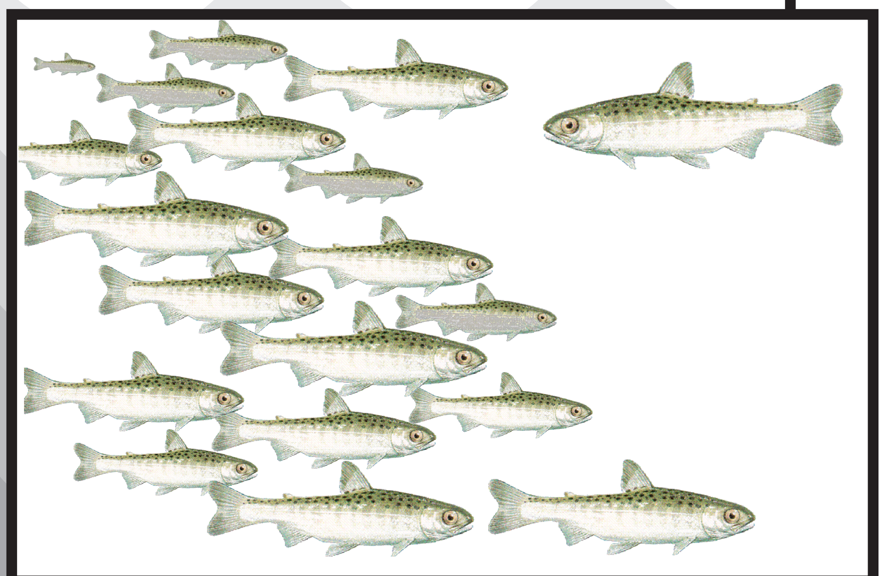
STATE OF WASHINGTON June 2013

Green River Juvenile Salmonid Production Evaluation: 2012 Annual Report



by Peter C. Topping, and Mara S. Zimmerman

Washington Department of Fish and Wildlife
Fish Program
Science Division

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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, by Tacoma Water between 2008 and 2011 and by the Army Corp of Engineers (USACE) in 2012.

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Executive Summary

This report provides the 2012 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 of natural-origin Chinook in the Green River. Tissue samples were collected from 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 2011 via Genetic Mark Recapture.. 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 trap was operated from January 24 through July 12, 2012. During this period, the trap fished 87% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (sub yearling), coho, chum and pink. Because of channel configuration and flow conditions at the trap site, we were unable to recapture any of the marked steelhead smolts that had been released for trap efficiency trails, so no production estimate was calculated. (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 2012. 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	3,631	90,260 (10.9%)	63.3 (± 19.4)	28-Apr
Chinook – Yrlg	15	---[a]	106.6 (± 21.3)	26-Mar [b]
Coho – Yrlg	1,083	48,148 (24.9%)	106.1 (± 12.7)	7-May
Steelhead – Smolt	395		166.1 (± 17.9)	16-May [b]
Chum	36,647	2,989,000 [c]		5-Apr
Pink	494,600	13,841,000 [c]		8-Apr

[a] Capture rates were not high enough to derive a production estimate or describe migration timing for yearling Chinook.
[b] These are median catch dates which are not adjusted for trap efficiency and therefore serves as an index of migration timing.
[c] Production estimate was derived by applying sub-yearling Chinook efficiency data to the chum and pink catch.

Chinook salmon spawn above and below the juvenile trap and a basin-wide production was derived by applying estimated survival 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 2012 outmigration (2011 brood) was estimated to be 6.0%, yielding a basin-wide production estimate of 146,909 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 47% of all sub yearling migrants and peaked in mid-March , parr migrants (45+ mm fork length) represented 53% of the migration and peaked in early June.

Introduction

This report provides the 2012 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, pink 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 and 2012, 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) (McElhaney et al. 2000, Crawford 2007). 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 from 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 from redd counts obtained 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 and 2012, 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. 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 2012 were the second sample in the study designed to estimate the number of adult Chinook returning to the Green River in the fall 2011.

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. This report includes results from the 2012 field season. In 2012, an additional objective was to collect genetic samples from juvenile Chinook migrants over the entire period of their outmigration.

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 2012, the trap operated between January 24 and July 12 for a total of 3,551 of 4,087 possible hours (87% of the time). Over the course of the season, trapping was suspended 29 times; the duration of outages ranged from 0.75 to 96.0 hours. Trapping was suspended three times for high water, three times for hatchery fish releases, and 21 times during day time periods late in the trapping season when catches were low and recreational use was high. One outage during hatchery releases occurred over 60 continuous hours (during the yearling Chinook release); during the other two releases the trap was spot fished throughout the night.

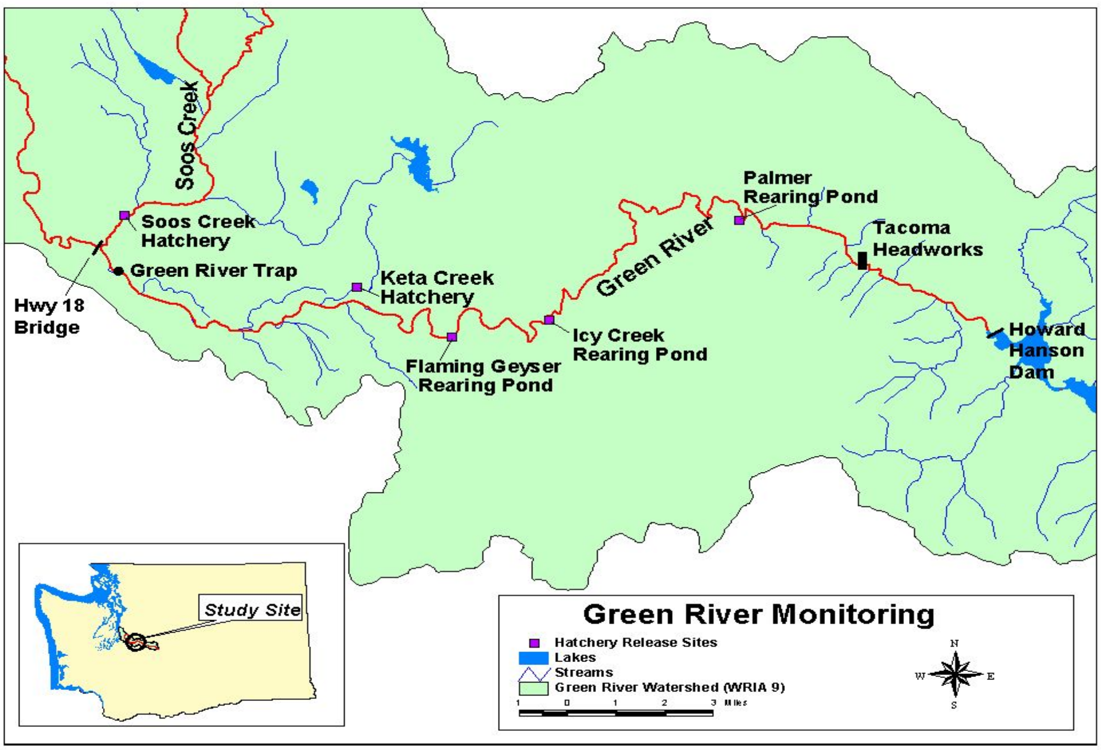

Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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 30% and 13 of the 15 yearling smolts were sampled. Caudal fin clips for genetic analysis were collected from 50% of the juvenile Chinook caught from the start of the season through May 4 and from virtually all the Chinook captured from May 5 through the end of the trapping season. Scale samples were collected from all captured natural-origin steelhead smolts to determine smolt age composition.

Chinook were enumerated as sub yearlings and yearlings. Yearling Chinook emigrate between February and April and range in size from 76 to 156-mm FL. Sub yearling Chinook emigrate between January and July, range between 34 mm and 107-mm FL. Sub yearlings are distinguished from yearling migrants by the body size and date of migration. During the time period that yearlings typically migrant, sub-yearling migrants average in size between 39 mm and 50 mm FL. 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 some period of time 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 225 mm FL) and with many spots along the dorsal surface and tail. 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 2012 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. A group of hatchery steelhead released above the trap were not ad-clipped but were tagged with a visual implant eye mark and a CWT, so every unmarked steelhead captured in the trap was electronically scanned for the presence of a CWT. 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 2012. 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	Ad-clip + CWT	CWT only	Ad-Clip only	Unmarked
Chinook – SubYrlg	2011	Palmer Pond	44,095	0	813,479	67,420
Chinook – Yrlg	2010	Icy Creek	92,200	600	222,118	2,242
Coho – Yrlg	2010	Keta Creek	46,824	136	201,902	1,138
Chum - SubYrlg	2011	Keta Creek	0	0	26,650	2,849,950
Summer Steelhead	2011	Icy Creek	0	0	19,864	120
Winter Steelhead	2011	Icy Creek	0	10,280*	0	210
Winter Steelhead	2011	Icy Creek	0	0	19,824	160
Winter Steelhead	2011	Flaming Geyser	0	0	14,990	0

*Tagged with blank tag wire and red elastomer 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 between upper and lower caudle fin 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 thalweg located in the center of the river. Two release sites were selected in order to test the assumption that marked and unmarked fish were well mixed prior to (re)capture in the screw trap. 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 and below the trap site. In future years, we anticipate using abundance estimates from the new smolt trap operated by the Muckleshoot Indian Tribe within Soos Creek rather than the assumption of equivalent survival within the Green River and Soos Creek.

