.12%
19	05/01	05/07	63.06	7.78	50	84	47	842	5.58%
20	05/08	05/14	68.12	8.10	50	91	92	1,293	7.12%
21	05/15	05/21	69.54	7.14	55	82	35	290	12.07%
22	05/22	05/28			No sample			682	0.00%
23	05/29	06/04	79	8.15	60	93	33	310	10.65%
24	06/05	06/11	82.36	10.10	49	104	33	416	7.93%
25	06/12	06/18	79.39	6.70	65	92	38	1,319	2.88%
26	06/19	06/25	76.33	11.93	63	86	3	220	1.36%
27	06/26	07/02			No sample			21	0.00%
28	07/03	07/09	92.75	5.50	88	98	4	10	40.00%
29	07/10	07/16			No sample			3	0.00%
SEASON TOTAL			51.39	16.53	34	104	932	12,356	7.54%

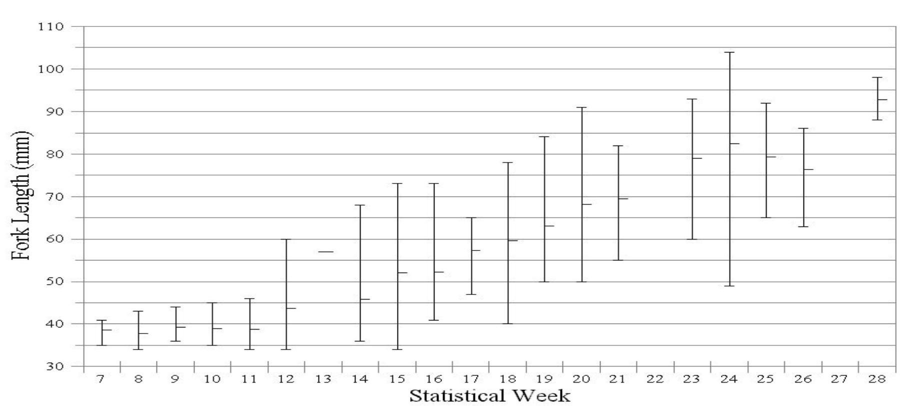

Figure 2. Weekly average, minimum, and maximum 0+ chinook fork lengths (mm) measured at the Green River screw trap, 2000.

and smaller chinook were newly emerged fry; therefore, we believe that the increase in the minimum size was an indication that incubation was completed.

Catch Expansion

The trap was operated 3,254 hours out of 3,720 hours in the 155-day trapping period, or 87.5% of the time. Trapping was suspended for 63.4-hours during six events when woody debris jammed or threatened to jam the screw. These events included a 42-hour high water event between March 3 and March 5, when trapping was suspended due to large amounts of debris. Trapping was suspended by choice at other times, and particularly during daylight hours when few fish were caught.

Immediately prior to the March 3 through March 5 suspended trapping period, the hourly age 0+ chinook catch rate was 159 migrants/hour. When trapping resumed the evening of March 5, the capture rate was down to ten migrants/hour. A regression of day/night ratios relative to flow was attempted to try and develop some predictive capabilities relative to estimating daytime catch over the 42-hour period that fishing was suspended. Unfortunately, it was determined that flow was a very poor predictor of day/night ratios, explaining only 2% of the variation. Therefore, expansion during this period was accomplished by interpolating between the two catch rates described above to estimate nighttime catch rates and applying the weekly day/night ratio to these estimates to develop daytime rates. Using Equations 1 - 11, we estimated that 2,683 additional age 0+ chinook would have been caught during the March 3 - 5 outage period. The catch expected for March 4 was estimated at 1,740 migrants, which would have been the highest single day catch over the season.

Using these techniques, we estimate an additional 3,415 age 0+ wild chinook would have been captured if continuous trapping had occurred between February 10 and July 13 (Appendix A). This represents a 28% increase over the actual catch of wild migrants. Expansion also resulted in the addition of 12 ad-marked age 0+ hatchery chinook; a 3% increase over the actual seasonal catch of 355 chinook migrants.

The chinook migration exhibited a bi-modal timing distribution. The first major migration occurred in February and March, with the downstream migration of newly emerged fry. The second migration occurred in May and June, with the downstream movement of smolted chinook. Weekly day/night catch rate ratios ranged from 0.35 to 1.3 during the fry migration and from 0.07 to 2.5 during the smolt migration (Figure 3). No discernable trend was noted among weekly day/night catch rate ratios except that after week 20 (mid-May); day/night ratios were substantially lower than in previous weeks.

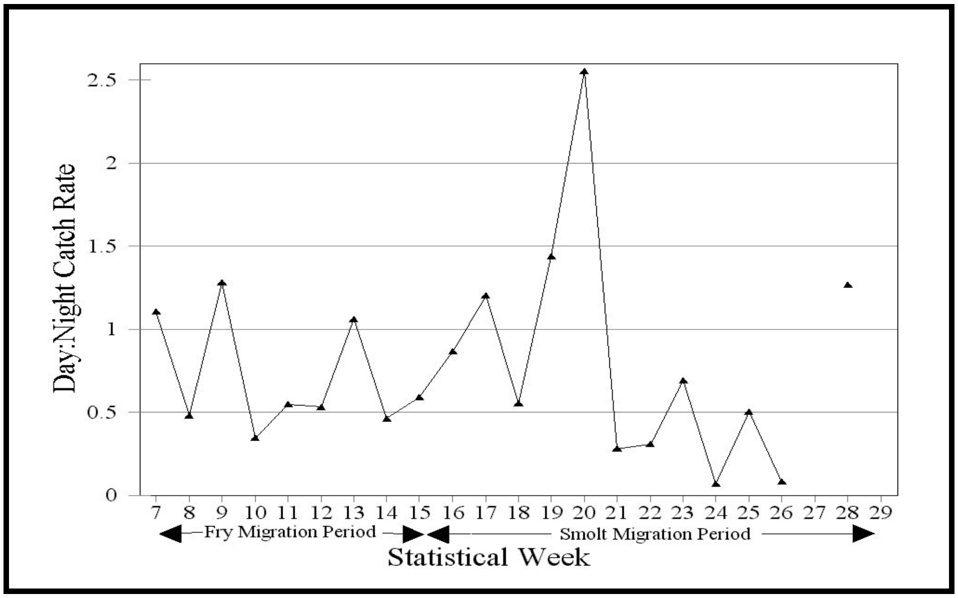

Figure 3. Weekly ratio of day/night chinook catch rates from the Green River screw trap, 2000.

Trap Efficiency

A total of 751 age 0+ wild chinook migrants in seven groups were marked and released a half mile upstream of the trap at the Nealy Bridge crossing (Table 3). The number of fish released in each group ranged from 71 to 206 chinook. Recapture rates averaged 3.43% and ranged from 1.35% to 7.00%. In addition to the chinook releases, 2,737 marked chum were released in eleven groups. Chum recapture rates averaged 6.60% and ranged from 1.96% to 10.27%. A Wilcoxin two-sample test was used to test for differences between the distributions of the chinook-based and chum-based efficiency test results. The test indicated that differences between these two distributions were significant ($p<0.05$); therefore, we decided not to include the tests using chum salmon in our estimation of the chinook capture rate.

Over the interval that we conducted the trap efficiency tests, flows ranged from 1,400 cubic feet per second (cfs) to 2,280-cfs; however, all tests but one were conducted when flows were between 1,400 and 1,700-cfs (Table 3). Using linear regression, flow explained very little of the variation between tests and was not significant ($p>0.60$).

The tests were stratified by morning and evening tests to determine if differences in capture rates existed between these two time periods. Casual examination of the data suggested there were no differences in capture rates between morning and evening strata, therefore, tests were pooled for estimation of the trap efficiency. Using all of the chinook tests, trap efficiency for chinook averaged 3.43%. This estimate was used in Equation 12 to estimate chinook migration throughout the trapping period.

Table 3. Chinook 0+ trap efficiency tests performed on the Green River screw trap, 2000.

			RELEASES			RECAPTURES	
Date	Time	Flow	Number	Mark	Location	Number	Percentage
03/20	PM	1,580	71	dye	0.5 mi fr trap	3	4.23%
05/22-23	PM	1,570	206	LC	0.5 mi fr trap	3	1.46%
05/25	AM	1,450	100	UCV	0.5 mi fr trap	5	5.00%
05/27	AM	1,400	100	UCV	0.5 mi fr trap	7	7.00%
05/28	AM	1,400	74	LC	0.5 mi fr trap	1	1.35%
06/14	AM	2,280	100	UCV	0.5 mi fr trap	3	3.00%
06/16	AM	1,700	100	UCV	0.5 mi fr trap	2	2.00%
		Sum	751			24	
					Average		3.43%
					Variance		0.000414

Chinook Production

From February 10 through July 13 we estimate 459,368 wild age 0+ chinook migrants passed the screw trap (Table 4). Extrapolation of the migration back to January 1, the date we selected to approximate the start of the chinook migration, resulted in an additional 76,340 wild 0+ migrants

Table 4. Estimated age 0+ wild and hatchery chinook migration past the Green River screw trap, 2000.

Period	Actual Catch	Expanded Catch	Estimated Migration	CV	95% CI Low	95% CI High
Wild 0+ Chinook Migrants						
Jan 1 - Feb 9	N/A	N/A	76,340	[a]12.26%	[a]57,993	[a]94,686
Feb 10 - Jul 13	12,356	15,771	459,368	18.38%	293,909	624,828
Total	12,356	15,771	535,708	15.85%	369,235	702,182
Hatchery 0+ Chinook Migrants						
Jan 1 - Feb 9	N/A	N/A	0	N/A	N/A	N/A
Feb 10 - Jul 13	355	367	10,686	37.41%	2,851	18,522
Total	355	367	10,686	37.41%	2,851	18,522
All Chinook 0+ Migrants						
Jan 1 - Feb 9	N/A	N/A	76,340	12.26%	57,993	94,686
Feb 10 - Jul 13	12,711	16,138	470,055	18.50%	299,650	640,459
Total	12,711	16,138	546,394	16.00%	375,005	717,783

[a] The CV and confidence interval about this estimate reflect variability around the slope of the extrapolation line only (Figure 4), and does not include uncertainty associated with the shape of the extrapolation line or the January 1 migration start date.

for a total wild migration of 535,708 (Figure 4). In addition to the wild fish, we estimate 10,686 ad-marked hatchery age 0+ chinook migrated by the trap during the February 10 through July 13 trapping period. Since there were no marked age 0+ hatchery migrants captured prior to their release on March 27 - 28, this estimate includes the entire hatchery ad-marked migration.

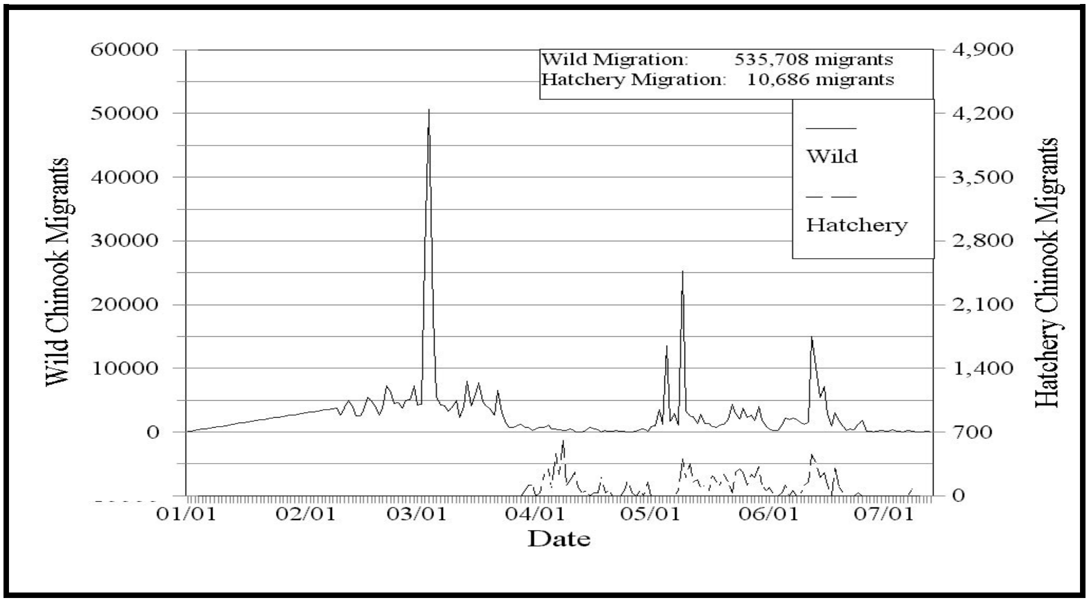

Figure 4. Estimated daily wild and hatchery age 0+ chinook migration past the Green River screw trap, 2000.

