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Green River Juvenile Salmonid Production Evaluation: 2019 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 Brent Trim. Logistical support was provided by Wild Salmon Production Evaluation Unit biologist Josh Weinheimer.

A number of other individuals and agencies contributed to this project. Burr 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 between 2013 and 2019.

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Executive Summary

This report provides the 2019 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 23 through July 12, 2019. During this period, the trap fished 87% of the time. We estimated the freshwater production (juvenile abundance) of subyearling Chinook. (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 2019. 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	28,695 [a]	1,032,185 (9.38%)	52.50 (±19.13) [a]	12-Mar
Chinook – Yrlg	2			
Coho – Yrlg	1,278 [a]			22-Apr [b]
Steelhead – Smolt	49		169.95 (±17.87)	18-May [b]
Chum	211,760 [a]			24-Mar [b]

[a] This figure includes unmarked 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.

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. Egg-to-migrant survival of Green River Chinook for the 2019 outmigration (2018 brood) was estimated to be 10.90% yielding a basin-wide production estimate of 1,320,791 natural-origin juveniles.

Juvenile migrant Chinook in the Green River are predominantly subyearlings. Outmigration timing of natural origin subyearling Chinook was multimodal. The fry (≤45 mm fork length) represented 86% of the natural subyearling migrants and peaked in the second half of March. Parr migrants (>45 mm fork length) represented 14% of the total abundance and their migration peaked 3 times, in mid-April, mid-May and again in late June.

Introduction

This report provides the 2019 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). 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 several 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 mainstem Green River (river mile 34.5, rkm 55), approximately a 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 2019 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 2019, the trap operated between January 23 and July 12 for a total of 3560.79 of 4,069.54 possible hours (87% of the time). Over the course of the season, trapping was suspended 12 times; the duration of outages ranged from 12.75 to 79.00 hours. Trapping was suspended once for high water, twice for hatchery fish releases, twice for trap repairs and 7 times late in the season because of staffing issues.

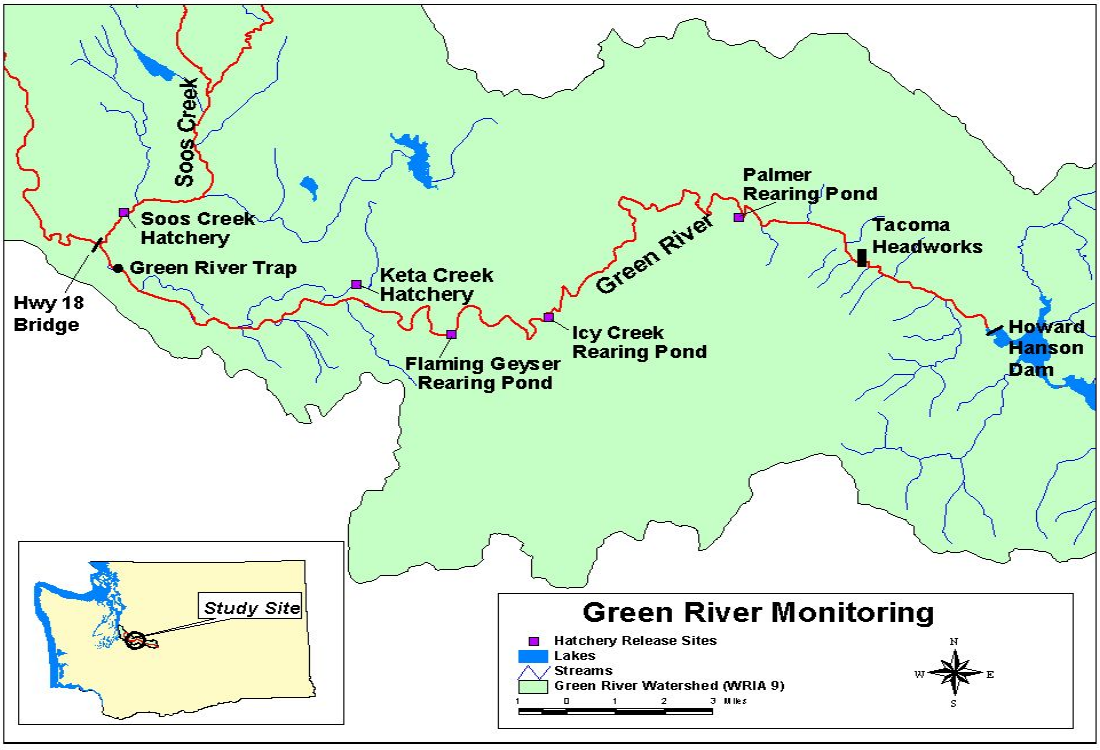

Figure 1. Location of Green River screw trap in relation to existing hatchery release sites and Howard Hanson Dam.

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 daily. Subyearling Chinook were length sampled at a rate of approximately 10% during the first half of the season when there was little sign of growth and at 75% in the second half of the season because of the otolith sampling to estimate the number of hatchery fish in our catch.

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, and 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 (Anderson and Topping 2018; Hall et al. 2018; Zimmerman et al. 2015). 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 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 150mm 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 2019 included Chinook, coho, chum and summer and winter steelhead. 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 coded wire tag (CWT). Therefore, every unmarked steelhead captured in the trap was electronically scanned for the presence of a CWT. Chum and coho could not be assigned to origin because all hatchery chum and coho released upstream of the trap where unmarked.

In total, 3 million hatchery subyearling hatchery Chinook (one million otolith marked only and two million ad-marked only) were planted in Palmer Ponds from late February thru March for rearing and acclimation prior to volitional release on June 18th. 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 2019, 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. We began randomly sacrificing non-externally marked Chinook at the smolt trap on March 23rd and continued thru the end of the trapping season, with 5 to 35 fish sacrificed or collected from natural mortalities per week, with 281 readable samples collected in total. These samples were evaluated for thermal otolith marks and used to estimate the proportion of otolith marked fish present in our catch.

Table 2. Number of hatchery fish by mark type released above the Green River screw trap in 2019. 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	2018	Palmer Pond			2,000,641	1,097,011[1]
Chinook – Yrlg	2017	Icy Creek	199,012	1,767	111,280	677
Coho – Yrlg	2017	Keta Creek		63,791		701,111
Chum - Subyrlg	2018	Keta Creek				6,025,320
Summer steelhead	2018	Icy Creek			45,411	366
Winter steelhead	2018	Icy Creek		33,688		
Winter steelhead	2018	Flaming Geyser				9,990[1]

[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. We have used these same release locations throughout 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. Individual efficiency trials were summed by statistical week to form an efficiency strata (group). Weekly groups with less than 5 recoveries were grouped with the follow week or weeks until a minimum of 5 recoveries were achieved to form the next strata. (Sokal and Rohlf 1981).

(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 origin chinook, we used the otolith mark information. We first assumed that none of the migrants were of hatchery origin prior to March 31st when the first otolith marked fish was identified. Of the otolith sampled fish with corresponding lengths, all hatchery-origin fish except the first encountered (40mm, March 31) were > 45 mm (Table 5). Within the three strata containing otolith marked hatchery fish, we applied the proportion of hatchery vs natural parr based on otolith mark rates observed in our samples to the parr migration estimate, 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

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

And the associated variance was calculated as

Equation 8

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

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 in Soos Creek above the hatchery. 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 and Soos creek.

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. It also does not include natural-origin adult returns captured for hatchery broodstock. For comparison, we report SAR for the Soos Creek hatchery Chinook salmon with data queried from the Regional Mark Information System (RMIS) though brood year 2014.

Results

Subyearling Chinook

The total estimated catch of non-externally marked Chinook ($\hat{u}$ = 29,745) included 28,695 captures in the trap and an estimated missed catch during trap outage periods of 1,050 (Table 3, Appendix B).

We released a total of 12,702 Chinook salmon within 115 distinct trials to estimate trap efficiency. Release numbers ranging from 2 to 360 fish per trial. Statistical weeks with less than 5 recoveries were combined with the subsequent statistical week, forming 7 groups (strata), with trap efficiencies ranging between 1.35% and 5.53% (Table 3). We estimated a total unmarked (hatchery plus natural) abundance of 832,735 subyearling juvenile Chinook salmon across the seven efficiency strata during the trapping season.