Results

Sub Yearling Chinook

The total estimated catch of natural-origin Chinook ($\hat{u}$ = 3,631) included 3,302 captures in the trap and 329 missed catch estimated for trap outage periods (Table 3, Appendix B). A total of 730 ad-marked Chinook were captured between April 27 and July 10. Positive identification of the unmarked hatchery Chinook was not possible because of their similar size and appearance to the natural origin Chinook, for that reason all unmarked Chinook were identified as natural origin.

A total of 53 efficiency trials, ranging between 8 and 53 fish, were conducted and used a total of 2,256 natural-origin Chinook. To test for thorough mixing, releases were performed from two locations, the first was the traditional site 150 meters 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 did not differ between the two release locations; therefore releases from both sites were included in the analysis. Individual trials were combined to achieve a minimum of 5 recoveries, forming 13 groups prior to stratification. The *G*-test pooled the 13 groups into two strata, with trap efficiencies of 4.0% and 4.3% (Table 3).

The trapping season of January 24 through July 12 encompassed the majority of the sub yearling Chinook migration. A total of 85,631 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 3,759 Chinook were estimated to have migrated prior to the trapping season and 870 migrants were estimated following the trapping season. This extrapolation assumed migration began January 1 and ended July 31, 2012.

A total of 90,260 ± 21,810 (±95% C.I.) sub yearling Chinook of natural origin were estimated to have migrated past the screw trap between January 1 and July 31, 2012. Coefficient of variation for this estimate was 10.9%.

Table 3. Catch, marked and recaptured fish, and estimated abundance of sub yearling Chinook migrants at the Green River screw trap in 2012. Release groups were pooled to form two 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	1/01-1/24						3,759	1.40E+06
1	1/25-5/8	1,793	315	2.27E+03	770	31	50,790	7.74E+07
2	5/9-7/12	1,509	14	1.81E+01	1,486	64	34,841	1.83E+07
After	7/13-7/31						870	2.55E+04
	Season Total	3,302	329	2.29E+03	2,256	95	90,260	9.72E+07

Freshwater productivity of natural-origin Chinook for brood year 2011 was estimated to be 271 juveniles per female and 6.0% egg-to-migrant survival. This calculation was based on the number of sub yearling Chinook passing the trap ($\hat{N}_T$ = 90,260), 333 female spawners above the trap site (personal communication, Darcy Wildermuth, WDFW Region 4), and an estimated P.E.D above the trap site of 1,498,500 eggs.

Basin-wide abundance of sub yearling Chinook of natural origin was estimated to be 146,909 juvenile migrants (Table 4). This included 90,260 migrants from above the trap, 5,150 juveniles from the main stem below the trap, and 51,499 from Big Soos Creek.

An estimated 47% (42,133) of the Chinook migrated as fry and 53% (48,127) migrated as parr. The migration periods of fry and parr overlapped between late February and the middle of May.

The median migration date for sub yearling Chinook was on April 28. Timing of the outmigration was bimodal (Figure 2); however, we observed multiple peaks within the fry and parr portions of the emigration. The first peak to the fry migration occurred during statistical week 6 (3,300 fry migrants between January 30 and February 5), and the second peak occurred during statistical week 9 (~4,500 fry migrants between February 20 and 26). The first peak to the parr migration occurred during statistical week 19 (~4,800 parr migrants between April 30 and May 6), and the second peak occurred during statistical week 24 (~7,600 parr migrants between June 4 and June 10).

The seasonal average length of sub yearling Chinook was 63.3 ± 19.4 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the sub yearling Chinook increased slowly each week thru the early portion of the season, statistical weeks 5-15 (January 24- April 8) with just one week not showing an increase in size. The weekly average growth over this period increased 0.5 mm FL per week. Chinook sub-yearling growth increased rapidly from week 16 thru the end of trapping season (April 9-July 12) increasing an average of 3.7 mm FL per week. Week 20 (May 7- May 15) saw the largest weekly increase of 14-mm FL, this corresponded with high water, full moon (super moon) and the release of Keta Creek hatchery coho. (Figure 3, Appendix C).

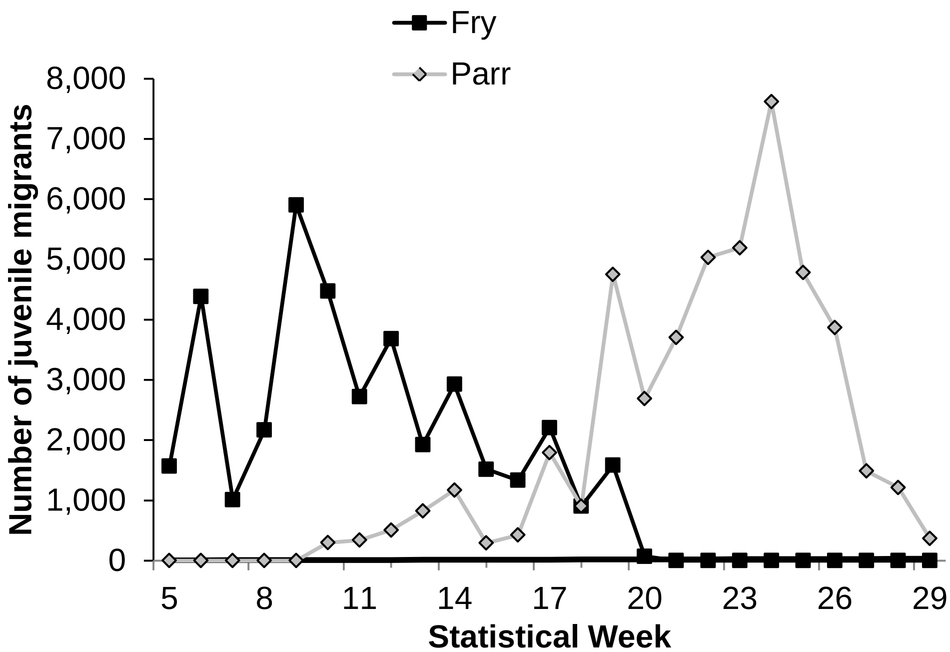

Figure 2. Weekly migration of sub yearling Chinook migrants of natural origin at the Green River screw trap in 2012. Sub yearling migrants are partitioned into two freshwater rearing strategies fry (<45-mm FL) and parr (> 45-mm FL) migrants.

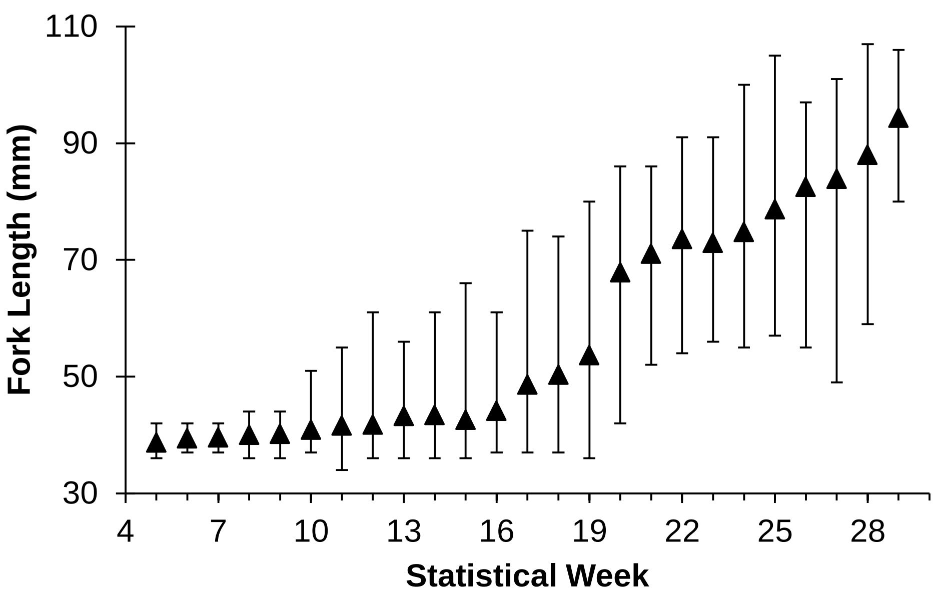

Figure 3. Fork lengths (mm) of sub yearling Chinook migrants of natural origin captured in the Green River screw trap in 2012. Data are mean, minimum, and maximum values by statistical week.

Table 4.Abundance of juvenile migrant Chinook (sub yearling) in the Green River. 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	1,835	8,257,500	475,207	5.75%	826	3,717,000	213,908	1,616	7,272,000	275,125	991,883
2000	2001	1,425	6,412,500	809,616	12.63%	936	4,212,000	531,790	1,580	7,110,000	275,000	1,331,940
2001	2002	2,167	9,751,500	584,151	5.99%	480	2,160,000	129,392	995	4,477,500	275,000	962,579
2002	2003	2,324	10,458,000	449,956	4.30%	2,314	10,413,000	448,020	1,239	5,575,500	275,000	1,000,990
2003	2004	1,793	8,068,500	236,650	2.93%	1,038	4,671,000	137,001	720	3,240,000	95,029	369,822
2004	2005	2,738	12,321,000	470,334	3.82%	827	3,721,500	142,062	623	2,803,500	107,019	613,338
2005	2006	966	4,347,000	99,796	2.30%	82	369,000	8,471	598	2,691,000	61,779	143,493
2006	2007	1,792	8,064,000	127,491	1.58%	883	3,973,500	62,821	313	1,408,500	22,268	175,592
2007	2008	1,486	6,687,000	400,763	5.99%	438	1,971,000	118,125	676	3,042,000	182,312	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
2011	2012	333	1,498,500	90,260	6.02%	19	85,500	5,150	190	855,000	51,500	146,909

Yearling Chinook

Fifteen yearling Chinook of natural origin were captured (Appendix B). Four were caught in February, five in March, and six in April. Fork length of the thirteen measured individuals averaged 106.6 mm (range 76 to 156 mm).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}$ =1,163) included 1,083 captures in the trap and 80 missed catch estimated for trap outage periods and were captured between February 28 and June 18 (Table 5, Appendix D). In total, 1,755 (1,409 Ad-mark and 346 Ad-CWT) hatchery coho were captured between March 23 and June 12. Twenty-three trap efficiency trials using natural origin coho were conducted over the trapping season. All efficiency trials were pooled to form a single strata with an efficiency of 2.26%.

