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Chinook Salmon Spawning Ground Surveys on the Entiat River, 2015

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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 2015. 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 2015, a total of 212 spring Chinook Salmon redds (ten of the 212 were identified on the Mad River) and 172 summer Chinook Salmon redds were identified in the Entiat River basin. The spawning run escapements were estimated at 509 spring Chinook Salmon and 413 summer Chinook Salmon. Superimposition rates of summer Chinook Salmon redds on spring Chinook Salmon redds were 13.9% in total and were lower in upstream reaches than in downstream reaches.

In 2015, carcass recoveries consisted of 137 spring Chinook Salmon (three of the 137 were recovered on the Mad River) and 215 summer Chinook Salmon, with carcass recovery rates for each run estimated at 0.26 and 0.52, respectively. Natural-origin fish accounted for 82% of the spring Chinook Salmon spawning run escapement and 72% of the summer Chinook Salmon spawning run escapement. The majority of the hatchery-origin spring Chinook Salmon originated from Clearwater Hatchery (44%), followed by Chiwawa Hatchery (24%), Umatilla Hatchery (16%), Cle Elum Hatchery (10%), Nez Perce Tribal Hatchery (3%), and the Chewuch Acclimation Pond (3%). The majority of hatchery summer Chinook Salmon carcasses recovered on the spawning grounds originated from Entiat National Fish Hatchery (75%) and out-of-basin hatcheries including; Chelan Falls (9%), Dryden Ponds (6%), Wells (6%) and Clearwater (4%). The age class composition of spring Chinook Salmon was made up of by 10% age-3, 77% age-4, and 13% age-5 fish. The age class composition for summer Chinook Salmon was represented by 1% age-2, 16% age-3, 43% age-4, and 40% age-5 fish.

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Table of Contents

List of Figures

List of Tables

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 2015 return year. The United States Fish and Wildlife Service (USFWS) Mid-Columbia River Fisheries Resource Office (MCRFRO) 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 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, 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.

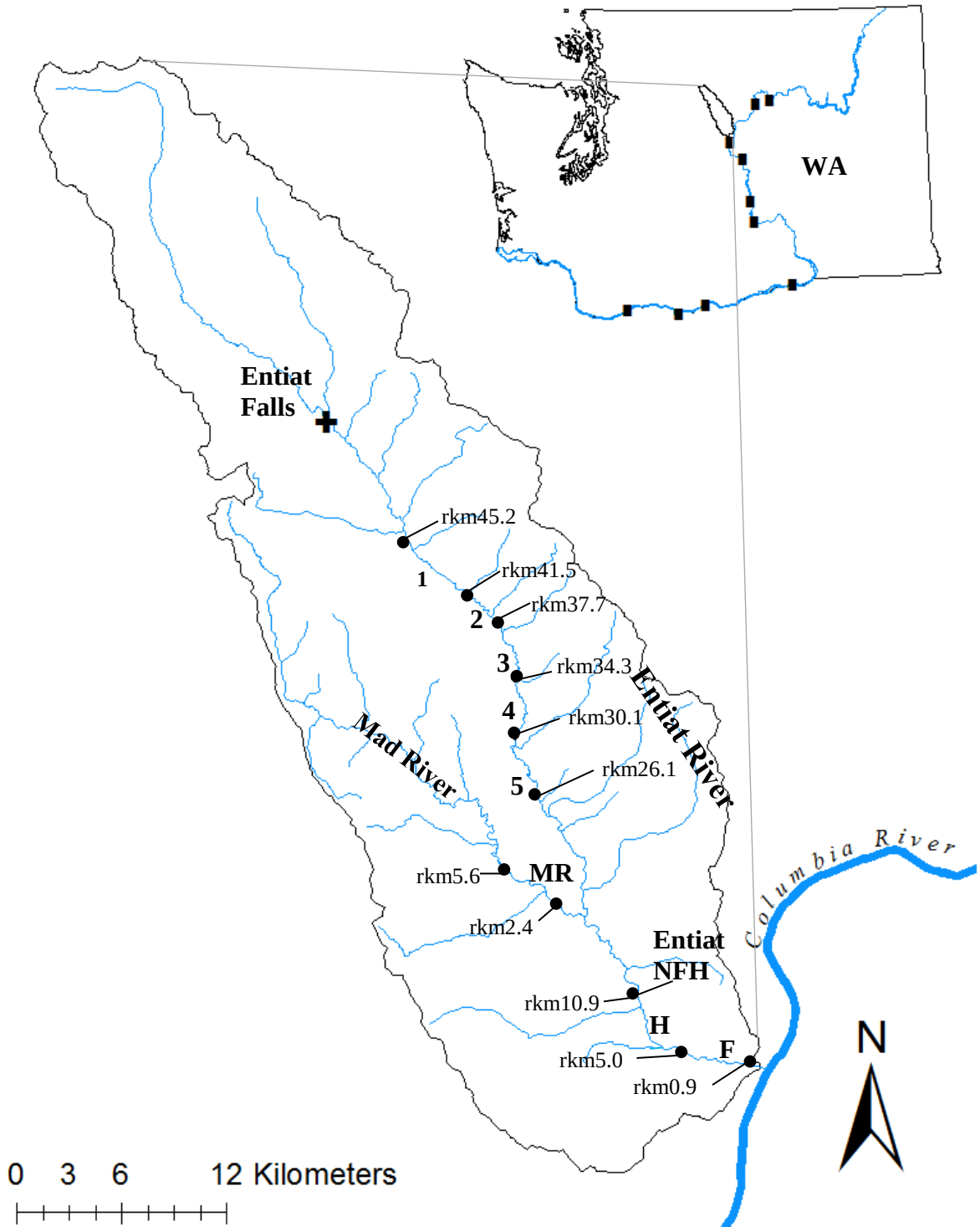

FIGURE 1.—Map of the Entiat River basin and the spawning ground survey reaches. The beginning and end of all surveyed reaches are marked with black dots. The survey reaches are located between the black dots and labeled 1–5, H, F, and MR. Main-stem Columbia River dams are represented by black squares 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 to many national fish hatcheries (NFH) including: Leavenworth, Entiat, and Winthrop (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. The last mill was closed in 1979 and with it the last channel-spanning dam on the Entiat River was removed.

