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Green River Juvenile Salmonid Production Evaluation: 2014 Annual Report

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Washington Department of Fish and Wildlife
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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 and Matt Pollack. 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 and Nathanael Overman, 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), the King County Flood Control District Cooperative Watershed Management Grant Program (WIRA 9), and Tacoma Water in 2014.

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Executive Summary

This report provides the 2014 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. 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 7, 2014. During this period, the trap fished 83% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (subyearling), coho, steelhead and pink. (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 2014. 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	7,384	396,623 (21.25%)	61.1 (± 18.7)	5-Mar
Chinook – Yrlg	6	---[a]	---	5-Apr [b]
Coho – Yrlg	3,049	106,365 (11.4%)	103.6 (± 14.0)	11-May
Steelhead – Smolt	1,279	31,638 (15.70%)	171.2 (±18.33)	5-May
Pink	239,150	14,396,053 (11.09%)	3.9 (± 1.6)	7-Mar
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 2014 outmigration (2013 brood) was estimated to be 11.39%, yielding a basin-wide production estimate of 520,406 juveniles. Included in this estimate was a preliminary estimate of 101,748 Chinook migrating from Big Soos Creek with a egg-to-migrant survival of 15.17%. 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 subyearlings. Outmigration timing of subyearling Chinook was bimodal. The fry (≤45 mm fork length) represented 80% of all subyearling migrants and peaked in early March, parr migrants (>45 mm fork length) represented 20% of the migration and peaked in early June.

Introduction

This report provides the 2014 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) (Crawford 2007, McElhaney et al. 2000). The Green River supports a demographically independent population of Chinook salmon (Ruckelhaus et al. 2006). Puget Sound steelhead were listed as *threatened* in May of 2007. Winter-run steelhead in the Green River were designated as a demographically independent population within the Central and South Sound Major Population Group (Myers et al. 2015).

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 , the trapping data will allow us to determine if production increases as fish recolonize of the approximately 106 miles of river and stream habitat above the dam. 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 2014 field season. In 2014, an additional objective was to provide wild steelhead smolts captured in the trap to the Puget Sound Marine Survival Project for acoustic tagging and release. The tagging project was aimed at evaluating early marine survival of migrating steelhead from the Green and Nisqually rivers.

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 2014, the trap operated between January 24 and July 7 for a total of 3,229 of 3,904 possible hours (83% of the time). Over the course of the season, trapping was suspended 26 times; the duration of outages ranged from 0.67 to 211 hours. Trapping was suspended two times for high water, three times for hatchery fish releases where the trap was spot fished throughout the night, 21 times mostly during day time periods late in the trapping season when catches were low and recreational use was high.

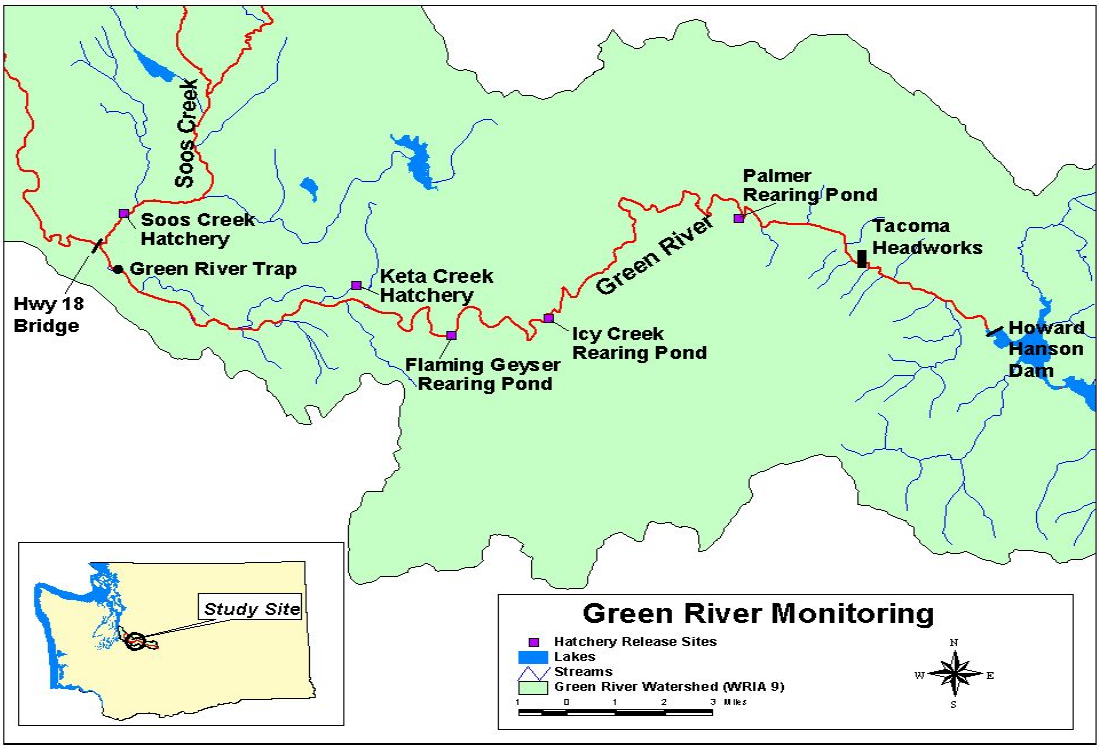

Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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. Subyearling Chinook were length sampled at a rate of approximately 16% and all six of the natural origin yearling Chinook captured were length

sampled. Scale and length samples were collected from 1,251 captured natural-origin steelhead smolts and weight samples were collected on 1,248.

Chinook were enumerated as subyearlings and yearlings. Based on previous years data yearling Chinook emigrate between February and April and range in size from 76 to 156 mm FL. Subyearling Chinook emigrate between January and July, range between 34 mm and 107 mm FL. Subyearlings are distinguished from yearling migrants by the body size and date of migration. During the time period that yearlings typically migrate, subyearling migrants average in size between 39 mm and 50 mm FL. For the purpose of analysis, subyearling 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 46 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 2014 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. A group of over one million unmarked subyearling hatchery Chinook were volitionally released from Palmer rearing ponds starting on July 8th after the screw trap finished fishing for the season. Because the fish were not externally marked differentiating them from the naturally produced Chinook would have been nearly impossible so the release was delayed to avoid this problem.

Table 2. Number of hatchery fish by mark type released above the Green River screw trap in 2014. 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	2013	Palmer Pond		215,931		809,174
Chinook – Yrlg	2012	Icy Creek			328,493	
Coho – Yrlg	2012	Keta Creek	50,404	894	547,094	1,306
Chum - Subyrlg	2013	Keta Creek				3,600,000
Summer steelhead	2013	Flaming Gyser			15,000	
Winter Steelhead	2013	Icy Creek			64,825	800
Winter Steelhead	2013	Icy Creek	0	30,050		

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 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. 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

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

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

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

(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 ($\alpha = 0.05$). 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

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

(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 subyearling Chinook strategies, the subyearling 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 subyearling 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, Nathanael Overman, 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.

Smolt to adult return rate for Chinook Salmon

In order to understand patterns of marine survival, we estimated smolt to adult return rate (SAR) for Green River Chinook salmon. This analysis required age data obtained from scale samples, escapement estimates and the hatchery mark rate among Chinook salmon spawning naturally in the Green River. Escapement and hatchery mark rate data were used to estimate the total number of naturally produced adult Chinook salmon returning to the area upstream of the smolt trap (river mile 34.5), including Newaukum Creek. Age data, restricted to samples collected from unmarked fish, were used to allocate adults from each return year to the corresponding brood year. The scale samples were collected from areas both upstream and downstream of the smolt trap, so our approach assumes a common age structure in both locations. For each outmigrant year class, total adult returns were calculated by summing the number of natural-origin adult Chinook salmon returning to the Green River upstream from the screw trap at age 3, 4, 5, 6. SAR was calculated by dividing the total number of natural-origin adult returns from all age classes by the total natural origin juvenile migration from above the trap site. Our metric of adult returns was based on escapement to the spawning grounds, and does not account for variation in harvest over the years of study. For comparison, the same approach was used to evaluate the hatchery Chinook stock returning to the Soos Creek Salmon hatchery with data queried from the Regional Mark Information System (RMIS).

Results

Subyearling Chinook

The total estimated catch of natural-origin Chinook ($\hat{u}$ = 9,517) included 7,384 captures in the trap and an estimated missed catch during trap outage periods of 2,133 (Table 3, Appendix B). In 2014 none of the hatchery origin Chinook fry released from Palmer Pond were adipose fin clipped (ad-marked), however approximately 20% were Coded Wire Tagged (CWT). The volitional release date was July 8th, after the screw trap finished trapping for the season. The outlet of Palmer Pond is fitted with a drum screen that is designed to prevent fish from escaping. However, the screen has not been properly maintained and allows some fish to escape. Shortly after the hatchery Chinook were transferred to Palmer Ponds in March, we began capturing subyearling Chinook that were larger (heavier) than the majority of the natural origin Chinook we had been capturing prior to that point, indicating that hatchery fish were escaping. Additional Chinook transfers to Palmer Ponds, this time with fish receiving CWT, occurred in May. In total we captured 28 unmarked CWTed hatchery subyearling Chinook that escaped from Palmer Pond. Expanding this catch by the tag rate of 21% estimates approximately 133 unmarked hatchery fish from Palmer Pond were captured. The technicians working the trap visually identified 420 unmarked untagged hatchery origin Chinook. We decided to use the visual identification catch number instead of the estimated number from CWT expansion because we captured 54 unmarked untagged hatchery fish between March and May prior to the date fish were given CWT and because of the years of experience of the Green River trap crew (Table 2).

