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Green River Juvenile Salmonid Production Evaluation: 2017 Annual Report

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Washington Department of Fish and Wildlife
Fish Program
Science Division

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Acknowledgements

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

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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 between 2013 and 2016.

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Executive Summary

This report provides the 2017 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 18 through June 29, 2017. During this period, the trap fished 93% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (subyearling), coho, pink 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 2017. 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	41,565 [a]	2,034,861 (10.6)	53.00 (±16.99) [a]	22-Mar
Chinook – Yrlg	0			
Coho – Yrlg	1,347	79,491 (21.25%)	111.77(± 14.60)	27-Apr
Steelhead – Smolt	670	32,215 (26.70%)	168.02(±16.73)	22-May
Chum	22,564 [c]			12-Apr [b]

[a] This figure includes hatchery and natural origin fish.
[b] This catch is median catch date which is 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 2017 outmigration (2016 brood) was estimated to be 12.86%, yielding a basin-wide production estimate of 2,389,934 juveniles. Included in this estimate was an estimate of 60,493 Chinook migrating from Big Soos Creek. 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 78% of all subyearling migrants and peaked in early-February and mid-March, and late April. Parr migrants (>45 mm fork length) represented 22% of the migration and parr migration peaked in the first week of May.

Introduction

This report provides the 2017 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, McElhany 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. 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 finished. 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 the approximately 106 miles of river and stream habitat above the dam.

Objectives

The primary objective of this study was to estimate the abundance of juvenile migrants produced by naturally spawning Chinook salmon 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 2017 field season.

Methods

Trap Operation

A floating rotary 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 2017, the trap operated between January 18 and June 29 for a total of 3,537.84 of 3,871.59 possible hours (93% of the time). Over the course of the season, trapping was suspended 10 times; the duration of outages ranged from 6.5 to 92.5 hours. Trapping was suspended 4 times for high water, three times for hatchery fish releases and 2 times during day time periods late in the trapping season when catches were low and recreational use of the river was high.

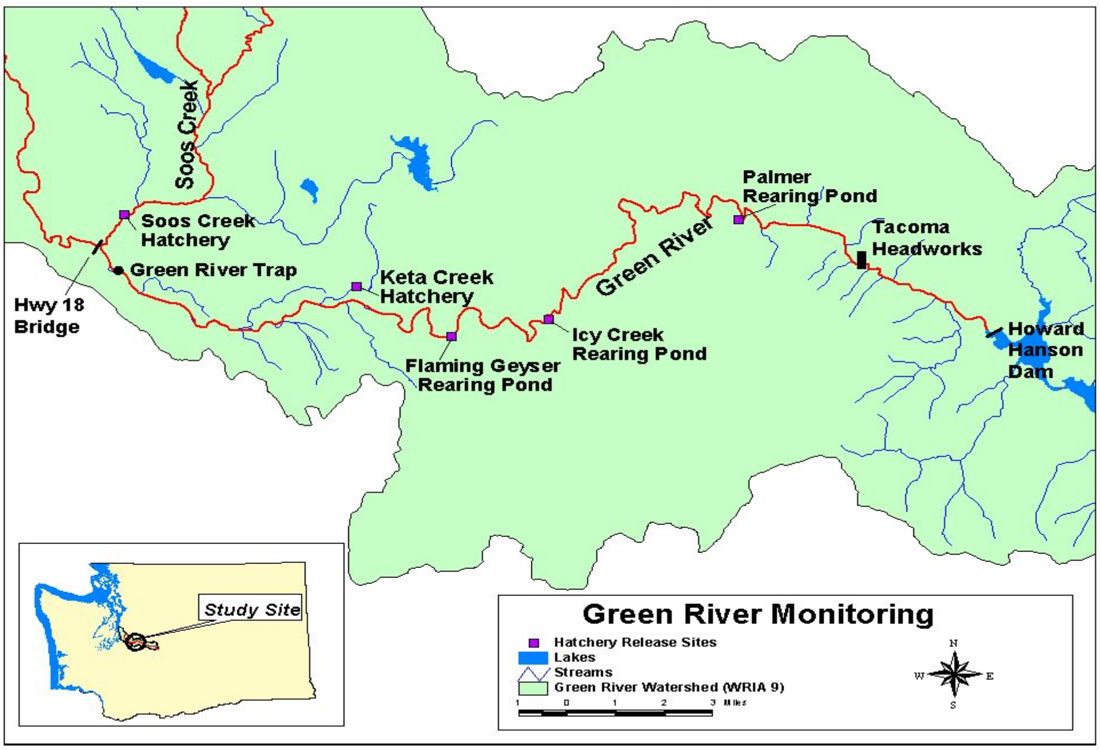

Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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 10%.

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 121 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 migrant's 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) 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 2017 included Chinook, coho, chum and summer and winter steelhead. 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. Therefore, 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 otolith marked only (no external mark) subyearling hatchery Chinook were planted in Palmer Ponds in late February for rearing and acclimation prior to volitional release on June 30th, when the screw trap finished fishing for the season. Because these fish were not externally marked, their release was delayed to avoid the problem of differentiating them from naturally produced Chinook salmon. However, over the previous two years of trapping, we have observed fish reared at Palmer Ponds escaping the hatchery facility, beginning shortly after planting. Similarly, shortly after the hatchery Chinook were transferred to Palmer Ponds in late February 2017, we began capturing subyearling Chinook that were larger (and heavier) than the majority of the natural-origin Chinook we had been capturing prior to that point, suggesting that some hatchery fish were escaping the ponds. Therefore, we began randomly sacrificing non-externally marked Chinook at the smolt trap on March 28th and continued thru the end of the trapping season, with 30 fish sacrificed in total. To increase our sample size, we saved 126 incidental trap mortalities between February 28th and the end of the trapping season. These samples were evaluated for thermal otolith hatchery marks, and used to estimate the number of hatchery-origin Chinook salmon in our catch.

Table 2. Number of hatchery fish by mark type released above the Green River screw trap in 2017. 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	Externally unmarked
Chinook – Subyrlg	2016	Palmer Pond				1,420,000[1]
Chinook – Yrlg	2015	Icy Creek	240,285			
Coho – Yrlg	2015	Keta Creek	15,777		284,716	676
Chum - Subyrlg	2016	Keta Creek				3,205,614
Summer steelhead	2016	Icy Creek			26,308	4,336
Winter Steelhead	2016	Icy Creek		10,600		

[1] This release was thermally otolith marked, with a goal of 100% marking.

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. Release groups alternated the fin clip position 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 one of two upstream locations at dusk. The release locations have served as the primary release locations over the many years of this project. The first location was 150 m upstream of the trap and the second location was the Neely Bridge site, approximately a third of a mile above the trap site.

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

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

(2) Efficiency strata. A *G*-test (Sokal and Rohlf 1981) was used to determine whether adjacent efficiency trials were statistically different. *A priori* pooling prior to the G-test occurred for efficiency trials with expected frequencies of less than five (Sokal and Rohlf 1981). Of the marked fish released in each efficiency trial (*M)*, a portion are recaptured (*m*) and a portion are not seen (*M-m*). If the *seen:unseen* [*m*:(*M-m*)] ratio differed between trials, the trial periods were considered as separate strata. However, if the ratio did not differ between trials, the two trials were pooled into a single stratum. A *G*-test determined whether adjacent efficiency trials were statistically different ($\alpha = 0.05$). 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) Natural origin abundance. To estimate the catch and migration of the natural and hatchery chinook we used both the otolith mark information and the randomly sampled fork length data collected over the entire season. Of the otolith sampled fish with corresponding lengths, none of the marked hatchery fish were ≤ 45 mm (Table 5). Therefore, we portioned the total estimated migration of all non-externally marked Chinook into fry ≤ 45mm and parr > 45mm migrations by statistical week. We assumed that all estimated fry migrants ≤ 45 mm were of natural origin. Because of the small otolith sample size and because the otolith marked fish were detected more frequently early and late in the season, we consolidated the nine efficiency strata (Table 3) into seven strata for estimating the proportion of hatchery vs natural parr based on otolith mark rates (Table 4). Within these seven strata, otolith mark rates were applied to the parr migration estimate for each statistical week, providing a separate estimate of hatchery parr and natural parr. (Table 3 and Table 4, Appendix B).

The abundance estimate of unmarked natural origin Chinook parr in stratum *h* was calculated as:

Equation 7

$$\hat{U}_{uh} = \hat{U}_h * \hat{p}_{uh}$$

And the associated variance was calculated as

Equation 8

$$Var(\hat{U}_{uh}) = Var(\hat{U}_h)(\hat{p}_{uh})^2 + (\hat{U}_h^2)Var(\hat{p}_{uh}) + Var(\hat{U}_h)Var(\hat{p}_{uh})$$

Where the proportion of unmarked natural origin Chinook parr for a given stratum *h* ($\hat{p}_{uh}$) was calculated from the number of unmarked otolith samples (x_{uh}) and the number of otolith samples (o_h) collected in stratum *h*.

Equation 9

$$\hat{p}_{uh} = \frac{x_{uh}}{o_h}$$

variance associated with the proportion of unmarked natural origin Chinook parr present in stratum *h* was:

Equation 10

$$Var(\hat{p}_{uh}) = \frac{\hat{p}_{uh}(1 - \hat{p}_{uh})}{(n_h - 1)}$$

where:

n_h = number of tests to establish the sample proportion in stratum h

(5) 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 occurred. 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 11

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

Variance associated with the extrapolated migration was:

Equation 12

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

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

Equation 13

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

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

Equation 14

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

Confidence intervals were calculated from the variance:

Equation 15

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

Coefficient of variation was:

Equation 16

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

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

Equation 17

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

Where:

Equation 18

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

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 Subyearling 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 Subyearling Chinook

A portion of the Chinook spawning occurs below the juvenile trap in the mainstem 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 estimated 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.

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, age-4, age-5, and age-6. SAR was calculated by dividing the total number of natural-origin adult returns from all age classes by the total natural origin juvenile abundance 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, we report SAR for the Soos Creek hatchery Chinook salmon with data queried from the Regional Mark Information System (RMIS), though information from the most recent brood year 2012 was not yet available at the time of reporting.

Results

Subyearling Chinook

The total estimated catch of non-externally marked Chinook ($\hat{u}$ = 47,359) included 41,565 captures in the trap and an estimated missed catch during trap outage periods of 5,794 (Table 3, Appendix B).