Beginning in mid-March we observed larger sized fish believed to be otolith-marked hatchery fish in our catch. On March 23rd we began lethally sampling from 5 to 35 subyearling Chinook at the trap per week through the remainder of the trapping season. In total, 287 samples were collected for otolith analysis with 281 (225 unmarked natural, 56 marked hatchery fish) readable. Few hatchery marked fish were identified thru most of the sampling period with just 9 hatchery fish identified between March 23rd and June 22nd (Table 5).

We estimated natural-origin subyearling Chinook from spawning and rearing locations upstream of the trapping site. The trapping season of January 23 through July 12 encompassed most of the natural-origin subyearling Chinook migration; we estimated 811,303 Chinook salmon during the trapping season, plus 194,986 before the trapping season and 2,083 after the trapping season.

We estimated a total hatchery Chinook salmon migration of 21,432 fish during the trapping season. The highest daily migration periods for hatchery fish was during the last 4 weeks of trapping with 78 % migrating during this period. (Table 4). Our hatchery abundance estimate does not include hatchery fish migrating after the end of trapping season on July 12.

Table 3. Catch, marked and recaptured fish, and estimated abundance of subyearling Chinook migrants at the Green River screw trap in 2019. Release groups were pooled to form seven strata. Missed catch and associated variance were estimated for periods that the trap did not fish. These numbers include both natural and hatchery fish marked only by thermal otolith mark; they exclude adipose marked hatchery fish.

Strata	Date	Hatchery plus natural catch			Marked	Recaptured	Total Abundance	
		Actual	Missed	Variance			Estimated	Variance
Before	1/1-1/23						194,986	6.68E+09
1	1/20-2/9	2,797	42	8.48E+02	2,215	39	157,281	6.03E+08
2	2/10-2/23	2,389	504	3.74E+04	2,044	73	79,948	1.13E+08
3	2/24-3/23	18,025	0	0.00E+00	4,664	258	324,659	3.88E+08
4	3/24-3/30	2,282	0	0.00E+00	1,400	56	56,089	5.33E+07
5	3/31-5/11	2,055	352	6.80E+03	1,296	18	164,309	1.37E+09
6	5/12-6/8	787	0	2.41E-01	712	29	18,704	1.12E+07
7	6/9-7/12	360	152	2.99E+02	371	5	31,744	1.45E+08
After	7/13-7/31						4,464	1.15E+06
Season Total		28,695	1,050	4.53E+04	12,702	478	1,032,185	9.37E+09

a. Post migration estimate only includes natural origin fish.

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 2019.

Strata	Date	Otolith sample		Abundance		
		Natural	Hatchery	Natural	Variance	Hatchery
Before	1/1-1/23			194,986	6.68E+09	
1	1/20-2/9			157,281	6.03E+08	
2	2/10-2/23			79,948	1.13E+08	
3	2/24-3/23	4	0	324,659	3.88E+08	
4	3/24-3/30	19	0	56,089	5.33E+07	
5	3/31-5/11	104	2	161,432	1.35E+09	2,878
6	5/12-6/8	68	7	17,000	1.01E+07	1,704
7	6/9-7/12	30	47	14,894	3.54E+07	16,850
After	7/13-7/31			2,083	2.82E+05	
Season Total				1,008,372	9.23E+09	

Freshwater productivity of natural-origin Chinook for brood year 2018 above the trap site was estimated to be 490 juveniles per female, with an egg-to-migrant survival of 10.90%. This calculation was based on the estimated number of natural origin subyearling Chinook passing the trap ($\hat{N}_T$ = 1,008,372), 2,056 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 9,252,000 eggs.

Basin-wide abundance of subyearling unmarked natural origin Chinook was estimated to be 1,320,791 migrants. This included 1,008,372 migrants from above the trap and 263,373 juveniles from the mainstem below the trap and 49,045 from Soos Creek above the hatchery (Table 6).

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 12 (Table 7). Over the entire migration period we estimated that 88.27% of the natural origin Chinook migrated as fry (≤ 45 mm) and 11.73% migrated as parr (> 45 mm). From March 31 to June 1, based on otolith analysis, some fry sized fish ≤ 45 mm were encountered in the known natural-origin group, while the small number of non-externally marked hatchery-origin fish were all parr sized > 45 mm (Table 5). To estimate the number of natural origin fry and parr, from the start of the season thru March 22, we assumed all migrants were natural origin. Furthermore, from March 23, the first otolith sampling day thru the end of the season, we only used the lengths collected on the 225 Chinook confirmed as natural origin via otolith analysis to estimate natural-origin fry and parr abundance. The fry migration peaked in the second and third weeks of March. The natural origin parr migration peaked three times, mid-April, mid-May and again in mid-June. The migration periods of fry and parr overlapped between mid-February and late-May (Table 8, Figure 2).

We could not identify individual hatchery fish for most of our body size sample, so we report patterns of hatchery plus natural body size. The seasonal average length of subyearling hatchery plus natural Chinook was 52.50 (19.13 ± 1 S.D.; Appendix C). The weekly average lengths of the subyearling hatchery plus natural Chinook showed little increase (approximately 2 mm) during the early portion of the season, (January 15 – April 14). Chinook subyearling hatchery plus natural body size increased substantially thru the end of trapping season (April-June), averaging a 4.6 mm FL increase per week. The largest size increase occurred between May 5 and May 25 with an increase of 21 mm over this two-week period (Figure 3, Appendix C).

Length measurement was taken on all 287 Chinook that were otolith sampled. The sample included 225 identified as natural origin, 56 as hatchery origin fish and 6 samples were unreadable. 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 except for two weeks early in the season; the difference between the two groups averaged 33 mm over the entire season. In weeks with samples in each group, we observed overlap in the range of lengths in all but one week (Table 5).

Table 5. Comparison of size of natural and hatchery origin Chinook from otolith sampled fish for weeks that had both natural and hatchery origin fish 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
23-Mar	6-Apr	43.65	4.39	40	58	17	40.00	na	40	40	1
7-Apr	13-Apr	45.45	7.30	38	64	20					
14-Apr	20-Apr	47.23	8.16	37	67	13		no sample			
21-Apr	27-Apr	52.83	10.01	41	71	18	63.00	na	63	63	1
28-Apr	4-May	51.06	7.12	43	72	18					
5-May	11-May	56.22	10.06	43	78	18		no sample			
12-May	18-May	61.26	10.19	43	84	19	60.00	16.97	48	72	2
19-May	25-May	66.65	8.48	54	81	17	84.00	na	84	84	1
26-May	1-Jun	78.82	13.07	44	101	17	95.67	5.51	90	101	3
2-Jun	8-Jun	84.53	12.73	60	108	15	96.00	na	96	96	1
9-Jun	15-Jun	89.29	8.64	78	103	7					
16-Jun	22-Jun		no sample					no sample			
23-Jun	29-Jun	90.40	5.68	83	98	10	99.24	8.07	78	111	25
30-Jun	6-Jul	90.33	7.17	84	104	6	96.36	10.19	78	110	14
7-Jul	13-Jul	85.43	1.27	84	87	7	98.25	6.69	85	105	8
Grand total		60.89	18.54	37	108	225	94.75	13.98	40	111	56

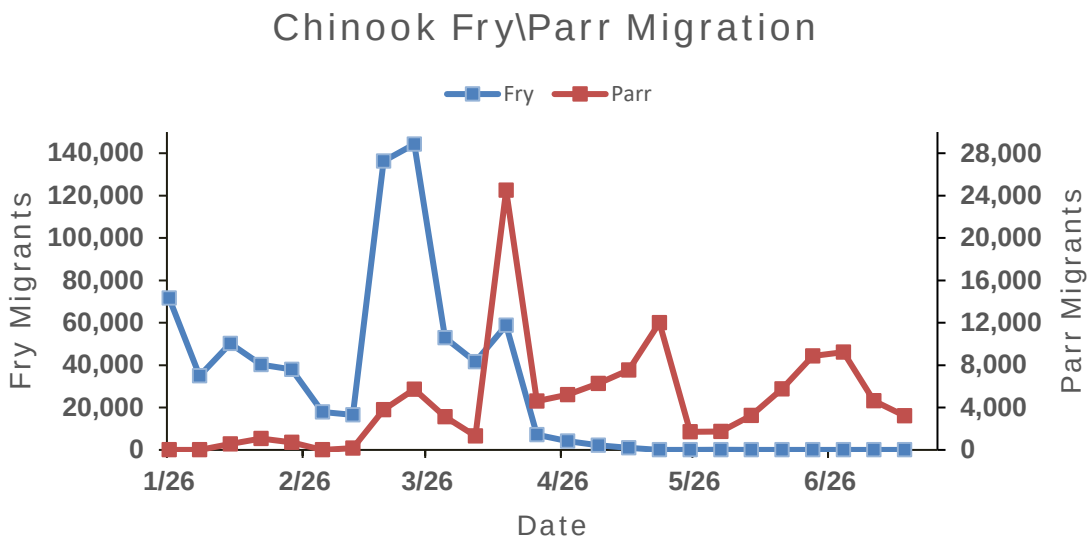

Figure 2. Weekly migration of natural-origin subyearling Chinook migrants at the Green River screw trap in 2019. Subyearling migrants are partitioned into two freshwater rearing strategies fry (≤45 mm FL) and parr (> 45 mm FL) migrants.