A total of 48,148 ± 23,479 (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 24.9%.

Table 5. Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2012. 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	1/25-7/12	1,083	80	1.56E+02	620	14	48,148	1.43E+08

The median migration date for coho smolts was May 7. The first coho smolt was captured on January 28, 2012. Daily migration of coho was low and averaged 125 smolts per day through April 20 (Figure 4). Peak daily migration occurred on May 6 when 4,800 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 July 8, 2012.

The seasonal average length of coho smolts was 106.1 ± 12.7 mm FL (± 1 S.D.; Appendix E). The weekly averages were generally smaller early and late in the migration with the largest weekly average size of 117.7 mm occurring in week 20 the peak of the natural coho migration (Figure 5).

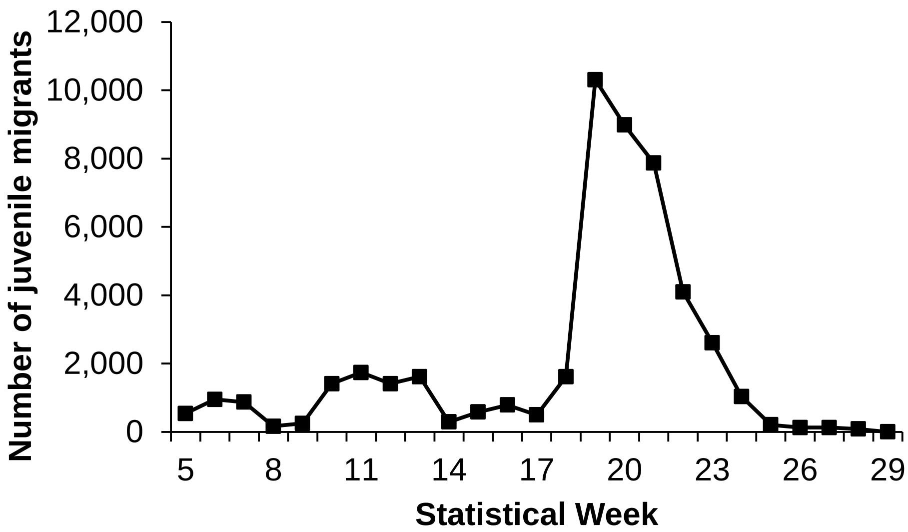

Figure 4. Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2012. Data are number of juvenile migrants by statistical week.

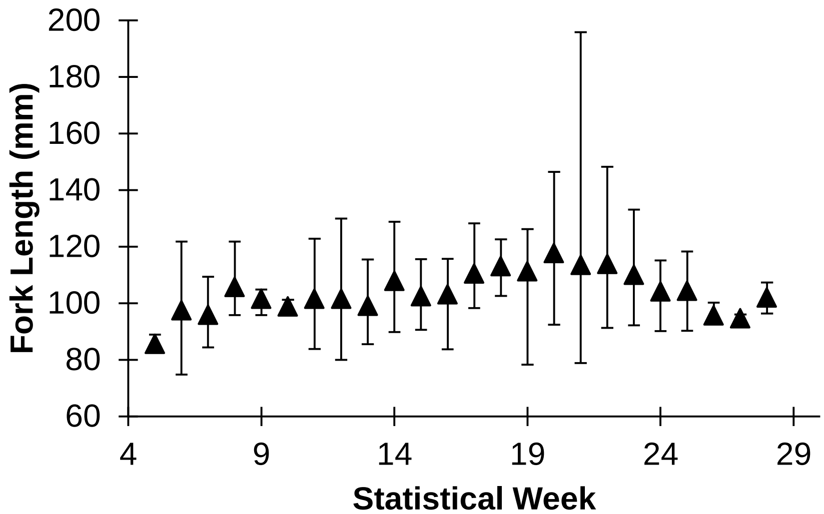

Figure 5. Fork lengths (mm) of natural-origin coho captured in the Green River screw trap in 2012. Data are mean, minimum, and maximum values by statistical week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 395) included 382 captures in the trap and 13 missed catch estimated for trap outage periods (Appendix D). Trap efficiency trials (19 in total) were conducted between May 4 and June 10, resulted in no recoveries from the 271 individuals released. No production estimate was calculated.

The first steelhead was captured on February 28. Early in the trapping season, daily catch of steelhead was low with only 91 individuals caught through April 30. Peak catch occurred on the night of May 16, with 42 smolts captured. Daily catch declined thru middle June and only 1 smolt was captured after June 15 (Figure 6).

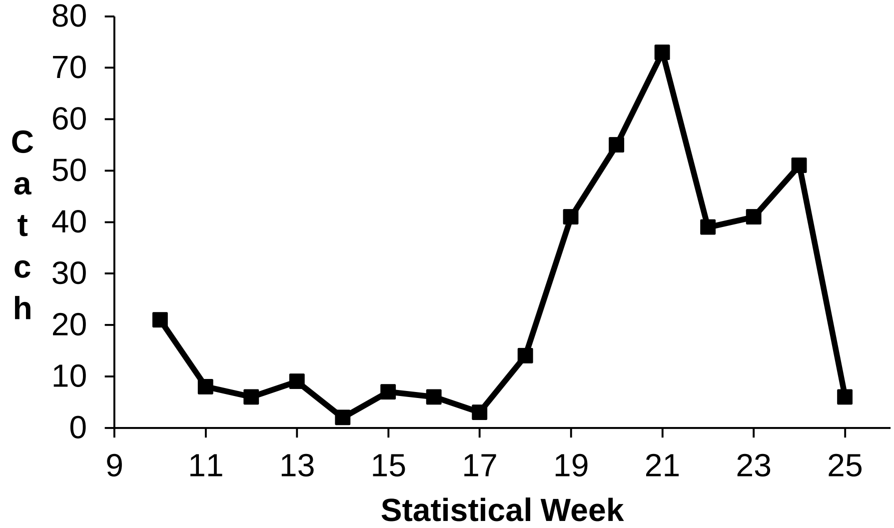

Figure 6. Weekly catch of natural-origin steelhead smolts captured in the Green River screw trap in 2012. Catch per week not adjusted for changes in trap efficiency, therefore represents an index of steelhead smolt migration timing.

The seasonal average length of natural-origin steelhead smolts was 166.1 ± 17.9 mm FL (± 1 S.D.; Appendix F, Figure 7).

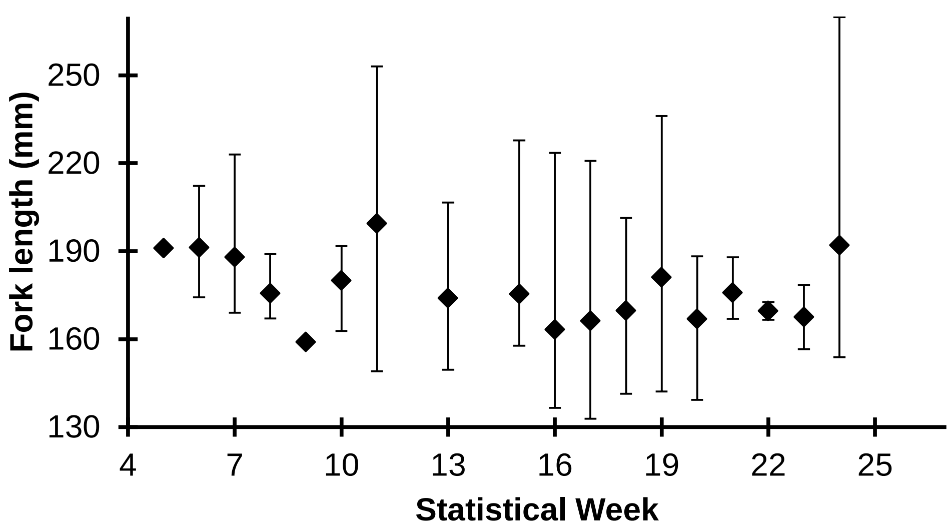

Figure 7. Fork lengths (mm) of natural-origin steelhead at the Green River screw trap in 2012. Data are mean, minimum, and maximum values by statistical week.

Length and scale samples were collected on all 382 natural-origin steelhead smolts captured to determine the age-length structure of the natural-origin steelhead smolt production. The sample included 279 readable and 103 regenerated or upside down samples. Scale sample results indicated that 52% were one year old and averaged 158.6-mm FL, 47% were two years old and averaged 171.7-mm FL, and 1% were three year old smolts and averaged 206.5-mm FL (Table6).

Table 6. Age and length of natural-origin steelhead smolts collected at the Green River juvenile trap, 2012.