Coho

Catch

Yearling coho salmon were captured on the first night of trapping, February 10. However, catch rates were low, generally less than five per day prior to mid-April. Migration past the trap during this period may have largely been the result of within-basin movement prior to smoltification. After mid-April, daily catches of age 1+ coho increased; peaking at 2,991 smolts on May 10 (Figure 5). Of these, 750 were ad-marked and 2,241 were unmarked. Daily catches declined thereafter to near zero by June 20. Over the 155-day trapping period, a total of 23,501 coho were captured, of which 5,167 were ad-marked and 18,334 were unmarked.

Ad-marked hatchery coho smolts began to show up in the catch in low numbers on February 11. Between February 11 and April 19, 21 ad-marked coho were caught. This period was prior to any known yearling hatchery coho releases in 2000. Therefore, these fish had likely escaped from Soos Creek and/or Keta Creek hatcheries. An additional 67 ad-marked coho smolts were captured between April 20 and May 1. This period was after the Soos Creek Hatchery coho release, but prior to the Keta Creek Hatchery release. The mouth of Big Soos Creek is located about a half-mile downstream of the smolt trap; therefore, it is assumed that these ad-marked coho were smolts that had swum upstream from Big Soos Creek to the trap. Following the May 2 release of ad-marked coho smolts from Keta Creek Hatchery, located about six miles upstream of the trap, we captured 5,079 ad-marked coho smolts. In order to estimate migration, we assumed all 88 ad-marked coho smolts captured prior to May 2 were Soos Creek Hatchery coho that had swum upstream. We assumed that all marked coho captured on or after May 2 were Keta Creek coho.

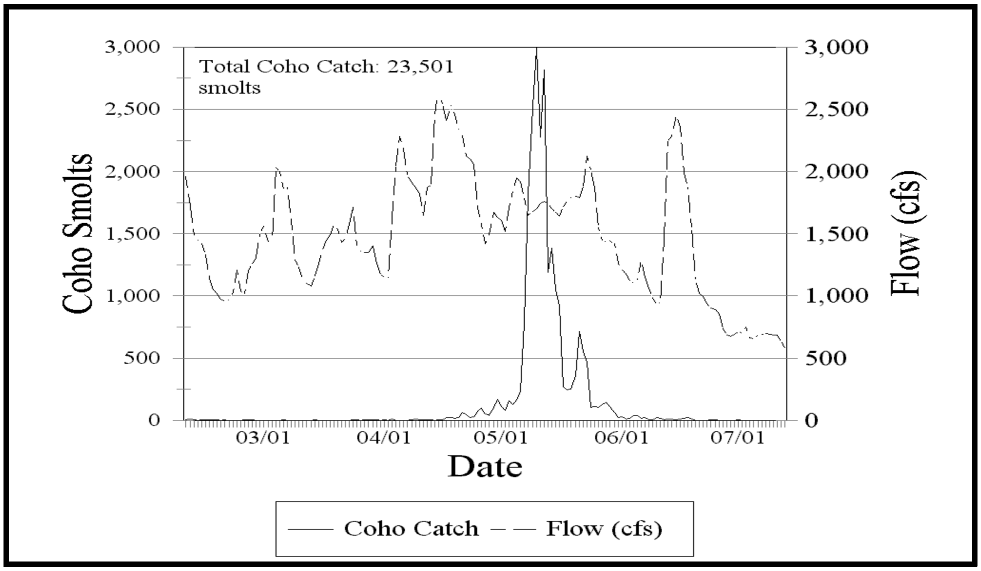

Figure 5. Daily catch of coho smolts in the Green River screw trap relative to stream discharge measured at USGS Gage #12113000, 2000.

Size

Over the trapping season, unmarked wild coho fork lengths averaged between 96-mm and 128-mm for most weeks that were sampled (Table 5, Figure 6). The sizes of individual age 1+ migrants ranged from 60-mm to 195-mm over the trapping season. Four smolts were captured that measured greater than 180-mm that were likely age 2+ migrants, although this was not verified by scale analysis.

Catch Expansion

Although trapping operations were suspended for a total of 466 hours over the course of the trapping period, almost all of the non-fished periods occurred outside the time of coho migration (at night from April through mid-June). If we can assume that the proportions of coho migrants caught during day and night fishing periods was the same, then the weekly day/night catch rate ratios for coho indicated that during the peak migration period generally less than one smolt in ten migrated during the day (Figure 7). As a result, catch expansion resulted in the addition of only ten smolts, nine unmarked and one marked, to the actual catch of 23,501 smolts. The expansion represents only a 0.04% increase to the actual catch.

STAT WEEK No.	Begin	End	Avg	s.d.	RANGE Min	Max	n	Captured	Percent Sampled
7	02/07	02/13	99.3	8.38	90	113	9	15	60%
8	02/14	02/20	99.0	8.83	85	111	6	14	43%
9	02/21	02/27	110.8	16.68	86	122	4	10	40%
10	02/28	03/05	96.0	2.65	94	99	3	2	150%
11	03/06	03/12	109.5	14.98	92	127	4	4	100%
12	03/13	03/19	112.0	N/A	112	112	1	5	20%
13	03/20	03/26	122.6	32.07	88	187	7	11	64%
14	03/27	04/02	118.9	18.84	102	172	12	16	75%
15	04/03	04/09	107.3	28.76	60	191	21	24	88%
16	04/10	04/16	104.9	16.95	62	147	19	29	66%
17	04/17	04/23	116.0	21.75	78	195	66	217	30%
18	04/24	04/30	110.4	5.22	104	119	7	568	1%
19	05/01	05/07			No sample			1,660	0%
20	05/08	05/14	127.7	11.77	104	150	30	14,978	0%
21	05/15	05/21			No sample			3,819	0%
22	05/22	05/28			No sample			1,614	0%
23	05/29	06/04	120.4	15.76	96	149	35	292	12%
24	06/05	06/11			No sample			128	0%
25	06/12	06/18			No sample			75	0%
26	06/19	06/25			No sample			16	0%
27	06/26	07/02			No sample			2	0%
28	07/03	07/09			No sample			2	0%
SEASON TOTAL			115.1	20.37	60	195	224	23,501	1%

Table 5. Mean fork lengths (mm), standard deviations, ranges, and sample sizes of unmarked coho smolts measured by statistical week, Green River 2000.

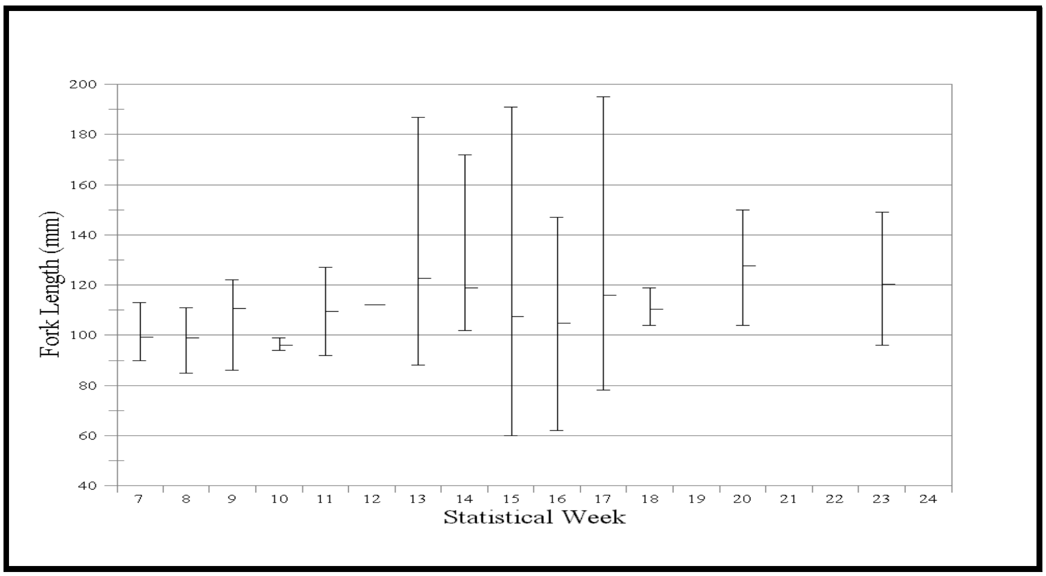

Figure 6. Weekly average, minimum, and maximum unmarked coho smolt fork lengths (mm) measured at the Green River screw trap, 2000.

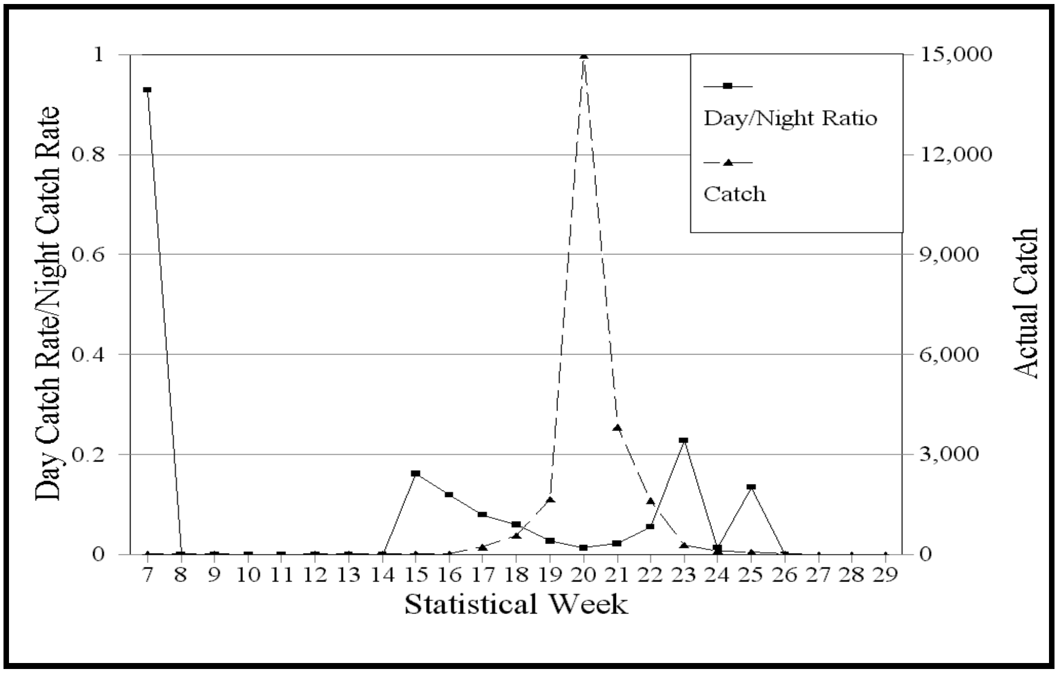

Figure 7. Weekly ratios of day/night coho catch rates relative to migration timing as described by catch, Green River screw trap 2000.

Coho Production

Coho trap efficiency was estimated at 9.97% based on the capture of 5,079 ad-marked coho out of 50,973 smolts released from Keta Creek Hatchery on May 2 (Table 6). This capture rate assumes all marked coho released from the hatchery survived and passed the trap. Applying this rate to our season catch yields a total coho migration estimate of 235,928 coho smolts.

Both Soos Creek and Keta Creek Hatcheries released unmarked coho smolts along with the ad-marked releases. We estimated 203,159 hatchery smolts, ad-marked and unmarked, migrated past the trap by expanding the estimated migration of ad-marked hatchery smolts by the ratio of unmarked to ad-marked hatchery smolts released from the two hatcheries (Table 6). Total wild migration was therefore estimated at 32,769 smolts, the difference between the total migration and hatchery migration estimates. Because the accuracy of the hatchery release numbers was unknown, we did not attempt to calculate variances or confidence intervals about these estimates.