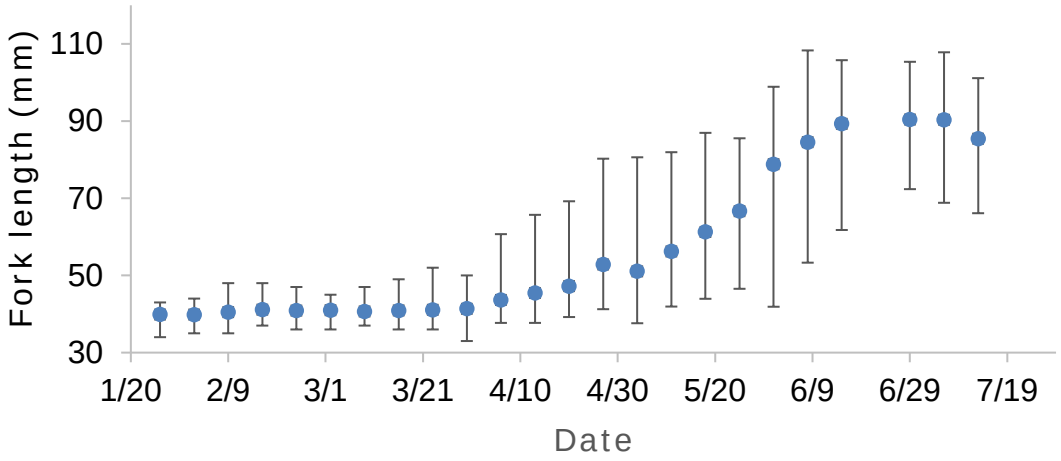

Figure 3. Fork length (mm) of subyearling Chinook migrants of both natural and hatchery origin captured in the Green River screw trap in 2019. Data are mean, minimum, and maximum values.

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)

Trap	Above Trap				Below Trap			Soos Crk			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		897,977
2004	1,793	8,068,500	236,650	2.93%	1,038	4,671,000	137,001	720	3,240,000		373,650
2005	2,738	12,321,000	470,334	3.82%	827	3,721,500	142,062	623	2,803,500		612,397
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	196,115	2.07%	282	1,269,000	26,248	504	2,268,000		222,362
2010	218	981,000	55,547	5.66%	57	256,500	14,524	759	3,415,500		70,070
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
2016	1,570	7,065,000	57,214	0.81%	65	378,000	2,369	152	684,000	16,987	76,570
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
2018	3,023	13,603,500	315,886	2.32%	320	1,440,000	33,438	No Females released upstream			349,324
2019	2,056	9,252,000	1,008,372	10.90%	537	2,416,500	263,373	100	450,000	49,045	1,320,791

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% - 1.5%) for brood years 2002 through 2014 (Table 9). Natural origin juveniles survived at a higher rate ten out of thirteen 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, except for trapping year 2014 thru 2018 when an unknown number of unmarked hatchery Chinook were present in the length sample, migration years 2000-2019.

	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
2018	315,886	192,691	439,081	19.90	58.2	21.8	19-Feb
2019	1,008,372	748,125	1,268,620	9.53	52.50	19.13	12-Mar

Table 8. Abundance of natural origin fry and parr subyearling migrants of Green River Chinook, from above the trap site, migration year 2000 to 2019.

Trapping Year	Fry Migrants			Parr Migrants		
	Migration Interval	Abundance	% of Migration	Migration Interval	Abundance	% of Migration
2000	1/01-4/29	266,481	56.10%	3/11-7/31	208,726	43.90%
2001	1/01-5/20	379,174	46.80%	3/8-7/31	430,442	53.20%
2002	1/01-5/23	357,602	61.20%	3/3-7/31	226,550	38.80%
2003	1/01-5/27	413,358	91.90%	2/16-7/13	36,598	8.10%
2004	1/01-4/29	136,144	57.50%	3/21-7/31	100,506	42.50%
2005	1/01-4/26	391,274	83.20%	2/20-7/31	79,061	16.80%
2006	1/01-5/01	29,946	30.00%	2/18-7/31	69,850	70.00%
2007	1/01-5/07	88,439	69.40%	3/21-7/31	39,053	30.60%
2008	1/01-6/08	251,815	62.80%	3/15-7/31	148,948	37.20%
2009	1/01-5/13	119,406	60.90%	2/6-7/31	76,709	39.10%
2010	1/01-4/20	5,559	10.00%	2/11-7/31	49,988	90.00%
2011	1/01-6/12	128,472	50.50%	2/7-7/31	125,710	49.50%
2012	1/01-5/13	42,133	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	1/1-5/8	21,285	37.20%	1/31-7/31	35,929	62.80%
2017	1/1-6/29	1,579,608	77.63%	1/28-7/31	455,253	22.37%
2018	1/1-5/26	274,337	86.85%	2/11-7/31	41,549	13.15%
2019	1/1-6/1	890,063	88.27%	2/9-7/31	118,309	11.73%

Table 9. Smolt to adult return (SAR) for adult Chinook in the Green River, brood years 2002-2014. Juvenile freshwater production and adult return estimates restricted to the area upstream from the smolt trap. Adult returns do not include natural-origin fish encountered in harvest or hatchery broodstock. 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%
2013	396,623	863	949	19	0	1,830	0.46%
2014	396,944	781	784	0	0	1,565	0.39%

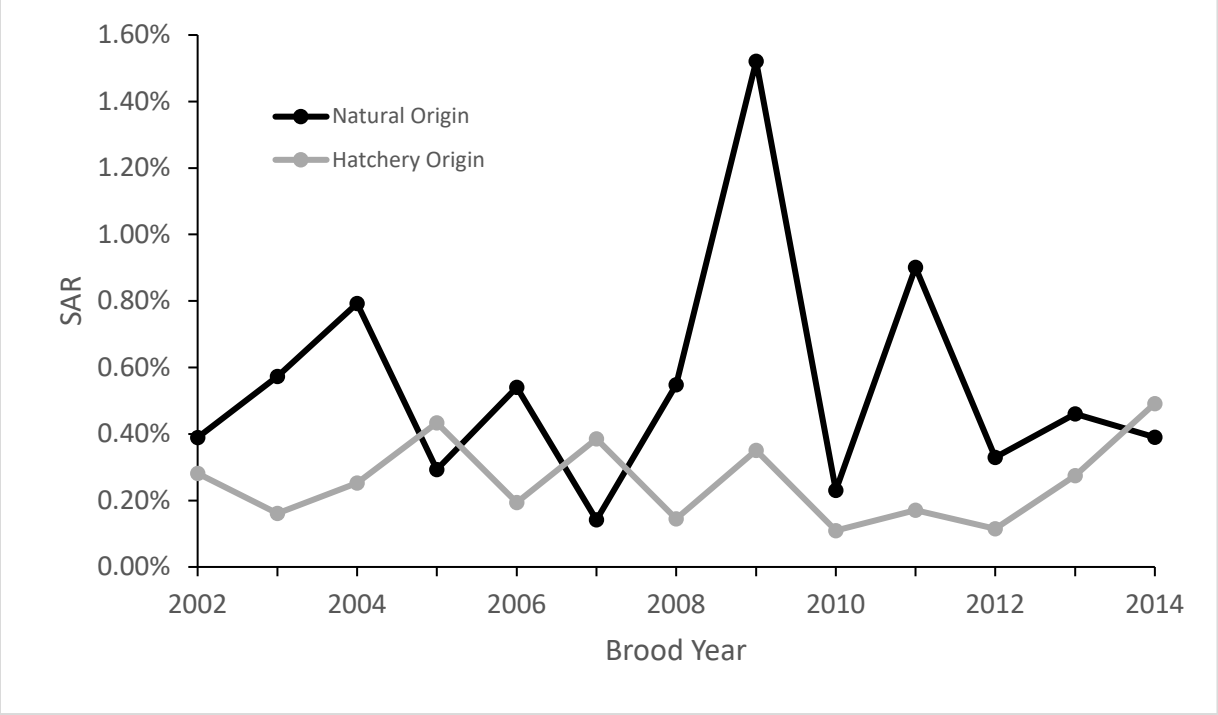

Figure 4. Smolt to adult return rate (SAR) of natural origin vs hatchery origin Chinook from the Green River, brood years 2002-2014. Does not include age 2 (jacks) returns, account for harvest or natural-origin adults captured for hatchery broodstock.

