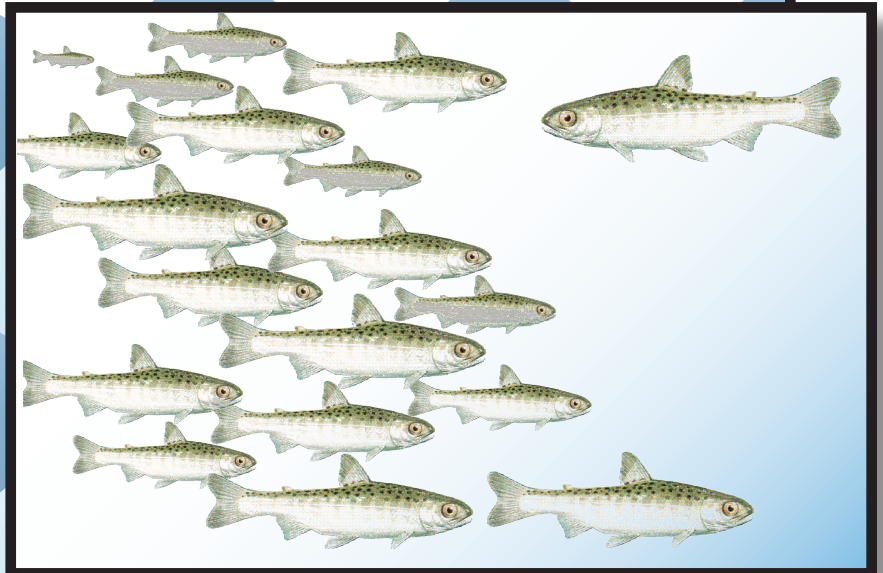


Green River Juvenile Salmonid Production Evaluation: 2013 Annual Report



by Peter C. Topping, and
Joseph H. Anderson



*Washington Department of
Fish and Wildlife
Fish Program
Science Division*

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**Peter C. Topping
Joseph H. Anderson**

**Washington Department of Fish and Wildlife
Fish Program, Science Division**

July 2014

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. Aaron Bosworth, 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), King County WIRA 9, and Tacoma Water in 2013.

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Executive Summary

This report provides the 2013 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 salmon 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 methods. Additional objectives were to estimate the number of juvenile migrants and life history characteristics of other salmonid species. 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 15, 2013. During this period, the trap fished 89% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (sub yearling), coho, and steelhead. (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 2013. 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	22,690	492,737 (6.3%)	48.1 (± 14.4)	21-Mar
Chinook – Yrlg	1	--- ^a	---	2-Mar ^b
Coho – Yrlg	1,149	50,642 (20.8%)	103.5 (± 16.8)	9-May
Steelhead – Smolt	444	15,339 (28.8%)	169.1 (± 17.7)	11-May
Chum	69,365	--- ^c	--- ^c	28-Mar ^b

^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 Unable to distinguish between natural origin and hatchery production

Chinook salmon spawn above and below the juvenile trap. A basin-wide production estimate was derived by applying estimated survival above the trap to spawning below the trap; a screw trap fished in Big Soos Creek estimated production from that tributary. Egg-to-migrant survival of Green River Chinook for the 2013 outmigration (2012 brood) was estimated to be 9.72%, yielding a basin-wide production estimate of 1,008,512 juveniles. Included in this estimate was a preliminary estimate of 468,119 Chinook migrating from Big Soos Creek with a egg-to-migrant survival of 15.3%. This estimate was generated by a screw trap located just above the hatchery and operated by the Muckleshoot Indian Tribe.

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 72% of all sub yearling migrants and peaked in early March, parr migrants (>45 mm fork length) represented 28% of the migration and peaked in early June.

Introduction

This report provides the 2013 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, 2012 and 2013, 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) (McElhany 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 2013).

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 (HHD) Additional Water Storage (AWS) 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. The final significant component remaining to complete the project is the construction of the juvenile salmon collection and transport facility in the pool above HHD. 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. Currently there are no adult salmon being trapped for transport and release above the dam. Once the juvenile collection facility has been constructed and adult salmon released above the dam to colonize the 106 miles of river and stream habitat, comparisons can be made and mitigation efforts evaluated. There is no time line in place for the construction of the juvenile salmon collection facility.

In 2011, 2012 and 2013, 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 study was to develop an unbiased estimate of known precision for Chinook escapement via Genetic Mark Recapture (GMR) 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 2013 helped estimate the number of adult Chinook returning to the Green River in the fall 2012, the third year of study for the GMR project on the Green River.

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 2013 field season. In 2013, 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 2013, the trap operated between January 23 and July 15 for a total of 3,680 of 4,147 possible hours (89% of the time). Over the course of the season, trapping was suspended 26 times; the duration of outages ranged from 0.75 to 80.28 hours. Trapping was suspended one time for high water, three times for hatchery fish releases where the trap was spot fished throughout the night, and 22 times during day time periods late in the trapping season when catches were low and recreational use was high.

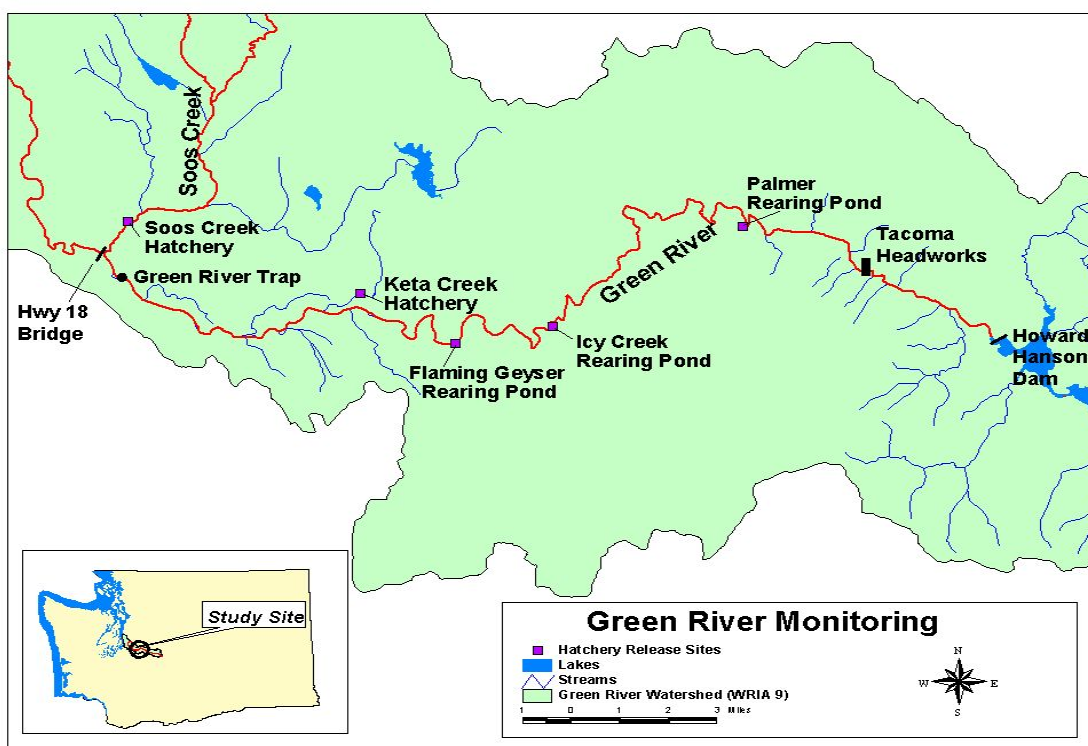


Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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 subsample 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 the single yearling Chinook captured was length sampled. Caudal fin clips for genetic analysis were collected from approximately 15% 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 and length samples were collected from all 444 captured natural-origin steelhead smolts and weight samples were collected on 428 to determine smolt age and weight composition.

Chinook were enumerated as sub yearlings and yearlings. Based on previous years data 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 migrate, 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 tail), 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 2013 included Chinook, coho, chum 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 wild brood hatchery reared steelhead released above the trap were not ad-clipped but were tagged with a blank wire 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 2013. 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	2012	Palmer Pond	54,849	108	1,098,394	550
Chinook – Yrlg	2011	Icy Creek			307,564	3,736
Coho – Yrlg	2011	Keta Creek	50,404	894	547,094	1,306
Chum - SubYrlg	2012	Keta Creek	0			3,557,000
Winter Steelhead	2011	Icy Creek			39,200	800
Winter Steelhead	2011	Icy Creek	0	11,482		

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 caudal fin in order to check for delayed migration of 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, for some species (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

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

where:

\bar{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

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

where:

Equation 4

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

(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 ($\alpha = 0.05$). 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

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

(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 estimate 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 below the trap. Soos Creek juvenile Chinook production was estimated separately with a screw trap operated by the Muckleshoot Indian Tribe. Egg deposition was estimated as described above. This approach assumes equivalent female fecundity and egg survival above and below the trap site.

Results

Sub yearling Chinook

The total estimated catch of natural-origin Chinook ($\hat{u} = 23,939$) included 22,690 captures in the trap and an estimated missed catch during trap outage periods of 1,249 (Table 3, Appendix B). A total of 336 ad-marked Chinook were captured between April 5 and July 15. 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. Very few ($< 0.1\%$) hatchery Chinook released upstream of the trap were unmarked (Table 2).

