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Chinook Salmon Spawning Ground Surveys on the Entiat River, 2016



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On the cover: A Chinook Salmon redd in the Entiat River.

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Abstract—This report summarizes the results of spring and summer Chinook Salmon (*Oncorhynchus tshawytscha*) spawning ground surveys conducted in the Entiat River basin in 2016. Data were collected on redd location, timing of redd construction, and redd superimposition rates by summer Chinook Salmon on spring Chinook Salmon. Salmon carcasses were recovered, identified to species, and analyzed for run, gender, age, rearing origin, and any research tags or marks they may have contained. The data were used to describe the population characteristics of returning adults from each run, using metrics including spawn escapement, natural- and hatchery-origin proportions, age class composition, and hatchery specific contribution to the spawning population. Opportunistic data were also collected on Sockeye Salmon (*O. nerka*) and Coho Salmon (*O. kisutch*) spawning in the Entiat River basin.

In 2016, a total of 147 spring Chinook Salmon redds and 363 summer Chinook Salmon redds were identified in the Entiat River basin. The spawning run escapements were estimated at 334 spring Chinook Salmon and 567 summer Chinook Salmon. Superimposition rates of summer Chinook Salmon redds on spring Chinook Salmon redds were 15.6% in total and were lower in upstream reaches than in downstream reaches.

In 2016, carcass recoveries consisted of 52 spring Chinook Salmon and 169 summer Chinook Salmon, with carcass recovery rates for each run estimated at 0.16 and 0.30, respectively. Natural-origin fish accounted for 84% of the spring Chinook Salmon spawning run escapement and 81% of the summer Chinook Salmon spawning run escapement. None of the hatchery-origin spring Chinook Salmon carcasses had a CWT so hatchery origin was not assigned. The majority of hatchery summer Chinook Salmon carcasses recovered on the spawning grounds originated from Entiat National Fish Hatchery (79%) and Dryden Ponds (21%). The age class composition of spring Chinook Salmon was made up of by 1 (2%) age-2, 3 (7%) age-3, 32 (73%) age-4, and 8 (18%) age-5 fish. The age class composition for summer Chinook Salmon was represented by 1 (1%) age-3, 45 (32%) age-4, 91 (65%) age-5, and 3 (2%) age-6 fish.

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Table of Contents

Introduction	1
Study Area	1
Salmon Populations	4
<i>Spring Chinook Salmon</i>	4
<i>Summer Chinook Salmon</i>	5
<i>Sockeye Salmon and Coho Salmon</i>	5
Methods	6
<i>Spring and Summer Chinook Salmon Redd Surveys</i>	6
<i>Spring and Summer Chinook Salmon Carcass Recoveries</i>	6
<i>Sockeye Salmon and Coho Salmon Redd Surveys</i>	7
<i>Estimating Salmon Spawning Escapement using Fish/Redd Ratio</i>	7
<i>Scale Analysis and Age Determination</i>	7
<i>Redd Superimposition</i>	8
Results	9
<i>Environmental Conditions</i>	9
<i>Spring Chinook Salmon</i>	10
<i>Summer Chinook Salmon</i>	13
<i>Redd Superimposition</i>	20
<i>Sockeye Salmon</i>	21
<i>Coho Salmon</i>	21
Discussion	22
Summary	25
Acknowledgements	25
References	26
APPENDIX A- Entiat River Survey Reach Descriptions	28
APPENDIX B- Spring and Summer Chinook Salmon Annual Redd Counts for the Entiat River	29
APPENDIX C- Sockeye Salmon and Coho Salmon Annual Redd Counts for the Entiat River	32

APPENDIX D- Spring and Summer Chinook Salmon Spawning Ground Survey Results in the Entiat River basin in 2015	33
APPENDIX E- Calculations	37
APPENDIX F- Hatchery- and Natural-origin Spring Chinook Salmon Composition by Year	40

List of Figures

Figure 1. Map of the Entiat River basin and the spawning ground survey reaches. The beginning and end of all surveyed reaches are marked with black dots. The survey reaches are located between the black dots and labeled 1–5, H, F, and MR. Main-stem Columbia River dams are represented by black squares on the Washington State outline map (WA).....	3
Figure 2. Mean daily flow in the Entiat River for 2016 (solid line) and the long-term mean (1957–2015; dotted line) during the potential Chinook Salmon spawning period from August 1–Nov 7. Flow data were collected at USGS gauge 12452800, Entiat River near Ardenvoir, WA..	9
Figure 3. Annual Entiat River spring Chinook Salmon redd counts in the Upper River section (white bars) and the Mad River section (black bars).....	10
Figure 4. Weekly counts of spring Chinook Salmon redds observed during spawning ground surveys in the Entiat River 2016 (black bars) and the 10-year average (2006–2015; white bars). Spring Chinook Salmon surveys ended on September 23.....	10
Figure 5. Entiat River basin spring Chinook Salmon redd counts for reaches 1–5 (rkm 26.1–45.2) in 2016 (black bars) and the 10-year average (2006–2015; white bars).....	11
Figure 6. Percent of hatchery- and natural-origin spring Chinook Salmon spawning run escapement into the Entiat River basin.....	12
Figure 7. Annual Entiat River summer Chinook Salmon redd counts differentiated by upstream reaches 1–5 (rkm 26.1–45.2) and downstream reaches F and H (rkm 0.5–10.9).....	14
Figure 8. Weekly counts of summer Chinook Salmon redds observed during spawning ground surveys in the Entiat River per week in 2016 compared to the 10-year average (2006–2015). No surveys were conducted from September 24–October 4.....	14
Figure 9. Entiat River summer Chinook Salmon redd counts for reaches F and H (rkm 0.5–10.9) and reaches 1–5 (rkm 26.1–45.2) in 2016 (black bars) compared to the 10-year average (2006–2015; white bars).....	15
Figure 10. Percent of hatchery- and natural-origin summer Chinook Salmon spawning run escapement into the Entiat River.	17
Figure 11. Estimated percent composition of hatchery and natural summer Chinook Salmon spawning in downstream reaches F and H (rkm 0.5–10.9) and upstream reaches 1–5 (rkm 26.1–45.2) of the Entiat River in 2016	177
Figure 12. Redd superimposition percentage by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2016	20

List of Tables

Table 1. Redd and carcass counts with calculated spawning run escapement (SRE) and carcass recovery rates (CRR) for spring Chinook Salmon in the Entiat River basin from 2006–2016	11
Table 2. Age composition for spring Chinook Salmon sampled from the Entiat River basin in 2016	13
Table 3. Coded-wire tag (CWT) recoveries collected from spring Chinook Salmon carcasses on the Entiat River basin in 2016	13
Table 4. Surveyed number of redds and carcasses with calculated spawning run escapement (SRE) and carcass recovery rates (CRR) for summer Chinook Salmon in the Entiat River basin from 2006–2016	15
Table 5. Entiat River summer Chinook Salmon gender and age composition as the proportion (pSRE) and quantity (SRE) of the spawning run escapement in 2016.....	16
Table 6. Juvenile life history types and percentages for summer Chinook Salmon sampled from the Entiat River in years 2006–2016	18
Table 7. Coded-wire tag (CWT) recoveries collected from summer Chinook Salmon carcasses on the Entiat River in 2016.....	19
Table 8. Redd superimposition by summer Chinook Salmon on spring Chinook Salmon by reach in the Entiat River in 2016.....	20
Table 9. Entiat River natural-origin (NOR), hatchery-origin (HOR), and Entiat National Fish Hatchery-origin (ENFH) summer Chinook Salmon redd counts, superimposition rates (SI) and superimposition rates by origin in reaches 1–5, 2013–2016	21
Table 10. Coded-wire tag (CWT) data recovered from Sockeye Salmon carcasses in the Entiat River in 2016	21
Table 11. Coded-wire tag (CWT) data recovered from Coho Salmon carcasses in the Entiat River in 2016	21

Introduction

The Entiat River has been surveyed for Chinook Salmon (*Oncorhynchus tshawytscha*) spawning activity since 1962 for the spring run and since 1957 for the summer run. Chinook Salmon spawning ground surveys consist of both redd counts and carcass recovery, and are intended to be a complete census of the primary spawning areas in the Entiat River basin. In the past two decades, these surveys have progressively become more rigorous in regards to effort and areas surveyed. This report details the methods and results of spawning ground surveys for Chinook Salmon in the Entiat River for the 2016 return year. The United States Fish and Wildlife Service (USFWS) Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) has been conducting these surveys since 1994.

The objectives of the spawning ground surveys are to:

- Assess the quantity and distribution of redds to estimate the spawning population of spring and summer Chinook Salmon within portions of the Entiat and Mad rivers.
- Evaluate the contribution of hatchery-origin spring and summer Chinook Salmon to the spawning population, which includes documenting redd superimposition by summer Chinook Salmon on Endangered Species Act (ESA)-listed spring Chinook Salmon.
- Document the spawning occurrence of Sockeye Salmon (*O. nerka*) and Coho Salmon (*O. kisutch*) during Chinook Salmon surveys.

Study Area

The Entiat River basin is located in Chelan County, in north-central Washington State (Figure 1). The river originates in a glaciated basin of the Cascade Mountains and flows approximately 69 river kilometers (rkm) to join the Columbia River at rkm 778 (Mullan et al. 1992). Peak discharge occurs during spring run-off, the highest flow recorded (1957–2015) was 6,430 cfs on June 10, 1972 (USGS gauge # 12452800, Entiat River near Ardenvoir, WA). The low-flow period occurs from August through March with mean daily flows of 133 cfs (1957–2015) and a record low flow of 22 cfs on November 25, 1994 (USGS gauge # 12452800, Entiat River near Ardenvoir, WA.) Sporadic weather events during this period may temporarily increase flows. The two major tributaries of the Entiat River are the Mad River and the North Fork which enter the Entiat River at rkm 16.3 and 54.7, respectively. The present upstream limit of anadromy is Entiat Falls (rkm 54.4). River kilometers are measured from the confluence of the Entiat River with the Columbia River (rkm 0).

The Entiat River basin drains an area of approximately 671 km². The watershed is nearly 68 km in length and varies in width from 8–23 km. The highest elevation in the basin is Mt. Fernow at 2,819 m and the lowest is the confluence with the Columbia River at approximately 213 m (USDA 1979). Fish migrating to the Entiat River travel through eight main-stem Columbia River

hydroelectric dams including; Bonneville, The Dalles, John Day, McNary, Priest Rapids, Wanapum, Rock Island, and Rocky Reach dams.

Chinook Salmon spawning ground surveys on the Entiat River include most of the known available spawning habitat. No surveys were conducted between the downstream end of reach 5 (rkm 26.1) and the Entiat NFH (rkm 10.9). The stretch of river between rkm 10.9–26.1 has been periodically surveyed since 1994 and very few redds were detected. The valley segment not surveyed has a steeper slope, faster currents and larger substrate than the surveyed regions (Godaire et al. 2010). The two runs of Chinook Salmon overlap in some of their spawning habitat and in other areas their spawning habitat is segregated. In the upstream section, reaches 1– 5 (rkm 26.1–45.2), both spring and summer Chinook Salmon spawning habitat is available. Only spring Chinook Salmon are known to spawn in the Mad River survey reach (rkm 2.4–5.6). Only summer Chinook Salmon are known to spawn in the downstream section, reaches H and F (rkm 0.5–10.9). Refer to Appendix A for additional reach descriptions.

