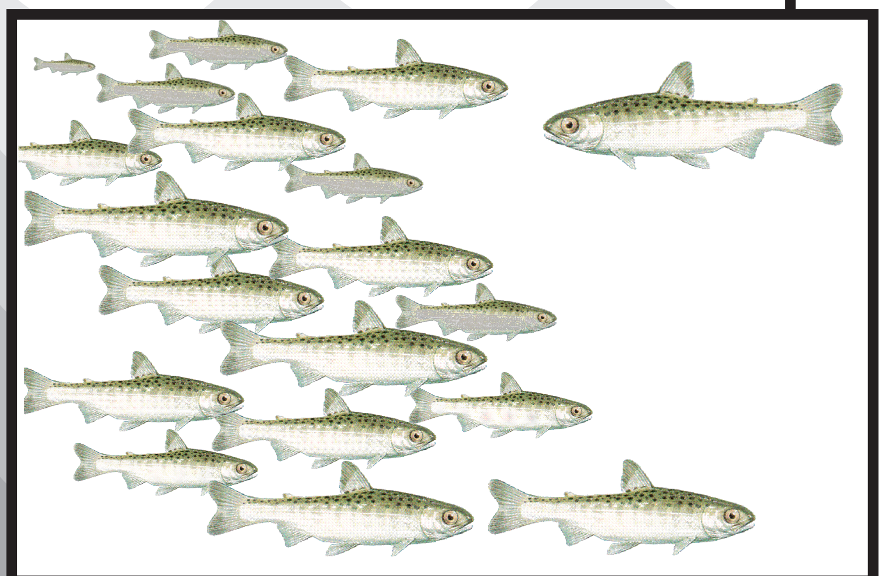
STATE OF WASHINGTON August 2012

Green River Juvenile Salmonid Production Evaluation: 2011 Annual Report



by Pete Topping, and Mara Zimmerman

Washington Department of Fish and Wildlife
Fish Program
Science Division

FPA 12-03

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Acknowledgements

Measuring juvenile salmon production from large river systems like the Green River involves a tremendous amount of work. Developing these estimates was possible due to the long hours of trap operation provided by our dedicated scientific technicians: Bob Green, Matt Pollack, and Paul Lorenz. Logistical support was provided by Wild Salmon Production Evaluation Unit biologist Josh Weinheimer.

A number of other individuals and agencies contributed to this project. Bill Mosby, the adjacent landowner, provided access to the trap site. Mike Wilson, manager of the WDFW Soos Creek hatchery, provided logistical support and a secure staging site near the trap. Darcy Wildermuth, WDFW Region 4, provided Chinook spawner survey data.

The juvenile salmonid production study on the Green River was initiated in 2000. This study was funded by the Washington State legislature between 2000 and 2002, by the Washington Salmon Recovery Funding Board (SRFB) between 2002 and 2007, and by Tacoma Water between 2008 and 2011.

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Executive Summary

This report provides the 2011 results from the juvenile salmonid monitoring study conducted on the Green River in central Puget Sound, Washington. The primary objective of this study was to estimate the juvenile abundance natural-origin Chinook in the Green River. Genetic samples were collected on a significant portion of the juvenile Chinook migrants captured over the season as part of a project to estimate the number of adult Chinook that returned to the Green River in the fall of 2010 and contributed to the 2011 juvenile production. This work is part of the Sentinel Stock Program, an effort to improve the accuracy of the adult Chinook escapement estimates for rivers across Puget Sound. Additional objectives were to estimate the number of juvenile migrants produced by other salmonid species and to describe life history characteristics of all juvenile migrants. Juvenile salmonids were captured in a five-foot screw trap located at river mile 34.5 (55 rkm). Catch was expanded to a total migration estimate using a time-stratified approach that relied on release and recapture of marked fish throughout the outmigration period. The number of juvenile migrants and associated variance were derived using a Bailey estimator.

The trap was operated from January 29 through June 30, 2011. During this period, the trap fished 92% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (sub yearling) and coho salmon. Because of channel configuration and flow conditions at the trap site, we were unable to effectively capture steelhead smolts and were unable to produce a production (abundance) estimate for this species (Table 1).

TABLE 1.─Catch, freshwater production, fork length (mm), and out-migration timing of natural origin juvenile salmonids caught in the Green River screw trap in 2011. Data represent freshwater production above the juvenile trap, which is located at river mile 34.5.

Species/Life Stage	Catch	Production (% CV)	Avg Fork Length (± 1 S.D.)	Median Migration Date
Chinook – SubYrlg	16,040	254,182 (5.8%)	51.0 (± 13.3)	4/21
Chinook – Yrlg	9	---[a]	108.0 (± 7.4)	---[a]
Coho – Yrlg	1,030	62,280 (30.1%)	109.4 (± 11.4)	5/7
Steelhead – Smolt	242	---[a]	175.9 (± 19.0)	---[a]
Chum	36,647[b]	---[b]	---[b]	---[b]

[a]Capture rates were not high enough to derive a production estimate or describe migration timing for yearling Chinook and steelhead smolts.
[b]Catch of unmarked chum were a combination of natural and hatchery production. No production, length, or migration timing were calculated for this species.

Chinook salmon spawn above and below the juvenile trap and a basin-wide production was derived by applying survival estimated above the trap to spawning below the trap (main-stem and above the Big Soos Creek weir). Egg-to-migrant survival of Green River Chinook for the 2011 outmigration (2010 brood) was estimated to be 8.0%, yielding a basin-wide production estimate of 445,718 juveniles.

Juvenile migrant Chinook in the Green River are predominantly sub yearlings. Outmigration timing of sub yearling Chinook was bimodal. The fry (<45-mm fork length) represented 51% of all sub yearling migrants and peaked in mid-March , whereas parr migrants (45+ mm fork length) represented 49% of the migration and peaked in late May.

Introduction

This report provides the 2011 results from the juvenile salmonid production evaluation conducted on the Green River in central Puget Sound, Washington. Throughout this report, the number of juvenile migrants will be referred to as "freshwater production" because they are the offspring of naturally spawning salmon and steelhead in the Green River. The Green River study was initiated in 2000 with a focus on freshwater production and survival of Chinook salmon but has also provided description of the abundance and juvenile life history of coho, chum, and steelhead in this watershed. Information on Green River Chinook and steelhead contribute to ongoing status evaluations for Puget Sound Chinook and steelhead, both listed as *threatened* under the Endangered Species Act by the National Marine Fisheries Service (NMFS). In addition, freshwater production estimates for all species provide a baseline to evaluate impacts of the Additional Water Storage (AWS) project for Howard Hanson dam. In 2011, the Green River juvenile trap results also contributed to the Genetic Mark Recapture (GMR) program conducted by WDFW Fish Science to validate escapement methodologies in Puget Sound watersheds, including the Green River (Seamons et al. 2012).

Under NMFS Listing Status Decision Framework, listing status of a species under the Endangered Species Act (ESA) will be evaluated based on biological criteria (abundance, productivity, spatial distribution, and diversity) and threats to population viability (i.e., harvest, habitat, etc) (Crawford 2007; McElhaney et al. 2000). The Green River has one of the largest stocks of Chinook in Puget Sound and is designated a *contributing* population to the recovery of the Puget Sound Chinook Evolutionary Significant Unit (ESU, Governor's_Salmon_Recovery_Office 2006; National_Marine_Fisheries_Service 2006). Puget Sound steelhead were listed as *threatened* in May of 2007. Winter-run steelhead in the Green River are proposed as a demographically independent population within the Central and South Sound Major Population Group (PSSTRT 2011).

The Green River watershed is distinguished by a number of factors including canyon geomorphology in a portion of the upper watershed, dikes and development in the lower watershed, regulated flows from Howard Hanson dam, and large-scale hatchery production. The productivity of salmonid populations, including Chinook salmon, is influenced by the cumulative effect of these natural and human-influenced features. From 2000 to present, a juvenile fish trap has operated in the main stem Green River (river mile 34.5, rkm 55), approximately one half mile upstream of the mouth of Big Soos Creek. The trap is located upstream of Big Soos Creek in order to avoid the capture of large numbers of hatchery fish released annually from Soos Creek hatchery. This study has produced a long-term data set on juvenile migrants produced by naturally spawning Chinook salmon as well as other salmonids in the Green River.

The combination of juvenile and spawner abundance data for Green River Chinook salmon allows brood-specific survival to be partitioned between the freshwater and marine environment. Spawner abundance is currently derived by WDFW Region 4 staff, although methodology for analyzing spawner data continues to be developed (Hahn et al. 2007; Seamons et al. 2012). Monitoring freshwater production over a range of spawner abundances should provide a measure of watershed capacity and stock productivity through the spawner-recruit function. This information will be critical to identifying the relative impacts of harvest, habitat, and hatchery stressors on this stock.

Results from the Green River juvenile salmonid production evaluation also provide baseline data useful for assessing impacts of a large-scale water storage project at Howard Hanson reservoir. In the mid-1990s U.S. Army Corps of Engineers and Tacoma Water began planning for the Howard Hanson Dam Additional Water Storage Project. The project includes raising the reservoir surface elevation in order to increase water storage for domestic use. The final design for the project was developed between 1999 and 2001. Construction began in 2001 and is ongoing. Juvenile migrant trapping in the Green River was considered important for evaluating the impacts and success of mitigation elements from the AWS project on the abundance, freshwater survival, and migration timing of juvenile Chinook.

In 2011, Green River juvenile Chinook data also contributed to the Sentinel Stock Program, an effort to improve the accuracy of the adult Chinook escapement estimates for rivers across Puget Sound. Tissue samples of juvenile Chinook migrants were the "second sample" in a GMR study conducted by WDFW Fish Science and funded by the Pacific Salmon Commission Sentinel Stocks Committee. The purpose of the GMR study was to develop an unbiased estimate of known precision for Chinook escapement and to compare this estimate to the redd-based estimate currently used for stock assessment and harvest management. Genetic tissue collected from juvenile Chinook migrants in 2011 were the "second sample" in the study designed to estimate the number of adult Chinook returning to the Green River in the fall 2010.

Objectives

The primary objective of this study was to estimate the abundance of juvenile migrants produced by Chinook salmon spawning naturally in the Green River. Additional objectives were to estimate the number of juvenile migrants produced by other salmonid species and to describe their juvenile life history. In 2011, an additional objective was to collect genetic samples from juvenile Chinook migrants over the entire period of their outmigration. This report includes results from the 2011 field season.

Methods

Trap Operation

A floating screw trap (5-ft or 1.5-m diameter) was used to capture juvenile migrants on the Green River (Seiler et al. 2002). The trap was located on the left bank at river mile 34.5 (rkm 55), approximately 3,200 ft (975-m) upstream of the Highway-18 bridge (Figure 1).

In 2011, the trap operated between January 29 and June 30 for a total of 3,368 of 3,645 possible hours (92% of the time). Over the course of the season, trapping was suspended 14 times; the duration of outages ranged from 0.75 to 94.5 hours. Trapping was suspended 4 times for high water, 8 times for hatchery fish releases, and 2 times because of staff furloughs mandated by the Washington State legislature.

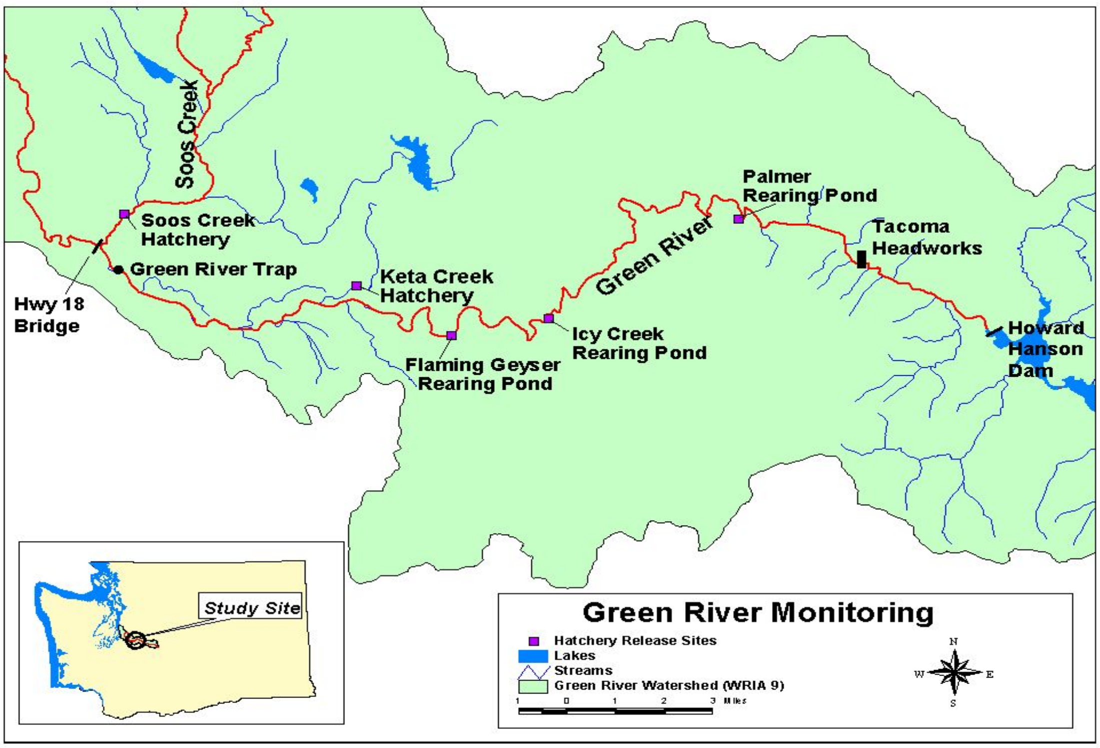

Figure 1.─Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson dam.