Yearling Chinook

Two natural-origin Chinook yearlings were captured. In total, 161 hatchery-origin yearling Chinook were captured (51 Ad-mark, 107 Ad-CWT, 1 CWT only and 2 unmarked).

Coho Smolts

We could not estimate catch of natural-origin coho smolts because all the hatchery smolts released upstream of the Screw Trap were unmarked. For the season we caught a total of 1,373 coho smolts, including 1,278 unmarked, 4 ad-marked and 91 CWT only. In addition, we estimated 155 more would have been caught had we fished continually. The first coho was captured on January 26th and the last on June 24th (Appendix D). Catch remained low and sporadic thru the first two full month of trapping averaging less than 2 fish per day. The catch ramped up in mid-April with the release of over 600,000 non externally marked hatchery coho. Peak daily catch occurred on April 21 with a one day catch of 124 fish. Daily catch declined gradually through May and early June. The last coho smolt was captured on June 24, 2019. No production estimate was made for natural origin coho smolts because of the large number of unmarked hatchery coho.

The seasonal average length of coho smolts was 122.47 ± 12.92 mm FL (± 1 S.D). The weekly average size was smaller early in the season prior to the release of the unmarked hatchery coho (Appendix E).

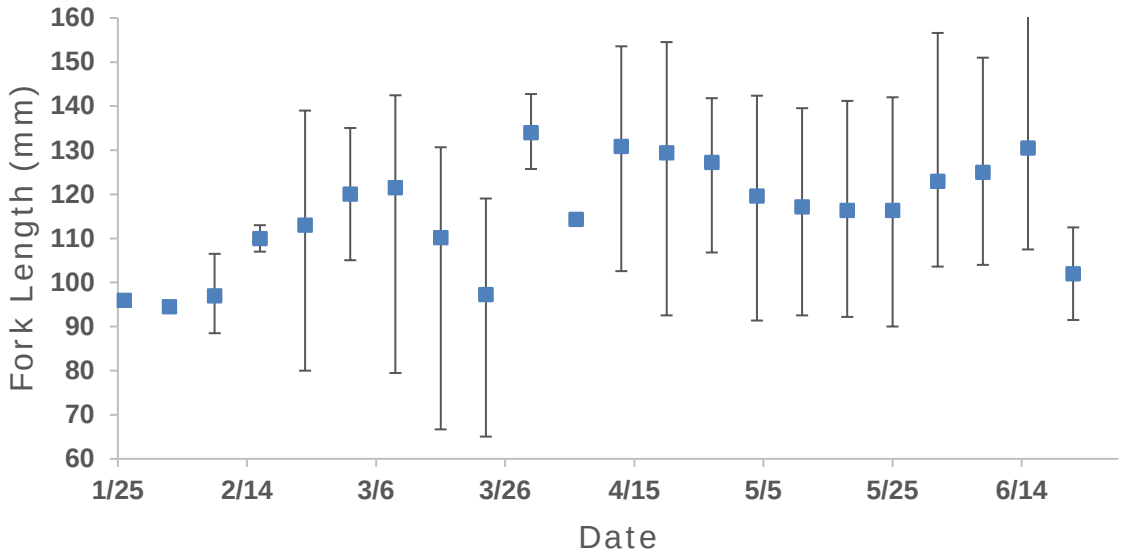

Figure 5. Fork length (mm) of mixed coho captured in the Green River screw trap in 2019. Data are mean, minimum, and maximum values by week.

Steelhead Smolts

The total estimated catch of natural-origin steelhead smolts ($\hat{u}$ = 52) included 49 captures in the trap and 3 missed catch estimated for trap outage periods (Appendix D). In total, 166 (105 Ad-only and 61 CWT-only) hatchery steelhead were captured between March 17 and June 16. We did not catch enough natural origin steelhead smolts to estimate trapping efficiency or production.

The median catch date for natural steelhead smolts was May 25. The first natural origin steelhead was captured on February 13. Peak daily catch occurred on May 12 when 5 smolts were caught. Daily catch became sporadic just after the peak with the last one for the season caught on July 10. (Figure 5).

Over the season, a total of 49 maiden captured unmarked steelhead were measured (fork length), 100% of the total catch. Individuals ranged from 135mm to 234 mm and averaged 172.0 mm for the season (Figure 7).

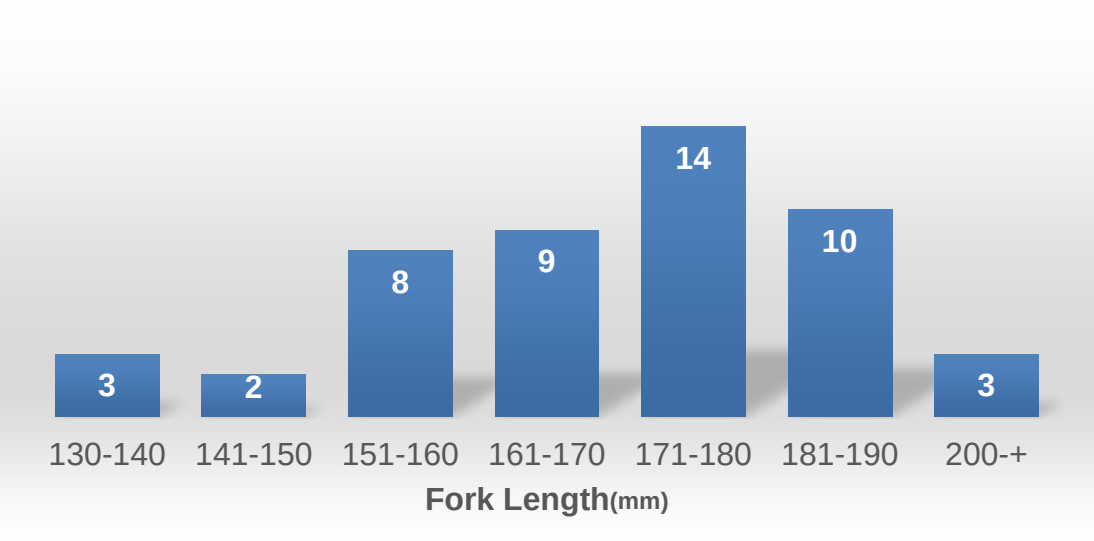

Figure 6. Fork length (mm) of natural-origin steelhead captured in the Green River screw trap in 2019.

Length samples were collected on all 49 natural-origin steelhead smolts captured. Scales, weights and DNA tissue samples were collected on 46 individuals to determine the age structure and body size of natural-origin steelhead smolts. In total 41 of the 46 scale samples collected were readable for age (Table 10).

Table 10. Age, average length (mm) and average weight of natural-origin steelhead smolts collected at the Green River juvenile trap, migration years 2011-2019.

Smolt Age Year	1+			2+			3+			4+		
	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	40%	39.8	177	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%	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	221.0	1%	93.4			
2018	157.2	36%	37.2	172.7	73%	50.2	185.0	1%	60.4			
2019	167.8	71%	45.3	190.3	24%	68.4	185.00	5%	62.8			

Chum

The total estimated catch of unmarked chum fry ($\hat{u}$ =214,820) included 211,760 captures in the trap and 3,060 missed catch estimated for trap outage periods (Appendix D). Chum migrants were captured between February 12 and July 10, 2019. 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 116 coho fry, nine sockeye fry, 38 trout parr, eight cutthroat smolts, one cutthroat adult and nine trout fry (Appendix D). Non-salmonid species captured included sculpin (*Cottus* spp.), three-spine sticklebacks (*Gasterosteus aculeatus*), longnose dace (*Rhynichthys cataractae*), and lamprey ammocoetes.