Age	Average	Standard Deviation	Min	Max	Number	Percent of Readable
1+	158.6	11.13	136	190	147	52.69%
2+	171.7	20.81	136	223	130	46.59%
3+	206.5	7.78	201	212	2	0.72%
Unreadable	---	---			103	---
Total Sampled	166.1	17.86	136	223	382	---

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$ =124,104) included 122,583 captures in the trap and 1,521 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between February 3 and July 9, 2012. Captured chum could not be separated by natural and hatchery origin because chum released from Keta Creek hatchery were unmarked.

No trap efficiency trials were conducted using chum fry. When Chinook trap efficiency data were applied to the season estimated catch of chum, an estimated 2,989,000 chum fry migrated past the trap. No variance or CV was calculated for this estimate.

Pink

The total estimated catch of wild pink fry ($\hat{u}$ =574,502) included 494,600 captures in the trap and 79,902 missed catch estimated for trap outage periods (Appendix D). Pink migrants were captured from the beginning of trapping until May 25, 2012. The daily catch steadily increased thru the early part of the season, averaging 150 fry in the first week to 4,900 per day by the third week of March. Between March 26 and April 20 approximately 78% of the season total catch occurred. The peak catch occurred on April 11 with 31,810 pink captured.

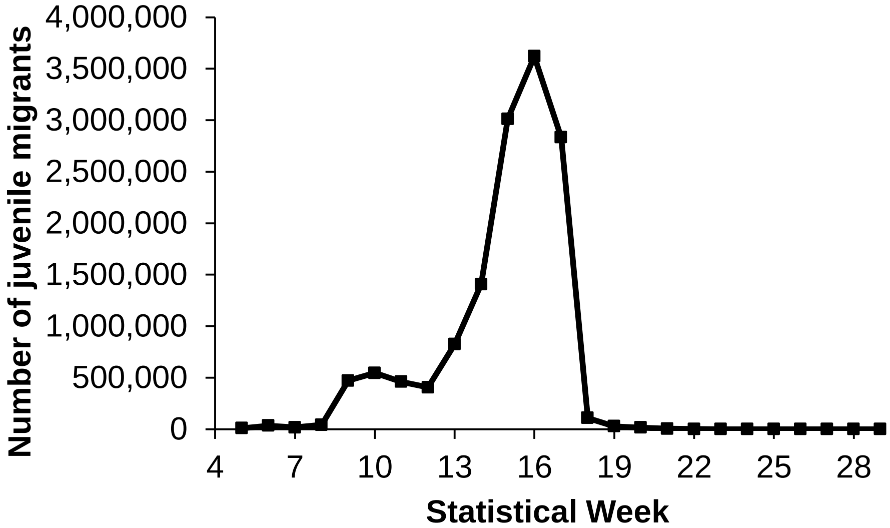

Figure 8. Weekly migration of pink fry originating from above the Green River screw trap in 2012. Data are number of juvenile migrants by statistical week.

No trap efficiency trials were conducted using pink fry. When Chinook trap efficiency data were applied to the season estimated catch of pink, estimates approximately 13,841,000 pink fry migrated past the trap. No variance or CV was calculated for this estimate.

Other Species

In addition to species and age classes described above, catch during the trapping season included 376 coho fry, 543 trout parr, 26 cutthroat smolts, and 2 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) coho, chum and pink salmon and steelhead emigrating from the Green River in 2012. 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. 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 (Seber 1973, Hayes et al. 2007). 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 and 2012 trappings season included quantitative tests of these assumptions.

Assumption 1. Population is closed with no immigration or emigration and no births or deaths. 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. To reduce the chance of mortality of the dyed Chinook post release, the dying process occurred 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 Chinook fry migrants. 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.

Assumption 2. All animals have the same probability of being caught. 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 2012 attempts were made to evaluate size bias of yearling smolts (coho or steelhead) by using a Kolmogorov-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 successfully complete this evaluation in 2012

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) 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 than redistribution of subyearling fish due to their larger size, and hence greater mobility. Early in the season prior to smoltification, yearling fish may actively search for foraging opportunities in the vicinity of the trap, undertaking back and forth movements rather than active downstream migration. This redistribution would increase their vulnerability to capture relative to downstream migrants, and could artificially inflate abundance estimates. To minimize this problem, trap efficiency trials were not started until early May when the majority of the coho and steelhead are fully smolted and in the traditional time period for peak migration. In 2012, both coho and steelhead were marked with alternating upper and lower caudal fin clips. Rotating the mark allowed us to assess delayed recaptures for these species. Delayed recaptures were rare for coho smolts. With the exception of one efficiency trial, all recaptures of marked coho smolts occurred within 3 day of their release. Delayed recaptures could not be determined for steelhead smolts due to the lack of recaptures for this species.

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. All fish (marked and unmarked) are equally likely to be captured in the second sample (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 and 2012, 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 2012. Between early February and mid-May, we conducted six 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 1/4 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 measured from two release locations in 2012.

Original Site			Neely Bridge Site				
Release Date	Number Released	Trap Efficiency	Release Date	Number Released	Trap Efficiency	Δ TE	*P*
3/12	34	5.88%	3/10	14	7.14%	-1.26%	0.60
3/21	23	4.35%	3/18	26	3.85%	0.50%	0.50
4/3	17	0.00%	3/31	59	0.00%	0.00%	0.00
5/16-5/20	154	5.19%	5/22-6/2	395	4.81%	0.38%	0.97
6/10	98	6.12%	6/8	85	7.06%	-0.94%	0.95
6/23	36	2.78%	6/20	109	3.67%	-0.89%	0.78

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 2012, 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 13th and correctly enumerated the sample which included 11 clipped, 9 Bismark Brown, and 8 unmarked fry. The second technician performed this test on March 14th and correctly enumerated the sample which included 6 clipped, 5 Bismark Brown, and 8 unmarked fry. This approach to assessing mark detection by trap technicians will continue on an annual basis in the future 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 current fish per redd expansion factor may be too low (Seamons et al. 2012). However, redd surveys in 2011 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 and 2012, 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 in both years indicated that all field-identified Chinook salmon sub-yearlings were correctly identified to species.

Identification of 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 be 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 2012 outmigration, 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 2012, this bias was anticipated to be minimal. A total of 748 ad-marked subyearling Chinook were caught, assuming that the proportion of unmarked Chinook was 7.7% (2012 mark rate at Palmer = 92.3%), this means that 3.1% (n = 58) of the 1,883 unmarked sub-yearling Chinook caught between April 27 (the first day hatchery ad-marked Chinook were captured) and July 12 were of hatchery origin.

Freshwater Production of Chinook Salmon

The 2012 freshwater production estimate of 90,260 sub yearling Chinook was the second lowest observed since juvenile monitoring began (55,000 to 800,000, 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 (6.0% egg-to-migrant survival and 271 juveniles/female) was the third highest observed over thirteen 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 53% of the freshwater production above the Green River trap in 2012 (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 thirteen 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 2000-2012.

	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
2012	90,260	68,450	112,069	10.92	63.3	19.35	4/28

Table 9. Abundance of natural-origin fry and parr subyearling migrants of Green River Chinook, migration year 2000 to 2012.

	Fry Migrants			Parr Migrants		
Trap Year	Migration Interval	Abundance	% of Migration	Migration Interval	Abundance	% of Migration
2000	1/01-4/29	266,481	56.10%	3/11-7/31	208,726	43.90%
2001	1/01-5/20	379,174	46.80%	3/8-7/31	430,442	53.20%
2002	1/01-5/23	357,602	61.20%	3/3-7/31	226,550	38.80%
2003	1/01-5/27	413,358	91.90%	2/16-7/13	36,598	8.10%
2004	1/01-4/29	136,144	57.50%	3/21-7/31	100,506	42.50%
2005	1/01-4/26	391,274	83.20%	2/20-7/31	79,061	16.80%
2006	1/01-5/01	29,946	30.00%	2/18-7/31	69,850	70.00%
2007	1/01-5/07	88,439	69.40%	3/21-7/31	39,053	30.60%
2008	1/01-6/08	251,815	62.80%	3/15-7/31	148,948	37.20%
2009	1/01-5/13	119,406	60.90%	2/6-7/31	76,709	39.10%
2010	1/01-4/20	5,559	10.00%	2/11-7/31	49,988	90.00%
2011	1/01-6/12	128,472	50.50%	2/7-7/31	125,710	49.50%
2012	1/01-5/13	42,133	46.68%	2/27-7/31	48,127	53.32%

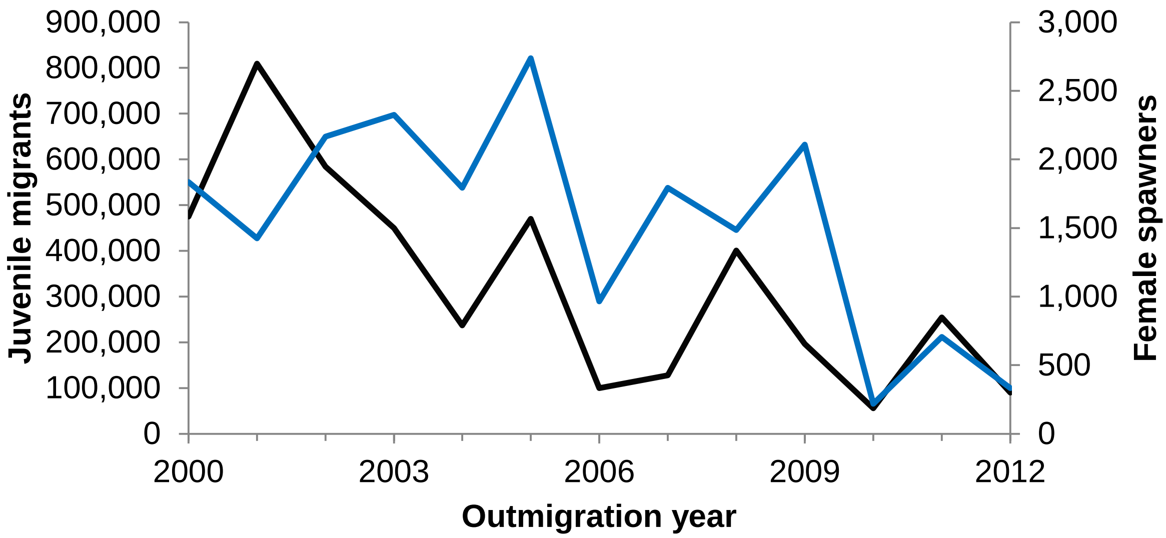

Figure 9. Number of sub yearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (blue line) above the juvenile trap, outmigration year 2000-2012.

