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Chinook Salmon Spawning Ground Surveys on the Entiat River, 2017

Gregory S. Fraser, Charles O. Hamstreet, Jakub Bednarek and Matt R. Cooper

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Mid-Columbia Fish and Wildlife Conservation Office
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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 2017. 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 and gender 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 2017, a total of 63 spring Chinook Salmon redds and 370 summer Chinook Salmon redds were identified in the Entiat River basin. The spawning run escapements were estimated at 101 spring Chinook Salmon and 591 summer Chinook Salmon. Superimposition rates of summer Chinook Salmon redds on spring Chinook Salmon redds were 9.5% in total and were lower in upstream reaches than in downstream reaches.

In 2017, carcass recoveries consisted of 19 spring Chinook Salmon and 184 summer Chinook Salmon, with carcass recovery rates for each run estimated at 0.19 and 0.31, respectively. Natural-origin fish accounted for 63% (pHOS = 0.37) of the spring Chinook Salmon spawning run escapement and 59% (pHOS = 0.41) of the summer Chinook Salmon spawning run escapement. Two CWTs were recovered from hatchery-origin spring Chinook Salmon carcasses, both were from Chiwawa Rearing Ponds (8%). The majority of hatchery summer Chinook Salmon carcasses recovered on the spawning grounds originated from Entiat National Fish Hatchery (90%) the remainder came from Dryden Ponds (9%) and Chelan Falls (1%). The age class composition for spring Chinook Salmon was 6% age-2, 25% age-3, 56% age-4, and 13% age-5 fish. The age class composition for summer Chinook Salmon was 2% age-3, 27% age-4, 65% age-5 fish and 6% age-6.

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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 2017 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 (1957–2017) 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 (1957–2017) 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 58.0). River kilometers were measured from the confluence of the Entiat River with the Columbia River (rkm 0).

The Entiat River basin drains an area of approximately 671 km^2. 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 26.6) and the Entiat NFH (rkm 10.9). The stretch of river between rkm 10.9–26.6 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 26.6–48.1), 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. Coho Salmon spawn in the lower reaches between rkm 0.5-10.9. Sockeye Salmon spawn in the upper reaches between rkm 26.6-48.1.

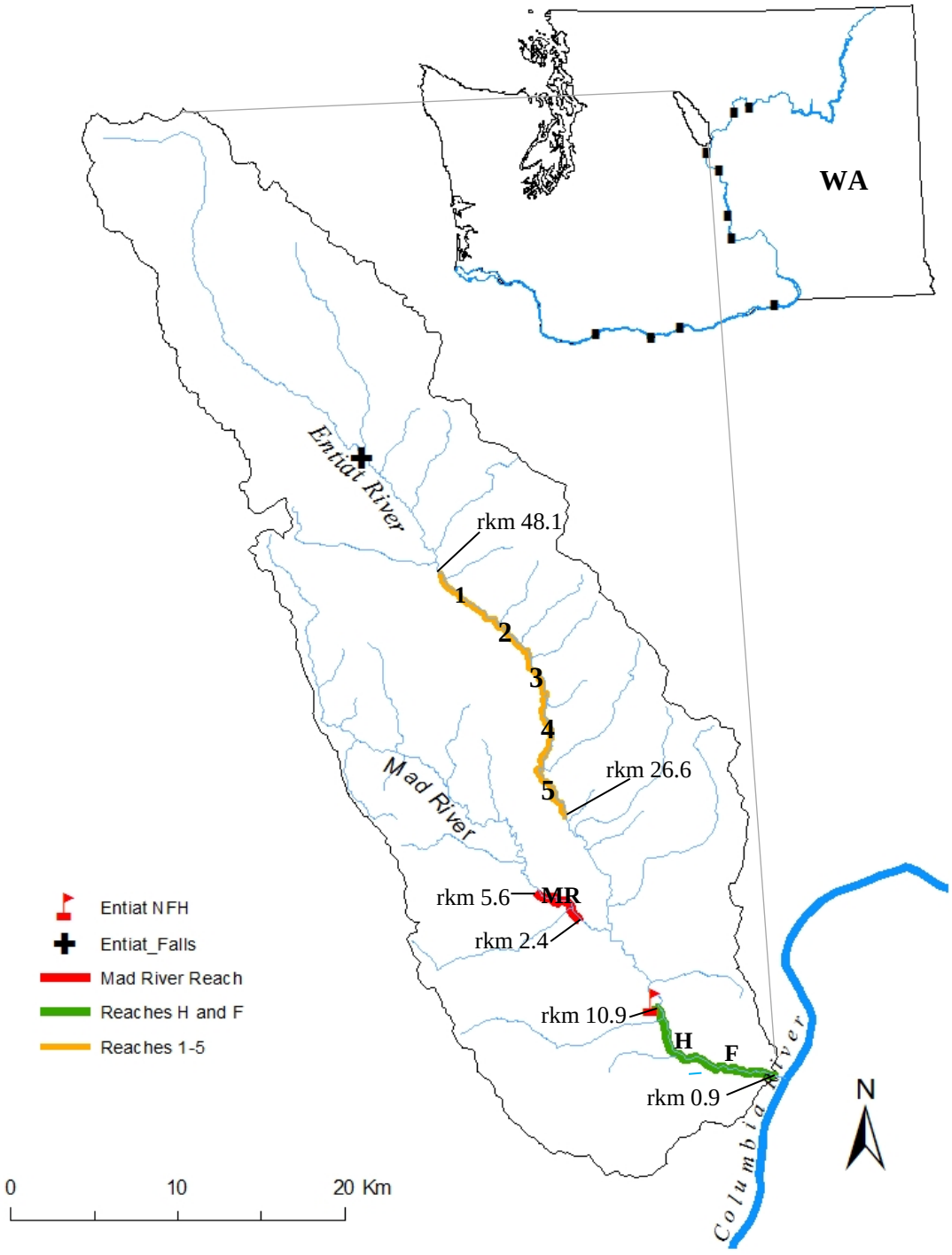

FIGURE 1.—Map of the Entiat River basin and the spawning ground survey reaches (1-5, H, F and MR). Black squares represent main-stem Columbia River dams on the Washington State outline map (WA).

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 35.9–48.1 (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 Enitat 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 26.6–35.9 (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 reared and released juvenile summer Chinook Salmon (in addition to other species and stocks) 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 to 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 functionally 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 July 12, 2017 and concluded on September 27. Summer Chinook Salmon spawning ground surveys in 2017 began October 2 and concluded on November 8. 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 in width with a distinguishable pit and tailspill area. Unlike in past years (1994–2015) no flagging or physical markers were used to mark redds in the Entiat River in 2017. 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 and photographed 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 2007–2016 averages (10-year average), as 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 freshwater 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.rmpc.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 ancillary to this effort. Coho Salmon continue to spawn after our surveys are complete so these data should not be considered a complete census of the Coho Salmon run into the Entiat River.

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 D.