A total of 52 efficiency trials, ranging between 15 and 308 fish, were conducted and used a total of 4,749 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. 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 14 groups prior to stratification. The *G*-test pooled the 14 groups into 6 strata, with trap efficiencies ranging between 1.5% and 11.2% (Table 3).

The trapping season of January 24 through July 7 encompassed the majority of the subyearling Chinook migration. A total of 392,085 subyearlings 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 4,030 Chinook were estimated to have migrated prior to the trapping season and 508 migrants were estimated following the trapping season. This extrapolation assumed migration began January 1 and ended July 31, 2014.

A total of 396,623 ± 165,387 (±95% C.I.) subyearling Chinook of natural origin were estimated to have migrated past the screw trap between January 1 and July 31, 2014. Coefficient of variation for this estimate was 21.25%.

Table 3. Catch, marked and recaptured fish, and estimated abundance of subyearling Chinook migrants at the Green River screw trap in 2014. Release groups were pooled to form ten strata. Missed catch and associated variance were estimated for periods that the trap did not fish.

		Catch					Abundance	
Strata	Date	Actual	Missed	Variance	Marked	Recaptured	Estimated	Variance
Before	1/1-1/24		166				4,030	6.39E+03
1	1/25-2/2	404			145	5	9,831	1.34E+07
2	2/3-2/9	139			182	20	1,211	6.80E+04
3	2/10-3/30	3,087	1,906	5.46E+04	810	12	311,486	7.06E+09
4	3/31-5/18	1,334	14	1.22E+00	1,268	51	32,896	2.03E+07
5	5/19-5/25	351			268	30	3,046	2.79E+05
6	5/26-7/7	2,069	213	1.30E+02	2,076	140	33,615	7.90E+06
After	7/8-7/31		35				508	6.40E+00
Season Total		7,384	2,333	5.47E+04	4,749	258	396,623	7.11E+09

Freshwater productivity of natural-origin Chinook for brood year 2013 was estimated to be 512 juveniles per female and 11.92% egg-to-migrant survival. This calculation was based on the number of subyearling Chinook passing the trap ($\hat{N}_T$ = 396,623), 774 female spawners above the trap site (personal communication, Aaron Bosworth, WDFW Region 4), and an estimated P.E.D above the trap site of 3,483,000 eggs.

Basin-wide abundance of subyearling natural-origin Chinook was estimated to be 520,406 juvenile migrants. This included 396,623 migrants from above the trap, 22,035 juveniles from the main stem below the trap and 101,748 (preliminary estimate) from Big Soos Creek. This estimate is approximately 120,000 fish below the average since 2000 but about 80,000 fish above the average over the last ten years. This production 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 inter-annual 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, 2013 and 2014 was Chinook production from Big Soos Creek measured directly.

An estimated 80% (319,241) of the Chinook migrated as fry and 20% (77,382) migrated as parr. The migration periods of fry and parr overlapped between mid- February and early May.

The median migration date for subyearling Chinook was on March 5 coinciding with the beginning of an extremely high flow event. 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 between February 17 and February 23 (95,857 fry migrants), and the largest peak occurred between March 3 and 9 (109,125 fry migrants). The first peak to

the parr migration occurred between May 12 and May 18 (~8,200 parr migrants), and the second peak occurred between May 26 and June 1 (~13,500 parr migrants).

The seasonal average length of subyearling Chinook was 61.1 ± 18.7 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the subyearling Chinook showed little increase (approximately 7 mm) during the early portion of the season, (January 24- April 27). Chinook subyearling body size increased substantially thru the end of trapping season (April 21-July 7), averaging 3.5 mm FL per week. The largest size increase occurred between April 28 and May 4 with an increase of 6.6-mm FL (Figure 3, Appendix C).

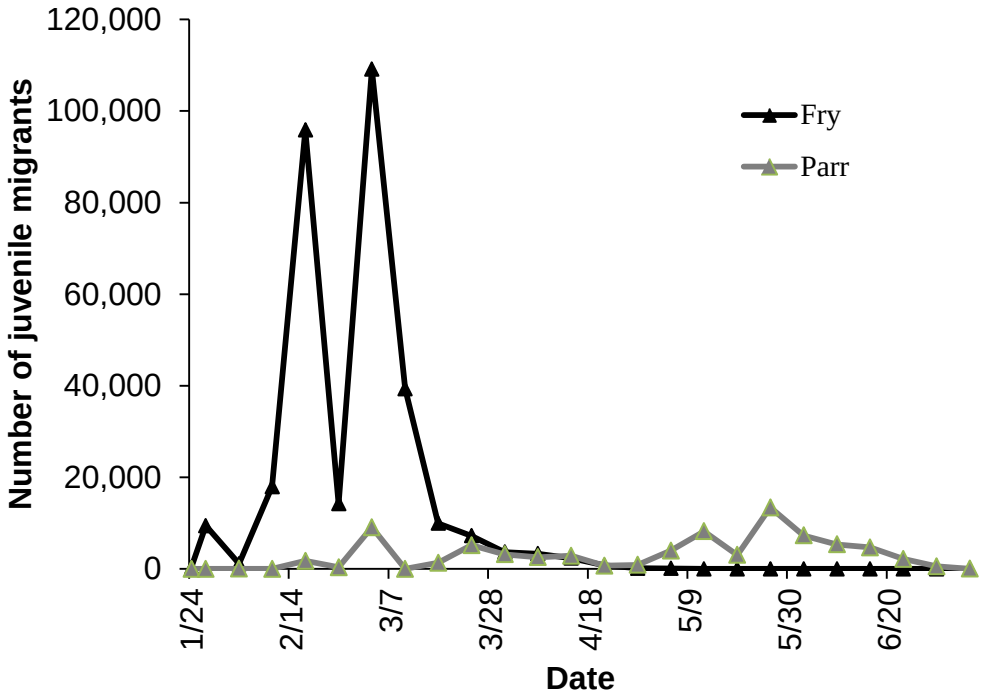

Figure 2. Weekly migration of sub- yearling Chinook migrants of natural-origin at the Green River screw trap in 2014. Subyearling migrants are partitioned into two freshwater rearing strategies fry (<45-mm FL) and parr (> 45-mm FL) migrants.

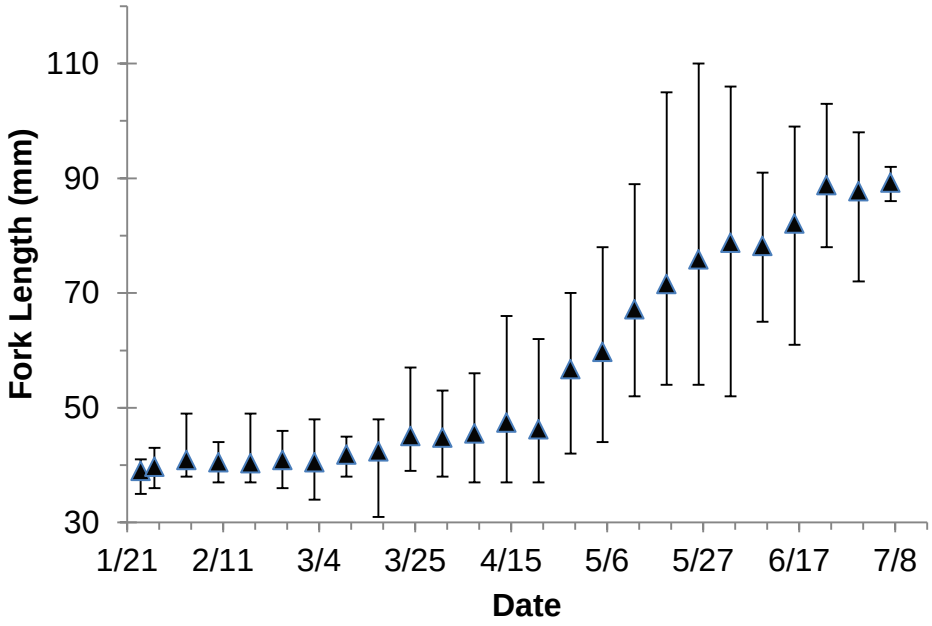

Figure 3. Fork length (mm) of subyearling Chinook migrants of natural origin captured in the Green River screw trap in 2014. Data are mean, minimum, and maximum values.

Table 4. Abundance of juvenile migrant Chinook (subyearling) 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	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	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
2013	2014	774	3,483,000	396,623	11.39%	43	193,500	22,035	149	670,500	101,748	520,406

Yearling Chinook

In total six natural-origin yearling Chinook were captured between February 16 and May 22 (Appendix B).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}$ =3,328) included 3,075 captures in the trap and an estimated missed catch during trap outage periods of 253 fish. Coho smolts were captured between January 24 and July 1 (Table 5, Appendix D). In total, 12,143 hatchery coho were captured between March 29 and June 19 (11,906 Ad-mark and 237 Ad-CWT). Thirty 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 3.09%.

We estimated a total of 106,365 ± 23,720 (95% C.I.) natural-origin coho smolts migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 11.38%.