A total of 132 efficiency trials, ranging between 13 and 997 fish, were conducted and used a total of 14,677 natural-origin Chinook. Efficiency 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. We compared the two locations using a *G*-test and found no difference between the two sites in 5 of the seven releases. In the two of the seven releases, we found a difference in the recapture rate between sites, but there was no consistent pattern, with each site having a higher efficiency in one of the two tests. With recapture rates similar between the two release locations; both sites were included in the analysis. Individual trials were combined by statistical week, with a minimum of 5 recoveries. Statistical weeks with less than 5 recoveries were combined with the subsequent statistical week, forming 19 groups prior to stratification. The *G*-test pooled the 19 groups into 10 strata, with trap efficiencies ranging between 1.6% and 20.3% (Table 3).

The trapping season of January 24 through July 15 encompassed the majority of the sub yearling Chinook migration. A total of 482,478 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 8,406 Chinook were estimated to have migrated prior to the trapping season and 1,853 migrants were estimated following the trapping season. This extrapolation assumed migration began January 1 and ended July 31, 2013.

A total of $492,737 \pm 72,660$ ($\pm 95\%$ C.I.) sub yearling Chinook of natural origin were estimated to have migrated past the screw trap between January 1 and July 31, 2013. Coefficient of variation for this estimate was 6.3%.

Table 3. Catch, marked and recaptured fish, and estimated abundance of sub yearling Chinook migrants at the Green River screw trap in 2013. Release groups were pooled to form ten strata. Missed catch and associated variance were estimated for periods that the trap did not fish.

Strata	Date	Catch			Marked	Recaptured	Abundance	
		Actual	Missed	Variance			Estimated	Variance
Before	1/01-1/20						8,406	3.72E+07
1	1/21-1/27	582		0	385	78	2,844	9.13E+04
2	1/28-2/3	1,261		0	1,231	61	25,057	9.93E+06
3	2/4-2/24	3,524		0	3,380	381	31,190	2.50E+06
4	2/25-3/3	4,036		0	3,337	262	51,225	9.75E+06
5	3/4-3/10	2,491		0	1,056	110	23,721	4.70E+06
6	3/11-4/21	7,048	1,053	2.21E+04	2,375	83	229,143	6.20E+08
7	4/22-5/5	729	170	4.23E+03	616	10	50,426	2.25E+08
8	5/6-6/9	2,477		0	1,836	79	56,878	3.94E+07
9	6/10-6/16	130		0	116	12	1,170	9.56E+04
10	6/17-7/15	412	26	1.19E+01	345	13	10,825	7.74E+06
After	7/16-7/31						1,853	4.28E+05
Season Total		22,690	1,249	2.64E+04	14,677	1,089	492,737	9.57E+08

Freshwater productivity of natural-origin Chinook for brood year 2012 was estimated to be 437 juveniles per female and 9.72% egg-to-migrant survival. This calculation was based on the number of sub yearling Chinook passing the trap ($\hat{N}_T = 492,737$), 1,127 female spawners above the trap site (personal communication, Darcy Wildermuth, WDFW Region 4), and an estimated P.E.D above the trap site of 5,071,500 eggs.

Basin-wide abundance of sub yearling natural-origin Chinook was estimated to be 1,008,512 juvenile migrants. This included 492,737 migrants from above the trap, 47,656 juveniles from the main stem below the trap, and 468,119 (preliminary estimate) from Big Soos Creek. This estimate is the largest in over a decade and the third highest since trapping began and can mostly be attributed to the moderate flows during egg incubation, resulting in the second highest egg-to-migrant survival we have estimated since 2000 (Table 4).

However, we note that the methods for estimating production from Big Soos Creek have changed over the years and would therefore affect interannual comparisons of the basin-wide estimate. Previous estimates of Chinook production from Big Soos Creek either assumed a carrying capacity of 275,000 (trap years 2001 – 2003) or applied egg-to-migrant survival measured at the mainstem trap to estimated egg deposition above the hatchery rack (trap years 2004 – 2012). Only in trap years 2000 and 2013 was Chinook production from Big Soos Creek measured directly.

An estimated 72% (357,952) of the Chinook migrated as fry and 28% (134,785) 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 March 21. 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 5 (25,057 fry migrants between January 28 and February 3), and the largest peak occurred during statistical week 11 (~70,000 fry migrants between Mar 11 and 17). The first peak to the parr migration occurred during statistical week 18 (~17,700 parr migrants between April 29 and May 5), and the second peak occurred during statistical week 22 (~20,000 parr migrants between May 27 and June 2).

The seasonal average length of sub yearling Chinook was 48.1 ± 14.4 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the sub yearling Chinook showed little increase (approximately 5 mm) during the early portion of the season, statistical weeks 4-16 (January 24-April 21). Chinook subyearling body size increased substantially from week 16 thru the end of trapping season (April 22-July 15), averaging 2.4 mm FL per week. Week 23 (June 3- June 9) saw the largest weekly increase of 6.6-mm FL (Figure 3, Appendix C).

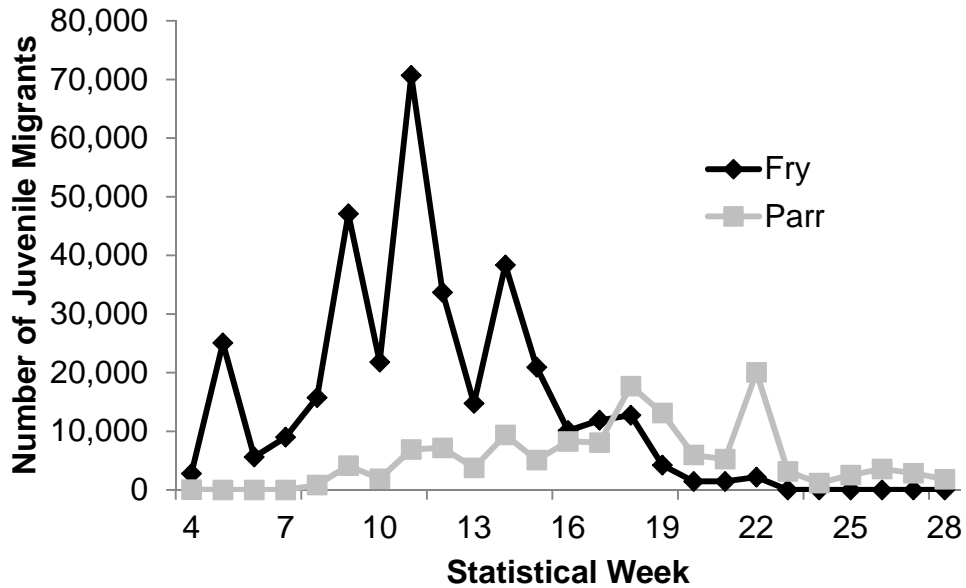


Figure 2. Weekly migration of sub yearling Chinook migrants of natural-origin at the Green River screw trap in 2013. Sub yearling migrants are partitioned into two freshwater rearing strategies fry (<45-mm FL) and parr (> 45-mm FL) migrants.

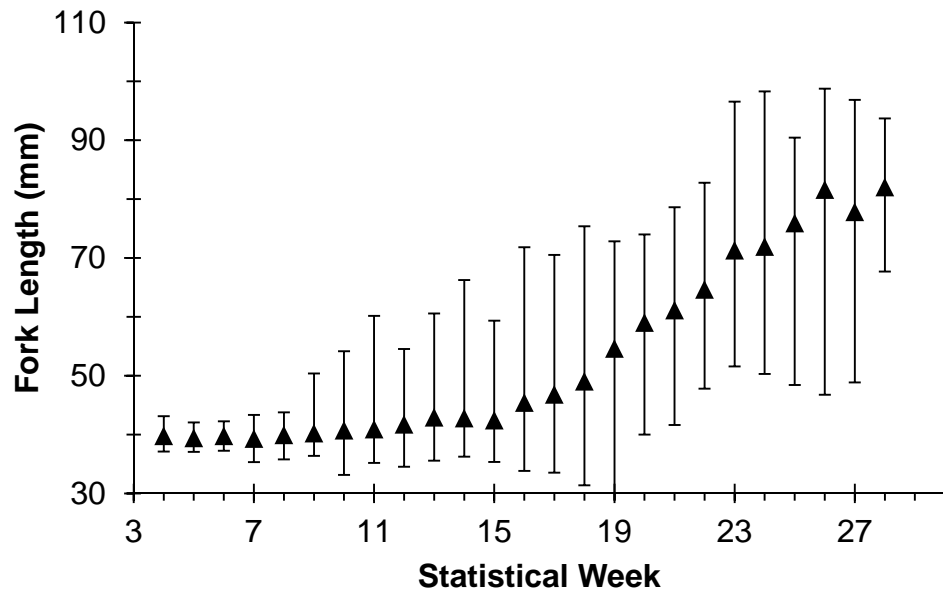


Figure 3. Fork lengths (mm) of sub yearling Chinook migrants of natural origin captured in the Green River screw trap in 2013. Data are mean, minimum, and maximum values by statistical week.