Freshwater Production of Coho Salmon

Freshwater production of coho above the Green River trap has been estimated for 10 of the 13 years of this study (Table 10). The 2012 freshwater production estimate of 48,000 coho smolts was intermediate to the range of approximately 20,000 to 200,000 smolts estimated over this time period.

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 2012 an abundance estimate was made, however with just 14 recoveries the precision of this estimate was low and the accuracy is questionable.

Estimating the freshwater production of species with yearling migrants (i.e., coho and steelhead) has proven to be more challenging than for species with sub yearling migrants (i.e., Chinook and pink). 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 2012, 7% of the natural origin coho and 3% of the natural origin steelhead catch were estimated missed catch during outages. These percentages are lower than in most years because of the long hours and hard work of the technicians keeping the trap operating more of the time following the hatchery releases. 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 2000-2012.

	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	12.4	5/1 [b]
2004	---	---	---	---	105.8	12.3	5/8 [a]
2005	---	---	---	---	106.8	14.93	5/4 [a]
2006	31,460	21,143	41,777	16.7%	106.9	16	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	10.9	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
2012	48,148	24,669	71,627	24.9%	106.1	12.68	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 only 2 of the 13 years of this study (Table 11). In 2009 and 2010, abundance estimates were derived directly from release and recaptures of natural-origin steelhead. However, few other years have yielded sufficient steelhead recaptures to generate trap efficiency estimates. Similarly, in 2012, no abundance estimate was made because we did not recovery any of the 271 marked steelhead smolts released over 19 efficiency trials.

In previous years with insufficient recaptures of marked natural-origin steelhead, we had made steelhead abundance estimates based on an assumed steelhead:coho catch ratios. However, upon revisiting the data supporting these assumptions, we had little confidence in these estimates. Thus, we did not use this approach to estimate steelhead smolt abundance for 2012, and have removed previous years' estimates using the coho:steelhead catch ration method from Table 11.

In 2012, steelhead smolts captured in the trap were shorter in length (average 166-mm FL) and younger in age (53% 1 year smolts) than smolts captured in 2011 (average 175-mm FL, 26% 1-year smolts). 2011 was the first year that size and age data were collected systematically from steelhead smolts. The high percentage of age-1 smolts in 2012 is higher than would be expected based on typical 2-year smolt age for winter steelhead in western Washington rivers (Scott and Gill 2008). This difference may have resulted from different brood class strengths or different smolting rates of the brood years; however, the difference may also have resulted if the trap was more size selective in 2012 than 2011. Although our monitoring protocols are designed to detect size selectivity, we could not evaluate selectivity in 2012 due to the lack of steelhead recaptures.

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 2000-2012.

	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	---	---	---	---	176.6	20.2	5/17[a]
2002	---	---	---	---	167.1	19.03	5/19[a]
2003	---	---	---	---	173.8	20.44	4/19[a]
2004	---	---	---	---	148.2	24.33	2/06[a]
2005	---	---	---	---	153.3	19.05	1/25[a]
2006	---	---	---	---	151.1	25.93	5/05[a]
2007	---	---	---	---	157.1	19.8	4/29[a]
2008	---	---	---	---	163.8	23.64	5/15[a]
2009	26,174	10,151	42,198	19.40%	171.4	20.3	5/11
2010	71,710	49,317	94,103	15.90%	178.7	22.87	5/16
2011	---	---	---	---	175.1	18.4	5/08[a]
2012	---	---	---	---	166.1	17.9	5/16[a]

a Median catch date

Summary

In 2012, 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 2012 was well below the average production of 355,000 sub-yearlings observed between 2000 and 2011 and consistent with a downward trend in freshwater production over this time period.

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,

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

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

$E\left(\hat{u}_i\right)$ = 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, 2012.

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, 2012. 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-Mark	Unmark
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
1/1-1/24	Pre-Trapping		0	0	0	3,759	0	0
1/25/12	16.50	7.50	5	2	7	169	0	0
1/26/12	0.00	24.00	0	18	18	434	0	0
1/27/12	24.00	0.00	26	0	26	626	0	0
1/28/12	24.00	0.00	11	0	11	265	0	0
1/29/12	24.00	0.00	3	0	3	72	0	0
1/30/12	16.50	7.50	67	1	68	1,638	0	0
1/31/12	0.00	23.00	0	38	38	916	0	0
2/1/12	25.00	0.00	16	0	16	386	0	0
2/2/12	9.00	15.00	1	10	11	265	0	0
2/3/12	24.00	0.00	14	0	14	337	0	0
2/4/12	24.00	0.00	22	0	22	530	0	0
2/5/12	9.00	15.00	3	10	13	313	0	0
2/6/12	24.00	0.00	10	0	10	241	0	0
2/7/12	24.00	0.00	4	0	4	96	0	0
2/8/12	24.00	0.00	7	0	7	169	0	0
2/9/12	24.00	0.00	1	0	1	24	0	0
2/10/12	24.00	0.00	6	0	6	145	0	1
2/11/12	24.00	0.00	4	0	4	96	0	0
2/12/12	24.00	0.00	10	0	10	241	0	0
2/13/12	24.00	0.00	3	0	3	72	0	0
2/14/12	23.00	0.00	7	0	7	169	0	0
2/15/12	25.00	0.00	15	0	15	361	0	0
2/16/12	24.00	0.00	1	0	1	24	0	0
2/17/12	21.00	0.00	2	0	2	48	0	0
2/18/12	27.50	0.00	45	0	45	1,084	0	0
2/19/12	24.00	0.00	17	0	17	410	0	0
2/20/12	24.00	0.00	10	0	10	241		0
2/21/12	20.50	0.00	19	0	19	458	0	0
2/22/12	0.00	27.00	0	44	44	1,060	0	0
2/23/12	0.00	24.00	0	38	38	916	0	0
2/24/12	0.00	24.00	0	38	38	916	0	0
2/25/12	0.00	21.00	0	35	35	843	0	0
2/26/12	27.50	0.00	61	0	61	1,470	0	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Time Fished Hours Out	Unmarked Sub-yearling Chinook Catch Actual	Estimated	Total	Migration	Estimated Catch Ad-mrk Fry	Estimated Catch Unmarked Yearling
2/27/12	8.75	15.25	15	44	59	1,422	0	1
2/28/12	24.00	0.00	50	0	50	1,205	0	2
2/29/12	23.00	0.00	29	0	29	699	0	1
3/1/12	24.00	0.00	29	0	29	699	0	1
3/2/12	24.50	0.00	8	0	8	193	0	0
3/3/12	24.00	0.00	10	0	10	241	0	0
3/4/12	24.00	0.00	13	0	13	313	0	0
3/5/12	24.50	0.00	19	0	19	458	0	0
3/6/12	23.50	0.00	25	0	25	602	0	1
3/7/12	24.00	0.00	20	0	20	482	0	0
3/8/12	24.00	0.00	14	0	14	337	0	0
3/9/12	24.00	0.00	11	0	11	265	0	0
3/10/12	24.00	0.00	5	0	5	120	0	0
3/11/12	24.50	0.00	33	0	33	795	0	0
3/12/12	24.50	0.00	36	0	36	867	0	0
3/13/12	23.00	0.00	42	0	42	1,012	0	0
3/14/12	24.50	0.00	20	0	20	482	0	0
3/15/12	24.50	0.00	8	0	8	193	0	0
3/16/12	23.50	0.00	22	0	22	530	0	0
3/17/12	24.50	0.00	27	0	27	651	0	0
3/18/12	24.00	0.00	19	0	19	458	0	0
3/19/12	24.00	0.00	36	0	36	867	0	0
3/20/12	24.00	0.00	5	0	5	120	0	0
3/21/12	24.00	0.00	13	0	13	313	0	0
3/22/12	24.00	0.00	25	0	25	602	0	0
3/23/12	24.00	0.00	17	0	17	410	0	0
3/24/12	24.00	0.00	7	0	7	169	0	1
3/25/12	24.00	0.00	11	0	11	265	0	0
3/26/12	24.00	0.00	6	0	6	145	0	1
3/27/12	24.00	0.00	6	0	6	145	0	0
3/28/12	24.00	0.00	10	0	10	241	0	0
3/29/12	24.00	0.00	14	0	14	337	0	1
3/30/12	24.00	0.00	41	0	41	988	0	0
3/31/12	24.00	0.00	70	0	70	1,687	0	0
4/1/12	24.00	0.00	23	0	23	554	0	1
4/2/12	24.00	0.00	7	0	7	169	0	0
4/3/12	24.00	0.00	5	0	5	120	0	0

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APPENDIX B.─continued.