Table 5. Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2014. 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	1/247/7	3,075	253	8.43E+02	2,428	75	106,365	1.46E+08

The median migration date for coho smolts was May 10. The first coho smolt was captured on January 24, 2014. Daily estimated migration of coho was low and averaged 146 smolts per day through April 21 (Figure 4). Peak daily migration occurred on May 14 when 5,337 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 natural-origin coho smolt was captured on June 30, 2014.

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).

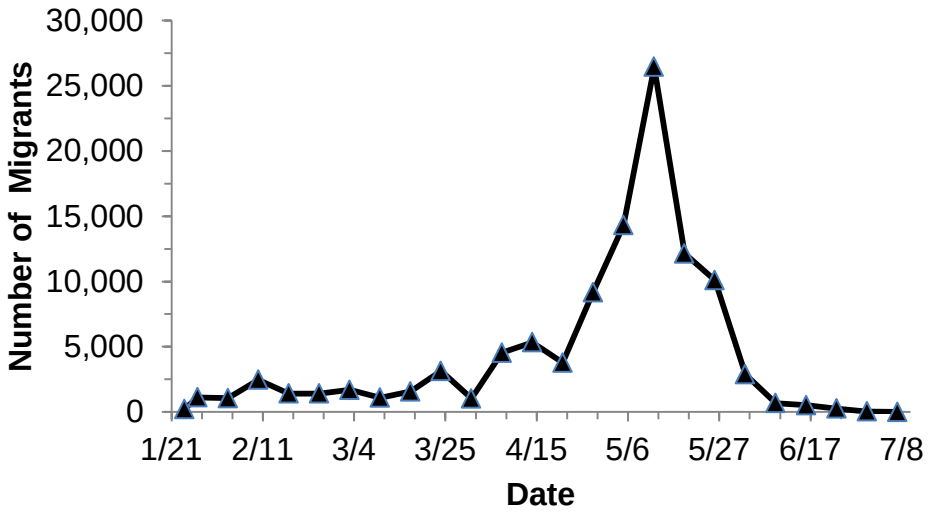

Figure 4. Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2014.

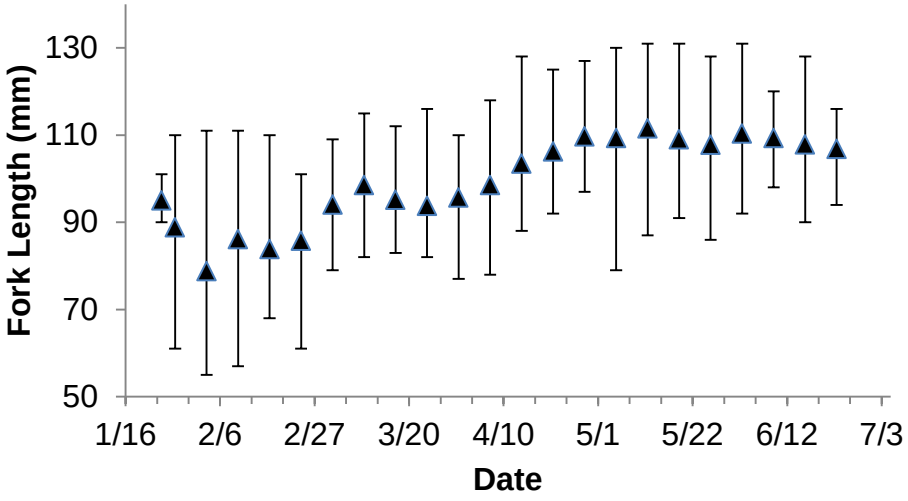

Figure 5. Fork lengths (mm) of natural-origin coho captured in the Green River screw trap in 2014. Data are mean, minimum, and maximum values by week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 1,371) included 1,279 captures in the trap and 92 missed catch estimated for trap outage periods (Table 6, Appendix D). In total, 2,154 hatchery steelhead were captured between March 22 and June 16 (1,519 Ad-mark, 634 CWT only and 1 Ad-CWT). Twenty seven 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 4.23%.

We estimated a total of 31,638 ± 9,737 (95% C.I.) natural-origin steelhead smolts migrated past the screw trap (Table 5). Coefficient of variation for this estimate was 15.7%.

Table 6. Catch, marked and recaptured fish, and estimated abundance of natural-origin steelhead smolts at the Green River screw trap in 2014. 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	1/25-7/7	1,279	92	1.09E+02	899	38	31,638	2.47E+07

The first steelhead was captured on January 28. Early in the trapping season, daily catch of steelhead was low with only 73 individuals caught through March 31. Peak catch occurred on the night of May 24, with 59 smolts captured. Daily catch declined thru middle June and the last natural-origin steelhead was captured on June 15 (Figure 6).

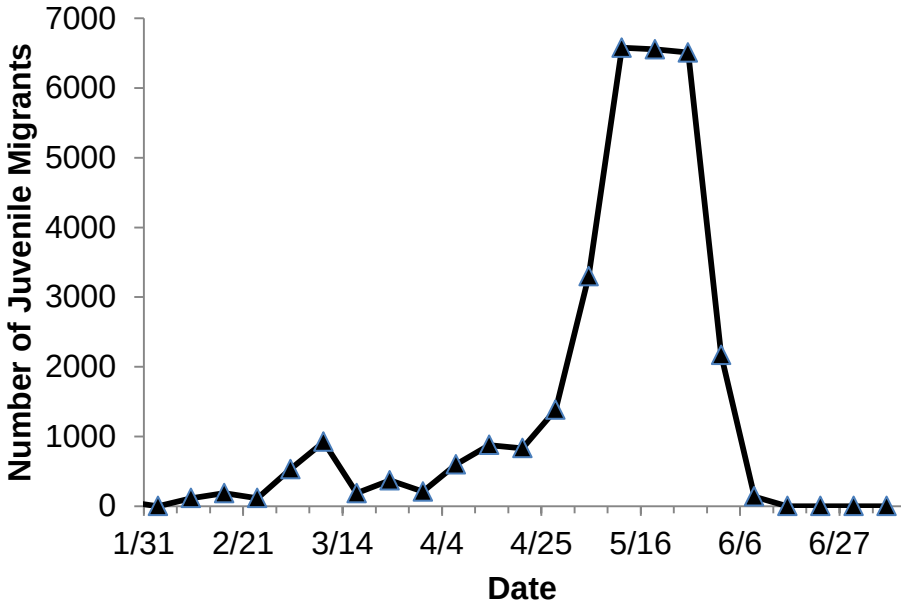

Figure 6. Weekly migration of natural-origin steelhead smolts captured in the Green River screw trap in 2014. Catch per week not adjusted for changes in trap efficiency, therefore represents an index of steelhead smolt migration timing.

The seasonal average length of natural-origin steelhead smolts was 171.2 ± 18.3 mm FL (± 1 S.D.; Appendix F, Figure 7).

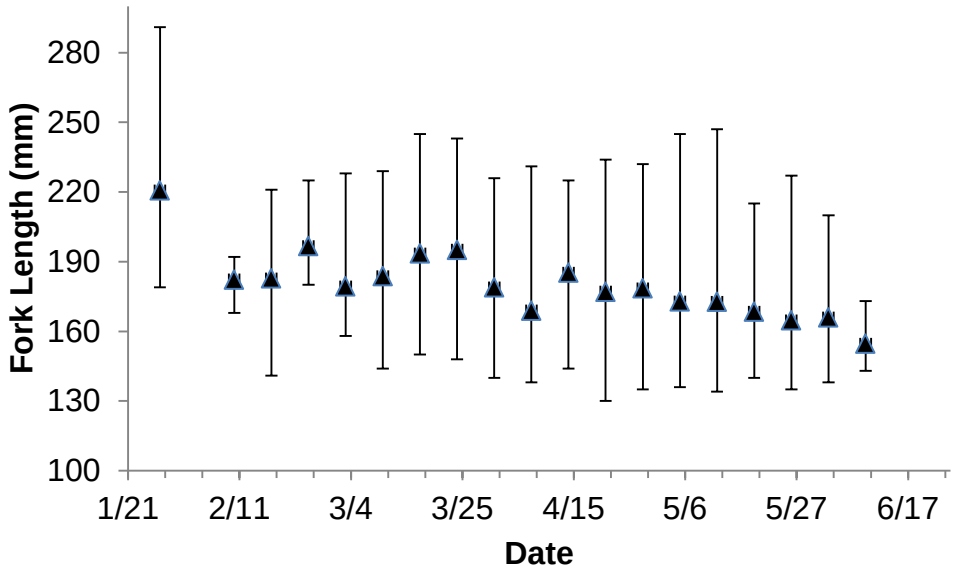

Figure 7. Fork lengths (mm) of natural-origin steelhead at the Green River screw trap in 2014. Data are mean, minimum, and maximum values by week.

Length and scale samples were collected on 1,251 of the 1,279 natural-origin steelhead smolts captured, and weights were collected on 1,248 to determine the age structure and body size of natural-origin steelhead smolts. The sample included 1007 readable and 244 regenerated or upside down samples. The age structure of Green River steelhead appears to oscillate with a majority of age-1 smolts in even years and a majority of age-2 smolts in odd years (Table 7). (Table 7).

Table 7. Age, average length and average weight of natural-origin steelhead smolts collected at the Green River juvenile trap, migration years 2011-2014.

