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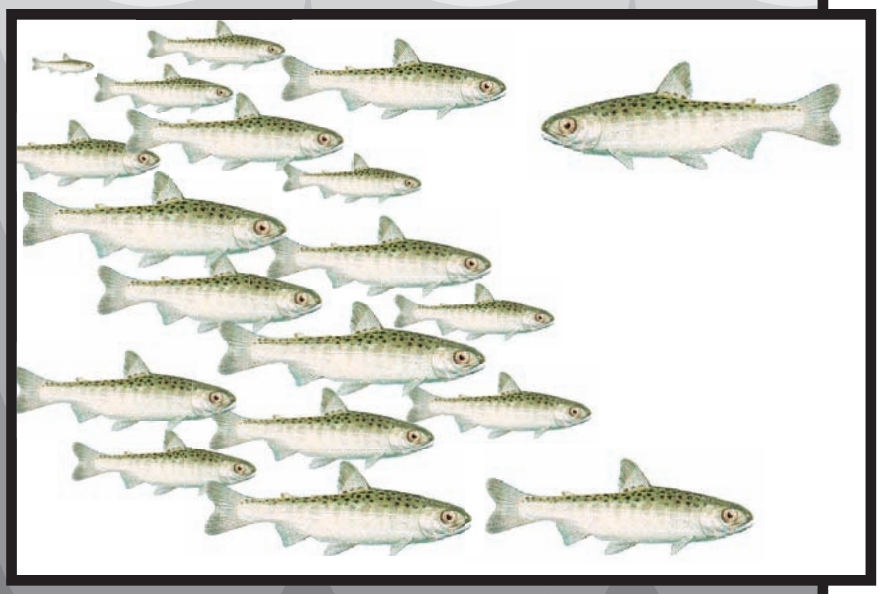
2002 Green River Juvenile Salmonid Production Evaluation Annual Report



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Washington Department of
FISH AND WILDLIFE
Fish Program
Science Division

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2002 Green River Juvenile Salmonid Production Evaluation

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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: Brett Brown, Matt Kinne, Blake Warnstadt, Lyle Miller, Rick Alford, and Scott Schueltzer. 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 the adjacent land owner, Bill Mosby. We also thank 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 in 2000 to estimate and monitor the production of chinook and coho salmon, and steelhead 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. This report documents our investigations during 2002, the third year of this project. Study objectives 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.

To accomplish these objectives, a floating screw trap was operated on the mainstem Green River at river mile 34.5. Trapping with this gear began in early February and ended in mid-July. A portion of all downstream migrating juvenile salmonids was captured in this trap. To estimate the capture efficiency, over the season groups of dye-marked or fin-marked fish were released upstream of the trap. Daily migration was estimated by dividing the daily catch by the estimate of trap efficiency.

Natural chinook production was estimated at 412,500 migrants in 2002. The chinook migration followed a bi-modal timing distribution. An earlier-timed "fry" component, comprised of newly emerged fry that migrated between January and early April, was followed by a later-timed "smolt" component, comprised of larger chinook migrants that rear upstream of the trap before migrating between May and June. This timing distribution has been observed in other rivers monitored in western Washington. During the 2002 season, 87% of the chinook migrated as fry through April. Relating our estimates of age 0+ chinook production to the number of eggs estimated to have been deposited above the trap resulted in egg-to-migrant survival estimates of 3.4%. By accounting for chinook production below our trap, we estimated total Green River natural production at 760,500 chinook.

In addition to naturally produced chinook, we also estimated 7,200 hatchery chinook, 246,500 unmarked coho smolts, 98,000 hatchery coho smolts, 53,000 wild steelhead, and 129,600 hatchery steelhead smolts migrated past the trap. Survival-to-the-trap estimates for the 2002 hatchery releases of chinook yearlings, coho and steelhead smolts ranged from 10.6% to 70.2%: 29.5% survival of Keta Creek coho smolts, 10.6% survival of Icy Creek chinook yearlings, and 70.2% survival of steelhead smolts released from four hatchery facilities above the trap.

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 22 chinook stocks included in the Puget Sound Evolutionary Significant Unit (ESU), Green River chinook is one of the largest with average escapement to natural spawning areas of 14,200 for 2000 to 2004. However, spawning abundance is slightly more than half of the proposed recovery planning target of 27,000 spawning adults (WRIA 9 Steering Committee 2005). Proposed recovery planning targets for spatial structure, diversity, and productivity are also not currently being met.

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 smolts/spawner 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 and the Salmon Recovery Funding Board 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. Based on these criteria, the Green River was considered a desirable candidate for monitoring.

Beginning in 2000, a floating juvenile migrant fish trap was operated in the main-stem Green River at river mile 34.5, approximately ½ mile upstream of the mouth of Big Soos Creek. Locating the trap upstream of Big Soos Creek was essential to avoid the capture of large numbers of hatchery fish produced in the Soos Creek Hatchery, located on Big Soos Creek. A second trap was also operated upstream of the hatchery in Big Soos Creek in 2000 to assess the production of naturally-reared chinook that resulted from hatchery spawners released above the Soos Creek Hatchery rack. Operation of the Big Soos Creek trap was not continued beyond that one year; however, information collected from its one year of operation was used to estimate total basin production of juvenile

chinook salmon in subsequent years. This report describes the third year of operation of the main-stem trap and the findings from those efforts.

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 located upstream of the trap site to test strategies for improving in-river survival of their releases. 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.

Methods

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). This trap is fully described in Seiler *et al*. 2002.

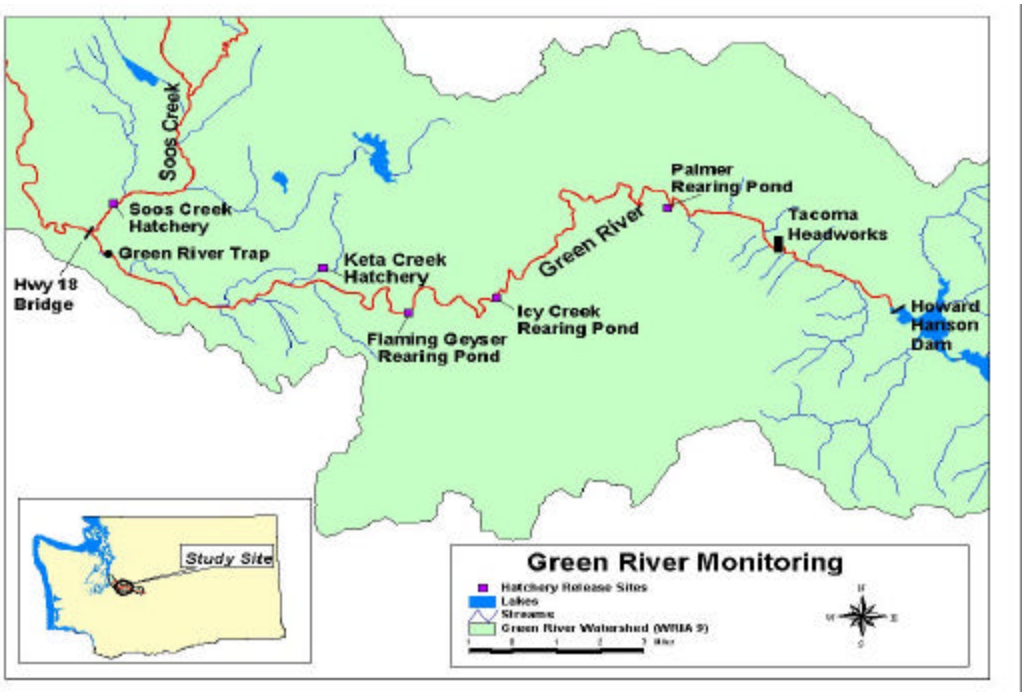

Figure 1. Location map of the Green River screw trap relative to hatcheries and hydro projects, Middle Green River.

The trap on the Green River was operated between early February and mid-July, except for periods when debris, mechanical failure, or large numbers of hatchery fish released caused the cessation of trapping. Trapping was also suspended during daytime periods late in the trapping season, when catches were low and recreational use of the river was high. Fish were usually removed from the trap and counted at dawn and dusk. 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 each trapping period, all fish captured in the trap were identified to species and enumerated. Fork length measurements were taken from a sample of the captured unmarked chinook, coho and steelhead.

