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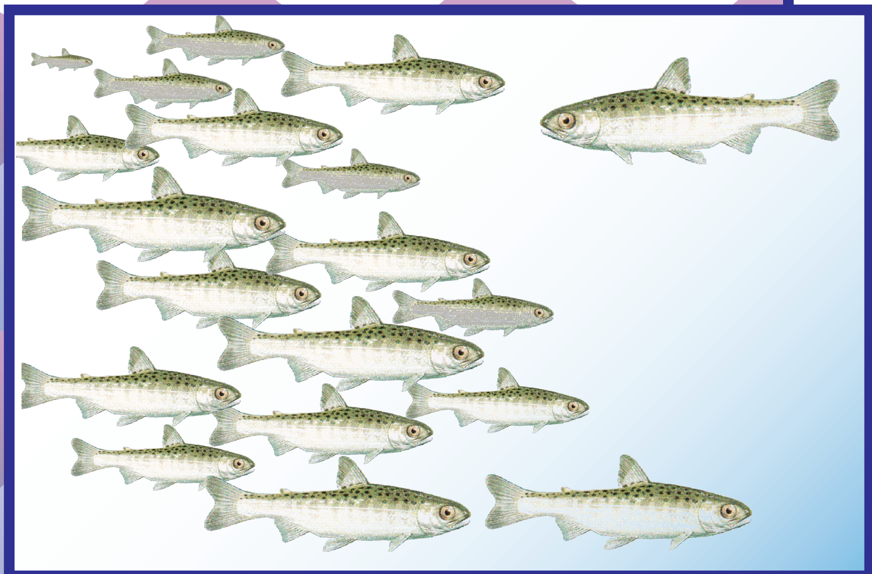
Green River Juvenile Salmonid Production Evaluation: 2015 Annual Report



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Fish and Wildlife
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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 2015.

Table of Contents

List of Tables

List of Figures

Executive Summary

This report provides the 2015 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 14 through June 22, 2015. During this period, the trap fished 90% of the time. We estimated the freshwater production (juvenile abundance) of Chinook (subyearling) and coho (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 2015. 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	6,826	396,944 (13.60%)	45.41 (± 14.60)	7-Feb
Chinook – Yrlg	0			
Coho – Yrlg	745	42,564 (27.7%)	104.9(± 11.7)	2-May
Steelhead – Smolt	97		168.7(±19.1)	9-May [a]
Chum	101,452 [b]			31-Mar [a]

[a] These are median catch dates which are not adjusted for trap efficiency and therefore serves as an index of migration timing.
[b] 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 2015 outmigration (2014 brood) was estimated to be 8.75%, yielding a basin-wide production estimate of 506,060 juveniles. Included in this estimate was an estimate of 76,037 Chinook migrating from Big Soos Creek with an egg-to-migrant survival of 13.20%. 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, however very few migrants remained in the system above the trap site to migrate as parr in 2015. The fry (≤45 mm fork length) represented 97% of all subyearling migrants and peaked in early February, parr migrants (>45 mm fork length) represented 3% of the migration and were observed during several periods: first in February and the typical peak in late May.

Introduction

This report provides the 2015 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 2015 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 2015, the trap operated between January 14 and June 22 for a total of 3,434 of 3,811 possible hours (90% of the time). Over the course of the season, trapping was suspended 24 times; the duration of outages ranged from 5.0 to 69.5 hours. Trapping was suspended once for high water, twice for trap repair, four times for hatchery fish releases and 17 times during day time periods late in the trapping season when catches were low and recreational use of the river was high.

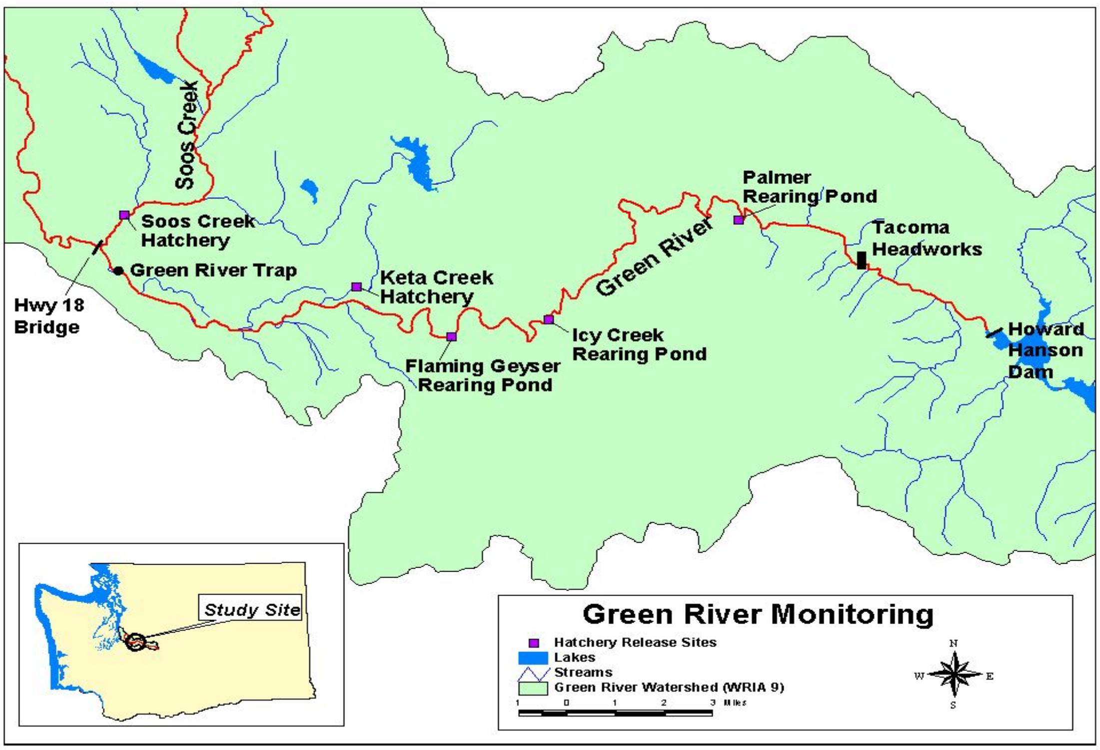

Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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 13%.

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) 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 2015 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 unmarked subyearling hatchery Chinook were volitionally released from Palmer rearing ponds starting on June 23rd, after 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.

Table 2. Number of hatchery fish by mark type released above the Green River screw trap in 2015. 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	2014	Palmer Pond				1,105,000
Chinook – Yrlg	2013	Icy Creek	101,945		186,088	
Coho – Yrlg	2013	Keta Creek	52,947		483,752	12,166
Chum - Subyrlg	2014	Keta Creek				2,796,154
Summer steelhead	2014	Icy Creek			41,600	
Winter Steelhead	2014	Icy Creek		6,716		

Trap Efficiency Trials

Trap efficiency trials were conducted for Chinook, coho, and steelhead with maiden-caught fish of natural origin throughout the season. Captured fish were anesthetized with tricaine methanesulfonate (MS-222) and marked with either Bismarck-brown dye or a partial caudal fin clip. Small Chinook (January to early-May) were marked with Bismarck Brown dye, whereas the large Chinook parr, coho, and steelhead were marked with a partial caudal fin clip. The fin clip position alternated between upper and lower caudal fin in order to check for delayed migration of marked fish. After recovery in freshwater for the day, marked fish were released at 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, located 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 (α = 0.05). Trials that did not differ were pooled and the pooled group compared to the next adjacent efficiency trial. Trials that did differ were held separately. Pooling of time-adjacent efficiency trials continued iteratively until the *seen:unseen* ratio differed between time-adjacent trials. Once a significant difference is identified, the pooled trials are assigned to one strata and the significantly different trial is the beginning of the next stratum.

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

Equation 5

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

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

Equation 6

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

(4) Extrapolated migration. Migration outside the trapping period ($\hat{N}_e$) was estimated based on an assumed number of days (*t*) outside the trapping period that the migration 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 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 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. 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, 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 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, 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 ($\hat{u}$ = 6,927) included 6,826 captures in the trap and an estimated missed catch during trap outage periods of 101 (Table 3, Appendix B). In 2015, the hatchery origin Chinook fry released from Palmer Pond were otolith marked but not adipose fin clipped (ad-marked), or Coded Wire Tagged (CWT). The volitional release was started on June 22nd, the same day 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 some hatchery fish were escaping. The technicians working the trap visually identified 101 unmarked untagged hatchery origin Chinook in our catch for the season. (Table 2, Appendix B).