We released a total of 21,285 Chinook salmon within 141 distinct trials to estimate trap efficiency. Release numbers ranging from 41 to 200 fish per trial. Statistical weeks with less than 5 recoveries were combined with the subsequent statistical week, forming 22 groups prior to stratification. The *G*-test procedure pooled the 22 groups into nine efficiency strata, with trap efficiencies ranging between 0.82% and 10.64% (Table 3). We estimated a total unmarked (hatchery plus natural) abundance of 2,102,136 juvenile Chinook salmon across the nine efficiency strata during the trapping season.

Beginning on March 3rd, we observed otolith-marked hatchery fish in our catch at the smolt trap. We organized the otolith mark rates into four distinct strata, plus three efficiency strata prior to the arrival of otolith marked hatchery fish, for a total of seven otolith strata (Table 4). The otolith strata groupings aimed to strike a balance between the lower sample size of otolith samples compared to efficiency trials vs. tracking changes in hatchery mark rate observed over the course of the season. Across four different otolith mark strata with hatchery marked fish present in the river, the otolith mark rate varied from 0% to 43% (Table 4). Hatchery mark rate was very low initially, increased during mid-March through April, dropped to near zero for much of May, and finally increased again during June (Table 4).

We estimated 2,034,861 natural-origin subyearling Chinook migrated from spawning and rearing locations upstream of the trapping site. The trapping season of January 18 through June 28 encompassed the vast majority of the natural-origin subyearling Chinook migration; we estimated 2,013,346 Chinook salmon during the trapping season, and only 21,515 natural origin Chinook migrating before and after the trapping season. An estimated 78% (1,579,608) of the unmarked Chinook migrated as fry < 45 mm. We assumed all of these fish were natural origin because none of the otolith marked hatchery fish were < 53 mm, and the marked hatchery fish were consistently larger than the known natural origin fish (Table 5).

We estimated a total hatchery Chinook salmon migration of 88,790 fish during the trapping season. The highest daily migration of hatchery fish appeared to be in late May and late June, when 39,075 fish (45% of seasonal total) migrated past the trap in a one month period (Table 4). Our hatchery abundance estimate does not include hatchery fish migrating after the end of trapping season on June 28. The trapping season was ended because of the intended hatchery release date of June 30.

Table 3. Catch, marked and recaptured fish, and estimated abundance of subyearling Chinook migrants at the Green River screw trap in 2017. Release groups were pooled to form nine strata. Missed catch and associated variance were estimated for periods that the trap did not fish. These numbers include both natural and otolith marked hatchery fish.

		Hatchery plus natural catch					Total Abundance	
Strata	Date	Actual	Missed	Variance	Marked	Recaptured	Estimated	Variance
Before	1/1-1/17		456	2.93E+03			8,332	9.26E+05
1	1/18-1/28	698	40	1.69E+01	639	35	13,120	4.61E+06
2	1/29-2/4	2,145	0	0.00E+00	1,090	116	20,002	3.19E+06
3	2/5-2/25	8,196	2,232	5.80E+04	2,651	65	419,016	2.67E+09
4	2/26-3/11	5,996	0	0.00E+00	2,383	99	142,945	1.97E+08
5	3/12-4/1	5,276	1,924	3.14E+04	2,929	24	843,840	2.77E+10
6	4/2-4/29	4,851	905	9.41E+03	3,751	84	254,077	7.63E+08
7	4/30-5/6	1,720	679	2.37E+05	583	6	200,145	6.81E+09
8	5/7-5/27	4,207	0	0.00E+00	3,049	108	117,719	1.25E+08
9	5/28-6/29	8,476	14	2.42E-01	4,310	400	91,273	1.97E+07
After	6/30-7/31		2,166	1.40E+04			13,183	5.28E+05
Season Total		41,565	8,416	3.52E+05	21,385	937	2,123,651	3.83E+10

Table 4. Otolith sampling results and estimated abundance by efficiency strata of natural and otolith marked juvenile Chinook migrating past the Green River screw trap in 2017.

Strata	Date	Otolith sample		Abundance			
		Natural	Hatch	Natural	Variance	Hatch	Variance
Before	1/1-1/17			8,332	9.3E+05		
1	1/18-1/28			13,120	4.6E+06		
2	1/29-2/4			20,002	3.2E+06		
3	2/5-2/25			419,016	2.7E+09		
4	2/26-3/11	11	0	142,945	2.0E+08		
5	3/12-4/29	44	11	1,055,334	2.7E+10	42,582	1.1E+09
6	4/30-5/27	30	1	310,731	6.8E+09	7,133	1.6E+08
7	5/28-6/29	30	23	52,198	1.1E+07	39,075	8.4E+06
After	6/30-7/31			13,183	5.3E+05		
	Season Total	115	35	2,034,861	3.7E+10	88,790	1.3E+09

Freshwater productivity of natural-origin Chinook for brood year 2016 above the trap site was estimated to be 579 juveniles per female and an egg-to-migrant survival of 12.86%. This calculation was based on the estimated number of natural origin subyearling Chinook passing the trap ($\hat{N}_T$ = 2,034,861), 3,516 redds assuming 1 female spawner per redd above the trap site (personal communication, Nathanael Overman, WDFW Region 4), and an estimated P.E.D above the trap site of 15,822,000 eggs.

Basin-wide abundance of subyearling unmarked natural origin Chinook was estimated to be 2,389,934 migrants. This included 2,034,861 migrants from above the trap, 294,580 juveniles from the mainstem below the trap and 60,493 from Big Soos Creek. This production is the highest estimated since the project began in 2000. The high production can be attributed to the steady moderate flow during egg incubation. Flows measured at the USGS Auburn flow gauge (12113000) never reached levels that exceeded 3,700 cfs until mid-march, providing excellent incubation conditions and resulted in the third best egg to migrant survival we have estimated since 2000 (Table 6). In addition to the good incubation flow, from mid-March and continuing thru May river flows remained above average with one flow event exceeding 7,000 cfs watering up off channel rearing areas and increasing the amount of available rearing habitat for the newly immerged Chinook fry to occupy.

We estimated migration timing for natural-origin Chinook salmon by excluding hatchery Chinook from daily migration estimates. The median migration date for natural-origin subyearling Chinook was on March 22nd (Table 7). We estimated that 78% of the natural origin Chinook migrated as fry (≤ 45 mm) and 22% migrated as parr (> 45 mm). The fry migration peaked three times, mid- February, mid-March closer to the typical fry migration peak timing and a third time in late April; all three peaks were associated with an increase in flow. The parr migration was relatively stable between mid-March and early June, averaging between 20,000 to 40,000 per week, with the exception of the early May migration peak of 117,000. Although the total estimated abundance of parr (455,253) was the largest across the 18-year study, the inclusion of non-externally marked hatchery fish in the length only (no otolith) sample likely inflated the proportion and abundance of natural-origin parr relative to natural-origin fry (see discussion for details). The migration periods of fry and parr overlapped between late January and late June (Table 8, Figure 2).

Unfortunately we could not identify individual hatchery fish for the majority of our body size sample and so report patterns of hatchery plus natural body size. The seasonal average length of subyearling hatchery plus natural Chinook was 53.00 ± 16.99 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the subyearling hatchery plus natural Chinook showed little increase (approximately 4 mm) during the early portion of the season, (January 15 - March 27). Chinook subyearling hatchery plus natural body size increased substantially thru the end of trapping season (April-June), averaging a 3 mm FL increase per week. The largest size increase occurred between May 7 and May 13 with an increase of 6 mm (Figure 3, Appendix C).

Length measurement were taken on 150 of the 156 Chinook that were otolith sampled. The sample included 115 identified as natural and 35 as hatchery fish. The length samples were grouped by origin and statistical week for analysis. The hatchery fish were significantly larger than the natural fish in every week; the difference between the two groups and ranged from 11mm to 36mm and averaged 21 mm larger over the entire period. In six of the ten weeks with samples in each group, we observed overlap in the range of lengths (Table 5).

Table 5. Comparison of size of natural and hatchery Chinook organized by statistical week.

Date		Unmarked natural origin					Otolith marked hatchery				
Start	End	Fkl (mm)	Std Dev	Min	Max	n	Fkl (mm)	Std Dev	Min	Max	n
26-Feb	4-Mar	39.67	2.08	38	42	3					
5-Mar	11-Mar	39.38	1.77	37	42	8					
12-Mar	18-Mar	39.00	na	39		1					
19-Mar	25-Mar	42.50	3.54	40	45	2					
26-Mar	1-Apr	41.00	1.00	40	42	3	57.00	2.83	55	59	2
2-Apr	8-Apr	45.33	7.57	40	54	3	62.00	0.00	62	62	2
9-Apr	15-Apr	52.83	8.54	40	62	6	64.00	9.49	53	76	4
16-Apr	22-Apr	51.17	14.29	38	71	6					
23-Apr	29-Apr	48.61	10.94	36	77	23	76.67	1.15	76	78	3
30-Apr	6-May	43.36	5.14	36	50	11					
7-May	13-May	48.60	10.43	37	65	5	85.00	na	85		1
14-May	20-May	53.50	10.31	46	74	6					
21-May	27-May	51.63	7.91	44	67	8					
28-May	3-Jun	73.82	11.86	62	92	11	91.80	3.35	88	96	5
4-Jun	10-Jun	73.00	7.07	68	78	2	88.50	7.55	78	96	4
11-Jun	17-Jun	65.50	4.95	62	69	2	88.00	na	88		1
18-Jun	24-Jun	75.57	10.56	64	97	7	100.40	10.88	82	108	5
25-Jun	1-Jul	87.00	7.62	75	99	8	104.75	11.76	80	118	8
Grand Total		55.02	16.56	36	99	115	87.14	17.96	53	118	35