In order to estimate migration, groups of chinook, coho, and chum were used to test the capture efficiency of the trap. Fish used for trap efficiency testing were anesthetized with tricaine methanesulfonate (MS 222), identified to species, counted, 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 from the Neely Bridge (RM 35) or 150 yards upstream of the trap. Capture rates were estimated by the proportion of marked fish that were recaptured in the trap after release.

Production Estimate

Estimating chinook, coho, and steelhead production from the Green River 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. These methods were used to estimate the adipose-marked (ad-marked) and unmarked components of the daily catches, the trap efficiency, and migration for each species.

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 daybreak and twilight periods. Catch during trapping intervals not fished were estimated by interpolating between catch rates from the previous and following dates of the same diel stratum, and then expanding by the hours not fished. When a trapping interval was interrupted by debris, catch was either estimated for the entire night or, if available, the outage interval was estimated based on the expected number of trap rotations (RPM x fishing time) compared to the count of the revolution counter. Catch for the hours not fished was then estimated using the average catch rate from the previous and following diel stratum and the interval fished. Catch rates were estimated by;

$$R_{fj} = \frac{C_{fj}}{T_{fj}} \qquad \textbf{Equation 1}$$

where:

$R_{fj} = the\ catch\ rate\ during\ \ fishing\ \ period\ \ f\ \ in\ diel\ \ stratum\ \ j,$

$C_{fj} = catch\ during\ \ fishing\ \ period\ \ f\ \ in\ diel\ \ stratum\ \ j, and$

$T_{fj} = the\ duration\ of\ \ fishing\ \ period\ \ f\ \ in\ diel\ \ stratum\ \ j.$

The variance of the interpolated catch rate was estimated by;

$$V(\overline{R}_{fj}) = \frac{\sum (R_{fj} - \overline{R}_{fj})^2}{n(n-1)} \qquad \textbf{Equation 2}$$

Catch during the un-fished interval was then estimated by multiplying the mean catch rate by the hours not fished (T). The catch variance was then estimated by;

$$V(\hat{C}) = V(\overline{R}_{fj})\,T^2 \qquad \textbf{Equation 3}$$

In order to estimate the capture rate of the trap, groups of marked migrants were released upstream of the trap and subsequently recaptured. The capture rate was calculated for individual tests using;

$$e_i = \frac{r_i}{m_i} \qquad \textbf{Equation 4}$$

where;

e_i = *the capture rate for trap efficiency test i,*

r_i = *the number of marked or dyed migrants captured from trap efficiency test release i, and*

m_i = *the number of marked or dyed migrants released in trap efficiency test i.*

The variance of each trap efficiency test was calculated using the variance of a binominal expression;

$$V(e_i) = \frac{e_i(1-e_i)}{m_i} \qquad \textbf{Equation 5}$$

Daily migration was estimated by dividing the estimated catch by the estimated trap efficiency. Where mean daily flow failed to show a relationship with individual trap efficiencies, the average trap efficiency was used. If flow marginally explained variation between efficiency tests, averages within flow strata were used to estimate efficiency where flows correspond with individual strata. The variance of the average trap efficiency was calculated using Equation 2, substituting $\bar{e}$ for $\overline{R}_{fj}$ and e_i for R_{fj}. Daily migration was estimated by summing daytime and nighttime catch intervals to estimate 24 hour catch and dividing by the estimated efficiency. Total season migration was estimated by the sum of the daily estimated migrations, and the season migration variance for each species was estimated by;

$$V(\hat{N}) = \hat{N}^2 \left(\frac{V(\bar{e})}{\bar{e}^2} + \frac{\sum V(\hat{C})}{\hat{C}_t^{\,2}} \right) \qquad \textbf{Equation 6}$$

where;

$\hat{N}$ = *the season migration estimate, and*

C_t = *the total actual and estmimated catch during the trapping season.*

Where flow strata were used to estimate efficiency, the season migration estimate variance would be calculated for each flow strata using Equation 6 and then summed.

Results

Estimating the production of naturally-produced chinook, coho, and steelhead 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 2002.

Table 1. Hatchery releases resulting in possible catches in the Green River screw trap in 2002.

Species	Release Date(s)	Release Location	Brood Year	CWT Only	CWT Ad-mark	Ad-mark Only	Unmarked
2001 Releases Above the Howard Hansen Dam							
Coho	5/07-5/09	Howard Hansen Dam	2000				559,625
Chinook	4/02-4/06	Howard Hansen Dam	2000			313,984	
2002 Releases							
Coho	04/15	Keta Creek	2000	1,979	47,445	284,043	11,618
	04/06	Soos Creek	2000	44,920	82,973	501,852	
	4/05-4/10	Howard Hansen Dam	2001				495,700
Steelhead	05/06	Keta Creek	2001			28,000	
	05/04	Flaming Geyser	2001			15,000	
	05/21	Icy Creek	2001			40,000	
	05/01	Palmer	2001			101,620	
	05/01	Soos Creek	2001			33,700	
Chinook	5/23-6/07	Soos Creek	2001	162,160	178,119	3,143,456	18,319
	3/20-3/28	Howard Hansen Dam	2001			502,633	
	05/21	Icy Creek	2000			309,000	
Chum	3/19-4/12	Keta Creek	2001				1,159,300

Chinook

Catch

Over the 155-day season, we captured 17,586 unmarked and 319 ad-marked age 0+ chinook migrants (Appendix A). Daily unmarked age 0+ chinook catch averaged 41 migrants over the first two complete days of trapping (February 7 and 8). Daily catch of unmarked migrants increased to 1,457 on March 11. After March 11, daily catches ranged from 620 on March 12 to zero on April 14. By early May, daily catches declined to approximately 25 migrants. Catches of unmarked age 0+ chinook migrants began to increase slightly again in June when 463 migrated on June 29, before declining to less than fifty migrants by July 11 when the trap was pulled for the season.

A total of 319 ad-marked age 0+ chinook were captured throughout the trapping season. Ad-marked age 0+ chinook first entered catches on April 7 when two were caught and peaked on June 15 when 25 were caught.

Over the season, we also caught 15 wild unmarked and 1,377 hatchery ad-marked age 1+ chinook migrants. Ad-marked age 1+ chinook were caught beginning on April 16, 35 days before the first

scheduled release from the Icy Creek facility. Seventy-nine percent of the ad-marked catch passed the trap before the first scheduled release. Those migrants either were released from the hatchery early or were 2001 fry plants above the Howard Hansen Dam.

Size

Wild chinook 0+ averaged less than 45-mm through the mid-April. They grew rapidly afterwards, averaging over 75-mm by mid-June (Table 2, Figure 2). Migrants measuring less than 40-mm were found through the middle of May, after which, the minimum size increased to over 50-mm during the last month and a half of the trap operation.

Table 2. Mean fork length (mm), standard deviation, range, and sample size of wild age 0+ chinook measured by statistical week, Green River 2002.

Statistical Week			Average	s.d.	Range		Number		Percent
#	Begin	End			Min	Max	Sampled	Caught	Sampled
6	02/04	02/10	39.2	0.8	38	40	5	107	4.7%
7	02/11	02/17	39.9	2.1	36	44	56	246	22.8%
8	02/18	02/24	39.7	2.0	36	44	29	1,209	2.4%
9	02/25	03/03	40.3	2.1	35	51	156	467	33.4%
10	03/04	03/10	40.2	2.0	35	46	97	758	12.8%
11	03/11	03/17	40.4	1.7	37	45	117	2,977	3.9%
12	03/18	03/24	41.8	3.0	37	61	318	1,006	31.6%
13	03/25	03/31	42.0	2.2	38	52	146	1,143	12.8%
14	04/01	04/07	41.4	2.1	37	53	178	1,391	12.8%
15	04/08	04/14	41.9	1.9	39	50	87	797	10.9%
16	04/15	04/21	44.1	3.2	39	54	55	678	8.1%
17	04/22	04/28	46.0	4.2	39	59	105	820	12.8%
18	04/29	05/05	49.6	7.6	39	72	56	207	27.1%
19	05/06	05/12	59.4	7.9	49	73	14	155	9.0%
20	05/13	05/19	60.7	9.3	45	78	13	150	8.7%
21	05/20	05/26	58.5	10.2	38	73	37	147	25.2%
22	05/27	06/02	63.6	10.3	51	95	29	147	19.7%
23	06/03	06/09	66.9	9.3	49	87	42	527	8.0%
24	06/10	06/16	75.5	9.7	60	90	14	882	1.6%
25	06/17	06/23	77.4	9.7	59	98	36	1,383	2.6%
26	06/24	06/30	74.1	10.6	52	90	39	898	4.3%
27	07/01	07/07	79.8	9.5	64	98	26	981	2.7%
28	07/08	07/14	86.1	9.8	59	105	32	510	6.3%
Season Total			46.8	12.5	35	105	1,687	17,586	9.6%