Table 6. Estimated coho trap efficiency and migration of wild and hatchery coho smolts past the Green River screw trap, 2000.

Hatchery Group	Expanded Marked Catch	Trap Efficiency	Marked Migration	Unmarked/ Marked Ratio	Unmarked Migration	Total Migration
Soos Coho (Captured prior to 5/2)	89[a]	9.97%	889	9.10	8,090	8,979
Keta Coho (Captured on/after 5/2)	5,079[b]	9.97%	50,973	2.81	143,207	194,180
Total	5,168	9.97%	51,862		151,297	203,159
					Estimated Total Migration	235,928
					Estimated Hatchery Migration	203,159
					Estimated Wild Migration	32,769

[a] Assumes that all ad-marked smolts captured prior to the Keta Creek Hatchery coho release date were Soos Creek coho smolts that migrated upstream and were captured in the trap.
[b] Assumes that all ad-marked coho captured on and after May 2 were from the Keta Creek Hatchery coho release.

Steelhead and Cutthroat

Catch

Over the trapping season, we caught 2,855 unmarked wild steelhead smolts (Figure 8) and 33 juvenile cutthroat. We also captured 3,661 ad-marked steelhead that had been released from the Palmer Ponds, Keta Creek Hatchery, and Flaming Geyser Ponds, resulting in a total steelhead catch of 6,516. Three cutthroat were identified as adipose-marked at the trap. However, since there was no record of marked cutthroat releases in the basin, we believe these fish had naturally missing adipose fins.

The migration of both ad-marked and unmarked steelhead occurred between mid-April and the end of May. Outside of this period, total catches of ad-marked and unmarked steelhead were generally less than five per day. The catch of unmarked wild smolts peaked on May 11 with a catch of 211 smolts. The catch of ad-marked fish peaked on May 7, with a catch of 613 smolts.

Juvenile cutthroat were intermittently captured throughout the trapping period. The majority of cutthroat were caught between April 1 and May 15.

Size

A total of 27 steelhead fork lengths were taken during the first half of the trapping period. Increasing work load resulted in lengths not being taken after April 30, when most of the

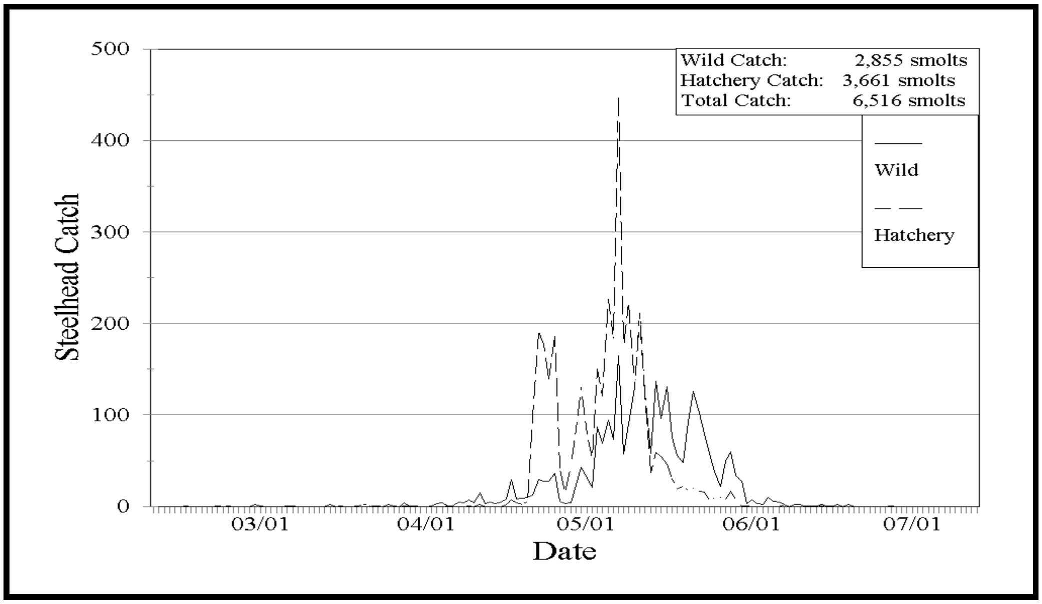

Figure 8. Daily catch of ad-marked and unmarked steelhead smolts in the Green River screw trap, 2000.

steelhead migration occurred. Therefore, a size trend could not be developed due to the low sample size; however, length frequency information using all of the data show that most smolts were between 100-mm and 160-mm (Figure 9). The mean length was 145-mm.

Fifteen cutthroat fork lengths were taken over the trapping period. Cutthroat ranged in size from 85-mm to 175-mm. The distribution was skewed to the right with the largest proportion of the fork lengths being found in the smaller size categories (Figure 10). Cutthroat lengths averaged 120-mm for all fish sampled.

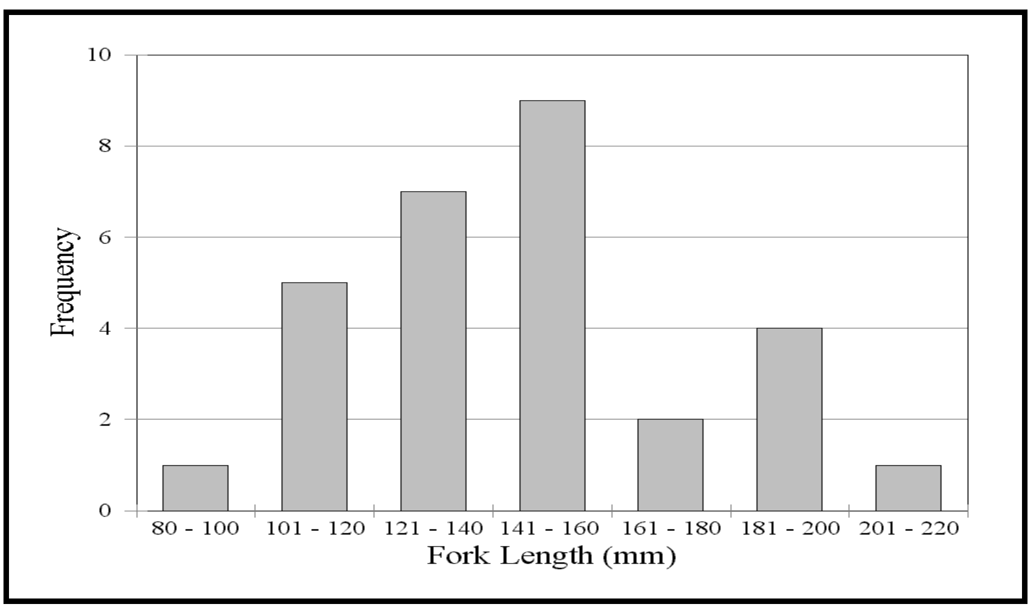

Figure 9. Frequency distribution of wild steelhead fork lengths (mm) taken at the Green River screw trap, 2000.

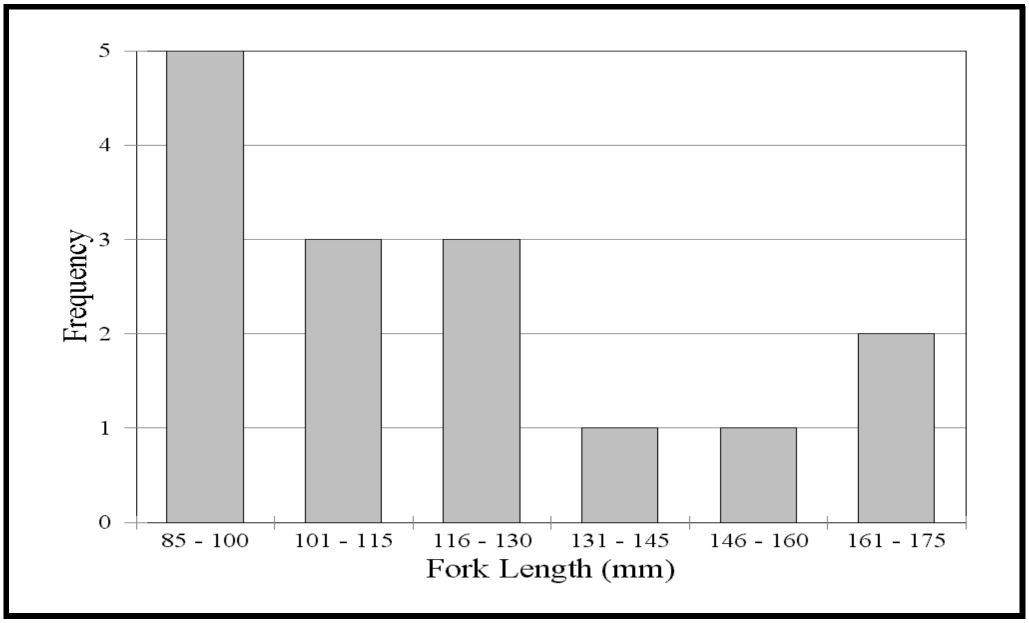

Figure 10. Frequency distribution of cutthroat smolt fork lengths (mm) taken at the Green River screw trap, 2000.

Catch Expansion

As was the case with coho salmon, most of the suspended trapping periods and outages occurred during times when few steelhead and cutthroat were migrating. Catch expansion resulted in the addition of just three steelhead smolts and one cutthroat smolt. Of the three steelhead, we estimated that one was wild and two were ad-marked. These expansions resulted in 0.05% and 3.0% increases to the actual steelhead and cutthroat catches, respectively.

Trap Efficiency

In any migrant trapping operation, trap efficiency is influenced by a number of variables such as the channel configuration, the size/swimming ability of the captured fish, the velocity of water entering the trap, the position in the channel/water column preferred by the migrant, and the design of the trap itself. In most western Washington stream systems, steelhead and cutthroat smolts are similar in size and therefore, we believe, are caught at about the same rate.

Trap efficiency was not measured for steelhead and cutthroat during this study. However, measurements taken in previous years in the Toutle, Green, and White Salmon Rivers showed that steelhead smolts were captured at 79%, 54%, and 47%, respectively, of the coho capture rates (Seiler and Neuhauser 1985, Seiler *et al.* 1992). The average steelhead-to-coho capture rate ratio from these three studies (60%) was adjusted to account for site-specific factors and used to estimate steelhead and cutthroat trap efficiencies on the Green River from the coho trap efficiency data. Because we believed conditions at the Green River during this study resulted in higher steelhead capture rates, the 60% steelhead-to-coho capture rate ratio was increased to a range of 70 to 80%. This adjustment was made since the other studies captured fish using inclined-plane (scoop) traps, whereas screw traps, which are more efficient at capturing larger migrants than are scoop traps, were used in this study (Seiler *et al.* 2001). In addition, stream velocities at this location on the Green River were higher than at the other sites. Applying these ratios to the 9.97% coho trap efficiency resulted in a steelhead and cutthroat capture rate range of 6.98% to 7.98%. No variance estimates were made for these rates.

Steelhead and Cutthroat Smolt Production

Application of the steelhead/cutthroat trap efficiency estimate to the expanded steelhead catch, estimated the migration of 35,701 to 40,801 wild steelhead smolts and 45,786 to 52,326 ad-marked hatchery steelhead smolts during the period of trap operation. Using the same trap efficiency estimates, total migration of cutthroat during trapping operations is estimated between 423 and 484 cutthroat. We made no attempts to adjust this figure to represent production beyond the period we trapped or to develop confidence intervals about these estimates.

Other Species

A number of other fish species and other salmonid age classes were captured and enumerated in the catch. Over the trapping period, a total of 70,781 chum fry, 725 age 0+ coho fry, 1,200 pink fry, 43 sockeye fry, 310 age 0+ trout, and 2,254 age 1+ chinook were captured in the trap (Table 7). Of the 2,254 age 1+ chinook caught, 2,218 were ad-marked. As discussed earlier, we believe nearly all of these fish were from a yearling chinook release from Icy Creek Hatchery.