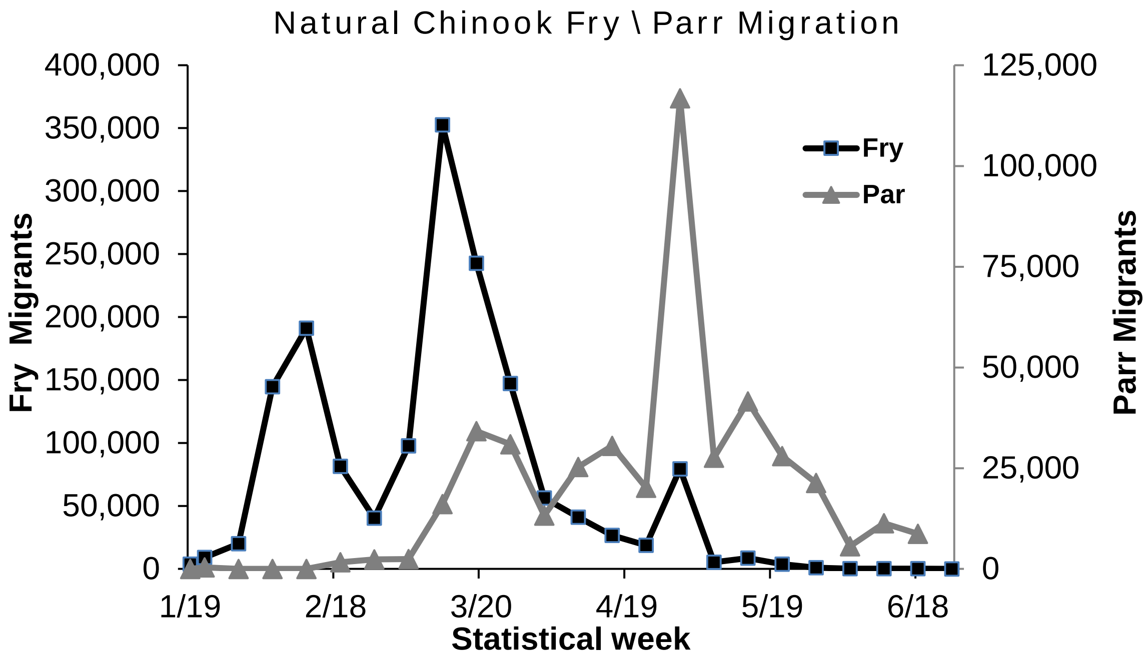

Figure 2. Weekly migration of sub- yearling Chinook migrants of natural-origin at the Green River screw trap in 2017. Subyearling migrants are partitioned into two freshwater rearing strategies fry (≤45 mm FL) and parr (> 45 mm FL) migrants.

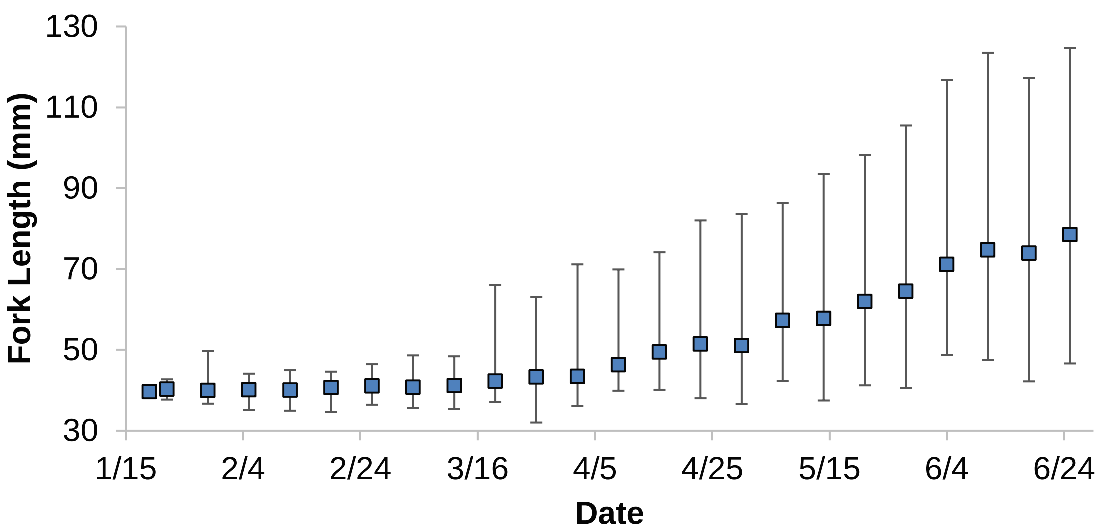

Figure 3. Fork length (mm) of subyearling Chinook migrants of both natural and hatchery origin captured in the Green River screw trap in 2017. Data are mean, minimum, and maximum values.

Table 6. Abundance of juvenile natural origin subyearling migrant Chinook salmon 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		1,341,406
2001	2002	2,167	9,751,500	584,151	5.99%	480	2,160,000	129,392	995	4,477,500		713,543
2002	2003	2,324	10,458,000	449,956	4.30%	2,314	10,413,000	448,020	1,239	5,575,500		897,977
2003	2004	1,793	8,068,500	236,650	2.93%	1,038	4,671,000	137,001	720	3,240,000		373,650
2004	2005	2,738	12,321,000	470,334	3.82%	827	3,721,500	142,062	623	2,803,500		612,397
2005	2006	966	4,347,000	99,796	2.30%	82	369,000	8,471	598	2,691,000		108,267
2006	2007	1,792	8,064,000	127,491	1.58%	883	3,973,500	62,821	313	1,408,500		190,312
2007	2008	1,486	6,687,000	400,763	5.99%	438	1,971,000	118,125	676	3,042,000		518,888
2008	2009	2,107	9,481,500	196,115	2.07%	282	1,269,000	26,248	504	2,268,000		222,362
2009	2010	218	981,000	55,547	5.66%	57	256,500	14,524	759	3,415,500		70,070
2010	2011	706	3,177,000	254,182	8.00%	71	319,500	25,562	461	2,074,500		279,744
2011	2012	333	1,498,500	90,260	6.02%	19	85,500	5,150	190	855,000		95,410
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
2014	2015	1,008	4,536,000	396,944	8.75%	84	378,000	33,079	128	576,000	76,037	506,060
2015	2016	1,570	7,065,000	57,214	0.81%	65	378,000	2,369	152	684,000	16,987	76,570
2016	2017	3,516	15,822,000	2,034,861	12.86%	509	2,290,500	294,580	136	612,000	60,493	2,389,934

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 2011 (Table 9). Natural origin juveniles survived at a higher rate nine out of eleven years than hatchery origin non-ad marked CWT juveniles released from Soos Creek Hatchery (Table 9, Figure 4). As data accumulate in future years, we will continue to explore this pattern and the mechanisms that influence SAR rates for both hatchery and natural origin Chinook.

Table 7. 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 2000-2017.

	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	16.2	51.4	16.53	13-Mar
2001	809,616	641,195	978,038	10.61	45	12.32	16-May
2002	584,151	343,533	824,769	21.02	46.8	12.52	20-Apr
2003	449,956	265,175	634,738	20.98	47.1	12.41	10-Mar
2004	236,650	201,917	271,382	7.49	48.8	16.42	25-Mar
2005	470,334	410,369	530,300	6.5	52.7	18.11	8-Mar
2006	99,796	79,088	120,504	10.59	57.7	21.22	28-May
2007	127,491	107,242	147,740	8.1	69.9	23.47	5-Mar
2008	400,763	361,048	440,477	5.06	54.1	17.16	28-Mar
2009	196,118	171,529	220,706	6.4	54.7	17.49	2-Apr
2010	55,547	39,445	71,648	14.79	67.3	21.43	9-Jun
2011	254,182	225,327	283,037	5.79	51	13.29	2-Apr
2012	90,260	68,450	112,069	10.92	63.3	19.35	28-Apr
2013	492,737	420,077	565,397	6.28	48.1	14.41	21-Mar
2014	396,623	231,236	562,010	21.25	61.1	18.66	5-Mar
2015	396,944	290,947	502,941	13.60	45.4	14.60	7-Feb
2016	57,214	43,873	70,556	11.70	63.8	20.92	23-Apr
2017	2,034,861	1,613,904	2,455,817	10.60	53.0	16.99	22-Mar

Table 8. Abundance of natural-origin fry and parr subyearling migrants of Green River Chinook, migration year 2000 to 2017.

	Fry Migrants			Parr Migrants		
	Migration		% of	Migration		% of
Trap Year	Interval	Abundance	Migration	Interval	Abundance	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	1/23-6/2	357,952	72.45%	1/23-7/14	134,785	27.55%
2014	1/01-5/11	319,241	80.49%	2/3-7/31	77,382	19.51%
2015	1/01-5/3	383,580	96.63%	2/2-7/31	13,364	3.37%
2016	1/01-5/8	21,285	37.20%	1/31-7/31	35,929	62.80%
2017	1/01-6/29	1,579,608	77.63%	1/28-7/31	455,253	22.37%

Table 9. Smolt to adult return (SAR) for adult Chinook in the Green River, brood years 2002-2012. Juvenile freshwater production and adult return estimates restricted to the area upstream from the smolt trap. Does not include age 2 (jack) returns.

Brood Year	Juvenile Freshwater Production	Age 3	Age 4	Age 5	Age 6	Total	Survival to return
2002	449,956	314	1,341	95	0	1,750	0.39%
2003	236,650	573	718	67	0	1,357	0.57%
2004	470,334	702	3,025	0	0	3,726	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	1,076	0.55%
2009	55,547	408	394	42	0	845	1.52%
2010	254,182	54	493	50	0	597	0.23%
2011	90,260	162	586	64	0	813	0.90%
2012	492,737	244	1314	89	0	1,647	0.33%

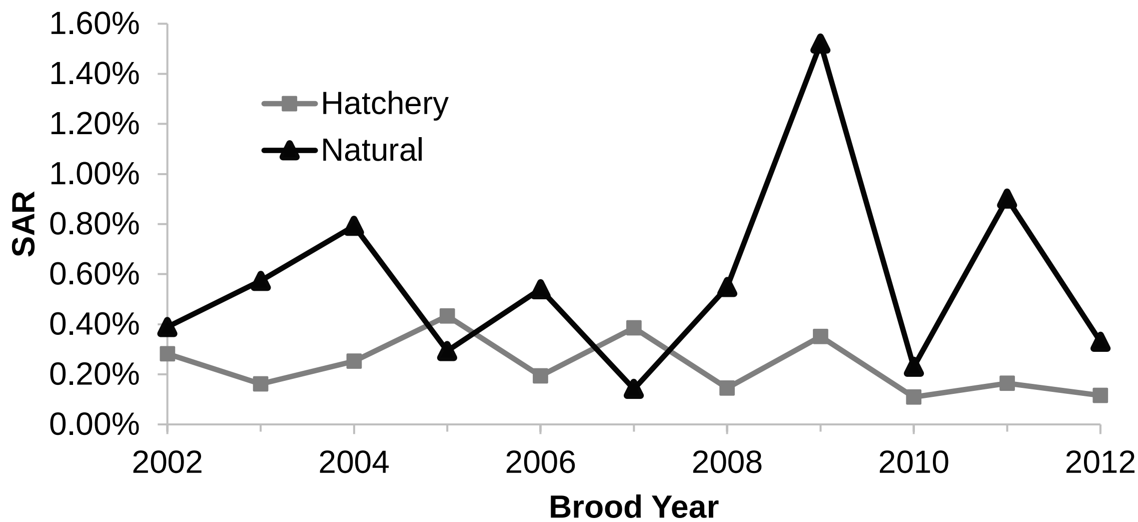

Figure 4. Smolt to adult return rate (SAR) of natural origin vs hatchery origin Chinook from the Green River, brood years 2002-2012. Does not include age 2 (jacks) returns or account for harvest.