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 a tributary 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 where spring and Summer Chinook Salmon spawning overlaps 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 apportioned among rearing facilities based on carcass CWT recoveries to derive the Entiat NFH contribution 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 2017, the Entiat River flow regime was above average and peak flows were more than double the 58-year average (Figure 2). Following peak flows the 2017 flow regime mimicked the long-term mean. Spawning ground surveys began on July12 and concluded on November 8. Beginning in mid-October rain events increased flows and turbidity, which reduced visibility and potentially moved carcasses downstream out of the survey reaches. Periodic fall rain events are not uncommon during fall months.

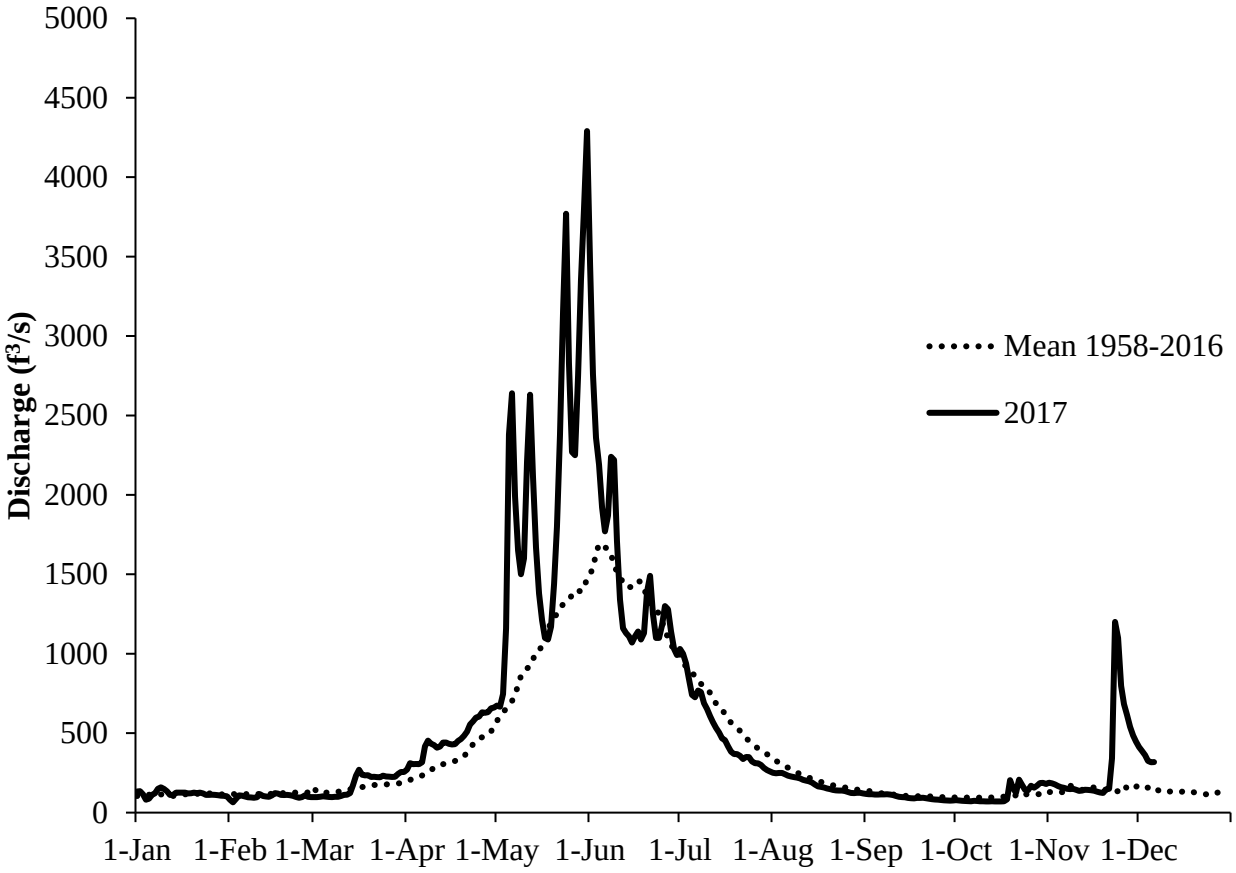

Figure 2.—Mean daily flow in the Entiat River for 2017 (solid line) and the long-term mean (1958–2016; dotted line). Flow data were collected at USGS gauge 12452800, Entiat River near Ardenvoir, WA.

Spring Chinook Salmon

In 2017, a total of 62 spring Chinook Salmon redds were identified throughout the surveyed portions of the Entiat River and one in the Mad River. The number of spring Chinook Salmon redds observed in 2017 was 40% of the 10-year average of 156 redds/year (Figure 3). Peak spawning in 2017 occurred on the week of September 5 which was similar to the 10-year average (Figure 4).

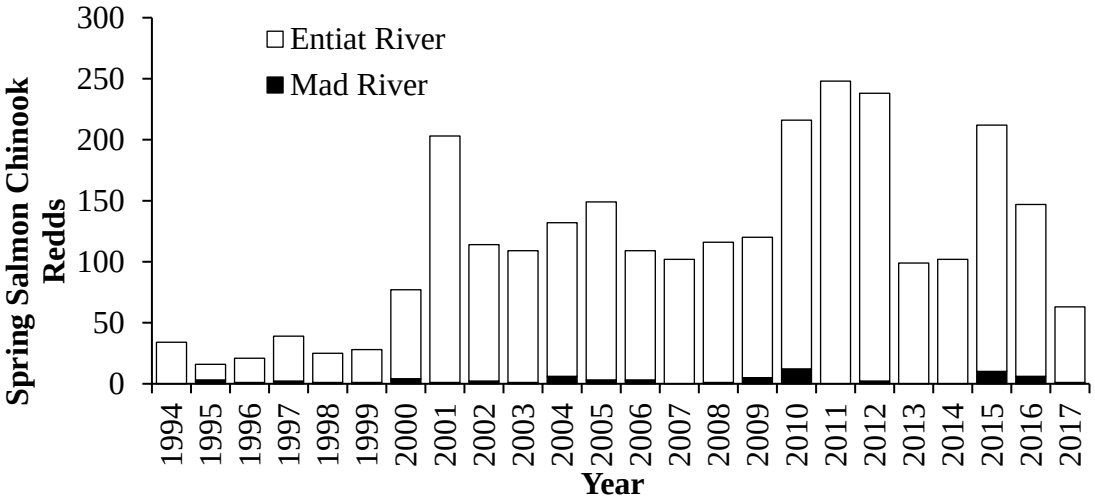

Figure 3.—Annual Entiat River spring Chinook Salmon redd counts in the Entiat River (white bars) and the Mad River (black bars).