We conducted a total of 87 efficiency trials with release numbers ranging between 2 and 298 fish and used a total of 8,968 fish (4,773 natural-origin Chinook and 4,195 chum). Chinook fry were exclusively used from the start of the season thru April 5th when maiden catch of natural-origin Chinook fry became too low to supply adequate numbers for efficiency trials. From April 6th thru the end of the season paired releases of Chinook and chum fry were performed. The paired releases were compared using the *G*-test and found to be statistically similar so the releases were combined. Efficiency releases were performed from two locations, the first was the traditional site 150 m 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 17 groups prior to stratification. The *G*-test pooled the 17 groups into 7 strata, with trap efficiencies ranging between 1.3% and 10.9% (Table 3).

The trapping season of January 14 through June 22 encompassed the majority of the subyearling Chinook migration. A total of 378,148 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 18,384 Chinook were estimated to have migrated prior to the trapping season and 412 migrants were estimated following the trapping season. This extrapolation assumed migration began January 1 and ended July 31, 2015.

A total of 396,944 ± 105,997 (±95% C.I.) subyearling Chinook of natural origin were estimated to have migrated past the screw trap between January 1 and July 31, 2015. Coefficient of variation for this estimate was 13.60%.

Table 3. Catch, marked and recaptured fish, and estimated abundance of subyearling Chinook migrants at the Green River screw trap in 2015. 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	1/1-1/13		255				18,384	7.73E+03
1	1/14-2/15	4,239	64	494.8351	2,380	32	310,468	2.82E+09
2	2/16-3/8	1,542	0	0	1,540	87	27,003	8.17E+06
3	3/9-4/5	765	11	3.86E+00	648	13	35,973	8.59E+07
4	4/6-4/12	12	0	0.00E+00	802	39	241	5.83E+03
5	4/13-4/26	25	0	0.00E+00	1,196	130	228	2.20E+03
6	4/27-5/24	165	26	1.07E+02	1,945	111	3,319	1.78E+05
7	5/25-6/22	78	0	0.00E+00	457	38	916	2.88E+04
After	6/23-7/31		35				412	9.13E+01
Season Total		6,826	391	1.11E+02	8,968	450	396,944	2.91E+09

Freshwater productivity of natural-origin Chinook for brood year 2014 was estimated to be 394 juveniles per female and an egg-to-migrant survival of 8.75%. This calculation was based on the number of subyearling Chinook passing the trap ($\hat{N}_T$ = 396,944), 1,008 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 4,536,000 eggs.

Basin-wide abundance of subyearling natural-origin Chinook was estimated to be 506,060 juvenile migrants. This included 396,944 migrants from above the trap, 33,079 juveniles from the main stem below the trap and 76,037 from Big Soos Creek. The above trap estimate is approximately 50,000 fish above the average since 2000 and about 125,000 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 fourth 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 main stem trap to estimated egg deposition above the hatchery rack (trap years 2004 – 2012). Only in trap years 2000 (operated by WDFW) and 2013-2015 (operated by the Muckleshoot Indian Tribe) was Chinook production from Big Soos Creek measured directly with a 5 foot Screw trap. 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 reducing 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 productions estimates represented in (Table 4).

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)

Trap	Above Trap				Below Trap			Soos Creek			Total Green
Year	Redds	Deposition	Production	Survival	Redds	Deposition	Production	Females	Deposition	Production	Production
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
2001	1,425	6,412,500	809,616	12.63%	936	4,212,000	531,790	1,580	7,110,000		1,341,406
2002	2,167	9,751,500	584,151	5.99%	480	2,160,000	129,392	995	4,477,500		713,543
2003	2,324	10,458,000	449,956	4.30%	2,314	10,413,000	448,020	1,239	5,575,500		897,976
2004	1,793	8,068,500	236,650	2.93%	1,038	4,671,000	137,001	720	3,240,000		373,651
2005	2,738	12,321,000	470,334	3.82%	827	3,721,500	142,062	623	2,803,500		612,396
2006	966	4,347,000	99,796	2.30%	82	369,000	8,471	598	2,691,000		108,267
2007	1,792	8,064,000	127,491	1.58%	883	3,973,500	62,821	313	1,408,500		190,312
2008	1,486	6,687,000	400,763	5.99%	438	1,971,000	118,125	676	3,042,000		518,888
2009	2,107	9,481,500	196,118	2.07%	282	1,269,000	26,248	504	2,268,000		222,366
2010	218	981,000	55,547	5.66%	57	256,500	14,524	759	3,415,500		70,071
2011	706	3,177,000	254,182	8.00%	71	319,500	25,562	461	2,074,500		279,744
2012	333	1,498,500	90,260	6.02%	19	85,500	5,150	190	855,000		95,410
2013	1,127	5,071,500	492,737	9.72%	109	490,500	47,656	682	3,069,000	468,119	1,008,512
2014	774	3,483,000	396,623	11.39%	43	193,500	22,035	149	670,500	101,748	520,406
2015	1,008	4,536,000	396,944	8.75%	84	378,000	33,079	128	576,000	76,037	506,060

The median migration date for subyearling Chinook was on February 7. Timing of the outmigration was much earlier than observed in any previous year of the study with 95% of the migration passing the trap by March 15th (Table 5, Figure 2). The fry migration peaked in early February corresponding to an increase in flow. A second much smaller fry migration peak occurred in mid-March closer to the typical fry migration peak timing. The parr migrants peaked three times with the two largest occurring at the same time as the two fry migrant peaks, and the smallest parr peak occurred in mid-May closer to the typical parr migration peak timing. An estimated 97% (383,580) of the Chinook migrated as fry and 3% (13,364) migrated as parr. The migration periods of fry and parr overlapped between early February and early May.

Parr migrants were approximately 3.4% of the freshwater production above the Green River trap, which is far lower than the previous low of 8% observed in 2003 (Table 6). Parr production, which represents fish that have spent some time rearing in freshwater above the Green River trap, has ranged 32-fold (13,364 to 430,000 parr) over sixteen 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.

The seasonal average length of subyearling Chinook was 45.41 ± 14.60 mm FL (± 1 S.D.; Appendix C). The weekly average lengths of the subyearling Chinook showed little increase (approximately 6 mm) during the early portion of the season, (January 15- April 19). Chinook subyearling body size increased substantially thru the end of trapping season (April 20-June 22), averaging a 5 mm FL increase per week. The largest size increase occurred between April 20 and May 17 with an average weekly size increase of 8.8 mm (Figure 3, Appendix C).

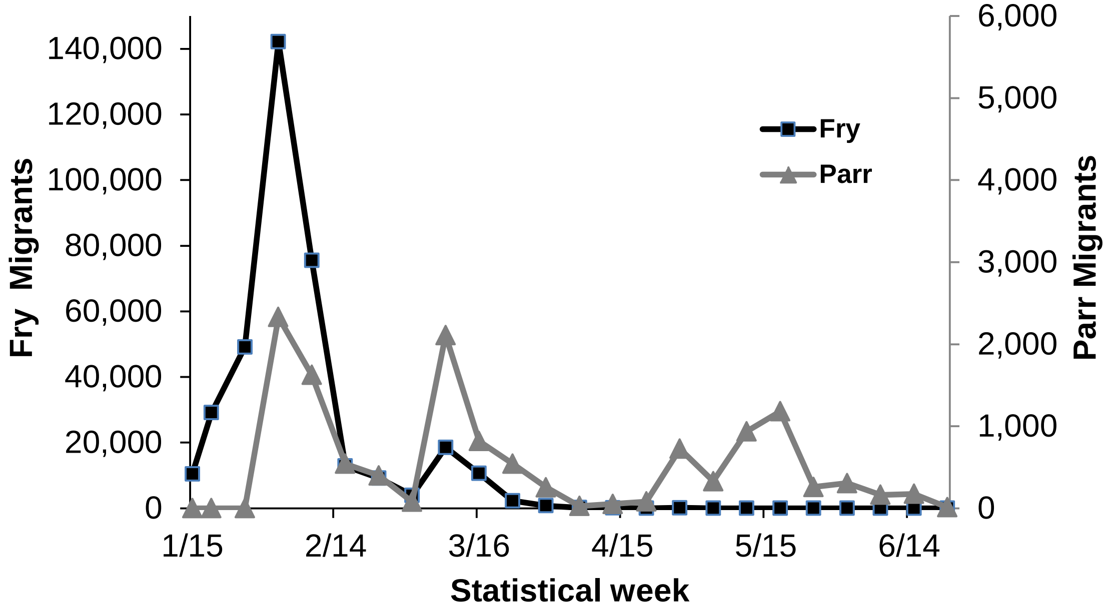

Figure 2. Weekly migration of subyearling Chinook migrants of natural-origin at the Green River screw trap in 2015. Subyearling migrants are partitioned into two freshwater rearing strategies fry (<45-mm FL) and parr (> 45-mm FL) migrants.