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, MCRFRO assumed responsibility for monitoring spring Chinook Salmon redds in the Enitat River. At that time MCRFRO 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, MCRFRO 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, MCRFRO 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 have only been 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 July 23 and concluded on September 23 (Appendix D). Above average water temperatures prompted staff to begin surveys earlier than in prior years. Wildfires in August and early September periodically prevented crews from accessing all of reach 1 but spot checks were done on the areas of highest redd concentration based on historic data. Summer Chinook Salmon spawning ground surveys in 2015 began October 5 and concluded on November 5 (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. Each redd was marked with colored flagging hung on nearby vegetation and redd descriptions were recorded, including length, width, presence of fish, GPS coordinates using a Garmin *Rino*™530, and 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 2006–2014 averages (9-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 presence of flagging on the riparian zone, notes from previous surveys, GIS software, 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 (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 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 MCRFRO, 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. In past years the number of Sockeye Salmon and Coho Salmon were counted and included in this report, however in 2015 these data were not reported due to large numbers of Chinook Salmon redds and carcasses.

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:

$$\text{SRE} = \#\ \text{redds} * 2.4\ \text{fish/redd} \quad \text{(Mullan 1990)}$$

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

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 field, then the total number was split between hatchery and wild based on the population composition in reaches 1–5. The hatchery superimposition rate was then further divided by Entiat NFH-origin fish and other hatchery-origin fish based on the Entiat NFH percentage in reaches 1–5, not the total 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 2015, the flow regimes for June and July were the fifth and third lowest, respectively, in 58 years of record (Figure 2). Such extreme low flows prompted us to begin surveys a month earlier than in previous years. Spawning ground surveys began on July 23 and concluded on November 5. Temporary peaks in flow from rain events can increase turbidity which hinders visibility and can move carcasses from upstream to downstream survey reaches. On October 11, flows increased rapidly and moved fine sediment from recently burned areas downstream to the study reaches. The river turned black and turbid which hindered visibility for a week. Another large flow occurred on October 31, when surveys on the upper reaches (1–5) were completed and crews were only surveying the lower reaches (F–H).

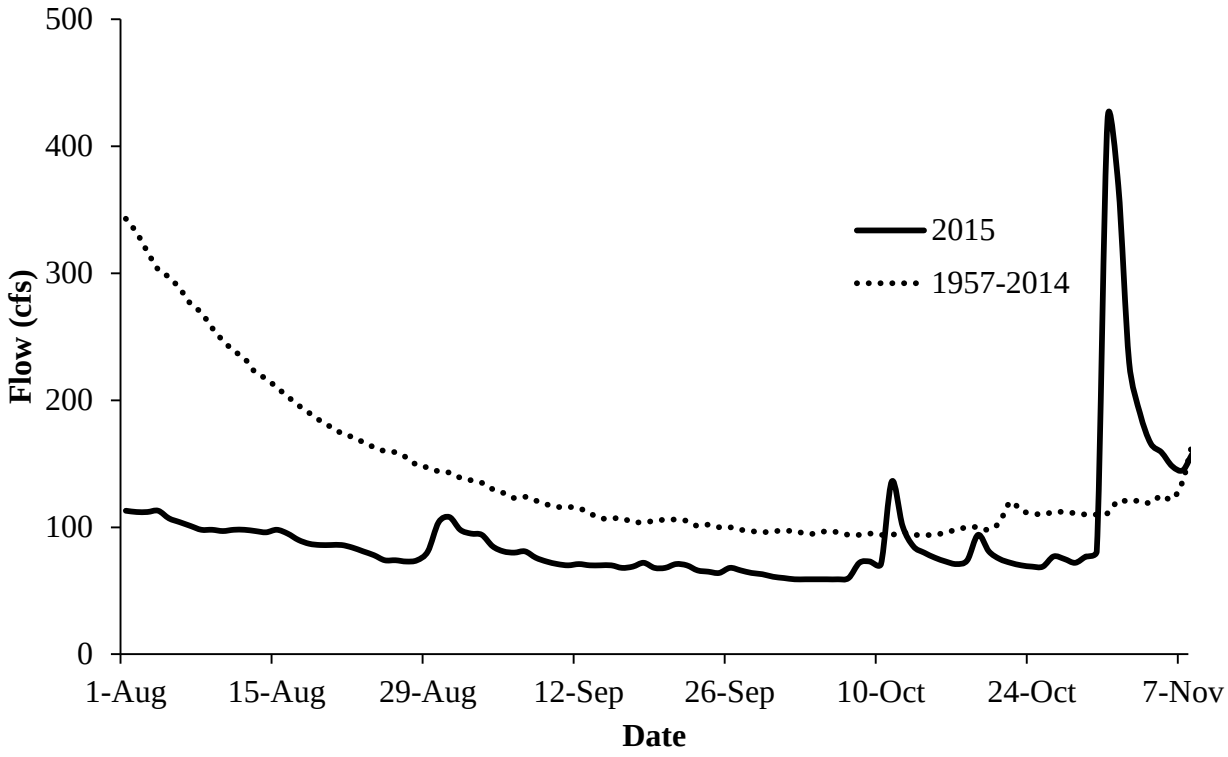

FIGURE 2.—Mean daily flow in the Entiat River for 2015 (solid line) and the long-term mean (1957–2014; dotted line) during the potential Chinook Salmon spawning period from August 1–Nov 7. Flow data were collected at USGS gauge 12452800, Entiat River near Ardenvoir, WA.

Spring Chinook Salmon

In 2015, a total of 212 spring Chinook Salmon redds were identified throughout the surveyed portions of the Entiat River. This was 137% of the 9-year average of 147 redds/year. The number of spring Chinook Salmon redds observed in 2015 was among the highest in the previous ten years (Figure 3). Peak spawning based on our surveys occurred during the first week in September, which was a week earlier than the 9-year average (Figure 4).

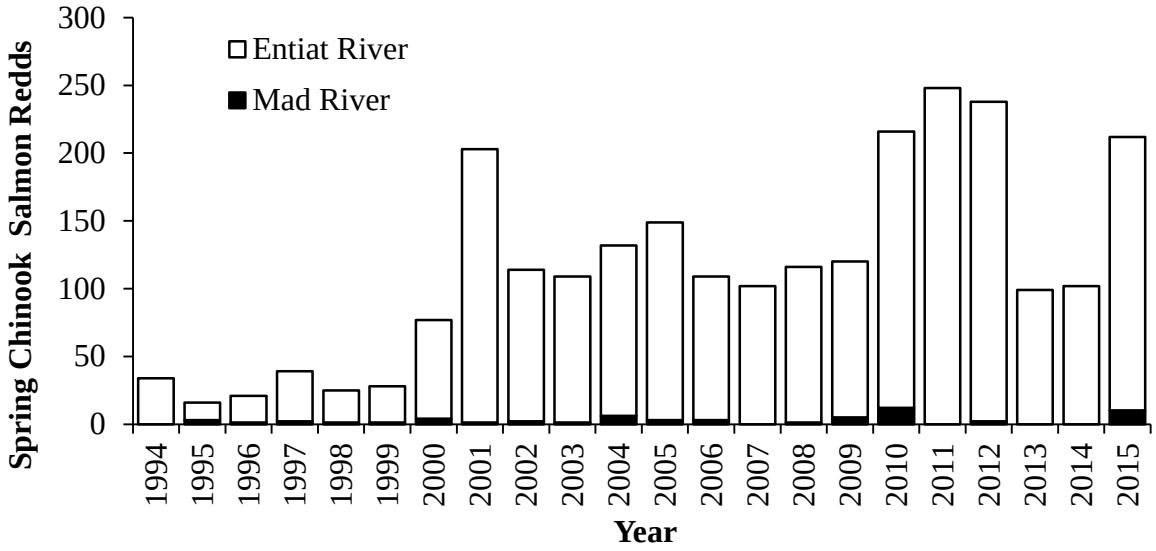

FIGURE 3.—Annual Entiat River spring Chinook Salmon redd counts in the Entiat River (white bars) and the Mad River (black bars).