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 within the Green River, and above Soos Creek hatchery rack. Note that the methods for estimating production from Big Soos Creek have changed over the years (see text of results for details)

Brood Year	Trap Year	Above Trap			Below Trap			Soos Ck			Total Green Production	
		Redds	Deposition	Production	Survival	Redds	Deposition	Production	Females	Deposition		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	964,240
2000	2001	1,425	6,412,500	809,616	12.63%	936	4,212,000	531,790	1,580	7,110,000	275,000	1,616,406
2001	2002	2,167	9,751,500	584,151	5.99%	480	2,160,000	129,392	995	4,477,500	275,000	988,543
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	1,172,977
2003	2004	1,793	8,068,500	236,650	2.93%	1,038	4,671,000	137,001	720	3,240,000	95,029	468,680
2004	2005	2,738	12,321,000	470,334	3.82%	827	3,721,500	142,062	623	2,803,500	107,019	719,416
2005	2006	966	4,347,000	99,796	2.30%	82	369,000	8,471	598	2,691,000	61,779	170,046
2006	2007	1,792	8,064,000	127,491	1.58%	883	3,973,500	62,821	313	1,408,500	22,268	212,580
2007	2008	1,486	6,687,000	400,763	5.99%	438	1,971,000	118,125	676	3,042,000	182,312	701,200
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	146,910
2012	2013	1,127	5,071,500	492,737	9.72%	109	490,500	47,656	682	3,069,000	468,119	1,008,512

Yearling Chinook

One natural-origin yearling Chinook was captured on March 2 (Appendix B).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}=1,227$) included 1,149 captures in the trap and an estimated missed catch during trap outage periods of 78 fish. Coho smolts were captured between January 24 and July 1 (Table 5, Appendix D). In total, 3,948 hatchery coho were captured between January 29 and June 14 (3,706 Ad-mark, 241 Ad-CWT and 1 No Ad-CWT). Thirty-six 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 2.32%.

We estimated a total of $50,642 \pm 20,642$ (95% C.I.) natural-origin coho smolts migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 20.8%.

Table 5. Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2013. Release groups were pooled to form a single strata. Missed catch and associated variance were calculated for periods that the trap did not fish.

Strata	Date	Catch			Marked	Recaptured	Abundance	
		Actual	Missed	Variance			Estimated	Variance
1	1/24-7/15	1,149	78	9.19E+01	907	21	50,642	1.11E+08

The median migration date for coho smolts was May 9. The first coho smolt was captured on January 24, 2013. Daily estimated migration of coho was low and averaged 95 smolts per day through April 21 (Figure 4). Peak daily migration occurred on May 12 when 2,765 smolts were estimated to have passed the trap in a single night. Daily estimated migration declined gradually through the remainder of May and early June. The last three natural-origin coho smolts were captured on July 1, 2013.

The seasonal average length of coho smolts was 103.5 ± 16.8 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 127.5 mm occurring during the middle of the migration (week 18, Figure 5).

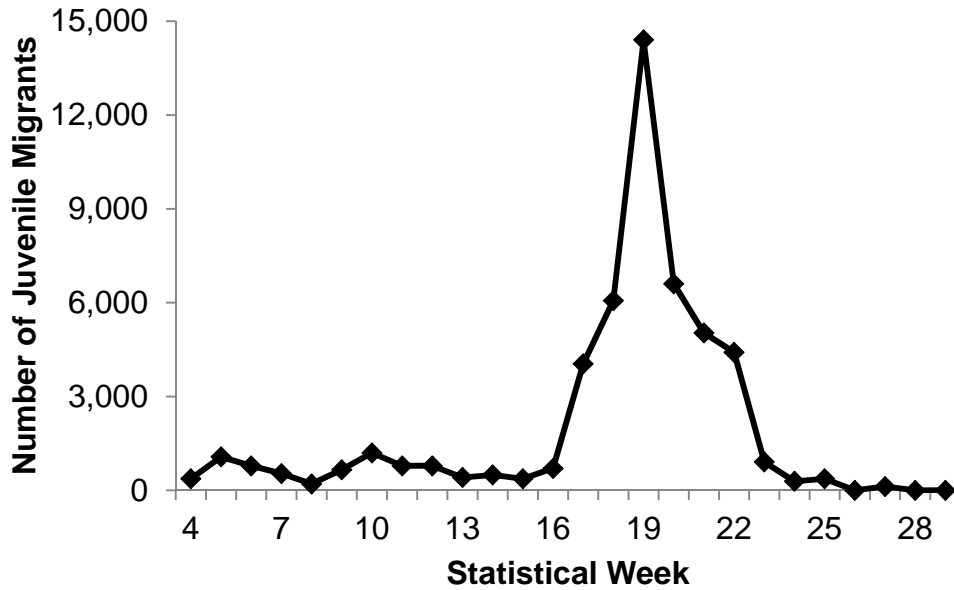


Figure 4. Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2013. Data are number of juvenile migrants by statistical week.

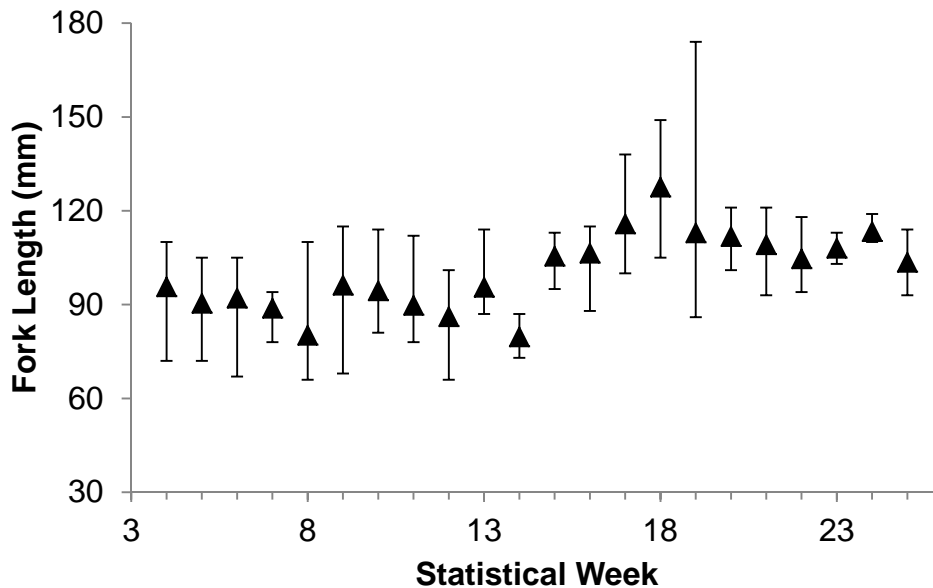


Figure 5. Fork lengths (mm) of natural-origin coho captured in the Green River screw trap in 2013. Data are mean, minimum, and maximum values by statistical week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u} = 470$) included 444 captures in the trap and 26 missed catch estimated for trap outage periods (Table 6, Appendix D). In total, 423 hatchery steelhead were captured between February 8 and June 16 (94 Ad-mark, 296 Ad-CWT and 33 No Ad-CWT). Thirty trap efficiency trials using natural origin steelhead were

conducted over the trapping season. All efficiency trials were pooled to form a single strata with an efficiency of 2.79%.

We estimated a total of $15,339 \pm 8,647$ (95% C.I.) natural-origin steelhead smolts migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 28.8%.

Table 6. Catch, marked and recaptured fish, and estimated abundance of natural-origin steelhead smolts at the Green River screw trap in 2013. Release groups were pooled to form a single strata. Missed catch and associated variance were calculated for periods that the trap did not fish.

Strata	Date	Catch			Marked	Recaptured	Abundance	
		Actual	Missed	Variance			Estimated	Variance
1	1/24-7/15	444	26	1.24E+01	358	10	15,339	1.95E+07

The first steelhead was captured on January 29. Early in the trapping season, daily catch of steelhead was low with only 13 individuals caught through March 31. Peak catch occurred on the night of May 28, with 47 smolts captured. Daily catch declined thru middle June and the last two natural-origin steelhead were captured on June 13 (Figure 6).

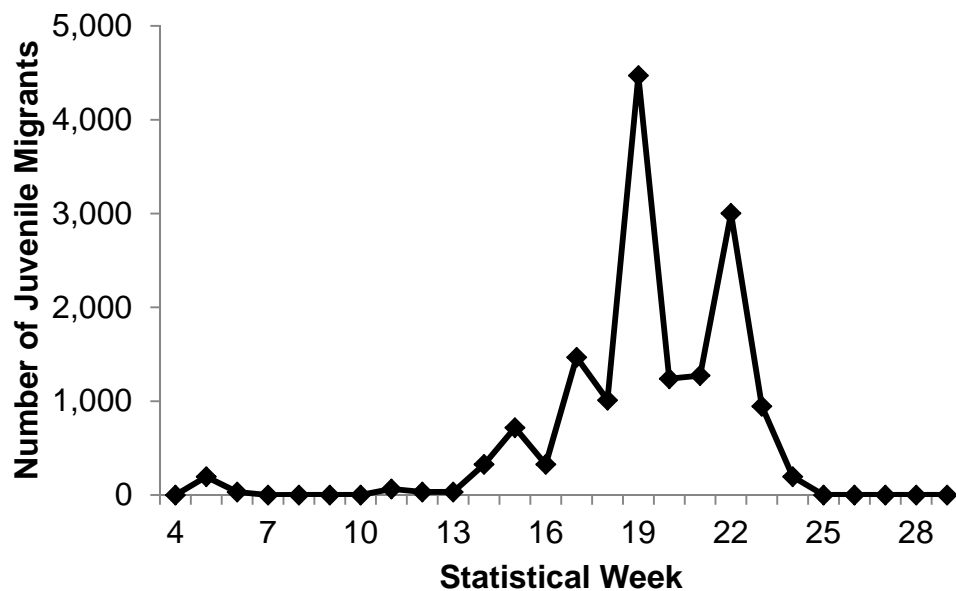


Figure 6. Weekly migration of natural-origin steelhead smolts captured in the Green River screw trap in 2013. Catch per week not adjusted for changes in trap efficiency, therefore represents an index of steelhead smolt migration timing.

The seasonal average length of natural-origin steelhead smolts was 169.1 ± 17.7 mm FL (± 1 S.D.; Appendix F, Figure 7).