Smolt	2011		2012		2013			2014		
Age	Length	Percent	Length	Percent	Length	Percent	Weight(g)	Length	Percent	Weight(g)
1+	158.17	25.85%	158.60	52.69%	156.96	39.66%	39.76	161.37	61.17%	27.91
2+	180.14	67.32%	171.70	46.59%	176.97	59.48%	56.69	182.17	37.24%	41.16
3+	189.86	6.83%	206.50	0.72%	189.00	0.86%	78.8	211.07	1.49%	59.71
4+								224.00	0.10%	101.30
Season	175.12		166.1		169.28			170.89		

A total of 133 wild steelhead smolts collected at the trap between 4/23 and 5/23 were provided to the Puget Sound Early Marine Survival Project. The study was designed to evaluate early marine survival of wild steelhead smolts migrating from river entering into Puget Sound. A total of 103 steelhead smolts received acoustic tags and were released, 53 into the Green River and 50 transferred to the Nisqually River. In addition 30 wild steelhead smolts were collected and sacrificed for fish heath analysis of pathogens.

Pink

The total estimated catch of wild pink fry ($\hat{u}$ =261,626) included 239,150 captures in the trap and 22,476 missed catch estimated for trap outage periods (Appendix D). Pink migrants were captured from the beginning of trapping until June 3, 2014. The daily catch steadily increased thru the early part of the season and peaked on the nights of April 13 and 14 with over 18,000 fry captured each night. Between March 24 and April 24 approximately 82% of the season total catch occurred.

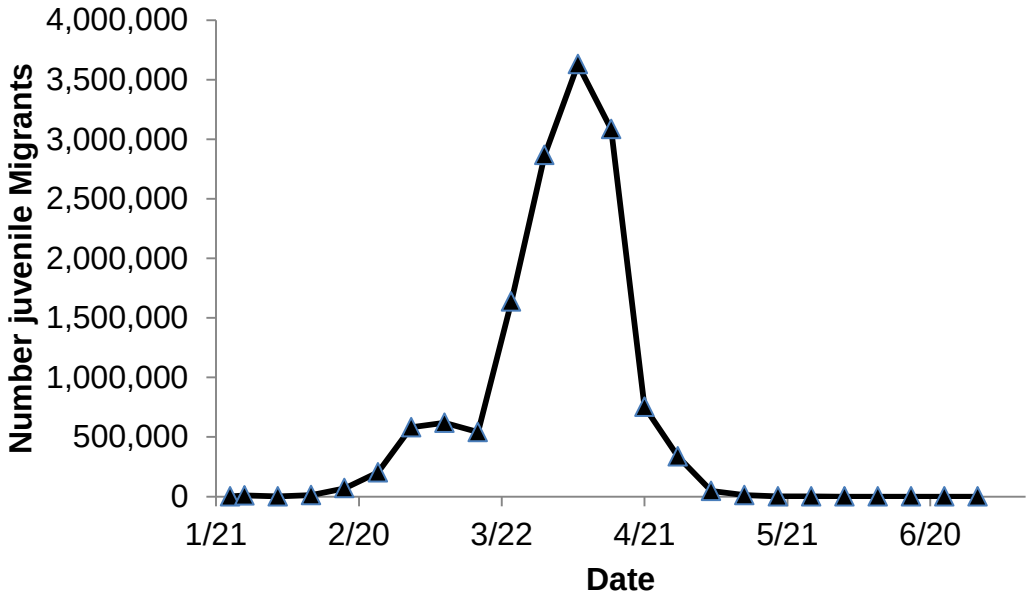

Figure 8. Weekly migration of pink fry originating from above the Green River screw trap in 2014. Data are number of juvenile migrants by week.

Twenty three trap efficiency trials were conducted using pink fry. All the efficiency trials were pooled to form a single strata with a trapping efficiency of 1.8%. We estimated a total of 14,396,053 ± 3,129,781 (95% C.I.) pink fry. Coefficient of variation for this estimate was 15.7%.

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$ =35,869) included 37,671 captures in the trap and 1,802 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between February 2 and June 26, 2014. 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 262 coho fry, 678 trout parr, 33 cutthroat smolts and 6 cutthroat adults. (Appendix D). Non-salmonid species captured included Eulachon (*Thaleichthys pacificus*), 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 (subyearling) coho and pink salmon and steelhead emigrating from the Green River in 2014. Only six natural origin 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 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 2013 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 2014, 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 in 2014 none of the 1,025,105 Chinook released from Palmer were ad-marked (809,174 no mark, 215,931 CWT only). The Palmer facility was not fish tight when the fish were transferred there and we began capturing unmarked hatchery fish that were escaping from the facility in mid-March. The hatchery fish were identified and assigned based on their larger size and rounder body shape.

Freshwater Production of Chinook Salmon

The 2014 freshwater production estimate of 396,623 subyearling Chinook was slightly higher than the 343,000 fish average production over all 15 years of this project (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 (11.39% egg-to-migrant survival and 512 juveniles/female) was the second highest observed over fifteen years of study. During the fifteen years of juvenile monitoring, several different methodologies have been used to estimate adult escapement. Results from the three years of the GMR study showed that the GMR method of estimating adult spawner abundance above the trap site is 2,500 fish higher than the redd based estimate (Seamons 2012). If the GMR estimates are correct this would reduce the egg to migrant survival and production per female estimates that have been produced using the redd based estimates.

Parr migrants were approximately 20% of the freshwater production above the Green River trap, which is the second lowest percentage of parr observed in the fifteen years of this study (Table 9). Parr production, which represents fish that have spent some time rearing in freshwater above the Green River trap, has ranged 11-fold (37,000 to 430,000 parr) over fifteen 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.

Smolt to adult return rate of Chinook Salmon

Estimating the survival from juvenile outmigration to return as adults will aid recovery efforts by providing information on population dynamics. SAR ranged 10-fold (0.14% and 1.5%) for brood years 2002 through 2009 (Table 10). Natural origin juveniles survived at a higher rate five out of ten years than hatchery origin non-ad marked CWT juveniles released from Soos Creek Hatchery (Figure 10). As data accumulate in future years, we will continue to explore this pattern and the mechanisms the influence SAR rates for both hatchery and natural origin Chinook.

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 2000-2014.

	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
2013	492,737	420,077	565,397	6.28	48.1	14.41	3/21
2014	396,623	231,236	562,010	21.25%	61.1	18.66	3/05

Table 9. Abundance of natural-origin fry and parr subyearling migrants of Green River Chinook, migration year 2000 to 2014.

	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	44.81%	2/27-7/31	48,127	55.19%
2013	1/01-6/02	357,952	72.45%	2/18-7/31	134,785	27.55%
2014	1/01-5/11	319,241	80.49%	2/3-7/31	77,382	19.51%

Table 10 Smolt to adult return (SAR) for adult Chinook in the Green River, brood year 2002-2009. Juvenile freshwater production and adult return estimates restricted to the area upstream from the smolt trap. Does not include age 2 (jack) returns.

	Juvenile	Adults					
Brood Year	Freshwater Production	Age 3	Age 4	Age 5	Age 6	Total	Survival at Return
2002	449,956	314	1,341	95	0	1,750	0.39%
2003	236,650	573	718	67	0	1,358	0.57%
2004	470,334	702	3,025	0	0	3,727	0.79%
2005	99,796	152	77	63	0	292	0.29%
2006	127,491	52	633	4	0	689	0.54%
2007	400,763	151	309	107	0	567	0.14%
2008	196,118	57	978	40	0	1,075	0.55%
2009	55,547	408	394	42	0	844	1.52%

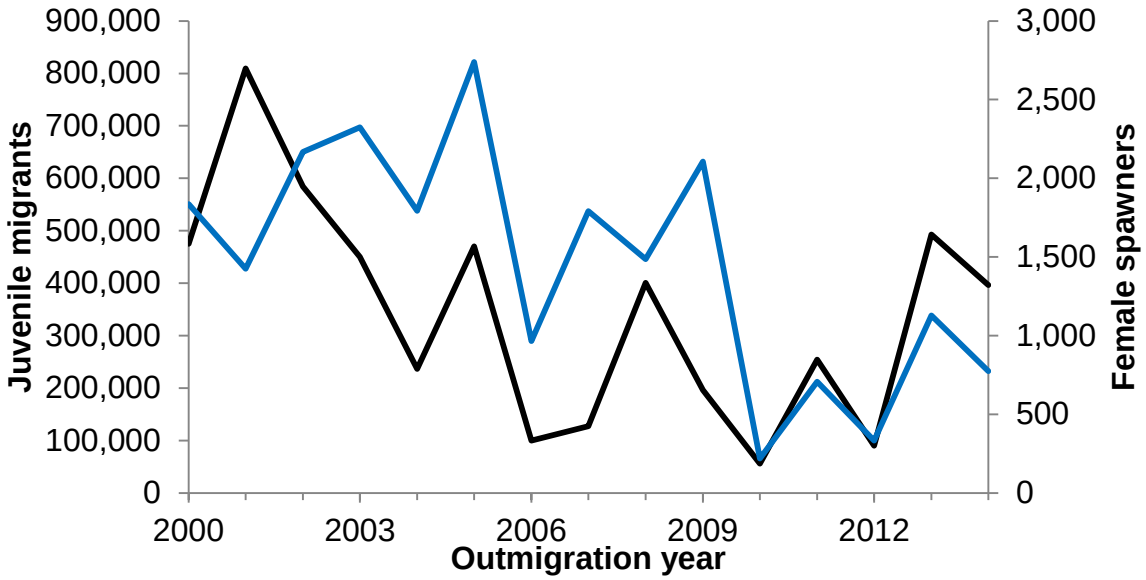

Figure 9. Number of subyearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (blue line) above the juvenile trap, outmigration year 2000-2014.