Yearling Chinook

No natural-origin Chinook yearlings were captured. In total, 33 hatchery-origin yearling Chinook were captured (3 Ad-mark, 28 Ad-CWT and 2 CWT only).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}$ =1,560) included 1,347 captures in the trap and an estimated missed catch during trap outage periods of 213 fish. Coho smolts were captured throughout the season with individuals captured on both the first and last days of the season. (Table 8, Appendix D). In total, 6,868 hatchery coho were captured between February 15 and June 27 (6,175 Ad-mark and 693 Ad-CWT). Seventy efficiency trials were conducted over the trapping season. All efficiency trials were pooled to two strata with efficiencies of 1.54% and 3.57%.

We estimated a total of 79,491 ± 33,106 (95% C.I.) natural-origin coho smolts migrated past the screw trap (Table 10). Coefficient of variation for this estimate was 21.25%.

Table 10. Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2017. Release groups were pooled to form two strata. Missed catch and associated variance were calculated for periods that the trap did not fish.

			Catch				Abundance	
Strata	Date	Actual	Missed	Variance	Marked	Recaptured	Estimated	Variance
1	1/18-5/14	892	213	2.55E+03	976	15	67,474	2.77E+08
2	5/15-6/29	455	0	0	448	16	12,017	8.01E+06
Season Total		1,347	213	2.55E+03	1,424	31	79,491	2.85E+08

The median migration date for coho smolts was April 27. The first coho smolt was captured on January 18, our first day of trapping. Daily estimated migration of coho averaged 90 smolts per day through April 1 (Figure 5). Peak daily migration occurred on April 27 when 4,702 smolts were estimated to have passed the trap in a single night. Daily estimated migration declined gradually through May and early June. The last natural-origin coho smolt was captured on June 29, 2017.

The seasonal average length of coho smolts was 111.77 ± 14.6 mm FL (± 1 S.D), Appendix E). The weekly averages were smaller early in the season averaging 93.34 mm thru early April and increasing abruptly to average 115.66 mm thru May and decreasing in size through the remainder of the season (Figure 6, Appendix E).

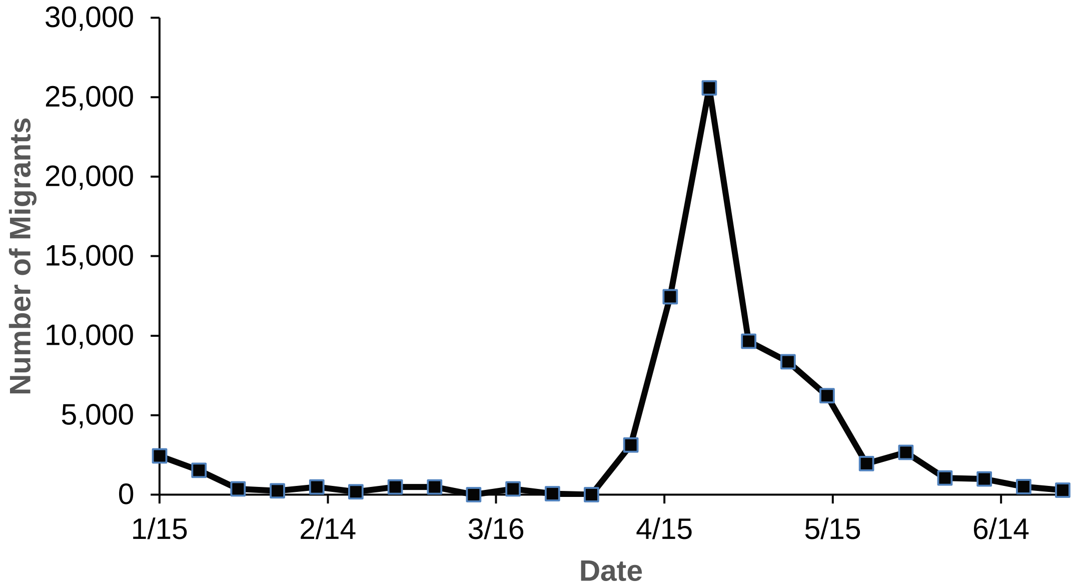

Figure 5. Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2017.

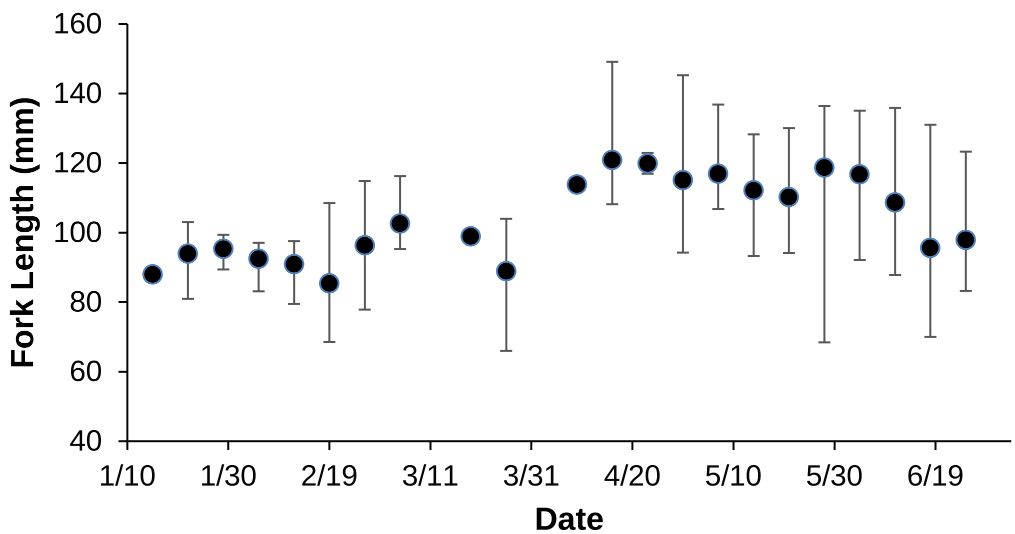

Figure 6. Fork length (mm) of natural-origin coho captured in the Green River screw trap in 2017. Data are mean, minimum, and maximum values by week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 698) included 670 captures in the trap and 28 missed catch estimated for trap outage periods (Table 11, Appendix D). In total, 602 (190 Ad-only, 327 CWT-only, 5 Ad-CWT and 80 unmarked) hatchery steelhead were captured between April 9 and June 22. Sixty three trap efficiency trials using natural origin steelhead were conducted over the trapping season with 599 marks released and 12 recovered. We estimated a total of 32,215 ± 16,861(95% C.I.) natural-origin steelhead smolts migrated past the screw trap (Table 11). Coefficient of variation for this estimate was 26.70%

Table 11. Catch, marked and recaptured fish, and estimated abundance of natural-origin steelhead smolts at the Green River screw trap in 2017. 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	1/18-6/29	670	28	5.89E+01	599	12	32,215	7.40E+07

The median migration date for steelhead smolts was May 22. The first natural-origin steelhead was captured on January 19. Daily estimated migration of steelhead averaged 24 smolts per day through April 1. Peak daily migration occurred on May 17 when 1,338 smolts were estimated to have passed the trap in a single night. Daily estimated migration declined gradually through June. The last natural-origin steelhead smolt was captured on June 27, 2017 (Figure 7).

Over the season, a total of 670 unmarked steelhead were measured (fork length), 100% of the total catch. Individuals ranged from 130 to 229 mm, and averaged 168.2 mm for the season (Figure 8).

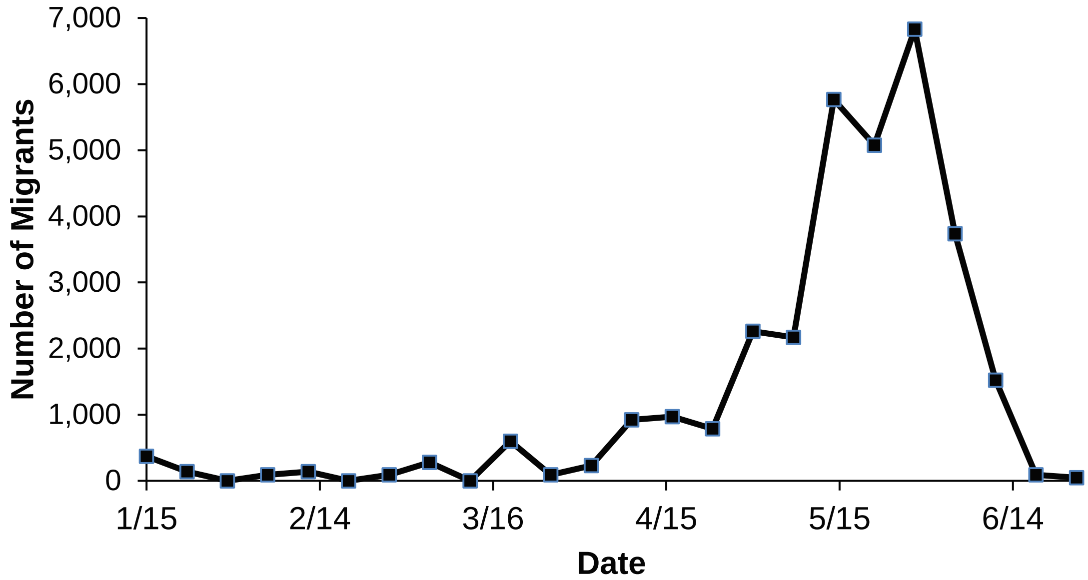

Figure 7. Weekly migration of natural-origin steelhead smolts rearing above the Green River screw trap in 2017.