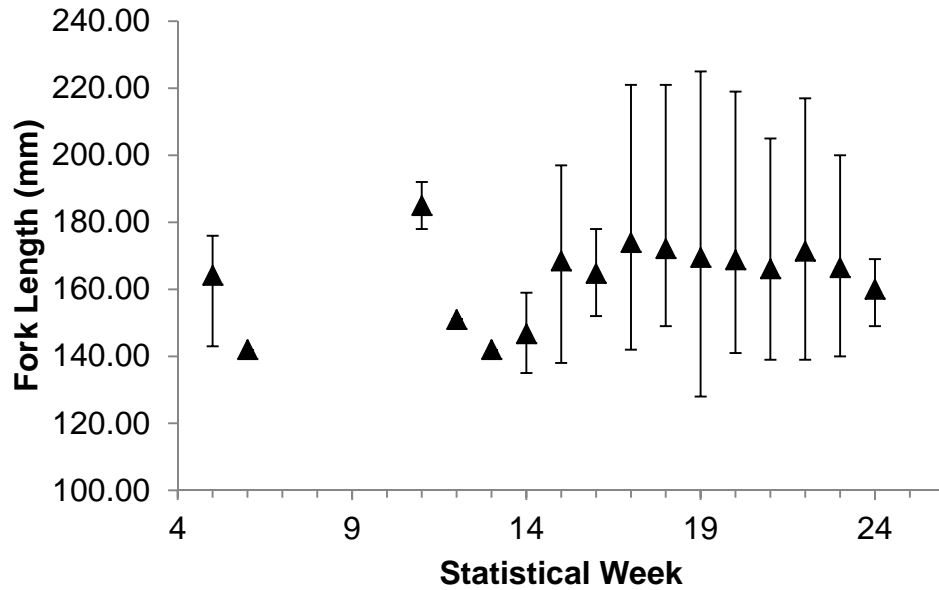


Figure 7. Fork lengths (mm) of natural-origin steelhead at the Green River screw trap in 2013. Data are mean, minimum, and maximum values by statistical week.

Length and scale samples were collected on all 444 natural-origin steelhead smolts captured, and weights were collected on 428 to determine the age structure and body size of natural-origin steelhead smolts. The sample included 348 readable and 96 regenerated or upside down samples. Scale sample results indicated that 40% were one year old and averaged 157.0-mm FL and 40 grams, 59% were two years old and averaged 177.0-mm FL and 57 grams, and 1% were three year old smolts and averaged 189.0-mm FL and 79 grams (Table 7).

Table 7. Age and length of natural-origin steelhead smolts collected at the Green River juvenile trap, migration years 2011-2013.

Smolt	2011 (N = 205)		2012 (N =279)		2013 (N = 348)		
	Average	Percent	Average	Percent	Average	Percent	Weight (g)
1+	158.17	25.85%	158.60	52.69%	156.96	39.66%	39.76
2+	180.14	67.32%	171.70	46.59%	176.97	59.48%	56.69
3+	189.86	6.83%	206.50	0.72%	189.00	0.86%	78.8
Season	175.12		166.1		169.28		

Chum

The total estimated catch of unmarked chum fry ($\hat{u}=78,937$) included 69,365 captures in the trap and 9,572 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between January 29 and July 8, 2013. Captured chum could not be separated by natural and hatchery origin because chum released from Keta Creek hatchery were unmarked. No production estimate was calculated.

Other Species

In addition to species and age classes described above, catch during the trapping season included 10,883 coho fry, 369 trout parr, 33 cutthroat smolts, and 83 sockeye fry (Appendix D). Non-salmonid species captured included sculpin (*Cottus* spp.), three-spine sticklebacks (*Gasterosteus aculeatus*), longnose dace (*Rhynchichthys cataractae*), and lamprey ammocoetes.

Discussion and Synthesis

This report provides the freshwater production estimates for Chinook (sub yearling) and coho salmon and steelhead emigrating from the Green River in 2013. Only one yearling Chinook smolt was 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 of 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.

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 live box.

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 2013, attempts were made to evaluate size bias of yearling smolts (coho and 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 2013

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 recaptured sub yearling Chinook were encountered within a one day following release, indicating they were in process of a downstream migration. Redistribution of yearling fish is more likely than redistribution of sub yearling 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 late April when the majority of the coho and steelhead are fully smolted and in the traditional time period for peak migration. In 2013, 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 small number 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 vs. 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. In both these years we found no difference in the recovery rates between these two locations. In 2013, we conducted seven sequential releases between late February and mid-May of marked (Bismarck Brown and Caudle fin clipped) sub yearling Chinook from both sites. We compared adjacent releases from the two locations using a *G*-test and found no difference between the two sites in 5 of the seven releases. In the two of the seven releases, we found a difference in the recapture rate between sites, but there was no consistent pattern, with each site having a higher efficiency in one of the two tests. 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.

In 2013, both release locations were used for coho and steelhead smolts. Efficiency releases for both species started in late April and continued until maiden catch numbers became too low to perform these tests. Releases were conducted starting at the original location and was changed to the Neely bridge location in mid-May because low flow conditions changed the original release site and reduced the amount of mixing and dispersal. No comparison was made between these two sites.

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 mark detection should also have been high given the highly trained staff performing both the marking procedure and collecting the recapture data. The two technicians operating the trap in 2013 have 18 years of combined experience.

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 relative proportion of spawners estimated above and below the Green River juvenile trap is accurate. Redd surveys in 2012 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 above and below the trap. The juvenile production estimated from the main stem Green River below the trap was relatively small (approximately 5%) compared to that directly measured from the Green River and tributaries above the trap plus Big Soos Creek.

In previous years, to estimate production from Big Soos Creek, we had applied egg-to-migrant survival measured at the mainstem trap to the estimated egg deposition above the hatchery rack or assumed production from the creek was at carry capacity. However, in 2013, Big Soos Creek production was directly measured by the Muckleshoot Indian Tribe, substantially improving the quality of the basin-wide Chinook 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 and by the long-term consistency of trained field staff.

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 2013 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 2013, this bias was anticipated to be minimal. Prior to release a trained technician from the WDFW coded-wire tag lab sampled 2000 sub yearling hatchery Chinook from the Palmer rearing pond and identified one Chinook that was not marked. A total of 369 ad-marked sub yearling Chinook were caught, assuming that the proportion of unmarked Chinook was .05% (2013 mark rate at Palmer = 99.95%), this means that .05% ($n = 3$) of the 6181 unmarked sub yearling Chinook caught between April 4 (the first day hatchery ad-marked Chinook were captured) and July 15 were of hatchery origin.

Freshwater Production of Chinook Salmon

The 2013 freshwater production estimate of 492,737 sub yearling Chinook was the third highest observed above the trap since juvenile monitoring began (range = 56,000 to 810,000, (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 8), as the freshwater productivity (9.72% egg-to-migrant survival and 437 juveniles/female) was the second highest observed over fourteen years of study. Freshwater productivity results should be interpreted with caution until issues surrounding the different escapement estimation methodologies (redd count and Genetic mark recapture) have been resolved (see discussion above).

Parr migrants were approximately 28% of the freshwater production above the Green River trap in 2013 (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 fourteen years of study. In comparison, fry production, which represents juveniles emigrating from freshwater soon after emergence, has ranged 74-fold (6,000 to 413,000 fry). Thus, there is much greater fluctuation in fry abundance than parr abundance.

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 2000-2013.

Migration Year	Abundance				Fork Length		Migration Timing
	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
2013	492,737	420,077	565,397	6.28	48.1	14.41	3/21

Table 9. Abundance of natural-origin fry and parr subyearling migrants of Green River Chinook, migration year 2000 to 2013.

Trap Year	Fry Migrants			Parr Migrants		
	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%
2013	1/23-6/02	357,952	72.45%	1/23-7/14	134,785	27.55%

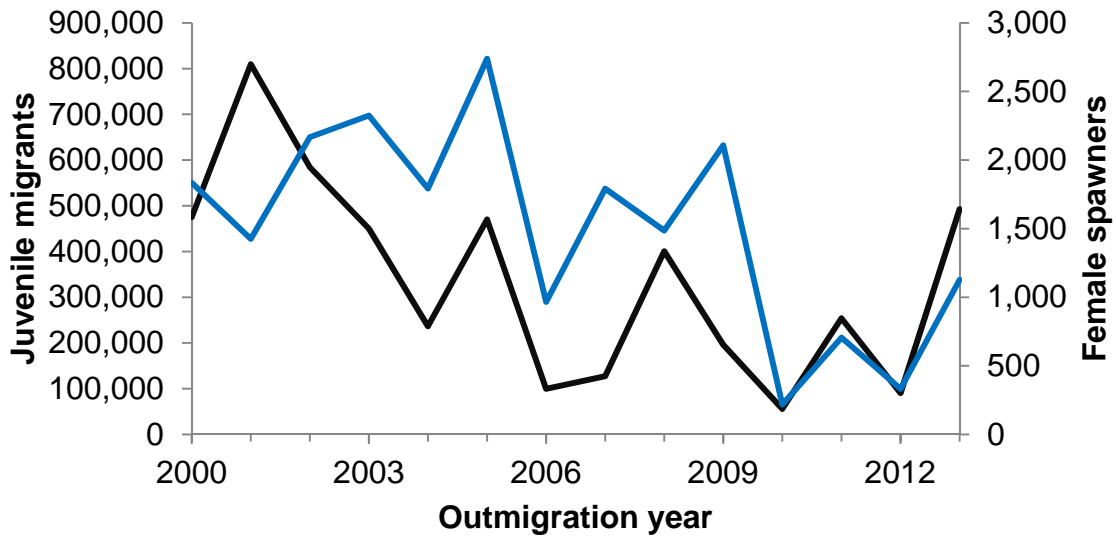


Figure 8. Number of sub yearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (blue line) above the juvenile trap, outmigration year 2000-2013.