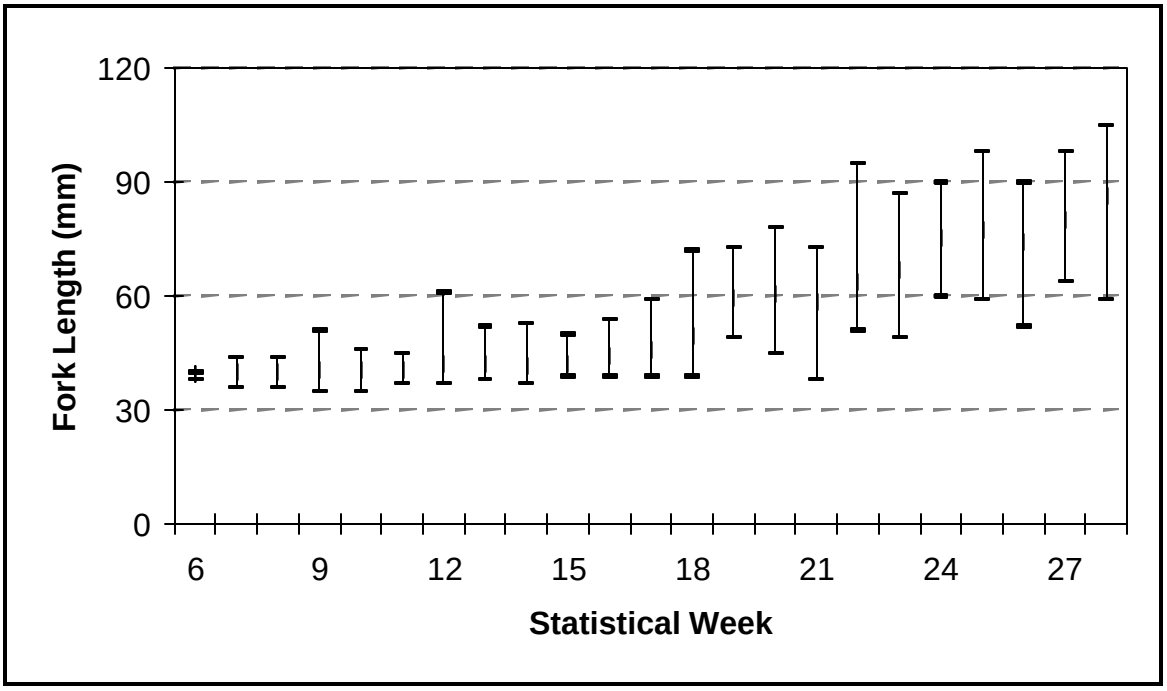

Figure 2. Weekly average, minimum, and maximum 0+ chinook fork lengths (mm) measured at the Green River screw trap, 2002.

Catch Expansion

The trap was operated 3,547 hours out of 3,719 possible hours in the 155-day trapping period, or 95.5% of the time. Catch was expanded during seven of eight intervals when trapping was suspended due to debris impeding the rotation of the trap screw (screw stopper), maintenance, or repairs. Trapping was suspended for a total of 6.5-hours during three dates (March 12, April 15, and June 19) when trap repairs were needed. Expansion for those intervals resulted in an estimated missed catch of one hatchery and 69 wild chinook. Screw stoppers occurred during five fishing intervals (February 22, March 26, April 13 and 30, and June 9). The time intervals not fished during the nights when screw stoppers occurred were estimated by comparing the predicted to actual count on the rotation counter mounted on the trap. The screw stopper on March 26 was estimated to have occurred at the end of the trapping interval and therefore no catch was estimated. We estimated one hatchery and 52 wild chinook migrated during the other four intervals.

The trap was pulled during ten daylight intervals beginning on June 20. Trapping was suspended for a total of 147-hours during the daytime when recreational use of the river was high and few fish were caught. By interpolating between the daylight periods fished, we estimate that two hatchery and 126 wild chinook would have migrated during those intervals.

Expanding the actual catches for periods when trapping was suspended resulted in the addition of 247 age 0+ wild chinook. We estimate a total of 17,833 wild chinook would have been captured if continuous trapping had occurred between February 7 and July 11. This represents a 1.4% increase over the actual catch of wild migrants. Expansion also resulted in the addition of four hatchery age 0+ chinook, and five hatchery age 1+ chinook to the actual catch.

Trap Efficiency

A total of 2,401 age 0+ wild chinook migrants in 28 groups were marked and released from 150-yards upstream of the trap or from Neely Bridge. The number of fish released in each group ranged from 35 to 200 chinook. Recapture rates averaged 6.6% and ranged from 0% to 17.6%.

Flows ranged from 652 to 1,920 cubic feet per second (cfs) during the trap efficiency tests. A relationship between flow and capture rate was observed, although it was not statistically significant and could not be used for predictive purposes (Figure 3). It was also observed that capture rates increased late in the season, coinciding with the increase in chinook size and the degree of smoltification. Using a Wilcoxon two-sample test, distributions of efficiencies were significantly different between fry (February through April) and smolt (May through July) stages ($p<0.01$). Within each stage, flow relationships were observed. The relationship between flow and efficiency during the fry stage was not statistically significant across the range of observed flows. However, using the Wilcoxon two-sample test, the distribution of efficiencies was significantly different for tests made at flows higher than 1,300 cfs relative to those made at lower flow levels during the fry stage ($p<0.05$). Therefore, we chose to use two flow strata to estimate trap efficiency during this life stage (Table 3). The first stratum is the flow range of 0 to 1,300 cfs, which the chinook efficiency tests conducted during that range averaged 6.0%. The second stratum is the flow range greater than 1,300 cfs, which the chinook efficiency tests conducted during that range averaged 1.5%. The lack of significance between flow strata during the smolt stage was due to the low sample size, and the average capture rate (11.2%) was used to estimate smolt production (Table 3).

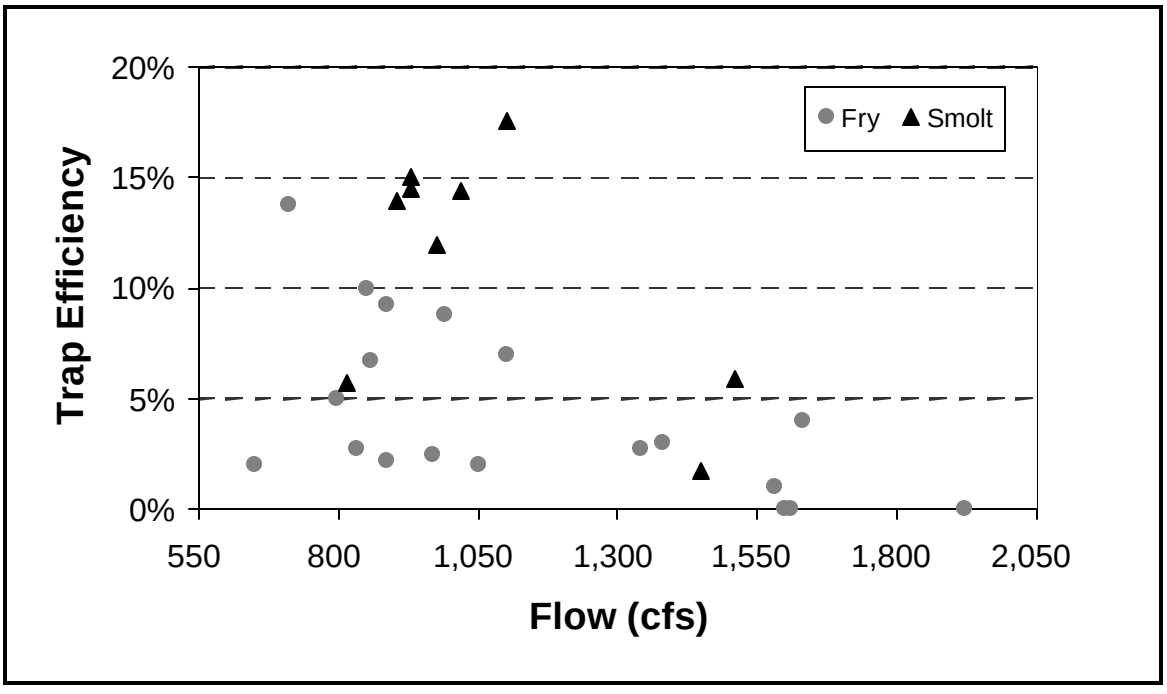

Figure 3. Observed chinook trap efficiency tests decreasing with increasing daily average flows, Green River 2002.