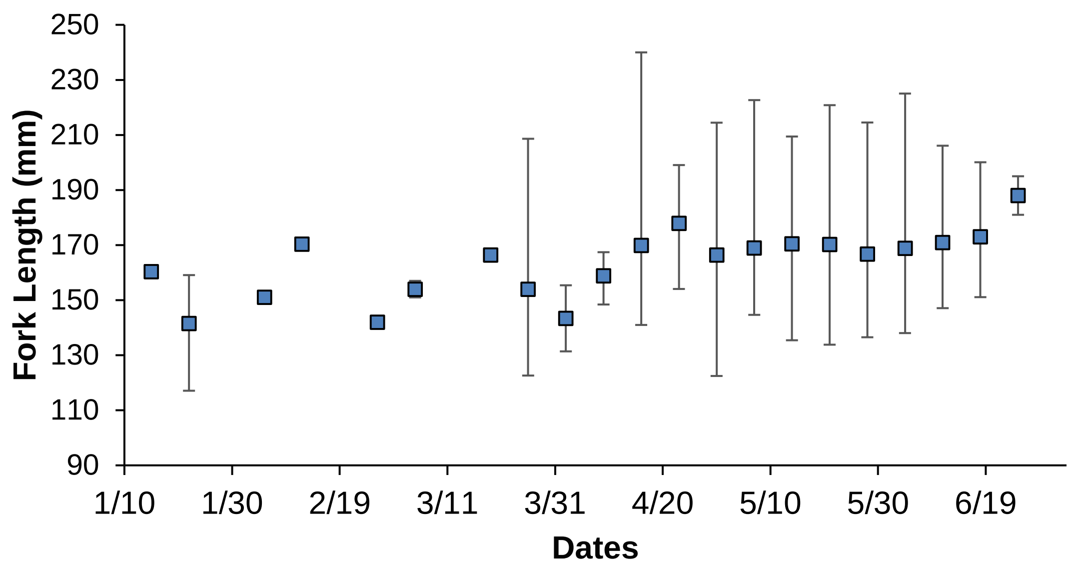

Figure 8. Fork length (mm) of natural-origin steelhead captured in the Green River screw trap in 2017. Data are mean, minimum, and maximum values by week in 2017.

Length samples were collected on 670 natural-origin steelhead smolts captured, scales, weights and DNA were collected on 100 individuals to determine the age structure and body size of natural-origin steelhead smolts. The sample included 87 readable and 13 regenerated or upside down samples (Table 12).

Table 12. Age, average length (mm) and average weight of natural-origin steelhead smolts collected at the Green River juvenile trap, migration years 2011-2017.

Smolt Age	1+			2+			3+			4+		
Year	Ave FL	%	Ave Wgt (g)	Ave FL	%	Ave Wgt (g)	Ave FL	%	Ave Wgt (g)	Ave FL	%	Ave Wgt (g)
2011	158.2	26%		180.1	67%		189.9	7%				
2012	158.6	53%		171.7	47%		206.5	1%				
2013	157.0	40%	39.8	177.0	59%	56.7	189.0	1%	78.8			
2014	161.4	61%	27.9	182.2	37%	41.2	211.1	1%	59.7	224.0	0%	101.3
2015	158.7	59%	40.1	185.8	38%	60.1	190.0	3%	78.5			
2016	164.6	37%	43.7	170.3	61%	49.8	188.1	2%	77.7	232.5	1%	124.4
2017	163.1	70%	46.4	186.7	29%	66.0	221.0	1%	93.4			

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$ =25,796) included 22,564 captures in the trap and 3,232 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between January 30 and June 25, 2017. Captured chum could not be separated into 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 2,126 coho fry, 40 sockeye fry, 419 trout parr, 50 cutthroat smolts and 30 trout fry (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 subyearling Chinook salmon, coho salmon, and steelhead trout smolts emigrating from the Green River in 2017. No natural-origin yearling Chinook smolts were captured. 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 2016 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 mainstream Green River below the trap was 294,580 and represented 12% of the total production compared to that directly measured from the Green River and tributaries above the trap was 2.034,861 (85%) and Big Soos Creek was 60,493 (3%).

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, starting in 2013 and continuing thru 2017, Big Soos Creek production was directly measured by the Muckleshoot Indian Tribe, substantially improving the quality of the basin-wide Chinook estimate. Comparisons of egg to migrant survive between the Green River above the trap and Soos Creek for the years that production was directly measured indicates that egg to migrant survival is much higher in Soos Creek that in the Green River. Several factors likely contribute to the higher survival. Soos Creek is lower gradient than the Green River reducing the amount of potential redd scour during periods of high water. The Soos Creek screw trap is located much closer to the spawning area, minimizing the distance and time the migrants have to travel before reaching the trap, reducing the potential for predation. Given these differences, only the years that were directly measured were included in the total basin production estimates (Table 6).

Identification of Species and Origin

The estimate of natural-origin Chinook production assumes that juvenile fish were correctly identified to species and origin. Hatchery origin Chinook salmon are typically identified by the presence of an adipose-mark or coded-wire tag, and unmarked fish are assumed to be natural origin. However, in 2014 and continuing thru 2017, the primary hatchery mark strategy for the Palmer Pond release was an internal thermal otolith mark, with a goal of 100% marking. None of the 2014-2017 Palmer Pond releases were ad-marked; only in 2014 did a portion of the release receive CWT. In 2017, the Palmer facility was assumed not to be fish tight when the fish were transferred to the facility in mid-March. Shortly after stocking the juvenile trap began capturing Chinook that were much larger than any previously captured prior to the stocking. Similar to 2016, we obtained an ESA take permit to allow the deliberate sacrifice of 30 unmarked subyearling Chinook for otolith analysis. Unlike 2016 when all the samples were collected on a single day (June 10th) and selecting only larger sized fish believed to be hatchery fish, we randomly selected the 30 fish over the course of the 2017 season. The 2016 samples results identified three marked hatchery fish an incidence of just 10%. The 2016 results demonstrated that size and appearance were not reliable indicators of hatchery origin. In 2017, we collected 156 fish (30 lethal, 126 incidental trap mortalities) for otolith assessment in 2017. The otolith sample results identified 118 natural and 38 hatchery origin, an incidence of 24% hatchery fish. Length measurement were taken on 150 of the 156 Chinook that were otolith sampled. The sample included 115 identified as natural and 35 as hatchery fish. The length samples were grouped by origin and statistical week for analysis. The hatchery fish were significantly larger than the natural fish in every week that contained both groups; the difference between the two groups ranged from 11mm to 36mm and averaged 21 mm larger over the entire period. In six of the ten weeks with samples in each group, we observed overlap in the range of lengths (Table 5).

Freshwater Production of Chinook Salmon

In total we estimated 2,013,346 natural and 88,790 hatchery Chinook migrating past the juvenile fish trap site during the trapping season. The abundant hatchery migration is notable because it occurred prior to intended hatchery release date. We believe the results from the otolith sampling does a fair job of estimating the number of otolith marked fish present in our catch because both the intentional 30 fish samples and the 126 mortalities were collected randomly over the entire period that hatchery fish where present in Palmer Pond upstream of the trap and not selected based on size or physical appearance.

The total estimated natural origin production for the entire Green River was 2,389,934 Chinook salmon (2,034,861 from above trap, 294,580 main-stem below the trap and 60,493 from Soos Creek) (Table 6). This production is by far the largest estimated in the 18 years of this project and exceeds the second highest estimated in 2001 by over a million fish. This large production can be attributed to the largest female spawning escapement estimated since the project inception (4,161 redds) and to moderate flow conditions during incubation, leading to highest estimated egg to migrant survival rate of 12.86%. Over the course of this study we have observed a downward trend in freshwater production which can be partially explained by a downward trend in chinook escapement. This trend was reversed for brood year 2016; the large number of redds estimated in 2016 produced the largest juvenile Chinook production we have measured (Figure 9).

Parr migrants were approximately 22.4% of the freshwater production above the Green River trap and the largest number of parr estimated by this 18 year project (Table 8). Parr production, which represents fish that have spent some time rearing in freshwater above the Green River trap, has ranged from 13,364 to 455,253 parr over eighteen years of this study. Parr rearing capacity may fluctuate among years according to biological (competitors, predators, spatial distribution of spawning sites) and environmental conditions (temperature, stream flow). The large parr production observed in 2017 is very similar to the number of parr estimated in 2001 (430,442) and may represent the maximum rearing potential for parr in the Green River above our trap site under the best possible set of conditions. In comparison, fry production, which represents juveniles emigrating from freshwater soon after emergence, has ranged from 6,000 to 1,579,608 fry. Thus, there is much greater fluctuation in fry abundance than parr abundance.

We likely over-estimated the proportion and abundance of natural-origin parr relative to natural origin fry due to the presence of hatchery-origin Chinook in the length only (no otolith) sample. We measured a total of 4,235 Chinook across the season for which we had no otolith mark data, and these samples were used to segregate fry from parr. Within the otolith sample, hatchery fish were consistently larger than natural origin fish, and no hatchery fish were detected in the fry size category (Table 5). The presence of hatchery fish in the length only sample likely increased the relative proportion of parr compared to fry. This issue was most problematic during mid-March and April, when both fry and parr were present in the catch (Figure 2) and hatchery fish composed approximately 20% of the parr catch (Table 4). During May, very few hatchery fish were present in the parr catch (approximately 3%) and during June, very few fry were present in the catch (Figure 2).

Yearling Chinook migrants appear to be a minor component of the outmigration and in some years undetectable with use of a partial capture screw trap. In 2017, we did not catch a single natural origin yearling. Our trap did encounter yearling hatchery-origin Chinook salmon, so the lack of natural-origin yearling Chinook salmon was not due to the inability of the fishing gear to capture them.

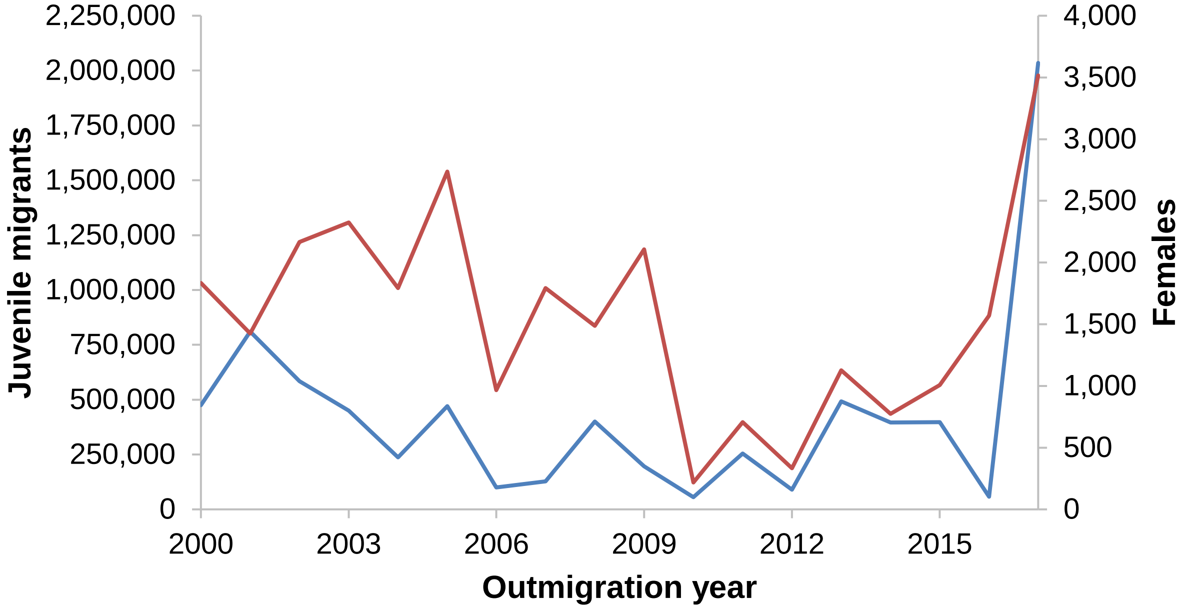

Figure 9. Number of unmarked natural origin subyearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (Red line) above the juvenile trap, outmigration year 2000-2017.