	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
4/4/12	24.50	0.00	11	0	11	265	0	1
4/5/12	24.00	0.00	6	0	6	145	0	0
4/6/12	24.00	0.00	10	0	10	241	0	0
4/7/12	27.50	0.00	27	0	27	651	0	0
4/8/12	24.00	0.00	9	0	9	217	0	0
4/9/12	22.00	0.00	9	0	9	217	0	0
4/10/12	25.50	0.00	4	0	4	96	0	0
4/11/12	23.00	0.00	11	0	11	265	0	0
4/12/12	25.00	0.00	25	0	25	602	0	0
4/13/12	24.50	0.00	15	0	15	361	0	0
4/14/12	24.00	0.00	6	0	6	145	0	0
4/15/12	24.00	0.00	3	0	3	72	0	0
4/16/12	24.00	0.00	3	0	3	72	0	1
4/17/12	0.00	24.00	0	7	7	169	0	1
4/18/12	0.00	24.00	0	7	7	169	0	1
4/19/12	12.00	11.50	0	6	6	145	0	0
4/20/12	24.50	0.00	42	0	42	1,012	0	1
4/21/12	24.00	0.00	82	0	82	1,976	0	0
4/22/12	24.00	0.00	19	0	19	458	0	0
4/23/12	24.00	0.00	5	0	5	120	0	0
4/24/12	24.00	0.00	7	0	7	169	0	0
4/25/12	24.00	0.00	8	0	8	193	0	0
4/26/12	24.00	0.00	7	0	7	169	0	0
4/27/12	24.00	0.00	24	0	24	578	12	1
4/28/12	24.00	0.00	12	0	12	289	16	0
4/29/12	24.50	0.00	12	0	12	289	11	0
4/30/12	23.00	0.00	50	0	50	1,205	9	1
5/1/12	24.00	0.00	36	0	36	867	28	0
5/2/12	24.50	0.00	21	0	21	506	9	0
5/3/12	23.50	0.00	30	0	30	723	34	0
5/4/12	25.00	0.00	62	0	62	1,494	48	0
5/5/12	24.00	0.00	32	0	32	771	44	0
5/6/12	25.75	2.23	28	4	32	771	33	0
5/7/12	15.43	8.57	20	13	33	795	19	0
5/8/12	19.85	0.17	16	0	16	386	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	Total	Migration	Estimated Catch Ad-mrk Fry	Estimated Catch Unmarked Yearling
5/9/12	24.00	0.00	21	0	21	480	12	0
5/10/12	24.00	0.00	10	0	10	229	6	0
5/11/12	24.00	0.00	14	0	14	320	3	0
5/12/12	24.00	0.00	11	0	11	252	3	0
5/13/12	24.00	0.00	13	0	13	297	2	0
5/14/12	24.00	0.00	14	0	14	320	0	0
5/15/12	24.00	0.00	13	0	13	297	0	0
5/16/12	24.00	0.00	39	0	39	892	4	0
5/17/12	22.00	0.00	29	0	29	663	4	0
5/18/12	26.25	0.00	28	0	28	641	3	0
5/19/12	38.00	0.00	20	0	20	458	1	0
5/20/12	24.00	0.00	19	0	19	435	0	0
5/21/12	23.50	0.00	22	0	22	503	1	0
5/22/12	24.00	0.00	49	0	49	1,121	7	0
5/23/12	24.00	0.00	37	0	37	846	3	0
5/24/12	24.50	0.00	76	0	76	1,739	7	0
5/25/12	23.50	0.00	12	0	12	275	1	0
5/26/12	24.50	0.00	15	0	15	343	2	0
5/27/12	24.00	0.00	9	0	9	206	2	0
5/28/12	23.50	0.00	28	0	28	641	4	0
5/29/12	24.00	0.00	50	0	50	1,144	3	0
5/30/12	24.00	0.00	38	0	38	869	3	0
5/31/12	24.00	0.00	19	0	19	435	4	0
6/1/12	24.00	0.00	33	0	33	755	3	0
6/2/12	24.00	0.00	31	0	31	709	3	0
6/3/12	24.50	0.00	28	0	28	641	3	0
6/4/12	24.00	0.00	37	0	37	846	3	0
6/5/12	24.00	0.00	73	0	73	1,670	2	0
6/6/12	24.00	0.00	50	0	50	1,144	4	0
6/7/12	23.50	0.00	49	0	49	1,121	4	0
6/8/12	24.00	0.00	26	0	26	595	4	0
6/9/12	24.00	0.00	48	0	48	1,098	8	0
6/10/12	24.00	0.00	50	0	50	1,144	12	0
6/11/12	21.00	0.00	34	0	34	778	5	0
6/12/12	25.00	2.00	42	0	42	961	13	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Out	Unmarked Sub-yearling Chinook Catch Actual	Estimated	Total	Migration	Estimated Catch Ad-mrk Fry	Unmarked Yearling
6/13/12	24.00	0.00	36	0	36	824	28	0
6/14/12	25.00	0.00	29	0	29	663	39	0
6/15/12	22.00	0.00	45	0	45	1,029	26	0
6/16/12	12.00	13.00	6	2	8	183	13	0
6/17/12	11.00	13.00	13	2	15	343	15	0
6/18/12	11.00	13.00	28	2	30	686	20	0
6/19/12	12.00	13.00	33	2	35	801	33	0
6/20/12	23.50	0.00	38	0	38	869	16	0
6/21/12	11.50	12.50	17	2	19	435	7	0
6/22/12	10.50	13.00	11	2	13	297	10	0
6/23/12	11.50	12.50	10	2	12	275	11	0
6/24/12	23.00	0.00	22	0	22	503	13	0
6/25/12	12.00	13.00	10	0	10	229	20	0
6/26/12	11.50	12.50	13	0	13	297	16	0
6/27/12	24.00	0.00	11	0	11	252	18	0
6/28/12	12.00	12.00	7	0	7	160	16	0
6/29/12	23.00	0.00	8	0	8	183	10	0
6/30/12	13.00	12.00	4	0	4	92	0	0
7/1/12	12.50	11.50	12	0	12	275	5	0
7/2/12	12.00	12.00	13	0	13	297	4	0
7/3/12	24.00	0.00	5	0	5	114	2	0
7/4/12	12.00	12.50	13	0	13	297	6	0
7/5/12	12.50	11.50	9	0	9	206	2	0
7/6/12	12.50	11.50	6	0	6	137	6	0
7/7/12	12.00	12.00	4	0	4	92	1	0
7/8/12	12.00	12.00	3	0	3	69	2	0
7/9/12	12.00	12.50	5	0	5	114	2	0
7/10/12	11.50	12.50	2	0	2	46	1	0
7/11/12	11.00	13.00	3	0	3	69	0	0
7/12/12	11.00	0.00	6	0	6	137	0	0
7/13-7/31	Post -Trapping		0	0	0	870	0	0
Total	3551.03	536.21	3,302	329	3,631	90,260	748	18

Appendix C

Fork length of natural-origin, sub yearling Chinook in the Green River, 2012

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 2012.

Statistical Week					Range		Number		Percent
Number	Begin	End	Average	St.Dev.	Min	Max	Sampled	Caught	Sampled
5	1/25/2012	1/29/2012	38.68	1.92	36	42	19	45	42.22%
6	1/30/2012	2/5/2012	39.40	1.64	37	42	15	123	12.20%
7	2/6/2012	2/12/2012	39.56	1.46	37	42	18	42	42.86%
8	2/13/2012	2/19/2012	40.00	2.30	36	44	18	90	20.00%
9	2/20/2012	2/26/2012	40.17	2.44	36	44	12	90	13.33%
10	2/27/2012	3/4/2012	40.88	3.08	37	51	32	154	20.78%
11	3/5/2012	3/11/2012	41.58	4.48	34	55	36	127	28.35%
12	3/12/2012	3/18/2012	41.76	5.26	36	61	33	174	18.97%
13	3/19/2012	3/25/2012	43.23	5.72	36	56	30	114	26.32%
14	3/26/2012	4/1/2012	43.37	6.53	36	61	35	170	20.59%
15	4/2/2012	4/8/2012	42.55	6.33	36	66	31	75	41.33%
16	4/9/2012	4/15/2012	44.10	7.79	37	61	29	73	39.73%
17	4/16/2012	4/22/2012	48.62	10.33	37	75	29	146	19.86%
18	4/23/2012	4/29/2012	50.31	10.14	37	74	26	75	34.67%
19	4/30/2012	5/6/2012	53.66	9.55	36	80	56	259	21.62%
20	5/7/2012	5/13/2012	67.82	10.69	42	86	39	105	37.14%
21	5/14/2012	5/20/2012	71.02	9.94	52	86	48	162	29.63%
22	5/21/2012	5/27/2012	73.54	10.88	54	91	46	220	20.91%
23	5/28/2012	6/3/2012	72.88	8.93	56	91	51	227	22.47%
24	6/4/2012	6/10/2012	74.75	10.07	55	100	112	333	33.63%
25	6/11/2012	6/17/2012	78.64	9.91	57	105	67	205	32.68%
26	6/18/2012	6/24/2012	82.51	7.40	55	97	83	159	52.20%
27	6/25/2012	7/1/2012	83.87	9.18	49	101	53	65	81.54%
28	7/2/2012	7/8/2012	87.98	10.34	59	107	42	53	79.25%
29	7/9/2012	7/15/2012	94.36	6.98	80	106	14	16	87.50%
	Season Total		63.31	19.35	34	107	974	3,302	29.50%

Appendix D

Daily catch of coho, chum and pink salmon, steelhead and cutthroat trout in the Green River, 2012

APPENDIX D.─Daily catches of coho, chum and pink salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2012. 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.