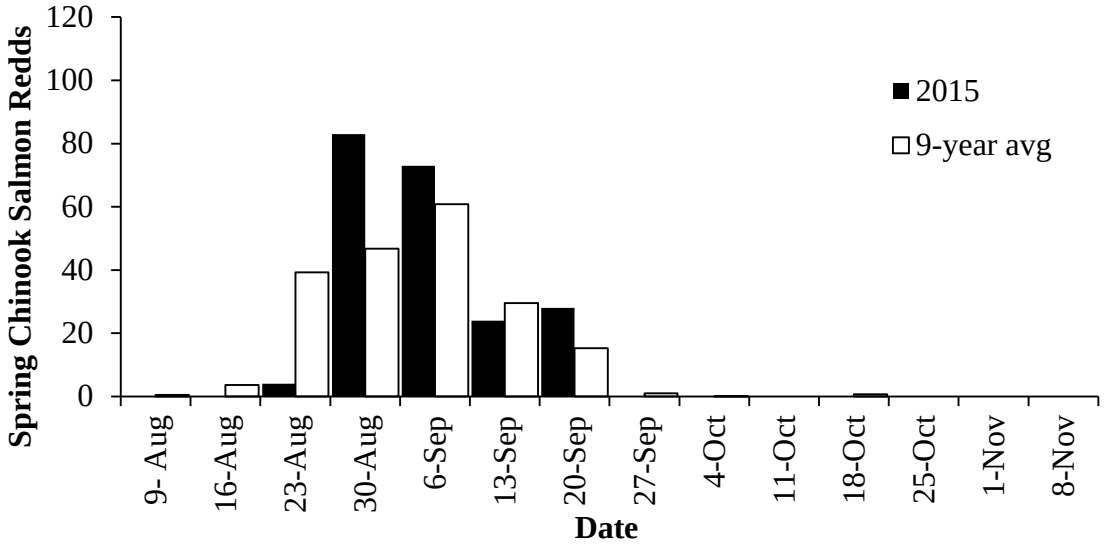

FIGURE 4.—Weekly counts of spring Chinook Salmon redds observed during spawning ground surveys in the Entiat River 2015 (black bars) and the 9-year average (2006–2014; white bars). Spring Chinook Salmon surveys ended on September 23.

Spatial distributions of redds from reach 1 downstream to reach 5 in 2015 were similar to the 9-year average in which redd abundance was greatest in reach 2 and progressively decreased downstream (Figure 5). Ten redds were identified in the Mad River and was the second highest redd count in the Mad River since surveying began in 1994.

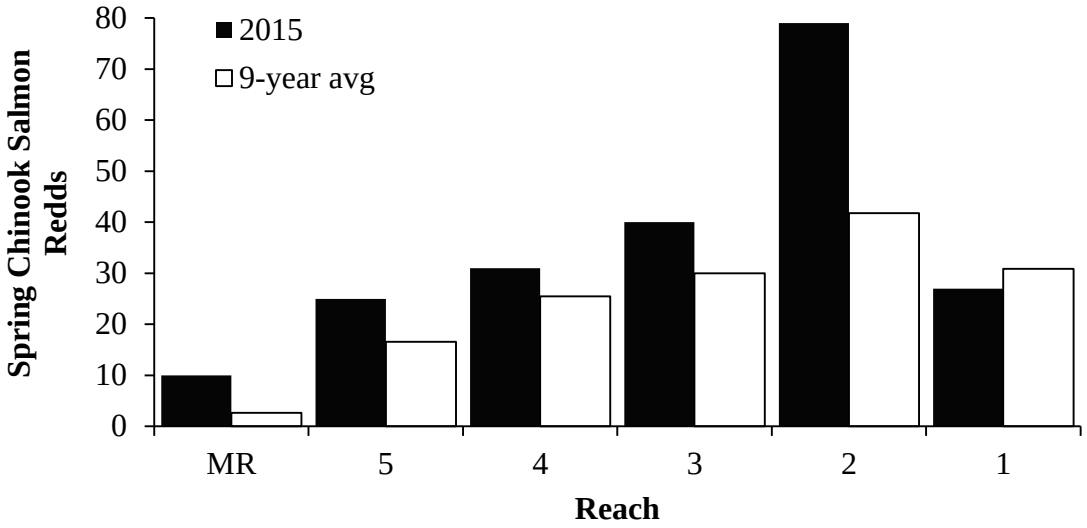

FIGURE 5.—Entiat River spring Chinook Salmon redd counts for reaches 1–5 (rkm 26.1–45.2) in 2015 (black bars) and the 9-year average (2006–2014; white bars).

Spring Chinook Salmon spawning run escapement in the Entiat River basin in 2015 was estimated at 509 fish (Table 1). Carcasses of 137 Chinook Salmon were recovered and resulted in a carcass recovery rate of 0.26 (Appendix E). Due to poor condition of some carcasses not all were assigned a sex. Female carcasses outnumbered male carcasses 69 to 62 (53%). All female carcasses were determined to have undergone some level of spawning (no carcasses had fully intact ovaries indicating pre-spawn mortality), 59 (85%) carcasses were completely spent, six (9%) were partially spent and four (6%) 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 2006–2015.

Year	Redds	SRE	Carcasses	CRR
2006	106	254	75	0.30
2007	102	245	41	0.17
2008	115	276	80	0.29
2009	115	276	79	0.29
2010	204	490	93	0.19
2011	248	595	173	0.29
2012	236	566	125	0.22
2013	99	238	22	0.09
2014	102	245	26	0.11
2015	212	509	137	0.26

Age and origin were determined for 114 of the 137 spring Chinook Salmon carcasses recovered in 2015 in the Entiat River basin. Natural-origin spring Chinook Salmon constituted 82% (n=93) of the carcasses, resulting in an estimated natural-origin spawning escapement of 415 fish. Hatchery-origin adults constituted 18% (n=21) of the carcasses examined in 2015, resulting in an estimated hatchery-origin spawning escapement of 94 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 adults spawning in the Entiat River has substantially increased (Figure 6).