Fish Collection

The trap was checked for fish at dawn and dusk each day and at additional times when required by heavy debris loads or large catches. At the end of each trapping period, all captured fish were sorted by species and mark status (adipose fin clips or coded-wire tags) and then enumerated. Fork length (FL) was measured from a sub sample of natural origin Chinook, coho and steelhead smolts on a daily basis. Sub-yearling Chinook were length sampled at a rate of approximately 10 % and yearling smolts were sampled as heavily as possible given work load and the daily catch rate. Caudal fin clips for genetic analysis were collected from 50% of the juvenile Chinook caught from the start of the season thru 5/9 and from virtually all the Chinook captured from May 10 through the end of the trapping season. Scale samples were collected on all but two of the natural-origin steelhead smolts captured to determine age composition of the smolt production.

Chinook were enumerated as sub yearlings and yearlings. Yearling Chinook out migrate between January and April and range in size from 85 to 150-mm FL. Sub yearling Chinook emigrate between January and July, range between 38mm and 90-mm FL. Sub yearlings are distinguished from yearling migrants by the body size and date of migration. Sub-yearling migrants average in size between 38 mm and 50mm during the time period that yearling migrants typically outmigrate. For the purpose of analysis, sub yearling migrants were further partitioned into "fry" and "parr", two freshwater rearing strategies observed in the Green River as well as other watersheds in Puget Sound (Kinsel et al. 2008; Kiyohara and Zimmerman 2011; Topping and Zimmerman 2011). Fry migrants were less than 45-mm fork length (FL) and emigrate after minimal to no rearing in freshwater. Parr migrants were longer than 45-mm FL, and became the dominant component of the catch by late April. Based on their size, parr migrants have reared in freshwater for several months prior to emigration.

Coho were enumerated as either fry or smolts (yearlings). Defining characteristics of coho fry were a bright orange-brown color, elongated white anal fin ray, small eye and small size (under 60-mm FL). Yearling coho were larger in size (approximately 90 to 160 mm FL), with silver sides, black tips on the caudal fin and large eye compared to the size of the head.

Trout were enumerated by two different age classes: parr, and smolt. Parr were trout that were not "smolted" in appearance, typically between 50 and 150 mm FL, dark in color (brown with spots on the tale), and caught throughout the trapping season. Smolts were chrome in appearance, larger in size (90 to 350 mm FL) and with many spots along the dorsal surface and tail. Parr and smolts were assigned as either steelhead or cutthroat based on mouth size and presence or absence of red coloration on the ventral surface of the gill covers.

Origin was assigned based on the mark status of each species and known marks of hatchery fish released above the trap (Table 2). Hatchery releases above the screw trap in 2011 included Chinook, coho, chum, summer steelhead, and winter steelhead. Chinook, coho, and steelhead were assigned to origin based on the presence (natural) or absence (hatchery) of an adipose fin. None of the fish were scanned for CWTs; therefore, the release of hatchery steelhead (CWT, unmarked) could only be distinguished based on phenotypic traits typical of hatchery rearing (i.e., stunted dorsal fins). Chum could not be assigned to origin because all hatchery chum were unmarked.

Table 2. Number of hatchery fish by mark type released above the Green River screw trap in 2011. Fish released below the trap are not included in this table as they do not impact the quality of the freshwater production estimate.

Species	Brood Year	Release Location	CWT	Ad-Clip	Unmarked
Chinook – SubYrlg	2010	Palmer Pond	0	939,330	40,670
Chinook – Yrlg	2009	Icy Creek	0	297,429	2,499
Coho – Yrlg	2009	Keta Creek	49,177	363,321	1,502
Chum - SubYrlg	2010	Keta Creek	0	0	3,476,200
Summer Steelhead	2010	Icy Creek	0	25,000	0
Winter Steelhead	2010	Icy Creek	10,564*	0	0
Winter Steelhead	2009	Icy Creek	0	25,000	0
Winter Steelhead	2009	Flaming Geyser	0	9,947	50

*Tagged with blank tag wire and yellow elastamer visual implant eye mark.

Trap Efficiency Trials

Trap efficiency trials were conducted for Chinook, coho, and steelhead with maiden-caught fish of natural origin throughout the season. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and marked with either Bismarck-brown dye or a partial caudal fin clip. Small Chinook (January to early-May) were marked with Bismarck Brown dye, whereas the large Chinook parr, coho, and steelhead were marked with a partial caudal fin clip. The fin clip position alternated in order to check for delayed migration of the marked fish.. After recovery in freshwater for the day, marked fish were released at two upstream locations at dusk. The first location was 150-m upstream of the trap with the fish released approximately 10 feet from shore into fast moving downstream current. This location was selected because it is above a bend in the river that pushes the main current against a cliff that mixes the entire river, providing thorough mixing of marked and unmarked fish while minimizing in-river predation between release and recapture. This location has been the primary release location for this study since 2000. The second location was the Neely Bridge site, located approximately a third of a mile above the trap site. Fish released at this site were lowered from the bridge in a bucket and released into the thalwag located in the center of the river. Two release sites were selected in order to test these assumptions. Dyed or clipped fish caught in the trap were recorded as recaptures.

Freshwater Production Estimate

Freshwater production is the number of juvenile migrants leaving freshwater in a given year. In most cases, freshwater production corresponds to a single brood year of spawners; however, in some cases (e.g., steelhead) freshwater production may represent more than one brood year.

Freshwater production was estimated using a single partial-capture trap design (Volkhardt et al. 2007). Data were stratified by time over the outmigration period in order to accommodate for temporal changes in trap efficiency. The general approach was to estimate (1) missed catch, (2) efficiency strata, (3) time-stratified abundance, (4) extrapolated migration outside the trapping season, and (5) total abundance.

(1) Missed catch. Total catch ($\hat{u}$) was the actual catch (n_i) for period *i* summed with missed catch ($\hat{n}_i$) during periods of trap outages.

Equation 1

$$\hat{u}_i = n_i + \hat{n}_i$$

Missed catch for a given period *i* was estimated as:

Equation 2

$$\hat{n}_i = \overline{R} * T_i$$

where:

$\overline{R}$ = Mean catch rate (fish/hour) from adjacent fished periods, and

T_i = time (hours) during the missed fishing period.

Variance associated with $\hat{u}_i$ was the sum of estimated catch variances for this period. Catch variance was:

Equation 3

$$Var(\hat{u}_i) = Var(\hat{n}_i) = Var(\overline{R}) * T_i^2$$

where:

Equation 4

$$V(\overline{R}) = \frac{\sum_{i=1}^{i=k} (R_i - \overline{R})^2}{k(k-1)}$$

(2) Efficiency strata. A *G*-test (Sokal and Rohlf 1981) was used to determine whether adjacent efficiency trials were statistically different. *A priori* pooling prior to the G-test occurred for efficiency trials with expected frequencies of less than five (Sokal and Rohlf 1981) Of the marked fish released in each efficiency trial (*M)*, a portion are recaptured (*m*) and a portion are not seen (*M-m*). If the *seen:unseen* [*m*:(*M-m*)] ratio differed between trials, the trial periods were considered as separate strata. However, if the ratio did not differ between trials, the two trials were pooled into a single stratum. A *G*-test determined whether adjacent efficiency trials were statistically different (α = 0.05). Trials that did not differ were pooled and the pooled group compared to the next adjacent efficiency trial. Trials that did differ were held separately. Pooling of time-adjacent efficiency trials continued iteratively until the *seen:unseen* ratio differed between time-adjacent trials. Once a significant difference is identified, the pooled trials are assigned to one strata and the significantly different trial is the beginning of the next stratum.

(3) Time-stratified abundance. Abundance for a given stratum *h* ($\hat{U}_h$) was calculated from maiden catch ($\hat{u}_h$), marked fish released (M_h), and marked fish recaptured (m_h). Abundance was estimated with a Bailey estimator (Carlson et al. 1998; Volkhardt et al. 2007).

Equation 5

$$\hat{U}_h = \frac{\hat{u}_h (M_h + 1)}{m_h + 1}$$

Variance associated with the Bailey estimator was modified to account for variance of the estimated catch during trap outages (derivation in Appendix A):

Equation 6

$$V(\hat{U}_h) = V(\hat{u}_h)\left(\frac{(M_h+1)(M_h m_h + 3M_h + 2)}{(m_h+1)^2(m_i+2)}\right) + \left(\frac{(M_h+1)(M_h - m_h)\hat{u}_h(\hat{u}_h + m_h + 1)}{(m_h+1)^2(m_h+2)}\right)$$

(4) Extrapolated migration. Migration outside the trapping period ($\hat{N}_e$) was estimated based on an assumed number of days (*t*) outside the trapping period that the migration was assumed to occur. Extrapolation was used for Chinook salmon (January 1 – July 31) due to their extended outmigration period and the low levels of catch occurring at the beginning and end of the trapping season. Extrapolation was calculated based on the estimated daily migration ($\hat{N}_d$) for the first *k* days of trapping (and the last *k* days of trapping).

Equation 7

$$\hat{N}_e = \frac{\sum_{d=1}^{d=k} \hat{N}_d}{k} * \frac{t}{2}$$

Variance associated with the extrapolated migration was:

Equation 8

$$V(\hat{N}_e) = \frac{\sum_{d=1}^{d=k} (\hat{N}_d - \overline{N})^2}{k(k-1)} * \left(\frac{t}{2}\right)^2$$

(5) Total abundance. Total abundance of juvenile migrants was the sum of in-season stratified estimates and extrapolated estimates.

Equation 9

$$\hat{N}_T = \sum_{h=1}^{h=k} \hat{U}_h + \sum \hat{N}_e$$

Variance was the sum of variances associated with all in-season and extrapolated estimates:

Equation 10

$$V(\hat{N}_T) = \sum_{h=1}^{h=k} V(\hat{U}_h) + \sum V(\hat{N}_e)$$

Confidence intervals were calculated from the variance:

Equation 11

$$\hat{N}_{95\%ci} = \hat{N}_T \pm 1.96\sqrt{V(\hat{N}_T)}$$

Coefficient of variation was:

Equation 12

$$CV = \frac{\sqrt{V(\hat{N}_T)}}{\hat{N}_T}$$

Daily migration estimates were calculated from the daily catch and the trap efficiency for strata *h*:

Equation 13

$$\hat{U}_d = \frac{\hat{u}_{dh}}{e_h}$$

Where:

Equation 14

$$e_h = \frac{\hat{u}_h}{\hat{U}_h}$$

Freshwater Life History Diversity

Juvenile length statistics and median migration dates were summarized for all species. Median migration date was the date that 50% of juvenile migrants were estimated to have passed the trap and was derived from daily migration data. If daily migration estimates were not available for a species (e.g., no production estimate due to low trap efficiency), median catch date was reported as a proxy for median migration date. The use of catch data to estimate migration timing should be viewed with caution as catch numbers have limited meaning without trap efficiency information.

In order to describe abundance and migration of the two sub yearling Chinook strategies, the sub yearling Chinook production was divided into fry and parr migrants. For a given statistical week, the proportion of Chinook within each size class (< 45-mm FL, > 45-mm FL) was applied to the migration estimate for that week.

Egg-to-Migrant Survival for Sub Yearling Chinook

Freshwater productivity of sub yearling Chinook was estimated as juveniles/female and egg-to-migrant survival. Juvenile migrants were estimated as described above. Female spawners were based on foot, boat, and aerial surveys of Chinook redds conducted by WDFW Region 4 and the Muckleshoot Indian Tribe (Footen et al. 2011). These estimates assume one female per redd (personal communication, Darcy Wildermuth, WDFW Region 4). Egg-to-migrant survival was the number of juvenile migrants divided by potential egg deposition (P.E.D.). Potential egg deposition was the product of female spawners estimated above the trap site and a Chinook fecundity of 4,500 eggs per female. Fecundity was the long-term average of Chinook fecundity measured at Soos Creek Hatchery (personal communication, Mike Wilson, WDFW Hatchery Division).

Basin-wide Abundance of Sub Yearling Chinook

A portion of the Chinook spawning occurs below the juvenile trap in the main stem Green River and above the hatchery rack on Soos Creek. In order to make a basin-wide abundance estimate for juvenile migrant Chinook, egg-to-migrant survival above the trap was applied to the number of eggs deposited in the lower river and in Soos Creek. Egg deposition was estimated as described above. This approach assumes equivalent female fecundity and egg survival above the below the trap site.