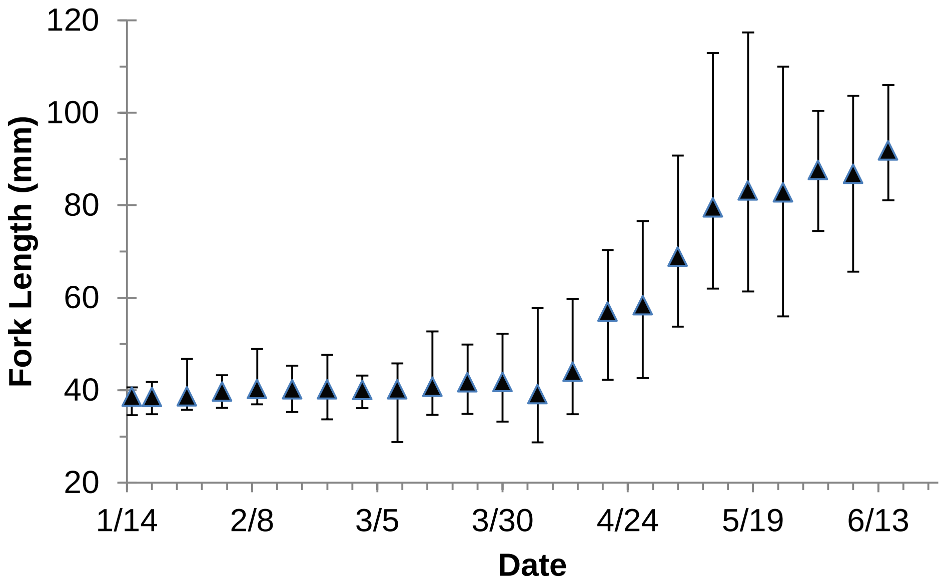

Figure 3. Fork length (mm) of subyearling Chinook migrants of natural origin captured in the Green River screw trap in 2015. Data are mean, minimum, and maximum values.

Table 5. 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 2000-2015.

	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	45.41	14.60	7-Feb

Table 6. Abundance of natural-origin fry and parr subyearling migrants of Green River Chinook, migration year 2000 to 2015.

	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	1/23-6/2	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%

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 2010 (Table 7). Natural origin juveniles survived at a higher rate seven out of nine years than hatchery origin non-ad marked CWT juveniles released from Soos Creek Hatchery (Figure 4). 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 7. Smolt to adult return (SAR) for adult Chinook in the Green River, brood years 2002-2010. 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%

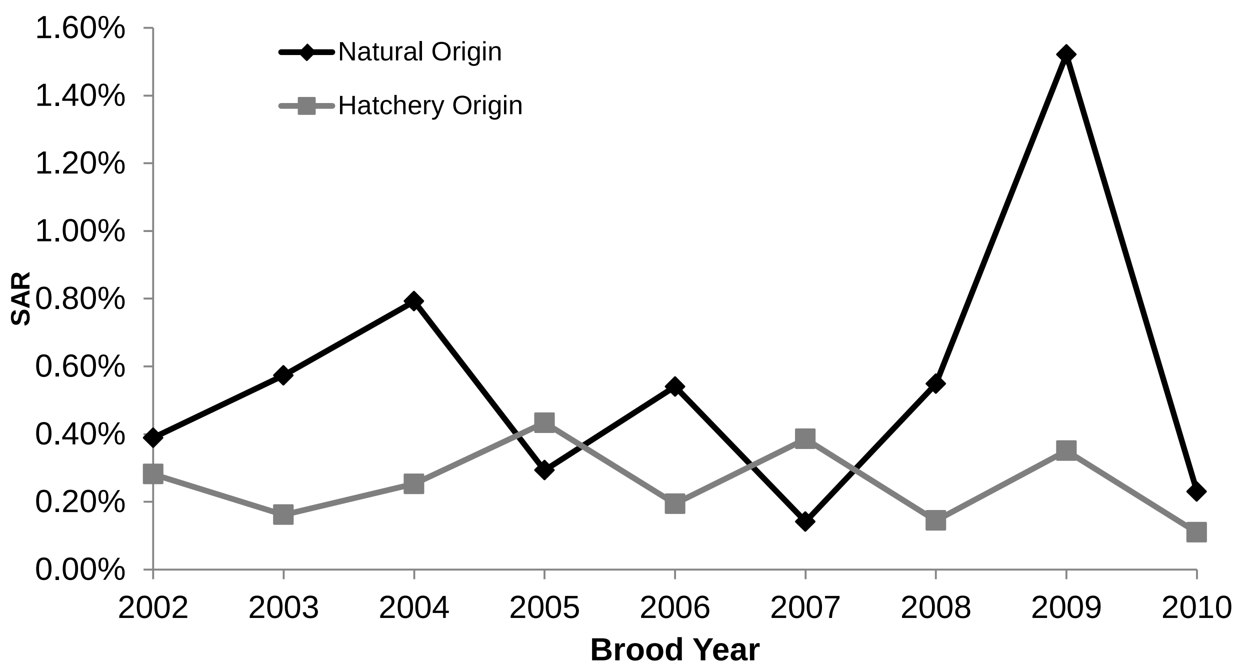

Figure 4. Smolt to adult return rate (SAR) of natural origin vs hatchery origin Chinook from the Green River, brood years 2002-2010. Does not include age 2 (jacks) returns or account for harvest.

Yearling Chinook

No natural-origin Chinook yearlings were captured. In total, 622 hatchery-origin yearling Chinook were captured (477 Ad-mark and 145 Ad-CWT).

Coho Smolts

The total estimated catch of natural-origin coho smolts ($\hat{u}$ =917) included 746 captures in the trap and an estimated missed catch during trap outage periods of 171 fish. Coho smolts were captured between January 15 and June 16 (Appendix D). In total, 1,479 hatchery coho were captured between March 30 and June 18 (1,284 Ad-mark and 195 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 1.98%.

We estimated a total of 42,564 ± 23,456 (95% C.I.) natural-origin coho smolts migrated past the screw trap. Coefficient of variation for this estimate was 28.12% (Table 8).

Table 8. Catch, marked and recaptured fish, and estimated abundance of natural-origin coho smolts at the Green River screw trap in 2015. 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	1/15-6/16	746	171	2.19E+03	556	11	42,564	1.43E+08

The median migration date for coho smolts was May 3. The first coho smolt was captured on January 15, our first day of trapping. Daily estimated migration of coho was low and averaged 31 smolts per day through April 1 (Figure 5). Peak daily migration occurred on April 29 when 4,178 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 16, 2015.

The seasonal average length of coho smolts was 104.9 ± 11.7 mm FL (± 1 S.D.; Appendix E). The weekly averages were smaller early in the season averaging 91 mm thru March and increasing in size thru the remainder of the season averaging 107 mm (Figure 6).

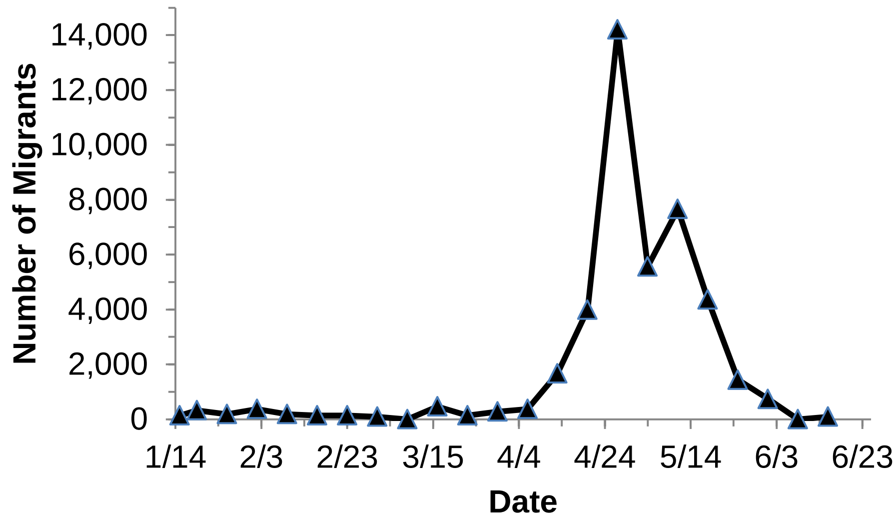

Figure 5. Weekly migration of natural-origin coho smolts rearing above the Green River screw trap in 2015.