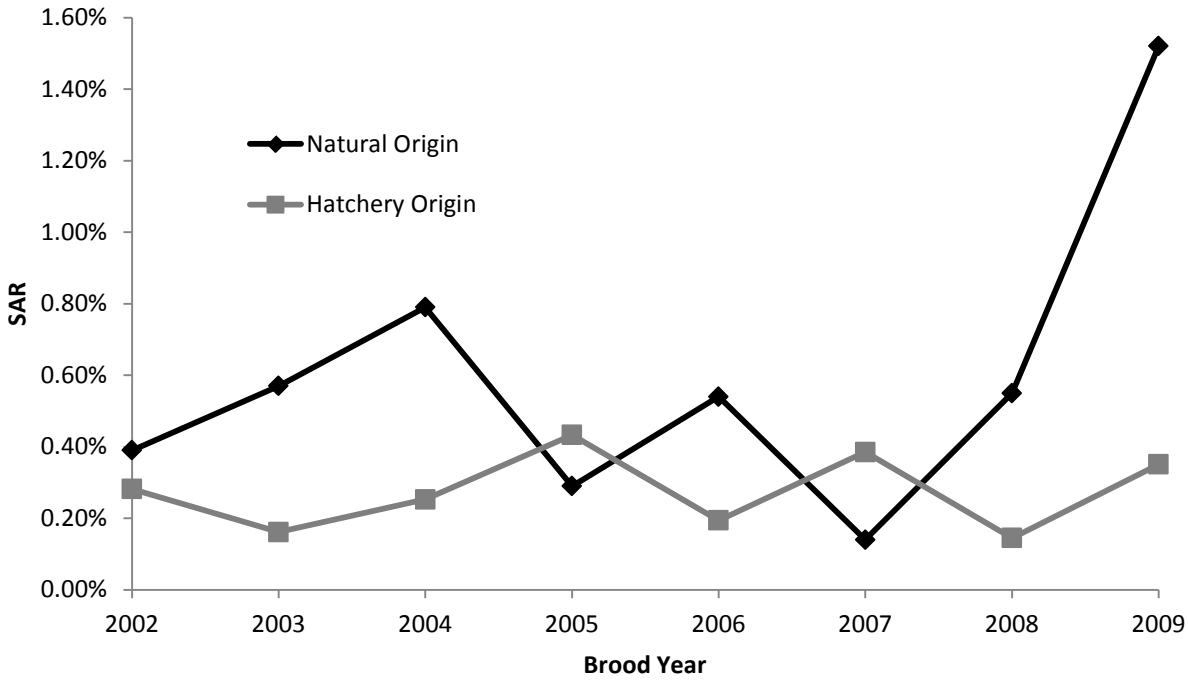

Figure 10. Smolt to adult return rate (SAR) of natural origin vs hatchery origin Chinook from the Green River, brood years 2002-2009. Does not include age 2 (jacks) returns.

Freshwater Production of Coho Salmon

Freshwater production of coho above the Green River trap has been estimated for 12 of the 15 years of this study (Table 10). The 2014 freshwater production estimate of 106,365 coho smolts was the second largest production estimate, with 2002 migration being the only year with a larger production estimated at 194,000 smolts, 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. Our confidence in the 2014 abundance estimate is high because of the large numbers of fish released and recovered.

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, perhaps 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 2014, with only 7% of the natural origin coho and 7% 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 11. 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 2000-2014.

	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
2013	50,642	30,000	71,284	20.8%	103.5	16.75	5/9
2014	106,365	82,645	130,084	11.38	104.0	13.13	5/11

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 4 of the 15 years of this study. The 2014 freshwater production estimate of 31,638 was slightly lower than the (36,000 smolt) average for the four years we have made production estimates. The 2014 production estimate was derived directly from release and recapture of natural-origin steelhead. Of the 899 marked steelhead that were released, 38 were recaptured, providing the most precise estimate of steelhead smolt abundance that we have achieved in the long term study.

In 2014, steelhead smolts captured in the trap were similar in length and age as we observed in 2011 and 2012. In 2013, we began 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 was 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 ENREF 11). It is possible that this difference in age structure resulted from the two year cycle in which Green River pink salmon are extremely abundant in odd years but absent in even years. In 2012 and 2014, smolts had access to millions of pink salmon eggs the previous and millions of juvenile pink salmon fry in the spring

immediately prior to downstream migration. Faster growth rates are associated with younger age at smolting (Beakes et al. 2010), and so it seems plausible that the food subsidy provided by pink salmon increased the proportion of age-1 smolts in 2012 and 2014.

Table 12. 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 2000-2014.

	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
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
2014	31,638	21,901	41,376	15.70%	171.2	18.30	5/5

a Median catch date

Appendix A

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

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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 $E\left(\hat{u}^2\right)$,

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

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

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

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

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

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

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

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

Appendix B

Daily catch and migration estimate for natural-origin, subyearling Chinook in the Green River, 2014.

APPENDIX B. ─Actual and estimated daily catches and migration for natural-origin subyearling Chinook migrants and daily estimated catch of Ad-marked hatchery Chinook fry and unmarked Chinook yearlings, in the Green River, 2014. Migration estimate is based on daily catch adjusted by the trap efficiency for each pooled time stratum.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
1/1-1/24	Pre-Trapping		0	0	0	4030	0	0
1/25/2014	25.00	0.00	12	0	12	292	0	0
1/26/2014	24.00	0.00	3	0	3	73	0	0
1/27/2014	23.75	0.00	6	0	6	146	0	0
1/28/2014	24.00	0.00	7	0	7	170	0	0
1/29/2014	23.75	0.00	41	0	41	998	0	0
1/30/2014	24.25	0.00	241	0	241	5,864	0	0
1/31/2014	24.25	0.00	49	0	49	1,192	0	0
2/1/2014	24.00	0.00	26	0	26	633	0	0
2/2/2014	15.00	0.00	19	0	19	462	0	0
2/3/2014	9.00	0.00	12	0	12	105	0	0
2/4/2014	24.00	0.00	32	0	32	279	0	0
2/5/2014	24.25	0.00	24	0	24	209	0	0
2/6/2014	23.75	0.00	8	0	8	70	0	0
2/7/2014	24.00	0.00	32	0	32	279	0	0
2/8/2014	24.00	0.00	13	0	13	113	0	0
2/9/2014	24.00	0.00	18	0	18	157	0	0
2/10/2014	24.25	0.00	5	0	5	312	0	0
2/11/2014	23.75	0.00	66	0	66	4,117	0	0
2/12/2014	24.00	0.00	23	0	23	1,435	0	0
2/13/2014	24.25	0.00	117	0	117	7,299	0	0
2/14/2014	24.25	0.00	10	0	10	624	0	0
2/15/2014	24.00	0.00	25	0	25	1,560	0	0
2/16/2014	24.00	0.00	42	0	42	2,620	0	1
2/17/2014	24.00	0.00	933	0	933	58,205	0	0
2/18/2014	24.25	0.00	362	0	362	22,583	0	0
2/19/2014	24.00	0.00	152	0	152	9,482	0	0
2/20/2014	23.75	0.00	28	0	28	1,747	0	0
2/21/2014	24.00	0.00	19	0	19	1,185	0	0
2/22/2014	24.00	0.00	41	0	41	2,558	0	0
2/23/2014	24.00	0.00	30	0	30	1,872	0	0
2/24/2014	24.00	0.00	44	0	44	2,745	0	0
2/25/2014	24.00	0.00	11	0	11	686	0	0
2/26/2014	24.50	0.00	40	0	40	2,495	0	0

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APPENDIX B.–continued.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
2/27/2014	24.00	0.00	25	0	25	1,560	0	0
2/28/2014	24.00	0.00	15	0	15	936	0	0
3/1/2014	23.75	0.00	50	0	50	3,119	0	0
3/2/2014	24.00	0.00	49	0	49	3,057	0	0
3/3/2014	24.25	0.00	258	0	258	16,095	0	0
3/4/2014	24.25	0.00	316	0	316	19,714	0	0
3/5/2014	0.00	23.75	0	293	293	18,279	0	0
3/6/2014	0.00	24.00	0	284	284	17,717	0	0
3/7/2014	0.00	24.00	0	284	284	17,717	0	0
3/8/2014	0.00	24.00	0	284	284	17,717	0	0
3/9/2014	0.00	24.00	0	176	176	10,980	0	0
3/10/2014	0.00	24.00	0	176	176	10,980	0	0
3/11/2014	0.00	24.00	0	176	176	10,980	0	0
3/12/2014	0.00	24.00	0	176	176	10,980	0	0
3/13/2014	4.50	19.50	10	21	31	1,934	0	0
3/14/2014	24.00	0.00	22	0	22	1,372	0	0
3/15/2014	24.50	0.00	21	0	21	1,310	0	0
3/16/2014	22.50	0.00	29	0	29	1,809	0	0
3/17/2014	9.20	15.50	18	17	35	2,183	0	1
3/18/2014	24.30	0.00	19	0	19	1,185	0	0
3/19/2014	24.00	0.00	23	0	23	1,435	1	0
3/20/2014	24.25	0.00	19	0	19	1,185	1	0
3/21/2014	23.75	0.00	19	0	19	1,185	2	0
3/22/2014	24.33	0.00	36	0	36	2,246	0	0
3/23/2014	24.17	0.00	30	0	30	1,872	8	0
3/24/2014	29.33	0.00	45	0	45	2,807	6	0
3/25/2014	13.83	9.58	7	17	24	1,497	1	0
3/26/2014	18.07	2.02	6	2	8	499	0	0
3/27/2014	23.92	0.00	33	0	33	2,059	0	0
3/28/2014	24.25	0.00	18	0	18	1,123	0	0
3/29/2014	24.00	0.00	27	0	27	1,684	0	0
3/30/2014	24.00	0.00	44	0	44	2,745	0	0
3/31/2014	24.00	0.00	39	0	39	952	15	0
4/1/2014	24.00	0.00	48	0	48	1,171	5	0
4/2/2014	24.00	0.00	43	0	43	1,049	3	0
4/3/2014	22.25	0.00	40	0	40	976	0	0