Results

Sub Yearling Chinook

The total estimated catch of natural-origin Chinook ($\hat{u}$ = 16,040) included 15,098 captures in the trap and 942 missed catch estimated for trap outage periods (Table 3, Appendix B). A total of 516 ad- marked Chinook were captured between April 9 and June 30. In addition to the marked hatchery fish, 11 hatchery unmarked Chinook were captured between April 13 and May 3. Positive identification of the unmarked hatchery Chinook became increasing more difficult as the body sizes of natural-origin Chinook increased. After May 3, all unmarked fish were identified as natural origin because of the similarity in size between natural and hatchery Chinook.

A total of 62 efficiency trials, ranging between 17 and 225 fish, were conducted and used a total of 6,532 natural-origin Chinook. To test for thorough mixing, releases were performed from two locations, the first was the traditional site 150 yards upstream of the trap, used every year, and the second was at the Neely Bridge located approximately a third of a mile above the trap location. Recapture rates were similar for the two locations so releases from both sites were included in the analysis. The trials were combined to achieve a minimum of 5 recoveries, forming 40 groups prior to stratification. The *G*-test pooled the 40 groups into twelve strata, with trap efficiencies ranging between 2.9% and 21.9% (Table 3).

The trapping season of January 30 through June 30 encompassed the majority of the sub yearling Chinook migration. A total of 242,226 sub yearlings were estimated to have migrated during the trapping season. However, some fish migrated both before and after our trapping season, which was evident by the catch of Chinook migrants on our first and last days of trapping. A total of 6,384 Chinook were estimated to have migrated prior to the trapping season and 5,572 migrants were estimated following the trapping season.

A total of 254,182 ± 28,855 (±95% C.I.) sub yearling Chinook of natural origin were estimated to have migrated past the screw trap between January 1 and July 31, 2011. Coefficient of variation for this estimate was 5.8%.

TABLE 3.─Catch, marked and recaptured fish, and estimated abundance of natural-origin sub yearling Chinook migrants at the Green River screw trap in 2011. Release groups were pooled to form twelve strata. Missed catch and associated variance were calculated for periods that the trap did not fish.

		Catch					Abundance	
Strata	Date	Actual	Missed	Variance	Marked	Recaptured	Estimated	Variance
Before	1/01-1/29						6,384	1.05E+06
1	1/30-2/13	1,073			459	41	20,864	9.40E+06
2	2/14-3/02	2,080	180	7.79E+00	334	73	5,899	3.82E+05
3	3/03-3/06	604			179	16	2,954	4.66E+05
4	3/07-3/14	3,496			206	6	13,307	2.17E+07
5	3/15-3/15	415			649	75	29,900	1.05E+07
6	3/16-3/16	305			377	23	11,340	4.98E+06
7	3/17-3/25	1,256			553	76	9,037	9.57E+05
8	3/26-3/26	129			280	9	18,462	3.03E+07
9	3/27-4/07	1,283	652	1.99E+04	158	14	14,914	1.27E+07
10	4/08-4/24	1,053	38	2.85E+01	533	18	36,733	6.60E+07
11	4/25-5/08	504	15	1.22E+01	70	11	1,793	2.49E+05
12	5/09-6/30	2,900	57	1.07E+02	2,734	104	77,023	5.57E+07
After	7/01-7/31						5,572	2.26E+06
	Season Total	15,098	942	2.01E+04	6,532	466	254,182	2.17E+08

Freshwater productivity of natural-origin Chinook for brood year 2010 was estimated to be 360 juveniles per female and 8.0% egg-to-migrant survival. This calculation was based on the number of sub yearling Chinook passing the trap ($\hat{N}_T$ = 254,182), 706 female spawners above the trap site (personal communication, Darcy Wildermuth, WDFW Region 4), and an estimated P.E.D above the trap site of 3,177,000 eggs.

Basin-wide abundance of sub yearling Chinook of natural origin was estimated to be 445,718 juvenile migrants (Table 4). This included 254,182 migrants from above the trap, 25,562 juveniles from the main stem below the trap, and 165,974 from Big Soos Creek.

An estimated 51% (128,472) of the Chinook migrated as fry and 49% (125,710) migrated as parr. The migration periods of fry and parr overlapped between early February and the middle of June.

The median migration date for sub yearling Chinook was on April 2. Timing of the outmigration was bimodal (Figure 2); however, both fry and parr migrants had multiple peaks to their emigration. The first peak to the fry migration occurred during statistical week 8 (10,000 fry migrants between February 14 and February 20), and the second peak occurred during statistical week 11 (~20,000 fry migrants between March 7 and March 13). The first peak to the parr migration occurred during statistical week 22 (22,000 parr migrants between May 23 and May 29), and the second peak occurred during statistical week 26 (13,000 parr migrants between June 20 and June 26).

The seasonal average length of sub yearling Chinook was 51.0 ± 13.3 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the sub yearling Chinook remained consistent from the first week of trapping through statistical week 14 (March 28 to April 3) and ranged between 39.9-mm and 44.5-mm FL during this time period. Beginning in mid-April, sub yearling Chinook increased in size by an average of 2 mm per week, and averaged 76-mm FL by the end of the trapping season (Figure 3, Appendix C).

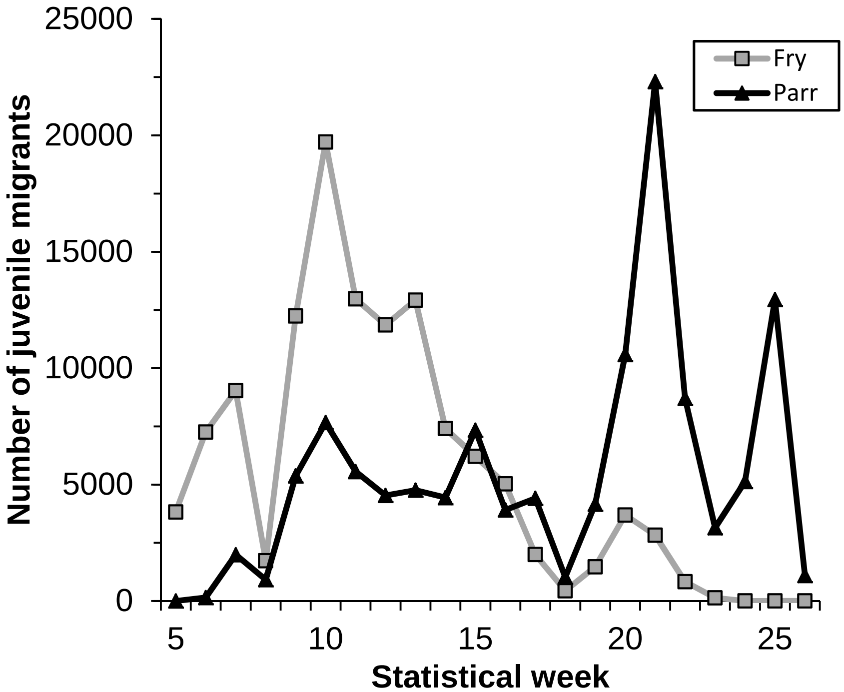

Figure 2.─Weekly migration of sub yearling Chinook migrants of natural origin at the Green River screw trap in 2011. Sub yearling migrants are partitioned into two freshwater rearing strategies – fry (<45-mm FL) and parr (> 45-mm FL) migrants.

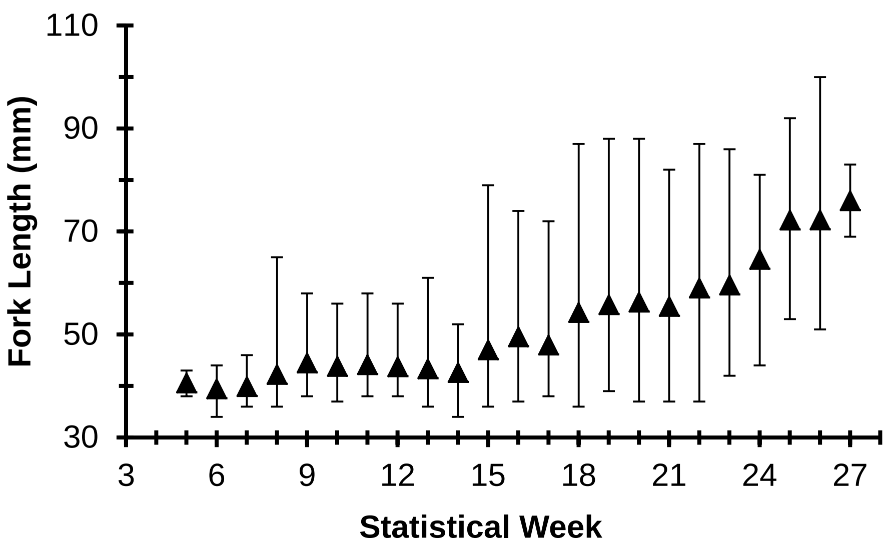

Figure 3.─Fork lengths (mm) of sub yearling Chinook migrants of natural origin captured in the Green River screw trap in 2011. Data are mean, minimum, and maximum values by statistical week.

Table 4.—Abundance of natural-origin juvenile migrant Chinook (sub yearling) in the Green River, outmigration year 2000-2011. Abundance is partitioned into regions above the juvenile trap site, below the juvenile trap site, and above Soos Creek hatchery rack.

Brood	Trap	Above Trap				Below Trap			Soos Crk			Total Green
Year	Year	Redds	Deposition	Production	Survival	Redds	Deposition	Production	Females	Deposition	Production	Production
1999	2000	1,625	7,312,500	475,207	6.50%	826	3,717,000	241,551	1,616	7,272,000	275,125	991,883
2000	2001	3,064	13,788,000	809,616	5.87%	936	4,212,000	247,324	1,580	7,110,000	275,000	1,331,940
2001	2002	2,711	12,199,500	584,151	4.79%	480	2,160,000	103,428	995	4,477,500	275,000	962,579
2002	2003	3,772	16,974,000	449,956	2.65%	2,314	10,413,000	276,034	1,239	5,575,500	275,000	1,000,990
2003	2004	3,124	14,058,000	236,650	1.68%	1,038	4,671,000	78,631	720	3,240,000	54,542	369,822
2004	2005	4,769	21,460,500	470,334	2.19%	827	3,721,500	81,561	623	2,803,500	61,442	613,338
2005	2006	1,553	6,988,500	99,796	1.43%	82	369,000	5,269	598	2,691,000	38,428	143,493
2006	2007	3,170	14,265,000	127,491	0.89%	883	3,973,500	35,512	313	1,408,500	12,588	175,592
2007	2008	2,435	10,957,500	400,763	3.66%	438	1,971,000	72,088	676	3,042,000	111,259	584,109
2008	2009	2,107	9,481,500	196,115	2.07%	282	1,269,000	26,248	504	2,268,000	46,911	269,274
2009	2010	218	981,000	55,547	5.66%	57	256,500	14,524	759	3,415,500	193,395	263,465
2010	2011	706	3,177,000	254,182	8.00%	71	319,500	25,562	461	2,074,500	165,974	445,719

Yearling Chinook

Nine yearling Chinook of natural origin were captured (Appendix B). Seven were caught in February and two in April. Fork length of the six five measured individuals averaged 108.9 mm (range 95 to 114 mm).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}$=1,200) included 1,030 captures in the trap and 170 missed catch estimated for trap outage periods (Table 5, Appendix D). A total of 4,528 (1 CWT only, 3,972 Ad-mark and 555 Ad-CWT) hatchery coho were captured between March 29 and June 23. Thirty-three trap efficiency trials using natural origin coho were conducted over the trapping season. All efficiency trials were pooled into one strata with an efficiency of 1.7%.

A total of 62,280 ± 36,785 (95% C.I.) natural-origin coho smolts are estimated to have migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 30.1%.

Table 5.─Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2011. Release groups were pooled to form a single strata. Missed catch and associated variance were calculated for periods that the trap did not fish.

		Catch					Abundance	
Strata	Date	Actual	Missed	Variance	Marked	Recaptured	Estimated	Variance
1	1/30-6/30	1,030	170	1.20E+03	518	9	62,280	3.52E+08

The median migration date for coho smolts was May 7. The first coho smolt was captured on January 30, 2011. Daily migration of coho was low and averaged 160 smolts per day through April 20 (Figure 4). Peak daily migration occurred on May 6 when 6,167 smolts are estimated to have passed the trap in a single night. Daily migration declined gradually through the remainder of May and early June. The last natural-origin coho smolt was captured on June 21, 2011.

The seasonal average length of coho smolts was 109.4 ± 11.4 mm FL (± 1 S.D.; Appendix E). The weekly averages had no apparent seasonal trend (Figure 5).