In addition to salmonids, a number of other species were captured (Table 8). The most numerous non-salmonids captured were sculpin, three-spine stickleback, longnose dace, and lamprey ammocoetes. Whereas sculpin were caught throughout the trapping period, the other taxa were primarily caught after May 1, when the water temperature began to rise (Figure 11).

Predation

Stomach samples were taken from 216 fish over the season to evaluate predation rates on other fish. Samples were taken from sculpin, steelhead smolts, coho smolts, chinook 1+ smolts, cutthroat smolts, and trout parr. Sculpin were found to have the highest average number of fish prey per sample, 10.1 (Table 9). Consumption rates for other species averaged less than one fish per sample. We believe that the high predation rate found in sculpin was related to their being held in close proximity to their prey in the trap live well.

Table 7. Weekly catches of non-targeted salmonids in the Green River screw trap, 2000.

STAT WEEK			CATCH						
								Chinook 1+	
No.	Begin	End	Chum	Coho 0+	Pink	Sockeye	Trout 0+	Unmarked	Marked
7	02/07	02/13	0	0	0	0	5	0	0
8	02/14	02/20	13	1	4	1	3	0	0
9	02/21	02/27	29	12	2	0	10	0	1
10	02/28	03/05	27	15	1	0	7	0	0
11	03/06	03/12	306	52	25	8	3	0	0
12	03/13	03/19	6,676	182	157	22	10	0	0
13	03/20	03/26	1,561	112	217	2	15	0	0
14	03/27	04/02	6,234	113	421	4	18	0	0
15	04/03	04/09	8,369	49	271	6	53	3	0
16	04/10	04/16	36,004	28	90	0	38	1	0
17	04/17	04/23	5,083	2	11	0	29	4	562
18	04/24	04/30	3,114	1	1	0	7	1	1,223
19	05/01	05/07	1,482	1	0	0	9	0	302
20	05/08	05/14	890	4	0	0	41	15	99
21	05/15	05/21	595	8	0	0	18	2	13
22	05/22	05/28	261	7	0	0	15	3	4
23	05/29	06/04	70	13	0	0	9	1	4
24	06/05	06/11	34	15	0	0	6	1	1
25	06/12	06/18	31	68	0	0	11	1	9
26	06/19	06/25	2	30	0	0	1	4	0
27	06/26	07/02	0	6	0	0	1	0	0
28	07/03	07/09	0	5	0	0	0	0	0
29	07/10	07/16	0	1	0	0	1	0	0
SEASON TOTAL			70,781	725	1,200	43	310	36	2,218

Table 8. Weekly catches of non-salmonid fishes in the Green River screw trap, 2000.									
STAT WEEK			CATCH						
No.	Begin	End	Sculpin	Three-spine Stickleback	Lamprey	Peamouth	Sucker	Longnose Dace
7	02/07	02/13	4	2	1	0	0	0
8	02/14	02/20	1	8	4	0	0	0
9	02/21	02/27	1	10	6	1	0	0
10	02/28	03/05	7	4	2	0	0	0
11	03/06	03/12	3	8	3	0	2	0
12	03/13	03/19	7	9	1	0	0	0
13	03/20	03/26	11	4	2	0	0	0
14	03/27	04/02	12	3	2	0	0	0
15	04/03	04/09	18	1	6	0	0	3
16	04/10	04/16	7	3	5	0	2	3
17	04/17	04/23	10	1	2	0	1	6
18	04/24	04/30	12	1	1	0	0	20
19	05/01	05/07	9	3	10	0	0	17
20	05/08	05/14	2	4	5	0	4	50
21	05/15	05/21	4	3	4	1	2	43
22	05/22	05/28	2	7	6	4	0	20
23	05/29	06/04	4	37	1	0	7	14
24	06/05	06/11	6	10	4	0	3	9
25	06/12	06/18	0	14	36	0	5	15
26	06/19	06/25	4	27	3	0	3	4
27	06/26	07/02	1	1	6	0	0	2
28	07/03	07/09	3	0	1	0	0	0
29	07/10	07/16	0	0	0	0	0	0
SEASON TOTAL			128	160	111	6	29	206

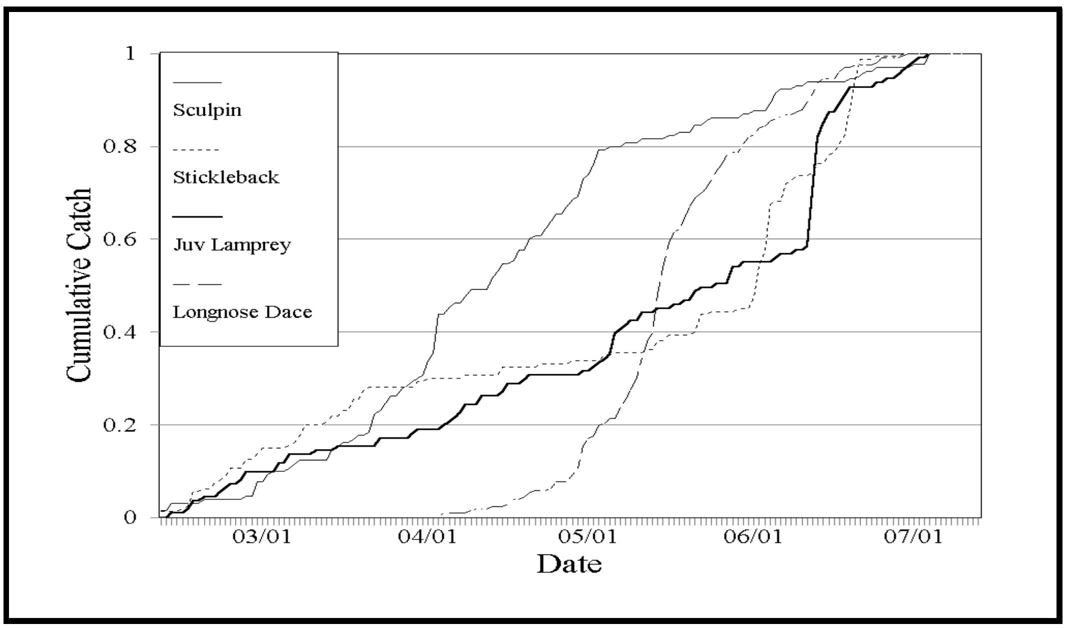

Figure 11. Cumulative catch distribution for sculpin, three-spine stickleback, lamprey, and long-nose dace captured in the Green River screw trap, 2000.

Table 9. Fish prey items found in the stomach samples of fish captured in the Green River screw trap, 2000.

Data Categories	Species Sampled: Sculpin	Steelhead	Trout Parr	Coho	Chinook 1+	Cutthroat
# Sampled	63	44	45	50	8	6
Prey Found						
Chinook	34	6	0	0	0	0
Chum	297	23	7	16	2	1
Coho	5	1	1	0	0	0
Trout	4	0	0	0	0	0
Pink	28	3	4	0	0	0
Unid Salmonids	262	2	23	10	1	1
Lamprey	7	0	0	0	0	0
Sucker fry	1	0	0	0	0	0
Dace	1	0	0	0	0	0
Prey/Sample	10.14	0.80	0.78	0.52	0.38	0.33

Big Soos Creek

We operated the trap for a total of 3,304.75 hours out of the 3,495.75 hours over the 147-day trapping period, or 94.5% of the time. Trap operation was suspended during three time intervals over the trapping period. The first occurred during the day on February 9, when trapping was suspended for three hours (0830 to 1130) after a large log damaged the trash drum. It was also suspended during the day for 10.5 hours (0830 to 1900) on May 2 as a result of operator error. The last occurrence was between June 12 and June 20, when trapping was suspended for 177.5 hours due to damage to the bearings.

In addition to these repairs, large woody debris stopped the screw several times during the season. These stoppages occurred on February 9, 10, and 29, March 5, and May 22. In each case, we examined catch rates during the fishing periods preceding and following the interrupted period. Since in all cases trap rates during these periods were similar to the interrupted period, we assumed that the stoppage events had likely occurred shortly before the trap check, and thus did not require catch expansion.

Chinook

Catch

On February 1, the first night of trapping, we caught 226 age 0+ chinook (22 migrants/hour), indicating that the migration was already underway. Daily catches increased sharply, shortly after trapping began, and peaked on February 23, with 6,511 migrants. In total we captured 90,283 age 0+ chinook during the trapping season (Table 10).

Age 0+ chinook catches were expanded to estimate the catch that would have occurred when trapping was suspended. For the three-hour daytime trap outage on February 9 , we used the daytime catch rate (11.1 migrants/hour) observed during the 5.5 hours the trap fished on that date to estimate 33 additional migrants. To estimate catch during the 10.5 hour daytime trap outage on May 2, we used the average of the daytime catch rates for the days preceding and following that day (1.4 migrants/hour). As the chinook migration appeared to be over by mid-June, we did not interpolate catches for the 177.5-hour trap outage between June 12 and June 20 (Table 10).

In addition to the age 0+ chinook migrants, we captured ten yearling chinook migrants during the trapping period. All chinook captured were unmarked, naturally-produced fish.

Table 10. Actual and estimated catches of juvenile chinook, coho, steelhead, and cutthroat in the Big Soos Creek screw trap, 2000.				
Period	**Chinook 0+**	**Coho 1+**	**Steelhead Smolts**	**Cutthroat Smolts**
February 1 to June 26	90,283	6,266	238	152
Trap Outages				
February 9	33	0	0	0
May 2	15	31	0	0
June 12 to 20	0	42	0	0
Total	90,331	6,339	238	152
Actual	99.9%	98.8%	100.0%	100.0%
Estimated	0.1%	1.2%	0.0%	0.0%

Trap Efficiency

Trap efficiency tests began on March 22. As it turned out, the chinook migration was nearly over by this date, therefore, only one group of 121 age 0+ chinook was released on March 22. All of the recaptured marks (seven total) were recovered the same day (Table 11). Substantial variability is often observed between individual efficiency tests, particularly at trap sites with low velocity flow. Since velocities at the Big Soos Creek trap site were low over much of the season, we were not comfortable estimating chinook migration from the results of a single test. We opted, therefore, to base the chinook capture rate on the rates measured for coho salmon. We used an approach similar to the one used to estimate steelhead and cutthroat capture rates at the

Table 11. Summary of age 0+ chinook and coho smolt mark release-recapture tests, Big Soos Creek 2000.

DATE		RELEASE			RECAPTURE		Average
Start	**End**	**Species**	**No.**	**Mark**	**No.**	**%**	**Flow**
03/22	03/22	chin 0+	121	dye	7	5.8%	189
03/24	03/27	coho 1+	37	RV	10	27.0%	164
03/28	04/01		37	UCV	7	18.9%	138
04/02	04/05		25	LV	3	12.0%	120
04/06	04/09		19	LCV	6	31.6%	118
04/10	04/13		32	UCH	5	15.6%	111
04/14	04/17		68	LCH	8	11.8%	154
04/18	04/21		171	UCV	19	11.1%	112
04/22	04/26		369	RV	25	6.8%	107
04/27	04/29		181	LV	6	3.3%	105
04/30	05/05		630	LCV	69	11.0%	108
05/06	05/09		386	UCH	34	8.8%	126
05/10	05/13		295	LC	39	13.2%	159
05/15	05/24		259	UC	12	4.6%	107
05/19	05/22		236	LC	9	3.8%	113
		Total	2,745		252	9.2%	124

Green River trap.

A total of 2,745 ad-marked coho smolts in 14 mark groups were released, of which we recovered a total of 252 smolts (Table 11). Recapture rates ranged from 3.3% to 31.6%, with average test period flows ranging from 105 to 164-cfs. Average daily flows during the test periods ranged from 90 to 186-cfs. Recovery rates were regressed against flow, using several transformations to find the best fit (linear, inverse, power, exponential, and log). The best fit was achieved using logarithmically transformed flow data, although the fit was only marginally better than straight line regression (Figure 12). The fit was greatly improved by removing the results of the trap efficiency test conducted between April 6 and April 9[2]. This test resulted in a much higher capture rate compared to other tests conducted at similar flow levels. We believe this result was at least partially due to the small sample size as only 19 marked coho were released in this group.