Freshwater Production of Coho Salmon

Freshwater production of coho smolts above the Green River trap has been estimated for 15 of the 18 years of this study (Table 13). The 2017 freshwater production estimate of 79,491 coho smolts is above the average of (64,405) observed over the last 9 consecutive years we have estimated natural coho smolt productions.

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.

Estimating the freshwater production of species with yearling migrants (i.e., coho and steelhead) has proven to be more challenging than for species with subyearling migrants (i.e., Chinook and pink). In general, larger body size of yearling migrants compared to subyearling 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. Over the last eight consecutive years we have been able to estimate coho production mainly because of the stability and consistency of the river channel at our trapping location. This location has provided a well-defined slot with good water velocities enabling the trap to capture enough coho smolts to generate these estimates.

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 coincides 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 the case for coho in 2017, as 12% of the total catch was estimated missed catch but not for the steelhead, as missed catch accounted for only 4% of the total natural origin steelhead catch. Virtually all of the estimated missed catch for coho occurred during the outages corresponding to hatchery fish release.

Table 13. 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 2000-2017.

	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	17.00%	99.5	12.76	5/12[a]
2003	207,442	67,404	347,480	34.40%	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	16.70%	106.9	16	5/15
2007	22,671	14,735	30,607	17.90%	111.6	11.34	5/7
2008	---	---	---	---	105.1	11.95	5/9[a]
2009	81,079	56,522	105,636	11.90%	103	10.9	5/5
2010	43,763	32,663	54,864	12.90%	115.9	11.21	5/8
2011	62,280	25,495	99,065	30.10%	109.4	11.4	5/7
2012	48,148	24,669	71,627	24.90%	106.1	12.68	5/7
2013	50,642	30,000	71,284	20.80%	103.5	16.75	5/9
2014	106,365	82,645	130,084	11.38%	104	13.13	5/11
2015	42,564	19,108	66,020	28.12%	104.9	11.76	5/2
2016	62,074	43,038	81,109	15.65%	113.8	11.04	4/29
2017	79,491	46,385	112,597	21.25%	111.8	14.60	4/27

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 6 of the 18 years of this study (Table 14). In 2017, steelhead smolts captured in the trap were similar in age as we observed in 2014. The percentage of age-1 smolts in 2017 was higher than observed in any other year and higher than would be expected based on typical 2-year smolt age for winter steelhead in western Washington rivers (Scott and Gill 2008). It is possible that the difference in age structure in 2014 resulted from the two year cycle in which Green River pink salmon are extremely abundant in odd years but absent in even years. In 2014, smolts had access to millions of pink salmon eggs the previous fall 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 2014. In addition to the 2017 steelhead production having the youngest migrant age, the smolts were larger at age (longer and heavier) than in previous years (Table 12). It is possible that the 2017 smolts benefited from the large increase in the chinook population observed in this year, similar to the pink effect mentioned above.

Table 14. 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 2000-2017.

	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	18.3	5/5
2015	---	---	---	---	168.7	19.00	5/08[a]
2016	32,936	8,606	57,266	37.69%	169.0	16.63	5/18
2017	32,215	15,354	49,077	26.70%	168.2	16.73	5/22

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

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

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

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

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

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

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

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

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

Appendix B

Daily catch and migration estimate for unmarked natural origin subyearling Chinook in the Green River, 2017.

APPENDIX B. — Actual and estimated daily catches and migration for unmarked natural origin subyearling Chinook migrants in the Green River, 2017. Migration estimate is based on daily catch adjusted by the trap efficiency and estimated number of otolith marked hatchery fish for each pooled time stratum.

	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			
Date	In	Out	Actual	Est	Total	Migration
1/1-1/17	Pre-Trapping					8,332
1/18/2017	4.00		29		29	516
1/19/2017	6.00	18.00	23	40	63	1,120
1/20/2017	24.00		59		59	1,049
1/21/2017	24.00		63		63	1,120
1/22/2017	25.00		54		54	960
1/23/2017	24.00		71		71	1,262
1/24/2017	24.00		69		69	1,227
1/25/2017	24.00		39		39	693
1/26/2017	24.00		66		66	1,173
1/27/2017	24.00		146		146	2,596
1/28/2017	24.00		79		79	1,404
1/29/2017	24.00		86		86	802
1/30/2017	24.00		130		130	1,212
1/31/2017	24.00		97		97	905
2/1/2017	24.50		390		390	3,637
2/2/2017	24.00		630		630	5,875
2/3/2017	24.00		413		413	3,851
2/4/2017	23.50		399		399	3,721
2/5/2017	24.50		1,197		1,197	48,098
2/6/2017	23.50		400		400	16,073
2/7/2017	24.00		198		198	7,956
2/8/2017	24.00		117		117	4,701
2/9/2017	16.00	8.00	533	89	622	24,993
2/10/2017		24.00		540	540	21,698
2/11/2017		23.00		529	529	21,256
2/12/2017	25.50		532		532	21,377
2/13/2017	24.00		345		345	13,863
2/14/2017	23.50		422		422	16,957
2/15/2017	24.00		418		418	16,796
2/16/2017	18.50	5.50	1,208	90	1,298	52,156
2/17/2017		24.00		984	984	39,539
2/18/2017	24.50		758		758	30,458
2/19/2017	24.00		447		447	17,961

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APPENDIX B.— continued.

	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			
Date	In	Out	Actual	Est	Total	Migration
2/20/2017	24.00		348		348	13,983
2/21/2017	23.50		332		332	13,340
2/22/2017	24.00		402		402	16,153
2/23/2017	24.00		131		131	5,264
2/24/2017	24.50		273		273	10,970
2/25/2017	24.50		135		135	5,425
2/26/2017	24.00		429		429	10,227
2/27/2017	24.00		328		328	7,820
2/28/2017	23.25		270		270	6,437
3/1/2017	24.25		60		60	1,430
3/2/2017	23.75		98		98	2,336
3/3/2017	24.00		107		107	2,551
3/4/2017	25.00		500		500	11,920
3/5/2017	23.75		154		154	3,671
3/6/2017	23.75		279		279	6,651
3/7/2017	23.75		280		280	6,675
3/8/2017	24.25		741		741	17,665
3/9/2017	23.75		185		185	4,410
3/10/2017	24.50		1,762		1,762	42,006
3/11/2017	24.25		803		803	19,144
3/12/2017	28.84		255	0	255	25,984
3/13/2017	21.50		447	0	447	45,533
3/14/2017		27.00	0	448	448	45,615
3/15/2017		24.00	0	390	390	39,669
3/16/2017		24.00	0	390	390	39,669
3/17/2017	6.75	17.50	17	312	329	33,478
3/18/2017	24.25		286	0	286	29,080
3/19/2017	24.25		605	0	605	61,580
3/20/2017	23.75		522	0	522	53,109
3/21/2017	22.75		262	0	262	26,717
3/22/2017	24.75		168	0	168	17,106
3/23/2017	23.50		114	0	114	11,567
3/24/2017	23.75		136	0	136	13,847
3/25/2017	25.50		141	0	141	14,336
3/26/2017	24.00		116	0	116	11,811
3/27/2017	24.25		210	0	210	21,423

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APPENDIX B.─ continued.

Date	Time Fished Hours In	Out	Unmarked Sub-yearling Chinook Catch Actual	Est	Total	Migration
3/28/2017	22.50		148	0	148	15,069
3/29/2017	24.00		186	0	186	18,979
3/30/2017	24.33		271	0	271	27,613
3/31/2017	24.17		190	0	190	19,305
4/1/2017	25.00		147	0	147	14,988
4/2/2017	24.00		209	0	209	21,260
4/3/2017	24.00		219	0	219	22,319
4/4/2017	22.25		154	0	154	15,721
4/5/2017	24.50		154	0	154	15,721
4/6/2017	23.75		166	0	166	16,943
4/7/2017	23.75		248	0	248	25,251
4/8/2017	26.25		168	0	168	17,106
4/9/2017	23.50		184	0	184	18,735
4/10/2017	24.00		146	0	146	14,825
4/11/2017	22.00		142	0	142	14,499
4/12/2017	25.50		183	0	183	18,653
4/13/2017	23.75		276	0	276	28,102
4/14/2017	16.25	7.50	103	73	176	17,920
4/15/2017		24.00	0	211	211	21,504
4/16/2017		24.00	0	211	211	21,504
4/17/2017	13.50	13.50	82	110	192	19,549
4/18/2017	12.00	0.00	90	84	174	17,676
4/19/2017	16.50	0.00	113	35	148	15,069
4/20/2017	23.50		221	0	221	22,482
4/21/2017	23.75		122	0	122	12,381
4/22/2017	26.25		105	0	105	10,671
4/23/2017	23.75		88	0	88	8,960
4/24/2017	24.00		106	0	106	10,834
4/25/2017	22.25		146	0	146	14,906
4/26/2017	24.00		182	0	182	18,490
4/27/2017	23.75		99	0	99	10,100
4/28/2017	25.25		102	0	102	10,345
4/29/2017	24.50		72	0	72	7,331
4/30/2017	23.50		127	0	127	6,162
5/1/2017	24.00		84	0	84	4,092
5/2/2017	22.75		108	0	108	5,268
5/3/2017	24.50		99	0	99	4,798

Table continued next page

APPENDIX B.─ continued.