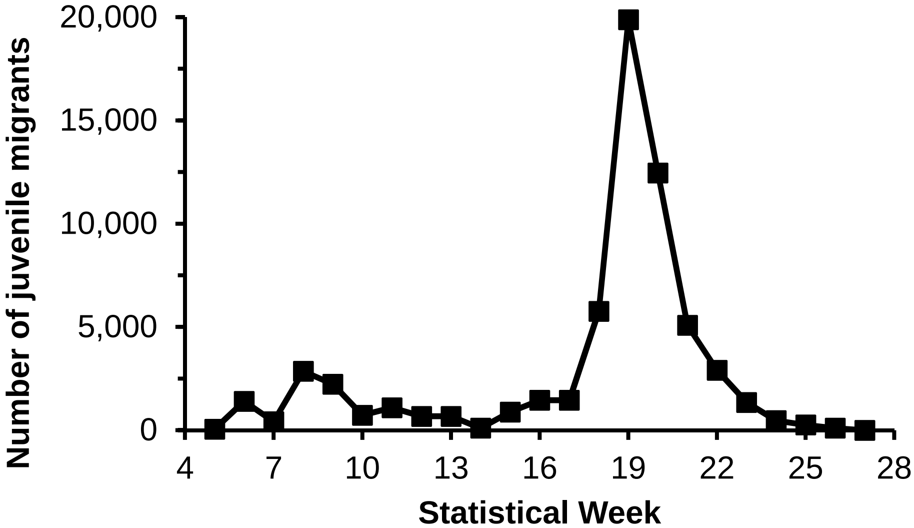

Figure 4.—Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2011. Data are number of juvenile migrants by statistical week.

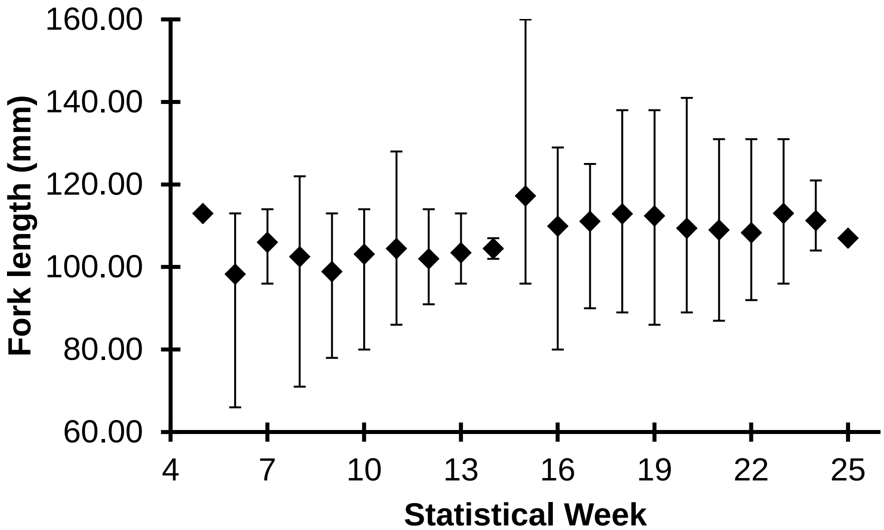

Figure 5.—Fork lengths (mm) of natural-origin coho captured in the Green River screw trap in 2011. Data are mean, minimum, and maximum values by statistical week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 283) included 256 captures in the trap and 27 missed catch estimated for trap outage periods (Appendix D). Trap efficiency trials (25 in total) were conducted between April 19 and June 2, resulted in no recoveries from the 132 individuals released. Therefore, no production estimate was made for the 2011 smolt migration.

Catch of unclipped steelhead smolts, assumed to be of natural origin, may have included a minimal number of hatchery steelhead smolts due to the release of unclipped, coded-wire tagged steelhead from Icy Creek on May 6, 2011. Steelhead smolts were not electronically scanned for CWTs. However, none of the captured steelhead smolts were observed to have characteristic hatchery features such as stunted dorsal fins.

The first steelhead was captured on January 30, 2011. Early in the trapping season, daily catch of steelhead was low with only 100 individuals caught through April 30. Peak catch occurred on the night of May 21, with 17 smolts captured. Daily catch quickly declined and only 4 smolts were captured in the entire month of June.

The seasonal average length of natural-origin steelhead smolts was 175.1 ± 18.4 mm FL (± 1 S.D.; Appendix F, Figure 6).

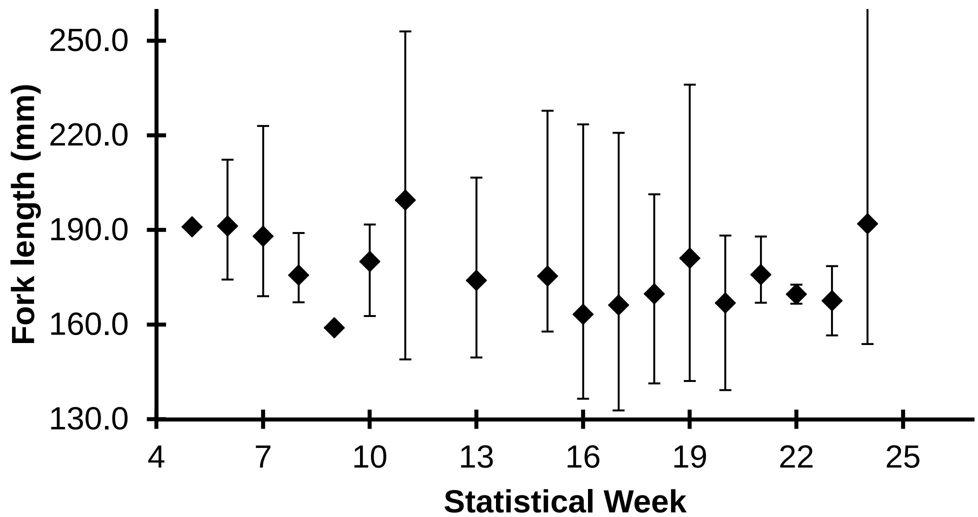

Figure 6.—Fork lengths (mm) of natural-origin steelhead at the Green River screw trap in 2011. Data are mean, minimum, and maximum values by statistical week.

Length and scale samples were collected on 254 of the 256 natural-origin steelhead smolts captured to determine the age-length structure of the natural-origin steelhead smolt production. The sample included 205 readable and 49 regenerated samples. Scale sample results indicated that 26% were one year old and averaged 158.2-mm FL, 67% were two years old and averaged 180.1-mm FL, and 7% were three year old smolts and averaged 189.9-mm FL (Table 6).

Table 6. Age and length of natural-origin steelhead smolts collected at the Green River juvenile trap, 2011.

Age	Average	Standard Deviation	Min	Max	Number	Percent of Readable
1+	158.2	10.27	140	180	53	25.85%
2+	180.1	16.28	143	236	138	67.32%
3+	189.9	30.05	160	253	14	6.83%
Unreadable	---	---	---	---	49	---
Total Sampled	175.1	19.21	140	253	254	---
Not Sampled	---	---	---	---	2	---

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$=49,515) included 36,647 captures in the trap and 12,868 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between February 5 and June 29, 2011. Chum catch could not be separated by natural and hatchery origin because chum released from Keta Creek hatchery were unmarked.

Other Species

In addition to species and age classes described above, catch during the trapping season included 1,030 coho fry, 163 trout parr, 40 cutthroat smolts, and 7 adult cutthroat (Appendix D). Non-salmonid species captured included sculpin (*Cottus* spp.), three-spine sticklebacks (*Gasterosteus aculeatus*), longnose dace (*Rhynichthys cataractae*), and lamprey ammocoetes.

Discussion and Synthesis

This report provides the freshwater production estimates for Chinook (sub yearling) and coho salmon emigrating from the Green River in 2011. Although a few yearling Chinook smolts were captured, no production estimate was made for this life stage and the low catch rates suggest that yearling migrants are a minor, yet present, contribution to the total freshwater production for Chinook salmon. We also report catch of steelhead smolts and juvenile chum migrants; however, we were not able to make an estimate of freshwater production for these species. In addition to abundance estimates, we provide summaries of body length, age, and outmigration timing that describe the duration of time that juvenile salmonids are using freshwater habitat for rearing.

Assumptions for Mark-Recapture Estimates

The mark-recapture approach used to derive juvenile abundance estimates was based on five assumptions (Hayes et al. 2007; Seber 1973). These assumptions must be met, or accommodated, in order to ensure an unbiased abundance estimate. The study design for the Green River juvenile production evaluation was developed to minimize violating the estimator assumptions. In addition, study protocols for the 2011 trapping season included quantitative tests of these assumptions.

<u>Assumption 1. Population is closed with no immigration or emigration and no births or deaths.</u> The emigration assumption is technically violated because the trap catches fish that are emigrating from the river. However, we assume that the entire cohort is leaving the system within a defined period and that the abundance of juveniles can be estimated at a fixed station during this migration. This assumption is supported by the modality of downstream movement and the condition of the yearling fish (visibly undergoing a process of smoltification).

Two potential sources of deaths due to the trapping operations are mark-related mortality and in-river predation. The stress associated with handling or marking is minimized by gentle handling and dying by trained staff. In 2011, mark-related mortality was evaluated by holding three groups Bismark brown dyed Chinook for a period of at least 24-hours prior to release with no observed mortalities. In addition to these tests the majority of the Chinook dyed throughout the season, where dyed following the morning trap check when the majority of the daily Chinook catch is processed. The dyed Chinook were then allowed to recover in fresh water for the day prior to release following the evening trap check. Death between release and recapture due to in-river predation or live box predation is expected to be an important issue for the small fry migrants (Chinook and chum). For this reason, the release site was selected to be close enough to the trap to minimize in-river predation but far enough from the trap to maximize mixing of marked and unmarked fish (see discussion for assumption #4 below). Predation in the live box is an addition source of mortality of marked fish, this becomes a larger problem during the peak of the steelhead and coho smolt migrations. The amount of live box predation was not quantified but observations were made that some of the captured coho and steelhead smolts had enlarged abdomens from recently consumed salmon fry. It is unknown if the predation occurred prior to capture or within the livebox.

<u>Assumption 2. All animals have the same probability of being caught</u>. This assumption would be violated if trap efficiency changes over time, if small fish are caught at a different rate than large fish, or if fish are moving downstream at different rates. In order to accommodate for seasonal variation in trap efficiency, the data were stratified into time periods based on statistically different trap efficiencies. In 2011 attempts were made to evaluate size bias of

yearling smolts (coho or steelhead) by using a Kolomogorov-Smirnov test to compare the lengths of released and recaptured juveniles. Unfortunately, due to the low capture and recapture rates of yearling smolts, we were unable to evaluate size selectivity for the 2011. The potential for size biased capture was greater for yearling smolts than for the sub yearling migrants, however given the dificult.

Equal probability of capture would also be violated if a portion of the juvenile fish were caught because they were redistributing in the river rather than in process of a downstream migration. In this study, most if not all of the captured sub yearling fish (Chinook and chum) were recaptured within a one day time frame following release indicating they were in process of a downstream migration. Redistribution of yearling fish is more likely as rearing habitat does occur below the trap site location. In 2011, the low number of recaptures of yearling migrants (coho and steelhead) did not allow delayed recaptures to be assessed.

Assumption 3. Marking does not affect catchability. This assumption would be violated if marked fish were better able to avoid the trap or were more prone to capture than maiden caught fish. Behavioral differences between maiden captures and recaptured fish are currently unknown. Handling and marking the fish may also make them more prone to capture if the stress of handling compromises fish health. To minimize this effect, fish held for release are monitored for the 10+ hours between initial capture and release. During this period, fish are held in a perforated bucket that allows water to be exchanged between the bucket and stream. Fish that do not appear to be swimming naturally are removed prior to release.

Assumption 4. Marked fish mix at random with unmarked fish. This assumption would be violated if marked and unmarked fish were spatially or temporally distinct in their downstream movements. The most important factor contributing to equal mixing is the selection of the release site. In study years prior to the 2011 season, all marked fish were released at the same location approximately 150 meters upstream of the trap. Below this location, a bend occurs in the river and fast flowing water around this bend was expected to maximize dispersal of marked fish. This release site was selected specifically for the target species, sub yearling Chinook, in order to maximize mixing of marked and unmarked while minimizing in-river predation. However, the requirements for mixing and for avoiding predation may be different for sub yearling and yearling migrants due to their body size and swimming abilities.

In 2011, we tested the potential impact of the release site on the sub yearling Chinook abundance estimate by comparing the trap efficiency from the traditional site to that of a second release location (Neely Bridge) which was an additional 1/4 mile upstream. Releases of marked (Bismarck Brown) sub yearling Chinook from both sites were conducted sequentially throughout the season. We were not able to repeat this comparison for the yearling smolts (coho and steelhead) due to low catches in 2011. If catches allow in 2012, at least one additional upstream release site will be paired with the original site for both sub yearlings and yearling smolts.