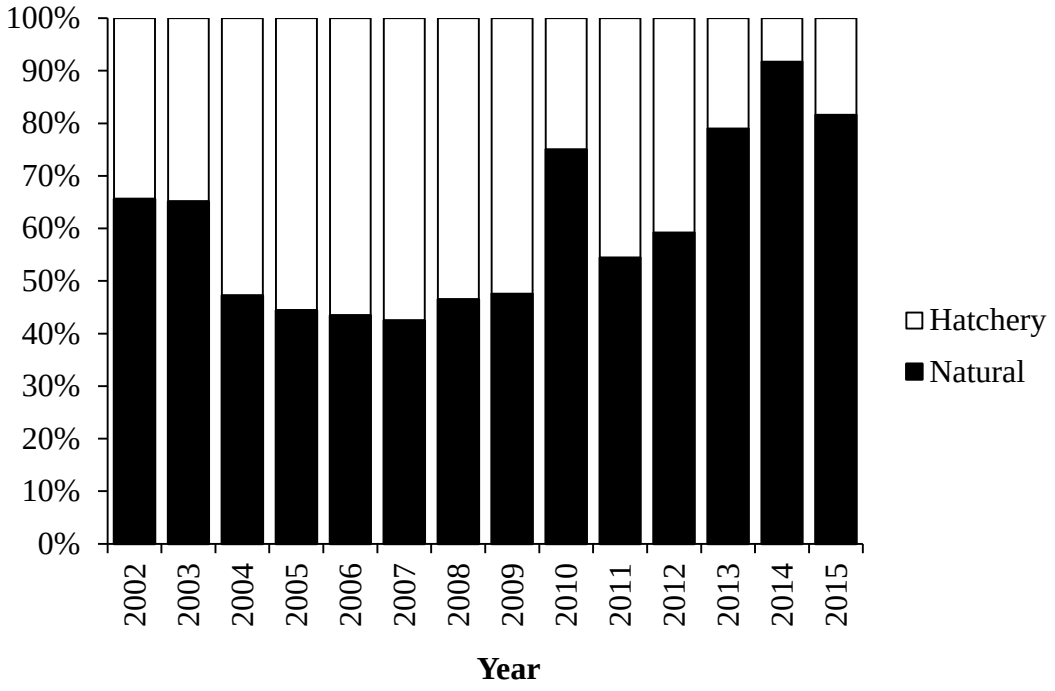

FIGURE 6.—Percent of hatchery- and natural-origin spring Chinook Salmon spawning run escapement into the Entiat River basin.

In 2015 the run composition of both hatchery- and natural-origin spring Chinook Salmon contained various ages and genders (Table 2). Hatchery-origin fish were represented by five age-3 males, eight age-4 males, one age-5 male, and seven age-4 females. Natural-origin fish were represented by six age-3 males, 30 age-4 males, six age-5 males, 43 age-4 females, and eight age-5 females. 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 2015.

Origin	Age description	Total Age	Male		Female		Total		pSRE[1]	SRE
			N	%	N	%	N	%		
Natural	1.1	3	6	14	0	0	6	6	0.05	27
	1.2	4	30	72	43	85	73	79	0.64	326
	1.3	5	6	14	8	15	14	15	0.12	63
Total			42	45	51	55	93		0.82	415
Hatchery	1.1	3	5	36	0	0	5	24	0.04	22
	1.2	4	8	57	7	100	15	71	0.13	67
	1.3	5	1	7	0	0	1	5	0.01	4
Total			14	67	7	33	21		0.18	94
Total[2]			56		58		114		1	509

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=137) were checked for adipose fin condition and scanned for CWTs and PIT tags. In 2015, 15 coded-wire tags and 10 PIT tags were recovered from spring Chinook Salmon in the Entiat River basin (Table 3; Appendix G). Expansion of recovered CWTs by the tagging rate revealed that an estimated 44% of the hatchery-origin fish were from the Clearwater Hatchery, this extrapolated to an Entiat NFH spawning run escapement rate based on coded-wire tags (SRECWT) of 41 fish. The remaining (56%) hatchery-origin fish were attributed to Chiwawa Hatchery (24%), Umatilla Hatchery (16%), Cle Elum Hatchery (10%), Nez Perce Tribal Hatchery (3%) and the Chewuch Acclimation Pond (3%).

TABLE 3.—Coded-wire tag (CWT) recoveries collected from spring Chinook Salmon carcasses on the Entiat River in 2015.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered	Tag Rate	CWT Expanded	pCWT	SRE CWT
100195	2011	IDFG	CLEARWATER	1	0.08	46.54	0.40	38
100237	2011	IDFG	CLEARWATER	1	0.99	3.89	0.04	4
190320	2011	YAKA	CLE ELUM	1	1.00	3.85	0.04	4
190332	2011	YAKA	CLE ELUM	1	1.00	3.85	0.03	3
190380	2012	YAKA	CLE ELUM	1	1.00	3.85	0.03	3
220134	2012	NEZP	NEZ PERCE	1	1.00	3.86	0.03	3
635664	2011	WDFW	CHEW ACC	1	1.00	3.86	0.03	3
635675	2011	WDFW	CHIWAWA	2	0.99	7.79	0.07	6
636094	2011	WDFW	CHIWAWA	2	0.99	7.75	0.07	6
636485	2012	WDFW	CHIWAWA	3	0.98	11.72	0.10	9
090643*	2011	ODFW	UMATILLA	1	0.21	18.00	0.16	15

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 2015 based on CWTs. pCWT is the proportion of CWTs that a given CWT group represents. For calculations see Appendix E.
*Carcass found in the Mad River

Summer Chinook Salmon

In 2015, a total of 172 summer Chinook Salmon redds were identified during spawning ground surveys. The redd count in 2015 was 83% of the 9-year average of 207 redds and continued a declining trend since 2012 (Figure 7). Most spawning occurred in the reaches 1–5 (75%), which was consistent with prior years. Peak spawning occurred during the last week of September and was two weeks earlier than the 9-year average (Figure 8).