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APPENDIX B.–continued.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
4/4/2014	24.75	0.00	50	0	50	1,220	0	0
4/5/2014	25.00	0.00	29	0	29	708	1	1
4/6/2014	24.00	0.00	33	0	33	805	1	1
4/7/2014	24.00	0.00	34	0	34	830	0	0
4/8/2014	24.00	0.00	27	0	27	659	1	0
4/9/2014	24.00	0.00	25	0	25	610	0	0
4/10/2014	24.50	0.00	20	0	20	488	0	0
4/11/2014	22.00	0.00	23	0	23	561	0	0
4/12/2014	26.00	0.00	30	0	30	732	0	0
4/13/2014	23.50	0.00	82	0	82	2,001	0	0
4/14/2014	24.00	0.00	60	0	60	1,464	1	0
4/15/2014	23.50	0.00	30	0	30	732	1	0
4/16/2014	23.00	0.00	25	0	25	610	1	0
4/17/2014	25.25	0.00	47	0	47	1,147	0	1
4/18/2014	22.75	0.00	20	0	20	488	0	0
4/19/2014	25.50	0.00	7	0	7	171	0	0
4/20/2014	24.00	0.00	25	0	25	610	0	0
4/21/2014	24.00	0.00	10	0	10	244	1	0
4/22/2014	23.50	0.00	7	0	7	171	0	0
4/23/2014	23.83	0.00	13	0	13	317	1	0
4/24/2014	23.17	0.00	17	0	17	415	0	0
4/25/2014	25.00	0.00	11	0	11	268	0	0
4/26/2014	24.50	0.00	2	0	2	49	0	0
4/27/2014	23.50	0.00	2	0	2	49	0	0
4/28/2014	24.50	0.00	4	0	4	98	0	0
4/29/2014	23.50	0.00	12	0	12	293	0	0
4/30/2014	26.83	1.42	8	0	8	195	0	0
5/1/2014	0.00	19.75	0	4	4	98	0	0
5/2/2014	0.00	24.00	0	5	5	122	0	0
5/3/2014	0.00	22.00	0	5	5	122	0	0
5/4/2014	26.75	0.00	5	0	5	122	0	0
5/5/2014	23.75	0.00	17	0	17	415	0	0
5/6/2014	23.50	0.00	39	0	39	952	0	0
5/7/2014	24.00	0.00	32	0	32	781	0	0
5/8/2014	23.00	0.00	13	0	13	317	0	0

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APPENDIX B.–continued.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
5/9/2014	25.00	0.00	15	0	15	366	0	0
5/10/2014	25.00	0.00	17	0	17	415	0	0
5/11/2014	23.00	0.00	36	0	36	879	0	0
5/12/2014	24.00	0.00	45	0	45	1,098	0	0
5/13/2014	24.00	0.00	85	0	85	2,074	1	0
5/14/2014	24.00	0.00	43	0	43	1,049	2	0
5/15/2014	24.00	0.00	39	0	39	952	0	0
5/16/2014	24.00	0.00	47	0	47	1,147	0	0
5/17/2014	24.00	0.00	48	0	48	1,171	0	0
5/18/2014	24.00	0.00	30	0	30	732	0	0
5/19/2014	24.50	0.00	21	0	21	182	0	0
5/20/2014	23.50	0.00	35	0	35	304	0	0
5/21/2014	24.00	0.00	37	0	37	321	0	0
5/22/2014	24.50	0.00	24	0	24	208	0	1
5/23/2014	24.00	0.00	40	0	40	347	0	0
5/24/2014	24.00	0.00	100	0	100	868	1	0
5/25/2014	24.00	0.00	94	0	94	816	0	0
5/26/2014	23.00	0.00	70	0	70	1,031	1	0
5/27/2014	24.50	0.00	158	0	158	2,327	0	0
5/28/2014	24.00	0.00	118	0	118	1,738	0	0
5/29/2014	24.00	0.00	143	0	143	2,106	0	0
5/30/2014	24.00	0.00	164	0	164	2,416	2	0
5/31/2014	23.50	0.00	102	0	102	1,503	0	0
6/1/2014	13.50	11.25	91	67	158	2,327	0	0
6/2/2014	13.00	11.25	67	62	129	1,900	1	0
6/3/2014	23.00	0.00	79	0	79	1,164	3	0
6/4/2014	15.50	9.00	69	2	71	1,046	6	0
6/5/2014	24.00	0.00	165	0	165	2,431	15	0
6/6/2014	14.25	9.75	10	2	12	177	61	0
6/7/2014	13.00	12.00	17	2	19	280	12	0
6/8/2014	12.50	11.50	20	2	22	324	10	0
6/9/2014	22.75	0.00	28	0	28	412	15	0
6/10/2014	13.75	10.50	55	1	56	825	28	0
6/11/2014	12.50	11.00	65	1	66	972	28	0
6/12/2014	24.50	0.00	25	0	25	368	11	0

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APPENDIX B.–continued.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Ad-mrk	Unmarked
Date	In	Out	Actual	Estimated	Total	Migration	Fry	Yearling
6/13/2014	14.00	10.75	60	0	60	884	6	0
6/14/2014	12.50	11.00	93	0	93	1,370	87	0
6/15/2014	13.25	10.25	35	0	35	516	31	0
6/16/2014	23.50	0.00	26	0	26	383	4	0
6/17/2014	14.75	10.00	57	0	57	840	2	0
6/18/2014	13.50	10.00	76	0	76	1,120	12	0
6/19/2014	24.50	0.00	65	0	65	957	5	0
6/20/2014	14.00	9.50	47	0	47	692	3	0
6/21/2014	13.50	12.00	25	0	25	368	3	0
6/22/2014	0.00	24.00	0	22	22	324	3	0
6/23/2014	12.50	11.50	20	0	20	295	4	0
6/24/2014	11.50	11.00	15	0	15	221	2	0
6/25/2014	14.00	10.00	33	0	33	486	8	0
6/26/2014	25.50	0.00	11	0	11	162	1	0
6/27/2014	11.00	12.50	25	0	25	368	8	0
6/28/2014	0.00	24.50	0	22	22	324	11	0
6/29/2014	0.00	23.50	0	21	21	309	11	0
6/30/2014	13.00	10.00	21	0	21	309	15	0
7/1/2014	25.25	0.00	7	0	7	103	4	0
7/2/2014	22.25	0.00	1	0	1	15	3	0
7/3/2014	14.50	11.50	2	0	2	29	4	0
7/4/2014	0.00	24.00	0	3	3	44	3	0
7/5/2014	0.00	24.00	0	3	3	44	3	0
7/6/2014	0.00	23.00	0	3	3	44	3	0
7/7/2014	13.00	0.00	4	0	4	59	4	0
7/13-7/31	Post -Trapping		0	0	0	508	0	0
Total	3229.23	674.77	7,384	2,133	9,517	396,623	487	6

Appendix C

Fork length of natural-origin, subyearling Chinook in the Green River, 2014

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 2014.

Week				Range		Number		Percent
Begin	End	Average	St.Dev.	Min	Max	Sampled	Caught	Sampled
1/24/2014	1/26/2014	39.00	2.10	35	41	6	15	40.00%
1/27/2014	2/2/2014	39.72	1.43	36	43	39	389	10.03%
2/3/2014	2/9/2014	40.85	2.37	38	49	20	139	14.39%
2/10/2014	2/16/2014	40.49	1.93	37	44	39	288	13.54%
2/17/2014	2/23/2014	40.29	2.21	37	49	55	1,565	3.51%
2/24/2014	3/2/2014	40.88	2.25	36	46	41	234	17.52%
3/3/2014	3/9/2014	40.49	2.81	34	48	39	574	6.79%
3/10/2014	3/16/2014	41.85	2.15	38	45	13	82	15.85%
3/17/2014	3/23/2014	42.38	3.02	31	48	34	164	20.73%
3/24/2014	3/30/2014	45.06	4.28	39	57	36	180	20.00%
3/31/2014	4/6/2014	44.80	4.31	38	53	54	282	19.15%
4/7/2014	4/13/2014	45.53	5.82	37	56	53	241	21.99%
4/14/2014	4/20/2014	47.37	7.30	37	66	51	214	23.83%
4/21/2014	4/27/2014	46.21	7.02	37	62	34	62	54.84%
4/28/2014	5/4/2014	56.70	7.63	42	70	20	29	68.97%
5/5/2014	5/11/2014	59.73	7.25	44	78	63	169	37.28%
5/12/2014	5/18/2014	67.13	7.21	52	89	82	337	24.33%
5/19/2014	5/25/2014	71.55	10.52	54	105	66	351	18.80%
5/26/2014	6/1/2014	75.82	9.79	54	110	104	846	12.29%
6/2/2014	6/8/2014	78.73	10.08	52	106	82	427	19.20%
6/9/2014	6/15/2014	78.18	6.51	65	91	78	361	21.61%
6/16/2014	6/22/2014	82.09	7.71	61	99	75	296	25.34%
6/23/2014	6/29/2014	88.76	5.46	78	103	62	104	59.62%
6/30/2014	7/6/2014	87.74	6.79	72	98	23	31	74.19%
7/7/2014	7/7/2014	89.25	2.75	86	92	4	4	100.00%
Season Total		61.10	18.66	31	110	1,173	7,380	15.89%