Between early February and mid-May, we conducted seven sub yearling Chinook releases from the Neely Bridge location (Table 7). These releases were interspersed with releases from the original location. We compared adjacent releases from the two locations using a *G*-test and found no difference between the two sites. Comparable recovery rates from the two release locations supports the assumption that marked sub yearling Chinook released from the original site have mixed randomly with unmarked Chinook prior to recapture in the screw trap. In addition, these results did not suggest that increasing the distance between release and recapture by 1/3 mile had a detectable influence on in-river mortality of the released fish.

Table 7. Trap efficiency of the Green river screw trap for sub yearling Chinook salmon based on two release locations in 2011.

Original Site			Neely Bridge Site				
Release Date	Number Released	Trap Efficiency	Release Date	Number Released	Trap Efficiency	Δ TE	*P*
2/12	92	2.17%	2/10	70	1.43%	0.74%	.81
2/18	109	19.27%	2/19	74	18.92%	.35%	.95
3/3	68	7.35%	3/2	111	9.91%	-2.56%	.75
3/12	150	8.00%	3/14	224	11.16%	-3.16%	.31
3/22	80	10.00%	3/24	138	16.67%	-6.67%	.19
4/20	61	4.92%	4/23	35	5.71%	-.79%	.75
5/13	45	2.22%	5/11	57	1.75%	0.47%	.57

Assumption 5. No marks are lost and all marks are detected. This assumption would be violated if dye or fin clips were not retained or detected on recaptured fish. Mark retention was very likely given the types of marks used and the time period between release and recapture. Bismarck Brown dye is known to stain fish for up to two weeks and fin regeneration takes much longer than the one to two day time frame between release and recapture. Correct detection should also have been low given the highly trained staff performing both the marking procedure and collecting the recapture data.

In 2011, mark detection was quantitatively assessed by asking each trap technician to enumerate a dish pan containing Chinook fry. The Chinook were either unmarked or marked with Bismark Brown dye or a partial caudal fin clip. The first technician performed the test on March 3rd and correctly enumerated the sample which included 76 clipped, 84 Bismark Brown, and 28 unmarked fry. The second technician performed this test on March 14th and correctly enumerated the sample which included 90 clipped, 88 Bismark Brown, and 45 unmarked fry. In the future, this approach to assessing mark detection by trap technicians will continue on an annual basis in order to confirm that complete and proper mark identification is occurring

Assumptions for Basin-Wide Chinook Estimate

The basin-wide estimate of Chinook freshwater production, including that from Soos Creek, relies on two assumptions. The first assumption is that the number of spawners estimated above and below the Green River juvenile trap are accurate. The accuracy of Green River Chinook escapement estimates are currently being studied by WDFW Fish Program as part of the Genetic Mark-Recapture Program. Results from the first year of the GMR Program on the Green River were consistent with earlier work of Hahn et al (2007) and suggested that the currently used fish per redd expansion factor may be too low (Seamons et al. 2012). However, redd surveys in 2010 were conducted on a weekly basis throughout the watershed and the relative number of redds observed above and below the trap was not likely to be biased by time or visibility. Therefore, the redd counts above and below the juvenile trap provide a reasonable approach for estimating juvenile production below the trap.

The second assumption is that egg-to-migrant survival of Chinook salmon is comparable above and below the juvenile trap. For estimation purposes, our calculation of egg-to-migrant survival is no different than juveniles per female because the same fecundity is applied to each female spawner. However, differences in watershed geomorphology, land use, spawner distribution and relative reproductive success of natural and hatchery origin spawners, add uncertainty to the assumption that freshwater productivity is comparable throughout the watershed. Without a better current alternative, one survival (or productivity) was applied to make the watershed-level estimate.

Assumptions for Identification of Species and Origin

The estimate of natural-origin Chinook production assumes that juvenile fish were correctly identified to species and origin. Accurate species identification is ensured by careful oversight during the training of new field staff and by the long-term consistency of trained field staff. However, independent methods of verifying species identity are not typically employed. In 2011, the addition of the genetic mark-recapture study allowed for an independent verification juvenile outmigrants identified as Chinook salmon in the field. Results from the genetic analysis indicated that all 1950 field-identified Chinook salmon subyearlings were correctly identified to species.

Identification Chinook origin is typically done by assigning ad-marked or coded-wire tagged Chinook as being of hatchery origin and assuming that unmarked fish are of natural origin. However, a small portion of hatchery Chinook are not marked. In these cases, origin of the unmarked Chinook can assigned based on phenotype if the differences are noticeable (e.g., large size discrepancy or body shape difference). When differences are not noticeable, as was the case during the latter part of the 2011 outmigration (i.e., after May 3), the catch of unmarked Chinook was assigned as natural origin. Error in these assignments may result in a positive bias to the natural-origin estimate. In 2011, this bias was anticipated to be minimal. A total of 486 ad-marked subyearling Chinook were caught between May 3 and the end of the trapping season (June 30). Assuming that the proportion of unmarked Chinook was 5% (2011 mis-mark rates were Palmer = 95.9% and Icy Creek = 99.4%), this means that just 0.08% (n = 26) of the 3,122 unmarked subyearling Chinook caught between May 3 and June 30 were of hatchery origin.

Freshwater Production of Chinook Salmon

The 2011 freshwater production estimate of 254,000 sub yearling Chinook was at the low end of the 55,000 to 800,000 range over the long-term monitoring study (Table 8). Yearling Chinook migrants appear to be a minor component of the outmigration and the inability to estimate yearling production should not have a large impact on the quality of our estimate. A downward trend in freshwater production is at least partly explained by a downward trend in Chinook escapement (Figure 7) as the freshwater productivity (8.0% egg-to-migrant survival and 360 juveniles/female) was the highest observed over twelve years of study (Table 4). Freshwater productivity results should be interpreted with caution until issues surrounding the escapement estimation have been resolved (see discussion above).

Parr migrants were approximately 50% of the freshwater production above the Green River trap in 2011 (Table 9). Parr production, which represents the freshwater rearing above the Green River trap, has ranged 11-fold (37,000 to 430,000 parr) over twelve years of study. In comparison, fry production, which represents juveniles emigrating from freshwater soon after emergence, has ranged 74-fold (6,000 to 410,000 fry).

Table 8.─Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median migration date for natural-origin Chinook produced above the Green River juvenile trap, migration years 2000-2011.

	Abundance				Fork Length		Migration Timing
Migration Year	Estimate	Lower C.I.	Upper C.I.	CV	Average	St.Dev.	Median Date
2000	475,207	324,315	626,098	16.20	51.4	16.53	3/13
2001	809,616	641,195	978,038	10.61	45.0	12.32	5/16
2002	584,151	343,533	824,769	21.02	46.8	12.52	4/20
2003	449,956	265,175	634,738	20.98	47.1	12.41	3/10
2004	236,650	201,917	271,382	7.49	48.8	16.42	3/25
2005	470,334	410,369	530,300	6.50	52.7	18.11	3/8
2006	99,796	79,088	120,504	10.59	57.7	21.22	5/28
2007	127,491	107,242	147,740	8.10	69.9	23.47	3/5
2008	400,763	361,048	440,477	5.06	54.1	17.16	3/28
2009	196,118	171,529	220,706	6.40	54.7	17.49	4/2
2010	55,547	39,445	71,648	14.79	67.3	21.43	6/9
2011	254,182	225,327	283,037	5.79	51.0	13.29	4/2

Table 9.─Abundance of two sub-yearling life histories (fry and parr) of natural-origin Green River Chinook outmigrants, migration year 2000 to 2011.

	Fry Migrants			Parr Migrants		
Trap Year	Migration Interval	Abundance	% of Migration	Migration Interval	Abundance	% of Migration
2000	1/01-4/29	266,481	56.1%	3/11-7/31	208,726	43.9%
2001	1/01-5/20	379,174	46.8%	3/8-7/31	430,442	53.2%
2002	1/01-5/23	357,602	61.2%	3/3-7/31	226,550	38.8%
2003	1/01-5/27	413,358	91.9%	2/16-7/13	36,598	8.1%
2004	1/01-4/29	136,144	57.5%	3/21-7/31	100,506	42.5%
2005	1/01-4/26	391,274	83.2%	2/20-7/31	79,061	16.8%
2006	1/01-5/01	29,946	30.0%	2/18-7/31	69,850	70.0%
2007	1/01-5/07	88,439	69.4%	3/21-7/31	39,053	30.6%
2008	1/01-6/08	251,815	62.8%	3/15-7/31	148,948	37.2%
2009	1/01-5/13	119,406	60.9%	2/6-7/31	76,709	39.1%
2010	1/01-4/20	5,559	10.0%	2/11-7/31	49,988	90.0%
2011	1/01-6/12	128,472	50.5%	2/7-7/31	125,710	49.5%

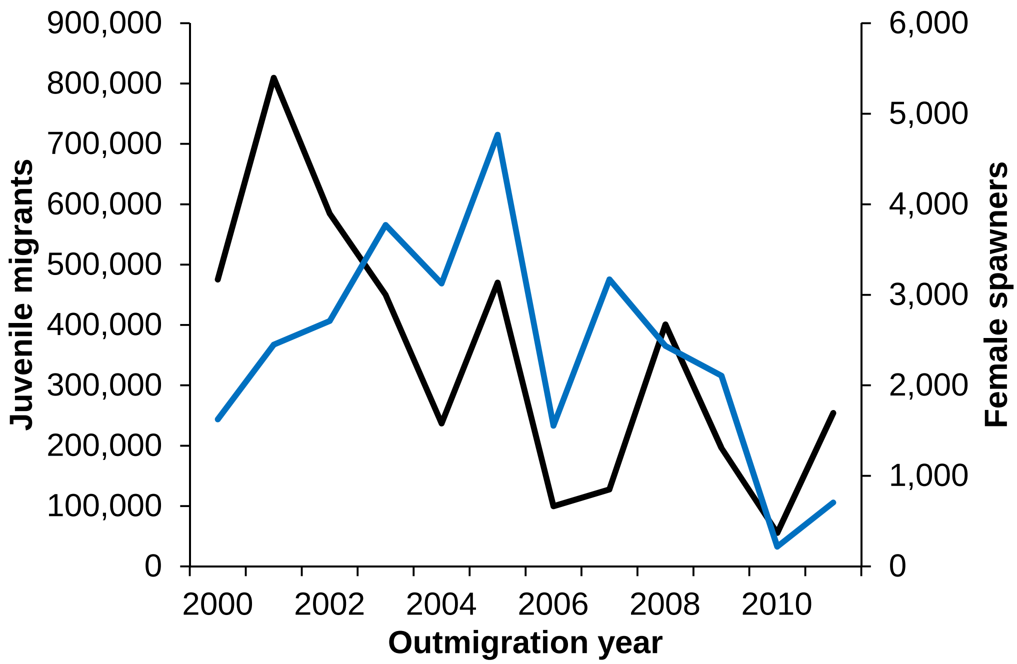

Figure 7.─Number of sub yearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (blue line) above the juvenile trap, outmigration year 2000-2011.

Freshwater Production of Coho Salmon

Freshwater production of coho above the Green River trap has been estimated for 9 of the 12 years of this study (Table 10). The 2011 freshwater production estimate of 62,000 coho smolts was intermediate to the range of approximately 20,000 to 200,000 smolts estimated over the long-term monitoring study.

The quality of the coho smolt estimates have varied widely among years and trends in these data should be interpreted with caution. In the first two years of the study (2000 and 2001), coho estimates were based on just one or two trap efficiency tests with hatchery fish and no associated variance was calculated. No estimates were generated for trapping years 2004 and 2005 because a large percentage of the coho released from the Keta Creek Hatchery (above the trap site) were unmarked, making positive identification of the natural-origin coho smolts impossible. In trapping year 2008, an abundance estimate was not made because recapture rates were so low that no reliable coho efficiency data were available. In 2011 an abundance estimate was made, however with just 9 recoveries the precision of this estimate was low and the accuracy is questionable.

Estimating the freshwater production of yearling migrants (i.e., coho and steelhead) has proven to be more challenging than for sub yearling fish. Several factors have contributed to this challenge including few fish caught and trap avoidance by these larger stronger swimming migrants. Slow water velocity at the trap location has minimized the recapture rates of marked coho and steelhead smolts used in the efficiency trials. The degree to which water velocity has been a problem has varied by year depending on the channel configuration above the trap.

A second challenge associated with estimating abundance for coho and steelhead smolts is the release of hatchery fish above the trap. The release timing of the hatchery fish typically coincide with the peak migration period for the natural-origin smolts of the same species. As a result, missed catch estimated during this period is high as is the corresponding uncertainty (variance) of this catch. Hatchery yearling smolts (Chinook, coho, and steelhead) have a tendency to migrate downstream in large groups resulting in large catches that can overwhelm the live box of the juvenile trap. In order to accommodate for these catches, the trap is either completely lifted from the water or is operated intermittently during the hatchery migration. In addition, the catch of natural-origin smolts increases during the hatchery fish migration, presumably because the natural-origin fish are following the hatchery fish out of the system. This results in high numbers of missed catch of coho and steelhead estimated during the outage period. In 2011, 14% of the natural origin coho and 10% of the natural origin steelhead catch were estimated missed catch during outages. Virtually all of the estimated missed catch for both species occurred during the outages corresponding to hatchery fish releases.