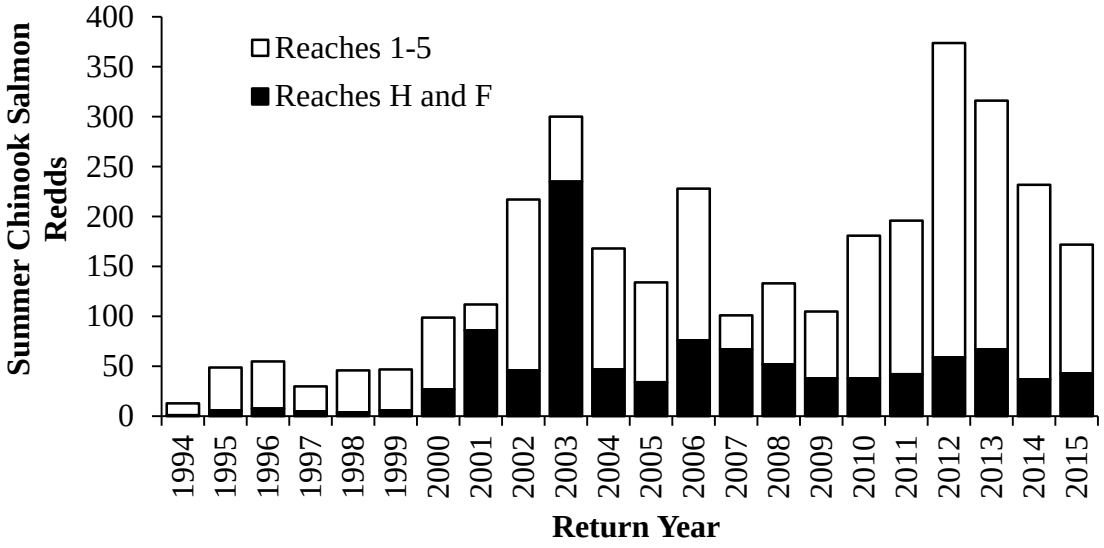

FIGURE 7.—Annual Entiat River summer Chinook Salmon redd counts differentiated by upstream reaches 1–5 (rkm 26.1–45.2) and downstream reaches F and H (rkm 0.5–10.9).

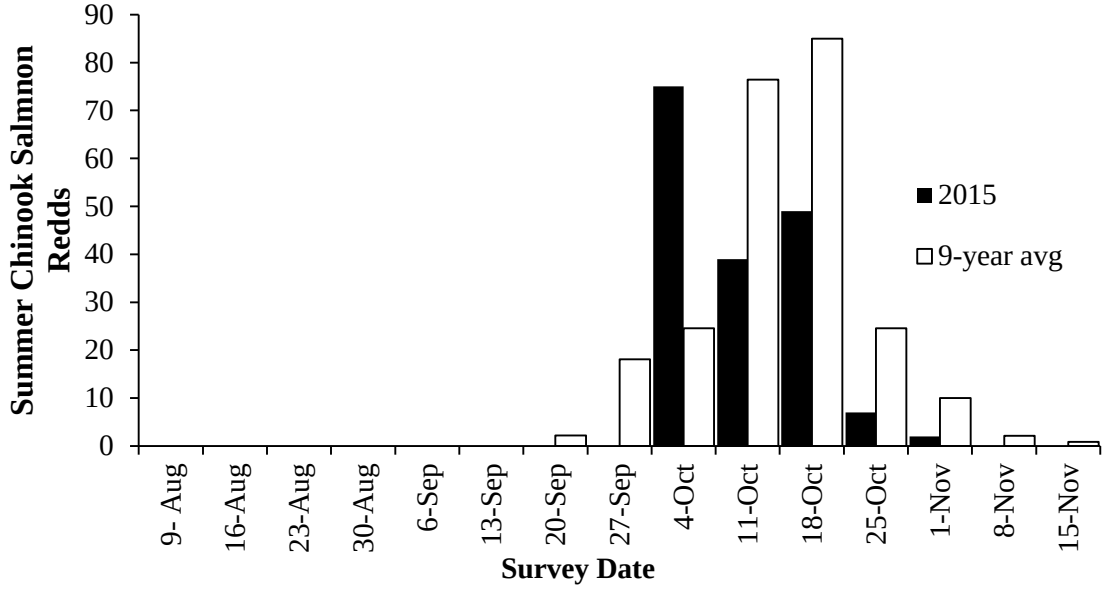

FIGURE 8.—Weekly counts of summer Chinook Salmon redds observed during spawning ground surveys in the Entiat River per week in 2015 compared to the 9-year average (2006–2014). No surveys were conducted from September 24–October 4.

The abundance of redds in reaches 1–5 was greater in downstream reaches than in the upstream reaches which was similar to the 9-year average (Figure 9). In 2015, there were twice as many summer Chinook Salmon redds in reach H than in reach F.

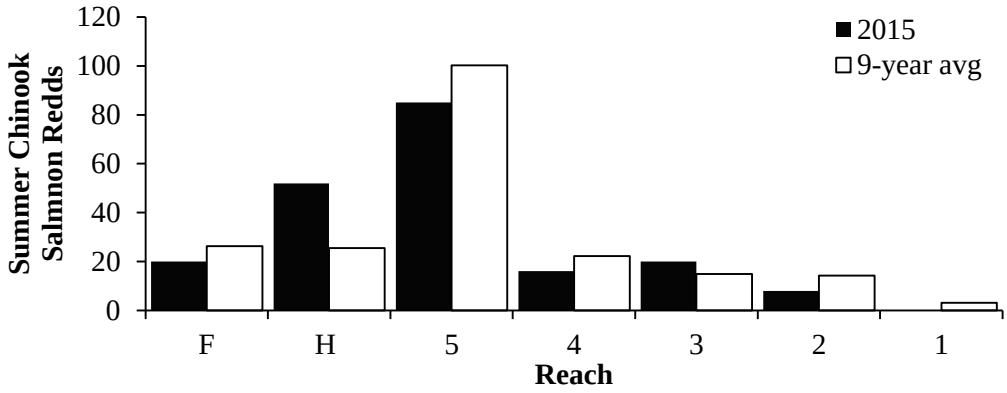

FIGURE 9.—Entiat River summer Chinook Salmon redd counts for reaches F and H (rkm 0.5–10.9) and reaches 1–5 (rkm 26.1–45.2) in 2015 (black bars) compared to the 9-year average (2006–2014; white bars).

The 2015 spawning run escapement for Entiat River summer Chinook Salmon was estimated to be 413 fish (Table 4). Carcasses of 215 summer Chinook Salmon were recovered, which resulted in a carcass recovery rate of 0.52. Unlike spring Chinook Salmon, the summer Chinook Salmon males outnumbered females 101 to 88. All 88 female carcasses were examined for spawning success; 65 (74%) were completely spent, 5 (6%) were partially spent, 8 (9%) had full egg skeins indicative of pre-spawn mortality, and 10 (11%) were undetermined due to decomposition. An additional three summer Chinook Salmon carcasses were recovered during spawning ground surveys and were not included in any analysis in this report. The carcasses were found filleted and it could not be determined whether or not they were harvested in the Entiat River. The carcasses age and origin were: one male age unknown, one male age-4 and one female age-5. Two were hatchery-origin with coded-wire tags, these data are presented later in this report.