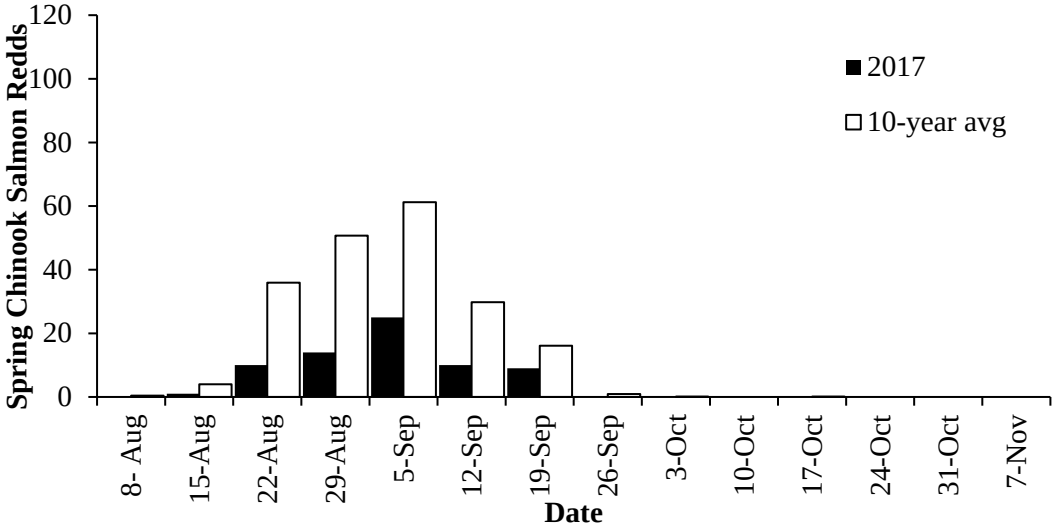

FIGURE 4.—Weekly counts of spring Chinook Salmon redds observed during spawning ground surveys in the Entiat River 2017 (black bars) and the 10-year average (2007–2016; white bars). Spring Chinook Salmon surveys ended on September 27.

Spatial distributions of redds from reach 1 downstream to reach 5 in 2017 were similar to the 10-year average in which redd abundance was greatest in reach 2 and progressively decreased downstream (Figure 5). One redd was identified in the Mad River, the 10-year average was four.

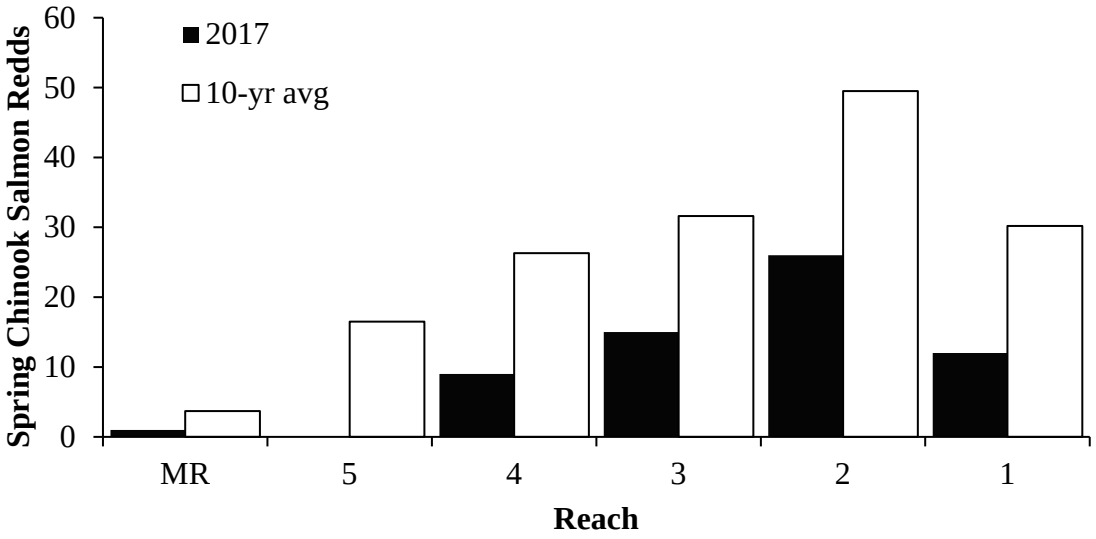

FIGURE 5.—Entiat River spring Chinook Salmon redd counts for reaches 1–5 (rkm 26.6–48.1) in 2017 (black bars) and the 10-year average (2007–2016; white bars).

Spring Chinook Salmon spawning run escapement in the Entiat River basin in 2017 was estimated at 101 fish (Table 1). Carcasses of 19 spring Chinook Salmon were recovered and resulted in a carcass recovery rate of 0.19 (Appendix D). Due to poor condition, two carcasses were not assigned a sex. Female carcasses outnumbered male carcasses 10 (59%) to 7 (41%). All female carcasses were examined to determine spawning success, 9 (90%) carcasses were completely spent, and one (10%) could not be determined due to poor condition.

TABLE 1.—Redd and carcass counts with spawning run escapement (SRE) and carcass recovery rates (CRR) for spring Chinook Salmon in the Entiat River basin from 2005–2017.

Year	Redds	SRE	Carcasses	CRR
2017	63	101	19	0.19
2016	147	343	52	0.15
2015	212	406	137	0.34
2014	102	189	26	0.14
2013	99	189	22	0.12
2012	236	403	125	0.31
2011	248	505	173	0.34
2010	204	345	93	0.27
2009	115	198	79	0.40
2008	114	228	80	0.35
2007	102	194	41	0.21
2006	106	159	75	0.47
2005	146	253	53	0.21

Origin was determined for all of the 19 spring Chinook Salmon carcasses recovered in 2017 in the Entiat River basin. Natural-origin spring Chinook Salmon constituted 63% (n=12) of the carcasses, resulting in an estimated natural-origin spawning escapement of 60 fish. Hatchery-origin adults constituted 37% (n=7) of the carcasses examined in 2017, resulting in an estimated hatchery-origin spawning escapement of 35 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 had substantially increased until 2017 (Figure 6).

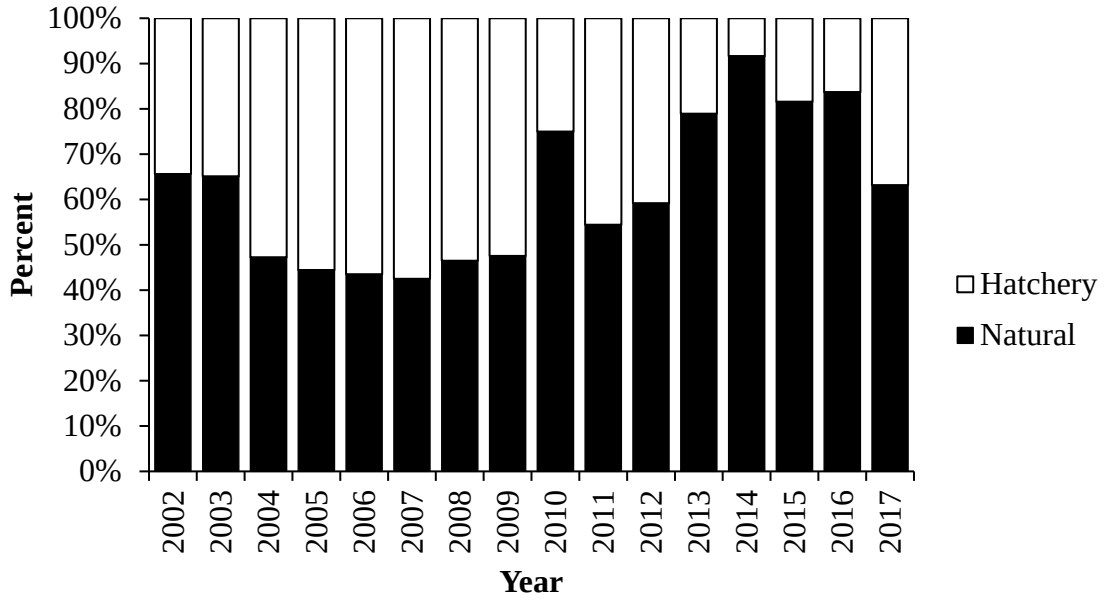

FIGURE 6.—Percent of hatchery- and natural-origin spring Chinook Salmon spawning run escapement into the Entiat River basin.