			Coho		Chum	Pink	Steelhead		Cutthroat		Trout
	Times		Smolts		Fry	Fry	Smolts		Smolt	Adult	Parr
Date	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat	Nat
1/25/12	16.50	7.50	4	0	0	34	0	0	0	0	1
1/26/12	0.00	24.00	3	0	0	105	0	0	0	0	2
1/27/12	24.00	0.00	0	0	0	160	0	0	0	0	2
1/28/12	24.00	0.00	3	0	0	43	0	0	0		1
1/29/12	24.00	0.00	3	0	0	22	0	0	0	0	1
1/30/12	16.50	7.50	1	0	0	442	0	0	0	0	1
1/31/12	0.00	23.00	1	0	0	271	0	0	0	0	1
2/1/12	25.00	0.00	2	0	0	166	0	0	0	0	1
2/2/12	9.00	15.00	4	0	1	131	0	0	1	0	2
2/3/12	24.00	0.00	5	0	1	158	0	0	1	0	3
2/4/12	24.00	0.00	4	0	2	120	0	0	0	0	6
2/5/12	9.00	15.00	6	0	1	103	0	0	0	0	4
2/6/12	24.00	0.00	8	0	0	120	0	0	0	0	2
2/7/12	24.00	0.00	7	0	0	91	0	0	0	0	1
2/8/12	24.00	0.00	1	0	0	79	0	0	0	0	5
2/9/12	24.00	0.00	5	0	0	45	0	0	0	0	3
2/10/12	24.00	0.00	0	0	0	65	0	0	1	1	1
2/11/12	24.00	0.00	0	0	0	131	0	0	0	0	4
2/12/12	24.00	0.00	0	0	0	192	0	0	0	0	1
2/13/12	24.00	0.00	0	0	0	215	0	0	0	0	2
2/14/12	23.00	0.00	0	0	0	164	0	0	1	0	3
2/15/12	25.00	0.00	1	0	0	162	0	0	0	0	0
2/16/12	24.00	0.00	0	0	0	76	0	0	0	0	2
2/17/12	21.00	0.00	0	0	1	157	0	0	0	0	1
2/18/12	27.50	0.00	2	0	13	775	0	0	0	0	4
2/19/12	24.00	0.00	1	0	2	195	0	0	0	0	0
2/20/12	24.00	0.00	0	0	3	239	0	0	0	0	3
2/21/12	20.50	0.00	2	0	5	525	0	0	0	0	0
2/22/12	0.00	27.00	1	0	9	3,557	0	0	0	0	1
2/23/12	0.00	24.00	1	0	8	3,013	0	0	0	0	0
2/24/12	0.00	24.00	1	0	8	3,013	0	0	0	0	0
2/25/12	0.00	21.00	1	0	8	2,917	0	0	0	0	0
2/26/12	27.50	0.00	0	0	12	6,300	0	0	0	0	1
2/27/12	8.75	15.25	2	0	10	4,557	4	0	0	0	6
2/28/12	24.00	0.00	5	0	7	3,872	8	0	0	0	10

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APPENDIX D.─continued.

	Times		Coho Smolts		Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
Date	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat	Nat
2/29/12	23.00	0.00	10	0	6	3,023	2	1	0	0	8
3/1/12	24.00	0.00	5	0	13	2,215	2	0	1	0	8
3/2/12	24.50	0.00	5	0	1	3,080	5	0	0	0	29
3/3/12	24.00	0.00	1	0	4	2,900	1	0	1	0	23
3/4/12	24.00	0.00	6	0	5	3,000	2	0	1	0	35
3/5/12	24.50	0.00	6	0	7	2,110	2	0	0	0	50
3/6/12	23.50	0.00	4	0	31	2,250	1	0	0	0	16
3/7/12	24.00	0.00	6	0	20	1,363	0	0	1	1	14
3/8/12	24.00	0.00	4	0	22	1,650	2	0	0	0	16
3/9/12	24.00	0.00	14	0	19	4,350	0	0	0	0	28
3/10/12	24.00	0.00	3	0	2	2,850	1	0	0	0	11
3/11/12	24.50	0.00	5	0	22	4,550	0	0	1	0	11
3/12/12	24.50	0.00	4	0	23	3,210	1	0	0	0	10
3/13/12	23.00	0.00	4	0	21	1,810	0	0	0	0	3
3/14/12	24.50	0.00	9	0	10	1,090	1	0	0	0	8
3/15/12	24.50	0.00	4	0	15	1,770	0	0	0	0	6
3/16/12	23.50	0.00	4	0	16	2,700	0	0	0	0	4
3/17/12	24.50	0.00	5	0	37	3,570	3	0	0	0	3
3/18/12	24.00	0.00	4	0	29	2,700	2	0	0	0	4
3/19/12	24.00	0.00	2	0	19	3,120	2	0	0	0	5
3/20/12	24.00	0.00	3	0	45	2,660	1	0	1	0	5
3/21/12	24.00	0.00	4	0	43	2,220	2	0	0	0	7
3/22/12	24.00	0.00	10	0	5,772	3,335	3	0	0	0	16
3/23/12	24.00	0.00	9	5	7,750	8,550	2	0	0	0	12
3/24/12	24.00	0.00	6	1	1,880	6,300	0	0	0	0	5
3/25/12	24.00	0.00	5	6	965	8,020	0	0	0	0	0
3/26/12	24.00	0.00	4	0	501	12,260	0	0	0	0	5
3/27/12	24.00	0.00	0	2	308	5,660	1	0	0	0	15
3/28/12	24.00	0.00	0	1	237	5,210	1	0	0	0	10
3/29/12	24.00	0.00	0	1	1,463	4,662	0	0	0	0	3
3/30/12	24.00	0.00	0	0	6,500	22,100	0	0	0	0	1
3/31/12	24.00	0.00	2	1	982	5,100	0	0	0	0	1
4/1/12	24.00	0.00	1	0	62	3,400	0	1	0	0	1
4/2/12	24.00	0.00	3	0	227	8,800	3	0	0	0	6
4/3/12	24.00	0.00	3	0	180	10,500	2	0	0	0	8
4/4/12	24.50	0.00	2	2	32,800	23,600	1	0	0	0	6
4/5/12	24.00	0.00	2	0	18,800	19,400	0	0	0	0	2
4/6/12	24.00	0.00	1	0	5,410	4,810	0	0	1	0	3

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APPENDIX D.—continued.

	Times		Coho Smolts		Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
Date	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat	Nat
4/7/12	27.50	0.00	3	0	8,397	29,690	0	0	0	0	8
4/8/12	24.00	0.00	0	0	1,550	28,200	1	0	0	0	5
4/9/12	22.00	0.00	1	0	554	25,750	0	2	0	0	3
4/10/12	25.50	0.00	0	0	687	20,630	0	0	0	0	4
4/11/12	23.00	0.00	4	0	1,376	31,810	2	0	0	0	4
4/12/12	25.00	0.00	4	0	10,446	19,070	2	1	0	0	12
4/13/12	24.50	0.00	4	0	5,850	22,300	1	0	0	0	6
4/14/12	24.00	0.00	3	0	1,880	18,900	0	0	0	0	4
4/15/12	24.00	0.00	3	0	375	11,800	1	2	1	0	7
4/16/12	24.00	0.00	2	1	453	30,000	0	1	0	0	0
4/17/12	0.00	24.00	1	1	501	21,436	1	6	0	0	0
4/18/12	0.00	24.00	1	1	501	21,436	1	6	0	0	0
4/19/12	12.00	11.50	1	1	412	20,021	1	6	0	0	0
4/20/12	24.50	0.00	1	0	979	19,000	2	11	0	0	0
4/21/12	24.00	0.00	4	0	424	4,400	0	6	0	0	0
4/22/12	24.00	0.00	2	0	239	1,300	1	0	0	0	1
4/23/12	24.00	0.00	2	0	342	883	1	1	0	0	2
4/24/12	24.00	0.00	1	0	317	436	1	0	0	0	1
4/25/12	24.00	0.00	1	0	139	266	0	0	0	0	0
4/26/12	24.00	0.00	0	0	132	227	0	0	0	0	1
4/27/12	24.00	0.00	5	0	174	985	6	6	0	0	1
4/28/12	24.00	0.00	11	0	108	1,310	1	3	0	0	0
4/29/12	24.50	0.00	19	0	88	415	5	7	0	0	1
4/30/12	23.00	0.00	12	0	111	324	2	7	0	0	0
5/1/12	24.00	0.00	9	1	615	226	7	12	2	0	1
5/2/12	24.50	0.00	7	0	187	136	0	8	0	0	1
5/3/12	23.50	0.00	12	0	46	91	0	9	0	0	0
5/4/12	25.00	0.00	29	0	370	96	12	16	1	0	0
5/5/12	24.00	0.00	64	2	459	70	13	32	0	0	0
5/6/12	25.75	2.23	116	1	273	187	7	136	0	0	0
5/7/12	15.43	8.57	42	523	113	120	6	70	0	0	4
5/8/12	19.85	0.17	51	444	13	92	12	20	0	0	2
5/9/12	24.00	0.00	42	373	41	69	16	23	0	0	6
5/10/12	24.00	0.00	29	246	35	84	13	9	2	0	6
5/11/12	24.00	0.00	12	104	56	111	5	20	1	0	1
5/12/12	24.00	0.00	20	72	25	142	1	5	0	0	1
5/13/12	24.00	0.00	21	92	26	71	10	6	0	0	1
5/14/12	24.00	0.00	27	35	34	54	7	4	0	0	0

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APPENDIX D.─continued.