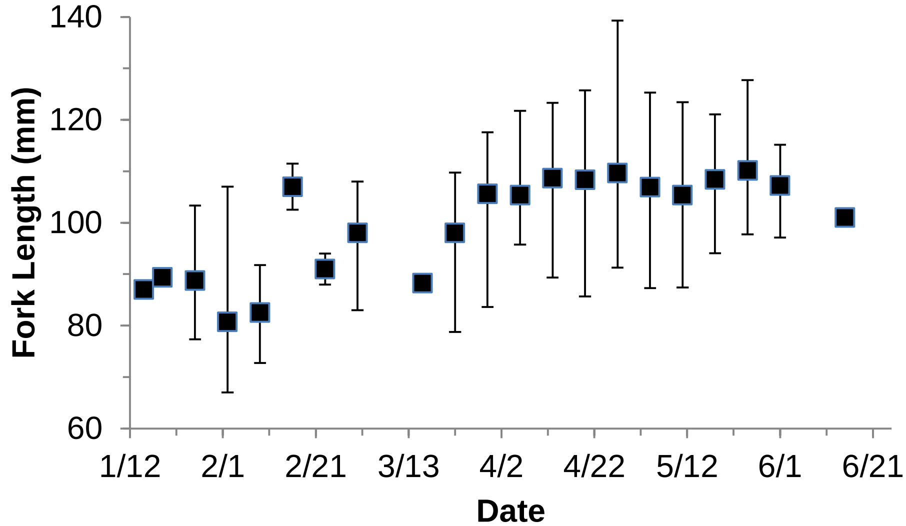

Figure 6. Fork lengths (mm) of natural-origin coho captured in the Green River screw trap in 2015. Data are mean, minimum, and maximum values by week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 103) included 97 captures in the trap and 6 missed catch estimated for trap outage periods (Appendix D). In total, 171 hatchery steelhead were captured between April 5 and June 1 (111 Ad-mark and 60 CWT only). Twenty trap efficiency trials using natural origin steelhead were conducted over the trapping season with 73 marks released and only 1 recovered. With only a single mark recovery for the season, no production estimate was generated for the number of natural-origin steelhead smolts that migrated past the screw trap.

The first steelhead was captured on January 15, the first day of trapping. Throughout the season daily catches of wild steelhead smolts remained low. Peak catch occurred on the night of May 20, with 12 smolts captured. The last wild steelhead smolt was captured on May 28th.

Over the season, a total of 94 unmarked steelhead were measured (fork length), 97% of the total catch. Individuals ranged from 144 to 223 mm, and averaged 168.5 mm for the season (Figure 7).

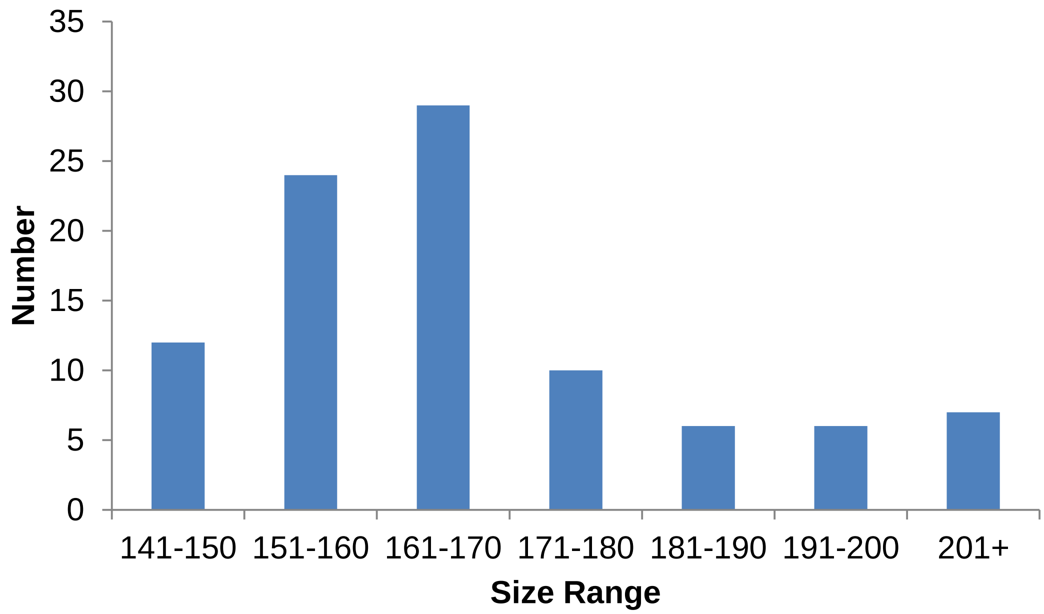

Figure 7. Length frequency of natural-origin steelhead fork length (mm) at the Green River screw trap in 2015.

Length samples were collected on 94 of the 97 natural-origin steelhead smolts captured, scales and weights were collected on 48 of the measured fish to determine the age structure and body size of natural-origin steelhead smolts. The sample included 37 readable and 11 regenerated or upside down samples (Table 9).

Table 9. Age, average length (mm) and average weight of natural-origin steelhead smolts collected at the Green River juvenile trap, migration years 2011-2015.

Smolt Age	1+			2+			3+			4+		
	Ave		Ave	Ave		Ave	Ave		Ave	Ave		Ave
Year	FL	%	Wgt(g)	FL	%	Wgt(g)	FL	%	Wgt(g)	FL	%	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			

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$ =105,757) included 101,452 captures in the trap and 4,305 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between February 6 and June 22, 2015. 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, 11 pink, 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) and coho smolts emigrating from the Green River in 2015. No natural-origin yearling Chinook smolt was 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 2014 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 relatively small and represented 7% of the total production compared to that directly measured from the Green River and tributaries above the trap (78%) and Big Soos Creek (15%).

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 in 2015, 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 and again in 2015 none of the Chinook released from Palmer were ad-marked and unlike 2014 when a portion of the release received CWT, none of the Palmer chinook released in 2015 received CWT. The Palmer facility was not fish tight when the fish were transferred 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. We acknowledge that this is a subjective judgment decision based on appearance, but emphasize the fish identification experience of trap technicians and the low number of unmarked hatchery fish (N = 101) encountered relative to natural-origin fish (N = 6,826). Thus, we feel the unmarked, untagged hatchery Chinook salmon had a minimal impact on the freshwater production estimate, primarily because their release was delayed until after our trapping season.

Freshwater Production of Chinook Salmon

The 2015 freshwater production estimate of 396,944 subyearling Chinook was the same as 2014 and slightly higher than the 346,000 fish average production over all 16 years of this project (range = 56,000 to 810,000) (Table 4). 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 that failed to 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. A downward trend in freshwater production is at least partly explained by a downward trend in Chinook escapement (Figure 8), as the freshwater productivity (8.75% egg-to-migrant survival and 394 juveniles/female) was the third highest observed over sixteen years of study. During the sixteen 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.