Discussion and Synthesis

This report provides the freshwater production estimates for natural origin subyearling Chinook salmon emigrating from the Green River in 2019. 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 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 2018 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 mainstem Green River below the trap was 263,373 and 49,045 from Soos Creek and represented 23.7% of the total production.

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 2019, the primary hatchery mark strategy for the Palmer Pond release was an internal thermal otolith mark, with a goal of 100% marking. However, in 2019 an additional 2 million Ad-mark only subyearling Chinook were reared and released from Palmer Ponds. None of the 2014-2018 Palmer Pond releases were ad-marked; only in 2014 did a portion of the release receive CWT. In 2019, we did not assume the Palmer facility was fish tight when the non-externally marked fish were transferred to the facility in early-March. About three weeks later, the two million Ad-marked Chinook were added to the pond. Shortly after the initial stocking, the juvenile trap began capturing Chinook that were larger than any fish captured prior to the stocking. In 2019, we lethally sampled non externally marked Chinook for otolith analysis, 287 in total. When possible, trap mortalities were used in the weekly sample to reduce the number intentionally killed per week. In total, 287 were collected for otolith analysis (255 sacrificed, 32 trap mortalities). The otolith sample results identified 225 natural and 56 hatchery origin and six unreadable sample, an incidence of 20% hatchery fish. Length measurement were taken on all the Chinook that were otolith sampled. The hatchery fish were larger than the natural fish in all but two weeks early in the collection when the fish were smaller. The hatchery fish averaged 33mm larger over the entire sample (Table 5).

Freshwater Production of Chinook Salmon

In total we estimated 811,303 natural and 21,432 hatchery Chinook migrating past the juvenile fish trap site during the trapping season. The abundant hatchery migration is notable because it occurred prior to the intended hatchery release date. We believe the results from the otolith sampling accurately estimated the number of otolith marked fish present in our catch because the sample was collected randomly over the entire period the hatchery Chinook were present in Palmer Ponds upstream from the trap site.

The total estimated natural origin production for the entire Green River was 1,320,791 Chinook salmon, including 1,008,372 from above trap and 263,373 from the main-stem below the trap and 49,045 from Soos Creek (Table 6).

We estimated a total of 118,309 Chinook salmon parr > 45 mm, which was 11.73 % of the total migration estimate of 1,008,372. Estimating parr was complicated by the presence of non-externally marked hatchery origin fish in our catch. For this reason, we estimated the number of natural parr migrants by using the length sample from all externally unmarked fish encountered from the start of the season thru March 22nd, when the otolith sampling began and hatchery-origin fish were first observed. From March 23 thru the end of the season we restricted the size measurements used to allocate fry vs. parr to the 225 fish confirmed as natural-origin via otolith analysis. This parr estimate is almost identical to a parr estimate (119,427, 11.57%) made using the 2,711 externally unmarked Chinook measured throughout the season for which we have no otolith data, a group that contains an unknown number of hatchery-origin fish Chinook. The similarity of the two parr estimates increases our confidence that we have accurately estimated parr abundance despite the complication of the non-externally marked hatchery-origin fish.

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 twenty 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 productions observed in 2001 (430,442) and 2017 (455,253) are very similar 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.

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 2019, we captured two natural origin yearlings.

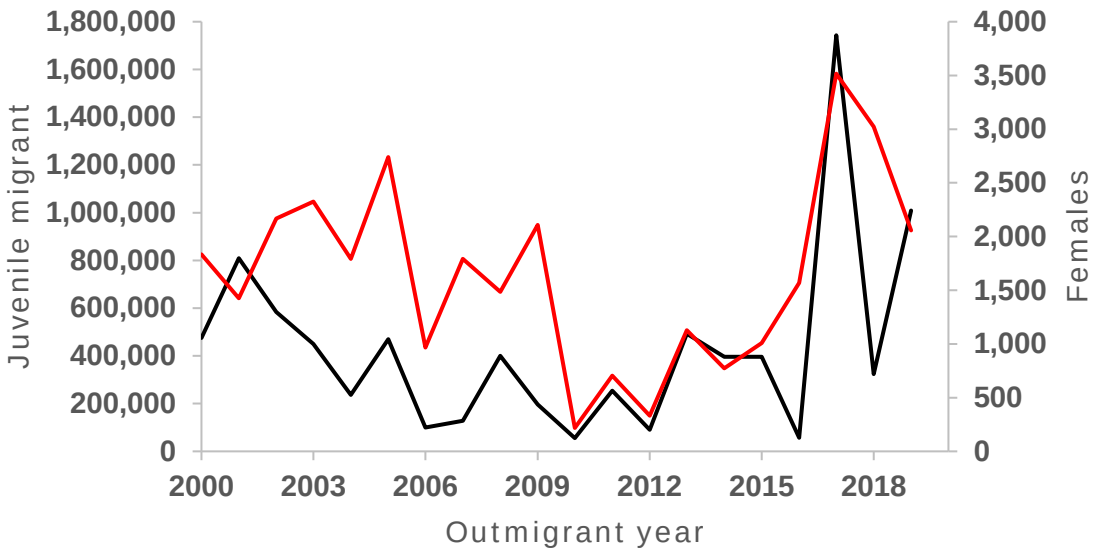

Figure 7. Number of unmarked natural origin subyearling Chinook migrants (black line) passing the Green River juvenile trap and the corresponding number of female spawners (Red line) above the juvenile trap, outmigration year 2000-2019.

Freshwater Production of Coho Salmon

Freshwater production of coho smolts above the Green River trap has been estimated for 14 of the 20 years of this study (Table 11). The 2019 freshwater production was not estimated because none of the hatchery origin coho released from Keta Creek Hatchery were externally marked, making positive identification impossible.

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, 2005 and 2019 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 ten consecutive year period between 2009 and 2018 we were able to estimate coho production mainly because of the stability and consistency of the river channel at our trapping location. This location provided a well-defined slot with good water velocities enabling the trap to capture enough coho smolts to generate these estimates. In 2019, the channel at the trap site widened and became more uniform in depth across the entire channel resulting in slower velocities across the entire river, and likely reduced capture efficiency.

A second challenge associated with estimating abundance for coho and steelhead smolts is the release of hatchery fish above the trap. We encounter challenges with natural origin abundance estimation even when the hatchery origin fish are externally marked. 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) tend 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.

Table 11. Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin coho smolts rearing above the Green River juvenile trap, migration years 2000-2019.

	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
2018	57,609	34,616	80,603	20.36%	105.2	10.66	5/7
2019	59,398	12,322	106,474	40.44%	122.5	12.92	4/22

[a] Median catch date.

[b] Abundance estimate includes 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 20 years of this study (Table 12). In 2019 natural steelhead smolt production was not estimated. Low maiden catch and no recoveries from 43 individuals marked and released for efficiency trials precluded us from estimating trapping efficiency or making a production estimate. The percentage of age-1 smolts in 2019 was the highest observed in the 20 years of the project and very similar to the age structure observed in 2017. Additionally, the individuals in the one and two year old smolt categories were larger than in any other year. The high percentage of one-year old smolts in our catch might be a sign of poor capture efficiency caused by slow water and larger fish avoiding the trap. (Table 12).

Table 12. Abundance (estimate, 95% confidence interval, coefficient of variation), fork length (average, standard deviation), and median catch or migration date for natural-origin steelhead smolts rearing above the Green River juvenile trap, migration years 2000-2019.

	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
2018	6,025	3,439	8,611	21.90%	168.9	17.13	5/12
2019	---	---	---	---	172.0	19.08	5/18

a Median catch date

Appendix A

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

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

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

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

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

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

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

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

Derivation:

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

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

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

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

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

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

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

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

Note that,

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

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

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

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

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

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

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

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

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

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

Appendix B

Daily catch and migration estimate for unmarked natural origin subyearling Chinook in the Green River, 2019

APPENDIX B. – Actual and estimated daily catches and migration for unmarked natural origin subyearling Chinook migrants in the Green River, 2019. 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.