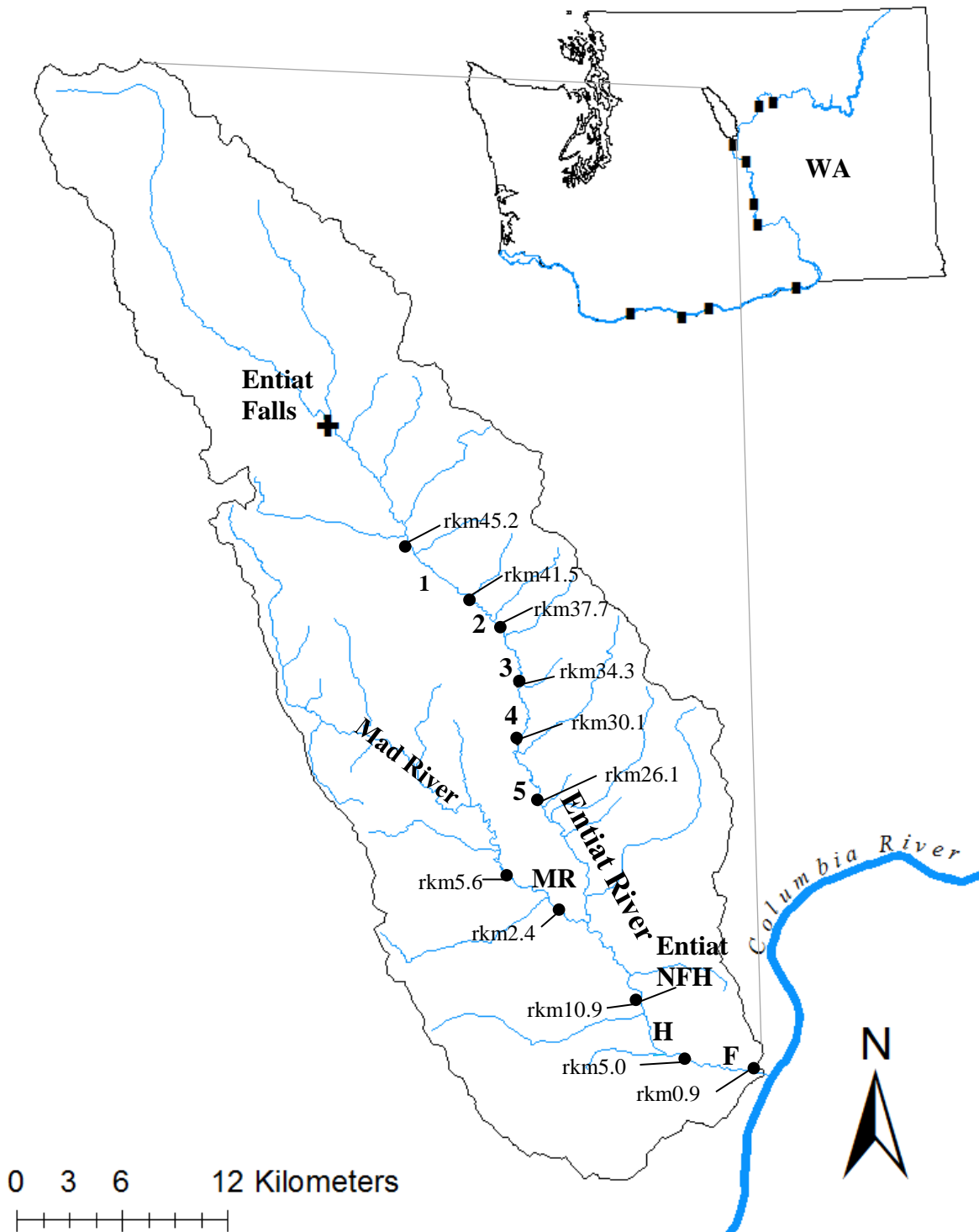


FIGURE 1.—Map of the Entiat River basin and the spawning ground survey reaches. The beginning and end of all surveyed reaches are marked with black dots. The survey reaches are located between the black dots and labeled 1–5, H, F, and MR. Main-stem Columbia River dams are represented by black squares on the Washington State outline map (WA).

Salmon Populations

The Entiat River has historically supported salmon runs consisting of Chinook Salmon and Coho Salmon (Craig and Suomela 1941). In the late 19th century, numerous dams were constructed on the lower 16 rkm of the Entiat River for milling, logging and power generation (Long 2001). These dams impeded the migration of salmon to their natal spawning grounds. By 1939 salmon were extirpated from the Entiat River (Craig and Suomela 1941). Some mill dams on the Entiat River had fish ladders, but were ineffective in passing fish (USBF 1934/1935/1936). From 1939 to 1943, as part of the Grand Coulee Fish Maintenance Project, late-returning adult salmon (mainly summer and fall Chinook Salmon) were trapped at Rock Island Dam and relocated to tributaries below Grand Coulee Dam including the Entiat River. Some of the fish collected were also relocated and spawned at national fish hatcheries (NFH) in the area including: Leavenworth, Entiat, and Winthrop NFHs (Fish and Hanavan 1948). The goal of the relocation effort was to rebuild salmon runs in mid-Columbia tributaries in an effort to mitigate for the loss of natural salmon production above Grand Coulee Dam. In 1948, the largest flood on record removed the last of the channel-spanning dams in the Entiat River and it remains undammed.

Spring Chinook Salmon

In the final years of construction of Grand Coulee Dam (1939–1941), little effort was made to re-establish natural spring Chinook Salmon runs in the Entiat River. From 1942 to 1944, the Entiat NFH used brood stock from upriver stocks collected at Rock Island Dam to rear and release a total of 1.3 million sub-yearlings and ~50,000 yearling spring Chinook Salmon (Mullan 1987). Spring Chinook Salmon production at Entiat NFH was terminated in 1945 and re-activated in 1974. Egg sources included: Cowlitz River (1974), Carson NFH (1975–1982), Little White Salmon NFH (1976, 1978, 1979, 1981), Leavenworth NFH (1979–1981, 1994), and Winthrop NFH (1988). Adults that voluntarily returned to the hatchery were the primary broodstock in 1980 and from 1983 to 2006. The last spring Chinook Salmon juvenile release into the Entiat River was in 2007, after which the program was again terminated. No Entiat NFH spring Chinook Salmon have been observed since 2010 when the oldest age-class returned to the hatchery.

Natural-origin spring Chinook Salmon were observed spawning in the Entiat River above rkm 29.6 as early as 1956 (French and Wahle 1960). From 1962–1993, Washington Department of Fish and Wildlife (WDFW) annually walked the Entiat River after peak spawning between rkm 34.3–45.2 (reaches 1–3, also referred to in past reports as the *index* area), to count spring Chinook Salmon redds (Appendix B). In 1994, MCFWCO assumed responsibility for monitoring spring Chinook Salmon redds in the Entiat River. At that time MCFWCO also expanded the survey area so that additional known downstream spawning reaches were included (below the *index* area), from rkm 26.1–34.3 (referred to as the *expanded* section in prior reports) and based on indications of limited but consistent spawning activity a section on the Mad River, from rkm 2.4–5.6.

Summer Chinook Salmon

Summer Chinook Salmon are not considered endemic to the Entiat River basin, however several efforts have been made to establish them following completion of Grand Coulee Dam (Craig and Suomela 1941). In 1939 and 1940, a total of 3,015 adult summer Chinook Salmon, collected at Rock Island Dam from mixed upriver stocks, were placed in upper Entiat River spawning areas, only an estimated 1,308 of these survived to spawn (Fish and Hanavan 1948). The Entiat NFH in addition to other species and stocks reared and released juvenile summer Chinook Salmon into the Entiat River from 1941–1964, and in 1976 (Mullan 1987). After termination of the spring Chinook Salmon program at Entiat NFH in 2007, the summer Chinook Salmon program was reinitiated in 2009 and the first juvenile release occurred in 2011. The Entiat NFH summer Chinook Salmon egg sources have included mixed upriver stocks intercepted at Rock Island Dam (1939–1943), Methow River (1944), Carson NFH (1944), Entiat River (1946–1964), Spring Creek NFH (1964), and Wells Hatchery (1974, 2009–2013). Adult summer Chinook Salmon returning to Entiat NFH have been the primary brood source since 2014.

From 1957 to 1991, the Chelan County Public Utility District (PUD) conducted aerial surveys to monitor summer Chinook Salmon spawning in the lower 16.3 rkm. No summer Chinook Salmon spawning surveys were conducted in the lower section in 1992 and 1993. In 1994, MCFWCO began surveying redds on foot in the upper river (Upper River Section rkm 26.1–45.2) and portions of the lower river, which included spot checks at the confluence of the Mad River (rkm 16.3) and various sections below the hatchery (< rkm 10.9). In 2006, MCFWCO began using rafts for annual surveys for a continuous stretch of the downstream portion of the Entiat River starting at the hatchery and concluding at the influence of the Columbia River (rkm 0.5–10.9).

Sockeye and Coho Salmon

Sockeye Salmon are not indigenous to the Entiat River and were stocked on two occasions (1943 and 1944) from Lake Quinault and Lake Whatcom stocks (Craig and Suomela 1941; Mullan 1986). A small run of Sockeye Salmon became established in the Entiat River enabling the Entiat NFH to collect Sockeye Salmon from 1944 to 1963 and distribute juveniles outside of the Entiat River watershed (Mullan 1986). The Sockeye Salmon population in the Entiat River is a mix of both natural-origin and out-of-basin hatchery strays.

Coho Salmon runs were largely extirpated in the mid-Columbia River basin prior to 1941 (Mullan 1983). Propagation of Coho Salmon at the federal mid-Columbia hatcheries began in the 1940s and extended into the early 1970s. Chelan and Douglas County PUDs, in cooperation with WDFW, started propagation of Coho Salmon in the 1970s and continued until 1994. In 1996, the Yakama Nation initiated the Mid-Columbia Coho Restoration Program, which is reintroducing the species into the Wenatchee and Methow sub-basins. Although no Coho Salmon have been released in the Entiat River, Coho Salmon have been observed in the Entiat River since 2001 (Appendix C).

Methods

Spring and Summer Chinook Salmon Redd Surveys

Spring Chinook Salmon spawning ground surveys began on August 4, 2016 and concluded on September 23 (Appendix D). Summer Chinook Salmon spawning ground surveys in 2016 began October 3 and concluded on November 16 (Appendix D). Although ESA-listed Bull Trout *Salvelinus confluentus* are present in the Entiat River they are not known to spawn in the reaches surveyed during this study (Nelson et al. 2008).

Redd surveys consisted of surveying reaches of the Entiat River by walking or rafting downstream throughout the spawning period. Redds were identified as areas of gravel disturbance larger than 1.5 m in length x 0.5 m with a distinguishable pit and tailspill area. Unlike in past years no flagging or physical markers were used to mark redds in the Entiat River. In 2016 the USFWS switched from paper notebooks, a GPS unit, a camera and flagging to a tablet computer. Each redd was marked on satellite images using the GIS Pro App by Garafa on an iPad®.

Spawn timing and spatial distribution of redds were examined for both runs. Peak spawning was designated as the week in which the greatest number of new redds were observed. Spatial distribution of redds was examined throughout the surveyed sections. Spawn timing and the spatial distribution of redds was compared to the 2006–2015 averages (10-year average), because this was a period of consistent survey methods.

Superimposition was determined by visual inspection of summer Chinook Salmon redds to evaluate whether the redd was excavated on top of a spring Chinook Salmon redd. When a summer Chinook Salmon redd was observed we used the GIS software, associated pictures and professional judgment to determine whether the construction of the summer Chinook Salmon redd superimposed a spring Chinook Salmon redd. Superimposition was defined as any contact between spring and summer Chinook Salmon redds and estimates as to the percent of overlap or ranking of potential impact were not conducted.

Spring and Summer Chinook Salmon Carcass Recoveries

Carcasses recovered during spawning ground surveys were used to describe the characteristics of the spawning population. Carcasses recovered consisted of all mature adults, including age-2 (precocial or mini-jack) fish. While age-2 fish were sampled, their recovery rate was likely very low and their spawning contribution was unknown. For these reasons, they were not included in any of the spawning run escapement calculations.