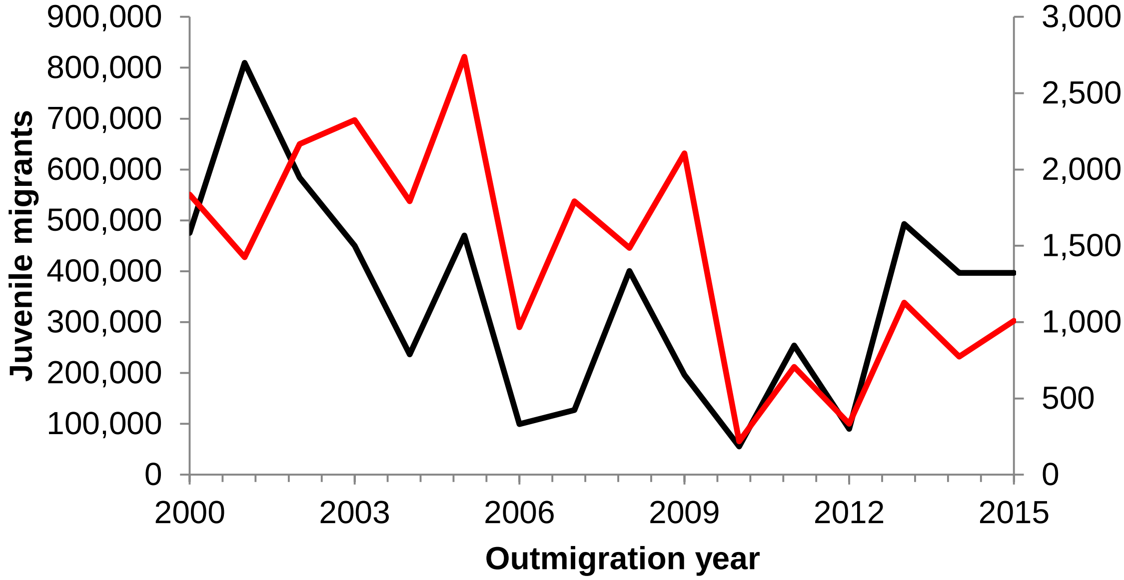

Figure 8. Number of subyearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (Red line) above the juvenile trap, outmigration year 2000-2015.

Freshwater Production of Coho Salmon

Freshwater production of coho above the Green River trap has been estimated for 13 of the 16 years of this study. The 2015 freshwater production estimate of 42,564 coho smolts was fourth lowest production estimate, and 30,000 smolts below the average, over this time period (Table 10).

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.

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 the case in 2015, with 19% of the natural origin coho and 6% of the natural origin steelhead catch were estimated as missed catch during outages. Virtually all of the estimated missed catch for both species occurred during the outages corresponding to hatchery fish releases.

Table 10. Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin coho smolts rearing above the Green River juvenile trap, migration years 2000-2015.

	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

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 catch of natural-origin steelhead in 2015 was too low to allow for adequate trap efficiency trials, so no production estimate was generated (Table 11).

In 2015, 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 and 2014 was higher than 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). 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 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 2012 and 2014. The 2015 steelhead smolts had a high proportion of age-1 smolts, similar to the 2012 and 2014 migrations (Table 9). One possible reason for this result may be the unusually warm and dry winter of 2014-15 in which flows dropped and temperature warmed earlier than typically observed.

Table 11. Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin steelhead smolts rearing above the Green River juvenile trap, migration years 2000-2015.

	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					168.5	19.00	5/08[a]

a Median catch date

Appendix A

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

Author: Kristen Ryding, WDFW Biometrician

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

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

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

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

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

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

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

Derivation:

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

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

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

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

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

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

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

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

Note that,

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

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

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

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

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

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

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

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

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

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

Appendix B

Daily catch and migration estimate for natural-origin, subyearling Chinook in the Green River, 2015.

APPENDIX B. ─Actual and estimated daily catches and migration for natural-origin subyearling Chinook migrants and daily estimated catch of unmarked hatchery Chinook subyearling (0+) and unmarked Chinook yearlings (1+), in the Green River, 2015. Migration estimate is based on daily catch adjusted by the trap efficiency for each pooled time stratum.

	Time Fished Hours		Unmarked Subyearling Chinook Catch				Estimated Catch	
Date	In	Out	Actual	Estimated	Total	Migration	Unmk H 0+	Unmk Natural 1+
1/1-1/14	Pre-Trapping		0	0	0	18,384	0	0
1/15/2015	25.50	0.00	28	0	28	2,020	0	0
1/16/2015	25.00	0.00	13	0	13	938	0	0
1/17/2015	24.00	0.00	20	0	20	1,443	0	0
1/18/2015	24.00	0.00	84	0	84	6,061	0	0
1/19/2015	9.00	15.00	6	41	47	3,391	0	0
1/20/2015	24.00	0.00	37	0	37	2,670	0	0
1/21/2015	24.00	0.00	44	0	44	3,175	0	0
1/22/2015	24.00	0.00	21	0	21	1,515	0	0
1/23/2015	24.00	0.00	39	0	39	2,814	0	0
1/24/2015	24.00	0.00	64	0	64	4,618	0	0
1/25/2015	24.00	0.00	152	0	152	10,967	0	0
1/26/2015	24.00	0.00	147	0	147	10,606	0	0
1/27/2015	24.00	0.00	121	0	121	8,730	0	0
1/28/2015	24.00	0.00	91	0	91	6,566	0	0
1/29/2015	24.00	0.00	92	0	92	6,638	0	0
1/30/2015	24.00	0.00	157	0	157	11,328	0	0
1/31/2015	24.00	0.00	45	0	45	3,247	0	0
2/1/2015	22.00	0.00	28	0	28	2,020	0	0
2/2/2015	26.00	0.00	35	0	35	2,525	0	0
2/3/2015	24.00	0.00	89	0	89	6,421	0	0
2/4/2015	24.00	0.00	127	0	127	9,163	0	0
2/5/2015	24.00	0.00	279	0	279	20,130	0	0
2/6/2015	23.50	0.00	441	0	441	31,819	0	0
2/7/2015	24.50	0.00	485	0	485	34,993	0	0
2/8/2015	24.00	0.00	547	0	547	39,467	1	0
2/9/2015	24.50	0.00	196	0	196	14,142	0	0
2/10/2015	23.50	0.00	132	0	132	9,524	0	0
2/11/2015	16.00	7.50	267	23	290	20,924	0	0
2/12/2015	24.50	0.00	153	0	153	11,039	0	0
2/13/2015	24.50	0.00	91	0	91	6,566	0	0
2/14/2015	24.00	0.00	94	0	94	6,782	0	0
2/15/2015	24.00	0.00	114	0	114	8,225	0	0
2/16/2015	24.00	0.00	122	0	122	2,136	0	0

Table continued next page.

APPENDIX B.—continued.

	Time Fished		Unmarked Subyearling				Estimated Catch	
	Hours		Chinook Catch				Unmk	Unmk
Date	In	Out	Actual	Estimated	Total	Migration	H 0+	Natural 1+
2/17/2015	23.50	0.00	108	0	108	1,891	0	0
2/18/2015	24.00	0.00	116	0	116	2,031	0	0
2/19/2015	23.50	0.00	172	0	172	3,012	0	0
2/20/2015	25.00	0.00	127	0	127	2,224	0	0
2/21/2015	24.00	0.00	79	0	79	1,383	0	0
2/22/2015	24.00	0.00	41	0	41	718	0	0
2/23/2015	24.00	0.00	56	0	56	981	0	0
2/24/2015	24.00	0.00	70	0	70	1,226	0	0
2/25/2015	24.00	0.00	28	0	28	490	0	0
2/26/2015	24.00	0.00	29	0	29	508	2	0
2/27/2015	24.00	0.00	92	0	92	1,611	1	0
2/28/2015	24.00	0.00	161	0	161	2,819	0	0
3/1/2015	24.00	0.00	112	0	112	1,961	0	0
3/2/2015	24.00	0.00	10	0	10	175	1	0
3/3/2015	23.50	0.00	96	0	96	1,681	0	0
3/4/2015	24.50	0.00	43	0	43	753	0	0
3/5/2015	24.00	0.00	12	0	12	210	0	0
3/6/2015	23.50	0.00	13	0	13	228	0	0
3/7/2015	25.00	0.00	27	0	27	473	0	0
3/8/2015	24.50	0.00	28	0	28	490	0	0
3/9/2015	21.00	0.00	39	0	39	1,808	0	0
3/10/2015	26.50	0.00	27	0	27	1,252	0	0
3/11/2015	24.00	0.00	12	0	12	556	0	0
3/12/2015	24.50	0.00	37	0	37	1,715	0	0
3/13/2015	23.50	0.00	15	0	15	695	0	0
3/14/2015	24.00	0.00	5	0	5	232	0	0
3/15/2015	24.50	0.00	311	0	311	14,417	0	0
3/16/2015	24.00	0.00	205	0	205	9,503	1	0
3/17/2015	24.50	0.00	19	0	19	881	0	0
3/18/2015	26.00	0.00	6	0	6	278	1	0
3/19/2015	9.50	10.50	0	3	3	139	0	0
3/20/2015	0.00	25.00	0	4	4	185	0	0
3/21/2015	0.00	22.00	0	4	4	185	0	0
3/22/2015	27.00	0.00	6	0	6	278	0	0
3/23/2015	24.00	0.00	7	0	7	325	0	0
3/24/2015	23.00	0.00	8	0	8	371	0	0

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APPENDIX B.─continued.