In 2017, 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 one age-2 male, one age-3 male, two age-4 males, one age-3 female, five age-4 females and two age-5 females. Hatchery-origin fish were represented by two age-3 males, one age-4 male, and two age-4 females. The spawning run escapement was represented by 6% age-2, 25% age-3, 56% age-4, and 13% age-5 fish.

TABLE 2.—Age composition for spring Chinook Salmon sampled from the Entiat River basin in 2017.

Origin	Age description	Total Age	Male		Female		Total	pSRE[1]	SRE
Natural	1.0	2	1		0		1	N/A[2]	N/A[2]
	1.1	3	1		1		2	0.12	12
	1.2	4	2		5		7	0.39	39
	1.3	5	0		2		2	0.12	12
Natural Total			4 (33.3%)		8 (66.6%)		12	0.63	63
Hatchery	1.1	3	2		0		2	0.11	12
	1.2	4	1		2		5*	0.26	26
Hatchery Total			3	60	2	40	7	0.37	38
Total*			7		10		19		101

1) pSRE is the Proportion of the Spawning Run Escapement
2) Age-2 recoveries were not included in spawning run escapement (SRE) estimates.
*) Two age-4 hatchery-origin fish were recovered but sex was indeterminable

Recovered carcasses (n=19) were checked for adipose fin condition and scanned for CWTs and PIT tags. In 2017, two coded-wire tags and one PIT tag was recovered from spring Chinook Salmon in the Entiat River basin (Table 3; Appendix F).

TABLE 3.—Coded-wire tag (CWT) recoveries collected from spring Chinook Salmon carcasses on the Entiat River in 2017.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered	Tag Rate	CWT Expanded	pCWT	SRE CWT
636653	2013	WDFW	Chiwawa	1	0.98	5.67	0.50	4
636804	2014	WDFW	Chiwawa	1	0.98	5.66	0.50	4

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 2017 based on CWTs. pCWT is the proportion of CWTs that a given CWT group represents. For calculations see Appendix D.

Summer Chinook Salmon

In 2017, a total of 370 summer Chinook Salmon redds were identified during spawning ground surveys. The redd count in 2017 was 181% of the 10-year average of 204 redds and continued to reverse 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).

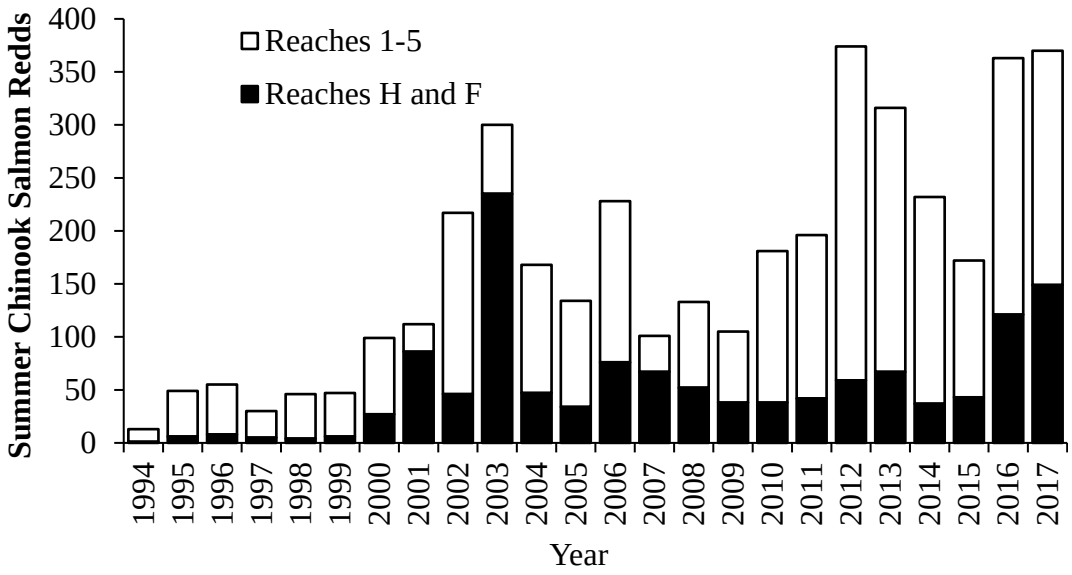

FIGURE 7.—Annual Entiat River summer Chinook Salmon redd counts differentiated by upstream reaches 1–5 (rkm 26.6–48.1) and downstream reaches F and H (rkm 0.5–10.9).

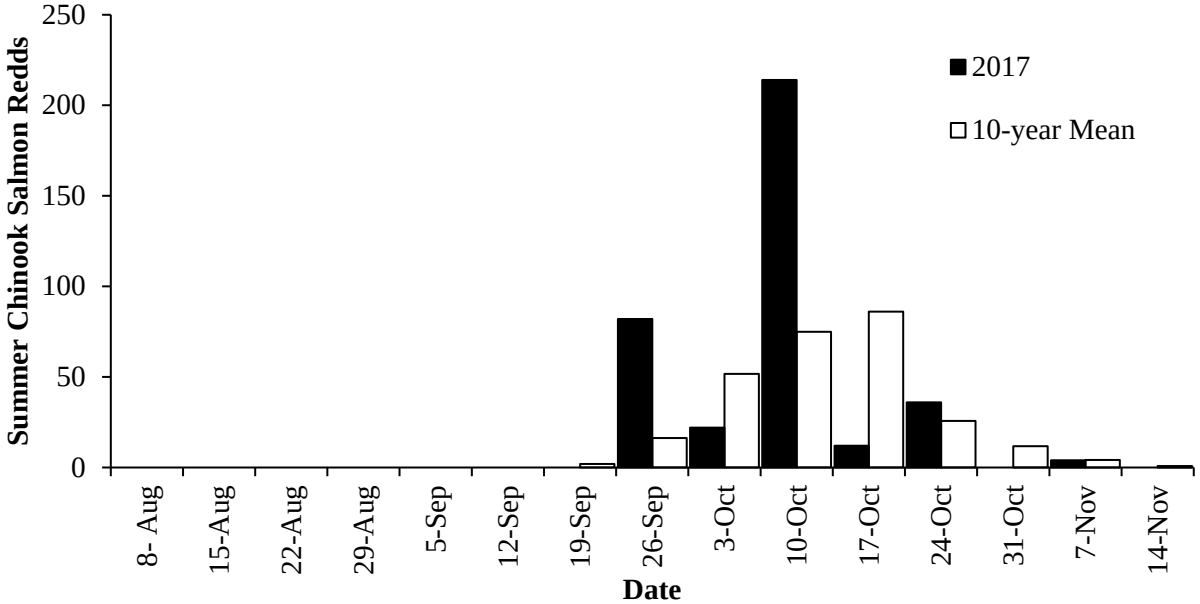

FIGURE 8.—Weekly counts of summer Chinook Salmon redds observed during spawning ground surveys in the Entiat River per week in 2017 compared to the 10-year average (2007–2016). No surveys were conducted from September 27–October 2.