Genders were determined by an external examination of morphological characteristics of the carcass followed by an internal examination of the gonads (Crawford et al. 2007). Spawning success was categorized only for females by visually estimating the number of eggs retained within the body cavity with the following parameters: completely spent was defined as very few

to no eggs remaining in the skeins, partially spent was defined as many eggs retained in loose skeins indicating some eggs had been released, and pre-spawn mortality was defined as near total egg retention with intact skein. Other physical attributes recorded included: fork length, post-orbital hypural length, and adipose fin presence (absent, intact, or partial). Scales were removed from carcasses and read to determine age, origin (natural or hatchery), and juvenile life history type (ocean, reservoir or stream). Tissue samples (fin clips) were taken and archived for future DNA analysis. Carcasses were also scanned for Passive Integrated Transponder (PIT) tags and coded-wire tags (CWT) with portable handheld detectors. If a CWT was detected, the snout was removed for tag extraction. Detected PIT tags were recorded but not retained. The caudal (tail) fin was removed from each carcass to indicate that it had been sampled and was then placed back in the stream.

After the completion of the surveys, CWTs and scales were read and recorded. Data was entered into an archived database housed at the MCFWCO, and uploaded to regional databases including the Regional Mark Processing Center (www.rmhc.org), the PIT Tag Information System (www.ptagis.org), and StreamNet (www.streamnet.org).

Sockeye and Coho Salmon Redd Surveys

During Chinook Salmon spawning ground surveys, Sockeye Salmon and Coho Salmon spawning activities were documented, and carcasses sampled. Coho Salmon and Sockeye Salmon redds were determined by the presence of live adults and/or redds of less than 1.5 m x 0.5 m wide in substrate predominately composed of small to medium sized gravel (Burner 1951; Quinn et al. 1995). All recovered Sockeye Salmon and Coho Salmon carcasses were scanned for CWT and PIT tags. No scales, genetics, or spawn success data were collected for these species. The number of Sockeye Salmon and Coho Salmon were counted and included in this report, however annual trends and analysis are not presented as data on these species are considered auxiliary to this effort.

Estimating Salmon Spawning Escapement using Fish/Redd Ratio

Estimating the spawning run escapement (SRE) for both spring and summer Chinook Salmon returning to the Entiat River was calculated as follows:

$$\text{SRE} = \# \text{ redds} * \left(\left(\frac{\# \text{ male}}{\# \text{ female}} \right) + 1 \right)$$

For further calculations used in this report refer to Appendix E.

In previous reports SRE was calculated using a 2.4 expansion method.

Scale Analysis and Age Determination

Scales were used to identify growth periods (freshwater age and saltwater age) and origin (hatchery or natural) using Gilbert (1912). Age descriptions are presented with the first numeral

as the number of winters spent in freshwater (not including the winter of egg incubation), followed by a period, and then the second numeral as the number of winters spent in saltwater (Koo 1962). Total age, therefore, is equal to one plus the sum of the two numerals. For example, a five-year-old fish that emigrated to the marine environment as a sub-yearling and returned to the Entiat River would be classified as age 0.4.

Summer Chinook Salmon scales were further examined to determine juvenile life history strategy and primary rearing location. Life histories include ocean-type which enter the marine environment as a sub-yearling, reservoir-type which spend their first winter in the Columbia River, and stream-type which spend their first winter in their natal tributary (Gilbert 1912; Connor et al. 2005)

Natural-origin summer Chinook Salmon can exhibit one of three distinct freshwater life histories: (age-0) ocean-reared juveniles that spend their first year wintering in the ocean, (age-1) stream-reared juveniles that spend their first year wintering in the stream, and (age-1) reservoir-reared juveniles that spend their first year winter in a reservoir (Healy 1991; Connor et al. 2005).

Redd Superimposition

Redd superimposition rates were documented in the Entiat River in reaches 1–5. To determine the contribution by origin the total number of superimposed redds was apportioned based on the population composition in reaches 1–5 assuming equal likelihood of superimposition between origins. Then the hatchery superimposition rate was divided by Entiat NFH-origin fish and other hatchery-origin fish based on the Entiat NFH percentage. Spring Chinook Salmon are not thought to spawn in the lower reaches (F and H) therefore, we felt it was inaccurate to use the total hatchery wild composition and the total Entiat NFH percentage.

Results

Environmental Conditions

In 2016, the Entiat River flow regime was above average and peak flows occurred two months earlier than the 57-year average (Figure 2). Lower than average flows during July prompted surveys to begin August 4, which was a week earlier than in past years. Spawning ground surveys began on August 4 and concluded on November 16. Beginning in mid-October rain events increased flows and turbidity, which reduced visibility and potentially moved carcasses downstream out of the survey reaches. During some surveys, water was too high to survey both sides of the river effectively for carcasses. Periodic fall rain events are not uncommon however; the duration of increased flows during 2016 was above average from mid-October through November.

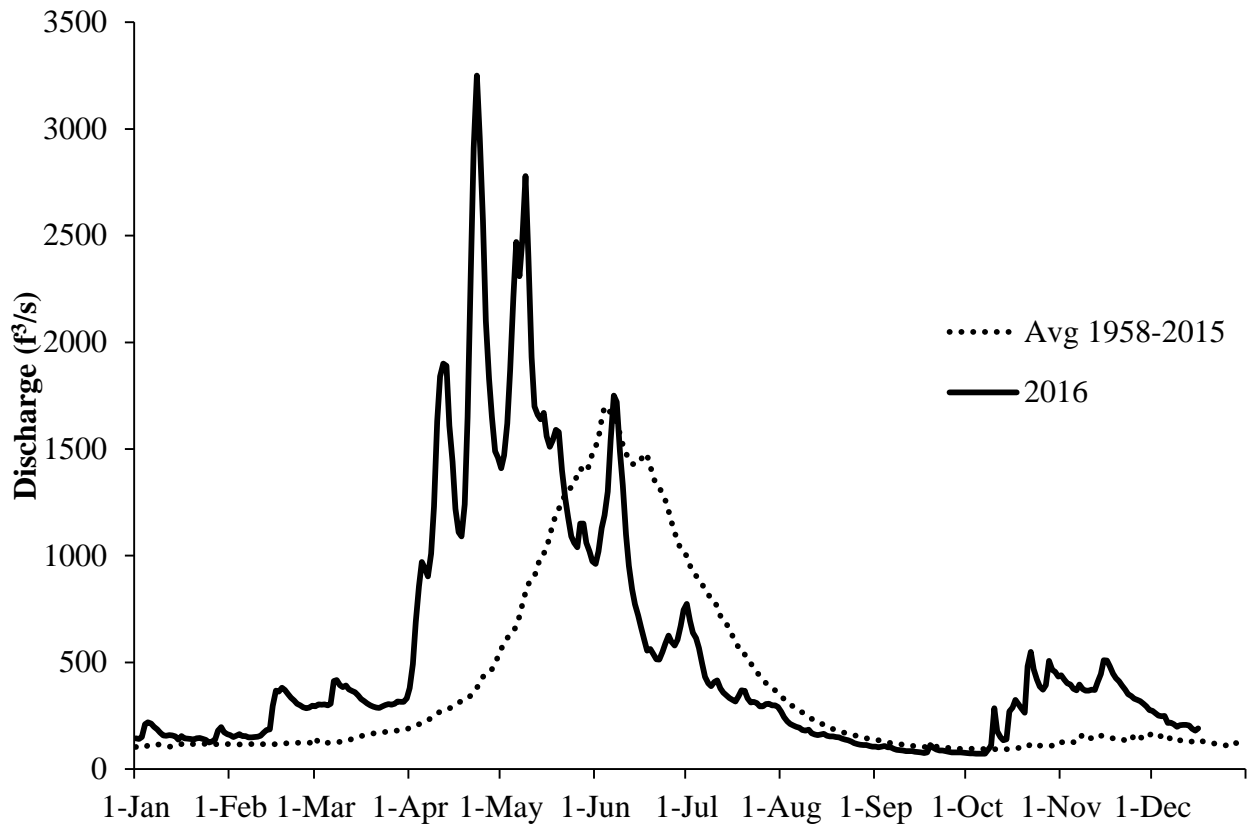


FIGURE 2.—Mean daily flow in the Entiat River for 2016 (solid line) and the long-term mean (1958–2015; dotted line). Flow data were collected at USGS gauge 12452800, Entiat River near Ardenvoir, WA.

Spring Chinook Salmon

In 2016, a total of 141 spring Chinook Salmon redds were identified throughout the surveyed portions of the Entiat River and six in the Mad River. The number of spring Chinook Salmon redds observed in 2016 was 96% of the 10-year average of 153 redds/year (Figure 3). Unlike past years, there was no single peak week in spawning in 2016, peak spawning occurred over a protracted three-week period from August 29-Sept 18. The timing of the peak spawning was similar to the 10-year average (Figure 4).

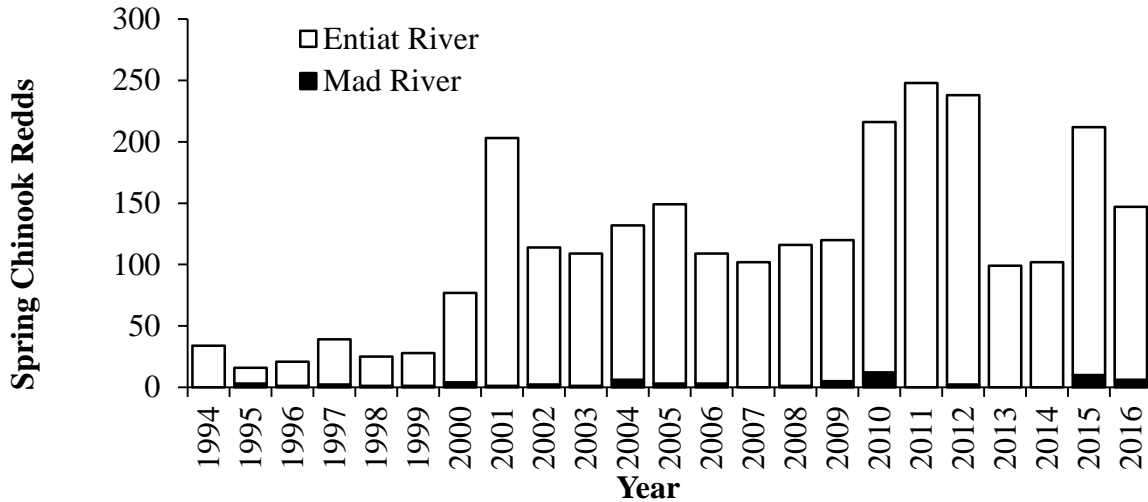


FIGURE 3.—Annual Entiat River spring Chinook Salmon redd counts in the Entiat River (white bars) and the Mad River (black bars).