Table 10.—Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin coho smolts rearing above the Green River juvenile trap, migration years 2000-2011.

	Abundance				Fork Length		Migration Timing
Migration Year	Estimate	Lower C.I.	Upper C.I.	CV	Average	St.Dev.	Median Date
2000	32,769	---	---	---	115.1	20.37	5/11[a]
2001	55,113	---	---	---	114.3	13.68	5/16[a]
2002	194,393	129,500	259,286	17.0%	99.5	12.76	5/12[a]
2003	207,442	67,404	347,480	34.4%	104.3	12.40	5/1[b]
2004	---	---	---	---	105.8	12.30	5/8[a]
2005	---	---	---	---	106.8	14.93	5/4[a]
2006	31,460	21,143	41,777	16.7%	106.9	16.00	5/15
2007	22,671	14,735	30,607	17.9%	111.6	11.34	5/7
2008	---	---	---	---	105.1	11.95	5/9[a]
2009	81,079	56,522	105,636	11.9%	103.0	10.90	5/5
2010	43,763	32,663	54,864	12.9%	115.9	11.21	5/8
2011	62,280	25,495	99,065	30.1%	109.4	11.4	5/7

a Median catch date.

b Abundance estimate includes an estimated 51,183 unmarked hatchery coho.

Freshwater Production of Steelhead

The abundance of steelhead smolts rearing above the Green River trap has been estimated for 7 of the 12 years of this study (Table 11). Freshwater production estimates for this time period have ranged from approximately 2,000 to 70,000 steelhead smolts. In 2011, the age structure of steelhead smolts captured in the juvenile trap was typical for many western Washington rivers with smolts varying from one to three years old and a majority smolting at two years old.

Similar to coho, steelhead smolt abundance has been estimated using different approaches due to the challenges of estimating production of yearling migrants in the Green River. Trends in the steelhead smolt data should be interpreted with caution. Prior to 2009, all the abundance estimates were based on a steelhead:coho capture ratio applied to the coho efficiency data. The steelhead:coho capture ratio used was 75% for trap years 2001 to 2003 and 60% for trap years 2006 to 2008. No variance or confidence intervals were developed for those estimates. In 2009 and 2010, catch rates of steelhead improved at the trapping location and abundance estimates were derived directly from release and recaptures of natural-origin steelhead. Variance and confidence intervals were developed for the 2009 and 2010 estimates. In 2011 no abundance estimate was made. We had zero recoveries from 139 marked steelhead smolts released over 25 efficiency trials . We did not apply a steelhead:coho capture ratio because the coho estimate itself was considered weak in quality.

Table 11.— Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin steelhead smolts rearing above the Green River juvenile trap, migration years 2000-2011.

	Abundance				Fork Length		Timing
Migration Year	Estimate	Lower C.I.	Upper C.I.	CV	Average	St.Dev.	Median Date
2000	---	---	---	---	171.5	29.12	5/12[a]
2001	14,529	---	---	---	176.6	20.2	5/17[a]
2002	53,077	---	---	---	167.1	19.03	5/19[a]
2003	12,612	---	---	---	173.8	20.44	4/19[a]
2004	---	---	---	---	148.2	24.33	2/6[a]
2005	---	---	---	---	153.3	19.05	1/25[a]
2006	16,748	---	---	---	151.1	25.93	5/5[a]
2007	2,285	---	---	---	157.1	19.80	4/29
2008	---	---	---	---	163.8	23.64	5/15[a]
2009	26,174	10,151	42,198	19.4%	171.4	20.30	5/11
2010	71,710	49,317	94,103	15.9%	178.7	22.87	5/16
2011	---	---	---	---	175.1	18.40	5/8[a]

a Median catch date

Summary

In 2011, WDFW Fish Program engaged in several efforts to improve or assure the quality of salmonid abundance and productivity estimates in the Green River. This report details the efforts to ensure quality of the juvenile abundance and life history information including the quantitative assessment of estimator assumptions and the collection and summary of steelhead smolt age data.

Since 2000, the focal species of the juvenile production evaluation has been Chinook salmon, although information for all species is summarized when available. Freshwater production of Green River Chinook salmon in 2011 was well below the 355,000 average production observed between 2000 and 2010 and consistent with a downward trend in freshwater production over this time period. Parr migrants, sub yearlings that rear in freshwater prior to emigration, represented 50% of the total production.

Appendix A

Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants, is estimated.

Author: Kristen Ryding, WDFW Biometrician

APPENDIX A.—Variance of total unmarked smolt numbers, when the number of unmarked juvenile out-migrants, is estimated.

The estimator for $\hat{U}_i$ is,

$$\hat{U}_i = \frac{\hat{u}_i\left(M_i+1\right)}{\left(m_i+1\right)}$$

the estimated variance of $\hat{U}_i$, $Var\left(U_i\right)$ is as follows,

$$Var\left(\hat{U}_i\right) = Var\left(\hat{u}_i\right)\left(\frac{\left(M_i+1\right)\left(M_i m_i+3M_i+2\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}\right)+Var\left(\hat{U}_i \middle| E\left(\hat{u}\right)\right)$$

where $Var\left(\hat{U}_i \middle| E\left(\hat{u}\right)\right) = \dfrac{\left(M_i+1\right)\left(M_i-m_i\right)E\left(\hat{u}_i\right)\left(E\left(\hat{u}_i\right)+m_i+1\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}$,

$E\left(\hat{u}_i\right)$ = the expected value of $\hat{u}_i$ either in terms of the estimator (equation for $\hat{u}_i$) or just substitute in the estimated value and, $Var\left(\hat{u}_i\right)$ depends on the sampling method used to estimate $\hat{u}_i$.

Derivation:

Ignoring the subscript i for simplicity, the derivation of the variance estimator is based on the following unconditional variance expression,

$$Var\left(\hat{U}\right) = Var\left(E\left(\hat{U}\middle|u\right)\right)+E\left(Var\left(\hat{U}\middle|u\right)\right).$$

The expected value and variance $\hat{U}$ given u is as before, respectively,

$$E\left(\hat{U}_i\middle|u\right) = \frac{u_i\left(M_i+1\right)}{\left(m_i+1\right)} \text{ and,}$$

$$Var\left(\hat{U}\middle|u\right) = \frac{u\left(u+m+1\right)\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}.$$

Substituting in $\hat{u}$ for u gives the following,

$$Var\left(\hat{U}\right) = Var\left(\frac{\hat{u}\left(M+1\right)}{\left(m+1\right)}\right)+E\left[\frac{\left(M+1\right)\left(M-m\right)\hat{u}\left(\hat{u}+m+1\right)}{\left(m+1\right)^2\left(m+2\right)}\right]$$

$$Var\left(\hat{U}\right) = \left(\frac{\left(M+1\right)}{\left(m+1\right)}\right)^2 Var\left(\hat{u}\right)+\frac{\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}\left[E\left(\hat{u}^2\right)+E\left(\hat{u}\right)\left(m+1\right)\right]$$

Note that,

$$E\left(\hat{u}^2\right) = Var\left(\hat{u}\right)+\left(E\hat{u}\right)^2$$

Substituting in this value for $E\left(\hat{u}^2\right)$,

$$Var\left(\hat{U}\right)=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u})+\left(E(\hat{u})\right)^2+E(\hat{u})(m+1)\right]$$

$$=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var(\hat{u})+E(\hat{u})\left[E(\hat{u})+m+1\right]\right]$$

$$Var\left(\hat{U}\right)=\left(\frac{(M+1)}{(m+1)}\right)^2 Var(\hat{u})+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}Var(\hat{u})+\frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u})+m+1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2}+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right)+\frac{(M+1)(M-m)E(\hat{u})\left[E(\hat{u})+m+1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)^2}{(m+1)^2}+\frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=\frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{(M+1)(m+2)}{(m+2)}+\frac{(M-m)}{(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=\frac{(M+1)}{(m+1)^2}Var(\hat{u})\left(\frac{Mm+2M+m+2+M-m}{(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

$$Var\left(\hat{U}\right)=Var(\hat{u})\left(\frac{(M+1)(Mm+3M+2)}{(m+1)^2(m+2)}\right)+Var\left(\hat{U}\middle|E(\hat{u})\right)$$

Appendix B

Daily catch and migration estimate for natural-origin, sub yearling Chinook in the Green River, 2011.

APPENDIX B. ─Actual and estimated daily catches and migration for natural-origin sub-yearling Chinook migrants and daily estimated catch of Ad-marked hatchery Chinook fry and unmarked Chinook yearlings, in the Green River, 2011. Migration estimate is based on daily catch adjusted by the trap efficiency for each pooled time stratum.