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 2017, there were twice as many summer Chinook Salmon redds in the lower river reaches H and F than the 10-year average.

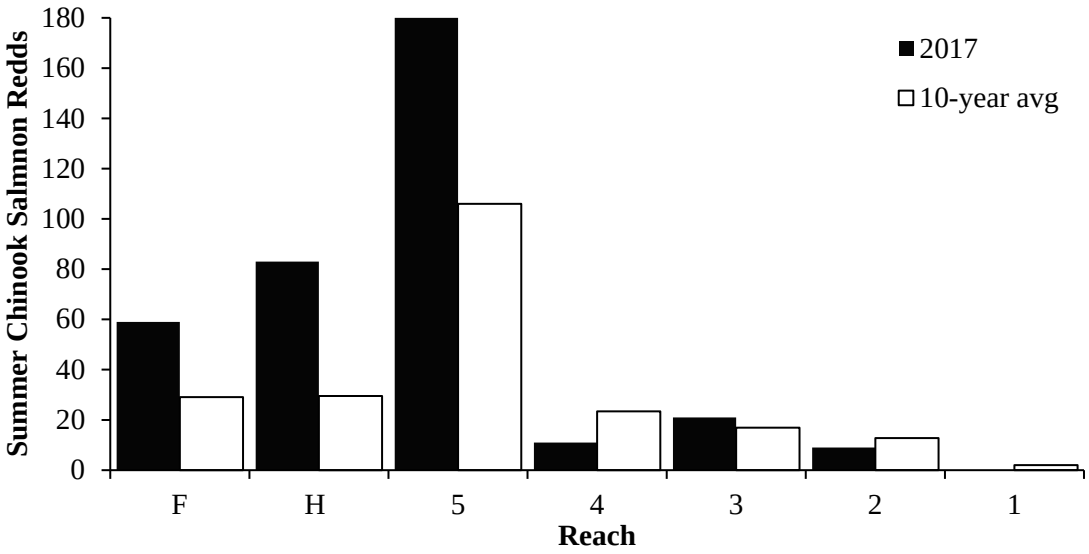

FIGURE 9.—Entiat River summer Chinook Salmon redd counts for reaches F and H (rkm 0.5–10.9) and reaches 1–5 (rkm 26.6–48.1) in 2017 (black bars) compared to the 10-year average (2007–2016; white bars).

The 2017 spawning run escapement for Entiat River summer Chinook Salmon was estimated to be 591 fish (Table 4). Carcasses of 184 summer Chinook Salmon were recovered, which resulted in a carcass recovery rate of 0.31. Summer Chinook Salmon females outnumbered males 104 (63%) to 62 (37%), sex was not determined for 18 carcasses due to advanced decomposition. All 104 female carcasses were examined for spawning success; 85 (81%) were completely spent, five (5%) were partially spent, four (4%) had a full egg skein indicative of pre-spawn mortality, and ten (10%) were undetermined due to decomposition.

TABLE 4.—Redds and carcasses with spawning run escapement (SRE) and carcass recovery rates (CRR) for summer Chinook Salmon in the Entiat River basin from 2006–2017.

Year	Redds	SRE	Carcasses	CRR
2017	370	591	184	0.31
2016	363	567	169	0.30
2015	172	382	218	0.57
2014	233	592	89	0.15
2013	316	472	154	0.33
2012	374	645	207	0.32
2011	196	295	137	0.46
2010	181	262	96	0.37
2009	105	182	83	0.46
2008	134	215	82	0.38
2007	101	142	88	0.62
2006	228	400	180	0.45

A total of 184 summer Chinook Salmon carcasses were recovered in 2017, origin was determined for 180 and both age and origin were determined for 155 (84%; Table 5). Natural-origin summer Chinook Salmon constituted 59% (n=106) of the carcasses, which resulted in an estimated natural-origin spawning escapement of 349 fish. Hatchery-origin adults constituted 41% (n=74) of the carcasses resulting in an estimated hatchery-origin escapement of 242 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, 27% age-4, 65% age-5 fish and 6% 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 2017.

Origin	Age description	Total Age	Male	Female	Total	pSRE	SRE
Natural	0.2	3	5	0	5	0.03	20
	0.3	4	13	12	25	0.16	96
	0.4	5	18	33	51	0.33	195
	0.5	6	1	1	2	0.01	8
	1.2	4	1	5	6	0.04	23
	1.3	5	2	5	7	0.05	27
Natural Total			40 (41.7%)	56 (58.3%)	96	0.62	368
Hatchery	1.0	2	1	0	1	N/A	N/A
	1.2	4	6	4	10	0.06	39
	1.3	5	12	29	41	0.26	157
	1.4	6	2	5	7	0.05	27
Hatchery Total			21 (35.6%)	38 (64.4%)	59	0.38	223
Total*			61	94	155		591

*Age-2 recoveries 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 2017, the ratio of hatchery- to natural-origin summer Chinook Salmon carcasses were 12 to 81 in the upper reaches and 61 to 22 in the lower reaches (Figure 11). The spatial distribution between the upper and lower reaches is consistent with data from previous years.

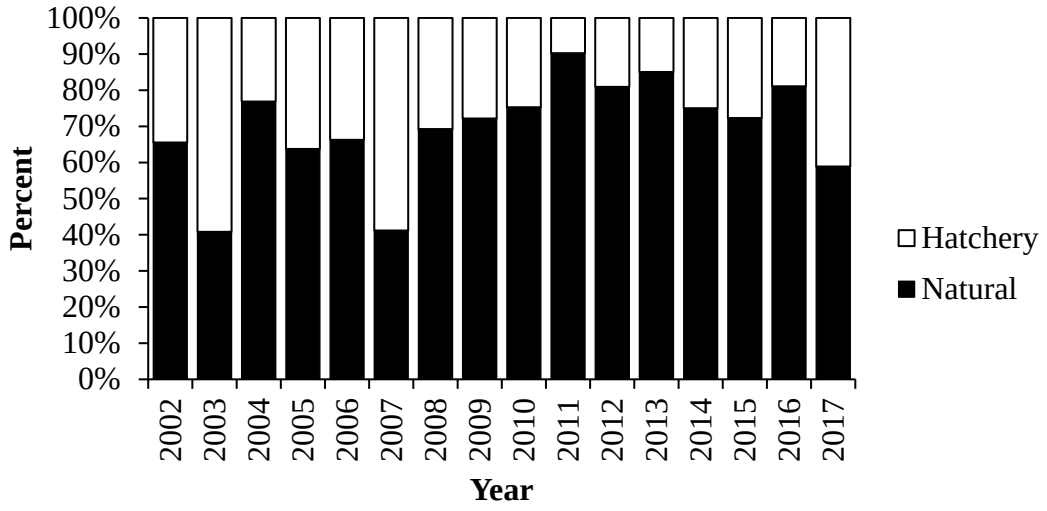

FIGURE 10.—Percent of hatchery- and natural-origin summer Chinook Salmon spawning run escapement into the Entiat River.