Appendix D

Daily catch of coho , chum and pink salmon, steelhead and cutthroat trout in the Green River, 2014

APPENDIX D.–Daily catches of coho, chum and pink salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2014. 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			Chum	Pink	Steelhead		Cutthroat	Trout
			Smolts		Fry	Fry	Fry	Smolts		Smolt	Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
01/25/14	25.00	0.00	2	0	0	0	8	0	0	0	1
01/26/14	24.00	0.00	5	0	0	0	3	0	0	0	3
01/27/14	23.75	0.00	3	0	0	0	2	0	0	1	1
01/28/14	24.00	0.00	3	0	0	0	1	0	0	0	1
01/29/14	23.75	0.00	4	0	14	0	9	1	0	0	21
01/30/14	24.25	0.00	11	0	0	0	131	2	0	0	6
01/31/14	24.25	0.00	5	0	0	0	8	0	0	0	8
02/01/14	24.00	0.00	5	0	0	0	11	0	0	1	5
02/02/14	15.00	0.00	4	0	0	0	9	0	0	0	2
02/03/14	9.00	0.00	2	0	0	0	3	0	0	1	9
02/04/14	24.00	0.00	4	0	0	0	4	0	0	0	6
02/05/14	24.25	0.00	4	0	0	0	3	0	0	0	4
02/06/14	23.75	0.00	3	0	0	0	2	0	0	1	4
02/07/14	24.00	0.00	4	0	0	0	5	0	0	0	3
02/08/14	24.00	0.00	8	0	0	0	0	0	0	0	6
02/09/14	24.00	0.00	8	0	0	0	0	0	0	0	2
02/10/14	24.25	0.00	8	0	0	0	3	0	0	0	4
02/11/14	23.75	0.00	12	0	0	0	1	1	0	0	4
02/12/14	24.00	0.00	13	0	0	0	32	0	0	2	14
02/13/14	24.25	0.00	20	0	0	4	108	3	0	0	12
02/14/14	24.25	0.00	8	0	0	0	36	0	0	0	18
02/15/14	24.00	0.00	9	0	0	0	14	1	0	1	5
02/16/14	24.00	0.00	7	0	0	0	30	0	0	0	6
02/17/14	24.00	0.00	9	0	30	24	478	1	0	0	2
02/18/14	24.25	0.00	6	0	8	7	158	0	0	1	4
02/19/14	24.00	0.00	4	0	4	7	97	3	0	0	3
02/20/14	23.75	0.00	5	0	1	1	68	0	0	1	6
02/21/14	24.00	0.00	10	0	1	2	21	3	0	1	18
02/22/14	24.00	0.00	4	0	0	4	277	1	0	0	8
02/23/14	24.00	0.00	6	0	0	3	151	0	0	0	13
02/24/14	24.00	0.00	8	0	1	2	264	1	0	0	6
02/25/14	24.00	0.00	1	0	0	0	174	0	0	1	9
02/26/14	24.50	0.00	5	0	1	2	218	2	0	0	11
02/27/14	24.00	0.00	8	0	0	1	211	0	0	0	6

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Coho Fry	Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
02/28/14	24.00	0.00	6	0	0	8	349	0	0	1	5
03/01/14	23.75	0.00	7	0	1	8	1,680	0	0	0	7
03/02/14	24.00	0.00	9	0	0	13	779	2	0	0	10
03/03/14	24.25	0.00	2	0	7	17	1,152	5	0	0	4
03/04/14	24.25	0.00	13	0	11	17	1,820	2	0	1	6
03/05/14		23.75	7	0	8	15	1,327	3	0	0	4
03/06/14		24.00	8	0	9	17	1,458	3	0	0	5
03/07/14		24.00	8	0	9	17	1,458	3	0	0	5
03/08/14		24.00	8	0	9	17	1,458	3	0	0	5
03/09/14		24.00	7	0	6	19	1,886	4	0	0	4
03/10/14		24.00	7	0	6	19	1,886	4	0	0	4
03/11/14		24.00	7	0	6	19	1,886	4	0	0	4
03/12/14		24.00	7	0	6	19	1,886	4	0	0	4
03/13/14	4.50	19.50	3	0	2	21	1,635	7	0	0	4
03/14/14	24.00	0.00	1	0	2	25	2,053	6	0	0	3
03/15/14	24.50	0.00	5	0	2	3,498	1,250	12	0	0	8
03/16/14	22.50	0.00	4	0	7	119	642	3	0	0	8
03/17/14	9.20	15.50	3	0	8	1,144	1,057	2	0	0	6
03/18/14	24.30	0.00	3	0	9	2,268	1,456	0	0	0	4
03/19/14	24.00	0.00	2	0	3	34	1,161	0	0	0	5
03/20/14	24.25	0.00	3	0	0	1,449	1,145	1	0	0	8
03/21/14	23.75	0.00	3	0	0	49	1,955	0	0	0	5
03/22/14	24.33	0.00	7	0	3	49	2,320	3	0	0	7
03/23/14	24.17	0.00	28	0	0	20	740	2	4	0	30
03/24/14	29.33	0.00	30	0	6	145	4,785	8	113	0	49
03/25/14	13.83	9.58	32	0	2	211	5,307	2	1,048	0	53
03/26/14	18.07	2.02	9	0	0	62	1,722	0	156	0	6
03/27/14	23.92	0.00	7	0	0	39	1,046	1	174	0	12
03/28/14	24.25	0.00	10	0	2	140	2,317	0	202	0	12
03/29/14	24.00	0.00	7	1	1	161	6,030	0	133	0	3
03/30/14	24.00	0.00	3	0	0	95	8,510	5	38	0	1
03/31/14	24.00	0.00	3	0	3	1,220	3,517	3	22	0	0
04/01/14	24.00	0.00	7	0	3	3,038	5,197	2	14	0	8
04/02/14	24.00	0.00	4	0	3	497	6,002	1	23	0	6
04/03/14	22.25	0.00	0	0	3	151	7,880	1	19	0	8
04/04/14	24.75	0.00	6	1	1	404	8,654	2	17	1	4
04/05/14	25.00	0.00	7	0	3	194	9,410	0	16	0	11
04/06/14	24.00	0.00	5	0	1	290	11,423	0	8	0	6

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Fry	Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
04/07/14	24.00	0.00	11	0	0	115	6,324	2	1	1	2
04/08/14	24.00	0.00	31	1	1	139	7,948	3	2	0	4
04/09/14	24.00	0.00	6	2	1	87	6,336	2	2	1	1
04/10/14	24.50	0.00	1	2	1	169	11,619	1	1	0	2
04/11/14	22.00	0.00	29	0	2	128	7,017	5	14	0	0
04/12/14	26.00	0.00	12	3	3	2,144	7,966	3	2	1	2
04/13/14	23.50	0.00	52	13	4	1,639	18,730	10	9	1	2
04/14/14	24.00	0.00	50	11	3	636	18,508	4	5	1	10
04/15/14	23.50	0.00	29	11	2	223	12,124	4	2	0	4
04/16/14	23.00	0.00	26	0	0	175	8,718	0	7	0	0
04/17/14	25.25	0.00	19	6	0	2,868	7,898	4	19	3	1
04/18/14	22.75	0.00	25	0	2	424	2,832	17	12	0	0
04/19/14	25.50	0.00	11	2	1	82	2,871	5	3	0	1
04/20/14	24.00	0.00	7	7	2	86	3,084	4	14	1	0
04/21/14	24.00	0.00	16	0	0	51	2,101	2	2	0	0
04/22/14	23.50	0.00	11	2	0	110	3,269	2	2	1	0
04/23/14	23.83	0.00	12	3	0	808	3,289	9	2	0	0
04/24/14	23.17	0.00	21	0	1	1,843	2,705	6	2	1	1
04/25/14	25.00	0.00	19	0	0	205	819	10	4	0	1
04/26/14	24.50	0.00	20	1	0	53	654	4	3	1	0
04/27/14	23.50	0.00	19	3	0	45	856	3	2	0	2
04/28/14	24.50	0.00	8	0	0	1,812	569	7	4	0	1
04/29/14	23.50	0.00	37	2	0	2,346	2,008	9	7	0	0
04/30/14	26.83	1.42	119	997	0	182	1,485	16	19	0	2
05/01/14		19.75	26	389	0	65	543	6	4	0	2
05/02/14		24.00	36	577	0	86	717	9	6	0	3
05/03/14		22.00	35	577	0	82	683	9	6	0	3
05/04/14	26.75	0.00	26	738	0	22	92	4	5	1	4
05/05/14	23.75	0.00	38	515	0	41	94	8	5	0	2
05/06/14	23.50	0.00	85	2,541	0	101	192	33	11	0	6
05/07/14	24.00	0.00	70	2,006	0	445	184	21	14	1	7
05/08/14	23.00	0.00	57	946	0	237	176	18	5	0	2
05/09/14	25.00	0.00	55	832	0	96	108	23	11	0	2
05/10/14	25.00	0.00	55	288	1	59	63	24	9	0	3
05/11/14	23.00	0.00	88	405	0	37	23	16	19	0	1
05/12/14	24.00	0.00	116	453	1	20	7	43	11	0	4
05/13/14	24.00	0.00	149	618	0	32	42	53	27	0	3
05/14/14	24.00	0.00	167	632	0	50	41	48	23	0	4