Freshwater Production of Coho Salmon

Freshwater production of coho above the Green River trap has been estimated for 11 of the 14 years of this study (Table 10). The 2013 freshwater production estimate of 50,642 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 2013 an abundance estimate was made, however with just 21 recoveries the precision of this estimate was low.

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). In general, larger body size of yearling migrants compared to sub yearling migrants increases swimming strength and ability to avoid the trap. Slow water velocity at the trap location tends to reduce trap efficiency for yearling smolts, resulting in few recaptures of marked coho and steelhead smolts and low precision in our abundance estimates. The degree to which water velocity has limited catch 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 (i.e., not fished) or is operated intermittently during the hatchery migration. Any periods of trap outages due to inundation by hatchery fish requires an estimate of missed catch, which increases the variance and reduces the precision of the annual abundance estimate. Catch of natural-origin smolts often increases during the hatchery fish migration, presumably because the natural-origin fish are following the hatchery fish out of the system. This can result in high numbers of missed catch of coho and steelhead estimated during the outage period. This was not the case in 2013, with only 6% of the natural origin coho and 6% of the natural origin steelhead catch were estimated missed catch during outages. The percentages of missed catch was held to a low level 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 2000-2013.

Migration Year	Abundance				Fork Length		Migration Timing
	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
2013	50,642	30,000	71,284	20.8%	103.5	16.75	5/9

^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 3 of the 14 years of this study. The 2013 freshwater production estimate of 15,339 was much lower than the previous low production estimate of 26,000 in 2009. The 2013 production estimate was derived directly from release and recaptures of maiden caught natural-origin steelhead. With the recapture of just 10 of the released fish the precision of this estimate is low. However we feel that this estimate is a good measure of the production of steelhead from above our trap. 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 have removed previous years' estimates from (Table 11).

In 2013, steelhead smolts captured in the trap were similar in length and age as we observed in 2011 and 2012. In 2013, we started collecting weight measurements in addition to the scale and length samples to get a measure of the relative condition and fitness of the migrants. The percentage of age-1 smolts in 2012 is higher than we observed in either 2011 or 2013 and 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 a large increase in the pink salmon population that has occurred in the Green. The 2012 smolts had access to millions of pink salmon eggs in the fall of 2011 and millions of juvenile pink salmon fry in the

spring of 2012. The smolt age difference could also be attributed to 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 or 2013. Although our monitoring protocols are designed to detect size selectivity, we have not been able to evaluate selectivity in 2012 and 2013 due to the lack of a suitable number 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 2000-2013.

Migration Year	Abundance				Fork Length		Timing
	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
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
2013	15,339	6,692	23,987	28.76%	169.1	17.73	5/11

^a Median catch date

Summary

In 2013, 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 2013 was higher than the average production of 338,000 sub-yearlings observed between 2000 and 2012.

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,

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

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

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

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

$E(\hat{u}_i)$ = 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, $Var(\hat{u}_i)$ 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,

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

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

$$E(\hat{U} | u) = \frac{u (M + 1)}{(m + 1)} \text{ and,}$$

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

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

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

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

Note that,

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

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

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

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

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

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

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

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

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

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

Appendix B

Daily catch and migration estimate for natural-origin, sub yearling Chinook in the Green River, 2013.

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, 2013. Migration estimate is based on daily catch adjusted by the trap efficiency for each pooled time stratum.

Date	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	Hours		Chinook Catch		Total	Migration	Ad-	Unmarked
	In	Out	Actual	Estimated			mrk	Yearling
1/1-1/23	Pre-Trapping		0	0	0	8406	0	0
1/24/2013	26.50	0.00	190	0	190	928	0	0
1/25/2013	23.50	0.00	124	0	124	606	0	0
1/26/2013	24.50	0.00	199	0	199	972	0	0
1/27/2013	23.50	0.00	69	0	69	337	0	0
1/28/2013	24.50	0.00	166	0	166	3,299	0	0
1/29/2013	24.00	0.00	259	0	259	5,147	0	0
1/30/2013	24.00	0.00	212	0	212	4,213	0	0
1/31/2013	24.00	0.00	347	0	347	6,895	0	0
2/1/2013	24.00	0.00	173	0	173	3,438	0	0
2/2/2013	24.00	0.00	42	0	42	835	0	0
2/3/2013	24.50	0.00	62	0	62	1,232	0	0
2/4/2013	24.00	0.00	71	0	71	628	0	0
2/5/2013	23.50	0.00	94	0	94	832	0	0
2/6/2013	24.00	0.00	106	0	106	938	0	0
2/7/2013	24.00	0.00	107	0	107	947	0	0
2/8/2013	24.00	0.00	107	0	107	947	0	0
2/9/2013	24.50	0.00	82	0	82	726	0	0
2/10/2013	24.00	0.00	68	0	68	602	0	0
2/11/2013	24.00	0.00	81	0	81	717	0	0
2/12/2013	23.50	0.00	97	0	97	859	0	0
2/13/2013	24.00	0.00	120	0	120	1,062	0	0
2/14/2013	24.00	0.00	131	0	131	1,159	0	0
2/15/2013	24.00	0.00	170	0	170	1,505	0	0
2/16/2013	25.00	0.00	227	0	227	2,009	0	0
2/17/2013	24.00	0.00	190	0	190	1,682	0	0
2/18/2013	24.00	0.00	203	0	203	1,797	0	0
2/19/2013	23.50	0.00	239	0	239	2,115	0	0
2/20/2013	24.00	0.00	356	0	356	3,151	0	0
2/21/2013	24.00	0.00	164	0	164	1,452	0	0
2/22/2013	24.00	0.00	151	0	151	1,336	0	0
2/23/2013	24.50	0.00	358	0	358	3,169	0	0
2/24/2013	24.00	0.00	402	0	402	3,558	0	0

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APPENDIX B.—continued.

Date	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	In	Out	Actual	Estimated	Total	Migration	Ad- mrk Fry	Unmarked Yearling
2/25/2013	24.00	0.00	189	0	189	2,399	0	0
2/26/2013	23.50	0.00	312	0	312	3,960	0	0
2/27/2013	24.00	0.00	290	0	290	3,681	0	0
2/28/2013	24.50	0.00	187	0	187	2,373	0	0
3/1/2013	24.25	0.00	650	0	650	8,250	0	0
3/2/2013	23.75	0.00	1250	0	1250	15,865	0	1
3/3/2013	24.00	0.00	1158	0	1158	14,697	0	0
3/4/2013	24.00	0.00	594	0	594	5,656	0	0
3/5/2013	23.50	0.00	238	0	238	2,266	0	0
3/6/2013	24.50	0.00	221	0	221	2,104	0	0
3/7/2013	24.00	0.00	479	0	479	4,561	0	0
3/8/2013	23.75	0.01	442	0	442	4,209	0	0
3/9/2013	24.25	0.00	263	0	263	2,504	0	0
3/10/2013	24.75	0.00	254	0	254	2,419	0	0
3/11/2013	24.25	0.00	188	0	188	5,318	0	0
3/12/2013	23.25	0.00	142	0	142	4,017	0	0
3/13/2013	24.00	0.00	163	0	163	4,611	0	0
3/14/2013	24.00	0.00	389	0	389	11,003	0	0
3/15/2013	24.00	0.00	656	0	656	18,555	0	0
3/16/2013	24.00	0.00	793	0	793	22,431	0	0
3/17/2013	24.75	0.00	412	0	412	11,654	0	0
3/18/2013	24.00	0.00	416	0	416	11,767	0	0
3/19/2013	23.25	0.00	285	0	285	8,061	0	0
3/20/2013	24.50	0.00	125	0	125	3,536	0	0
3/21/2013	23.75	0.00	253	0	253	7,156	0	0
3/22/2013	23.75	0.00	157	0	157	4,441	0	0
3/23/2013	25.00	0.00	43	0	43	1,216	0	0
3/24/2013	24.00	0.00	166	0	166	4,695	0	0
3/25/2013	24.00	0.00	157	0	157	4,441	0	0
3/26/2013	23.50	0.00	61	0	61	1,725	0	0
3/27/2013	23.50	0.00	35	0	35	990	0	0
3/28/2013	24.00	0.00	63	0	63	1,782	0	0
3/29/2013	24.00	0.00	93	0	93	2,631	0	0
3/30/2013	25.00	0.00	156	0	156	4,413	0	0
3/31/2013	24.00	0.00	90	0	90	2,546	0	0
4/1/2013	24.25	0.00	108	0	108	3,055	0	0
4/2/2013	23.75	0.00	436	0	436	12,333	0	0

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APPENDIX B.—continued.