Table 3. Chinook 0+ trap efficiency tests conducted on the Green River screw trap and separated by life stage and flow strata, 2002.

Strata		Date	Flow (cfs)	# Marked Released	# Marked Recaptured	Trap Efficiency
FRY	Flows: 0 - 1,300 cfs	02/18	652	50	1	2.0%
		03/11	710	80	11	13.8%
		02/12	798	40	2	5.0%
		03/25	833	75	2	2.7%
		03/28	850	50	5	10.0%
		03/18	858	75	5	6.7%
		03/16	886	65	6	9.2%
		03/22	887	45	1	2.2%
		03/12	969	200	5	2.5%
		03/30	992	80	7	8.8%
		04/01	1,050	100	2	2.0%
		04/03	1,100	100	7	7.0%
		Total		960	54	
		Average				6.0%
		Variance				1.26E-04
		n				12
	Flows: 1,300+ cfs	02/27	1,340	75	2	2.7%
		04/24	1,380	100	3	3.0%
		04/22	1,580	100	1	1.0%
		04/21	1,600	100	0	0.0%
		04/20	1,610	100	0	0.0%
		04/07	1,630	100	4	4.0%
		04/10	1,920	100	0	0.0%
		Total		675	10	
		Average				1.5%
		Variance				4.01E-05
		n				7
SMOLT		06/08	1,450	59	1	1.7%
		06/13	1,510	118	7	5.9%
		06/17	1,100	102	18	17.6%
		06/22	930	100	15	15.0%
		06/29	975	100	12	12.0%
		06/30	1,020	97	14	14.4%
		07/03	903	100	14	14.0%
		07/07	930	55	8	14.5%
		07/11	814	35	2	5.7%
		Total		766	91	
		Average				11.2%
		Variance				3.25E-04
		n				9

Production Estimate

From February 7 through July 11 we estimate 412,460 wild age 0+ chinook migrants passed the screw trap (Table 4, Figure 4). Due to the low catches early in the season, we believe the trap was operated throughout the migration period. In addition to the wild fish, we estimate 7,180 ad-marked hatchery age 0+ chinook migrated during the February 7 through July 11 trapping period (Table 4).

Yearling chinook and coho smolts were similar in size, so we assumed similar catch rates. Therefore, chinook yearling migration was estimated by applying the average coho trap efficiency estimate (Table 6) to the expanded catch estimate. Total migration of age 1+ chinook past the trap was estimated at 33,136 yearlings: 356 wild and 32,780 hatchery. Coefficient of variation of 21.8% results in 95% confidence intervals of 204 to 508 wild and 18,798 to 46,762 hatchery age 1+ chinook.

Table 4. Estimated age 0+ wild and hatchery chinook migration past the Green River screw trap, 2002.

Origin	Component	Catch			Migration Estimate	CV	95% CI	
		Actual	Estimated	Total			Low	High
Wild	Fry	11,661	98	11,759	358,313	26.3%	173,940	542,686
	Smolt	5,925	149	6,074	54,147	16.1%	37,075	71,219
	Total	17,586	247	17,833	412,460	22.9%	227,298	597,622
Hatchery	Total	319	4	323	7,180	28.1%	3,221	11,139

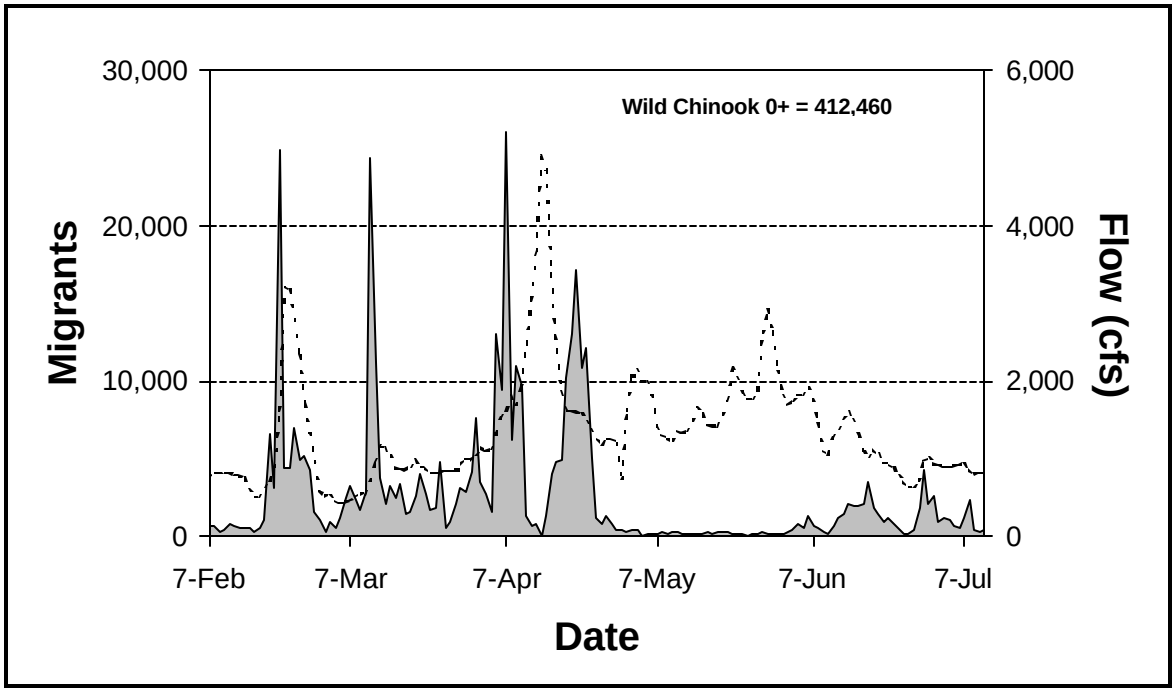

Figure 4. Daily migration of wild age 0+ chinook past the Green River screw trap, 2002.

Coho

Catch

Yearling coho salmon were captured on the first night of trapping, February 7. However, catch rates were low, averaging less than 13 per day throughout February. Coho smolt migration typically occurs from late March to June. Catches increased slightly through March and April, and peaked on May 11 when 1,276 wild coho smolts were caught. Catches declined and averaged only two per day during the month of July. Over the 155-day trapping period, a total of 14,426 coho were captured: 4,111 hatchery ad-marked and 10,315 unmarked.

Ad-marked hatchery coho smolts began to show up in the catch in moderate numbers on February 13. Between February 12 and April 14, 52 ad-marked coho were caught. This period was prior to any known yearling hatchery coho release in 2002. Therefore, these fish had likely escaped from Soos Creek and/or Keta Creek Hatcheries.

Size

Weekly average unmarked coho fork lengths ranged between 84 mm and 115 mm throughout the trapping season (Table 5, Figure 5). The sizes of individual migrants ranged from 56 mm to 145 mm and averaged 100 mm over the trapping season.

Table 5. Mean fork length (mm), standard deviation, range, and sample size of unmarked coho smolts measured by statistical week, Green River 2002.