	Time Fished Hours		Unmarked Subyearling Chinook Catch				Estimated Catch	
							Unmk	Unmk Natural
Date	In	Out	Actual	Estimated	Total	Migration	H 0+	1+
3/25/2015	24.50	0.00	26	0	26	1,205	2	0
3/26/2015	24.00	0.00	6	0	6	278	0	0
3/27/2015	23.00	0.00	4	0	4	185	0	0
3/28/2015	25.50	0.00	6	0	6	278	1	0
3/29/2015	24.00	0.00	4	0	4	185	2	0
3/30/2015	24.00	0.00	1	0	1	46	1	0
3/31/2015	24.00	0.00	1	0	1	46	3	0
4/1/2015	24.00	0.00	4	0	4	185	1	0
4/2/2015	14.00	10.00	1	0	1	46	2	0
4/3/2015	23.00	0.00	3	0	3	139	2	0
4/4/2015	25.00	0.00	7	0	7	325	2	0
4/5/2015	24.00	0.00	5	0	5	232	0	0
4/6/2015	24.00	0.00	0	0	0	0	0	0
4/7/2015	23.50	0.00	1	0	1	20	0	0
4/8/2015	24.50	0.00	0	0	0	0	1	0
4/9/2015	24.00	0.00	1	0	1	20	2	0
4/10/2015	24.00	0.00	4	0	4	80	1	0
4/11/2015	24.00	0.00	4	0	4	80	2	0
4/12/2015	24.00	0.00	2	0	2	40	2	0
4/13/2015	24.00	0.00	1	0	1	9	1	0
4/14/2015	24.00	0.00	6	0	6	55	9	0
4/15/2015	24.00	0.00	4	0	4	37	5	0
4/16/2015	24.50	0.00	3	0	3	27	2	0
4/17/2015	22.50	0.00	0	0	0	0	0	0
4/18/2015	25.50	0.00	0	0	0	0	0	0
4/19/2015	24.00	0.00	1	0	1	9	1	0
4/20/2015	24.00	0.00	0	0	0	0	1	0
4/21/2015	23.50	0.00	0	0	0	0	1	0
4/22/2015	24.00	0.00	2	0	2	18	1	0
4/23/2015	24.00	0.00	2	0	2	18	1	0
4/24/2015	23.00	0.00	1	0	1	9	4	0
4/25/2015	25.50	0.00	3	0	3	27	7	0
4/26/2015	24.00	0.00	2	0	2	18	4	0
4/27/2015	24.00	0.00	0	0	0	0	2	0
4/28/2015	24.00	0.00	0	0	0	0	2	0

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APPENDIX B.─continued.

Date	Time Fished Hours In	Out	Unmarked Subyearling Chinook Catch Actual	Estimated	Total	Migration	Estimated Catch Unmk H 0+	Unmk Natural 1+
4/29/2015	21.50	5.00	23	7	30	521	2	0
4/30/2015	0.00	21.00	0	5	5	87	0	0
5/1/2015	0.00	24.00	0	7	7	122	0	0
5/2/2015	0.00	24.50	0	7	7	122	0	0
5/3/2015	24.50	0.00	1	0	1	17	0	0
5/4/2015	24.00	0.00	1	0	1	17	2	0
5/5/2015	23.00	0.00	0	0	0	0	2	0
5/6/2015	24.00	0.00	3	0	3	52	1	0
5/7/2015	24.50	0.00	7	0	7	122	4	0
5/8/2015	24.00	0.00	1	0	1	17	2	0
5/9/2015	24.50	0.00	3	0	3	52	1	0
5/10/2015	24.00	0.00	4	0	4	70	2	0
5/11/2015	24.00	0.00	3	0	3	52	0	0
5/12/2015	24.00	0.00	2	0	2	35	1	0
5/13/2015	24.00	0.00	5	0	5	87	2	0
5/14/2015	24.00	0.00	11	0	11	191	4	0
5/15/2015	24.00	0.00	3	0	3	52	3	0
5/16/2015	24.00	0.00	13	0	13	226	0	0
5/17/2015	24.00	0.00	17	0	17	295	0	0
5/18/2015	24.00	0.00	22	0	22	382	0	0
5/19/2015	24.00	0.00	10	0	10	174	0	0
5/20/2015	24.00	0.00	12	0	12	209	0	0
5/21/2015	24.00	0.00	8	0	8	139	2	0
5/22/2015	24.00	0.00	7	0	7	122	0	0
5/23/2015	24.00	0.00	5	0	5	87	0	0
5/24/2015	24.00	0.00	4	0	4	70	0	0
5/25/2015	24.00	0.00	6	0	6	70	1	0
5/26/2015	24.00	0.00	7	0	7	82	0	0
5/27/2015	24.00	0.00	5	0	5	59	0	0
5/28/2015	24.00	0.00	2	0	2	23	0	0
5/29/2015	24.00	0.00	1	0	1	12	0	0
5/30/2015	24.00	0.00	0	0	0	0	0	0
5/31/2015	24.00	0.00	1	0	1	12	0	0
6/1/2015	24.00	0.00	4	0	4	47	0	0
6/2/2015	24.00	0.00	4	0	4	47	0	0

Table continued next page.

APPENDIX B.─continued.

	Time Fished Hours		Unmarked Subyearling Chinook Catch				Estimated Catch	
Date	In	Out	Actual	Estimated	Total	Migration	Unmk H-0+	Unmk Natural 1+
6/3/2015	24.00	0.00	7	0	7	82	0	0
6/4/2015	13.00	11.00	2	0	2	23	0	0
6/5/2015	12.00	12.50	6	0	6	70	0	0
6/6/2015	11.50	12.50	2	0	2	23	0	0
6/7/2015	12.00	12.50	1	0	1	12	0	0
6/8/2015	11.00	13.00	2	0	2	23	0	0
6/9/2015	11.00	13.50	2	0	2	23	0	0
6/10/2015	11.50	12.50	1	0	1	12	0	0
6/11/2015	11.50	12.00	0	0	0	0	0	0
6/12/2015	12.00	12.50	1	0	1	12	0	0
6/13/2015	12.00	12.00	4	0	4	47	0	0
6/14/2015	12.00	12.50	4	0	4	47	0	0
6/15/2015	11.00	12.50	2	0	2	23	0	0
6/16/2015	10.67	13.33	3	0	3	35	0	0
6/17/2015	9.75	13.25	2	0	2	23	0	0
6/18/2015	24.00	0.00	1	0	1	12	0	0
6/19/2015	12.50	12.00	3	0	3	35	0	0
6/20/2015	12.00	12.00	3	0	3	35	0	0
6/21/2015	12.50	12.00	1	0	1	12	0	0
6/22/2015	11.50	0.00	1	0	1	12	0	0
6/23-7/31	Post- Trapping					412		
Total	3434.42	376.08	6,826	101	6,927	396,944	101	0

Appendix C

Fork length of natural-origin, subyearling Chinook in the Green River, 2015

APPENDIX C.─Weekly mean fork length (mm), standard deviation (St. Dev.) range, and sample size of natural-origin subyearling Chinook caught in the Green River screw trap in 2015.