Date	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	Hours		Chinook Catch		Migration	Ad-	Unmarked	
	In	Out	Actual	Estimated		mrk	Yearling	
4/3/2013	24.00	0.00	317	0	317	8,967	0	0
4/4/2013	24.00	0.00	160	0	160	4,526	0	0
4/5/2013	23.00	0.00	265	0	265	7,496	11	0
4/6/2013	6.22	17.78	35	192	227	6,393	6	0
4/7/2013	0.00	24.00		176	176	4,978	6	0
4/8/2013	0.00	24.00		176	176	4,978	6	0
4/9/2013	9.50	14.50	10	160	170	4,809	7	0
4/10/2013	25.00	0.00	114	0	114	3,225	3	0
4/11/2013	23.00	0.00	86	0	86	2,433	2	0
4/12/2013	24.00	0.00	128	0	128	3,621	2	0
4/13/2013	25.50	0.00	144	0	144	4,073	8	0
4/14/2013	24.00	0.00	102	0	102	2,885	2	0
4/15/2013	25.75	2.00	84	16	100	2,829	1	0
4/16/2013	18.48	2.27	20	14	34	962	2	0
4/17/2013	13.00	11.00	2	75	77	2,178	1	0
4/18/2013	13.00	11.00	1	75	76	2,150	0	0
4/19/2013	11.00	11.00	46	75	121	3,423	2	0
4/20/2013	10.50	14.00	18	96	114	3,196	1	0
4/21/2013	24.00	0.00	129	0	129	3,649	1	0
4/22/2013	24.00	0.00	81	0	81	4,543	0	0
4/23/2013	24.50	0.00	54	0	54	3,029	2	0
4/24/2013	25.00	0.00	61	0	61	3,422	9	0
4/25/2013	24.00	0.00	47	0	47	2,636	3	0
4/26/2013	24.00	0.00	29	0	29	1,627	2	0
4/27/2013	23.00	0.00	33	0	33	1,851	1	0
4/28/2013	24.50	0.00	51	0	51	2,861	1	0
4/29/2013	24.00	0.00	49	0	49	2,748	4	0
4/30/2013	24.75	0.00	234	0	234	13,125	1	0
5/1/2013	25.67	1.33	43	4	47	2,636	0	0
5/2/2013	22.25	3.75	17	5	22	1,234	0	0
5/3/2013	18.50	2.25	20	2	22	1,234	0	0
5/4/2013	0.00	24.00	0	115	115	6,450	1	0
5/5/2013	12.00	11.50	10	44	54	3,029	1	0
5/6/2013	24.50	0.00	189	0	189	4,340	1	0
5/7/2013	23.00	0.00	102	0	102	2,342	2	0
5/8/2013	25.00	0.00	93	0	93	2,136	3	0
5/9/2013	23.50	0.00	120	0	120	2,756	3	0

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APPENDIX B.—continued.

Date	Time Fished		Unmarked Sub-yearling				Estimated Catch	
	Hours		Chinook Catch			Ad-	Unmarked	
	In	Out	Actual	Estimated	Total	Migration	mrk Fry	Yearling
5/10/2013	25.00	0.00	94	0	94	2,158	6	0
5/11/2013	23.50	0.00	91	0	91	2,090	7	0
5/12/2013	24.00	0.00	67	0	67	1,538	3	0
5/13/2013	21.50	0.00	58	0	58	1,332	1	0
5/14/2013	26.25	0.00	109	0	109	2,503	2	0
5/15/2013	24.25	0.00	31	0	31	712	1	0
5/16/2013	24.00	0.00	29	0	29	666	0	0
5/17/2013	24.00	0.00	19	0	19	436	1	0
5/18/2013	24.00	0.00	38	0	38	873	0	0
5/19/2013	24.00	0.00	39	0	39	896	1	0
5/20/2013	24.00	0.00	28	0	28	643	0	0
5/21/2013	23.50	0.00	8	0	8	184	0	0
5/22/2013	24.50	0.00	22	0	22	505	2	0
5/23/2013	24.50	0.00	39	0	39	896	2	0
5/24/2013	23.50	0.00	91	0	91	2,090	13	0
5/25/2013	24.17	0.00	95	0	95	2,181	1	0
5/26/2013	23.83	0.00	9	0	9	207	0	0
5/27/2013	24.00	0.00	44	0	44	1,010	0	0
5/28/2013	23.50	0.00	445	0	445	10,218	7	0
5/29/2013	24.50	0.00	209	0	209	4,799	4	0
5/30/2013	23.50	0.00	116	0	116	2,664	2	0
5/31/2013	24.00	0.00	78	0	78	1,791	3	0
6/1/2013	24.50	0.00	52	0	52	1,194	4	0
6/2/2013	24.00	0.00	24	0	24	551	8	0
6/3/2013	24.00	0.00	51	0	51	1,171	2	0
6/4/2013	23.50	0.00	19	0	19	436	6	0
6/5/2013	24.50	0.00	16	0	16	367	0	0
6/6/2013	24.50	0.00	7	0	7	161	4	0
6/7/2013	23.00	0.00	8	0	8	184	2	0
6/8/2013	24.50	0.00	12	0	12	276	3	0
6/9/2013	24.17	0.00	25	0	25	574	2	0
6/10/2013	24.08	0.00	15	0	15	135	0	0
6/11/2013	23.25	0.00	15	0	15	135	2	0
6/12/2013	25.00	0.00	20	0	20	180	3	0
6/13/2013	23.00	0.00	36	0	36	324	8	0
6/14/2013	20.00	0.00	15	0	15	135	1	0
6/15/2013	28.67	0.00	16	0	16	144	3	0

Table continued next page.

APPENDIX B.—continued.

Date	Time Fished		Unmarked Sub-yearling				Estimated Catch		
	Hours		Chinook Catch			Migration	Ad-	Unmarked	
	In	Out	Actual	Estimated	Total		mrk	Yearling	
6/16/2013	23.83	0.00	13	0	13	117	3	0	
6/17/2013	11.50	12.50	8	1	9	222	0	0	
6/18/2013	24.00	0.00	8	0	8	198	0	0	
6/19/2013	12.50	11.00	8	0	8	198	6	0	
6/20/2013	11.50	12.50	13	0	13	321	2	0	
6/21/2013	24.00	0.00	27	0	27	667	6	0	
6/22/2013	12.00	11.00	28	0	28	692	2	0	
6/23/2013	13.00	13.50	9	1	10	247	1	0	
6/24/2013	23.00	0.00	9	0	9	222	0	0	
6/25/2013	23.50	0.00	27	0	27	667	3	0	
6/26/2013	24.00	0.00	33	0	33	816	6	0	
6/27/2013	24.50	0.00	20	0	20	494	6	0	
6/28/2013	9.00	15.00	16	1	17	420	1	0	
6/29/2013	11.50	12.50	20	1	21	519	1	0	
6/30/2013	8.50	15.50	17	1	18	445	5	0	
7/1/2013	11.50	14.00	5	1	6	148	0	0	
7/2/2013	11.00	11.00	4	1	5	124	0	0	
7/3/2013	12.00	12.00	7	1	8	198	0	0	
7/4/2013	13.00	11.00	19	1	20	494	3	0	
7/5/2013	13.50	11.50	26	1	27	667	4	0	
7/6/2013	11.00	13.00	28	1	29	717	0	0	
7/7/2013	11.00	13.00	20	1	21	519	0	0	
7/8/2013	12.50	13.75	18	2	20	519	5	0	
7/9/2013	1.25	22.75	0	2	2	74	5	0	
7/10/2013	11.50	12.50	1	2	3	74	0	0	
7/11/2013	0.25	15.75	1	3	4	99	0	0	
7/12/2013	15.75	14.00	17	1	18	445	25	0	
7/13/2013	11.75	12.25	15	1	16	395	36	0	
7/14/2013	11.00	13.00	7	1	8	198	35	0	
7/15/2013	11.00	0.00	1	0	1	25	15	0	
7/16-7/31	Post -Trapping					1,853			
Total	3679.87	467.39	22,690	1,249	23,939	492,737	369	1	

Appendix C

Fork length of natural-origin, sub yearling Chinook in the Green River, 2013

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 2013.

Number	Statistical Week		Average	St.Dev.	Range		Number		Percent Sampled
	Begin	End			Min	Max	Sampled	Caught	
4	1/21/2013	1/27/2013	39.79	2.53	34	46	48	582	8.25%
5	1/28/2013	2/3/2013	39.45	2.05	34	44	107	1,261	8.49%
6	2/4/2013	2/10/2013	39.79	1.93	37	44	48	635	7.56%
7	2/11/2013	2/17/2013	39.33	2.25	35	44	64	1,016	6.30%
8	2/18/2013	2/24/2013	39.95	2.83	35	48	78	1,873	4.16%
9	2/25/2013	3/3/2013	40.24	2.98	36	50	99	4,036	2.45%
10	3/4/2013	3/10/2013	40.73	2.97	35	51	99	2,491	3.97%
11	3/11/2013	3/17/2013	40.93	3.09	36	50	90	2,743	3.28%
12	3/18/2013	3/24/2013	41.76	4.03	37	55	74	1,445	5.12%
13	3/25/2013	3/31/2013	42.94	5.44	37	60	54	655	8.24%
14	4/1/2013	4/7/2013	42.80	6.25	36	66	56	1,321	4.24%
15	4/8/2013	4/14/2013	42.45	4.79	35	60	56	584	9.59%
16	4/15/2013	4/21/2013	45.45	6.13	37	56	20	300	6.67%
17	4/22/2013	4/28/2013	46.83	7.74	38	71	42	356	11.80%
18	4/29/2013	5/5/2013	49.05	8.05	38	72	43	373	11.53%
19	5/6/2013	5/12/2013	54.64	11.25	37	85	78	756	10.32%
20	5/13/2013	5/19/2013	59.02	13.44	38	89	41	323	12.69%
21	5/20/2013	5/26/2013	61.16	14.01	39	91	37	292	12.67%
22	5/27/2013	6/2/2013	64.67	14.24	40	92	61	968	6.30%
23	6/3/2013	6/9/2013	71.32	15.76	46	92	31	138	22.46%
24	6/10/2013	6/16/2013	71.94	12.75	50	97	33	130	25.38%
25	6/17/2013	6/23/2013	75.94	15.13	50	105	16	101	15.84%
26	6/24/2013	6/30/2013	81.63	15.70	47	112	24	142	16.90%
27	7/1/2013	7/7/2013	77.83	15.44	55	110	24	109	22.02%
28	7/8/2013	7/15/2013	82.06	11.86	58	105	17	60	28.33%
Season Total			48.10	14.41	34	112	1,340	22,690	5.91%