	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			
Date	In	Out	Actual	Est	Total	Migration
5/4/2017	25.25		159	0	159	7,714
5/5/2017	13.75	9.75	1,088	45	1,133	55,081
5/6/2017		24.00	0	612	612	29,728
5/7/2017	24.00		106	0	106	5,174
5/8/2017	24.50		114	0	114	5,550
5/9/2017	22.50		107	0	107	5,221
5/10/2017	24.00		264	0	264	12,841
5/11/2017	24.75		144	0	144	7,009
5/12/2017	23.58		209	0	209	10,160
5/13/2017	26.67		221	0	221	10,725
5/14/2017	22.00		226	0	226	11,007
5/15/2017	24.50		175	0	175	8,514
5/16/2017	22.75		391	0	391	19,003
5/17/2017	24.25		360	0	360	17,498
5/18/2017	24.16		315	0	315	15,334
5/19/2017	24.00		178	0	178	8,655
5/20/2017	24.83		132	0	132	6,397
5/21/2017	24.00		106	0	106	5,174
5/22/2017	23.50		124	0	124	6,021
5/23/2017	23.50		188	0	188	9,125
5/24/2017	23.84		155	0	155	7,526
5/25/2017	24.50		196	0	196	9,549
5/26/2017	23.66		184	0	184	8,937
5/27/2017	25.00		174	0	174	8,467
5/28/2017	24.00		109	0	109	1,187
5/29/2017	24.17		183	0	183	1,986
5/30/2017	23.16		235	0	235	2,551
5/31/2017	23.92		289	0	289	3,142
6/1/2017	25.25		1,008	0	1,008	10,944
6/2/2017	22.67		113	0	113	1,230
6/3/2017	24.83		95	0	95	1,027
6/4/2017	23.25		61	0	61	658
6/5/2017	24.25		88	0	88	953
6/6/2017	23.25		37	0	37	406
6/7/2017	24.00		39	0	39	424
6/8/2017	24.00		35	0	35	381

Table continued next page

APPENDIX B.─ continued.

Date	Time Fished Hours In	Out	Unmarked Sub-yearling Chinook Catch Actual	Est	Total	Migration
6/9/2017	24.25		128	0	128	1,396
6/10/2017	23.75		134	0	134	1,451
6/11/2017	24.50		78	0	78	842
6/12/2017	24.00		58	0	58	627
6/13/2017	23.50		53	0	53	572
6/14/2017	24.25		76	0	76	830
6/15/2017	23.75		42	0	42	461
6/16/2017	24.50		198	0	198	2,146
6/17/2017	24.00		550	0	550	5,976
6/18/2017	24.50		202	0	202	2,189
6/19/2017	24.00		209	0	209	2,269
6/20/2017	23.00		126	0	126	1,371
6/21/2017	23.75		90	0	90	978
6/22/2017	24.25		71	0	71	775
6/23/2017	23.84		61	0	61	664
6/24/2017	13.17	12.00	52	4	55	603
6/25/2017	24.00		59	4	63	689
6/26/2017	23.50		57	0	57	615
6/27/2017	23.25		74	0	74	805
6/28/2017	24.25		97	0	97	1,057
6/29/2017	12.75		92	0	92	996
6/27-7/31	Post- Trapping					13,183
Total	3537.84	279.75	35,670	5,200	40,870	2,034,861

Appendix C

Fork length of non-externally marked subyearling Chinook in the Green River, 2017

APPENDIX C.─ Weekly mean fork length (mm), standard deviation (St. Dev.) range, and sample size of non-externally marked subyearling Chinook caught in the Green River screw trap in 2017.

Week				Range		Number		Percent
Begin	End	Average	St.Dev.	Min	Max	Sampled	Caught	Sampled
1/18/2017	1/21/2017	39.63	1.42	37	42	19	174	10.92%
1/22/2017	1/28/2017	40.33	2.57	37	50	27	524	5.15%
1/29/2017	2/4/2017	40.02	1.61	35	44	90	2,145	4.20%
2/5/2017	2/11/2017	40.14	1.63	35	45	199	2,445	8.14%
2/12/2017	2/18/2017	40.09	1.85	34	44	239	3,683	6.49%
2/19/2017	2/25/2017	40.70	2.04	36	46	149	2,068	7.21%
2/26/2017	3/4/2017	41.13	2.42	36	49	145	1,792	8.09%
3/5/2017	3/11/2017	40.76	2.00	35	48	414	4,204	9.85%
3/12/2017	3/18/2017	41.15	3.77	36	65	130	1,256	10.35%
3/19/2017	3/25/2017	42.26	5.28	31	62	274	2,434	11.26%
3/26/2017	4/1/2017	43.28	5.51	36	71	173	1,586	10.91%
4/2/2017	4/8/2017	43.43	4.63	37	67	154	1,649	9.34%
4/9/2017	4/15/2017	46.33	7.03	37	71	138	1,293	10.67%
4/16/2017	4/22/2017	49.46	9.20	36	80	117	915	12.79%
4/23/2017	4/29/2017	51.48	11.89	37	84	129	994	12.98%
4/30/2017	5/6/2017	51.04	11.51	36	80	126	1,720	7.33%
5/7/2017	5/13/2017	57.31	12.60	37	93	136	1,205	11.29%
5/14/2017	5/20/2017	57.78	12.29	37	94	188	1,837	10.23%
5/21/2017	5/27/2017	62.00	16.57	38	103	134	1,165	11.50%
5/28/2017	6/3/2017	64.51	15.56	42	110	391	3,589	10.89%
6/4/2017	6/10/2017	71.21	16.18	44	120	221	922	23.97%
6/11/2017	6/17/2017	74.72	16.34	43	118	260	1,863	13.96%
6/18/2017	6/24/2017	73.92	15.84	42	120	255	1,432	17.81%
6/25/2017	6/29/2017	78.55	14.76	55	121	127	670	18.96%
Season total		53.00	16.99	31	121	4,235	41,565	10.19%

Appendix D

Daily estimated catch of coho, chum and sockeye salmon, steelhead and cutthroat trout in the Green River, 2017

APPENDIX D.─ Daily estimated catches of coho, chum and sockeye salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2017. Catch represents actual and estimated catch for a given day. Time in and out reflect time fished (in) and not fished (out) on a given day.

			Coho			Chum	Sockeye	Steelhead		Cutthroat	Trout
Date	Times		Smolts		Fry	Fry	Fry	Smolts		Smolt	Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
1/18/2017	4.00		1	0	0	0	0	0	0	0	1
1/19/2017	6.00	18.00	13	0	0	0	0	3	0	2	26
1/20/2017	24.00		13	0	0	0	0	0	0	3	25
1/21/2017	24.00		13	0	0	0	0	5	0	0	27
1/22/2017	25.00		8	0	0	0	0	1	0	0	27
1/23/2017	24.00		1	0	0	0	1	2	0	0	8
1/24/2017	24.00		3	0	0	0	0	0	0	0	7
1/25/2017	24.00		4	0	0	0	0	0	0	0	7
1/26/2017	24.00		6	0	1	0	0	0	0	0	5
1/27/2017	24.00		3	0	0	0	0	0	0	0	3
1/28/2017	24.00		0	0	0	0	0	0	0	0	2
1/29/2017	24.00		0	0	0	0	0	0	0	0	5
1/30/2017	24.00		0	0	0	0	0	0	0	0	5
1/31/2017	24.00		1	0	0	0	0	0	0	0	5
2/1/2017	24.50		1	0	0	0	4	0	0	0	2
2/2/2017	24.00		1	0	0	0	0	0	0	0	0
2/3/2017	24.00		0	0	0	0	0	0	0	0	5
2/4/2017	23.50		3	0	0	0	0	0	0	0	4
2/5/2017	24.50		2	0	1	1	0	0	0	0	1
2/6/2017	23.50		0	0	0	0	0	0	0	0	4
2/7/2017	24.00		0	0	0	0	0	1	0	0	2
2/8/2017	24.00		2	0	0	0	0	1	0	0	2
2/9/2017	16.00	8.00	0	0	1	4	0	0	0	1	3
2/10/2017		24.00	0	0	1	3	0	0	0	1	2
2/11/2017		23.00	0	0	1	3	0	0	0	1	2
2/12/2017	25.50		1	0	0	4	0	0	0	0	2
2/13/2017	24.00		1	1	1	8	0	1	0	1	4
2/14/2017	23.50		1	0	0	1	0	1	0	0	9
2/15/2017	24.00		0	0	0	15	3	1	0	1	8
2/16/2017	18.50	5.50	0	0	0	81	1	0	0	1	4
2/17/2017		24.00	2	0	1	45	1	0	0	0	5
2/18/2017	24.50		3	0	1	14	1	0	0	0	5

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APPENDIX D.─ continued.

Date	Times		Coho			Chum	Sockeye	Steelhead		Cutthroat	Trout
			Smolts		Fry	Fry	Fry	Smolts		Smolt	Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
2/19/2017	24.00	0.00	1	0	3	46	1	0	0	0	5
2/20/2017	24.00		0	0	4	37	0	0	0	0	1
2/21/2017	23.50		0	0	4	42	0	0	0	0	0
2/22/2017	24.00		0	0	4	41	2	0	0	0	6
2/23/2017	24.00		1	0	0	21	0	0	0	0	12
2/24/2017	24.50		0	0	4	59	0	0	0	0	12
2/25/2017	24.50		1	0	4	74	2	0	0	0	11
2/26/2017	24.00		3	0	0	64	0	0	0	1	9
2/27/2017	24.00		0	0	4	46	0	0	0	0	6
2/28/2017	23.25		2	0	5	87	0	0	0	0	2
3/1/2017	24.25		0	0	5	89	2	0	0	1	2
3/2/2017	23.75		0	0	5	126	3	0	0	1	2
3/3/2017	24.00		3	0	8	272	3	2	0	0	3
3/4/2017	25.00		0	0	9	202	5	0	0	1	7
3/5/2017	23.75		0	0	4	156	0	0	0	0	7
3/6/2017	23.75		2	0	4	211	0	0	0	0	5
3/7/2017	23.75		0	0	3	256	0	1	0	0	3
3/8/2017	24.25		4	0	9	236	0	0	0	2	1
3/9/2017	23.75		0	0	10	289	1	1	0	1	0
3/10/2017	24.50		0	0	97	676	1	3	0	0	3
3/11/2017	24.25		2	0	34	216	1	1	0	0	6
3/12/2017	28.84		0	0	34	71	0	0	0	0	2
3/13/2017	21.50		0	0	32	98	0	0	0	0	1
3/14/2017		27.00	0	0	88	168	0	0	0	0	1
3/15/2017		24.00	0	0	73	148	0	0	0	0	0
3/16/2017		24.00	0	0	73	148	0	0	0	0	0
3/17/2017	6.75	17.50	0	0	79	165	0	0	0	0	0
3/18/2017	24.25		0	0	114	185	0	0	0	0	0
3/19/2017	24.25		0	0	181	312	0	1	0	0	2
3/20/2017	23.75		0	0	115	137	0	0	0	0	2
3/21/2017	22.75		1	0	86	131	0	2	0	1	3
3/22/2017	24.75		1	0	60	139	1	3	0	0	4

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APPENDIX D.─ continued.