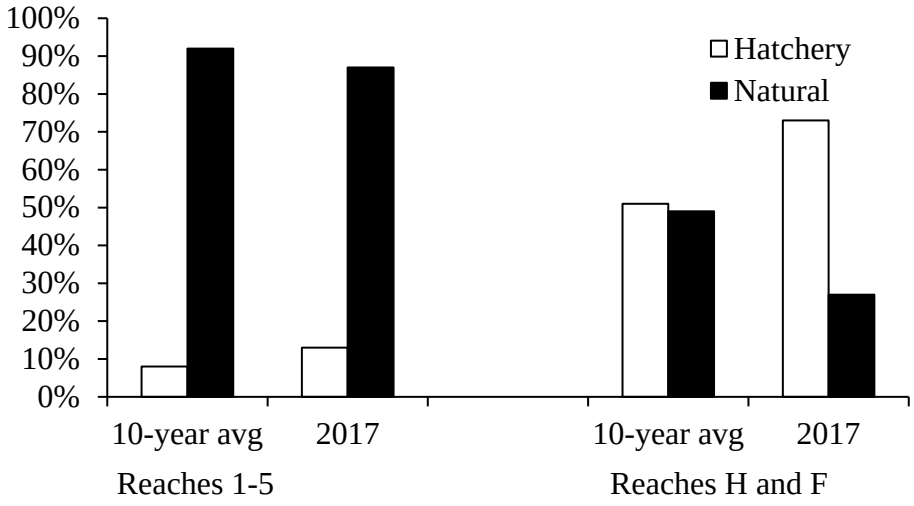

FIGURE 11.—Estimated percent composition of hatchery- and natural-origin summer Chinook Salmon spawning in downstream reaches F and H (rkm 0.5–10.9) and upstream reaches 1–5 (rkm 26.6–48.1) of the Entiat River in 2017.

Three juvenile life history types were identified for returning natural-origin summer Chinook Salmon in 2017; 86% migrated to saltwater at age-0, 11% overwintered (age-1) in a reservoir and 3% overwintered (age-1) in a stream (Table 6). Life history types could not be determined for 14 carcasses recovered due to poor scale condition, 65 were hatchery-origin.

TABLE 6.—Juvenile life history types and percentages for natural-origin summer Chinook Salmon sampled from the Entiat River in years 2006–2017.

	Ocean		Reservoir		Stream		Total
Year	(N)	%	(N)	%	(N)	%	(N)
2017	90	86	12	11	3	3	105
2016	70	56	53	43	1	1	124
2015	117	80	26	18	3	2	146
2014	50	79	13	21	0	0	63
2013	89	71	36	29	0	0	125
2012	124	74	44	26	0	0	168
2011	88	76	27	23	1	1	116
2010	49	72	19	28	0	0	68
2009	51	89	6	11	0	0	57
2008	42	84	8	16	0	0	50
2007	25	74	9	26	0	0	34
2006	84	73	27	23	4	4	115
Avg		75		24		1	

Of the 184 recovered summer Chinook Salmon carcasses 41 contained a CWT (Table 7). Recovered CWTs revealed that 90% of the hatchery-origin fish that returned to spawn in the Enitat River originated at the Enitat NFH, this extrapolated to an Entiat NFH spawning run escapement rate (SRECWT) of 217 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 10% of the hatchery-origin carcasses recovered on the spawning grounds, 9% were from Dryden Acclimation Ponds and 1% were from Chelan Falls.

TABLE 7.—Coded-wire tag (CWT) recoveries collected from summer Chinook Salmon carcasses on the Entiat River in 2017. (Note: Age-2 recoveries 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	USFWS	ENTIAT NFH	26	0.45	186.62	0.74	180
055362	2011	USFWS	ENTIAT NFH	4	0.65	19.94	0.08	19
055363	2011	USFWS	ENTIAT NFH	2	0.56	11.43	0.05	11
055758	2016	USFWS	ENTIAT NFH	1	0.48	6.65	0.03	6
636175	2011	WDFW	DRYDEN POND	1	0.99	3.27	0.01	3
636626	2013	WDFW	DRYDEN POND	1	1.00	3.24	0.01	3
636627	2013	WDFW	DRYDEN POND	3	1.00	9.70	0.04	9
636628	2013	WDFW	DRYDEN POND	1	0.99	3.24	0.01	3
636650	2013	WDFW	CHELAN FALLS	1	1.00	3.24	0.01	3
636672	2013	WDFW	DRYDEN POND	1	0.99	3.25	0.01	3

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 2017 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). None of the spring Chinook Salmon redds were superimposed in reach 1(the most upstream reach) and only 8% were superimposed on in reach 2 (Table 8). Further downstream, in reaches 3 and 4, superimposition rates were 13% and 21%, respectively. In 2017 the total superimposition rate was 9.5% and decreased by 6.1% compared to 2016 (Table 9). On average 17% (2013–2017) of spring Chinook Salmon redds are superimposed upon with the majority of superimposition (87% on average) attributed to natural-origin summer Chinook Salmon returning to the upper Entiat watershed where spring Chinook Salmon spawn. The 2017 level of superimposition attributed to Entiat NFH-origin summer Chinook Salmon (13% hatchery-origin for reaches 1–5 of which 77% were from Entiat NFH) was 0.95% and similar to 2016.

TABLE 8.—Redd superimposition by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2017.

Reach	Spring Chinook Salmon redds	Summer Chinook Salmon redds	Spring Chinook Salmon redds superimposed (%)
1	12	0	0 (0)
2	26	9	2 (8)
3	15	21	2 (13)
4	9	11	2 (22)
5	0	180	N/A

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, 2013–2017.

	Redds				SUS				
Year	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%	0.30%
2014	102	196	28	27.5%	95%	5%	26.1%	1.4%	1.40%
2015	202	172	28	13.9%	90%	10%	12.5%	1.4%	0.21%
2016	141	242	22	15.6%	93%	7%	14.5%	1.1%	0.94%
2017	63	221	6	9.50%	87%	13%	8.3%	1.2%	0.95%

Sockeye Salmon

42 Sockeye Salmon redds were observed in reaches 2-5 during our 2017 surveys. The spatial distribution of Sockey Salmon redds was similar to previous years. 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 2017.