	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
1/1-1/29	Pre-Trapping					6,384		
1/30/11	27.00	0.00	48	0	48	526	0	1
1/31/11	24.00	0.00	38	0	38	416	0	0
2/1/11	24.00	0.00	17	0	17	186	0	1
2/2/11	24.00	0.00	43	0	43	471	0	2
2/3/11	24.00	0.00	55	0	55	602	0	2
2/4/11	24.00	0.00	43	0	43	471	0	0
2/5/11	24.00	0.00	94	0	94	1,030	0	0
2/6/11	24.00	0.00	59	0	59	646	0	0
2/7/11	24.00	0.00	85	0	85	931	0	0
2/8/11	24.00	0.00	61	0	61	668	0	0
2/9/11	24.00	0.00	79	0	79	865	0	0
2/10/11	24.00	0.00	85	0	85	931	0	0
2/11/11	24.00	0.00	86	0	86	942	0	0
2/12/11	24.50	0.00	79	0	79	865	0	0
2/13/11	24.00	0.00	201	0	201	2,201	0	0
2/14/11	24.00	0.00	93	0	93	1,019	0	0
2/15/11	24.50	0.00	331	0	331	3,625	0	0
2/16/11	23.00	0.00	235	0	235	2,574	0	0
2/17/11	24.00	0.00	173	0	173	1,895	0	0
2/18/11	24.00	0.00	199	0	199	901	0	0
2/19/11	24.50	0.00	136	0	136	616	0	1
2/20/11	24.00	0.00	87	0	87	394	0	0
2/21/11		24.00		90	90	407	0	0
2/22/11		24.00		90	90	407	0	0
2/23/11	23.50	0.00	95	0	95	430	0	0
2/24/11	24.00	0.00	84	0	84	380	0	0
2/25/11	24.00	0.00	82	0	82	371	0	0
2/26/11	24.00	0.00	68	0	68	308	0	0
2/27/11	24.50	0.00	74	0	74	335	0	0
2/28/11	24.00	0.00	202	0	202	914	0	0
3/1/11	23.50	0.00	96	0	96	435	0	0
3/2/11	24.00	0.00	125	0	125	1,324	0	0
3/3/11	24.00	0.00	154	0	154	1,631	0	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Time Fished Hours Out	Unmarked Sub-yearling Chinook Catch Actual	Unmarked Sub-yearling Chinook Catch Estimated	Unmarked Sub-yearling Chinook Catch Total	Migration	Estimated Catch Ad-mrk Fry	Estimated Catch Unmarked Yearling
3/4/11	24.00	0.00	131	0	131	3,874	0	0
3/5/11	24.50	0.00	125	0	125	3,696	0	0
3/6/11	24.00	0.00	194	0	194	5,737	0	0
3/7/11	24.00	0.00	258	0	258	2,207	0	0
3/8/11	23.50	0.00	142	0	142	1,214	0	0
3/9/11	25.00	0.00	319	0	319	2,728	0	0
3/10/11	22.83	0.00	1929	0	1929	16,498	0	0
3/11/11	25.17	0.00	220	0	220	1,882	0	0
3/12/11	24.00	0.00	139	0	139	1,189	0	0
3/13/11	24.50	0.00	194	0	194	1,659	0	0
3/14/11	22.50	0.00	295	0	295	2,523	0	0
3/15/11	26.50	0.00	415	0	415	6,536	0	0
3/16/11	22.50	0.00	305	0	305	4,804	0	0
3/17/11	23.75	0.00	164	0	164	1,180	0	0
3/18/11	23.75	0.00	241	0	241	1,734	0	0
3/19/11	25.00	0.00	133	0	133	957	0	0
3/20/11	24.00	0.00	112	0	112	806	0	0
3/21/11	24.00	0.00	61	0	61	439	0	0
3/22/11	24.00	0.00	135	0	135	971	0	0
3/23/11	23.50	0.00	159	0	159	1,144	0	0
3/24/11	24.00	0.00	107	0	107	770	0	0
3/25/11	24.50	0.00	144	0	144	1,036	0	0
3/26/11	22.00	0.00	129	0	129	3,625	0	0
3/27/11	24.00	0.00	299	0	299	8,402	0	0
3/28/11	24.00	0.00	229	0	229	6,435	0	0
3/29/11	26.50	0.00	90	0	90	954	0	0
3/30/11	23.00	0.00	397	0	397	4,208	0	0
3/31/11		25.00		152	152	1,611	0	0
4/1/11		24.00		142	142	1,505	0	0
4/2/11		24.00		142	142	1,505	0	0
4/3/11		21.50		138	138	1,463	0	0
4/4/11	26.50	0.00	84	0	84	890	0	0
4/5/11	24.00	0.00	64	0	64	678	0	0
4/6/11	8.00	16.00	11	78	89	943	0	0
4/7/11	24.75	0.00	109	0	109	1,155	0	0
4/8/11	23.75	0.00	101	0	101	2,839	0	0
4/9/11	23.50	0.00	94	0	94	2,642	2	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Time Fished Hours Out	Unmarked Sub-yearling Chinook Catch Actual	Unmarked Sub-yearling Chinook Catch Estimated	Unmarked Sub-yearling Chinook Catch Total	Migration	Estimated Catch Ad-mrk Fry	Estimated Catch Unmarked Yearling
4/10/11	24.50	0.00	96	0	96	2,698	0	0
4/11/11	24.00	0.00	173	0	173	4,862	1	1
4/12/11	23.00	0.00	62	0	62	1,743	0	0
4/13/11	24.25	0.00	45	0	45	1,265	1	0
4/14/11	24.25	0.00	60	0	60	1,686	3	0
4/15/11	23.50	0.00	61	0	61	1,714	0	0
4/16/11	25.00	0.00	39	0	39	1,096	3	0
4/17/11	24.00	0.00	42	0	42	1,180	0	0
4/18/11	24.00	0.00	65	0	65	1,827	1	0
4/19/11	23.50	0.00	49	0	49	1,377	3	0
4/20/11	24.00	0.00	55	0	55	1,546	1	0
4/21/11	23.00	0.00	44	0	44	1,237	2	0
4/22/11		23.00		38	38	1,068	2	0
4/23/11	26.50	0.00	34	0	34	956	2	0
4/24/11	23.50	0.00	33	0	33	927	3	0
4/25/11	24.50	0.00	27	0	27	759	3	0
4/26/11	23.33	0.00	33	0	33	927	7	0
4/27/11	24.17	0.00	27	0	27	759	4	0
4/28/11	24.00	0.00	89	0	89	2,501	1	0
4/29/11	24.00	0.00	40	0	40	1,124	4	1
4/30/11	24.75	0.00	40	0	40	237	2	0
5/1/11	23.75	0.00	16	0	16	95	2	0
5/2/11	24.00	0.00	10	0	10	59	0	0
5/3/11	23.50	0.00	28	0	28	166	1	0
5/4/11	24.00	0.00	39	0	39	231	0	0
5/5/11	24.50	0.00	35	0	35	207	0	0
5/6/11	27.25	0.00	38	0	38	225	2	0
5/7/11	20.92	4.25	45	9	54	320	2	0
5/8/11	20.33	3.25	37	6	43	254	1	0
5/9/11	20.50	0.00	26	0	26	677	0	0
5/10/11	24.00	0.00	46	0	46	1,198	0	0
5/11/11	24.00	0.00	25	0	25	651	0	0
5/12/11	24.00	0.00	24	0	24	625	0	0
5/13/11	23.50	0.00	14	0	14	365	0	0
5/14/11	24.50	0.00	11	0	11	287	4	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Time Fished Hours Out	Unmarked Sub-yearling Chinook Catch Actual	Unmarked Sub-yearling Chinook Catch Estimated	Unmarked Sub-yearling Chinook Catch Total	Migration	Estimated Catch Ad-mrk Fry	Estimated Catch Unmarked Yearling
5/15/11	18.00	6.00	67	3	70	1,823	9	0
5/16/11		24.00		19	19	495	2	0
5/17/11		25.00		19	19	495	2	0
5/18/11	23.50	0.00	25	0	25	651	0	0
5/19/11	23.50	0.00	58	0	58	1,511	5	0
5/20/11	23.50	0.00	89	0	89	2,318	13	0
5/21/11	24.50	0.00	144	0	144	3,751	80	0
5/22/11	24.00	0.00	194	0	194	5,053	53	0
5/23/11	24.25	0.00	215	0	215	5,600	104	0
5/24/11	23.75	0.00	183	0	183	4,767	44	0
5/25/11	24.00	0.00	121	0	121	3,152	8	0
5/26/11	24.50	0.00	142	0	142	3,699	18	0
5/27/11	23.50	0.00	116	0	116	3,022	17	0
5/28/11	24.50	0.00	104	0	104	2,709	10	0
5/29/11	24.00	0.00	84	0	84	2,188	5	0
5/30/11	24.00	0.00	58	0	58	1,511	5	0
5/31/11	23.50	0.00	48	0	48	1,250	2	0
6/1/11	24.00	0.00	40	0	40	1,042	10	0
6/2/11	24.25	0.00	128	0	128	3,334	16	0
6/3/11	23.75	0.00	39	0	39	1,016	3	0
6/4/11	24.00	0.00	33	0	33	860	7	0
6/5/11	24.25	0.00	20	0	20	521	5	0
6/6/11	24.00	0.00	32	0	32	834	1	0
6/7/11	24.25	0.00	23	0	23	599	0	0
6/8/11	24.50	0.00	20	0	20	521	0	0
6/9/11	14.00	9.00	6	3	9	234	0	0
6/10/11		23.50		13	13	339	0	0
6/11/11	24.50	0.00	16	0	16	417	0	0
6/12/11	24.00	0.00	13	0	13	339	2	0
6/13/11	24.00	0.00	61	0	61	1,589	4	0
6/14/11	24.00	0.00	28	0	28	729	0	0
6/15/11	24.00	0.00	21	0	21	547	2	0
6/16/11	24.50	0.00	16	0	16	417	2	0
6/17/11	23.50	0.00	11	0	11	287	2	0
6/18/11	24.00	0.00	25	0	25	651	4	0

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APPENDIX B.—continued.

	Time Fished Hours		Unmarked Sub-yearling Chinook Catch				Estimated Catch	
							Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
6/19/11	23.00	0.00	35	0	35	912	2	0
6/20/11	25.00	0.00	31	0	31	807	3	0
6/21/11	24.00	0.00	45	0	45	1,172	0	0
6/22/11	24.50	0.00	42	0	42	1,094	1	0
6/23/11	24.00	0.00	56	0	56	1,459	5	0
6/24/11	24.00	0.00	56	0	56	1,459	12	0
6/25/11	22.50	0.00	240	0	240	6,251	12	0
6/26/11	25.00	0.00	27	0	27	703	2	0
6/27/11	24.00	0.00	12	0	12	313	3	0
6/28/11	24.00	0.00	16	0	16	417	0	0
6/29/11	24.00	0.00	6	0	6	156	0	0
6/30/11	14.50	0.00	8	0	8	208	1	0
7/1-7/31	Post -Trapping					5,572		
Total	3368.00	276.50	15098	942	16040	254,182	533	9

Appendix C

Fork length of natural-origin, sub yearling Chinook in the Green River, 2011

APPENDIX C.─Mean fork length (mm), standard deviation (St.Dev.) range, and sample size of natural-origin 0+ Chinook caught in the Green River screw trap in 2011.

Statistical Week			Average	St.Dev.	Range		Number		Percent
Number	Begin	End			Min	Max	Sampled	Caught	Sampled
5	1/24/11	1/30/11	40.6	1.20	38	43	23	48	47.92%
6	1/31/11	2/06/11	39.5	2.27	34	44	35	349	10.03%
7	2/07/11	2/13/11	39.9	2.39	36	46	50	676	7.40%
8	2/14/11	2/20/11	42.3	5.58	36	65	61	1,254	4.86%
9	2/21/11	2/27/11	44.5	5.62	38	58	26	403	6.45%
10	2/28/11	3/06/11	43.8	4.63	37	56	59	1,027	5.74%
11	3/07/11	3/13/11	44.2	5.23	38	58	50	3,201	1.56%
12	3/14/11	3/20/11	43.7	4.97	38	56	60	1,665	3.60%
13	3/21/11	3/27/11	43.3	5.43	36	61	47	1,034	4.55%
14	3/28/11	4/03/11	42.6	4.33	34	52	26	716	3.63%
15	4/04/11	4/10/11	47.0	9.41	36	79	64	559	11.45%
16	4/11/11	4/17/11	49.5	9.00	37	74	48	482	9.96%
17	4/18/11	4/24/11	48.0	9.12	38	72	32	280	11.43%
18	4/25/11	5/01/11	54.3	12.58	36	87	45	272	16.54%
19	5/02/11	5/08/11	55.8	13.74	39	88	57	232	24.57%
20	5/09/11	5/15/11	56.3	12.90	37	88	46	213	21.60%
21	5/16/11	5/22/11	55.4	12.65	37	82	58	510	11.37%
22	5/23/11	5/29/11	59.0	12.72	37	87	80	965	8.29%
23	5/30/11	6/05/11	59.6	11.70	42	86	46	366	12.57%
24	6/06/11	6/12/11	64.6	10.75	44	81	24	110	21.82%
25	6/13/11	6/19/11	72.3	12.82	53	92	32	197	16.24%
26	6/20/11	6/26/11	72.3	12.48	51	100	52	497	10.46%
27	6/27/11	7/03/11	76.0	7.00	69	83	3	42	7.14%
		Season Total	51.0	13.29	34	100	1,024	15,098	6.78%

Appendix D

Daily catch of coho and chum salmon, steelhead and cutthroat trout in the Green River, 2011

APPENDIX D.─Daily catches of coho and chum salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2011. Catch represents actual and estimated catch for a given day. Time in and out reflect time fished (in) and not fished (out) on a given day.

Date	Times		Coho Smolts		Chum Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
	In	Out	Nat	Hat	Total	Nat	Hat	Nat	Nat	Nat
1/30/11	27.00	0.00	1	0	0	2	0	0	1	2
1/31/11	24.00	0.00	1	0	0	1	0	0	1	5
2/01/11	24.00	0.00	1	0	0	1	0	0	0	6
2/02/11	24.00	0.00	1	0	0	5	0	0	0	3
2/03/11	24.00	0.00	7	0	0	2	0	0	1	5
2/04/11	24.00	0.00	10	0	0	4	0	0	0	12
2/05/11	24.00	0.00	6	0	2	2	0	0	0	6
2/06/11	24.00	0.00	1	0	0	0	0	0	0	2
2/07/11	24.00	0.00	0	0	0	0	0	0	0	1
2/08/11	24.00	0.00	0	0	1	0	0	0	0	1
2/09/11	24.00	0.00	0	0	1	0	0	0	0	1
2/10/11	24.00	0.00	1	0	2	0	0	0	0	1
2/11/11	24.00	0.00	3	0	0	1	0	0	1	2
2/12/11	24.50	0.00	4	0	0	5	0	1	0	12
2/13/11	24.00	0.00	0	0	0	1	0	1	0	2
2/14/11	24.00	0.00	6	1	0	1	0	0	0	3
2/15/11	24.50	0.00	11	0	2	1	0	0	0	3
2/16/11	23.00	0.00	8	0	1	1	0	0	0	4
2/17/11	24.00	0.00	0	0	6	1	0	1	0	2
2/18/11	24.00	0.00	15	0	7	1	0	0	0	2
2/19/11	24.50	0.00	8	0	49	0	0	0	0	2
2/20/11	24.00	0.00	7	0	25	0	0	1	0	4
2/21/11	0.00	24.00	0	0	0	0	0	0	0	0
2/22/11	0.00	24.00	0	0	0	0	0	0	0	0
2/23/11	23.50	0.00	12	0	9	1	0	0	0	2
2/24/11	24.00	0.00	4	0	11	0	0	0	0	2
2/25/11	24.00	0.00	2	0	49	0	0	0	0	1
2/26/11	24.00	0.00	3	0	15	0	0	0	0	1
2/27/11	24.50	0.00	4	0	14	0	0	0	0	0
2/28/11	24.00	0.00	1	0	35	1	0	0	0	0
3/01/11	23.50	0.00	0	0	19	2	0	0	0	1
3/02/11	24.00	0.00	1	0	49	0	0	0	0	3
3/03/11	24.00	0.00	5	0	64	1	0	0	0	0
3/04/11	24.00	0.00	1	0	3627	0	0	0	0	0
3/05/11	24.50	0.00	4	0	734	0	0	0	0	0
3/06/11	24.00	0.00	2	0	351	0	0	0	0	1
3/07/11	24.00	0.00	0	0	159	0	0	0	0	0

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APPENDIX D.─continued.