Flow levels above and below the range of daily flow observed during efficiency testing (90-cfs to 186-cfs) occurred in February, March, and June (Figure 13). We were not comfortable extrapolating trap efficiency from the regression equation when flows were substantially outside the range observed during the efficiency tests. We believe that trap efficiency was positively correlated with flow over this range because increasing velocities at higher flows improved the capture rate. Outside of this range of flows, however, other compensating mechanisms likely modified the flow relationship. For instance, as flows declined the regression equation predicted that efficiencies would approach zero or become negative (Figure 12); yet we still caught coho during those periods. At some point as flows exceeded the range of flows measured during the efficiency tests, the trap would be expected to become less efficient as water and fish, that were formerly confined to the channel at lower flows, begin to spill out onto flooding point bars, side channels, and the flood plain.

The lowest and highest capture rates measured were approximately 3% and 30%, respectively. Therefore, to avoid extrapolating capture rates beyond those observed during actual tests, we arbitrarily set these values as the minimum and maximum capture rates that were used to estimate migration. By inserting these values into the regression equation and solving for flow, the 3% and 30% capture rates were predicted when flows fell below 91-cfs or reached or exceeded 240-cfs, respectively (Figure 12).

Chinook capture rates were estimated from the regression-derived coho capture rate (Equation 16) using an average of the chinook:coho capture rate ratios observed in our Cedar River and Bear Creek screw traps in 1999 and 2000 (Seiler *et al. in press*). Chinook capture rates were 1.15 to 1.68 times higher than the coho rates measured in the Cedar River, and 1.49 to 1.66 times higher than the coho rates measured in Bear Creek. Therefore, we expanded the predicted coho rates by the average of these ratios (1.5) to estimate the chinook capture rates in Big Soos Creek.

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[2]The r^2 was improved from 0.231 to 0.486 by removing this outlier.

As a result of the maximum and minimum trap efficiency rate limits developed for coho, trap efficiencies for chinook ranged from 4.5% to 45% over the trapping period.

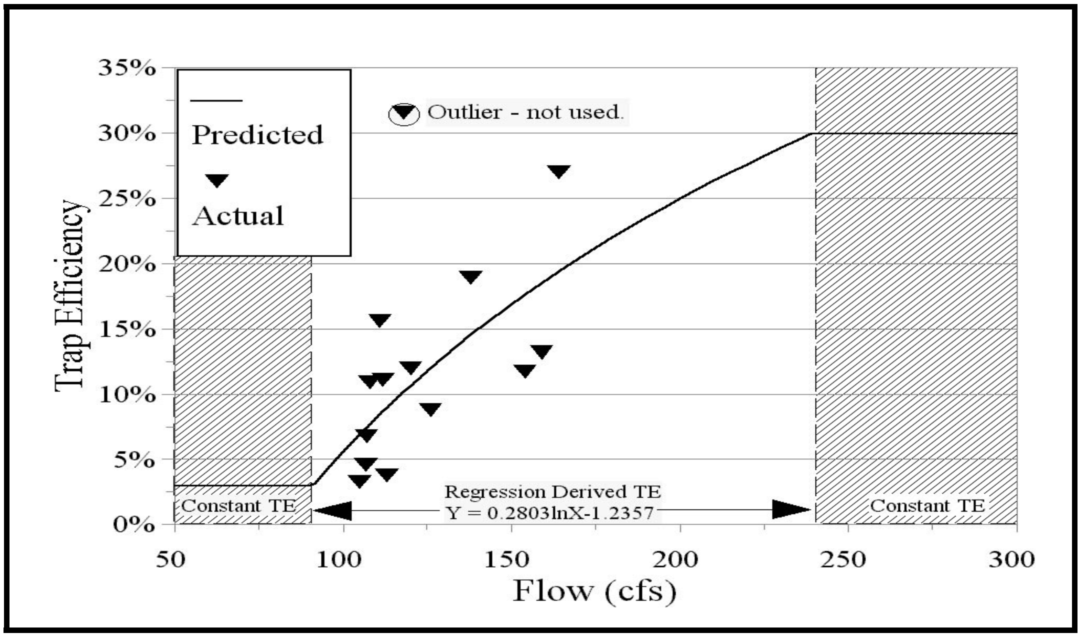

Figure 12. Regression-based and constant coho trap efficiency modeled over a range of stream flows, Big Soos Creek 2000.

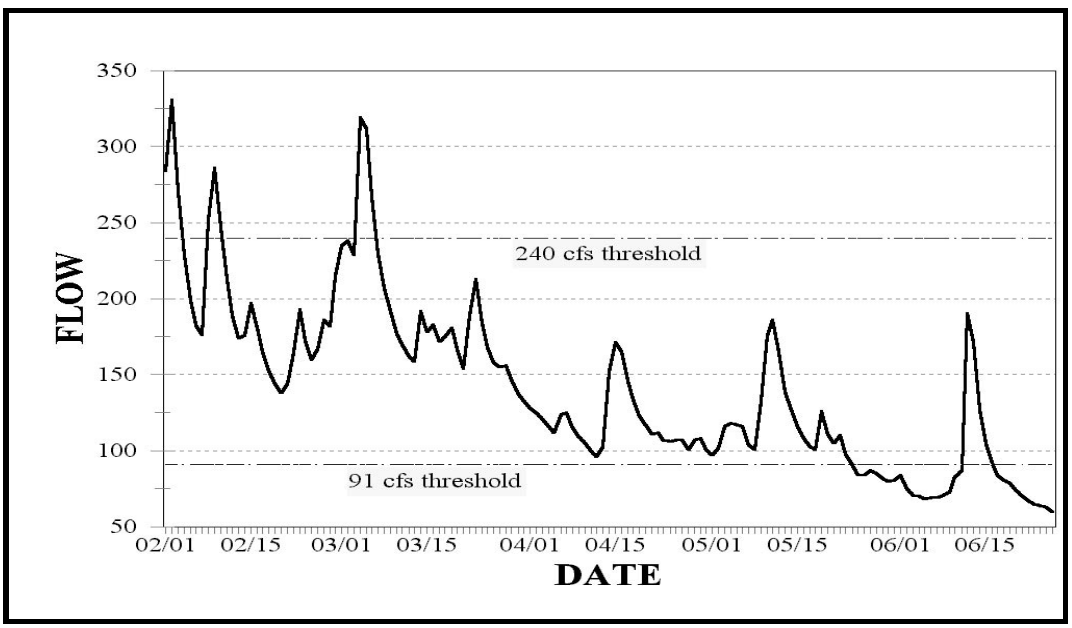

Figure 13. Daily mean flow (cfs) in Big Soos Creek between February 1 and June 26, 2000 and threshold values outside of which trap efficiency maxima and minima values were used; USGS Big Soos Creek flow station #12112600.

Chinook Production

We estimated a total of 266,977 age 0+ chinook migrated during the trapping period (Figure 14). Based on our findings from other Western Washington systems, we selected January 1, as the date on which the naturally-produced chinook migration began. The average of the first three full-days of trapping (February 2 to 4) was 526 migrants. Therefore, linear extrapolation estimated migration of an additional 8,148 age 0+ chinook between January 1 through January 31. Total migration was estimated at 275,125 age 0+ migrants. Confidence intervals about this migration estimate were not made.

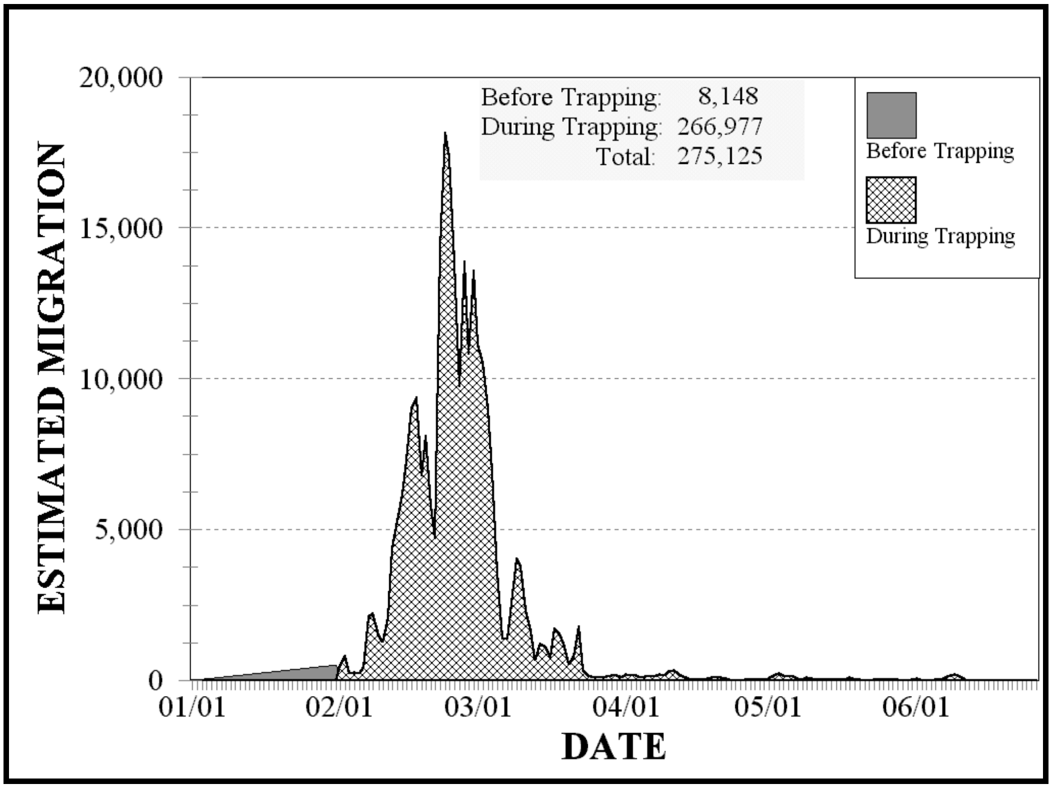

Figure 14. Estimated migration of age 0+ chinook, Big Soos Creek 2000.

Coho

Catch

Yearling coho were caught during the first day of trapping. Catch rates were low, and generally remained at less than ten smolts per day until early-March. Much of the early coho catch may have been within-system migration of pre-smolts. The coho smolt catch began to increase in early April, and peaked on May 11, with 623 smolts. Daily catches declined thereafter, with only one or two smolts per day caught during the last week of trapping in late-June. Over the 147-day trapping period, we caught a total of 6,266 coho smolts. All captured coho were unmarked, naturally-produced migrants.

Catch estimated for periods when the trap did not fish resulted in an additional 73 smolts, bringing the season total estimated catch to 6,339 smolts (Table 10). The additional coho added to the actual catch represented 1.2% of the total expanded coho catch.

We also captured 24,404 age 0+ coho fry during the trapping season. These catches were not expanded for trap outages.

Coho Production

Using the flow-based trap efficiency estimates described above and depicted in Figure 12, an estimated total of 64,341 coho smolts migrated past the trap in 2000 (Figure 15). Since the trapping period encompassed the entire coho migration, no extrapolation beyond this period was necessary. By May 8, more than 50% of the estimated naturally-produced coho migration passed the trap.