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 2006–2015.

Year	Redds	SRE	Carcasses	CRR
2006	228	547	180	0.33
2007	101	242	88	0.36
2008	133	319	82	0.26
2009	105	252	83	0.33
2010	181	434	96	0.22
2011	196	470	137	0.29
2012	374	898	207	0.23
2013	316	758	154	0.20
2014	232	557	89	0.16
2015	172	413	215	0.52

A total of 215 summer Chinook Salmon carcasses were recovered in 2015, and age and origin were determined for 189 (88%; Table 5). Natural-origin summer Chinook Salmon constituted 73% (n=138) of the carcasses, which resulted in an estimated natural-origin spawning escapement of 302 fish. Hatchery-origin adults constituted 27% (n=51) of the carcasses resulting in an estimated hatchery-origin escapement of 111 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 1% age-2, 16% age-3, 43% age-4 and 40% age-5 fish.

TABLE 5.—Entiat River summer Chinook Salmon gender and age composition as the proportion (pSRE) and quantity (SRE) of the spawning run escapement in 2015.

Origin	Age description	Total Age	Male		Female		Total		pSRE	SRE
			N	%	N	%	N	%		
Natural	0.1	2	1	1	0	0	1	1	0.01	2
	0.2	3	21	27	2	3	23	17	0.12	50
	0.3	4	30	39	15	25	45	33	0.24	98
	0.4	5	12	16	29	48	41	30	0.22	90
	1.1	3	1	1	1	2	2	1	0.01	5
	1.2	4	9	12	3	5	12	9	0.06	26
	1.3	5	3	4	11	18	14	10	0.07	31
Natural Total			77	56	61	44	138		0.73	302
Hatchery	0.3	4	0	0	2	7	2	4	0.01	4
	0.4	5	0	0	1	4	1	2	0.01	2
	1.1	3	6	25	0	0	6	12	0.03	13
	1.2	4	12	50	8	30	20	39	0.11	44
	1.3	5	6	25	16	59	22	43	0.12	48
			24	47	27	53	51		0.27	111
Total*			101		88		189			419

*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 have differed from year to year but since 2011 the percent hatchery-origin has been steadily increasing (Figure 10). Additionally, the composition of the summer Chinook run differs dramatically between the upper (reaches 1–5) and lower river (reaches F–H) sampling reaches. In 2015, the ratio of hatchery- to natural-origin summer Chinook Salmon carcasses were 10 to 90 in the upper reaches and 65 to 35 in the lower reaches (Figure 11). The spatial distribution between the upper and lower reaches is consistent with previous years data.

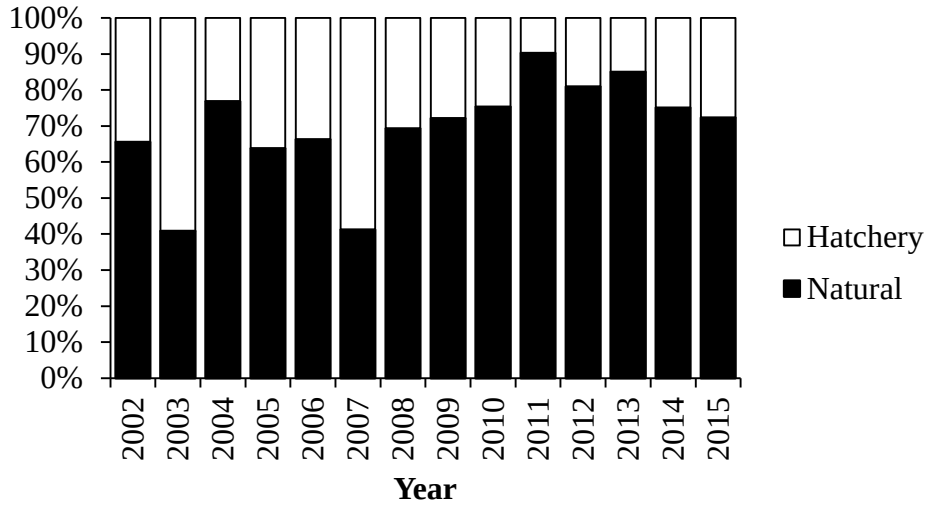

FIGURE 10.—Percent of hatchery- and natural-origin summer Chinook Salmon spawning run escapement into the Entiat River.

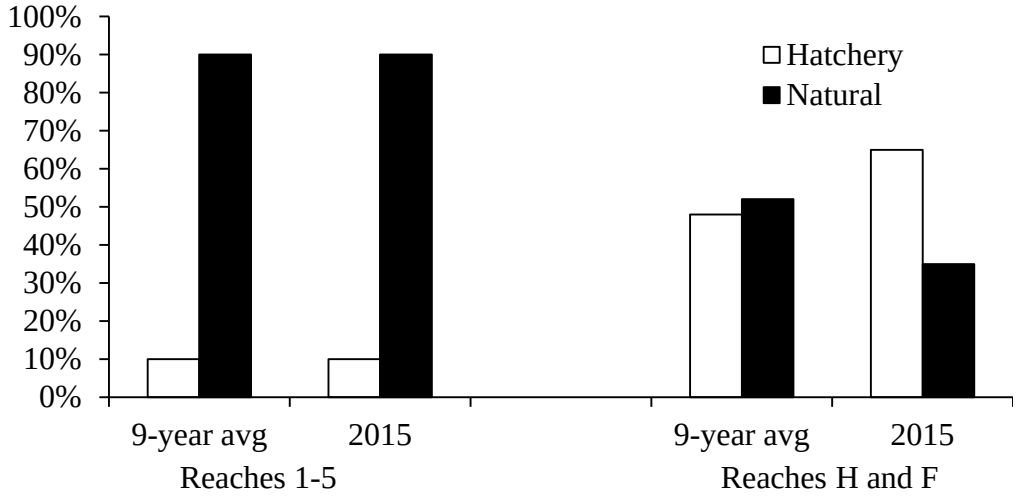

FIGURE 11.—Estimated percent composition of hatchery- and natural-origin summer Chinook Salmon spawning in downstream reaches F and H (rkm 0.5–10.9) and upstream reaches 1–5 (rkm 26.1–45.2) of the Entiat River in 2015.

Three juvenile life history types were identified for returning natural-origin summer Chinook Salmon in 2015; 80% migrated to saltwater at age-0, 18% overwintered (age-1) in a reservoir and 2% overwintered (age-1) in a stream (Table 6). Life history types could not be determined for 15 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 2006–2015.