Date	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			Migration
	In	Out	Actual	Est	Total	
1/1-1/23	Pre-trapping					194,986
1/24/2019	25.00		788		788	43,655
1/25/2019	24.00		304		304	16,842
1/26/2019	24.00		200		200	11,080
1/27/2019	24.00		123		123	6,814
1/28/2019	24.00		77		77	4,266
1/29/2019	24.00		73		73	4,044
1/30/2019	24.08		71		71	3,933
1/31/2019	24.17		67		67	3,712
2/1/2019	23.83		88		88	4,875
2/2/2019	24.42		131		131	7,257
2/3/2019	23.50		144		144	7,978
2/4/2019	24.00		138		138	7,645
2/5/2019	24.00		205		205	11,357
2/6/2019	23.75		198		198	10,969
2/7/2019	24.67		109		109	6,039
2/8/2019	25.25		65		65	3,601
2/9/2019	14.92	7.00	16	42	58	3,213
2/10/2019		24.00		168	168	4,643
2/11/2019		24.00		168	168	4,643
2/12/2019		24.00		168	168	4,643
2/13/2019	24.75		309		309	8,539
2/14/2019	24.00		333		333	9,203
2/15/2019	24.00		174		174	4,809
2/16/2019	24.00		175		175	4,836
2/17/2019	24.25		175		175	4,836
2/18/2019	23.75		185		185	5,113
2/19/2019	24.33		146		146	4,035
2/20/2019	23.83		246		246	6,798
2/21/2019	24.00		395		395	10,916
2/22/2019	23.08		143		143	3,952
2/23/2019	25.00		108		108	2,985
2/24/2019	24.00		98		98	1,765
2/25/2019	24.00		196		196	3,530

Table continued next page

APPENDIX B.– continued.

Date	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			Migration
	In	Out	Actual	Est	Total	
2/26/2019	24.33		134		134	2,414
2/27/2019	24.00		115		115	2,071
2/28/2019	24.08		183		183	3,296
3/1/2019	24.58		123		123	2,215
3/2/2019	23.25		147		147	2,648
3/3/2019	23.75		149		149	2,684
3/4/2019	24.00		169		169	3,044
3/5/2019	24.00		168		168	3,026
3/6/2019	24.75		111		111	1,999
3/7/2019	24.25		78		78	1,405
3/8/2019	23.91		76		76	1,369
3/9/2019	23.58		177		177	3,188
3/10/2019	24.75		175		175	3,152
3/11/2019	24.00		184		184	3,314
3/12/2019	24.92		6,053		6,053	109,024
3/13/2019	23.50		587		587	10,573
3/14/2019	24.09		384		384	6,916
3/15/2019	24.42		142		142	2,558
3/16/2019	23.66		249		249	4,485
3/17/2019	24.17		348		348	6,268
3/18/2019	24.00		728		728	13,112
3/19/2019	22.75		1,960		1,960	35,303
3/20/2019	24.25		2,858		2,858	51,477
3/21/2019	25.17		1,576		1,576	28,386
3/22/2019	24.17		445		445	8,015
3/23/2019	23.67		412		412	7,421
3/24/2019	24.17		387		387	9,512
3/25/2019	23.66		507		507	12,462
3/26/2019	24.59		359		359	8,824
3/27/2019	23.41		389		389	9,561
3/28/2019	24.59		217		217	5,334
3/29/2019	23.75		232		232	5,702
3/30/2019	23.83		191		191	4,695
3/31/2019	24.25		136		136	9,830
4/1/2019	23.75		57		57	4,096
4/2/2019	24.17		84		84	6,075

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APPENDIX B.– continued.

Date	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			Migration
	In	Out	Actual	Est	Total	
4/3/2019	24.08		26		26	1,911
4/4/2019	23.75		72		72	5,188
4/5/2019	24.25		58		58	4,164
4/6/2019	23.75		162		162	11,673
4/7/2019	24.33		62		62	4,232
4/8/2019	24.09		88		88	6,007
4/9/2019	23.83		591		591	40,344
4/10/2019	23.75		164		164	11,195
4/11/2019		24.00		105	105	7,168
4/12/2019		24.00		105	105	7,168
4/13/2019	10.58	14.00	8	97	105	7,168
4/14/2019	24.00		54		54	3,686
4/15/2019	24.17		16		16	1,092
4/16/2019	12.00	11.25	16	6	22	1,502
4/17/2019		24.00		20	20	1,365
4/18/2019		22.00		19	19	1,297
4/19/2019	26.00		18		18	1,229
4/20/2019	24.42		23		23	1,570
4/21/2019	23.91		20		20	1,434
4/22/2019	23.67		18		18	1,297
4/23/2019	24.50		17		17	1,229
4/24/2019	24.00		20		20	1,434
4/25/2019	24.33		14		14	1,024
4/26/2019	23.67		16		16	1,160
4/27/2019	24.00		25		25	1,775
4/28/2019	24.00		16		16	1,092
4/29/2019	24.17		19		19	1,297
4/30/2019	24.16		38		38	2,594
5/1/2019	23.67		15		15	1,024
5/2/2019	24.17		21		21	1,434
5/3/2019	23.58		7		7	478
5/4/2019	24.25		8		8	546
5/5/2019	24.25		14		14	956
5/6/2019	23.75		11		11	751
5/7/2019	24.16		12		12	819
5/8/2019	24.08		20		20	1,365

Table continued next page

APPENDIX B.– continued.

Date	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			Migration
	In	Out	Actual	Est	Total	
5/9/2019	24.00		22		22	1,502
5/10/2019	24.75		24		24	1,638
5/11/2019	23.66		22		22	1,502
5/12/2019	23.50		31		31	808
5/13/2019	24.00		50		50	1,307
5/14/2019	24.00		24		24	642
5/15/2019	24.00		21		21	547
5/16/2019	23.50		13		13	333
5/17/2019	24.41		185		185	4,848
5/18/2019	23.92		134		134	3,517
5/19/2019	24.25		21		21	523
5/20/2019	23.83		9		9	238
5/21/2019	24.42		8		8	190
5/22/2019	24.00		6		6	143
5/23/2019	23.50		6		6	143
5/24/2019	24.25		9		9	214
5/25/2019	11.50	12.75	10		10	261
5/26/2019	23.75		18		18	499
5/27/2019	11.25	13.00	10		10	285
5/28/2019	24.50		8		8	214
5/29/2019	23.25		5		5	143
5/30/2019	24.50		7		7	190
5/31/2019	23.50		9		9	261
6/1/2019	24.08		6		6	166
6/2/2019	24.17		8		8	190
6/3/2019	23.83		8		8	190
6/4/2019	24.50		18		18	452
6/5/2019	23.67		23		23	570
6/6/2019	24.50		8		8	214
6/7/2019	24.25		29		29	737
6/8/2019	23.00		35		35	879
6/9/2019	24.08		17		17	1,054
6/10/2019	23.92		19		19	1,178
6/11/2019	24.58		14		14	868
6/12/2019	23.66		13		13	806
6/13/2019	23.75		6		6	372

Table continued next page

APPENDIX B.– continued.

Date	Time Fished Hours		Unmarked Sub-yearling Chinook Catch			Migration
	In	Out	Actual	Est	Total	
6/14/2019	24.00		8		8	496
6/15/2019	11.00	13.00	16		16	992
6/16/2019		24.25		5	5	744
6/17/2019	25.00		4		4	558
6/18/2019	24.00		4		4	682
6/19/2019	24.00		9		9	1,426
6/20/2019	23.00		11		11	1,612
6/21/2019		25.00		13	13	1,922
6/22/2019	24.00		13		13	1,922
6/23/2019		25.00		8	8	1,736
6/24/2019	10.00	14.00	7		7	1,488
6/25/2019		24.00		5	5	1,178
6/26/2019	23.00		5		5	1,178
6/27/2019	24.33		5		5	1,178
6/28/2019	23.67		5		5	992
6/29/2019	11.00	13.00	7		7	1,488
6/30/2019		24.00		4	4	806
7/1/2019		24.50		4	4	806
7/2/2019	23.50		1		1	186
7/3/2019	11.00	13.00	5		5	1,054
7/4/2019		24.00	3		3	682
7/5/2019	24.16		2		2	372
7/6/2019	10.83	13.00	4		4	744
7/7/2019		24.00		6	6	744
7/8/2019		24.00		6	6	744
7/9/2019	24.00		6		6	744
7/10/2019	24.25		4		4	558
7/11/2019	23.75		2		2	248
7/12/2019	8.00		1		1	186
7/13-7/31	Post-trapping					2,083
Total	3,560.79	508.75	28,416	943	29,359	1,008,372

Appendix C

Fork length of non-externally marked subyearling Chinook in the Green River, 2019

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 2019.