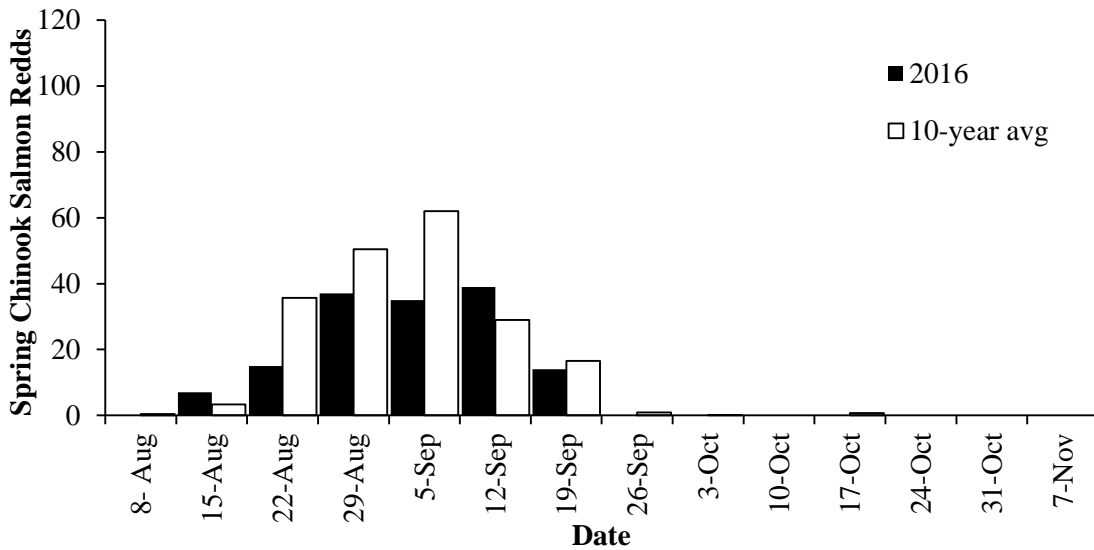


FIGURE 4.—Weekly counts of spring Chinook Salmon redds observed during spawning ground surveys in the Entiat River 2016 (black bars) and the 10-year average (2006–2015; white bars). Spring Chinook Salmon surveys ended on September 23.

Spatial distributions of redds from reach 1 downstream to reach 5 in 2016 were similar to the 10-year average in which redd abundance was greatest in reach 2 and progressively decreased downstream (Figure 5). Six redds were identified in the Mad River and was the fourth highest redd count in the Mad River since surveying began in 1994.

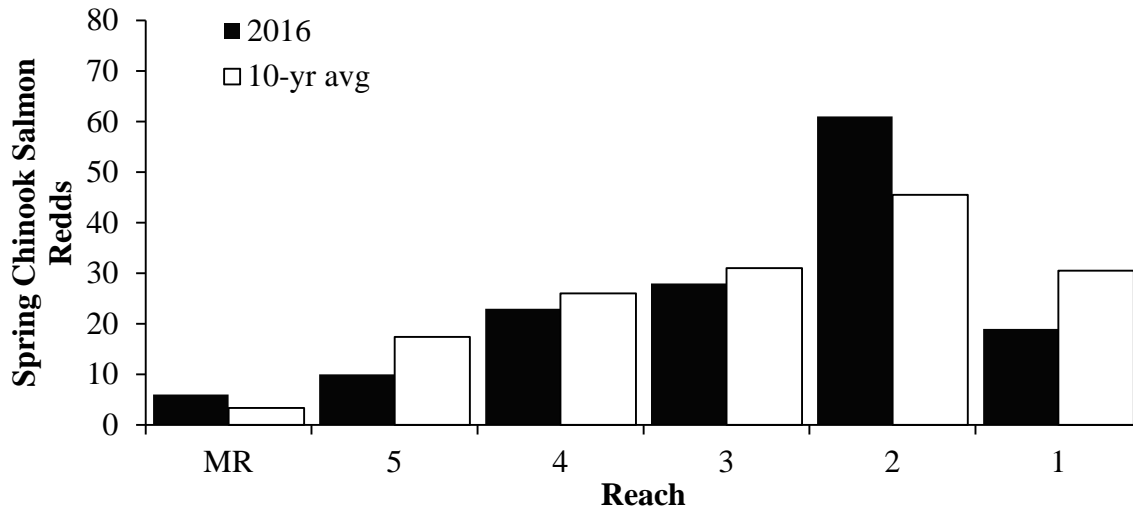


FIGURE 5.—Entiat River spring Chinook Salmon redd counts for reaches 1–5 (rkm 26.1–45.2) in 2016 (black bars) and the 10-year average (2006–2015; white bars).

Spring Chinook Salmon spawning run escapement in the Entiat River basin in 2016 was estimated at 334 fish (Table 1). Carcasses of 52 spring Chinook Salmon were recovered and resulted in a carcass recovery rate of 0.16 (Appendix E). Due to poor condition, two carcasses were not assigned a sex. Male carcasses outnumbered female carcasses 28 (56%) to 22 (44%). All female carcasses were examined to determine spawning success, 18 (82%) carcasses were completely spent, two (9%) had full egg skeins indicating pre-spawn mortality and two (9%) could not be determined due to poor condition.

TABLE 1.—Redd and carcass counts with calculated spawning run escapement (SRE) and carcass recovery rates (CRR) for spring Chinook Salmon in the Entiat River basin from 2006–2016.

Year	Redds	SRE	Carcasses	CRR
2006	106	166	75	0.45
2007	102	199	41	0.21
2008	115	230	80	0.35
2009	115	201	79	0.39
2010	204	345	93	0.27
2011	248	508	173	0.34
2012	236	406	125	0.31
2013	99	198	22	0.11
2014	102	168	26	0.16
2015	212	402	137	0.34
2016	147	334	52	0.16

Origin was determined for 43 of the 52 spring Chinook Salmon carcasses recovered in 2016 in the Entiat River basin. Natural-origin spring Chinook Salmon constituted 84% (n=36) of the carcasses, resulting in an estimated natural-origin spawning escapement of 281 fish. Hatchery-origin adults constituted 16% (n=7) of the carcasses examined in 2016, resulting in an estimated hatchery-origin spawning escapement of 53 fish. Hatchery- and natural-origin spawning proportions differ from year to year but since the termination of the Entiat NFH spring Chinook Salmon program in 2007 the portion of natural-origin spring Chinook Salmon adults spawning in the Entiat River has substantially increased (Figure 6).

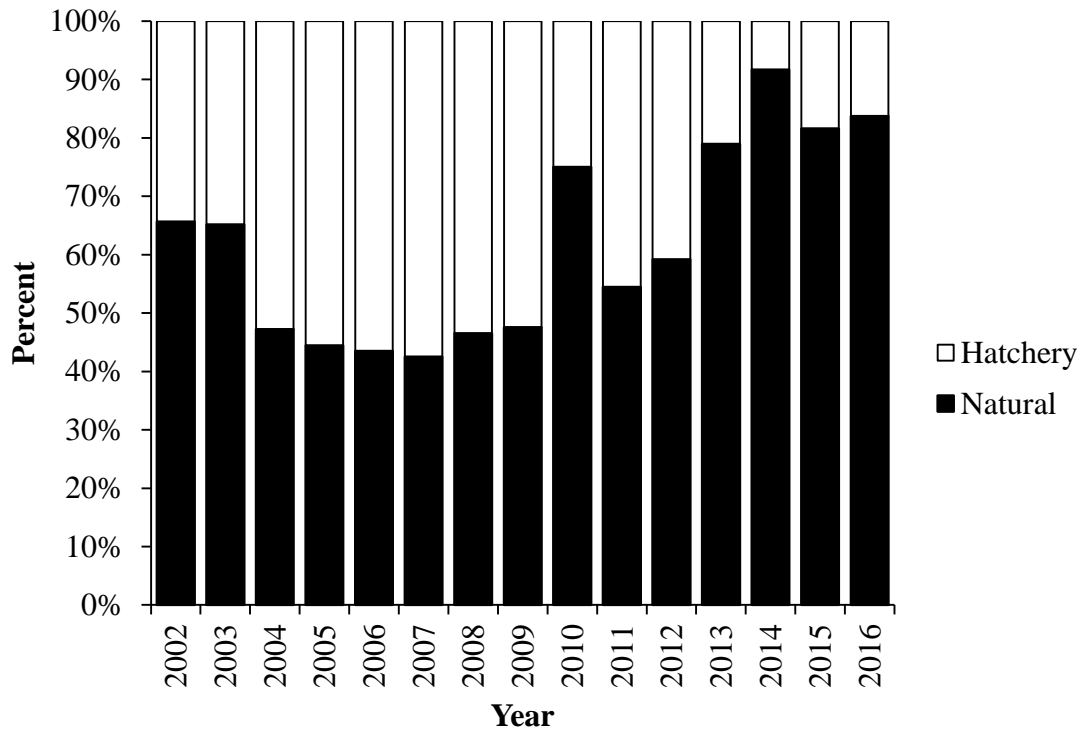


FIGURE 6.—Percent of hatchery- and natural-origin spring Chinook Salmon spawning run escapement into the Entiat River basin.

In 2016, the run composition of both hatchery- and natural-origin spring Chinook Salmon contained various ages and genders (Table 2). Natural-origin fish were represented by 17 age-4 males, five age-5 males, one age-2 female, 13 age-4 females and two age-5 females. Hatchery-origin fish were represented by two age-3 males, two age-4 males, one age-3 female, one age-4 female and one age-5 female. The spawning run escapement was represented by 10% age-3, 77% age-4, and 13% age-5 fish.

TABLE 2.—Age composition for spring Chinook Salmon sampled from the Entiat River basin in 2016.

Origin	Age description	Total Age	Male N(%)		Female N(%)		Total N(%)		pSRE	SRE
Natural	0.3	4	1	4.8	0	0	1	2.7	0.02	8
	1.0	2	0	0	1	6.3	1	2.7	0.02	8
	1.2	4	16	76.2	13	81.3	29	78.4	0.65	217
	1.3	5	5	23.8	2	12.5	7	18.9	0.15	50
Natural Total			21	56.8	16	43.2	37	100	0.84	288
Hatchery	1.1	3	2	50.0	1	33.3	3	42.9	0.07	23
	1.2	4	2	50.0	1	33.3	3	42.9	0.07	23
	1.3	5	0	0.0	1	33.3	1	14.3	0.02	7
Hatchery Total			4	57.1	3	42.9	7	100	0.16	53
Total*			25		19		44		1	334

1) pSRE is the Proportion of the Spawning Run Escapement

2) Age-2 recoveries were not included in spawning run escapement (SRE) estimates.

Recovered carcasses (n=52) were checked for adipose fin condition and scanned for CWTs and PIT tags. In 2016, no coded-wire tags and four PIT tags were recovered from spring Chinook Salmon in the Entiat River basin (Table 3; Appendix G).

TABLE 3.—Coded-wire tag (CWT) recoveries collected from spring Chinook Salmon carcasses on the Entiat River in 2016.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered	Tag Rate	CWT Expanded	pCWT	SRE CWT
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No CWTs were recovered in 2016, this table serves as a place holder for consistency with prior reports

Data associated with CWT #'s include the hatchery of origin, number of carcasses recovered and the percentage of fish released from the brood year at that hatchery that contained a CWT (tag rate). CWT Expanded and SRE CWT are used to estimate abundance of spring Chinook Salmon in the Entiat River in 2016 based on CWTs. pCWT is the proportion of CWTs that a given CWT group represents. For calculations see Appendix E.

Summer Chinook Salmon

In 2016, a total of 363 summer Chinook Salmon redds were identified during spawning ground surveys. The redd count in 2016 was 178% of the 10-year average of 204 redds and reversed the declining trend since 2012 (Figure 7). Most spawning occurred in the reaches 1–5 (67%), which

was consistent with prior years. Peak spawning occurred during the first week of October and was two weeks earlier than the 10-year average (Figure 8).