	Ocean		Reservoir		Stream		Total
Year	(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
Avg		77		22		1	

Forty-four of the 215 recovered summer Chinook Salmon carcasses contained a CWT (Table 7). Recovered CWTs revealed that 75% 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 83 fish. Out-of basin strays accounted for 25% of the hatchery-origin carcasses recovered on the spawning grounds and were composed of the following hatcheries: Chelan Falls (9%), Dryden Ponds (6%), Wells (6%), and Clearwater (4%).

TABLE 7.—Coded-wire tag (CWT) recoveries collected from summer Chinook Salmon carcasses on the Entiat River in 2015. (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
51267	2010	FWS	ENTIAT	10	1.00	19.31	0.21	23
53569	2010	FWS	ENTIAT	4	1.00	7.71	0.08	9
55362	2011	FWS	ENTIAT	5	0.65	14.86	0.16	19
55363	2011	FWS	ENTIAT	4	0.56	13.63	0.15	16
55364	2010	FWS	ENTIAT	7	0.99	13.54	0.15	16
100241	2011	IDFG	CLEARWATER	2	0.99	3.87	0.04	5
636282	2011	WDFW	CHELAN FALLS	1	1.00	1.93	0.02	2
635774	2010	WDFW	CHELAN FALLS	3	0.95	6.06	0.07	7
636175	2011	WDFW	DRYDEN POND	1	0.99	1.95	0.02	3
636176	2011	WDFW	DRYDEN POND	1	0.99	1.94	0.02	2
636177	2011	WDFW	DRYDEN POND	1	0.99	1.94	0.02	2
635773	2011	WDFW	WELLS	2	1.00	3.85	0.04	5
636370	2011	WDFW	WELLS	1	1.00	1.93	0.02	2
636178*	2011	WDFW	DRYDEN POND	1	--	--	--	--
051267*	2010	FWS	ENTIAT	1	--	--	--	--

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 2015 based on CWTs. pCWT is the proportion of CWTs that a given CWT represents.

*Carcasses were found in the Entiat River but had been fileted so it was not determined whether or not they were harvested in the Entiat River. These data were not used in any analysis.

Redd Superimposition

2015 was the third year that redd superimposition rates by summer Chinook Salmon on spring Chinook Salmon were assessed throughout the spring Chinook spawning reaches (reaches 1–5). 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 6% were superimposed on in reach 2 (Table 8). Further downstream, in reaches 3 and 4, superimposition rates were 10% and 13%, respectively. The highest superimposition rate was 60% in reach 5, the most downstream reach that spring Chinook Salmon surveys were conducted. Superimposition rates decreased by 13.6% in 2015 compared to 2014 (Table 9). On average 20% (2013–2015) of spring Chinook redds are superimposed upon by summer Chinook with the majority of superimposition (94% on average) attributed to natural origin summer Chinook returning to the upper Entiat watershed where spring Chinook spawn. The level of superimposition attributed to Entiat NFH-origin summer Chinook Salmon (10% hatchery-origin for reaches 1–5 of which only 8% of the hatchery-origin attributed to Entiat NFH) decreased from 1.4% to 0.2% as compared to the 2014 values.

TABLE 8.—Redd superimposition by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2015.

Reach	Spring Chinook Salmon redds	Summer Chinook Salmon redds	Spring Chinook Salmon redds superimposed (%)
1	27	0	0 (0)
2	79	8	5 (6)
3	40	20	4 (10)
4	31	16	4 (13)
5	25	85	15 (60)

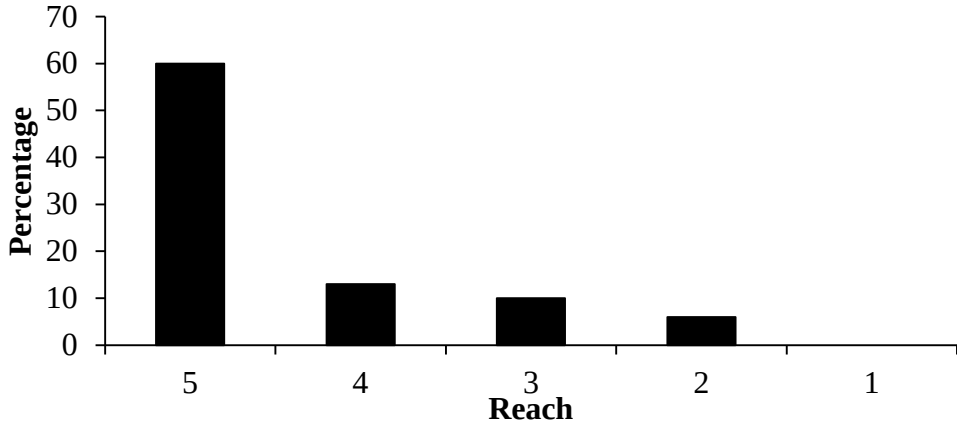

FIGURE 12.—Redd superimposition percentage by summer Chinook Salmon on spring Chinook Salmon redds by reach in the Entiat River in 2015.

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, 2013–2015.

	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%	0.3%
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%

Sockeye Salmon

Sockeye Salmon redds were observed during our 2015 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 two 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 2015.

Species	CWT	Brood Year	Release Agency	Hatchery	Recovered
Sockeye	636368	2011	WDFW	Lake Wenatchee	2

Coho Salmon

In 2015, 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. One Coho Salmon contained a CWT (Table 11).

TABLE 11.—Coded-wire tag (CWT) data recovered from Coho Salmon carcasses in the Entiat River in 2015.

CWT	Brood Year	Release Agency	Hatchery	Carcasses Recovered
190365	2012	Yakama Nation	Winthrop NFH	1

Discussion

Over the last six 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 2011–2015 the total hatchery-origin percentage of spring Chinook Salmon was reduced to an average of 26% 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 occurring 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 (26% 2011–2015). Changes in production and acclimation practices in other spring Chinook Salmon programs in the area have also likely contributed to the improving situation in the Entiat River. Notably the reduction in spring Chinook Salmon production levels at the Chiwawa Rearing Ponds (RP), 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. 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. Chiwawa RP fish comprised 72–81% of the hatchery-origin spring Chinook Salmon recovered in Entiat River red 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. Since 2012, the Chiwawa RP has released fewer fish each year and in 2015 only released 150,413 spring Chinook Salmon. In 2015, Chiwawa RP-origin spring Chinook Salmon accounted for only 28% of the hatchery-origin spring Chinook Salmon population 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.