Week				Range		Number		Percent
Begin	End	Average	St.Dev.	Min	Max	Sampled	Caught	Sampled
1/24/19	1/26/19	39.87	1.87	34	43	114	1,292	8.82%
1/27/19	2/2/19	39.86	2.13	35	44	71	630	11.27%
2/3/19	2/9/19	40.49	2.16	35	48	92	875	10.51%
2/10/19	2/16/19	41.13	2.00	37	48	115	991	11.60%
2/17/19	2/23/19	40.89	2.18	36	47	164	1,398	11.73%
2/24/19	3/2/19	40.99	1.87	36	45	108	996	10.84%
3/3/19	3/9/19	40.66	2.03	37	47	104	928	11.21%
3/10/19	3/16/19	40.93	2.31	36	49	222	7,774	2.86%
3/17/19	3/23/19	41.09	2.31	36	52	262	8,327	3.15%
3/24/19	3/30/19	41.35	2.61	33	50	215	2,282	9.42%
3/31/19	4/6/19	40.95	3.06	35	58	99	629	15.74%
4/7/19	4/13/19	43.75	5.69	36	64	68	913	7.45%
4/14/19	4/20/19	45.02	6.08	37	67	61	127	48.03%
4/21/19	4/27/19	48.58	7.73	37	76	108	137	78.83%
4/28/19	5/4/19	51.44	9.23	38	81	81	124	65.32%
5/5/19	5/11/19	52.29	7.49	38	78	110	125	88.00%
5/12/19	5/18/19	59.32	9.73	42	85	163	505	32.28%
5/19/19	5/25/19	67.11	9.84	47	86	54	72	75.00%
5/26/19	6/1/19	80.94	12.31	44	101	65	74	87.84%
6/2/19	6/8/19	84.23	9.76	53	108	113	136	83.09%
6/9/19	6/15/19	87.51	7.65	60	104	80	93	86.02%
6/16/19	6/22/19	89.61	9.06	62	111	85	100	85.00%
6/23/19	6/29/19	96.04	7.86	78	111	94	102	92.16%
6/30/19	7/6/19	92.51	9.92	71	110	37	37	100.00%
7/7/19	7/13/19	89.31	9.97	70	105	26	28	92.86%
Season Total		52.50	19.13	33	111	2,711	28,695	9.45%

Appendix D

Daily estimated catch of coho, chum and sockeye salmon, steelhead and cutthroat trout in the Green River, 2019

APPENDIX D.─ Daily estimated catches of coho, chum and sockeye salmon and steelhead and cutthroat trout caught in the Green River screw trap in 2019. Catch represents actual and estimated catch for a given day. Time in and out reflect time fished (in) and not fished (out) on a given day.

Date	Times		Coho		Chum	Sock	Steelhead	Cutt	Trout
			Smolts	Fry	Fry	Fry	Smolts	Smolt	Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
1/24	25.00	0.00	0	0	0	0	0	0	0
1/25	24.00	0.00	0	2	2	2	0	0	2
1/26	24.00	0.00	1	0	0	1	0	0	1
1/27	24.00	0.00	0	0	0	0	0	0	0
1/28	24.00	0.00	2	0	2	0	0	0	0
1/29	24.00	0.00	0	0	0	2	0	0	0
1/30	24.08	0.00	1	0	0	1	0	0	0
1/31	24.17	0.00	0	0	1	3	0	0	0
2/1	23.83	0.00	1	0	0	1	0	0	0
2/2	24.42	0.00	0	0	0	4	0	0	0
2/3	23.50	0.00	1	0	1	1	0	0	0
2/4	24.00	0.00	0	0	0	2	0	0	0
2/5	24.00	0.00	0	0	2	1	0	0	1
2/6	23.75	0.00	0	0	1	0	0	0	0
2/7	24.67	0.00	0	0	5	0	0	0	0
2/8	25.25	0.00	1	0	11	2	0	0	0
2/9	14.92	7.00	0	0	13	2	0	0	0
2/10	0.00	24.00	0	0	13	8	1	0	1
2/11	0.00	24.00	0	0	13	8	1	0	1
2/12	0.00	24.00	0	0	13	8	1	0	1
2/13	24.75	0.00	0	0	16	14	1	0	2
2/14	24.00	0.00	0	0	36	14	2	0	3
2/15	24.00	0.00	0	0	12	6	0	0	2
2/16	24.00	0.00	0	0	11	1	0	0	1
2/17	24.25	0.00	0	0	26	0	0	0	1
2/18	23.75	0.00	1	1	32	0	0	0	1
2/19	24.33	0.00	0	0	16	0	0	0	1
2/20	23.83	0.00	1	0	37	0	0	0	1
2/21	24.00	0.00	3	0	50	3	0	0	0
2/22	23.08	0.00	1	0	21	2	0	0	1
2/23	25.00	0.00	3	0	53	1	0	0	0
2/24	24.00	0.00	2	0	53	1	0	0	0

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APPENDIX D.– continued.

Date	Times		Coho		Chum	Sock	Steelhead	Cutt	Trout
			Smolts	Fry	Fry	Fry	Smolts	Smolt	Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
2/25	24.00	0.00	1	0	205	2	0	0	0
2/26	24.33	0.00	0	0	122	2	0	0	0
2/27	24.00	0.00	0	0	178	10	0	0	0
2/28	24.08	0.00	0	0	474	13	0	1	0
3/1	24.58	0.00	1	0	311	4	0	0	0
3/2	23.25	0.00	1	0	540	1	0	0	1
3/3	23.75	0.00	5	1	735	10	0	0	0
3/4	24.00	0.00	2	1	386	1	0	0	0
3/5	24.00	0.00	0	1	535	0	0	0	0
3/6	24.75	0.00	13	0	232	0	0	0	0
3/7	24.25	0.00	12	2	618	1	0	0	0
3/8	23.91	0.00	22	3	1,132	5	0	0	0
3/9	23.58	0.00	8	2	1,139	2	0	0	2
3/10	24.75	0.00	5	3	928	1	0	0	0
3/11	24.00	0.00	6	1	824	2	0	0	0
3/12	24.92	0.00	22	14	4,395	15	0	0	0
3/13	23.50	0.00	14	9	2,958	13	0	0	1
3/14	24.09	0.00	8	6	2,976	8	0	0	0
3/15	24.42	0.00	15	8	534	2	0	0	2
3/16	23.66	0.00	6	12	3,843	2	0	0	0
3/17	24.17	0.00	1	7	7,320	0	0	0	0
3/18	24.00	0.00	2	2	9,619	0	0	1	1
3/19	22.75	0.00	3	19	23,723	4	0	0	0
3/20	24.25	0.00	7	22	23,416	2	0	0	5
3/21	25.17	0.00	4	27	5,736	2	0	2	0
3/22	24.17	0.00	1	41	995	2	0	0	1
3/23	23.67	0.00	0	29	3,339	1	0	0	0
3/24	24.17	0.00	2	22	7,066	3	0	0	1
3/25	23.66	0.00	0	61	3,606	2	0	0	0
3/26	24.59	0.00	1	38	5,739	1	0	0	0
3/27	23.41	0.00	0	23	3,562	3	0	0	0
3/28	24.59	0.00	3	19	2,663	0	0	0	1

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APPENDIX D.– continued.

Date	Times		Coho Smolts	Fry	Chum Fry	Sock Fry	Steelhead Smolts	Cutt Smolt	Trout Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
3/29	23.75	0.00	0	34	5,087	0	0	0	0
3/30	23.83	0.00	0	53	4,268	0	0	0	0
3/31	24.25	0.00	1	38	3,528	4	0	0	0
4/1	23.75	0.00	0	45	2,229	1	0	0	0
4/2	24.17	0.00	0	63	4,091	0	0	0	0
4/3	24.08	0.00	0	59	3,867	1	0	0	0
4/4	23.75	0.00	0	104	7,937	0	0	0	0
4/5	24.25	0.00	0	51	3,550	1	0	0	0
4/6	23.75	0.00	1	110	9,160	0	0	0	0
4/7	24.33	0.00	0	54	6,562	2	0	0	0
4/8	24.09	0.00	3	72	5,427	0	0	0	0
4/9	23.83	0.00	2	265	8,087	2	0	0	0
4/10	23.75	0.00	0	8	611	0	0	0	1
4/11	0.00	24.00	7	16	721	0	0	0	0
4/12	0.00	24.00	7	16	721	0	0	0	0
4/13	10.58	14.00	8	14	737	0	0	1	1
4/14	24.00	0.00	14	26	771	0	0	1	0
4/15	24.17	0.00	11	6	433	0	1	0	0
4/16	12.00	11.25	68	12	256	0	0	0	0
4/17	0.00	24.00	59	12	410	0	0	0	0
4/18	0.00	22.00	59	12	389	0	0	0	0
4/19	26.00	0.00	54	13	698	0	0	0	1
4/20	24.42	0.00	86	8	354	0	0	0	0
4/21	23.91	0.00	128	8	246	0	0	0	0
4/22	23.67	0.00	96	7	73	0	0	1	0
4/23	24.50	0.00	59	11	513	0	0	0	1
4/24	24.00	0.00	25	9	341	1	0	0	1
4/25	24.33	0.00	23	7	323	0	0	0	0
4/26	23.67	0.00	40	5	598	0	0	1	0
4/27	24.00	0.00	18	1	1,431	0	0	0	3
4/28	24.00	0.00	27	3	304	0	1	0	0
4/29	24.17	0.00	17	3	485	0	0	1	0

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APPENDIX D.– continued.