Statistical Week			Average	s.d.	Range		Number		Percent
#	Begin	End			Min	Max	Sampled	Caught	Sampled
6	02/04	02/10	83.8	10.7	56	104	37	41	90.2%
7	02/11	02/17	86.1	11.5	67	109	20	73	27.4%
8	02/18	02/24	84.7	12.1	66	102	6	60	10.0%
9	02/25	03/03	84.6	9.8	66	111	39	152	25.7%
10	03/04	03/10					0	63	0.0%
11	03/11	03/17	89.8	17.5	69	112	6	120	5.0%
12	03/18	03/24	109.5	11.0	95	119	6	565	1.1%
13	03/25	03/31	89.5	9.2	66	104	18	338	5.3%
14	04/01	04/07	91.8	9.5	79	105	6	251	2.4%
15	04/08	04/14	88.8	7.3	82	99	6	131	4.6%
16	04/15	04/21	96.2	8.4	80	113	32	130	24.6%
17	04/22	04/28	92.3	11.1	71	106	12	333	3.6%
18	04/29	05/05	100.2	8.7	81	126	68	719	9.5%
19	05/06	05/12	102.4	9.2	85	125	36	2,190	1.6%
20	05/13	05/19	103.9	8.3	86	125	58	2,111	2.7%
21	05/20	05/26	102.9	8.7	84	125	99	1,760	5.6%
22	05/27	06/02	107.8	8.2	94	127	38	438	8.7%
23	06/03	06/09	107.4	10.6	87	136	32	257	12.5%
24	06/10	06/16	106.8	7.6	100	118	9	286	3.1%
25	06/17	06/23	115.2	12.0	99	145	21	194	10.8%
26	06/24	06/30	111.4	9.8	99	131	24	34	70.6%
27	07/01	07/07	100.7	3.8	98	105	3	58	5.5%
28	07/08	07/14					0	11	0.0%
Season Total			99.5	12.8	56	145	576	10,315	5.6%

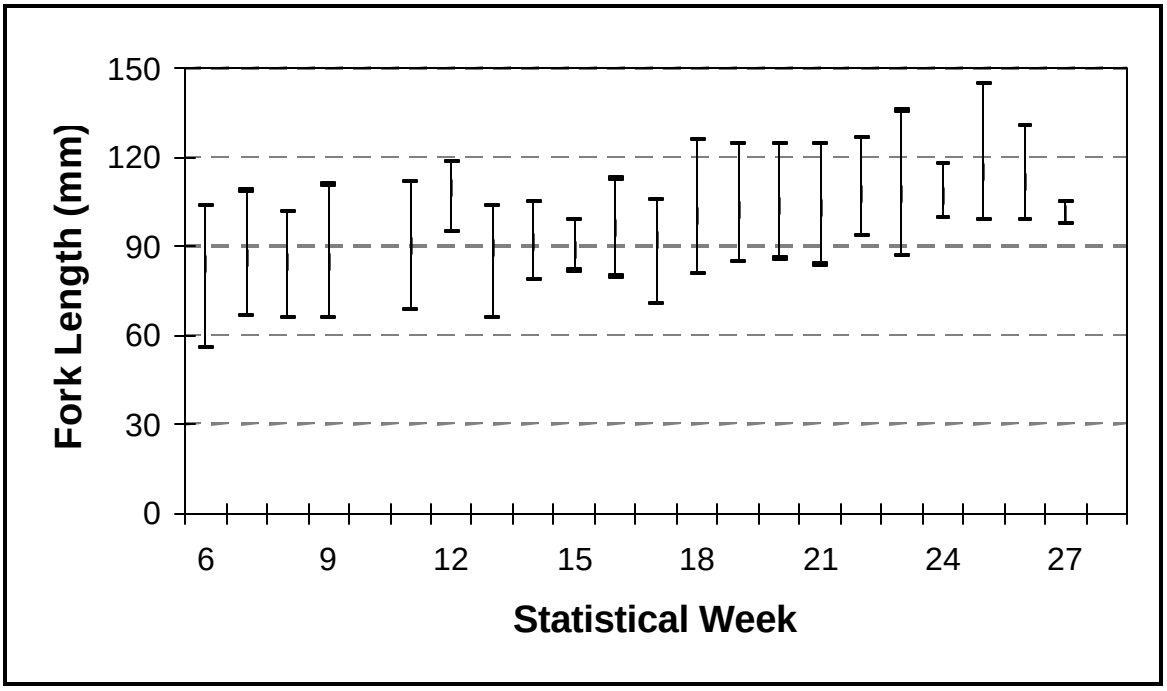

Figure 5. Weekly average, minimum, and maximum unmarked yearling coho fork lengths measured at the Green River screw trap, 2002.

Catch Expansion

Trapping operations were suspended for a total of 173 hours over the course of the trapping period, which are described in the Chinook-Catch Expansion section above. Catch expansion resulted in the addition of 15 ad-marked hatchery smolts and 80 unmarked smolts. The expansion represents a 0.7% increase to the actual catch of coho smolts.

Trap Efficiency

A total of 720 unmarked yearling coho were fin-clipped and released in 15 trap efficiency tests. Release groups ranged from eight to 100 marked smolts. In order to increase our confidence in results from tests using small release groups, we combined groups from adjacent releases to generate groups of at least 30 individuals. Grouped trap efficiencies tests ranged from 1.9% to 10.3% and averaged 5.3% (Table 6). The lack of a significant relationship between trap efficiency and average daily mean flow ($p>0.1$) resulted in the average efficiency (5.3%) being used to estimate daily unmarked and marked migrations.

Production Estimate

Applying our average coho capture rate to the expanded catch estimates yields a total unmarked coho migration estimate of 194,393 smolts with a coefficient of variation of 17% and a 95% confidence interval of 129,500 to 259,286 smolts (Figure 6). Total marked hatchery coho production is estimated at 77,167 smolts with a coefficient of variation of 17% and a 95% confidence interval of 51,406 to 102,908 smolts.

Table 6. Estimated unmarked coho recapture rates from efficiency tests, Green River screw trap 2002.

Date(s)	Flow (cfs)		Number		Trap	Variance
	Range	Average	Released	Recaptured	Efficiency	
02/12-02/14	780-798	786	39	2	5.1%	0.00125
02/27-03/14	1,140-1,340	1,240	49	3	6.1%	0.00117
03/17-03/19	863-897	880	43	1	2.3%	0.00053
03/23	824	824	97	10	10.3%	0.00095
03/26	839	839	100	9	9.0%	0.00082
04/04-04/11	1,130-2,470	1,800	52	1	1.9%	0.00036
04/28	1,250	1,250	50	1	2.0%	0.00039
05/12	1,340	1,340	90	6	6.7%	0.00069
05/18	1,420	1,420	100	6	6.0%	0.00056
05/21	1,750	1,750	100	4	4.0%	0.00038
	Total		720	39		
	Average				5.3%	
	Variance				8.3E-05	
	n				10	

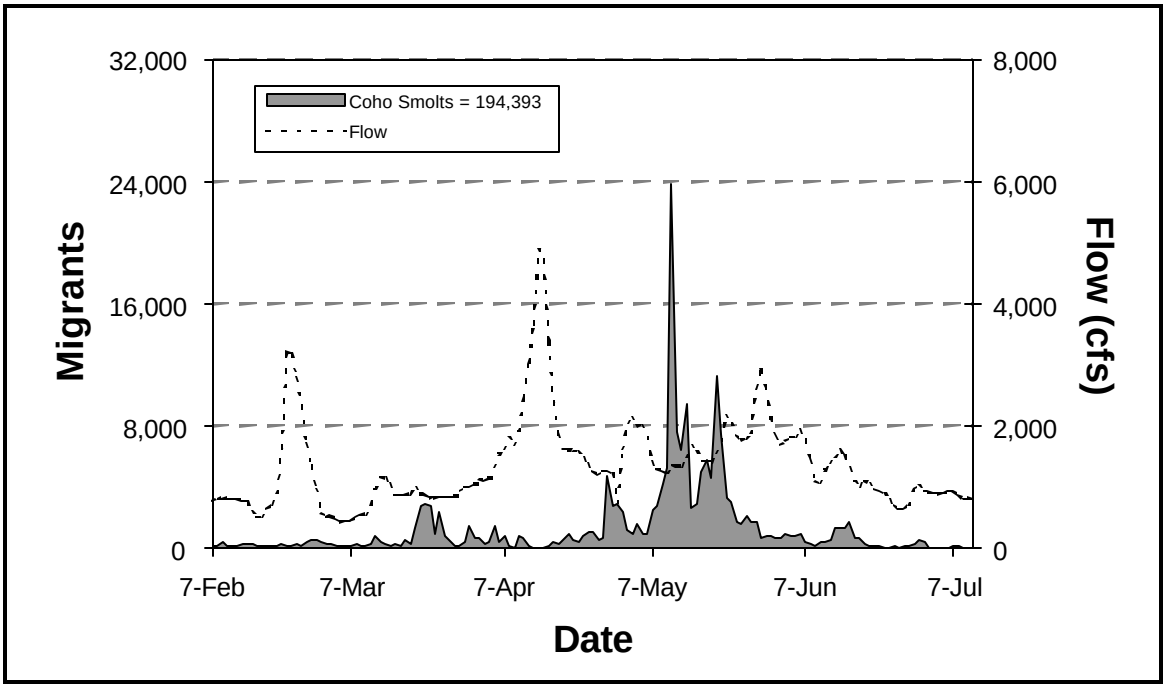

Figure 6. Daily migration of unmarked coho smolts in the Green River screw trap relative to daily average stream discharge measured at USGS Gage #12113000, 2002.