Date	Times		Coho Smolts		Chum Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
	In	Out	Nat	Hat	Total	Nat	Hat	Nat	Nat	Nat
3/08/11	23.50	0.00	5	0	61	0	0	0	0	0
3/09/11	25.00	0.00	2	1	131	0	0	0	0	0
3/10/11	22.83	0.00	2	3	906	1	0	0	0	1
3/11/11	25.17	0.00	6	1	410	3	0	0	0	2
3/12/11	24.00	0.00	3	9	228	0	0	1	0	2
3/13/11	24.50	0.00	3	2	167	0	0	1	0	0
3/14/11	22.50	0.00	0	0	735	0	0	1	1	2
3/15/11	26.50	0.00	2	6	1774	0	0	1	0	1
3/16/11	22.50	0.00	0	3	653	0	0	0	0	1
3/17/11	23.75	0.00	3	2	432	0	0	0	0	1
3/18/11	23.75	0.00	5	39	606	0	0	1	0	0
3/19/11	25.00	0.00	2	12	122	0	1	0	0	0
3/20/11	24.00	0.00	1	18	511	0	0	0	1	0
3/21/11	24.00	0.00	2	10	474	1	0	0	1	0
3/22/11	24.00	0.00	1	13	3301	0	0	0	0	2
3/23/11	23.50	0.00	2	5	1448	1	0	3	0	1
3/24/11	24.00	0.00	3	4	515	0	0	0	0	0
3/25/11	24.50	0.00	3	0	804	0	0	0	0	0
3/26/11	22.00	0.00	1	1	344	1	0	1	0	1
3/27/11	24.00	0.00	1	0	391	0	0	1	0	0
3/28/11	24.00	0.00	1	0	320	0	0	0	0	0
3/29/11	26.50	0.00	0	0	3613	0	0	0	0	0
3/30/11	23.00	0.00	1	0	3530	0	0	0	0	1
3/31/11	0.00	25.00	0	0	0	0	0	0	0	0
4/01/11	0.00	24.00	0	0	0	0	0	0	0	0
4/02/11	0.00	24.00	0	0	0	0	0	0	0	0
4/03/11	0.00	21.50	0	0	0	0	0	0	0	0
4/04/11	26.50	0.00	0	0	264	0	0	0	0	0
4/05/11	24.00	0.00	0	0	176	0	0	0	0	0
4/06/11	8.00	16.00	0	0	14	0	0	0	0	0
4/07/11	24.75	0.00	0	0	777	0	0	0	0	0
4/08/11	23.75	0.00	2	2	1028	5	1	0	0	0
4/09/11	23.50	0.00	9	0	49	12	11	2	0	1
4/10/11	24.50	0.00	6	0	70	5	13	0	0	4
4/11/11	24.00	0.00	3	0	166	3	7	2	0	2
4/12/11	23.00	0.00	5	1	62	4	30	2	0	3
4/13/11	24.25	0.00	4	0	73	0	4	0	0	2
4/14/11	24.25	0.00	6	0	151	0	10	0	0	1
4/15/11	23.50	0.00	2	3	115	2	3	0	0	0

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Chum Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
	In	Out	Nat	Hat	Total	Nat	Hat	Nat	Nat	Nat
4/16/11	25.00	0.00	2	0	294	0	1	0	0	1
4/17/11	24.00	0.00	6	0	463	0	3	0	0	1
4/18/11	24.00	0.00	3	0	434	1	4	1	0	1
4/19/11	23.50	0.00	2	1	206	3	16	0	0	2
4/20/11	24.00	0.00	4	1	223	0	10	0	0	3
4/21/11	23.00	0.00	1	0	152	0	1	0	0	0
4/22/11	0.00	23.00	0	0	0	0	0	0	0	0
4/23/11	26.50	0.00	6	1	155	4	6	0	0	0
4/24/11	23.50	0.00	9	2	79	1	3	0	0	0
4/25/11	24.50	0.00	5	4	203	1	13	3	0	1
4/26/11	23.33	0.00	19	0	683	10	24	0	0	8
4/27/11	24.17	0.00	9	1	472	0	8	0	0	2
4/28/11	24.00	0.00	16	0	1110	2	22	1	0	0
4/29/11	24.00	0.00	30	0	374	2	4	0	0	1
4/30/11	24.75	0.00	15	2	257	1	4	0	0	0
5/01/11	23.75	0.00	17	0	95	0	46	1	0	1
5/02/11	24.00	0.00	16	1	49	1	28	0	0	0
5/03/11	23.50	0.00	23	1	57	3	39	0	0	1
5/04/11	24.00	0.00	22	0	95	0	27	0	0	2
5/05/11	24.50	0.00	23	0	69	2	13	0	0	0
5/06/11	27.25	0.00	119	1988	469	20	123	1	0	1
5/07/11	20.92	4.25	42	735	81	2	11	0	0	1
5/08/11	20.33	3.25	34	420	154	7	7	1	0	1
5/09/11	20.50	0.00	6	76	33	1	1	0	0	0
5/10/11	24.00	0.00	38	244	65	1	2	0	0	1
5/11/11	24.00	0.00	52	204	79	0	0	1	0	1
5/12/11	24.00	0.00	49	283	111	2	6	0	0	1
5/13/11	23.50	0.00	34	146	72	2	4	0	0	0
5/14/11	24.50	0.00	39	88	97	2	0	0	0	0
5/15/11	18.00	6.00	22	53	46	7	1	0	0	0
5/16/11	0.00	24.00	0	0	0	0	0	0	0	0
5/17/11	0.00	25.00	0	0	0	0	0	0	0	0
5/18/11	23.50	0.00	6	14	44	6	2	0	0	0
5/19/11	23.50	0.00	13	10	43	9	2	0	0	0
5/20/11	23.50	0.00	11	13	22	12	7	1	0	0
5/21/11	24.50	0.00	7	9	21	14	5	0	0	0
5/22/11	24.00	0.00	17	11	6	17	8	0	0	0
5/23/11	24.25	0.00	18	9	10	13	7	0	0	0
5/24/11	23.75	0.00	2	8	5	0	3	2	0	0

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Chum Fry	Steelhead Smolts		Cutthroat		Trout Parr
								Smolt	Adult	
	In	Out	Nat	Hat	Total	Nat	Hat	Nat	Nat	Nat
5/25/11	24.00	0.00	5	5	3	2	1	0	0	1
5/26/11	24.50	0.00	5	2	7	2	1	0	0	0
5/27/11	23.50	0.00	3	2	7	3	0	0	0	0
5/28/11	24.50	0.00	8	5	7	2	5	0	0	1
5/29/11	24.00	0.00	15	10	3	3	0	0	0	0
5/30/11	24.00	0.00	3	7	11	0	2	0	0	0
5/31/11	23.50	0.00	10	6	2	1	3	0	0	0
6/01/11	24.00	0.00	3	5	0	1	2	1	0	0
6/02/11	24.25	0.00	4	5	5	6	2	0	0	0
6/03/11	23.75	0.00	2	2	0	0	0	1	0	0
6/04/11	24.00	0.00	1	2	4	0	0	0	0	0
6/05/11	24.25	0.00	3	2	2	0	2	0	0	0
6/06/11	24.00	0.00	1	4	3	0	0	0	0	1
6/07/11	24.25	0.00	4	4	3	1	0	0	0	0
6/08/11	24.50	0.00	1	0	2	1	0	0	0	0
6/09/11	14.00	9.00	1	1	38	0	0	0	0	0
6/10/11	0.00	23.50	0	0	0	0	0	0	0	0
6/11/11	24.50	0.00	1	2	29	0	0	0	0	0
6/12/11	24.00	0.00	0	1	9	0	0	0	0	0
6/13/11	24.00	0.00	1	0	3	1	0	0	0	0
6/14/11	24.00	0.00	0	0	1	1	0	0	0	0
6/15/11	24.00	0.00	0	0	4	0	1	0	0	0
6/16/11	24.50	0.00	0	1	2	0	0	0	0	0
6/17/11	23.50	0.00	1	0	5	0	0	0	0	0
6/18/11	24.00	0.00	1	0	0	0	0	0	0	0
6/19/11	23.00	0.00	2	0	0	0	0	0	0	0
6/20/11	25.00	0.00	1	0	1	0	0	0	0	0
6/21/11	24.00	0.00	1	0	0	0	0	0	0	0
6/22/11	24.50	0.00	0	0	5	0	0	0	0	0
6/23/11	24.00	0.00	0	1	2	0	0	0	0	0
6/24/11	24.00	0.00	0	0	3	0	0	0	0	0
6/25/11	22.50	0.00	0	0	1	0	0	0	0	0
6/26/11	25.00	0.00	0	0	0	0	0	0	0	0
6/27/11	24.00	0.00	0	0	2	0	0	0	0	0
6/28/11	24.00	0.00	0	0	1	0	0	0	0	0
6/29/11	24.00	0.00	0	0	1	0	0	0	0	0
6/30/11	14.50	0.00	0	0	0	0	0	0	0	0
Total	3368.00	276.50	1030	4528	36647	242	560	34	7	153

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2011

APPENDIX E.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2011.

	Statistical Week		Average	St.Dev.	Range		Number		Percent
No	Begin	End			Min	Max	Sampled	Captured	Sampled
5	1/24/11	1/30/11	113.0	n/a	113	113	1	1	100.00%
6	1/31/11	2/6/11	98.3	10.16	66	113	24	27	88.89%
7	2/7/11	2/13/11	106.0	7.65	96	114	8	8	100.00%
8	2/14/11	2/20/11	102.5	10.79	71	122	58	55	105.45%
9	2/21/11	2/27/11	98.9	10.06	78	113	14	25	56.00%
10	2/28/11	3/6/11	103.1	9.50	80	114	14	14	100.00%
11	3/7/11	3/13/11	104.5	9.08	86	128	18	21	85.71%
12	3/14/11	3/20/11	102.0	9.21	91	114	6	13	46.15%
13	3/21/11	3/27/11	103.5	7.78	96	113	8	13	61.54%
14	3/28/11	4/3/11	104.5	3.54	102	107	2	2	100.00%
15	4/4/11	4/10/11	117.3	13.64	96	160	16	17	94.12%
16	4/11/11	4/17/11	109.9	11.57	80	129	28	28	100.00%
17	4/18/11	4/24/11	111.1	8.41	90	125	25	25	100.00%
18	4/25/11	5/1/11	112.0	13.49	89	138	110	111	99.10%
19	5/2/11	5/8/11	112.4	10.23	86	138	215	279	77.06%
20	5/9/11	5/15/11	109.0	11.50	89	141	201	240	83.75%
21	5/16/11	5/22/11	109.0	8.99	87	131	45	54	83.33%
22	5/23/11	5/29/11	108.7	9.64	92	131	56	56	100.00%
23	5/30/11	6/5/11	113.0	7.97	96	131	25	26	96.15%
24	6/6/11	6/12/11	111.3	5.25	104	121	7	8	87.50%
25	6/13/11	6/19/11	107.0	n/a	107	107	1	5	20.00%
26	6/20/11	6/26/11						2	0.00%
27	6/27/11	6/30/11						0	0.00%
		Season Total	109.4	11.40	66	160	882	1030	85.63%

Appendix F

Fork lengths of natural-origin steelhead smolts in the Green River, 2011

APPENDIX F.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin steelhead smolts in the Green River in 2011.

Statistical Week			Average	St.Dev.	Range		Number		Percent
No	Begin	End			Min	Max	Sampled	Caught	Sampled
5	1/24/11	1/30/11	191.0	1.41	190	192	2	2	100.00%
6	1/31/11	2/6/11	189.9	12.19	173	211	17	17	100.00%
7	2/7/11	2/13/11	188.0	22.10	169	223	7	7	100.00%
8	2/14/11	2/20/11	176.6	9.13	168	190	5	5	100.00%
9	2/21/11	2/27/11	159.0	n/a	159	159	1	1	100.00%
10	2/28/11	3/6/11	177.3	12.26	160	189	4	4	100.00%
11	3/7/11	3/13/11	199.5	48.64	149	253	4	4	100.00%
12	3/14/11	3/20/11	----	----	----	----	----	0	
13	3/21/11	3/27/11	173.7	26.27	158	204	3	3	100.00%
14	3/28/11	4/3/11	----	----	----	----	----		
15	4/4/11	4/10/11	175.4	16.61	151	208	22	22	100.00%
16	4/11/11	4/17/11	163.2	14.63	140	195	11	11	100.00%
17	4/18/11	4/24/11	165.6	22.69	148	218	10	10	100.00%
18	4/25/11	5/1/11	169.7	21.82	143	230	15	16	93.75%
19	5/2/11	5/8/11	181.4	17.76	148	236	34	35	97.14%
20	5/9/11	5/15/11	168.4	16.61	140	200	16	16	100.00%
21	5/16/11	5/22/11	175.9	16.17	137	231	58	58	100.00%
22	5/23/11	5/29/11	167.6	14.22	140	189	33	33	100.00%
23	5/30/11	6/5/11	165.9	7.62	157	178	8	8	100.00%
24	6/6/11	6/12/11	192.0	4.24	189	195	2	2	100.00%
25	6/13/11	6/19/2011	176.0	15.56	165	187	2	2	100.00%
		Season Total	175.1	18.43	137	253	254	256	99.22%

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