Date	Times		Coho			Chum	Sockeye	Steelhead		Cutthroat	Trout
			Smolts		Fry	Fry	Fry	Smolts		Smolt	Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
3/23/2017	23.50		1	0	24	79	0	3	0	0	5
3/24/2017	23.75		1	0	42	132	0	1	0	0	4
3/25/2017	25.50		2	0	43	208	0	3	0	0	7
3/26/2017	24.00		0	0	21	115	0	0	0	0	6
3/27/2017	24.25		1	0	18	136	0	0	0	0	5
3/28/2017	22.50		0	0	37	131	0	0	0	0	0
3/29/2017	24.00		0	0	62	109	0	0	0	0	1
3/30/2017	24.33		0	0	63	186	0	1	0	0	3
3/31/2017	24.17		0	0	50	179	0	1	0	0	1
4/1/2017	25.00		0	0	69	139	0	0	0	0	1
4/2/2017	24.00		0	0	26	144	1	0	0	0	3
4/3/2017	24.00		0	0	34	177	2	0	0	0	2
4/4/2017	22.25		0	0	18	110	2	2	0	0	1
4/5/2017	24.50		0	0	21	304	0	0	0	0	2
4/6/2017	23.75		0	0	32	524	0	0	0	0	2
4/7/2017	23.75		0	0	30	1,273	1	2	0	0	4
4/8/2017	26.25		0	0	30	470	2	1	0	0	3
4/9/2017	23.50		3	0	19	465	0	2	1	0	0
4/10/2017	24.00		0	0	10	348	0	1	1	0	2
4/11/2017	22.00		5	0	7	313	0	6	4	0	6
4/12/2017	25.50		5	0	12	1,248	0	3	0	0	9
4/13/2017	23.75		4	1	14	2,601	0	0	0	0	7
4/14/2017	16.25	7.50	7	498	5	860	0	4	2	1	4
4/15/2017		24.00	27	395	8	729	0	4	13	0	3
4/16/2017		24.00	27	395	8	729	0	4	13	0	3
4/17/2017	13.50	13.50	28	414	11	485	0	4	33	0	3
4/18/2017	12.00	0.00	20	168	7	311	0	3	9	0	1
4/19/2017	16.50	0.00	22	4,443	6	846	0	0	168	0	6
4/20/2017	23.50		30	412	10	320	0	5	29	0	2
4/21/2017	23.75		29	348	1	137	0	4	26	1	3
4/22/2017	26.25		48	263	4	146	0	2	11	0	0
4/23/2017	23.75		47	28	4	68	0	4	5	1	1
4/24/2017	24.00		67	197	4	191	1	1	4	1	0
4/25/2017	22.25		57	116	8	2,575	0	2	9	0	2

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APPENDIX D.─ continued.

Date	Times		Coho Smolts		Coho Fry	Chum Fry	Sockeye Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
4/26/2017	24.00		59	129	7	1,233	0	3	1	1	1
4/27/2017	23.75		77	189	3	410	0	0	3	0	1
4/28/2017	25.25		64	131	3	226	0	2	6	1	1
4/29/2017	24.50		48	47	1	51	0	5	3	2	1
4/30/2017	23.50		21	188	1	161	0	2	14	0	0
5/1/2017	24.00		28	166	0	71	0	1	3	0	1
5/2/2017	22.75		16	143	1	39	0	3	5	0	0
5/3/2017	24.50		24	85	0	142	0	4	1	0	2
5/4/2017	25.25		36	125	0	75	0	10	20	1	1
5/5/2017	13.75	9.75	20	71	8	120	0	18	3	0	1
5/6/2017		24.00	13	42	4	83	0	10	1	0	1
5/7/2017	24.00		5	12	0	25	0	3	0	0	2
5/8/2017	24.50		2	2	4	10	0	1	2	0	0
5/9/2017	22.50		7	5	6	13	0	1	1	0	0
5/10/2017	24.00		52	4	1	35	0	12	5	0	2
5/11/2017	24.75		29	36	19	39	0	4	5	2	2
5/12/2017	23.58		19	25	0	31	0	9	9	0	0
5/13/2017	26.67		23	2	2	486	0	17	10	2	1
5/14/2017	22.00		27	36	2	132	0	12	17	0	1
5/15/2017	24.50		18	27	8	32	0	10	9	1	1
5/16/2017	22.75		32	2	4	39	0	17	9	1	0
5/17/2017	24.25		33	14	8	19	0	29	11	0	1
5/18/2017	24.16		41	5	4	14	0	18	13	0	0
5/19/2017	24.00		30	25	6	12	0	21	13	2	0
5/20/2017	24.83		19	12	3	9	0	18	13	0	0
5/21/2017	24.00		16	8	0	6	0	21	13	1	0
5/22/2017	23.50		18	7	16	3	0	24	11	1	2
5/23/2017	23.50		3	3	24	13	0	19	12	0	0
5/24/2017	23.84		12	5	8	5	0	10	10	0	1
5/25/2017	24.50		2	3	7	5	0	1	3	0	0
5/26/2017	23.66		5	1	6	4	0	10	8	0	1
5/27/2017	25.00		18	7	15	9	0	25	14	0	0
5/28/2017	24.00		7	5	51	7	0	18	10	1	0
5/29/2017	24.17		8	5	81	6	0	18	10	0	0

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APPENDIX D.– continued.

Date	Times In	Times Out	Coho Smolts Nat	Coho Smolts Hat	Coho Fry Total	Chum Fry Total	Sockeye Fry Nat	Steelhead Smolts Nat	Steelhead Smolts Hat	Cutthroat Smolt Nat	Trout Parr Nat
5/30/2017	23.16		12	7	28	0	0	25	10	0	0
5/31/2017	23.92		19	11	40	5	0	28	23	0	0
6/1/2017	25.25		16	3	23	10	0	17	12	0	0
6/2/2017	22.67		23	2	10	8	0	18	6	0	1
6/3/2017	24.83		16	5	7	4	0	24	9	4	0
6/4/2017	23.25		5	5	15	12	0	10	5	0	0
6/5/2017	24.25		5	7	15	86	0	19	11	0	0
6/6/2017	23.25		5	7	6	39	0	17	2	0	0
6/7/2017	24.00		5	1	4	46	0	16	9	0	0
6/8/2017	24.00		6	5	3	12	0	2	4	0	0
6/9/2017	24.25		10	9	9	37	0	9	9	1	0
6/10/2017	23.75		4	1	9	12	0	8	0	0	1
6/11/2017	24.50		6	2	1	7	0	13	1	0	0
6/12/2017	24.00		6	4	7	1	0	5	3	0	0
6/13/2017	23.50		3	5	4	4	0	5	6	1	0
6/14/2017	24.25		10	4	5	5	0	1	2	1	2
6/15/2017	23.75		1	1	7	1	0	2	3	1	3
6/16/2017	24.50		6	8	5	18	0	3	1	0	0
6/17/2017	24.00		5	7	13	5	0	4	3	1	0
6/18/2017	24.50		0	3	6	1	0	1	1	0	0
6/19/2017	24.00		3	5	7	0	0	0	0	0	0
6/20/2017	23.00		3	2	3	0	0	0	0	2	0
6/21/2017	23.75		4	2	3	0	0	1	0	1	0
6/22/2017	24.25		6	0	5	0	0	0	1	0	0
6/23/2017	23.84		1	1	1	0	0	0	0	0	0
6/24/2017	13.17	12.00	2	3	1	0	0	0	0	0	0
6/25/2017	12.00	12.00	3	0	3	1	0	0	0	1	0
6/26/2017	23.50		2	1	4	0	0	0	0	0	0
6/27/2017	23.25		2	3	0	1	0	1	0	2	0
6/28/2017	24.25		1	0	1	0	0	0	0	0	1
6/29/2017	12.75		3	0	1	1	0	0	0	0	0
Total	3537.84	279.75	1,560	9,360	2,470	25,796	42	698	717	54	469

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2017

APPENDIX E.—Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2017.

Dates		Sample results						
Start	End	Average	StdDev	Min	Max	Count	Catch	% sampled
1/15/2017	1/21/2017	88.00	7.80	75	97	6	27	22.22%
1/22/2017	1/28/2017	94.00	4.38	88	98	6	25	24.00%
1/29/2017	2/4/2017	95.40	5.55	86	100	5	6	83.33%
2/5/2017	2/11/2017	92.50	8.27	81	99	4	4	100.00%
2/12/2017	2/18/2017	91.00	16.71	74	114	4	6	66.67%
2/19/2017	2/25/2017	85.50	26.16	67	104	2	3	66.67%
2/26/2017	3/4/2017	96.38	8.16	89	110	8	8	100.00%
3/5/2017	3/11/2017	102.63	16.44	75	128	8	8	100.00%
3/12/2017	3/18/2017		No sample					
3/19/2017	3/25/2017	99.00	12.57	76	114	6	6	100.00%
3/26/2017	4/1/2017	89.00	na	89	89	1	1	100.00%
4/2/2017	4/8/2017		No sample					
4/9/2017	4/15/2017	113.88	9.50	101	142	16	24	66.67%
4/16/2017	4/22/2017	121.00	3.00	118	124	3	48	6.25%
4/23/2017	4/29/2017	119.95	10.46	99	150	57	419	13.60%
4/30/2017	5/6/2017	115.21	16.33	105	135	53	143	37.06%
5/7/2017	5/13/2017	117.02	8.56	98	133	47	137	34.31%
5/14/2017	5/20/2017	112.26	9.73	96	132	39	200	19.50%
5/21/2017	5/27/2017	110.32	13.25	60	128	25	74	33.78%
5/28/2017	6/3/2017	118.75	10.57	94	137	28	101	27.72%
6/4/2017	6/10/2017	116.81	15.16	96	144	16	40	40.00%
6/11/2017	6/17/2017	108.69	17.69	83	144	13	37	35.14%
6/18/2017	6/24/2017	95.71	10.94	81	121	14	19	73.68%
6/25/2017	7/1/2017	98.00	7.07	90	112	8	11	72.73%
Season total		111.77	14.60	15	150	369	1,347	27.39%

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