Species	CWT	Brood Year	Release Agency	Hatchery	Recovered
No CWTs were recovered from Sockeye Salmon in 2017					

Coho Salmon

In 2017, Coho Salmon redds were observed in reaches H and F similar to previous years but not documented during Chinook Salmon surveys on the Entiat River. Some Coho Salmon carcasses were observed and all were scanned for CWT and PIT tags, data were only collected on tagged fish. None of the Coho Salmon contained a CWT (Table 11). One Coho Salmon contained a PIT tag (Appendix F). Coho Salmon continued to spawn after our surveys were complete so these data should not be considered a complete census.

TABLE 11.—Coded-wire tag (CWT) data recovered from Coho Salmon carcasses in the Entiat River in 2017.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered
No CWTs were recovered from Coho Salmon in 2017				

Discussion

The 2017 return of spring Chinook Salmon to the Columbia River basin was one of the lowest in decades due to poor ocean conditions in 2015 when the majority of the salmon returning in 2017 migrated to the ocean (Daly et al. 2017). Fewer spring Chinook Salmon returned to the Entiat River in 2017 than any year since 2000. Over the previous six years the number and proportion of hatchery-origin spring Chinook Salmon migrating to the Entiat River basin to spawn had decreased, likely due to hatchery reform measures implemented throughout the upper Columbia River basin. In 2017, the overall number of hatchery-origin adults was again lower but the proportion increased to 37%. 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 which in part led to the decision to terminate the program. 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 E). 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 2017, the only hatchery-origin fish with CWTs were Chiwawa RP-origin spring Chinook, however it was only two fish and they were from releases of 100% CWT. Based on lower release numbers in 2014 and 2015 we expected 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. No Nason Creek-origin fish were found in 2017 but only 19 spring Chinook Salmon carcasses were recovered.

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 previous 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).

In contrast, the abundance and proportion of hatchery-origin summer Chinook Salmon in the Entiat River have increased over the last seven 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 2017 was the second highest since surveys began in 1994. The total proportion of hatchery-origin summer Chinook Salmon (pHOS) was 41% and of these hatchery-origin fish 90% originated from Entiat NFH. Hatchery-origin summer Chinook Salmon were only 13% of the spawning population upstream of the hatchery and 73% 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 most downstream section (reach 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 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 0.95% 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 six 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 low return in 2017 is a poignant reminder that ocean conditions can have huge impacts on anadromous species. Following years of high percentage of natural-origin spring Chinook Salmon and relatively high numbers of redds in the Entiat River without hatchery supplementation food availability in the ocean can disrupt recovery efforts for 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 2017 spawning ground surveys was 63, with an estimated adult spawning run escapement of 101 fish to the Entiat River basin. A total of 19 carcasses were recovered; female carcasses outnumbered male carcasses 10 to 7. All female carcasses were examined to determine spawning success, 9 (90%) carcasses were completely spent and one (10%) could not be determined due to poor condition. Recovered carcasses indicate that natural-origin spring Chinook Salmon comprised 63% of the adult return escapement to the Entiat River and the remaining 37% were of hatchery-origin. Two CWTs were recovered from spring Chinook Salmon in 2017 both were from Chiwawa Rearing Ponds.

In 2017, 370 summer Chinook Salmon redds were counted during spawning ground surveys, with an estimated adult spawning run escapement of 591 fish to the Entiat River. A total of 184 carcasses were recovered; females outnumbered males 104 to 62. All 104 female carcasses were examined for spawning success; 85 (81%) were completely spent, five (4%) were partially spent, four (4%) had a full egg skein indicative of pre-spawn mortality, and ten (10%) were undetermined due to decomposition. Recovered carcasses indicated that overall natural-origin fish compromised 59% of the adult spawning escapement to the Entiat River and 41% were of hatchery-origin. Spatially, hatchery-origin summer Chinook Salmon comprised 73% of the spawners in the lower river below Entiat NFH while natural-origin adults comprise 87% of the upriver spawning population. Scale analysis revealed natural-origin summer Chinook Salmon had three distinctive life histories; 86% were ocean-type juvenile migrants, 11% were reservoir-type juvenile migrants and 3% overwintered in a stream. A total of 41 CWTs were recovered from carcasses. Based on the CWT recoveries hatchery summer Chinook Salmon carcasses were from Entiat NFH (90%) and Dryden Ponds (10%).

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APPENDIX A- Entiat River Survey Reach Descriptions

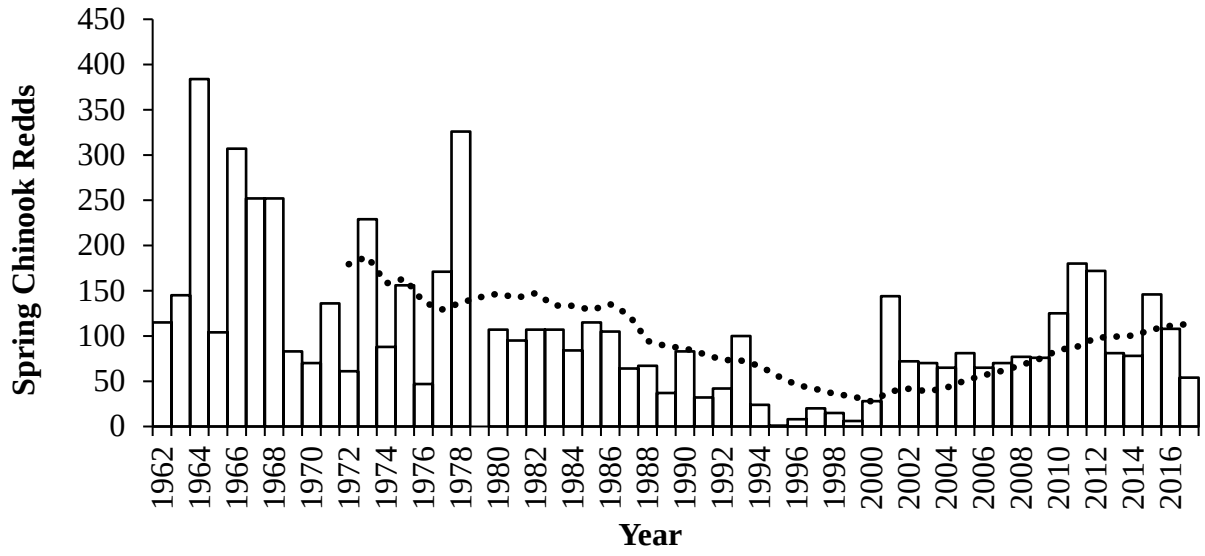
Reach	River Kilometer	Surveyed Kilometers	Description
1	48.1–44.6	3.5	Fox Creek Campground to Forest Service Boundary
2	44.6–40.1	4.5	Forest Service Boundary to Brief Bridge
3	40.1–35.9	4.2	Brief Bridge to Kelsey Lane Bridge
4	35.9–31.8	4.1	Kelsey Lane Bridge to Stormy Creek Preserve
5	31.8–26.6	5.2	Stormy Creek Preserve to McKenzie Diversion
H	10.9–5.0	5.9	Entiat NFH to Fire Station
F	5.0–0.5	4.5	Fire Station to Columbia River influence
MR	5.6–2.4	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 35.9–48.1, reaches 1–3), 1962–1993 (WDFW) and 1994–2017 (USFWS).