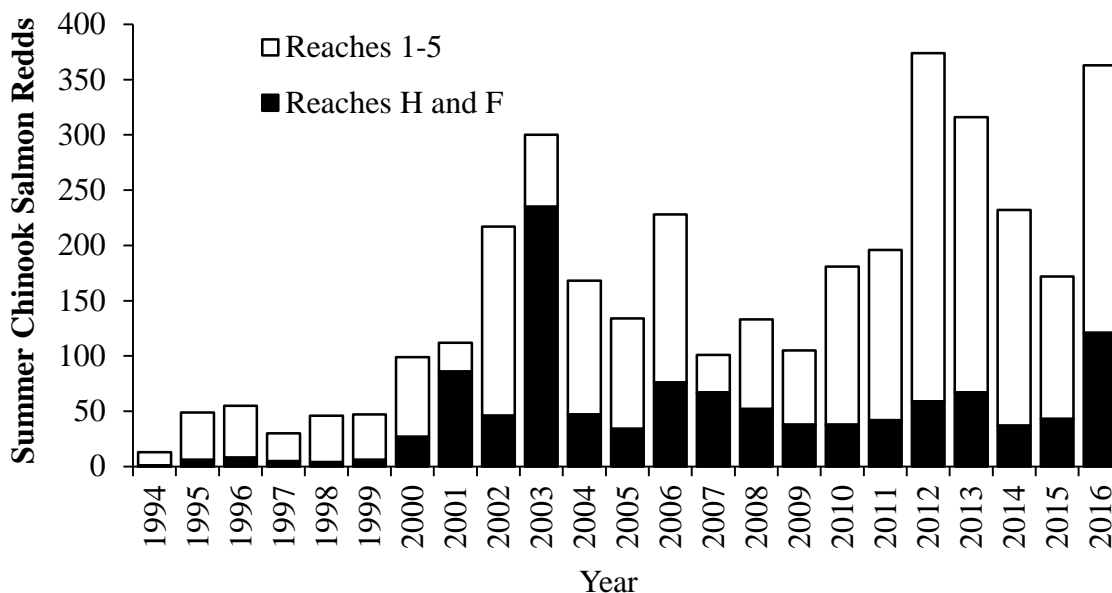


FIGURE 7.—Annual Entiat River summer Chinook Salmon redd counts differentiated by upstream reaches 1–5 (rkm 26.1–45.2) and downstream reaches F and H (rkm 0.5–10.9).

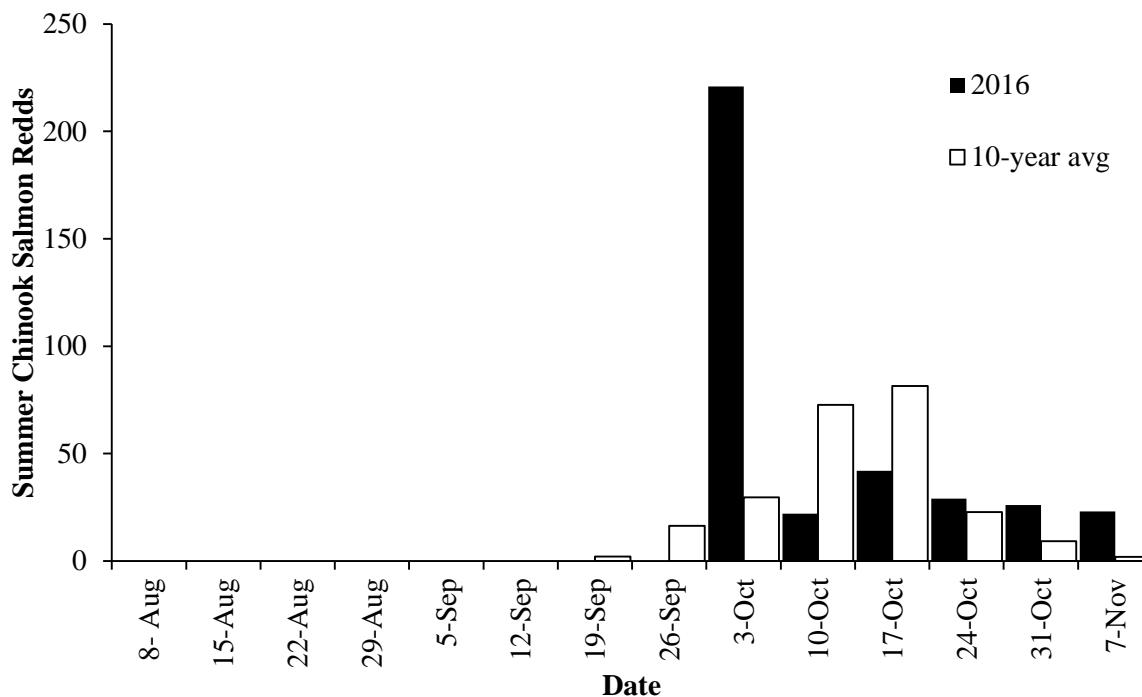


FIGURE 8.—Weekly counts of summer Chinook Salmon redds observed during spawning ground surveys in the Entiat River per week in 2016 compared to the 10-year average (2006–2015). No surveys were conducted from September 26–October 2.

The abundance of redds in reaches 1–5 was greater in downstream reaches than in the upstream reaches which was similar to the 10-year average (Figure 9). In 2016, there were twice as many summer Chinook Salmon redds in reaches H and F than the 10-year average.

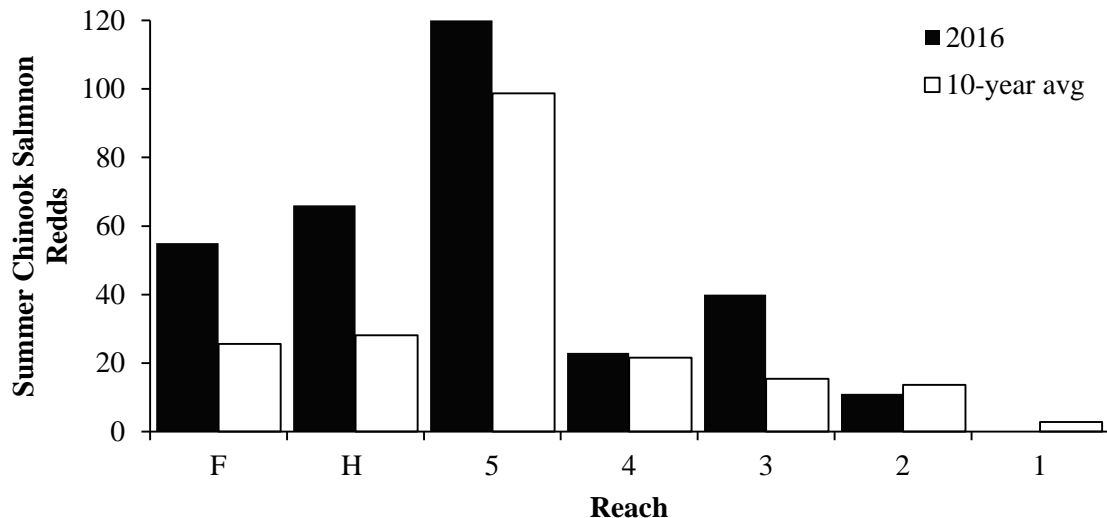


FIGURE 9.—Entiat River summer Chinook Salmon redd counts for reaches F and H (rkm 0.5–10.9) and reaches 1–5 (rkm 26.1–45.2) in 2016 (black bars) compared to the 10-year average (2006–2015; white bars).

The 2016 spawning run escapement for Entiat River summer Chinook Salmon was estimated to be 567 fish (Table 4). Carcasses of 169 summer Chinook Salmon were recovered, which resulted in a carcass recovery rate of 0.30. Unlike spring Chinook Salmon, the summer Chinook Salmon females outnumbered males 98 (64%) to 55 (36%), sex was not determined for 16 carcasses due to decomposition. All 98 female carcasses were examined for spawning success; 93 (95%) were completely spent, three (3%) were partially spent, one (1%) had a full egg skein indicative of pre-spawn mortality, and one (1%) were undetermined due to decomposition.

TABLE 4.—Surveyed number of redds and carcasses with calculated spawning run escapement (SRE) and carcass recovery rates (CRR) for summer Chinook Salmon in the Entiat River basin from 2006–2016.

Year	Redds	SRE	Carcasses	CRR
2006	228	400	180	0.45
2007	101	142	88	0.62
2008	133	214	82	0.38
2009	105	182	83	0.46
2010	181	262	96	0.37
2011	196	295	137	0.46
2012	374	645	207	0.32
2013	316	472	154	0.33
2014	232	590	89	0.15
2015	172	382	215	0.56
2016	363	567	169	0.30

A total of 169 summer Chinook Salmon carcasses were recovered in 2016, and age and origin were determined for 140 (83%; Table 5). Natural-origin summer Chinook Salmon constituted 81% (n=113) of the carcasses, which resulted in an estimated natural-origin spawning escapement of 458 fish. Hatchery-origin adults constituted 19% (n=27) of the carcasses resulting in an estimated hatchery-origin escapement of 109 fish. Coded-wire tag and scale analysis indicated various hatchery and natural-origin summer Chinook Salmon age-classes returned to the Entiat River (Table 5). The spawning run escapement was represented by 2% age-3, 31% age-4, 65% age-5 fish and 2% age-6.

TABLE 5.—Entiat River summer Chinook Salmon gender and age composition as the proportion (pSRE) and quantity (SRE) of the spawning run escapement in 2016.

Origin	Age description	Total Age	Male		Female		Total		pSRE	SRE
			N	(%)	N	(%)	N	(%)		
Natural	0.2	3	1	3	0	1	1	0.01	4	
	0.3	4	12	32	20	26	32	0.23	130	
	0.4	5	11	30	16	21	27	0.19	109	
	0.5	6		0	1	1	1	0.01	4	
	1.2	4	2	5	7	9	9	0.06	36	
	1.3	5	11	30	30	39	41	0.29	166	
	1.4	6			2	3	2	2	0.01	8
Natural Total			37	32.7	76		113	0.81	458	
Hatchery	1.2	4	2	18.2	2	13	4	15	0.03	16
	1.3	5	9	81.8	14	88	23	85	0.16	93
Hatchery Total			11	40.7	16		27	0.19	109	
Total*			48		92		140		567	

*Age-2 recoveries that did not spend at least one year in salt water were not included in spawning escapement estimates.

Hatchery- and natural-origin spawning proportions in the Entiat River vary annually but since 2011 the percent of hatchery-origin has increased (Figure 10). The composition of the summer Chinook Salmon run differs dramatically between the upper (reaches 1–5) and lower river (reaches F–H) sampling reaches. In 2016, the ratio of hatchery- to natural-origin summer Chinook Salmon carcasses were 7 to 93 in the upper reaches and 49 to 51 in the lower reaches (Figure 11). The spatial distribution between the upper and lower reaches is consistent with data from previous.

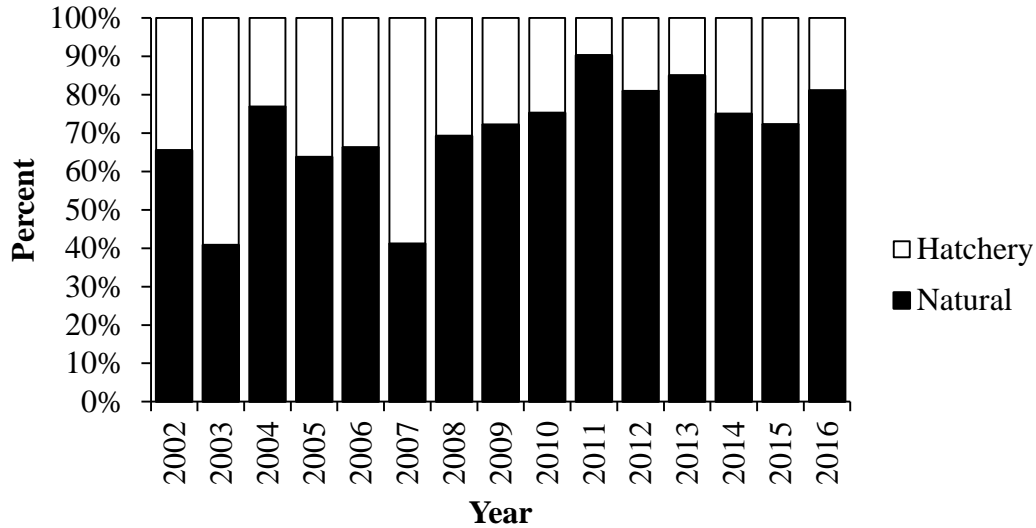


FIGURE 10.—Percent of hatchery- and natural-origin summer Chinook Salmon spawning run escapement into the Entiat River.