	Times		Coho Smolts		Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat		Trout Parr
									Smolt	Adult	
Date	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat	Nat
5/15/12	24.00	0.00	36	35	22	46	4	6	1	0	1
5/16/12	24.00	0.00	45	31	34	49	42	16	2	0	1
5/17/12	22.00	0.00	47	20	21	30	12	6	1	0	0
5/18/12	26.25	0.00	10	7	23	16	2	2	0	0	0
5/19/12	38.00	0.00	8	8	26	15	4	5	0	0	0
5/20/12	24.00	0.00	17	12	10	15	2	0	0	0	0
5/21/12	23.50	0.00	6	5	16	30	2	2	0	0	0
5/22/12	24.00	0.00	14	13	46	26	3	5	2	0	0
5/23/12	24.00	0.00	24	20	70	19	10	9	0	0	1
5/24/12	24.50	0.00	26	13	102	4	8	3	2	0	0
5/25/12	23.50	0.00	9	5	35	1	5	3	0	0	0
5/26/12	24.50	0.00	14	4	34	0	3	3	0	0	0
5/27/12	24.00	0.00	6	4	21	0	6	1	0	0	0
5/28/12	23.50	0.00	15	8	23	0	5	1	0	0	1
5/29/12	24.00	0.00	6	1	39	0	7	1	0	0	0
5/30/12	24.00	0.00	5	3	10	0	8	1	0	0	0
5/31/12	24.00	0.00	5	3	21	0	1	1	0	0	0
6/1/12	24.00	0.00	11	4	21	0	7	4	0	0	0
6/2/12	24.00	0.00	14	5	92	0	10	1	0	0	0
6/3/12	24.50	0.00	7	0	57	0	3	1	0	0	0
6/4/12	24.00	0.00	7	2	51	0	8	1	0	0	0
6/5/12	24.00	0.00	1	0	118	0	2	1	0	0	0
6/6/12	24.00	0.00	13	2	23	0	18	3	0	0	0
6/7/12	23.50	0.00	0	0	17	0	6	0	0	0	1
6/8/12	24.00	0.00	3	0	19	0	4	0	0	0	0
6/9/12	24.00	0.00	0	3	241	0	4	1	0	0	0
6/10/12	24.00	0.00	1	0	75	0	9	0	0	0	0
6/11/12	21.00	0.00	1	0	17	0	1	0	0	0	0
6/12/12	25.00	2.00	1	0	27	0	2	1	0	0	0
6/13/12	24.00	0.00	1	3	23	0	0	0	0	0	0
6/14/12	25.00	0.00	1	0	16	0	0	0	0	0	0
6/15/12	22.00	0.00	0	0	6	0	3	0	0	0	0
6/16/12	12.00	13.00	0	0	5	0	0	0	0	0	0
6/17/12	11.00	13.00	1	0	10	0	0	0	0	0	0
6/18/12	11.00	13.00	1	0	5	0	1	0	0	0	0
6/19/12	12.00	13.00	0	1	7	0	0	0	0	0	0
6/20/12	23.50	0.00	0	0	3	0	0	0	0	0	0

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APPENDIX D.─continued.

	Times		Coho Smolts		Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Cutthroat Adult	Trout Parr
Date	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat	Nat
6/21/12	11.50	12.50	0	0	2	0	0	0	0	0	0
6/22/12	10.50	13.00	0	0	1	0	0	0	0	0	0
6/23/12	11.50	12.50	0	0	3	0	0	0	0	0	0
6/24/12	23.00	0.00	2	0	2	0	0	0	0	0	0
6/25/12	12.00	13.00	0	0	4	0	0	0	0	0	0
6/26/12	11.50	12.50	0	0	2	0	0	0	0	0	0
6/27/12	24.00	0.00	0	0	4	0	0	0	1	0	0
6/28/12	12.00	12.00	0	0	1	0	0	0	0	0	0
6/29/12	23.00	0.00	1	0	3	0	0	0	0	0	0
6/30/12	13.00	12.00	2	0	4	0	0	0	0	0	0
7/1/12	12.50	11.50	0	0	4	0	0	0	0	0	0
7/2/12	12.00	12.00	0	0	3	0	0	0	0	0	0
7/3/12	24.00	0.00	0	0	2	0	0	0	0	0	0
7/4/12	12.00	12.50	0	0	5	0	0	0	0	0	0
7/5/12	12.50	11.50	0	0	1	0	0	0	0	0	0
7/6/12	12.50	11.50	0	0	3	0	0	0	0	0	0
7/7/12	12.00	12.00	1	0	3	0	0	0	0	0	0
7/8/12	12.00	12.00	1	0	2	0	0	0	0	0	0
7/9/12	12.00	12.50	0	0	1	0	0	0	0	0	0
7/10/12	11.50	12.50	0	0	1	0	0	0	0	0	0
7/11/12	11.00	13.00	0	0	1	0	0	0	0	0	0
7/12/12	11.00	0.00	0	0	0	0	0	0	0	0	0
Total	3551.03	536.21	1,163	2,128	124,104	574,502	395	515	27	2	561

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2012

APPENDIX E.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2012.

Statistical Week					Range		Number		Percent
Number	Begin	End	Average	St.Dev.	Min	Max	Sampled	Captured	Sampled
5	1/25/2012	1/29/2012	85.6	16.25	63	110	8	9	88.89%
6	1/30/2012	2/5/2012	97.5	8.74	86	111	13	13	100.00%
7	2/6/2012	2/12/2012	95.9	6.93	86	112	21	21	100.00%
8	2/13/2012	2/19/2012	105.7	4.93	100	109	3	4	75.00%
9	2/20/2012	2/26/2012	101.5	3.54	99	104	2	2	100.00%
10	2/27/2012	3/4/2012	98.8	10.08	81	120	32	32	100.00%
11	3/5/2012	3/11/2012	101.5	11.26	80	130	35	42	83.33%
12	3/12/2012	3/18/2012	101.5	8.47	88	118	32	34	94.12%
13	3/19/2012	3/25/2012	99.0	8.52	81	120	36	39	92.31%
14	3/26/2012	4/1/2012	107.9	10.93	96	121	7	7	100.00%
15	4/2/2012	4/8/2012	102.4	11.59	83	115	14	14	100.00%
16	4/9/2012	4/15/2012	103.2	9.15	91	121	19	19	100.00%
17	4/16/2012	4/22/2012	110.4	6.60	100	120	9	9	100.00%
18	4/23/2012	4/29/2012	113.0	10.30	80	128	30	39	76.92%
19	4/30/2012	5/6/2012	111.2	10.37	86	140	58	217	26.73%
20	5/7/2012	5/13/2012	117.7	21.55	83	200	26	192	13.54%
21	5/14/2012	5/20/2012	113.5	11.09	91	148	42	190	22.11%
22	5/21/2012	5/27/2012	113.8	10.08	96	137	35	99	35.35%
23	5/28/2012	6/3/2012	110.0	6.23	96	121	23	63	36.51%
24	6/4/2012	6/10/2012	104.1	9.26	90	118	15	25	60.00%
25	6/11/2012	6/17/2012	104.4	2.79	102	109	5	5	100.00%
26	6/18/2012	6/24/2012	95.7	1.53	94	97	3	3	100.00%
27	6/25/2012	7/1/2012	94.7	5.51	89	100	3	3	100.00%
28	7/2/2012	7/8/2012	102.0	1.41	101	103	2	2	100.00%
29	7/9/2012	7/15/2012					0	0	
Season Total			106.1	12.68	63	200	473	1,083	43.67%

Appendix F

Fork lengths of natural-origin steelhead smolts in the Green River, 2012

APPENDIX F.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin steelhead smolts in the Green River in 2012.

Statistical Week					Range		Number		Percent
Number	Begin	End	Average	St.Dev.	Min	Max	Sampled	Captured	Sampled
10	2/27/12	3/4/12	172.3	20.54	142	212	21	21	100.00%
11	3/5/12	3/11/12	165.3	25.20	136	212	8	8	100.00%
12	3/12/12	3/18/12	141.7	2.42	138	144	6	6	100.00%
13	3/19/12	3/25/12	146.8	9.68	136	163	9	9	100.00%
14	3/26/12	4/1/12	141.5	4.95	138	145	2	2	100.00%
15	4/2/12	4/8/12	146.1	9.39	139	166	7	7	100.00%
16	4/9/12	4/15/12	155.0	15.59	138	176	6	6	100.00%
17	4/16/12	4/22/12	145.3	11.02	138	158	3	3	100.00%
18	4/23/12	4/29/12	179.6	28.62	140	221	14	14	100.00%
19	4/30/12	5/6/12	172.9	19.16	141	223	41	41	100.00%
20	5/7/12	5/13/12	167.8	19.43	138	220	55	55	100.00%
21	5/14/12	5/20/12	166.0	17.32	139	222	73	73	100.00%
22	5/21/12	5/27/12	165.1	11.82	147	195	39	39	100.00%
23	5/28/12	6/3/12	166.3	12.86	139	197	41	41	100.00%
24	6/4/12	6/10/12	165.8	12.20	143	223	51	51	100.00%
25	6/11/12	6/17/12	165.3	8.24	151	174	6	6	100.00%
Season Total			166.1	17.86	136	223	382	382	100.00%

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