The unmarked migration estimate includes both hatchery and wild coho smolts. The Keta Creek coho hatchery release consisted of 13,597 unmarked smolts; 1,979 were CWT, however, fish were not checked for tags at the screw trap. Application of the 96% hatchery mark rate to the total catch would estimate a hatchery migration of 80,332 and a wild migration estimate of 191,228 smolts. The wild migration estimate still includes unmarked coho that were released upstream of the Howard Hansen Dam as fry and migrated downstream as smolts. The number of these hatchery smolts in the unmarked catch is believed to be low.

Steelhead

Catch

Over the trapping period, we caught 1,670 unmarked wild and 4,075 ad-marked hatchery steelhead smolts. We captured one wild steelhead smolt during our first night of trapping, and the first ad-marked steelhead was caught on February 13; two and a half months before the first reported hatchery release. A total of 505 hatchery ad-marked steelhead were caught before the first releases from Palmer Ponds and Soos Creek Hatchery on May 1. These smolts were either escapees from the hatcheries, or released in the previous year.

Size

A total of 274 unmarked steelhead fork lengths were recorded throughout the trapping season; 16% of the total catch. Fork lengths ranged from 110 to 229 mm, and averaged 167 for the season (Table 7, Figure 7).

Catch Expansion

We estimated an additional eight wild and 23 hatchery ad-marked smolts would have been caught had we fished continuously throughout the trapping season. This represents an increase of less than 0.5% to the wild catch and less than 0.6% to the hatchery catch.

Trap Efficiency

In any migrant trapping operation, trap efficiency is influenced by a number of variables such as 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. Steelhead smolts average approximately 1.5 times the size of coho smolts and are, therefore, generally captured at a lower rate. Trap efficiency was not measured for steelhead during this study. Therefore, to estimate trap efficiency for steelhead, we used the same approach applied in the 2000 and 2001 reports of multiplying a steelhead:coho capture rate ratio to the coho trap efficiency to estimate steelhead trap efficiency (Seiler *et al*. 2002). A steelhead:coho capture rate ratio of 75% was applied to the coho rate which resulted in a steelhead trap efficiency of 3.2%. Variance was not estimated for this rate.

Production Estimate

Application of the steelhead trap efficiency estimates to the expanded catch, estimated the migration during the period of trap operation of 53,077 unmarked steelhead smolts and 129,604 ad-marked hatchery steelhead smolts. The trapping interval encompassed the entire steelhead migration; therefore, expansion of the production estimates beyond the trapping period was unnecessary. Variance and confidence intervals were not developed for this estimate.

Table 7. Mean fork length (mm), standard deviation, range, and sample size of unmarked steelhead smolts measured by statistical week, Green River 2002.

Statistical Week			Average	s.d.	Range		Number		Percent
#	Begin	End			Min	Max	Sampled	Caught	Sampled
6	02/04	02/10	165.8	19.0	140	181	4	4	100.0%
7	02/11	02/17	167.6	13.2	149	181	7	7	100.0%
8	02/18	02/24					0	5	0.0%
9	02/25	03/03	150.3	10.1	135	165	7	12	58.3%
10	03/04	03/10						0	
11	03/11	03/17	163.0	15.0	148	178	3	6	50.0%
12	03/18	03/24	162.3	30.3	110	224	23	41	56.1%
13	03/25	03/31	161.2	19.8	130	195	11	21	52.4%
14	04/01	04/07	155.8	7.1	144	163	5	12	41.7%
15	04/08	04/14						0	
16	04/15	04/21	172.0	23.2	136	229	31	38	81.6%
17	04/22	04/28	177.0	26.3	129	207	11	58	19.0%
18	04/29	05/05	179.3	16.7	140	228	26	79	32.9%
19	05/06	05/12	174.1	19.3	141	222	27	303	8.9%
20	05/13	05/19	160.5	16.3	139	196	17	349	4.9%
21	05/20	05/26	162.6	11.1	145	184	24	318	7.5%
22	05/27	06/02	164.1	12.0	142	187	25	119	21.0%
23	06/03	06/09	167.4	13.6	143	194	22	121	18.2%
24	06/10	06/16	161.9	10.8	147	187	16	120	13.3%
25	06/17	06/23	166.5	12.6	147	195	12	53	22.6%
26	06/24	06/30	167.5	13.4	158	177	2	3	66.7%
27	07/01	07/07	137.0				1	1	100.0%
28	07/08	07/14						0	
Season Total			167.1	19.0	110	229	274	1,670	16.4%

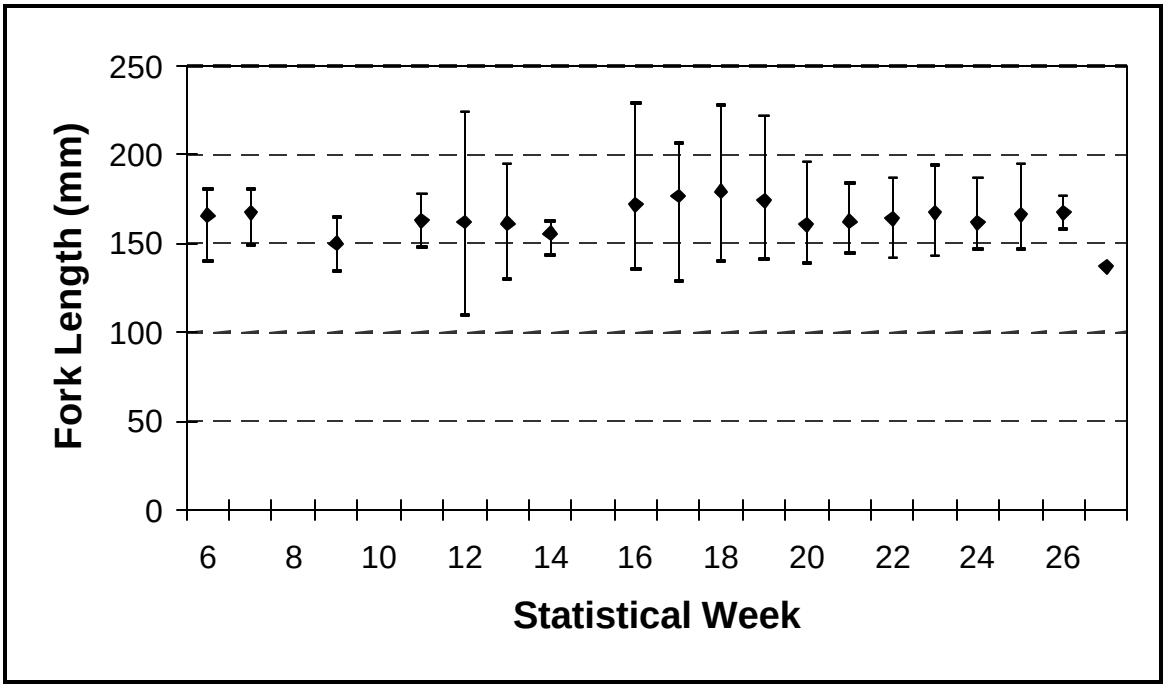

Figure 7. Weekly average, minimum, and maximum unmarked steelhead smolt fork lengths (mm) measured at the Green River screw trap, 2002.