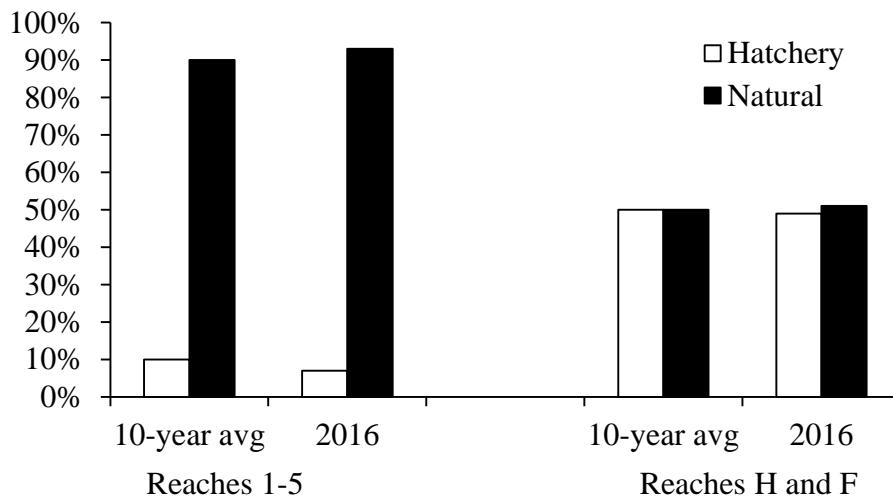


FIGURE 11.—Estimated percent composition of hatchery- and natural-origin summer Chinook Salmon spawning in downstream reaches F and H (rkm 0.5–10.9) and upstream reaches 1–5 (rkm 26.1–45.2) of the Entiat River in 2016.

Three juvenile life history types were identified for returning natural-origin summer Chinook Salmon in 2016; 56% migrated to saltwater at age-0, 43% overwintered (age-1) in a reservoir and 1% overwintered (age-1) in a stream (Table 6). Life history types could not be determined for 45 of the natural-origin carcasses recovered due to poor carcass condition.

TABLE 6.—Juvenile life history types and percentages for natural-origin summer Chinook Salmon sampled from the Entiat River in years 2006–2016.

Year	Ocean		Reservoir		Stream		Total (N)
	(N)	%	(N)	%	(N)	%	
2006	84	73	27	23	4	4	115
2007	25	74	9	26	0	0	34
2008	42	84	8	16	0	0	50
2009	51	89	6	11	0	0	57
2010	49	72	19	28	0	0	68
2011	88	76	27	23	1	1	116
2012	124	74	44	26	0	0	168
2013	89	71	36	29	0	0	125
2014	50	79	13	21	0	0	63
2015	117	80	26	18	3	2	146
2016	70	56	53	43	1	1	124
Avg		75		24		1	

16 of the 169 recovered summer Chinook Salmon carcasses contained a CWT (Table 7). Recovered CWTs revealed that 79% of the hatchery-origin fish that returned to spawn in the Entiat River originated at the Entiat NFH, this extrapolated to an Entiat NFH spawning run escapement rate (SRECWT) of 85 fish. Similar to previous years the majority of Entiat NFH-origin fish were recovered in the reaches downstream of Entiat NFH. Out-of-basin strays accounted for 21% of the hatchery-origin carcasses recovered on the spawning grounds and were all from Dryden Acclimation Ponds.

TABLE 7.—Coded-wire tag (CWT) recoveries collected from summer Chinook Salmon carcasses on the Entiat River in 2016. (Note: Age-2 recoveries that did not spend at least one year in salt water were not included in spawning run escapement estimates.)

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered	Tag Rate	CWT Expanded	pCWT	SRE CWT
054793	2012	FWS	ENTIAT NFH	2	0.45	23.42	0.18	20
055362	2011	FWS	ENTIAT NFH	5	0.65	40.66	0.32	34
055363	2011	FWS	ENTIAT NFH	4	0.56	37.30	0.29	31
636175	2011	WDFW	DRYDEN POND	1	0.99	5.33	0.04	5
636176	2011	WDFW	DRYDEN POND	1	0.99	5.30	0.04	5
636177	2011	WDFW	DRYDEN POND	1	0.99	5.32	0.04	5
636178	2011	WDFW	DRYDEN POND	2	0.99	10.60	0.08	9

Data associated with CWT #'s include the hatchery of origin, number of carcasses recovered and the percentage of fish released from the brood year at that hatchery that contained a CWT (tagging rate). CWT Expanded and SRECWT are calculations used to estimate abundance of summer Chinook Salmon in the Entiat River in 2016 based on CWTs. pCWT is the proportion of CWTs that a given CWT represents.

Redd Superimposition

Similar to previous years superimposition rates were the lowest in upstream reaches and progressively increased downstream (Table 8; Figure 12). None of the spring Chinook Salmon redds were superimposed in reach 1 (the most upstream reach) and only 7% were superimposed on in reach 2 (Table 8). Further downstream, in reaches 3 and 4, superimposition rates were 21% and 22%, respectively. The highest superimposition rate was 70% in reach 5, the most downstream reach that spring Chinook Salmon surveys were conducted or that spring Chinook are known to spawn. In 2016 the total superimposition rate was 15.6% and increased slightly by 1.7% compared to 2015 (Table 9). On average 19% (2013–2016) of spring Chinook Salmon redds are superimposed upon with the majority of superimposition (94% on average) attributed to natural-origin summer Chinook Salmon returning to the upper Entiat watershed where spring Chinook Salmon spawn. The 2016 level of superimposition attributed to Entiat NFH-origin summer Chinook Salmon (7% hatchery-origin for reaches 1–5 of which 86% of the hatchery-origin attributed to Entiat NFH) decreased from 1.4% to 0.9% as compared to the 2015 values.

TABLE 8.—Redd superimposition by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2016.

Reach	Spring Chinook Salmon redds	Summer Chinook Salmon redds	Spring Chinook Salmon redds superimposed (%)
1	19	0	0 (0)
2	61	11	4 (7)
3	28	40	6 (21)
4	23	23	5 (22)
5	10	168	7 (70)

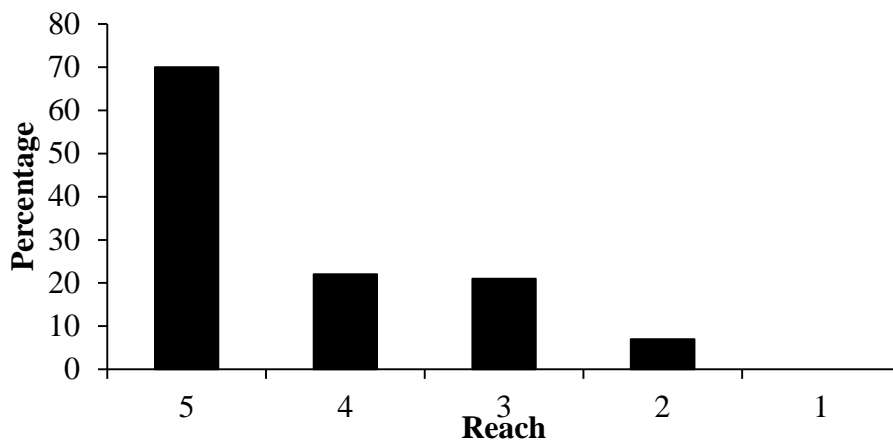


FIGURE 12.—Redd superimposition percentage by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2016.

TABLE 9.—Entiat River spring (SCS) and summer (SUS) Chinook Salmon redd counts and the percent natural-origin (NOR), hatchery-origin (HOR), and superimposition rates (SI) rates by origin in reaches 1–5 of the Entiat River, 2013–2016.

Year	Redds				SUS				
	SCS	SUS	SCS SI by SUS	SCS SI	NOR	HOR	NOR SI	HOR SI	ENFH SI
2013	99	249	19	19.2%	97%	3%	18.6%	0.6%	0.3%
2014	102	196	28	27.5%	95%	5%	26.1%	1.4%	1.4%
2015	202	172	28	13.9%	90%	10%	12.5%	1.4%	0.2%
2016	141	242	22	15.6%	93%	7%	14.5%	1.1%	0.9%

Sockeye Salmon

Sockeye Salmon redds were observed during our 2016 surveys however, the abundance of Chinook Salmon (both runs) redds and carcasses precluded our ability to document the number of Sockeye Salmon redds in the Entiat River. All of the Sockeye Salmon carcasses observed were scanned for tags of which none contained a CWT (Table 10) and none contained a PIT tag.

TABLE 10.—Coded-wire tag (CWT) data recovered from Sockeye Salmon carcasses in the Entiat River in 2016.

Species	CWT	Brood Year	Release Agency	Hatchery	Recovered
No CWTs were recovered from Sockeye Salmon in 2016					

Coho Salmon

In 2016, Coho Salmon redds were observed but not documented during Chinook Salmon surveys on the Entiat River. Some Coho Salmon carcasses were observed and all were scanned for tags but due to abundant Chinook Salmon no data were collected except for fish with tags. None of the Coho Salmon contained a CWT (Table 11).

TABLE 11.—Coded-wire tag (CWT) data recovered from Coho Salmon carcasses in the Entiat River in 2016.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered
No CWTs were recovered from Coho Salmon in 2016				

Discussion

Over the last seven years the number and proportion of hatchery-origin spring Chinook Salmon migrating to the Entiat River basin to spawn has decreased, likely due to hatchery reform measures implemented throughout the upper Columbia River basin. Hatchery-origin adults on average comprised almost half (46%) of the spawning escapement from 2000–2010. Of these hatchery-origin fish over half (54%) originated from Entiat NFH. Spring Chinook Salmon propagation programs from the Wenatchee and Methow basins provided consistent contributions (32% on average) during these same years. The remaining hatchery-origin adults on the spawning ground originated on an intermittent but occasionally substantial contribution basis (47% in 2006) from the Snake River basin. From 2011–2016 the total hatchery-origin percentage of spring Chinook Salmon was reduced to an average of 25% per year. Two key hatchery reform measures likely explain the notable decrease in hatchery spring Chinook Salmon spawners between these two time periods, a shift in hatchery production at Entiat NFH from spring to summer Chinook Salmon, and reductions in production and improvements to acclimation practices in the hatchery supplementation programs located in the Wenatchee River basin.