Appendix D

Daily catch of coho ,sockeye and chum salmon, steelhead and cutthroat trout in the
Green River, 2013

APPENDIX D.—Daily catches of coho and chum salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2013. 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	Sockeye Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat
1/24/13	26.50	0.00	5	0	0	0	0	0	0	1
1/25/13	23.50	0.00	0	0	0	0	0	0	0	4
1/26/13	24.50	0.00	2	0	0	0	0	0	1	3
1/27/13	23.50	0.00	2	0	0	0	0	0	0	3
1/28/13	24.50	0.00	1	0	0	0	0	0	0	1
1/29/13	24.00	0.00	1	1	1	0	1	0	0	2
1/30/13	24.00	0.00	1	1	0	0	3	0	1	10
1/31/13	24.00	0.00	5	0	3	0	0	0	0	9
2/1/13	24.00	0.00	6	0	0	0	1	0	1	6
2/2/13	24.00	0.00	7	0	0	0	1	0	0	6
2/3/13	24.50	0.00	5	0	1	0	0	0	0	5
2/4/13	24.00	0.00	8	0	2	0	0	0	1	7
2/5/13	23.50	0.00	4	0	2	0	0	0	1	5
2/6/13	24.00	0.00	4	0	0	0	0	0	0	4
2/7/13	24.00	0.00	2	0	2	0	1	0	0	1
2/8/13	24.00	0.00	0	0	3	0	0	1	0	1
2/9/13	24.50	0.00	1	0	8	0	0	0	0	3
2/10/13	24.00	0.00	0	0	23	0	0	0	0	3
2/11/13	24.00	0.00	2	0	21	0	0	0	0	0
2/12/13	23.50	0.00	3	0	15	1	0	0	0	1
2/13/13	24.00	0.00	7	0	23	0	0	0	1	3
2/14/13	24.00	0.00	0	0	27	0	0	0	0	2
2/15/13	24.00	0.00	1	0	25	0	0	0	0	1
2/16/13	25.00	0.00	0	0	20	0	0	0	0	1
2/17/13	24.00	0.00	0	0	54	6	0	0	0	0
2/18/13	24.00	0.00	0	0	58	7	0	0	0	2
2/19/13	23.50	0.00	0	0	7	0	0	0	0	0
2/20/13	24.00	0.00	1	0	10	1	0	0	0	3
2/21/13	24.00	0.00	0	0	16	3	0	0	0	0
2/22/13	24.00	0.00	1	0	27	0	0	0	0	2
2/23/13	24.50	0.00	2	0	517	2	0	0	0	1
2/24/13	24.00	0.00	1	0	1,479	4	0	0	0	0
2/25/13	24.00	0.00	4	0	242	1	0	0	0	4
2/26/13	23.50	0.00	1	0	844	1	0	0	0	0
2/27/13	24.00	0.00	3	0	3,624	0	0	0	0	0

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APPENDIX D.—continued.

Date	Times		Coho Smolts		Chum Fry Total	Sockeye Fry Nat	Steelhead Smolts		Cutthroat Smolt Nat	Trout Parr Nat
	In	Out	Nat	Hat			Nat	Hat		
2/28/13	24.50	0.00	0	0	2,574	0	0	0	0	0
3/1/13	24.25	0.00	3	0	2,290	1	0	0	1	3
3/2/13	23.75	0.00	3	0	826	0	0	0	0	4
3/3/13	24.00	0.00	2	0	371	0	0	0	0	4
3/4/13	24.00	0.00	4	1	191	0	0	0	0	0
3/5/13	23.50	0.00	9	0	115	0	0	1	0	4
3/6/13	24.50	0.00	3	0	219	0	0	0	0	1
3/7/13	24.00	0.00	3	0	4,821	0	0	0	0	1
3/8/13	23.75	0.01	2	0	2,160	0	0	0	0	1
3/9/13	24.25	0.00	4	1	293	0	0	0	0	1
3/10/13	24.75	0.00	4	0	368	0	0	0	0	2
3/11/13	24.25	0.00	6	0	507	0	0	0	0	0
3/12/13	23.25	0.00	1	0	644	17	0	0	0	1
3/13/13	24.00	0.00	0	0	933	12	0	0	0	0
3/14/13	24.00	0.00	0	0	507	1	1	0	0	4
3/15/13	24.00	0.00	0	0	2,013	3	0	0	0	6
3/16/13	24.00	0.00	7	0	3,264	0	1	0	1	4
3/17/13	24.75	0.00	5	0	1,970	0	0	0	0	2
3/18/13	24.00	0.00	6	0	609	0	0	0	0	4
3/19/13	23.25	0.00	3	0	643	0	0	0	0	2
3/20/13	24.50	0.00	2	0	447	0	0	0	0	6
3/21/13	23.75	0.00	1	0	779	0	1	0	0	10
3/22/13	23.75	0.00	0	0	369	0	0	0	0	1
3/23/13	25.00	0.00	4	0	68	0	0	0	0	3
3/24/13	24.00	0.00	3	0	1,899	1	0	0	0	4
3/25/13	24.00	0.00	5	0	1,709	3	0	0	0	8
3/26/13	23.50	0.00	1	0	569	2	0	0	0	4
3/27/13	23.50	0.00	2	0	743	0	0	0	0	4
3/28/13	24.00	0.00	0	0	1,338	0	0	0	0	3
3/29/13	24.00	0.00	0	0	1,225	0	1	0	2	4
3/30/13	25.00	0.00	1	0	1,262	1	0	0	1	5
3/31/13	24.00	0.00	1	0	762	6	0	0	0	6
4/1/13	24.25	0.00	0	0	848	2	1	0	0	5
4/2/13	23.75	0.00	5	0	3,251	1	3	0	0	21
4/3/13	24.00	0.00	3	0	3,276	2	0	0	0	12
4/4/13	24.00	0.00	0	0	1,132	3	1	0	0	7
4/5/13	23.00	0.00	2	0	2,855	0	2	1	0	7
4/6/13	6.22	17.78	1	0	2,031	1	2	0	0	7

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APPENDIX D.—continued.

Date	Times		Coho Smolts		Chum Fry Total	Sockeye Fry Nat	Steelhead Smolts		Cutthroat Smolt Nat	Trout Parr Nat
	In	Out	Nat	Hat			Nat	Hat		
4/7/13	0.00	24.00	1	0	1,870	0	1	0	0	5
4/8/13	0.00	24.00	1	0	1,870	0	1	0	0	5
4/9/13	9.50	14.50	1	0	1,731	0	1	0	0	5
4/10/13	25.00	0.00	1	0	1,226	0	0	0	0	3
4/11/13	23.00	0.00	1	0	743	0	9	0	0	6
4/12/13	24.00	0.00	2	0	1,042	0	4	0	0	9
4/13/13	25.50	0.00	1	0	883	0	5	0	2	2
4/14/13	24.00	0.00	2	0	670	2	2	0	0	4
4/15/13	25.75	2.00	2	0	1,334	0	3	58	3	5
4/16/13	18.48	2.27	0	0	285	0	0	98	2	0
4/17/13	13.00	11.00	4	0	465	0	1	2	0	2
4/18/13	13.00	11.00	2	0	619	0	1	2	0	2
4/19/13	11.00	11.00	2	0	1,747	0	1	4	0	2
4/20/13	10.50	14.00	3	1	793	0	2	4	0	3
4/21/13	24.00	0.00	4	0	285	0	2	5	0	2
4/22/13	24.00	0.00	3	0	420	0	2	3	0	0
4/23/13	24.50	0.00	18	0	633	0	11	4	1	0
4/24/13	25.00	0.00	34	0	889	0	15	15	0	3
4/25/13	24.00	0.00	0	0	522	0	4	7	0	0
4/26/13	24.00	0.00	8	0	488	0	4	5	0	1
4/27/13	23.00	0.00	25	0	271	0	0	4	0	7
4/28/13	24.50	0.00	10	0	160	0	9	18	0	6
4/29/13	24.00	0.00	5	0	522	0	4	5	0	4
4/30/13	24.75	0.00	6	0	229	0	5	5	1	2
5/1/13	25.67	1.33	38	244	113	0	2	17	0	4
5/2/13	22.25	3.75	17	582	133	0	1	5	0	6
5/3/13	18.50	2.25	19	478	81	0	0	2	0	2
5/4/13	0.00	24.00	47	308	84	0	15	10	0	7
5/5/13	12.00	11.50	15	268	69	0	4	6	2	3
5/6/13	24.50	0.00	45	298	143	0	16	12	1	7
5/7/13	23.00	0.00	61	428	55	0	21	10	0	8
5/8/13	25.00	0.00	48	319	60	0	11	14	2	3
5/9/13	23.50	0.00	33	191	42	0	17	12	3	4
5/10/13	25.00	0.00	48	213	40	0	21	12	2	3
5/11/13	23.50	0.00	47	135	46	0	33	9	0	5
5/12/13	24.00	0.00	67	113	29	0	18	3	1	3
5/13/13	21.50	0.00	26	83	5	0	12	7	0	2
5/14/13	26.25	0.00	55	105	24	0	8	3	1	3

Table continued next page

APPENDIX D.—continued.