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Coho Fry	Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
05/15/14	24.00	0.00	105	394	2	990	61	49	16	3	4
05/16/14	24.00	0.00	119	250	5	172	32	31	18	0	4
05/17/14	24.00	0.00	73	155	2	1,136	19	25	16	1	1
05/18/14	24.00	0.00	99	140	0	192	1	36	117	0	2
05/19/14	24.50	0.00	35	66	0	95	7	34	86	0	2
05/20/14	23.50	0.00	44	69	0	180	4	47	67	1	0
05/21/14	24.00	0.00	55	74	2	528	7	31	38	1	1
05/22/14	24.50	0.00	68	76	3	260	2	34	35	0	2
05/23/14	24.00	0.00	64	49	3	109	4	43	29	1	1
05/24/14	24.00	0.00	73	72	6	125	4	59	33	0	4
05/25/14	24.00	0.00	41	56	1	50	0	36	22	0	1
05/26/14	23.00	0.00	35	32	2	62	0	32	40	0	0
05/27/14	24.50	0.00	70	57	0	83	0	47	28	1	1
05/28/14	24.00	0.00	55	39	0	57	4	51	27	1	0
05/29/14	24.00	0.00	62	27	3	50	3	57	47	1	0
05/30/14	24.00	0.00	31	34	0	30	2	32	21	0	1
05/31/14	23.50	0.00	25	18	0	16	0	31	20	0	0
06/01/14	13.50	11.25	38	14	0	19	0	32	19	0	1
06/02/14	13.00	11.25	36	8	1	20	0	31	17	0	0
06/03/14	23.00	0.00	16	8	2	10	1	18	16	0	0
06/04/14	15.50	9.00	9	7	0	6	0	14	11	0	0
06/05/14	24.00	0.00	14	6	0	16	0	10	5	0	1
06/06/14	14.25	9.75	8	5	0	5	0	9	4	0	0
06/07/14	13.00	12.00	4	5	1	5	0	3	7	0	1
06/08/14	12.50	11.50	3	2	0	7	0	9	4	0	0
06/09/14	22.75	0.00	6	2	0	2	0	4	2	0	0
06/10/14	13.75	10.50	9	3	0	4	0	1	1	0	0
06/11/14	12.50	11.00	2	0	0	7	0	0	0	0	0
06/12/14	24.50	0.00	1	0	0	4	0	0	0	0	0
06/13/14	14.00	10.75	2	0	0	13	0	0	0	0	0
06/14/14	12.50	11.00	1	2	0	16	0	0	1	0	0
06/15/14	13.25	10.25	0	0	0	7	0	1	0	0	0
06/16/14	23.50	0.00	5	0	0	11	0	0	1	0	0
06/17/14	14.75	10.00	4	0	0	17	0	0	1	0	1
06/18/14	13.50	10.00	1	2	0	11	0	0	0	1	1
06/19/14	24.50	0.00	2	1	0	9	0	0	0	0	0
06/20/14	14.00	9.50	1	0	0	7	0	0	0	0	2
06/21/14	13.50	12.00	1	0	0	3	0	0	0	0	0

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APPENDIX D.–continued.

Date	Times		Coho Smolts		Coho Fry	Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
06/22/14		24.00	2	0	2	2	0	0	0	0	0
06/23/14	12.50	11.50	3	0	0	1	0	0	0	0	0
06/24/14	11.50	11.00	0	0	0	1	0	0	0	0	0
06/25/14	14.00	10.00	1	0	0	2	0	0	0	0	0
06/26/14	25.50	0.00	0	0	0	0	1	0	0	0	0
06/27/14	11.00	12.50	1	0	0	1	0	0	0	0	0
06/28/14		24.50	1	0	0	1	0	0	0	0	0
06/29/14		23.50	1	0	0	1	0	0	0	0	0
06/30/14	13.00	10.00	1	0	0	0	0	0	0	0	0
07/01/14	25.25	0.00	1	0	0	0	0	0	0	0	0
07/02/14	22.25	0.00	0	0	0	0	0	0	0	0	0
07/03/14	14.50	11.50	0	0	0	0	0	0	0	0	0
07/04/14		24.00	0	0	0	0	0	0	0	0	0
07/05/14		24.00	0	0	0	0	0	0	0	0	0
07/06/14		23.00	0	0	0	0	0	0	0	0	0
07/07/14	13.00	0.00	0	0	0	0	0	0	0	0	0
Total	3229.23	674.77	3,328	14,258	262	37,671	261,626	1371	3,032	39	678

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2014

APPENDIX E.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2014.

Week				Range		Number		Percent
Begin	End	Average	St.Dev.	Min	Max	Sampled	Captured	Sampled
1/24/14	1/26/14	95.00	4.29	90	101	6	7	85.71%
1/27/14	2/2/14	88.83	13.24	61	110	12	35	34.29%
2/3/14	2/9/14	78.75	13.67	55	111	12	33	36.36%
2/10/14	2/16/14	86.07	15.48	57	111	15	77	19.48%
2/17/14	2/23/14	83.79	11.34	68	110	14	44	31.82%
2/24/14	3/2/14	85.73	11.35	61	101	11	44	25.00%
3/3/14	3/9/14	94.00	21.21	79	109	2	15	13.33%
3/10/14	3/16/14	98.50	23.33	82	115	2	10	20.00%
3/17/14	3/23/14	95.13	8.81	83	112	16	46	34.78%
3/24/14	3/30/14	93.73	10.05	82	116	11	76	14.47%
3/31/14	4/6/14	95.60	10.01	77	110	10	32	31.25%
4/7/14	4/13/14	98.47	11.28	78	118	17	142	11.97%
4/14/14	4/20/14	103.39	8.89	88	128	41	167	24.55%
4/21/14	4/27/14	106.22	7.98	92	125	32	118	27.12%
4/28/14	5/4/14	109.65	7.93	97	127	23	171	13.45%
5/5/14	5/11/14	109.28	11.07	79	130	65	448	14.51%
5/12/14	5/18/14	111.51	8.49	87	131	70	828	8.45%
5/19/14	5/25/14	108.98	9.26	91	131	50	380	13.16%
5/26/14	6/1/14	107.71	9.11	86	128	41	299	13.71%
6/2/14	6/8/14	110.30	8.56	92	131	30	74	40.54%
6/9/14	6/15/14	109.29	6.88	98	120	14	21	66.67%
6/16/14	6/22/14	107.80	15.75	90	128	5	14	35.71%
6/23/14	6/29/14	106.75	10.24	94	116	4	5	80.00%
6/30/14	7/7/14			No sample			2	0.00%
Season Total		103.97	13.13	55	131	503	3,088	16.29%

Appendix F

Fork lengths of natural-origin steelhead smolts in the Green River, 2014

APPENDIX F.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin steelhead smolts in the Green River in 2014.

Week				Range		Number		Percent
Begin	End	Average	St.Dev.	Min	Max	Sampled	Caught	Sampled
1/24/14	1/26/14					0	0	
1/27/14	2/2/14	220.67	61.26	179	291	3	3	100.00%
2/3/14	2/9/14						0	
2/10/14	2/16/14	182.25	10.78	168	192	4	5	80.00%
2/17/14	2/23/14	182.75	25.33	141	221	8	8	100.00%
2/24/14	3/2/14	196.60	16.88	180	225	5	5	100.00%
3/3/14	3/9/14	179.29	25.32	158	228	7	7	100.00%
3/10/14	3/16/14	183.69	20.88	144	229	16	22	72.73%
3/17/14	2/23/14	193.50	39.87	150	245	6	6	100.00%
3/24/14	3/30/14	195.07	33.91	148	243	14	14	100.00%
3/31/14	4/6/14	178.89	29.34	140	226	9	9	100.00%
4/7/14	4/13/14	168.88	25.79	138	231	26	26	100.00%
4/14/14	4/20/14	185.24	22.72	144	225	37	38	97.37%
4/21/14	4/27/14	177.00	26.17	130	234	26	36	72.22%
4/28/14	5/4/14	178.43	19.77	135	232	30	35	85.71%
5/5/14	5/11/14	172.77	18.21	136	245	135	139	97.12%
5/12/14	5/18/14	172.67	16.88	134	247	286	287	99.65%
5/19/14	2/25/14	168.94	14.82	140	215	286	286	100.00%
5/26/14	6/1/14	165.76	13.30	135	227	268	268	100.00%
6/2/14	6/8/14	165.89	14.28	138	210	79	79	100.00%
6/9/14	6/15/14	154.67	11.00	143	173	6	6	100.00%
6/16/14	6/22/14						0	
6/23/14	6/29/14						0	
6/30/14	7/7/14						0	
Season Total		171.24	18.33	130	291	1,251	1,279	97.81%

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