Week				Range		Number		Percent
Begin	End	Average	St. Dev.	Min	Max	Sampled	Caught	Sampled
1/15/2015	1/18/2015	38.59	1.37	36	41	27	145	18.62%
1/19/2015	1/25/2015	38.50	1.83	35	43	58	363	15.98%
1/26/2015	2/1/2015	38.64	1.91	35	44	94	681	13.80%
2/2/2015	2/8/2015	39.70	2.20	35	46	124	2,003	6.19%
2/9/2015	2/15/2015	40.21	2.11	35	48	95	1,047	9.07%
2/16/2015	2/22/2015	40.19	2.24	36	48	99	765	12.94%
2/23/2015	3/1/2015	40.18	2.63	35	49	72	548	13.14%
3/2/2015	3/8/2015	40.00	2.23	35	47	52	229	22.71%
3/9/2015	3/15/2015	40.18	3.52	33	48	49	446	10.99%
3/16/2015	3/22/2015	40.75	2.86	37	48	28	236	11.86%
3/23/2015	3/29/2015	41.65	3.72	36	52	26	61	42.62%
3/30/2015	4/5/2015	41.75	4.48	36	52	16	22	72.73%
4/6/2015	4/12/2015	39.11	2.62	38	46	9	12	75.00%
4/13/2015	4/19/2015	44.00	6.14	38	57	13	15	86.67%
4/20/2015	4/26/2015	57.00	7.14	43	68	9	10	90.00%
4/27/2015	5/3/2015	58.33	10.03	45	71	6	24	25.00%
5/4/2015	5/10/2015	68.87	10.69	49	87	15	19	78.95%
5/11/2015	5/17/2015	79.52	7.98	56	92	33	54	61.11%
5/18/2015	5/24/2015	83.15	8.76	63	96	33	68	48.53%
5/25/2015	5/31/2015	82.73	12.57	59	96	11	22	50.00%
6/1/2015	6/7/2015	87.58	9.45	69	101	12	26	46.15%
6/8/2015	6/14/2015	86.75	10.37	72	94	4	14	28.57%
6/15/2015	6/21/2015	91.80	11.45	77	105	5	15	33.33%
6/22/2015							1	0.00%
Season Total		45.41	14.60	33	105	890	6,826	13.04%

Appendix D

Daily estimated catch of coho, chum and pink salmon, steelhead and cutthroat trout in the Green River, 2015

APPENDIX D.─Daily estimated catches of coho, chum and pink salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2015. Catch represents actual and estimated catch for a given day. Time in and out reflect time fished (in) and not fished (out) on a given day.

Date	Times		Coho Smolts		Coho Fry	Chum Fry	Pink Fry	Steelhead Smolts		Cutthroat Smolt	Trout Parr
	In	Out	Nat	Hat	Total	Total	Nat	Nat	Hat	Nat	Nat
1/15/2015	25.50	0.00	2	0	0	0	0	1	1	0	0
1/16/2015	25.00	0.00	0	0	0	0	0	0	0	0	2
1/17/2015	24.00	0.00	0	0	0	0	0	0	1	0	2
1/18/2015	24.00	0.00	1	0	0	0	0	1	0	0	0
1/19/2015	9.00	15.00	2	0	0	0	0	0	0	0	1
1/20/2015	24.00	0.00	3	0	0	0	0	0	0	1	2
1/21/2015	24.00	0.00	1	0	1	0	0	0	0	0	1
1/22/2015	24.00	0.00	0	0	0	0	0	0	0	0	0
1/23/2015	24.00	0.00	0	0	0	0	0	0	0	0	0
1/24/2015	24.00	0.00	1	0	0	0	0	0	0	0	4
1/25/2015	24.00	0.00	0	0	0	0	0	0	0	0	3
1/26/2015	24.00	0.00	0	0	1	0	0	0	0	0	1
1/27/2015	24.00	0.00	1	0	0	0	0	0	0	0	0
1/28/2015	24.00	0.00	1	0	0	0	0	0	0	0	0
1/29/2015	24.00	0.00	1	0	0	0	0	0	0	0	0
1/30/2015	24.00	0.00	0	0	1	0	0	0	0	0	0
1/31/2015	24.00	0.00	1	1	0	0	0	0	0	0	0
2/1/2015	22.00	0.00	0	1	0	0	0	0	0	0	2
2/2/2015	26.00	0.00	3	0	0	0	0	1	0	0	4
2/3/2015	24.00	0.00	1	0	0	0	0	0	0	0	1
2/4/2015	24.00	0.00	0	0	0	0	0	0	0	1	1
2/5/2015	24.00	0.00	2	0	0	0	0	0	0	0	0
2/6/2015	23.50	0.00	1	0	0	2	0	0	0	0	0
2/7/2015	24.50	0.00	1	0	2	0	0	0	0	0	0
2/8/2015	24.00	0.00	0	0	5	2	0	0	0	0	2
2/9/2015	24.50	0.00	2	0	0	2	0	0	0	0	1
2/10/2015	23.50	0.00	0	0	2	4	0	0	0	0	1
2/11/2015	16.00	7.50	1	0	4	6	0	0	0	0	0
2/12/2015	24.50	0.00	0	0	5	6	0	0	0	1	1
2/13/2015	24.50	0.00	0	0	2	0	0	0	0	0	1
2/14/2015	24.00	0.00	1	0	1	4	0	0	0	0	4
2/15/2015	24.00	0.00	0	0	4	2	0	0	0	1	2
2/16/2015	24.00	0.00	2	0	6	0	0	0	0	0	1
2/17/2015	23.50	0.00	1	0	5	4	0	0	0	1	2

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APPENDIX D.─continued.

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
2/18/2015	24.00	0.00	0	0	9	140	0	0	0	0	0
2/19/2015	23.50	0.00	0	0	33	44	0	0	0	0	1
2/20/2015	25.00	0.00	0	0	14	23	0	0	0	1	1
2/21/2015	24.00	0.00	0	0	16	31	1	0	0	0	3
2/22/2015	24.00	0.00	0	0	9	38	0	0	0	0	3
2/23/2015	24.00	0.00	1	0	18	47	0	0	0	0	2
2/24/2015	24.00	0.00	0	0	15	93	0	0	0	0	0
2/25/2015	24.00	0.00	0	0	4	225	0	0	0	0	4
2/26/2015	24.00	0.00	1	0	7	2,823	0	0	0	0	5
2/27/2015	24.00	0.00	1	0	17	1,464	0	0	0	0	0
2/28/2015	24.00	0.00	0	0	49	800	0	0	0	0	0
3/1/2015	24.00	0.00	0	0	36	549	2	0	0	0	0
3/2/2015	24.00	0.00	0	0	2	26	1	0	0	0	0
3/3/2015	23.50	0.00	1	0	18	1,710	0	0	0	0	1
3/4/2015	24.50	0.00	0	0	9	500	0	0	0	0	0
3/5/2015	24.00	0.00	0	0	2	242	0	0	0	0	1
3/6/2015	23.50	0.00	0	0	13	1,733	0	0	0	0	0
3/7/2015	25.00	0.00	1	0	15	8,351	0	0	0	0	2
3/8/2015	24.50	0.00	0	0	21	2,065	0	0	0	0	1
3/9/2015	21.00	0.00	0	0	41	1,390	1	0	0	0	1
3/10/2015	26.50	0.00	0	0	44	862	0	0	0	0	2
3/11/2015	24.00	0.00	0	0	20	310	0	0	0	0	0
3/12/2015	24.50	0.00	0	0	58	4,678	0	0	0	0	2
3/13/2015	23.50	0.00	0	0	31	2,794	1	0	0	0	1
3/14/2015	24.00	0.00	0	0	49	1,075	3	0	0	0	2
3/15/2015	24.50	0.00	0	1	389	2,107	1	0	0	0	1
3/16/2015	24.00	0.00	3	0	593	1,047	0	2	0	2	6
3/17/2015	24.50	0.00	3	0	77	143	0	1	0	2	3
3/18/2015	26.00	0.00	2	1	16	191	0	0	0	0	0
3/19/2015	9.50	10.50	0	0	24	658	0	0	0	0	0
3/20/2015	0.00	25.00	1	1	32	811	0	0	0	0	0
3/21/2015	0.00	22.00	1	1	29	750	0	0	0	0	0
3/22/2015	27.00	0.00	0	0	56	1,639	0	0	0	0	0
3/23/2015	24.00	0.00	0	0	3	563	0	0	0	0	0
3/24/2015	23.00	0.00	0	0	29	331	0	0	0	0	0
3/25/2015	24.50	0.00	0	0	66	1,500	0	0	0	0	0
3/26/2015	24.00	0.00	1	0	47	571	0	0	0	0	0
3/27/2015	23.00	0.00	0	0	26	510	0	0	0	0	0

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APPENDIX D.─continued.