Date	Times		Coho		Chum	Sockeye	Steelhead		Cutthroat	Trout
	In	Out	Smolts		Fry	Fry	Smolts		Smolt	Parr
			Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat
5/15/13	24.25	0.00	8	18	17	0	4	1	0	1
5/16/13	24.00	0.00	7	22	31	0	2	2	0	0
5/17/13	24.00	0.00	10	12	28	0	1	2	0	0
5/18/13	24.00	0.00	22	26	29	0	1	1	1	0
5/19/13	24.00	0.00	32	22	27	0	10	2	0	2
5/20/13	24.00	0.00	27	8	10	0	20	3	0	0
5/21/13	23.50	0.00	11	10	28	0	0	4	0	0
5/22/13	24.50	0.00	12	9	885	0	2	1	0	1
5/23/13	24.50	0.00	32	15	174	0	8	7	1	2
5/24/13	23.50	0.00	20	10	62	0	5	4	0	1
5/25/13	24.17	0.00	8	2	23	0	2	0	0	0
5/26/13	23.83	0.00	12	2	10	0	2	3	0	0
5/27/13	24.00	0.00	13	3	14	0	1	0	0	0
5/28/13	23.50	0.00	33	3	9	0	47	7	0	1
5/29/13	24.50	0.00	17	3	2	0	13	2	1	0
5/30/13	23.50	0.00	10	0	0	0	7	3	1	0
5/31/13	24.00	0.00	14	1	1	0	8	1	0	0
6/1/13	24.50	0.00	6	4	1	0	12	5	0	2
6/2/13	24.00	0.00	14	2	2	0	4	1	0	0
6/3/13	24.00	0.00	6	1	1	0	8	2	0	0
6/4/13	23.50	0.00	2	0	0	0	4	1	0	1
6/5/13	24.50	0.00	5	1	0	0	4	0	0	1
6/6/13	24.50	0.00	0	0	0	0	3	0	0	1
6/7/13	23.00	0.00	5	2	0	0	3	1	0	0
6/8/13	24.50	0.00	0	1	1	0	2	0	0	0
6/9/13	24.17	0.00	4	0	2	0	5	0	0	0
6/10/13	24.08	0.00	3	0	0	0	2	0	0	0
6/11/13	23.25	0.00	1	0	2	0	2	1	0	0
6/12/13	25.00	0.00	1	0	1	0	0	2	0	0
6/13/13	23.00	0.00	1	0	2	0	2	2	0	0
6/14/13	20.00	0.00	1	1	4	0	0	0	0	0
6/15/13	28.67	0.00	0	0	1	0	0	0	0	0
6/16/13	23.83	0.00	0	0	0	0	0	1	0	0
6/17/13	11.50	12.50	2	0	0	0	0	0	0	0
6/18/13	24.00	0.00	2	0	4	0	0	0	0	0
6/19/13	12.50	11.00	0	0	0	0	0	0	0	0
6/20/13	11.50	12.50	0	0	1	0	0	0	0	0
6/21/13	24.00	0.00	2	0	1	0	0	0	0	0

Table continued next page

APPENDIX D.—continued.

Date	Times		Coho Smolts		Chum Fry	Sockeye Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Nat	Nat	Hat	Nat	Nat
	6/22/13	12.00	11.00	3	0	3	0	0	0	0
6/23/13	13.00	13.50	0	0	1	0	0	0	0	0
6/24/13	23.00	0.00	0	0	1	0	0	0	0	0
6/25/13	23.50	0.00	0	0	1	0	0	0	0	0
6/26/13	24.00	0.00	0	0	1	0	0	0	0	0
6/27/13	24.50	0.00	0	0	0	0	0	0	1	0
6/28/13	9.00	15.00	0	0	0	0	0	0	0	1
6/29/13	11.50	12.50	0	0	0	0	0	0	0	0
6/30/13	8.50	15.50	0	0	0	0	0	0	0	0
7/1/13	11.50	14.00	3	0	0	0	0	0	0	0
7/2/13	11.00	11.00	0	0	0	0	0	0	0	0
7/3/13	12.00	12.00	0	0	0	0	0	0	0	0
7/4/13	13.00	11.00	0	0	0	0	0	0	0	0
7/5/13	13.50	11.50	0	0	0	0	0	0	0	1
7/6/13	11.00	13.00	0	0	0	0	0	0	0	0
7/7/13	11.00	13.00	0	0	0	0	0	0	0	0
7/8/13	12.50	13.75	0	0	1	0	0	0	0	0
7/9/13	1.25	22.75	0	0	0	0	0	0	0	1
7/10/13	11.50	12.50	0	0	0	0	0	0	0	4
7/11/13	0.25	15.75	0	0	0	0	0	0	0	1
7/12/13	15.75	14.00	0	0	0	0	0	0	0	3
7/13/13	11.75	12.25	0	0	0	0	0	0	0	1
7/14/13	11.00	13.00	0	0	0	0	0	0	0	1
7/15/13	11.00	0.00	0	0	0	0	0	0	0	0
Total	3679.87	467.39	1,227	3,948	78,937	84	470	423	37	419

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2013

APPENDIX E.—Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2013.

Number	Statistical Week		Average	St.Dev.	Range		Number		Percent
	Begin	End			Min	Max	Sampled	Captured	Sampled
4	1/24/13	1/27/13	95.67	11.31	72	110	9	9	100.00%
5	1/28/13	2/3/13	90.41	10.66	72	105	17	26	65.38%
6	2/4/13	2/10/13	92.06	9.43	67	105	17	19	89.47%
7	2/11/13	2/17/13	88.83	5.53	78	94	6	13	46.15%
8	2/18/13	2/24/13	80.20	18.42	66	110	5	5	100.00%
9	2/25/13	3/3/13	96.17	14.80	68	115	12	16	75.00%
10	3/4/13	3/10/13	94.41	10.49	81	114	17	29	58.62%
11	3/11/13	3/17/13	89.73	11.18	78	112	11	19	57.89%
12	3/18/13	3/24/13	86.11	9.66	66	101	9	19	47.37%
13	3/25/13	3/31/13	95.50	9.83	87	114	6	10	60.00%
14	4/1/13	4/7/13	79.67	4.68	73	87	6	10	60.00%
15	4/8/13	4/14/13	105.43	7.21	95	113	7	7	100.00%
16	4/15/13	4/21/13	106.40	10.95	88	115	5	8	62.50%
17	4/22/13	4/28/13	115.79	8.44	100	138	19	98	19.39%
18	4/29/13	5/5/13	127.54	10.62	105	149	24	82	29.27%
19	5/6/13	5/12/13	112.92	16.76	86	174	36	349	10.32%
20	5/13/13	5/19/13	111.73	6.45	101	121	15	160	9.38%
21	5/20/13	5/26/13	109.13	7.90	93	121	15	122	12.30%
22	5/27/13	6/2/13	104.64	7.97	94	118	14	107	13.08%
23	6/3/13	6/9/13	108.00	7.07	103	113	2	22	9.09%
24	6/10/13	6/16/13	113.33	4.93	110	119	3	7	42.86%
25	6/17/13	6/23/13	103.50	14.85	93	114	2	9	22.22%
26	6/24/13	6/30/13					0	0	0.00%
27	7/1/13	7/7/13	No Samples				0	3	0.00%
28	7/8/13	7/14/13					0	0	0.00%
Season Total			103.53	16.75	66	174	257	1149	22.37%

Appendix F

Fork lengths of natural-origin steelhead smolts in the Green River, 2013

APPENDIX F.—Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin steelhead smolts in the Green River in 2013.

Number	Statistical Week		Average	St.Dev.	Range		Number		Percent Sampled
	Begin	End			Min	Max	Sampled	Captured	
4	1/24/13	1/27/13			No Samples				0
5	1/28/13	2/3/13	164.17	14.01	143	176	6	6	100.00%
6	2/4/13	2/10/13	142.00	na	142	142	1	1	100.00%
7	2/11/13	2/17/13							0
8	2/18/13	2/24/13			No Samples				0
9	2/25/13	3/3/13							0
10	3/4/13	3/10/13							0
11	3/11/13	3/17/13	185.00	9.90	178	192	2	2	100.00%
12	3/18/13	3/24/13	151.00	na	151	151	1	1	100.00%
13	3/25/13	3/31/13	142.00	na	142	142	1	1	100.00%
14	4/1/13	4/7/13	146.71	10.19	135	159	7	10	70.00%
15	4/8/13	4/14/13	168.45	15.09	138	197	20	22	90.91%
16	4/15/13	4/21/13	164.75	10.63	152	178	4	10	40.00%
17	4/22/13	4/28/13	173.93	18.18	142	221	45	45	100.00%
18	4/29/13	5/5/13	172.13	15.94	149	221	16	31	51.61%
19	5/6/13	5/12/13	169.52	17.80	128	225	137	137	100.00%
20	5/13/13	5/19/13	168.79	20.75	141	219	38	38	100.00%
21	5/20/13	5/26/13	166.13	17.46	139	205	39	39	100.00%
22	5/27/13	6/2/13	171.38	16.99	139	217	78	92	84.78%
23	6/3/13	6/9/13	166.46	17.03	140	200	28	29	96.55%
24	6/10/13	6/16/13	160.00	9.01	149	169	6	6	100.00%
25	6/17/13	6/23/13							0
26	6/24/13	6/30/13			No Samples				0
27	7/1/13	7/7/13							0
28	7/8/13	7/14/13							0
Season Total			169.07	17.73	128	225	429	470	96.55%

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