Entiat NFH released its last cohort of spring Chinook juveniles in 2007 and the final adult returns occurred in 2010. With Entiat NFH no longer contributing to the spawning escapement the total percentage of hatchery-origin spring Chinook Salmon in the Entiat River was reduced by nearly half (25% 2011–2016). Changes in production and acclimation practices in other spring Chinook Salmon programs in the area have also likely contributed to the improving the situation in the Entiat River. Notably the reduction in spring Chinook Salmon production levels at the Chiwawa Rearing Ponds (CRP), in the Wenatchee River basin, has likely resulted in the notable decrease in the percentage of hatchery-origin adults straying from other nearby basins. For example, from 2011–2013 carcass recovery data showed a higher than expected hatchery-origin composition from the CRP program. Chiwawa RP fish comprised 72–81% of the hatchery-origin spring Chinook Salmon recovered in Entiat River redd surveys during 2011–2013 (Appendix F). Chiwawa RP release numbers peaked in 2010 when it released 609,789 spring Chinook Salmon into the Columbia River basin. The majority of those fish returned in 2012 and accounted for 81% of the hatchery-origin spring Chinook Salmon found in the Entiat River. The high numbers of hatchery-origin spring Chinook Salmon during these years were possibly the result of increased production and subsequent straying of spring Chinook Salmon released from the Chiwawa RP. Since 2012, the Chiwawa RP has released fewer fish each year and in 2015 only released 150,413 spring Chinook Salmon. In 2016, no Chiwawa RP-origin spring Chinook were documented spawning in the Entiat River. Based on lower release numbers in 2014 and 2015 we expect the percentage of Chiwawa RP-origin fish spawning in the Entiat River to continue to decrease. However, Nason Creek is a new facility that released its first cohort of fish into the Wenatchee River basin in spring of 2015 and the impact of those fish on the natural-origin Entiat River spring Chinook Salmon population will be evaluated in future reports. Although no CWTs from Nason Creek were found in 2016 one PIT tagged carcass from Nason Creek was found.

The percentage of hatchery-origin spring Chinook Salmon recorded in 2016 was among the lowest since the MCFWCO began surveying the Entiat River in 1994. Unlike 2015 no fish from the Snake River basin were encountered during spawning ground surveys. Presence of a high number of stray fish from Snake River basin production may have been an anomaly related to unusually high temperatures during the 2015 migration period. Continued monitoring is needed

to ensure that these out of basin production programs do not unduly effect natural populations of spring Chinook Salmon in the upper Columbia River.

A major concern for the viability of spring Chinook Salmon populations is the influence of hatchery-origin genes in the natural spawning population (UCSRB 2007). Hatchery-origin genes can degrade adaptation to local environments and reduce homing (Waples 2004; Utter 2005; Dittman et al. 2010). A review of spring Chinook Salmon population viabilities in the upper Columbia River rated the Entiat River population as high risk with a 25% chance of extinction within 100 years (UCSRB 2007). Since then, the Entiat NFH terminated its spring Chinook Salmon program and it was anticipated that this would result in very low (pHOS<5%) numbers of hatchery-origin spring Chinook Salmon on the spawning grounds in future years (2010 onward). However, hatchery-origin fish have averaged 25% of the spring Chinook Salmon population over the last six years. Although the period is short the hatchery-origin percentage remains well above the criteria for reducing the threat to the Entiat River spring Chinook Salmon population (UCSRB 2007). The abundance of redds and subsequently the abundance estimates of natural-origin spring Chinook Salmon in 2016 were lower than in 2015 but still above average which is encouraging for this ESA-listed native fish. However, the persistence of hatchery-origin fish remains a concern for the genetic integrity of the Entiat River spring Chinook Salmon population.

In contrast, the abundance and proportion of hatchery-origin summer Chinook Salmon in the Entiat River have increased over the last six years. The increase was most likely attributed to the switch from spring to summer Chinook Salmon production at the Entiat NFH. The total redd count in 2016 was among the highest since surveys began in 1994. The total proportion of hatchery-origin summer Chinook Salmon (pHOS) was 19% and of these hatchery-origin fish 79% originated from Entiat NFH. The overall percentage of hatchery-origin summer Chinook Salmon decreased 9% since 2015 but the hatchery proportion of Entiat NFH-origin summer Chinook Salmon remained high (79%). Hatchery-origin summer Chinook Salmon were only 7% of the population upstream of the hatchery and 49% downstream of the hatchery. The spatial distribution of hatchery-origin fish above and below the hatchery was comparable to previous years.

Although redds of both runs overlapped spatially there were substantial differences between the abundance of redds in upstream and downstream sections of the Entiat River. Summer Chinook Salmon redds were primarily found in the downstream sections (reaches 4–5) while the spring Chinook Salmon redds were primarily found in the upstream sections (reaches 1–3). Spring Chinook Salmon generally spawn earlier in the year which puts their redds at risk of superimposition by summer Chinook Salmon that typically spawn later in the year. Spring Chinook Salmon that spawned in the upper reaches of the Entiat River are at lower risk for superimposition than those that spawned farther downstream because fewer summer Chinook Salmon spawned in the upper reaches. Although superimposition rates from Entiat NFH-origin summer Chinook Salmon on spring Chinook Salmon redds were only 0.9% they remain a concern and warrant continued monitoring. Management goals for the Entiat NFH state the acceptable superimposition rates of Entiat NFH-origin Chinook Salmon on spring Chinook Salmon to be 10% (NMFS 2013). Monitoring superimposition rates will continue to be a priority for the MCFWCO because rates will likely continue to increase in the near future as full-production summer Chinook Salmon runs from the Entiat NFH return to the Entiat River.

In conclusion, the change in hatchery operations over the last five years affected both the abundance and the percent of hatchery-origin Chinook Salmon in the Entiat River. Spring Chinook Salmon abundance in the Entiat River has declined since the termination of the Entiat NFH spring Chinook Salmon program and the reduction in the production of spring Chinook Salmon at the Chiwawa RP. However, the high percentage of natural-origin spring Chinook Salmon and their continued presence in the Entiat River without hatchery supplementation is encouraging for the persistence of this ESA-listed population. Conversely, summer Chinook Salmon abundance and the proportion of hatchery-origin fish are increasing in part due to full production releases from Entiat NFH but also due to an increase in natural-origin returns.

Summary

The total number of spring Chinook Salmon redds counted during the 2016 spawning ground surveys was 147, with an estimated adult spawning run escapement of 353 fish to the Entiat River basin. A total of 52 carcasses were recovered; male carcasses outnumbered female carcasses 28 to 22. All female carcasses were examined to determine spawning success, 18 (82%) carcasses were completely spent, two (9%) had full egg skeins indicating pre-spawn mortality and two (9%) could not be determined due to poor condition. Recovered carcasses indicate that natural-origin spring Chinook Salmon comprised 84% of the adult return escapement to the Entiat River and the remaining 16% were of hatchery-origin. No coded-wire tags were recovered from spring Chinook Salmon carcasses in 2016.

In 2016, 363 summer Chinook Salmon redds were counted during spawning ground surveys, with an estimated adult spawning run escapement of 871 fish to the Entiat River. A total of 169 carcasses were recovered; females outnumbered males 98 to 55. All 98 female carcasses were examined for spawning success; 93 (95%) were completely spent, three (3%) were partially spent, one (1%) had a full egg skein indicative of pre-spawn mortality, and one (1%) were undetermined due to decomposition. Recovered carcasses indicated that overall natural-origin fish comprised 81% of the adult spawning escapement to the Entiat River and 19% were of hatchery-origin. Spatially, hatchery-origin summer Chinook comprised 49% of the spawners in the lower river below Entiat NFH while natural-origin adults comprise 93% of the upriver spawning population. Scale analysis revealed natural-origin summer Chinook Salmon had three distinctive life histories; 56% were ocean-type juvenile migrants, 43% were reservoir-type juvenile migrants and 1% overwintered in a stream. A total of 16 CWTs were recovered from carcasses. Based on the CWT recoveries hatchery summer Chinook Salmon carcasses were from Entiat NFH (79%) and Dryden Ponds (21%).

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APPENDIX A- Entiat River Survey Reach Descriptions

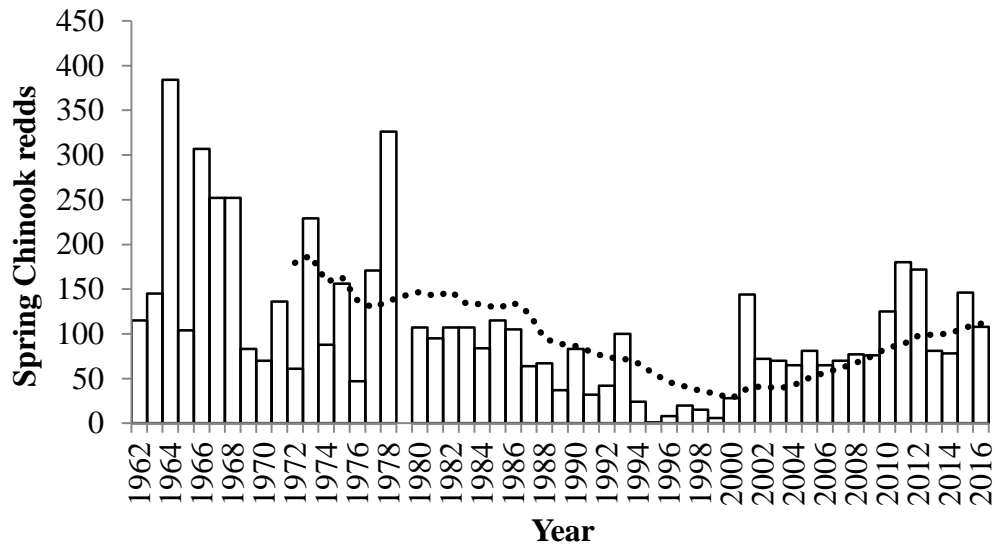
Reach	River Kilometer	Surveyed Kilometers	Description
1	41.5–45.2	3.7	Forest Service boundary to Fox Creek camp ground
2	37.7–41.5	3.8	Fox Creek camp ground to Brief Bridge
3	34.3–37.7	3.4	Brief Bridge to Kelsey Lane Bridge
4	30.1–34.3	4.2	Kelsey Lane Bridge to Stormy Creek preserve
5	26.1–30.1	4.0	Stormy Creek Preserve to McKenzie Diversion
H	5.0–10.9	5.9	Entiat NFH to Fire Station
F	0.5–5.0	4.5	Fire Station to Columbia River influence
MR	2.4–5.6	3.2	Mad River, Pine Flats Campground to road sign

*Kelsey Lane Bridge referred to as Foss Bridge in prior reports.

APPENDIX B- Spring and Summer Chinook Salmon Annual Redd Counts for the Entiat River

Entiat River spring Chinook Salmon redd counts (Redds) from annual surveys in old *index* area, Fox Creek C. G. to Dill Creek (rkm 34.3–45.2, reaches 1–3), 1962–1993 (WDFW) and 1994–2016 (USFWS).