Date	Times		Coho Smolts	Coho Fry	Chum Fry	Sock Fry	Steelhead Smolts	Cutt Smolt	Trout Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
4/30	24.16	0.00	12	5	4,777	0	0	0	1
5/1	23.67	0.00	6	6	3,575	0	0	0	0
5/2	24.17	0.00	16	2	1,344	0	0	0	0
5/3	23.58	0.00	9	3	1,707	0	0	0	0
5/4	24.25	0.00	14	0	526	0	0	0	0
5/5	24.25	0.00	15	4	874	0	1	0	0
5/6	23.75	0.00	12	2	444	0	1	0	0
5/7	24.16	0.00	8	0	556	0	0	0	0
5/8	24.08	0.00	12	0	1,663	0	0	0	0
5/9	24.00	0.00	12	0	1,323	0	1	0	0
5/10	24.75	0.00	19	0	868	0	4	0	0
5/11	23.66	0.00	17	1	510	0	0	0	0
5/12	23.50	0.00	19	2	258	0	4	0	0
5/13	24.00	0.00	20	0	236	0	5	0	0
5/14	24.00	0.00	15	0	113	0	1	0	0
5/15	24.00	0.00	8	1	182	0	0	1	0
5/16	23.50	0.00	8	0	167	0	2	0	0
5/17	24.41	0.00	23	3	395	1	0	0	0
5/18	23.92	0.00	34	2	132	0	1	0	0
5/19	24.25	0.00	13	1	44	0	0	0	0
5/20	23.83	0.00	16	0	39	0	1	0	0
5/21	24.42	0.00	9	0	36	0	1	1	0
5/22	24.00	0.00	8	1	37	0	0	0	0
5/23	23.50	0.00	6	2	40	0	0	0	0
5/24	24.25	0.00	8	0	31	0	0	0	0
5/25	11.50	12.75	9	0	29	0	2	0	0
5/26	23.75	0.00	10	0	95	0	3	0	0
5/27	11.25	13.00	7	0	80	0	1	0	0
5/28	24.50	0.00	5	1	28	0	0	0	0
5/29	23.25	0.00	12	1	10	0	1	0	0
5/30	24.50	0.00	3	3	8	0	2	0	0
5/31	23.50	0.00	5	0	19	0	0	0	0

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APPENDIX D.– continued.

Date	Times		Coho		Chum	Sock	Steelhead	Cutt	Trout
			Smolts	Fry	Fry	Fry	Smolts	Smolt	Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
6/1	24.08	0.00	4	2	10	0	0	0	0
6/2	24.17	0.00	4	3	9	0	2	0	0
6/3	23.83	0.00	3	2	9	0	1	0	0
6/4	24.50	0.00	3	0	10	0	1	0	0
6/5	23.67	0.00	4	2	21	0	1	0	0
6/6	24.50	0.00	0	4	5	0	0	0	0
6/7	24.25	0.00	5	3	11	0	0	0	0
6/8	23.00	0.00	1	0	20	0	0	0	0
6/9	24.08	0.00	2	0	8	0	2	0	0
6/10	23.92	0.00	0	1	11	0	0	0	0
6/11	24.58	0.00	2	2	7	0	1	0	0
6/12	23.66	0.00	2	0	4	0	1	0	0
6/13	23.75	0.00	1	0	10	0	2	0	0
6/14	24.00	0.00	0	0	3	0	1	0	0
6/15	11.00	13.00	0	0	9	0	0	0	0
6/16	0.00	24.25	0	0	6	0	0	0	0
6/17	25.00	0.00	1	1	5	0	0	0	0
6/18	24.00	0.00	1	0	0	0	0	0	0
6/19	24.00	0.00	0	0	2	0	0	0	0
6/20	23.00	0.00	0	0	5	0	0	0	0
6/21	0.00	25.00	0	0	4	0	0	0	0
6/22	24.00	0.00	0	0	1	0	0	0	0
6/23	0.00	25.00	1	1	1	0	0	0	0
6/24	10.00	14.00	1	1	0	0	0	0	0
6/25	0.00	24.00	0	1	0	0	0	0	0
6/26	23.00	0.00	0	1	1	0	0	0	0
6/27	24.33	0.00	0	0	1	0	0	0	0
6/28	23.67	0.00	0	0	0	0	0	0	0
6/29	11.00	13.00	0	1	1	0	0	0	0
6/30	0.00	24.00	0	1	1	0	0	0	0
7/1	0.00	24.50	0	1	1	0	0	0	0
7/2	23.50	0.00	0	0	0	0	0	0	0

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Date	Times		Coho		Chum	Sock	Steelhead	Cutt	Trout
			Smolts	Fry	Fry	Fry	Smolts	Smolt	Parr
	In	Out	Mixed	Nat	Mixed	Nat	Nat	Nat	Nat
7/3	11.00	13.00	0	1	0	0	0	0	0
7/4	0.00	24.00	0	1	0	0	0	0	0
7/5	24.16	0.00	0	1	0	0	0	0	0
7/6	10.83	13.00	0	0	0	0	0	0	0
7/7	0.00	24.00	0	1	0	0	0	0	0
7/8	0.00	24.00	0	1	0	0	0	0	0
7/9	24.00	0.00	0	2	0	0	0	0	0
7/10	24.25	0.00	0	0	1	0	1	0	0
7/11	23.75	0.00	0	1	0	0	0	0	0
7/12	8.00	0.00	0	1	0	0	0	0	0
Grand Total	3560.79	508.75	1,421	1,597	214,820	215	52	11	47

Appendix E

Fork lengths of Mixed-origin coho smolts in the Green River, 2019

APPENDIX E.─Mean fork length (mm), standard deviation (St.Dev.), range, and sample size of mixed-origin coho smolts in the Green River in 2019.

Dates		Sample results				
Start	**End**	**Average**	**StdDev**	**Min**	**Max**	**Count**
01/20/19	01/26/19	96.00	na	96	96	1
01/27/19	02/02/19	94.50	7.55	86	104	4
02/03/19	02/09/19	97.00	4.24	94	100	2
02/10/19	02/16/19	110.00	18.59	77	136	9
02/17/19	02/23/19	113.00	12.92	98	128	5
02/24/19	03/02/19	120.05	13.05	78	141	60
03/03/19	03/09/19	121.52	10.22	78	142	69
03/10/19	03/16/19	110.20	17.65	78	132	15
03/17/19	03/23/19	97.25	9.00	89	106	4
03/24/19	03/30/19	134.00	na	134	134	1
03/31/19	04/06/19	114.33	18.19	86	137	9
04/07/19	04/13/19	130.91	9.84	94	156	117
04/14/19	04/20/19	129.46	6.99	109	144	101
04/21/19	04/27/19	127.26	9.38	99	150	57
04/28/19	05/04/19	119.64	11.66	95	142	77
05/05/19	05/11/19	117.18	12.42	93	142	68
05/12/19	05/18/19	116.37	10.84	90	142	43
05/19/19	05/25/19	116.39	10.87	97	150	41
05/26/19	06/01/19	123.00	13.13	102	149	19
06/02/19	06/08/19	125.00	18.50	102	155	8
06/09/19	06/15/19	130.50	14.85	120	141	2
06/16/19	06/22/19	102.00	na	102	102	1
06/23/19	06/29/19					
06/30/19	07/06/19		No sample			
07/07/19	07/13/19					
Season Total		**122.47**	**12.92**	**77**	**156**	**713**

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