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
3/28/2015	25.50	0.00	1	0	19	1,983	0	1	0	0	2
3/29/2015	24.00	0.00	1	0	5	767	1	1	0	1	0
3/30/2015	24.00	0.00	1	0	15	3,817	0	0	0	0	2
3/31/2015	24.00	0.00	2	0	14	3,436	0	0	0	0	1
4/1/2015	24.00	0.00	2	0	7	1,727	0	1	0	1	2
4/2/2015	14.00	10.00	0	0	6	2,792	0	0	0	0	2
4/3/2015	23.00	0.00	1	0	24	9,929	0	0	0	0	2
4/4/2015	25.00	0.00	0	1	17	4,167	0	0	0	0	2
4/5/2015	24.00	0.00	0	2	8	1,519	0	0	1	0	1
4/6/2015	24.00	0.00	0	0	10	1,094	0	0	0	0	1
4/7/2015	23.50	0.00	0	0	4	783	0	0	0	0	0
4/8/2015	24.50	0.00	0	1	0	1,259	0	0	0	0	0
4/9/2015	24.00	0.00	1	0	9	5,276	0	1	0	0	1
4/10/2015	24.00	0.00	3	0	8	2,627	0	0	0	1	0
4/11/2015	24.00	0.00	1	2	5	1,817	0	0	0	0	2
4/12/2015	24.00	0.00	3	0	0	1,361	0	1	0	0	0
4/13/2015	24.00	0.00	0	1	0	878	0	0	0	1	0
4/14/2015	24.00	0.00	2	0	1	2,154	0	1	0	0	0
4/15/2015	24.00	0.00	9	2	0	1,086	0	1	0	1	2
4/16/2015	24.50	0.00	5	0	6	1,112	0	1	0	0	1
4/17/2015	22.50	0.00	7	1	0	543	0	1	1	1	0
4/18/2015	25.50	0.00	9	1	0	1,148	0	0	7	1	0
4/19/2015	24.00	0.00	4	1	0	518	0	1	6	1	1
4/20/2015	24.00	0.00	4	0	0	609	0	0	6	0	1
4/21/2015	23.50	0.00	6	1	0	479	0	0	0	1	0
4/22/2015	24.00	0.00	19	0	1	580	0	1	1	0	0
4/23/2015	24.00	0.00	11	0	0	353	0	0	4	1	0
4/24/2015	23.00	0.00	6	1	0	872	0	2	0	0	0
4/25/2015	25.50	0.00	21	0	2	2,756	0	2	2	1	2
4/26/2015	24.00	0.00	19	0	0	664	0	3	14	1	3
4/27/2015	24.00	0.00	6	0	1	107	0	0	0	0	0
4/28/2015	24.00	0.00	34	0	1	195	0	3	2	0	2
4/29/2015	21.50	5.00	90	790	1	337	0	1	7	0	3
4/30/2015	0.00	21.00	41	46	0	77	0	2	6	0	0
5/1/2015	0.00	24.00	54	60	0	95	0	2	8	0	0
5/2/2015	0.00	24.50	55	60	0	96	0	2	8	0	0
5/3/2015	24.50	0.00	26	160	0	27	0	6	45	1	0
5/4/2015	24.00	0.00	22	107	0	11	0	3	11	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
5/5/2015	23.00	0.00	11	69	0	25	0	1	5	0	0
5/6/2015	24.00	0.00	14	71	0	56	0	3	2	0	0
5/7/2015	24.50	0.00	19	43	0	147	0	0	0	0	0
5/8/2015	24.00	0.00	22	77	0	87	0	5	2	0	0
5/9/2015	24.50	0.00	22	120	0	61	0	2	1	0	0
5/10/2015	24.00	0.00	10	48	0	129	0	4	0	0	0
5/11/2015	24.00	0.00	27	45	0	80	0	2	0	0	0
5/12/2015	24.00	0.00	14	30	2	107	0	0	5	0	0
5/13/2015	24.00	0.00	23	25	0	739	0	2	0	0	0
5/14/2015	24.00	0.00	38	44	0	680	0	0	1	0	0
5/15/2015	24.00	0.00	22	9	0	294	0	2	1	0	0
5/16/2015	24.00	0.00	20	15	0	232	0	4	2	0	0
5/17/2015	24.00	0.00	21	13	0	77	0	1	23	0	0
5/18/2015	24.00	0.00	11	16	0	93	0	6	13	0	0
5/19/2015	24.00	0.00	25	4	2	109	0	1	2	1	1
5/20/2015	24.00	0.00	7	5	3	66	0	12	3	0	0
5/21/2015	24.00	0.00	15	3	0	27	0	4	1	0	0
5/22/2015	24.00	0.00	18	4	0	45	0	6	1	0	0
5/23/2015	24.00	0.00	7	3	0	26	0	1	0	0	0
5/24/2015	24.00	0.00	11	2	0	39	0	2	0	0	0
5/25/2015	24.00	0.00	11	3	1	54	0	0	0	1	0
5/26/2015	24.00	0.00	2	2	0	79	0	0	0	0	1
5/27/2015	24.00	0.00	7	2	0	66	0	1	0	0	0
5/28/2015	24.00	0.00	3	3	0	35	0	1	0	0	0
5/29/2015	24.00	0.00	5	1	0	24	0	0	0	0	0
5/30/2015	24.00	0.00	3	3	0	15	0	0	0	0	0
5/31/2015	24.00	0.00	0	0	0	16	0	0	0	0	0
6/1/2015	24.00	0.00	0	0	1	22	0	0	1	0	0
6/2/2015	24.00	0.00	3	1	1	34	0	0	0	0	0
6/3/2015	24.00	0.00	4	2	0	25	0	0	0	0	0
6/4/2015	13.00	11.00	4	0	0	28	0	0	0	0	0
6/5/2015	12.00	12.50	3	1	1	31	0	0	0	1	0
6/6/2015	11.50	12.50	2	1	1	27	0	0	0	0	0
6/7/2015	12.00	12.50	0	2	2	31	0	0	0	0	0
6/8/2015	11.00	13.00	0	2	0	24	0	0	0	0	0
6/9/2015	11.00	13.50	0	1	0	39	0	0	0	0	0
6/10/2015	11.50	12.50	0	0	4	38	0	0	0	0	0
6/11/2015	11.50	12.00	0	0	2	30	0	0	0	0	0

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APPENDIX D.─continued.

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
6/12/2015	12.00	12.50	0	0	0	28	0	0	0	0	0
6/13/2015	12.00	12.00	0	0	1	22	0	0	0	1	0
6/14/2015	12.00	12.50	0	0	0	11	0	0	0	0	0
6/15/2015	11.00	12.50	1	0	0	10	0	0	0	0	0
6/16/2015	10.67	13.33	1	0	3	6	0	0	0	0	1
6/17/2015	9.75	13.25	0	0	0	5	0	0	0	0	0
6/18/2015	24.00	0.00	0	1	0	5	0	0	0	0	0
6/19/2015	12.50	12.00	0	0	1	6	0	0	0	0	0
6/20/2015	12.00	12.00	0	0	0	7	0	0	0	0	0
6/21/2015	12.50	12.00	0	0	0	2	0	0	0	0	0
6/22/2015	11.50	0.00	0	0	2	1	0	0	0	0	0
Total	3,434	376	917	1,914	2,167	105,757	11	103	194	27	117

Appendix E

Fork lengths of natural-origin coho smolts in the Green River, 2015

APPENDIX E.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of natural-origin coho smolts in the Green River in 2015.

Week				Range		Number	
Begin	End	Average	St.Dev.	Min	Max	Sampled	Captured
1/15/2015	1/18/2015	87.00	1.41	86	88	2	3
1/19/2015	1/25/2015	89.40	10.76	78	104	5	5
1/26/2015	2/1/2015	88.75	18.63	75	115	4	4
2/2/2015	2/8/2015	80.75	8.00	71	90	8	8
2/9/2015	2/15/2015	82.50	6.36	78	87	2	4
2/16/2015	2/22/2015	107.00	3.00	104	110	3	3
2/23/2015	3/1/2015	91.00	13.23	76	101	3	3
3/2/2015	3/8/2015	98.00	0.00	98	98	2	2
3/9/2015	3/15/2015			Trap outage			
3/16/2015	3/22/2015	88.25	9.78	69	100	8	8
3/23/2015	3/29/2015	98.00	19.08	76	110	3	3
3/30/2015	4/5/2015	105.60	11.15	96	122	5	6
4/6/2015	4/12/2015	105.33	13.05	86	120	6	8
4/13/2015	4/19/2015	108.65	12.55	86	126	20	36
4/20/2015	4/26/2015	108.35	10.92	90	138	40	86
4/27/2015	5/3/2015	109.62	8.61	90	128	29	139
5/4/2015	5/10/2015	106.91	7.46	89	125	33	120
5/11/2015	5/17/2015	105.34	7.91	91	118	29	165
5/18/2015	5/24/2015	108.39	8.63	96	126	23	94
5/25/2015	5/31/2015	110.13	4.66	100	118	16	31
6/1/2015	6/7/2015	107.25	5.42	102	117	8	16
6/8/2015	6/14/2015			No catch			
6/15/2015	6/21/2015	101.00	na	101	101	1	2
Season Total		104.87	11.74	69	138	250	746

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