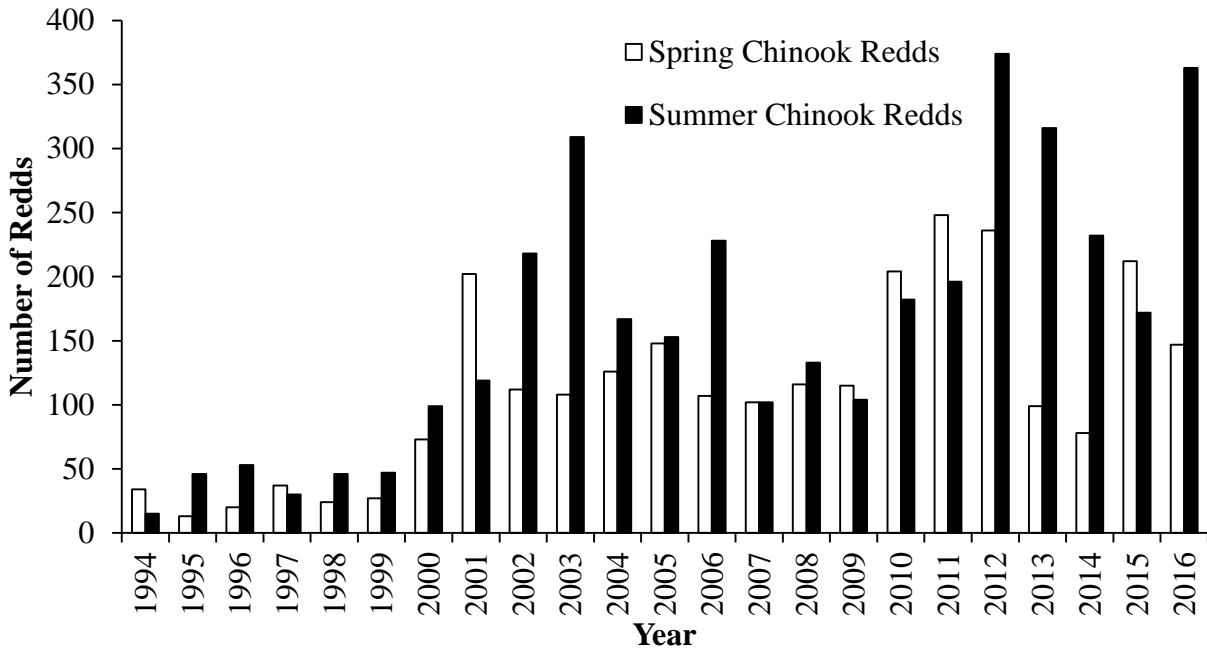
Year	Redds	Year	Redds	Year	Redds	Year	Redds
1962	115	1976	47	1990	83	2004	65
1963	145	1977	171	1991	32	2005	81
1964	384	1978	326	1992	42	2006	65
1965	104	1979	NA	1993	100	2007	70
1966	307	1980	107	1994	24	2008	77
1967	252	1981	95	1995	1	2009	76
1968	252	1982	107	1996	8	2010	125
1969	83	1983	107	1997	20	2011	180
1970	70	1984	84	1998	15	2012	172
1971	136	1985	115	1999	6	2013	81
1972	61	1986	105	2000	28	2014	78
1973	229	1987	64	2001	144	2015	146
1974	88	1988	67	2002	72	2016	108
1975	156	1989	37	2003	70		



Entiat River spring Chinook Salmon redd counts in the *index* area, rkm 34.3–45.2 (reaches 1–3), and the 10-year moving average (dotted line).

Entiat River spring and summer Chinook Salmon redd counts from the summation of redd surveys observed in reaches 1–5 (rkm 2.4–5.6), reaches H and F (rkm 0.5–10.9) and the Mad River, 1994–2016.

Year	Spring Chinook Salmon	Summer Chinook Salmon
1994	34	15
1995	13	49
1996	20	55
1997	37	30
1998	24	46
1999	27	47
2000	73	99
2001	202	112
2002	112	217
2003	108	300
2004	126	168
2005	146	155
2006	106	228
2007	102	101
2008	115	133
2009	115	105
2010	204	181
2011	248	196
2012	236	374
2013	99	316
2014	102	232
2015	212	172
2016	147	363



Spring and summer Chinook Salmon redd counts for the Entiat River, 1994–2016.

APPENDIX C- Sockeye Salmon and Coho Salmon Annual Redd Counts for the Entiat River

Year	Sockeye Salmon	Coho Salmon
1994	0	-
1995	0	-
1996	0	-
1997	0	-
1998	3	-
1999	0	-
2000	2	-
2001	10	12
2002	139	0
2003	15	0
2004	39	5
2005	42	2
2006	9	1
2007	1	6
2008	16	6
2009	23	0
2010	138	0
2011	35	10
2012	52	0
2013	180	10
2014	51	12
2015	-	-
2016	64	-

APPENDIX D- Spring and Summer Chinook Salmon Spawning Ground Survey Results in the Entiat River basin in 2016.

Reach	River Km	Date	Redds	Live Fish	Carcasses
1	41.5–45.2	8/17	0		0
		8/22	2		0
		8/29	2		0
		9/6	2		0
		9/12	13		3
		9/19	0		0
		Total	19		3
2	37.7–41.5	8/4	0		0
		8/15	0		0
		8/17	6		0
		8/22	11		0
		8/29	19		0
		9/6	12		3
		9/13	12		8
		9/19	1		5
Total	61		16		
3	34.3–37.7	8/3	0		0
		8/18	1		0
		8/25	1		0
		8/31	10		0
		9/7	8		5
		9/14	6		5
		9/20	2		1
Total	28		11		
4	30.1–34.3	8/1	0		0
		8/16	0		0
		8/26	1		0
		9/1	4		1
		9/8	10		4
		9/15	4		5
		9/22	4		2
Total	23		12		
5	26.1–30.1	8/1	0		0
		8/16	0		1
		8/26	0		1
		9/1	2		0
		9/9	3		3

**Spring Chinook Salmon spawning ground survey results in the Entiat River basin
in 2016 (cont'd).**

5	26.1–30.1	9/16	4	5
		9/23	1	0
		Total	10	10
Mad River	2.4–5.6	9/21	6	0
		Total	6	0
<u>Area Totals</u>				
	<i>Index</i> Area (R 1–3)		108	30
	<i>Expanded</i> Area (R 4–5)		33	22
	Upper River (R 1–5)		141	52
	Mad River		6	0

Summer Chinook Salmon spawning ground survey results on the Entiat River in 2016.

Reach	River Km	Date	Redds	Live Fish	Carcasses
1	41.5–45.2	10/3	0		0
		10/11	0		0
		10/17	0		0
		Total	0		0
2	37.7–41.5	10/3	2	5	0
		10/11	9		0
		10/17	0		0
		Total	11		0
3	34.3–37.7	10/5	26		2
		10/12	8		
		10/18	6		3
		10/24	0		3
		Total	40		8
4	30.1–34.3	10/6	16		2
		10/12	5		0
		10/20	0		4
		10/25	2		1
		11/1	0		3
		11/7	0		2
		Total	23		12
5	26.1–30.1	10/6	114		2
		10/14	0		17
		10/19	36		17
		10/25	11		12
		11/2	7		39
		11/10	0		8
Total	168		95		
H	5.0–10.9	10/7	55	77	3
		10/21	0		5
		10/28	0		3
		11/3	3		1
		11/8	8		7
Total	66		19		
F	0.5–5.0	10/7	8		3
		10/21	0		2
		10/28	16		14
		11/3	16		12
		11/8	15		0
		11/16	0		4
Total	55		35		
Mad River Mouth		--	--		--

Summer Chinook Salmon spawning ground survey results on the Entiat River
in 2016 (cont'd).

Area Totals		
Upper River (R 1-5)	242	115
Lower River (H, F)	121	54
Entiat River basin	363	169

APPENDIX E- Calculations

Carcass Recovery Rate

Estimating the carcass recovery rate (CRR) for both spring and summer Chinook Salmon returning to the Entiat River to spawn was calculated as follows:

$$\text{CRR} = \frac{\text{Carcasses}}{\text{SRE}}$$

Where: Carcasses is the number of examined carcasses, and SRE is the estimated total spawning run escapement of adults to the river.

Estimating Natural-origin Spawners

(1) To calculate the proportion of natural-origin spawners (pNOS);

$$\text{pNOS} = \frac{\text{NOC}}{\text{TC}}$$

Where: NOC is the number of natural-origin carcasses recovered, and TC is the total number of known origin carcasses recovered.

(2) To calculate the number of natural-origin spawners (NOS);

$$\text{NOS} = \text{pNOS} * \text{SRE}$$

Estimating Hatchery-origin Spawners

(1) To calculate the proportion of hatchery-origin spawners (pHOS);

$$\text{pHOS} = \frac{\text{HOC}}{\text{TC}}$$

Where: HOC is the number of hatchery-origin carcasses recovered.

(2) To calculate the number of hatchery-origin spawners (HOS);

$$\text{HOS} = \text{pHOS} * \text{SRE}$$

Estimating Hatchery Contribution by Release Facility

To determine the proportion and origin of hatchery fish found on the spawning grounds we used any combination of scale patterns, adipose fin presence/absence, or tags if present. Coded-wire tags were used to estimate the contribution of hatchery-origin spawners by release hatchery or program. Additionally, coded-wire tags were used to account for untagged hatchery-origin fish because hatcheries applied tags at different rates to their releases. To estimate the potential

number of hatchery-origin spawners represented by a coded-wire tag we expanded each unique tag using the following three-step process:

- (1) To calculate the expanded CWT (CWT Expanded) recoveries for each tag code (x) recovered;

$$CWT_{Expanded}^x = \frac{(CWT_{obs}^x / CWT_{rate}^x)}{CRR}$$

Where: CWT obs is the number of coded-wire tags recovered or observed for each specific CWT code, CWT rate is the tagging rate for each CWT code, and CRR is the calculated carcass recovery rate calculated in step 1.

- (2) To calculate the proportion of CWT (pCWT) by tag code (x);

$$pCWT_x = \frac{CWT_{expanded}^x}{\Sigma CWT_{expanded}}$$

- (3) To calculate the spawning run escapement (SRECWT) by tag code (x);

$$SRE_{CWTx} = pCWT_x * HOS$$

**APPENDIX F- Hatchery- and Natural-origin Spring Chinook Salmon Composition Data
2004–2016.**

Year	Redds	SRE	Carcasses	CRR	Natural %	Hatchery %	Origin of Hatchery Fish			
							ENFH %	LNFH %	CRP %	Other ¹ %
2004	126	302	43	0.14	47	53	92	0	0	8
2005	146	367	53	0.14	44	56	67	12	21	0
2006	106	254	75	0.30	43	57	12	8	23	56
2007	102	245	41	0.17	43	58	34	0	23	43
2008	115	276	80	0.29	46	54	39	0	61	0
2009	115	276	79	0.29	48	52	75	8	17	0
2010	204	490	93	0.19	75	25	19	0	26	55
2011	248	595	173	0.29	54	46	0	19	72	9
2012	236	566	125	0.22	59	41	0	0	81	19
2013	99	238	22	0.09	79	21	0	0	80	20
2014	102	245	26	0.11	92	8	0	0	0	100 ²
2015	212	509	137	0.26	82	18	0	0	28	72
2016	147	353	52	0.15	84	16	0	0	0	100 ²

¹Includes hatchery populations that were not recovered more than 2x from 2004-2016. These include CWT recoveries from Winthrop NFH, Methow FH, Chewuch Acclimation, Twisp Acclimation, Clearwater FH, Kooskia NFH, Dworshak NFH, Willamette SFH and Sawtooth SFH.

²All hatchery-origin carcasses recovered were of unknown origin.

APPENDIX G- PIT Tag Recoveries

Passive Integrated Transponder (PIT) tag interrogations from spring Chinook Salmon carcasses recovered on the Entiat River in 2016.

PIT Tag Code	Sex	Site	<u>Release</u>		<u>Last Detection</u>	
			Date	Site	Date	Site
384.3B23ACA607	M	Entiat River	3/18/2014	Entiat R.	ENF rkm 40.6	8/28/2016
3D9.1C2D9DBC33	M	Entiat River	10/17/2013	Entiat R.	ENF rkm 40.6	9/7/2016
3D9.1C2D704197	M	Entiat River	4/30/2014	Entiat R.	ENM rkm 26	9/6/2016
3DD.003B9E0905	M	Nason Creek	4/13/2015	Entiat R.	ENF rkm 40.6	9/13/2016

*PIT tag was recovered from a spring Chinook Salmon on the Mad River.

PIT tag interrogations from summer Chinook Salmon carcasses on recovered on the Entiat River in 2016.

PIT Tag Code	Sex	Site	<u>Release</u>		<u>Last Detection</u>	
			Date	Site	Date	Site
3DD.007797B14F	F	Bonneville D.	6/29/2016	Entiat R.	ENM rkm 26	11/2/2016

No PIT tags were recovered from Sockeye Salmon or Coho Salmon carcasses on the Entiat River in 2016.

**U. S. Fish and Wildlife Service
Mid-Columbia Fish and Wildlife Conservation Office
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Leavenworth, WA**



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