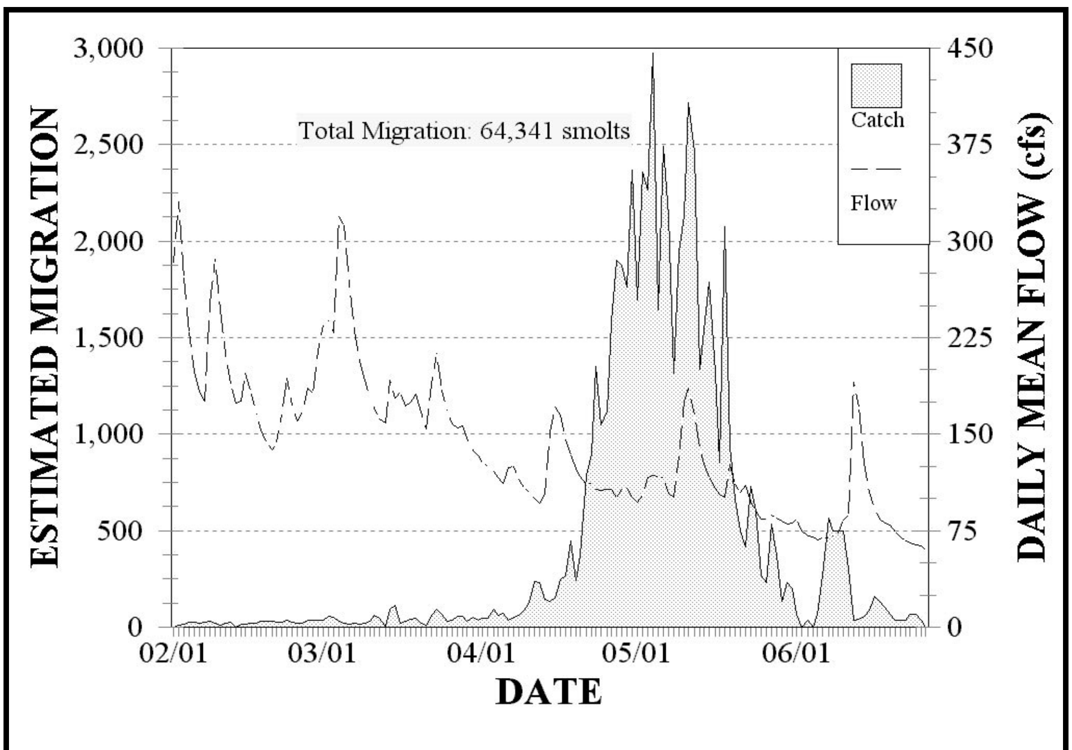

Figure 15. Estimated coho smolt migration relative to daily mean stream flow measured at USGS Gage #12112600, Big Soos Creek 2000.

Steelhead and Cutthroat

Catch

A total of 238 steelhead smolts and 152 juvenile cutthroat were captured over the trapping season (Table 10). One of the steelhead captured had a missing adipose fin. Since no known releases of hatchery steelhead occurred above the trap, either this fin was naturally missing or a hatchery steelhead migrated above the trap from the main river. Steelhead catches were generally less than five smolts per day over most of the trapping period. Catches rose in early May and peaked at 23 smolts on May 11 (Figure 16). The steelhead run was virtually over by late May.

Cutthroat catches never exceeded five fish per day over the trapping season. Prior to May 5, cutthroat catches ranged from zero to five fish per day and never exceeded one cutthroat per day after this date (Figure 16). No cutthroat were captured after June 11. In addition to the steelhead smolts and juvenile cutthroat, 288 age 0+ trout parr, and five adult cutthroat were caught in the trap.

Catch rates during fishing periods adjacent to un-fished periods were very low for both species. Therefore, the catch was not expanded to account for steelhead or cutthroat missed during those periods. No migration estimates were made for these species.

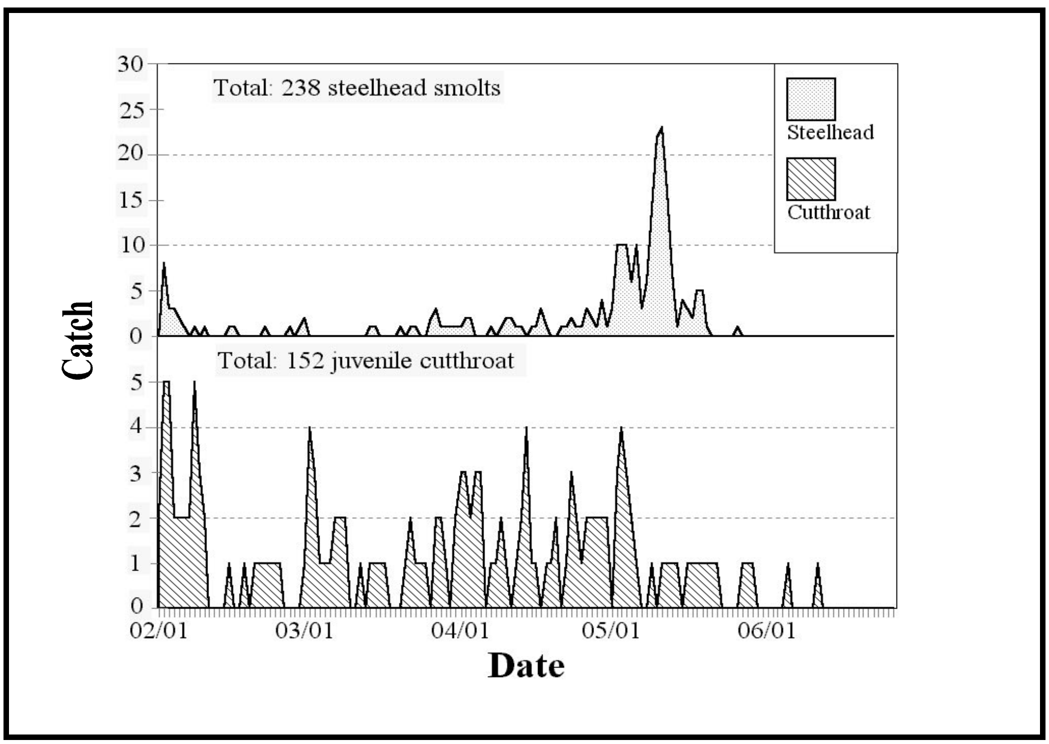

Figure 16. Daily catch of steelhead smolts and juvenile cutthroat trout, Big Soos Creek 2000.

Discussion

Production estimates were developed for Green River wild and hatchery age 0+ chinook, wild and hatchery yearling coho, wild and hatchery steelhead, and wild cutthroat smolts, as well as for Big Soos Creek naturally-produced age 0+ chinook and naturally-produced yearling coho. This section of the report will primarily focus on the work done in the Green River as well as the production estimates for Big Soos Creek naturally-produced age 0+ chinook. While the capture of coho, steelhead, and cutthroat, and the estimated production of naturally-produced coho 1+ in the Big Soos Creek provided useful information regarding the relative abundance of these species, these assessments were outside the scope of our objectives for trapping Big Soos Creek. Therefore, work in Big Soos Creek outside of that leading to a production estimate for age 0+ chinook was not included in this discussion.

Chinook

Green River Production

The accuracy of the wild age 0+ chinook production estimate for the Green River is partially dependent on the veracity of the estimated catch that was missed during periods when the trap was not fishing. We believe the highest proportion of this missed catch (79%) occurred between March 3 and March 5, during the period that the trapping was suspended due to high flows and debris entrainment. Interpolation of the catch rate data immediately prior to and following the suspension of trapping resulted in an estimated missed catch of 2,683 wild chinook migrants. Over the March 3 to 5 period, we estimate an average daily catch of 1,109 chinook migrants would have occurred. This compares to average daily catches of 180 and 159 chinook migrants for the three days prior to and following this period. Although the accuracy of this estimate is unknown, catches measured at other sites where trapping continued through this period corroborates the magnitude of the catch missed. For example, the catch of age 0+ wild chinook past the Skagit River traps on March 3 and 4 was 2,368 and 1,916 migrants, respectively; the highest catches of the year at that location (Seiler *et al.* 2001).

The accuracy of the wild age 0+ chinook production estimate is also dependent on the veracity of our estimated capture efficiency. Chinook migration estimates were developed based on a measured average trap efficiency of 3.43%. Efficiency release groups needed to be released far enough upstream of the trap for the migrants to assume the same distribution across the river as the migrants they represented, but close enough to the trap to minimize predation. Release of the fish a 0.5-miles above the trap may have exposed marked chinook to a substantial amount of predation. Un-quantified predation on these fish would bias capture rates low and migration estimates high.

The efficiency rates measured using chum salmon averaged over twice as high (6.6%) as the rate measured using chinook. This was not unexpected given the smaller size of the chum salmon used in the tests. Trap efficiency estimates measured for chinook and chum salmon were substantially lower than the 10% efficiency estimated for coho salmon. Of course whereas chinook and chum capture rates were measured using a number of mark-recapture tests, coho rates were measured using a single release of ad-marked coho from the Keta Creek Hatchery, which relied on different assumptions (see the Discussion Section for Green River Coho).

Typically, larger migrants such as coho salmon, steelhead, and cutthroat smolts are expected to be caught at lower rates than chinook salmon due to their larger size and faster swimming ability. At the Green River trapping site, this advantage may be reduced due to the high water velocity entering the trap. Taylor and McPhail (1985) found that sub-yearling wild coastal coho had a burst speed (speed that can be maintained for only seconds) that was as much as 2.16 times the sustained speed (speed that can be maintained for minutes) measured in swimming tests. Bell (1991) reported sustained swimming speeds for coho smolts at up to 2.1-feet per second (fps). Application of Taylor and McPhail's burst to sustained swim speed ratio to Bell's coho smolt sustained swim speed suggests the burst speed for coho smolts may be approximately 4.5-fps. Velocity at the mouth of the trap in 2001 when the river discharge was about 1,500-cfs was measured at 6.1-fps, well above the estimated burst swimming speed for coho smolts. Flow was at or above 1,500-cfs over most of the coho migration in 2000.

The low capture rates measured for chinook relative to coho salmon may indicate that chinook have a greater affinity for channel margin habitat. If this hypothesis is correct, the trap's placement in the thalweg of the stream may favor coho capture over chinook. Another possible explanation for the high coho capture rate relates to the behavior of hatchery coho themselves. It may be that the hatchery coho are much less inclined to avoid the trap relative to wild coho and chinook due to an acquired tolerance for disturbance.

Egg-to-migrant survival is a measure of freshwater productivity for naturally-reared salmon. The estimated migration of 535,708 wild age 0+ chinook migrants divided by the estimated egg deposition above the trap site results in an egg-to-migrant survival of 7.3%. The estimated egg deposition was derived using an above-the-trap escapement estimate of 1,625 chinook females based on a redd count of 1,625 redds and an average fecundity of 4,500 eggs per female (Wilson pers. comm.).

Big Soos Creek Production

The age 0+ chinook production estimate for Big Soos Creek was developed using trap efficiencies measured with naturally-produced coho salmon smolts. Since chinook trap efficiency was not measured directly, the accuracy of the age 0+ chinook production estimate is predicated on our use of the chinook capture rate to coho capture rate ratio of 1.5 and its accuracy in estimating the actual chinook capture rate. This ratio was the mean of ratios measured in two streams over a two year period (four data points). Due to the substantial variability in these ratios

(1.15 to 1.68), we did not attempt to calculate variances or confidence intervals about the chinook production estimate. The age 0+ chinook production estimate for Big Soos Creek of 275,125 migrants should be considered a reasonable approximation rather than a precise estimate.

The crew at Soos Creek Hatchery released a total of 1,616 female chinook upstream of the rack to spawn naturally. Using an average fecundity value for Soos Creek Hatchery chinook (4,500 eggs per female)(Wilson pers. comm.), resulted in a potential deposition of 7,272,000 eggs. Egg-to-migrant survival was therefore estimated at 3.8%, slightly more than half the rate observed for the Green River.

At this point, we do not have a firm understanding as to why Big Soos Creek chinook survived at a lower rate compared to the Green River chinook. Potential causes include degraded spawning habitat, impacts to redds from excessive numbers of spawners in a relatively small area, higher levels of predation in Big Soos Creek, and reduced genetic fitness in the Soos Creek stock. While we cannot rule out the effects of reduced genetic fitness, comparisons of habitat condition and spawner distribution between Big Soos Creek and the Green River suggest potential linkages between reduced egg-to-migrant survival in Big Soos Creek with the first three causes. The vicinity of the Big Soos Creek trap, where we believe most chinook spawn, received about the same number of spawners as the entire Green River above the trapping site. This concentrated spawning in a small area undoubtedly resulted in substantial egg loss. In addition, the stream gradient in this section is about half of that found in the first five miles above the Green River trap site (0.16% vs. 0.33% measured using 1:24k topographic maps). Because of its size, the Green River produces substantially more stream energy. These conditions result in less fine sediments in the Green River spawning substrates and higher stream velocities which carry migrants quickly past predatory species. Another possible cause is that chinook production was substantially over-estimated in the Green River or under-estimated in Big Soos Creek. Comparisons of the 2000 Green River chinook production estimate with that from future monitoring should uncover whether the 2000 estimate is biased.