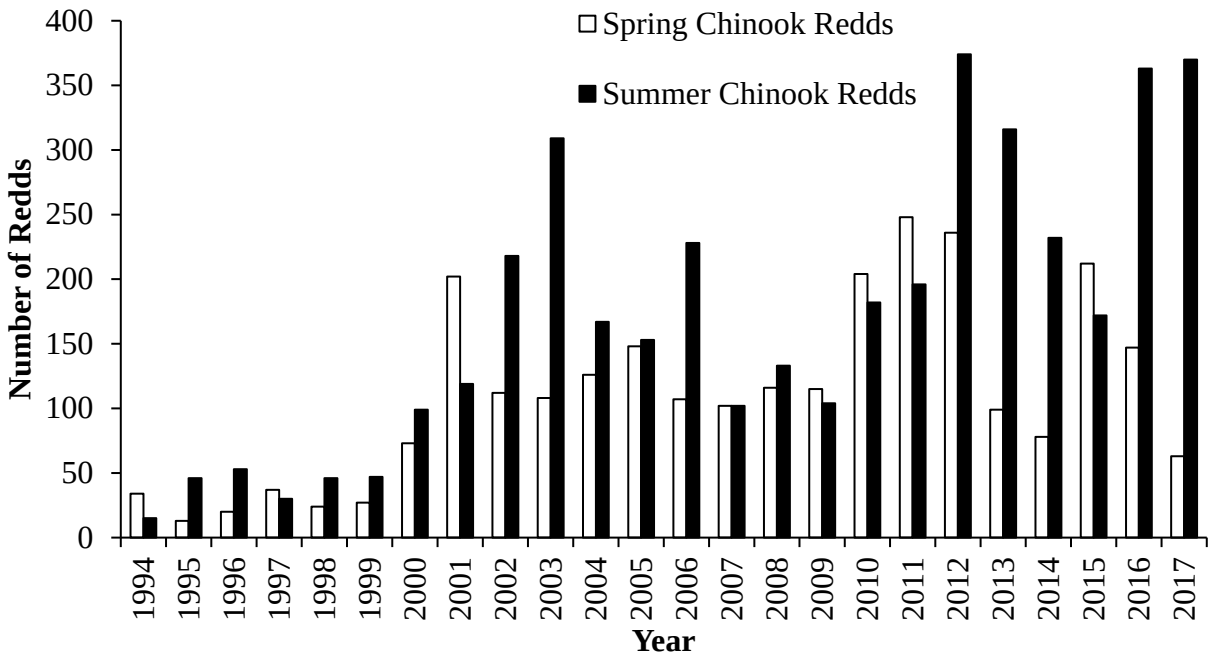
Year	Redds	Year	Redds	Year	Redds	Year	Redds
1962	115	1976	47	1990	83	2004	65
1963	145	1977	171	1991	32	2005	81
1964	384	1978	326	1992	42	2006	65
1965	104	1979	NA	1993	100	2007	70
1966	307	1980	107	1994	24	2008	77
1967	252	1981	95	1995	1	2009	76
1968	252	1982	107	1996	8	2010	125
1969	83	1983	107	1997	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	2017	54



Entiat River spring Chinook Salmon redd counts in the *index* area, rkm 35.9–48.1 (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 26.6–48.1), reaches H and F (rkm 0.5–10.9) and the Mad River (rkm 2.4-5.6), 1994–2017.

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
2017	63	370



Spring and summer Chinook Salmon redd counts for the Entiat River, 1994–2017.

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	-
2017	42	-

APPENDIX D- 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:

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

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);

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

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);

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

Estimating Hatchery-origin Spawners

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

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

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

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

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

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;

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

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*);

$$\mathrm{pCWT}_{x} = \frac{\mathrm{CWT_{expanded}}^{x}}{\Sigma\mathrm{CWT_{expanded}}}$$

(3) To calculate the spawning run escapement (SRECWT)[i] by tag code (*x*);

$$\mathrm{SRE}_{CWTx} = \mathrm{pCWT}_{x} * \mathrm{HOS}$$

i) Note: if all tag rates in a given year are high enough that they do not account for all the hatchery-origin SRE then the $\mathrm{SRE}_{\mathrm{CWTx}}$ equation uses a HOS capped by the proportion of the hatchery-origin SRE with CWTs

APPENDIX E- Hatchery- and Natural-origin Spring Chinook Salmon Composition Data 2004–2017.

Year	Redds	SRE	Carcasses	CRR	Natural %	Hatchery %	Origin of Hatchery Fish			
							ENFH %	LNFH %	CRP %	Other[1] %
2017	63	101	19	0.19	63	37	0	0	8	92
2016	147	353	52	0.15	84	16	0	0	0	100[2]
2015	212	509	137	0.26	82	18	0	0	28	72
2014	102	245	26	0.11	92	8	0	0	0	100[2]
2013	99	238	22	0.09	79	21	0	0	80	20
2012	236	566	125	0.22	59	41	0	0	81	19
2011	248	595	173	0.29	54	46	0	19	72	9
2010	204	490	93	0.19	75	25	19	0	26	55
2009	115	276	79	0.29	48	52	75	8	17	0
2008	115	276	80	0.29	46	54	39	0	61	0
2007	102	245	41	0.17	43	58	34	0	23	43
2006	106	254	75	0.3	43	57	12	8	23	56
2005	146	367	53	0.14	44	56	67	12	21	0
2004	126	302	43	0.14	47	53	92	0	0	8

[1]Includes hatchery populations that were not recovered more than 2x from 2004-2017. These include CWT recoveries from Winthrop NFH, Methow FH, Chewuch Acclimation, Twisp Acclimation, Clearwater FH, Kooskia NFH, Dworshak NFH, Willamette SFH and Sawtooth SFH.
[2]All hatchery-origin carcasses recovered were of unknown origin.

APPENDIX F- PIT Tag Recoveries

Passive Integrated Transponder (PIT) tag interrogations from spring Chinook Salmon carcasses recovered on the Entiat River in 2017.

PIT Tag Code	Sex	Release		Last Detection	
		Site	Date	Site	Date
3DD.007762640D	M	Entiat River	3/25/2015	Entiat R. ENF rkm 40.6	8/28/2017

PIT tag interrogations from summer Chinook Salmon carcasses on recovered on the Entiat River in 2017.

PIT Tag Code	Sex	Release		Last Detection	
		Site	Date	Site	Date
3DD.003BDCBEF7	M	Wells Dam	6/20/2017	Entiat R. ENA rkm 17.1	7/7/2017

PIT tag interrogations from Coho Salmon carcasses on recovered on the Entiat River in 2017.

PIT Tag Code	Sex	Release		Last Detection	
		Site	Date	Site	Date
3DD.00776F2496	F	Entiat River	9/10/2015	Entiat R. ENL	10/31/2017

No PIT tags were recovered from Sockeye Salmon carcasses on the Entiat River in 2017.

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