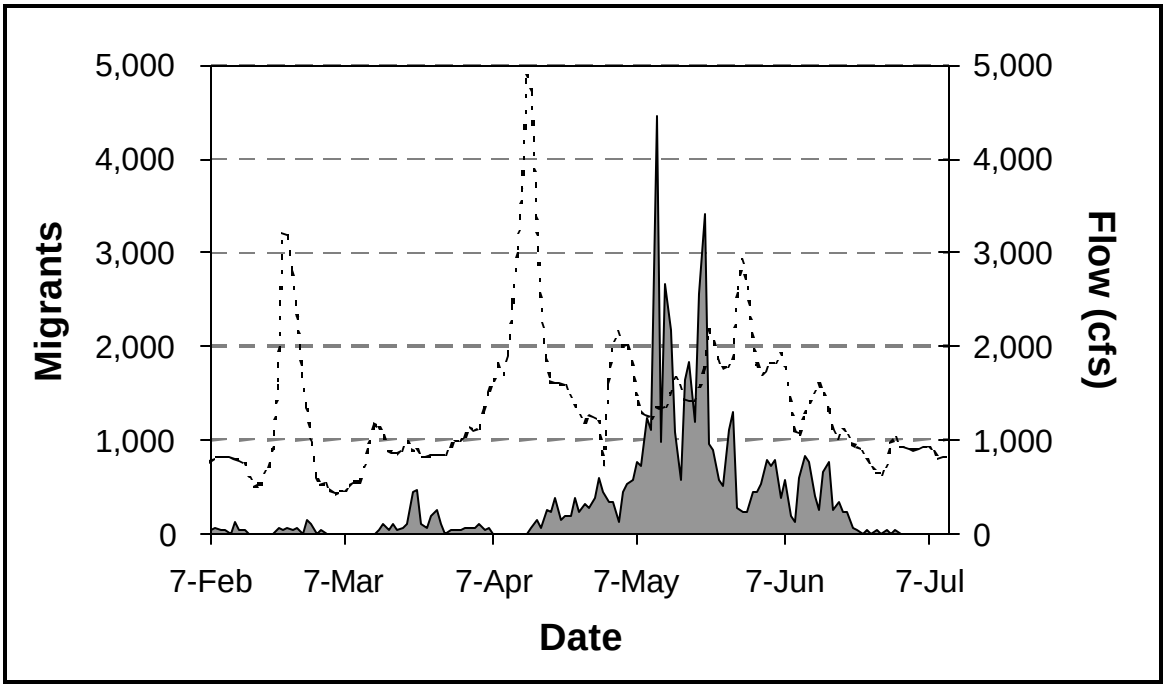

Figure 8. Daily migration of wild steelhead smolts in the Green River screw trap relative to daily average stream discharge measured at USGS Gage #12113000, 2002.

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 24,539 chum fry, 16,392 pink fry, and 779 age 0+ coho fry. We also captured 232 trout parr, 22 cutthroat smolts, one cutthroat adult, and one steelhead adult. In addition to salmonids, a number of other species were captured: sculpin, three-spine sticklebacks, longnose dace, and lamprey ammocoetes.

Discussion

Estimates of migration past the trap were developed for Green River wild and hatchery age 0+ chinook, wild and hatchery yearling coho, and wild and hatchery steelhead smolts. A number of assumptions used to develop these estimates are discussed below. In addition, the estimates for wild chinook migrants are expanded to represent total basin production. As an aid to managers of the Keta Creek Hatchery, Icy Creek Hatchery, and Palmer Ponds we attempt to estimate survival of release groups to the smolt trap and explain the assumptions that went into those estimates.

Chinook

The accuracy of the wild age 0+ chinook production estimates for the Green River are partially dependent on the veracity of the estimated catch that was missed during the periods when the trap was not fishing. Estimated missed catches were relatively low compared to actual catches, representing an increase of only 1.4% to the actual catch.

The accuracy of the wild chinook production is also dependent on the veracity of our estimated capture efficiency. The flow strata used to estimate fry migration may not best represent daily migration, but may be representative of the total migration. It is evident that trap efficiency decreases with increased flow. However, due to the variability of trap efficiency tests conducted at low to mid flows, that relationship could not be used to predict daily trap efficiency. Based on efficiency tests observed at high flows, use of average trap efficiency during smolt migration may underestimate production at high flows.

The wild chinook migration for the Green River had a bi-modal timing distribution. The earliest component consisted 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 in 2002 was 87% of the production upstream of the screw trap. Although the majority of chinook migrated as fry, these fish likely would have survived at a lower rate compared to smolts due to their smaller size.

Egg-to-migrant survival is a measure of freshwater productivity for naturally-reared salmon. The estimated migration of 412,460 wild chinook migrants divided by the estimated egg-deposition above the trap site resulted in an egg-to-migrant survival of 3.4% in 2002 above the screw trap. The estimated egg deposition was derived using an above the trap escapement estimate of 2,711 chinook redds above the trap (Cropp pers. comm.). Egg deposition was estimated using an average fecundity of 4,500 eggs per female.

The wild chinook production estimate made at the Green River trap site only represents the production that occurred upstream of the trap. An additional 480 females were estimated to have spawned downstream of the trap. Total basin production was estimated assuming the same egg-to-migrant survival occurred below the trap as was measured above it, and similar levels of naturally-produced chinook emigrated from Big Soos Creek as was observed in 2000, 275,000 migrants (Seiler *et al.* 2002). Based on these assumptions, we estimated the 2002 Green River total basin production at 760,489 naturally produced age 0+ chinook migrants (Table 8).

Table 8. Total chinook production estimate and egg-to-migrant survival, Green River 2002.

Interval	Estimated Migration	# of Females	PED	Egg-to-Migrant Survival
Above Trap	412,460	2,711	12,199,500	3.38%
Below Trap	73,029	480	2,160,000	3.38%
Soos Creek	275,000			
Total	760,489	3,191	14,359,500	

Coho

The accuracy of coho production estimates is dependent on the same issues as the chinook estimates: missed catch and trap efficiency estimates. Estimated missed catch in 2002 was relatively low, and variability among grouped efficiency tests accounted for the degree of error associated with the production estimate. In 2002, 96% of the coho smolts released from Keta Creek were marked. A large portion of those unmarked hatchery smolts were CWT, however, we did not scan smolts at the trap to detect these tags. The unmarked coho production estimate includes the hatchery smolts that were indistinguishable from the wild coho smolts. The wild migration estimate of 191,228 smolts assumes all marked coho were from the Keta Creek facility and none were from Soos Creek Hatchery. If a portion of the marked smolts were from Soos Creek Hatchery, the wild estimate would be slightly underestimated. The wild migration estimate still includes unmarked coho fry that were released upstream of the Howard Hansen Dam and migrated downstream as smolts. Approximately one-half million unmarked coho fry are released at various locations above the dam each year. Survival of these fry is unknown although it is believed to be low.

The trap efficiency for unmarked coho smolts is believed to be an accurate estimate, even though the use of the average may underestimate migrations at extreme high flows or overestimate migrations at flows less then 1,000 cfs. Excluded from the dataset were a total of 250 ad-marked hatchery smolts released during three trap efficiency tests in mid-April. The capture rates of two of the tests were 0%, while the third test was only 1.3%. These tests were excluded from the efficiency estimates using unmarked wild smolts because of the low recapture rate, and the lack of wild migration during these releases. Hatchery smolt migration past the trap was estimated using the rate estimated with unmarked smolts. Due to the observed difference in capture rates between marked and unmarked coho smolts, the hatchery coho migration is underestimated.

Steelhead

The accuracy of our steelhead migration estimates for the Green River are reliant on the accuracy of our catch estimates during intervals not fished and of our assumption relating trap efficiency for steelhead to coho salmon. Catch was estimated on only one day during the 2002 trapping season, therefore, we are confident in the number of steelhead caught during the season.

Survival of Hatchery Releases

Estimating hatchery survival for individual releases during the 2002 migration year was difficult due to numerous complications. Multiple hatcheries located above the screw trap utilized the same mark for chinook, coho, and steelhead. There were also releases in which hatchery salmonids were not marked. Survival for steelhead released above the screw trap was estimated by pooling all releases (Table 9). It is estimated that 70.2% of the smolts released from Palmer Ponds, Flaming Geyser, Icy Creek, and Keta Creek Hatcheries passed the trap.

Estimates of chinook yearlings are based on coho trap efficiencies, as we did not conduct trap efficiency tests using chinook yearlings. The veracity of chinook yearling survival is dependent on the assumption they are caught at the same rate as coho smolts. Survival to the trap for the Icy Creek Hatchery yearling chinook was estimated at 10.6%. The hatchery yearlings may have been released early, since 77% of the hatchery chinook yearlings caught arrived prior to the May 21 Icy Creek release date. This estimate may also include some chinook that were released as fry above the Howard Hansen Dam in 2001 and could not migrate out until 2002. Survival of Icy Creek chinook yearlings may be overestimated if this estimate includes Howard Hansen Dam releases.