Total Basin Production

The wild age 0+ chinook production estimate made at the Green River trap site only represents the production that occurred upstream of the trap. Since an additional 826 redds were counted below the trap, assuming the same egg-to-migrant survival we estimated the total Green River production at 808,012 wild chinook migrants. Adding the Big Soos Creek naturally-produced chinook estimate of 275,125 migrants results in a total basin production estimate of 1,083,137 naturally-produced age 0+ chinook migrants (Table 12).

Size at Migration

Our work in the Green River and Big Soos Creek has resulted in estimates of naturally-produced chinook production and egg-to-migrant survival; however, at this point in time, we don’t have a good understanding of the significance of these estimates. The wild age 0+ chinook migration for the Green River assumed a bi-modal timing distribution. The earliest component was composed of chinook "fry" that migrated past the trap in January through March which was followed by a "smolt" component that migrated from May through June. The fry component made up 68% of the production above the Green River trap, or 366,013 migrants and 99% of the production from Big Soos Creek, or 271,868 migrant (Table 12). If we assume that 68% of the production resulting from spawners below the trap also migrated as fry, total basin production of migrant fry was 823,928, or 76%. Because of their smaller size, these fish would have survived at a lower rate compared to smolt size fish. Two years of chinook production estimation in the Cedar River and Bear Creek (four data points) has shown that the proportion of total chinook production that emigrates as fry was not consistent between years (Seiler *et al.* in press). Future work will include evaluation of physical and biological attributes that correlate with the proportion of chinook production that emigrates as fry and smolts.

Table 12. Fry and smolt component size and production estimates for naturally-produced juvenile chinook, Green River 2000.

Component	Migration Interval	Average Fork Length (mm)	Migration Past Trap	Percentage Production	Total Migration
Green River					
Fry	Jan 1 - Apr 15	40	366,013	68.3%	552,060
Smolt	Apr 16 - Jul 13	72	169,695	31.7%	255,952
Big Soos Creek					
Fry	Jan 1 - Apr 15	NA	271,868	98.8%	271,868
Smolt	Apr 16 - Jul 13	NA	3,257	1.2%	3,257
Total Basin Production					
Fry	Jan 1 - Apr 15	NA		76.1%	823,928
Smolt	Apr 16 - Jul 13	NA		23.9%	259,209
Total					1,083,137

Nearly all (99%) of the chinook migrants passing the Big Soos Creek screw trap migrated as fry. We believe this is most likely due to the close proximity of the trap to the limited area that chinook used for spawning. In 1999, chinook began to show up at the hatchery rack around mid-August (Wilson pers. comm.), none were released upstream of the rack until September 27. Most were released well after the chinook run timing peaked which limited their ability to move very far upstream before spawning (Figure 17).

Disposition of Chinook Released above HHD

We estimated that 10,686 ad-marked age 0+ chinook migrated past the trap in 2000 out of a release of 289,594. This represents an age 0+ migration of 3.69% of the number released. Some number of these fish may have been retained upstream of HHD and will possibly migrate in the fall or as age 1+ smolts.

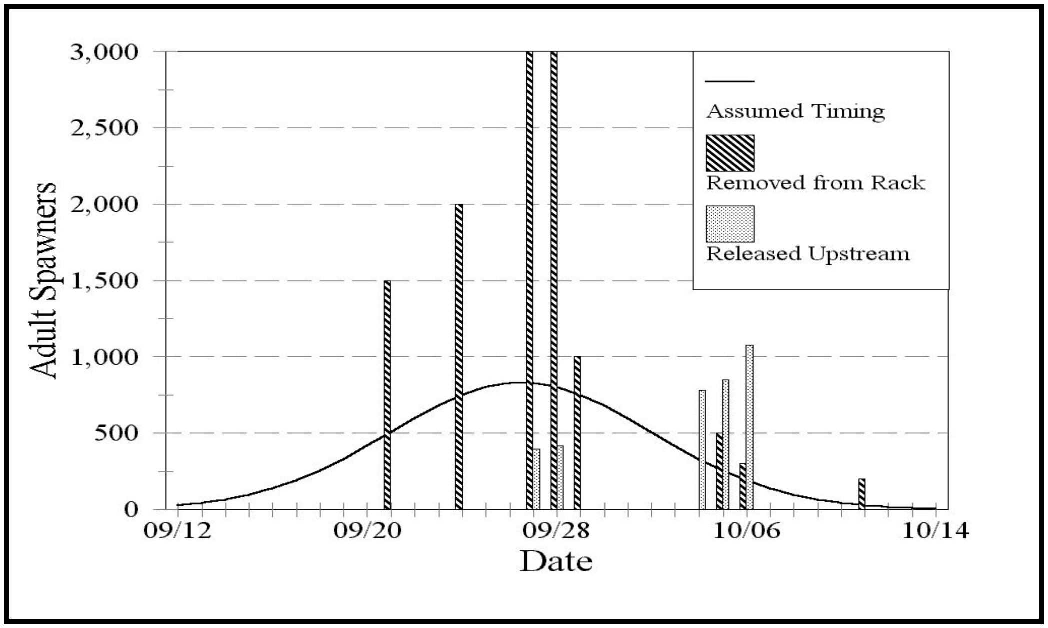

Figure 17. Numbers of adult chinook removed from the hatchery rack and released upstream, by date, relative to run timing in Big Soos Creek, 1999.

Green River Coho

Every production estimate is dependent on assumptions. Yet while both the chinook and coho estimates for the Green River are based on the estimation of catch rates from mark-recapture tests, we were able to replicate and better control the experiments for chinook. The catch rate for coho was estimated by a single measure of trap efficiency: the recovery of ad-marked fish released from the Keta Creek Hatchery. We had no control over when, where, or how many smolts were released in this test. Therefore, beyond the requisite assumptions applied to all mark-recapture experiments, a number of additional assumptions that apply to this test are discussed in detail below:

1. **The count of the number of ad-marked fish released is accurate.** The fish were counted when they were coded wire tagged on February 10 and 11, 2000. Afterwards, marked mortalities would have been counted when found. However, marked coho which escaped or were preyed upon/scavenged would not have been counted. We would expect these numbers to be small. Nevertheless, the reported number released represented the maximum number of ad-marked coho that would have been released from the hatchery. If the actual number released was overestimated, the actual capture rate for these coho would have been higher.

2. **No predation occurred between release and recovery.** We assumed that no predation occurred on the ad-marked coho smolts between the date and time released, and when they passed the screw trap. This assumption reflects the maximum survival rate that could occur. Predation on these fish would have resulted in under-estimation of the capture rate and over-estimation of the migration .

3. **All ad-marked recoveries are from the Keta Creek Hatchery release.** We assume all ad-marked recoveries that occurred on or after May 2 were Keta Creek smolts. If some of these fish were actually ad-marked Soos Creek smolts, the number of recovered Keta Creek marked coho would be over-estimated, which would result in an over-estimation of the actual capture rate.

4. **Wild and hatchery coho smolts are similarly distributed across the river and equally subject to capture.** We have no empirical knowledge as to the veracity of this assumption. As discussed above, wild coho smolts are typically captured at a lower rate than chinook migrants. Yet the coho capture rate measured using the Keta Creek Hatchery smolts yielded a trap efficiency estimate that was nearly three times the efficiency measured for chinook. If wild and hatchery coho smolts were distributed differently across the channel, the resulting trap efficiency estimate could have either over-estimated or under-estimated the actual capture rate for wild coho.

5. **All marks are identified at the trap.** We are fairly confident that this assumption was met. Typically, our crews are comprised of experienced technicians who routinely examine all salmonids for adipose and other marks. In 2000, the Green River screw trap was staffed by two inexperienced and two experienced crew members. The inexperienced technicians received training during the season. If there was error in mark recognition, the number of ad-marked recoveries reported represented the minimum number of marks actually recovered; resulting in an underestimation of the actual capture rate.

Of the assumptions that may result in an underestimation of the capture rate, we believe the reported number of ad-marked coho released was fairly accurate and that all or nearly all marks were identified at the trap. There most likely was some predation of ad-marked smolts prior to reaching the trap. Therefore, to provide some confidence around our 9.97% capture rate estimate, lets assume that Assumptions 1 and 2 overestimated the actual number of ad-marked coho passing the trap by 10%. In applying Assumption 3, we assume that all of the ad-marked fish captured prior to May 2 were Soos Creek smolts. In the week prior to the May 2 coho release from Keta Creek Hatchery, we captured an average of seven ad-marked (presumably Soos Creek) coho per day. Extending this rate through May 23, when the daily number of ad-marked smolts captured substantially declined, we estimate the total capture of ad-marked Keta Creek smolts at 4,926, a 3.03% reduction from our original estimate. Combining altered Assumptions 1, 2, and 3, we estimate that 4,926 ad-marked Keta Creek coho were captured out of 45,876 migrants that passed the trap which equals a 10.74% capture rate. This represents a 8% increase from the original 9.97% rate. Applying this rate to our catch data results in a wild migration estimate of 21,400 coho smolts, a decrease of 35% from our initial estimate of 32,800. Assuming that wild and hatchery smolts were equally susceptible to capture, these two estimates represent the range of values that we believe contains the actual number of migrating wild Green River coho.

Nearly a half million unmarked coho fry were planted, primarily upstream of the HHD, in 1999. The rate that these contributed to the estimated wild coho production of 21,400 to 32,800 smolts is unknown.

Green River Steelhead and Cutthroat

The accuracy of our steelhead and cutthroat migration estimates for the Green River are predicated on the accuracy of the trap efficiency estimates on which they are based. Although we were not able to measure trap efficiency for steelhead directly, our wild steelhead smolt production range of 35,701 to 40,801 was within the range of other, independent estimates. For instance, using a habitat model, Gibbons et al. (1985) estimated steelhead 1+ parr potential in the Green River system at 76,142. Assuming a parr to smolt survival of 40% (Rawding pers. comm.), production would be approximately 30,500 smolts. However, if the model were adjusted to only reflect habitat above the trap, potential production would be reduced to 21,280 smolts.

An alternative production estimate can be developed by analyzing escapement and productivity data. The parent brood (1997-1998) escapement above the smolt trap was estimated at 2,140, with females at 1,070 assuming an even sex ratio. Johnson and Cooper (1995) developed a steelhead spawner-recruit relationship for Snow Creek steelhead that indicated about 40 to 60 smolts per female spawner are produced at escapements above the MSY levels. Escapements into the Green River are generally at or above the MSY escapement goal (WDFW unpublished data), therefore, this spawner/recruit relationship would predict production above the trap at 42,800 and 64,200 smolts.

A third approach can be used to develop a range of steelhead smolt production by back-calculating smolt production potential from escapement. Wild steelhead escapement over the last five years (1995-2000, excluding 1997 due to lack of estimate) averaged 2,315 spawners. The harvest rate over this period averaged 9.6% (WDFW unpublished data), therefore, the average run size was 2,561 steelhead. If a 5% to 10% marine survival is assumed, wild steelhead production from the Green River should be between 25,610 and 51,220 smolts.

The range of production values derived from these approaches suggests that our estimated wild steelhead production estimate is reasonably accurate. If we assume a similar distribution of hatchery and wild smolts across the channel, then based on the ratio of ad-marked to unmarked steelhead captured in the trap, our estimated migration range of 45,786 to 52,326 ad-marked hatchery smolts must also be reasonably accurate. Therefore, from a combined release of 360,065 steelhead smolts (Table 1), we estimate the survival of hatchery steelhead smolts past the trap at 13% to 15%. While it is possible that some juvenile steelhead residualized upstream of the trap, the low survival past the trap indicates that a substantial in-river loss of smolts occurred before reaching the trap.