An estimated 7,180 marked chinook fry passed the trap in 2002 from 502,633 released above the Howard Hansen Dam survived at a rate of 1.4%. This rate would be underestimated if a portion of that release was retained behind the dam and migrated as yearlings in 2003.

Keta Creek Hatchery coho smolts released in 2002 had a mark rate of 96%, and applying that rate to the unmarked catch estimated total survival to the trap at 23.3%. This estimate may be biased low if unmarked coho trap efficiency is not representative of ad-marked coho smolts. Lower efficiency rates were observed during three trap efficiency tests using hatchery smolts, however, the average of those rates (0.4%) estimates a migration greater than the number of hatchery smolts released. The Keta Creek Hatchery coho smolt migration estimate may be slightly overestimated if some marked coho smolts from the Soos Creek facility swam upstream and were caught in the trap, but the numbers are assumed to be negligible. Survival of coho fry released above Howard Hansen Dam could not be estimated due to the lack of mass-marking, and the surviving individuals would be included in the total unmarked catch.

Table 9. Estimated survival of hatchery salmonid release groups above the Green River screw trap, 2002.

Species	Facility(s)	Released	Estimated	Survival
Coho Smolts	Keta Creek	345,085	80,332	23.3%
Steelhead Smolts	Keta, Flaming, Icy, & Palmer	184,620	129,604	70.2%
Chinook 1+	Icy Creek	309,000	32,780	10.6%

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Appendix A

Daily Actual and Estimated Catches and Migration Estimates for Wild and Hatchery Age 0+ Chinook Migrants, Green River 2002

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2002.

Date	Daily Average Flow	Wild Chinook			Hatchery Chinook		
		Catch		Migration	Catch		Migration
		Actual	Estimated		Actual	Estimated	
02/07	767	41		685			0
02/08	812	41		685			0
02/09	813	20		334			0
02/10	815	26		435			0
02/11	814	45		752			0
02/12	798	41		685			0
02/13	780	36		602			0
02/14	756	37		619			0
02/15	605	37		619			0
02/16	502	18		301			0
02/17	516	37		619			0
02/18	652	65		1,087			0
02/19	725	398		6,653			0
02/20	899	185		3,093			0
02/21	1,630	379		24,872			0
02/22	3,210	36	32	4,463		0	0
02/23	3,180	67		4,397			0
02/24	2,800	107		7,022			0
02/25	2,330	75		4,922			0
02/26	1,710	79		5,184			0
02/27	1,340	65		4,266			0
02/28	970	99		1,655			0
03/01	585	62		1,036			0
03/02	521	16		267			0
03/03	533	56		936			0
03/04	465	33		552			0
03/05	424	69		1,153			0
03/06	450	151		2,524			0
03/07	458	196		3,276			0
03/08	511	141		2,357			0
03/09	550	103		1,722			0
03/10	553	173		2,892			0
03/11	710	1,457		24,356			0
03/12	969	620	53	11,250		0	0
03/13	1,170	223		3,728			0
03/14	1,140	127		2,123			0
03/15	1,050	197		3,293			0
03/16	886	147		2,457			0
03/17	863	200		3,343			0
03/18	858	88		1,471			0
03/19	897	93		1,555			0
03/20	988	159		2,658			0
03/21	893	240		4,012			0
03/22	887	164		2,741			0
03/23	824	103		1,722			0

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2002, continued.

Date	Daily Average Flow	Wild Chinook			Hatchery Chinook		
		Catch		Migration	Catch		Migration
		Actual	Estimated		Actual	Estimated	
03/24	824	111		1,856			0
03/25	833	290		4,848			0
03/26	839	34		568			0
03/27	844	55		919			0
03/28	850	129		2,156			0
03/29	938	188		3,143			0
03/30	992	174		2,909			0
03/31	994	251		4,196			0
04/01	1,050	458		7,656			0
04/02	1,140	209		3,494			0
04/03	1,100	165		2,758			0
04/04	1,130	95		1,588			0
04/05	1,320	198		12,994			0
04/06	1,540	144		9,450			0
04/07	1,630	396		25,988	2		131
04/08	1,810	94		6,169	1		66
04/09	1,690	168		11,025			0
04/10	1,920	148		9,713			0
04/11	2,470	20		1,313			0
04/12	3,040	11		722			0
04/13	3,670	11	1	788	1	0	66
04/14	4,900	0		0			0
04/15	4,720	19	1	1,313	2	0	131
04/16	3,380	62		4,069	5		328
04/17	2,400	74		4,856	5		328
04/18	1,870	75		4,922	8		525
04/19	1,620	156		10,238	6		394
04/20	1,610	199		13,059	5		328
04/21	1,600	262		17,194	6		394
04/22	1,580	166		10,894	15		984
04/23	1,480	185		12,141	10		656
04/24	1,380	77		5,053	7		459
04/25	1,260	73		1,220	4		67
04/26	1,200	49		819	1		17
04/27	1,260	76		1,270	1		17
04/28	1,250	49		819	6		100
04/29	1,210	27		451	7		117
04/30	737	11	11	368		1	17
05/01	1,620	38		339	5		45
05/02	2,060	45		401	1		9
05/03	2,160	41		365			0
05/04	2,000	8		71	3		27
05/05	2,010	19		169			0
05/06	1,830	18		160	1		9
05/07	1,410	15		134			0

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2002, continued.

Date	Daily Average Flow	Wild Chinook			Hatchery Chinook		
		Catch		Migration	Catch		Migration
		Actual	Estimated		Actual	Estimated	
05/08	1,300	29		259	1		9
05/09	1,260	13		116	1		9
05/10	1,230	28		250			0
05/11	1,350	34		303			0
05/12	1,340	21		187			0
05/13	1,350	25		223			0
05/14	1,490	15		134			0
05/15	1,670	21		187	3		27
05/16	1,580	14		125			0
05/17	1,430	30		267			0
05/18	1,420	24		214			0
05/19	1,420	28		250			0
05/20	1,560	37		330	2		18
05/21	1,750	28		250			0
05/22	2,180	23		205			0
05/23	2,050	16		143			0
05/24	1,850	16		143			0
05/25	1,770	8		71			0
05/26	1,780	13		116			0
05/27	1,880	25		223	2		18
05/28	2,610	39		348	3		27
05/29	2,920	14		125	5		45
05/30	2,640	22		196	1		9
05/31	2,130	17		152			0
06/01	1,810	17		152			0
06/02	1,700	32		285	2		18
06/03	1,750	43		383	2		18
06/04	1,820	97		865	3		27
06/05	1,820	63		562	4		36
06/06	1,930	144		1,284	15		134
06/07	1,780	72		642			0
06/08	1,450	67		597	1		9
06/09	1,100	24	8	285	3	0	27
06/10	1,060	24		214	7		62
06/11	1,290	84		749	8		71
06/12	1,390	131		1,168	6		53
06/13	1,510	161		1,435	7		62
06/14	1,600	228		2,032	16		143
06/15	1,510	214		1,908	25		223
06/16	1,320	226		2,015	19		169
06/17	1,100	230		2,050	13		116
06/18	1,020	391		3,485	14		125
06/19	1,110	198	15	1,899	7	1	71
06/20	1,060	114	43	1,399	7	2	80
06/21	957	113		1,007	2		18

Appendix A. Daily actual and estimated catches and migration estimates for wild and hatchery age 0+ chinook migrants, Green River 2002, continued.

Date	Daily Average Flow	Wild Chinook			Hatchery Chinook		
		Catch		Migration	Catch		Migration
		Actual	Estimated		Actual	Estimated	
06/22	930	131		1,168	3		27
06/23	884	86		767	3		27
06/24	784	69		615			0
06/25	707	21	4	223	1	0	9
06/26	646	19		169	1		9
06/27	643	40	7	419		0	0
06/28	707	208		1,854	1		9
06/29	975	463	19	4,296	3	0	27
06/30	1,020	216	19	2,095		0	0
07/01	934	294		2,621	5		45
07/02	920	86	20	945	1	0	9
07/03	903	139		1,239	2		18
07/04	891	115		1,025	1		9
07/05	905	73		651	1		9
07/06	932	58	4	553		0	0
07/07	930	127	4	1,168	2	0	18
07/08	866	262		2,335	13		116
07/09	804	39	3	374		0	0
07/10	817	36	3	348	1	0	9
07/11	814	46		410			0
Season Totals		17,586	247	412,460	319	4	7,180