Cutthroat migration past the trap was estimated to range from 423 to 484. While we were unable to ascertain with only one year of data why cutthroat production was so low, we speculate that degraded habitat quality in the lower river estuary and Elliott Bay as a result of high density urban and commercial land-use may result in conditions that are poorly suited for cutthroat rearing. Lower river and estuarine habitats are especially important for cutthroat trout rearing (Trotter 1997).

Predation Studies

Predation rates by sculpin at the Green River trap were high relative to the other predators sampled. These rates can most likely be attributed to the high prey density in the trap live well. Expansion of the sculpin predation rate resulted in an estimated mortality of 69 age 0+ chinook migrants.

Predation rates measured for cutthroat were the lowest of all of the species sampled (0.33 prey items per cutthroat). These findings were unusual since similar testing in two Lake Washington tributaries has shown cutthroat predation rates in the live-box to be exceeded only by those of sculpin (Seiler *et al.* in press). Low cutthroat predation rates measured in this study may have been related to the low (six) sample size.

Recommendations

This report describes the first year of screw trap operation on the Green River. Our experiences indicated a need for improvement in a couple of areas. Therefore, the following recommendations are made for future smolt monitoring:

1. ***Expand trap efficiency testing to include coho and steelhead tests in addition to chinook.*** Sufficient numbers of coho and steelhead smolts were collected in the trap to enable efficiency testing using these species. This would provide another independent measure of efficiency for these species.

2. ***Collect length data over the entire migration.*** Length data collected in 2000 only occurred during the early part of the trapping season for steelhead. Effort should be made to collect at least 20 un-biased length measurements from age 0+ chinook, yearling coho, steelhead and cutthroat smolts each week, or if fewer numbers are caught, then lengths from all migrants.

3. ***Conduct efficiency tests using hatchery steelhead.*** Efficiency tests using hatchery steelhead should be made to evaluate their capture rates relative to coho and wild steelhead. This data would enable better estimation of migration and survival of hatchery steelhead past the trap.

4. ***Eliminate or reduce the amount of catch subsampling.*** During our first year of wild juvenile outmigrant production studies in the Green River system, large numbers of age 0+ chinook, chum, and age 0+ coho migrants required us to subsample some of the catches. Subsampling resulted in reduced accuracy of catch accounting for chum salmon at the Green River trap and age 0+ chinook and coho in Big Soos Creek. We expect the need for subsampling will be eliminated or much reduced in 2001. Since the Big Soos Creek trap will no longer be operated, the field crew will be able to concentrate their efforts at the Green River trap site. This would provide more time to completely enumerate the catches and would enable the crew to shorten the fishing periods when large numbers of migrants pass the gear.

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Appendix A

Daily Catch, Expanded Catch, and Migration Estimates for Age 0+ Chinook Migrants, Green River 2000

Appendix A. Daily Catch, Expanded Catch, and Migration Estimates for Age 0+ Chinook Migrants, Green River 2000.

		Wild Chinook 0+			Hatchery Chinook 0+		
Date	Hours Fished	Catch	Expanded Catch	Migration Estimate	Catch	Expanded Catch	Migration Estimate
02/10	8.25	30	91	2,642	0	0	0
02/11	24.00	131	131	3,816	0	0	0
02/12	15.00	103	171	4,994	0	0	0
02/13	15.00	83	138	4,024	0	0	0
02/14	13.75	63	86	2,493	0	0	0
02/15	15.25	70	89	2,602	0	0	0
02/16	16.50	100	122	3,550	0	0	0
02/17	24.00	186	186	5,418	0	0	0
02/18	24.00	167	167	4,864	0	0	0
02/19	24.00	139	139	4,049	0	0	0
02/20	24.00	90	90	2,621	0	0	0
02/21	24.00	128	128	3,728	0	0	0
02/22	15.75	107	249	7,248	0	0	0
02/23	24.00	213	213	6,204	0	0	0
02/24	24.00	155	155	4,515	0	0	0
02/25	24.00	159	159	4,631	0	0	0
02/26	24.00	130	130	3,786	0	0	0
02/27	24.00	171	171	4,981	0	0	0
02/28	24.00	174	174	5,068	0	0	0
02/29	24.00	250	250	7,282	0	0	0
03/01	24.00	144	144	4,194	0	0	0
03/02	24.00	147	147	4,282	0	0	0
03/03	21.66	584	956	27,831	0	0	0
03/04	0.00	0	1,740	50,674	0	0	0
03/05	6.00	60	631	18,392	0	0	0
03/06	24.00	192	192	5,592	0	0	0
03/07	24.00	146	146	4,252	0	0	0
03/08	24.00	140	140	4,078	0	0	0
03/09	24.00	113	113	3,291	0	0	0
03/10	24.00	133	133	3,874	0	0	0
03/11	24.00	168	168	4,893	0	0	0
03/12	24.00	81	81	2,359	0	0	0
03/13	24.00	136	136	3,961	0	0	0
03/14	24.00	274	274	7,981	0	0	0
03/15	24.00	142	142	4,136	0	0	0
03/16	24.00	192	192	5,592	0	0	0
03/17	24.00	266	266	7,748	0	0	0
03/18	23.41	163	166	4,826	0	0	0
03/19	21.12	126	143	4,177	0	0	0
03/20	24.00	124	124	3,612	0	0	0
03/21	24.00	93	93	2,709	0	0	0
03/22	24.00	225	225	6,553	0	0	0
03/23	24.00	104	104	3,029	0	0	0

Appendix A. Daily Catch, Expanded Catch, and Migration Estimates for Age 0+ Chinook Migrants, Green River 2000 (cont'd).

		Wild Chinook 0+			Hatchery Chinook 0+		
Date	Hours Fished	Catch	Expanded Catch	Migration Estimate	Catch	Expanded Catch	Migration Estimate
03/24	24.00	47	47	1,369	0	0	0
03/25	24.00	27	27	786	0	0	0
03/26	24.00	26	26	757	0	0	0
03/27	24.00	32	32	932	0	0	0
03/28	24.00	41	41	1,194	0	0	0
03/29	24.00	23	23	670	2	2	58
03/30	24.00	25	25	728	4	4	117
03/31	24.00	8	8	233	4	4	117
04/01	24.00	15	15	437	0	0	0
04/02	24.00	23	23	670	1	1	29
04/03	24.00	25	25	728	8	8	233
04/04	20.25	31	39	1,121	10	10	291
04/05	24.00	16	16	466	3	3	87
04/06	24.00	16	16	466	16	16	466
04/07	24.00	12	12	350	8	8	233
04/08	24.00	10	10	291	21	21	612
04/09	24.00	8	8	233	4	4	117
04/10	24.00	15	15	437	6	6	175
04/11	24.00	6	6	175	9	9	262
04/12	24.00	0	0	0	3	3	87
04/13	24.00	0	0	0	1	1	29
04/14	24.00	13	13	379	2	2	58
04/15	24.00	24	24	699	0	0	0
04/16	24.00	16	16	466	1	1	29
04/17	24.00	13	13	379	1	1	29
04/18	24.00	0	0	0	7	7	204
04/19	24.00	10	10	291	1	1	29
04/20	24.00	5	5	146	2	2	58
04/21	24.00	5	5	146	0	0	0
04/22	24.00	7	7	204	0	0	0
04/23	24.00	6	6	175	0	0	0
04/24	24.00	4	4	117	2	2	58
04/25	24.00	1	1	29	6	6	175
04/26	24.00	1	1	29	1	1	29
04/27	24.00	2	2	58	0	0	0
04/28	24.00	14	14	408	2	2	58
04/29	24.00	16	16	466	0	0	0
04/30	24.00	5	5	146	5	5	146
05/01	24.00	30	30	874	0	0	0
05/02	24.00	32	32	932	0	0	0
05/03	24.00	120	120	3,495	0	0	0
05/04	24.00	40	40	1,165	0	0	0
05/05	24.00	464	464	13,515	0	0	0

Appendix A. Daily Catch, Expanded Catch, and Migration Estimates for Age 0+ Chinook Migrants, Green River 2000 (cont'd).

		Wild Chinook 0+			Hatchery Chinook 0+		
Date	Hours Fished	Catch	Expanded Catch	Migration Estimate	Catch	Expanded Catch	Migration Estimate
05/06	24.00	56	56	1,631	0	0	0
05/07	24.00	100	100	2,913	0	0	0
05/08	24.00	39	39	1,136	2	2	58
05/09	24.00	868	868	25,282	14	14	408
05/10	20.27	73	113	3,290	7	7	204
05/11	24.00	86	86	2,505	12	12	350
05/12	24.00	84	84	2,447	5	5	146
05/13	24.00	47	47	1,369	6	6	175
05/14	24.00	96	96	2,796	3	3	87
05/15	24.00	45	45	1,311	4	4	117
05/16	24.00	47	47	1,369	2	2	58
05/17	24.00	31	31	903	8	8	233
05/18	24.00	24	24	699	5	5	146
05/19	24.00	36	36	1,049	4	4	117
05/20	24.00	42	42	1,223	8	8	233
05/21	24.00	65	65	1,893	5	5	146
05/22	24.00	149	149	4,340	1	1	29
05/23	24.00	98	98	2,854	9	9	262
05/24	24.00	72	72	2,097	10	10	291
05/25	24.00	127	127	3,699	9	9	262
05/26	24.00	81	81	2,359	4	4	117
05/27	24.00	92	92	2,680	8	8	233
05/28	24.00	63	63	1,835	7	7	204
05/29	24.00	137	137	3,990	11	11	320
05/30	24.00	68	68	1,981	4	4	117
05/31	24.00	29	29	845	2	2	58
06/01	24.00	19	19	553	3	3	87
06/02	24.00	10	10	291	0	0	0
06/03	24.00	9	9	262	0	0	0
06/04	24.00	38	38	1,107	1	1	29
06/05	24.00	76	76	2,214	4	4	117
06/06	24.00	64	64	1,864	0	0	0
06/07	24.00	75	75	2,184	2	2	58
06/08	9.00	60	67	1,956	0	0	0
06/09	24.00	50	50	1,456	1	1	29
06/10	24.00	40	40	1,165	4	4	117
06/11	19.50	51	53	1,544	5	5	151
06/12	23.00	495	515	14,993	15	16	459
06/13	9.50	200	354	10,313	7	12	361
06/14	24.00	188	188	5,476	7	7	204
06/15	14.25	202	243	7,082	5	9	250
06/16	24.00	97	97	2,825	4	4	117
06/17	24.00	32	32	932	0	0	0

Appendix A. Daily Catch, Expanded Catch, and Migration Estimates for Age 0+ Chinook Migrants, Green River 2000 (cont'd).

		Wild Chinook 0+			Hatchery Chinook 0+		
Date	Hours Fished	Catch	Expanded Catch	Migration Estimate	Catch	Expanded Catch	Migration Estimate
06/18	24.00	105	105	3,058	11	11	320
06/19	24.00	60	60	1,748	3	3	87
06/20	8.50	24	28	864	1	1	33
06/21	24.00	9	9	262	0	0	0
06/22	9.00	15	17	497	0	0	0
06/23	13.00	13	14	417	0	0	0
06/24	8.00	37	43	1,255	1	1	34
06/25	24.00	62	62	1,806	0	0	0
06/26	24.00	4	4	117	0	0	0
06/27	12.00	2	4	126	0	0	0
06/28	11.00	1	1	29	0	0	0
06/29	12.50	3	6	178	0	0	0
06/30	11.50	4	8	240	0	0	0
07/01	11.00	3	3	87	0	0	0
07/02	14.50	4	6	179	0	0	0
07/03	11.50	5	13	377	0	0	0
07/04	9.50	2	5	147	0	0	0
07/05	3.50	1	6	186	0	0	0
07/06	3.00	0	0	0	0	0	0
07/07	13.00	1	7	207	0	0	0
07/08	9.00	1	3	78	1	3	78
07/09	2.00	0	0	0	0	0	0
07/10	14.75	1	1	38	0	0	0
07/11	2.50	0	0	0	0	0	0
07/12	17.50	2	4	109	0	0	0
07/13	9.50	0	0	0	0	0	0
Sums	3,254.21	12,356	15,771	459,368	355	367	10,686

Note: Migration estimates were calculated using a fixed 3.43% trap efficiency for both hatchery and wild chinook migrants.