The percentage of hatchery-origin spring Chinook Salmon recorded in 2015 was among the lowest since the MCRFRO began surveying the Entiat River in 1994. However, it increased substantially from 8% in 2014 to 18% in 2015. The majority (44%) of the hatchery-origin spring Chinook Salmon recovered in 2015 in the Entiat River originated from Clearwater Hatchery in Idaho. The Clearwater Hatchery spring Chinook Salmon program is a segregated hatchery

program using the Clearwater / Rapid River spring Chinook Salmon stock. Adults recovered in 2015 were derived from annual releases of 2.2 million smolts in 2012 and 2013.

Presence of such a high number of stray fish from Snake River basin production may be an anomaly related to unusually high temperatures during the 2015 migration period. However, if the 2015 observations are repeated in coming years then the current planned increases in Snake River spring Chinook Salmon production may be a cause for concern. The State of Idaho, the Nez Perce Tribe, and the U.S. FWS are currently implementing increased production levels for spring Chinook Salmon production in the Clearwater and Snake River basins. These increases amount to an additional 1.36 million hatchery smolts released from Nez Perce Tribal Hatchery, Clearwater Fish Hatchery, and Dworshak NFH. All three hatchery programs produce Clearwater/Rapid River stock spring Chinook Salmon and for the purposes of assessing the effects to the Entiat River basin should be considered in aggregate. 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 low numbers of hatchery-origin spring Chinook Salmon were expected. However, hatchery-origin fish averaged 27% of the spring Chinook Salmon population over the last five years. Although the time frame 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 2015 were among the highest in the last decade 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 five 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 2015 was among the lowest but the carcass recovery was the highest since 2006. The total proportion of hatchery-origin summer Chinook Salmon (pHOS) was 28% and 75% (~21% of pHOS) of these hatchery-origin fish originated from Entiat NFH. The overall percentage of hatchery-origin summer Chinook Salmon increased 3% since last year and was the highest since Entiat NFH began producing summer Chinook Salmon. The high percentage of Entiat NFH origin fish indicates that these fish are beginning to substantially augment the population spawning in the river. Hatchery-origin summer Chinook Salmon were only 10% of the population upstream of the hatchery and 65% 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 0.2% 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 MCFRO 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 due to full production releases from Entiat NFH.

Summary

The total number of spring Chinook Salmon redds counted during the 2015 spawning ground surveys was 212, with an estimated adult spawning run escapement of 509 fish to the Entiat River basin. A total of 137 carcasses were recovered; female carcasses outnumbered male carcasses 68 to 61. All 69 female carcasses were examined for spawning success; 59 (85%) were completely spent, six (9%) were partially spent, 0 were incomplete, and four (6%) could not be determined because of poor carcass condition. Recovered carcasses indicate that natural-origin fish comprised 82% of the adult return escapement to the Entiat River and the remaining 18% were of hatchery-origin. A total of 15 coded-wire tags were recovered from spring Chinook Salmon carcasses in 2015. Based on CWT recoveries the hatchery-origin spring Chinook Salmon population was composed of: Clearwater Hatchery (44%), followed by Chiwawa Hatchery (24%), Umatilla (16%), Cle Elum Hatchery (10%), Nez Perce Tribal Hatchery (3%) and the Chewuch Acclimation Pond (3%).

In 2015, 172 summer Chinook Salmon redds were counted during spawning ground surveys, with an estimated adult spawning run escapement of 413 fish to the Entiat River. A total of 215 carcasses were recovered; males outnumbered females 101 to 88. All 88 carcasses were examined for spawning success; 74% were completely spent, 6% were partially spent, 9% were incomplete indicating a pre-spawn mortality and 11% were undetermined due to poor carcass condition. Recovered carcasses indicated that overall natural-origin fish compromised 72% of the adult spawning escapement to the Entiat River and 28% were of hatchery-origin. Spatially, hatchery-origin summer Chinook comprised 65% of the spawners in the lower river below Entiat NFH while natural-origin adults comprise 90% of the upriver spawning population. Scale analysis revealed natural-origin summer Chinook Salmon had three distinctive life histories; 80% were ocean-type juvenile migrants, 18% were reservoir-type juvenile migrants and 2% overwintered in a stream. A total of 40 CWTs were recovered from carcasses. Based on the CWT recoveries hatchery summer Chinook Salmon carcasses were from Entiat NFH (75%), Chelan Falls (9%), Dryden Ponds (6%), Wells (6%) and Clearwater (4%).

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References

Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fishery Bulletin 52(61):97 – 110. U.S. Fish and Wildlife Service, Washington, DC.

Connor, W.P., J.G. Sneva, K.F. Tiffan, R.K. Steinhorst, and D. Ross. 2005. Two alternative juvenile life history types for fall Chinook salmon in the Snake River. Transactions of the American Fisheries Society 134:291–304.

Craig, J.A. and A.J. Suomela. 1941. Time of appearance of the runs of salmon and steelhead trout native to the Wenatchee, Entiat, Methow, and Okanogan rivers. USFWS Unpublished Manuscript

Crawford, B., T.R. Mossey, and D.H. Johnson 2007. Carcass Counts. Pages 59–94 *in* D.H. Johnson, Shrier B.M., J.S. O'Neal, J.A. Knutzen, Augerot X., T.A. O'Neal, and T.N. Pearsons, editors. Salmonid Field Protocols Handbook:Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethseda, Maryland.

Dittman, A.H., D. May, D.A. Larsen, M.L. Moser, M. Johnston, and D. Fast. 2010. Homing and Spawning Site Selection by Supplemented Hatchery- and Natural-Origin Yakima River Spring Chinook Salmon. Transactions of the American Fisheries Society 139:1014–1028

Fish, F.F. and M.G. Hanavan. 1948. A report on the Grand Coulee Fish Management Project 1939–1947. USFWS Special Scientific Report 55

French, R.R. and R.J. Wahle. 1960. Salmon runs- upper Columbia River, 1956–1957. USFWS Special Scientific Report 364

Gilbert, C.H. 1912. Age at maturity of the pacific coast salmon of the the genus Oncorhynchus. Bulletin of the Bureau of Fisheries 32:1–22.

Godaire, J.E., K.L. Russel and J.A. Bountry. 2010. Fluvial Geomorphology of the Entiat River, WA, and implications for stream restoration.

Healy, M.C. 1991. Life history of Chinook salmon (Oncorhyncus tshawytscha). Pages 312–393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vanouver, Canada.

Koo, T.S.Y. 1962. Age designation in salmon. Pages 37–48 *in* T.S.Y. Koo, editors. Studies of Alaskan red salmon. University of Washington Press, Seattle, Washington.

Long, A. 2001. Under the Guard of the Ole Tyee. Wenatchee, WA.

Mullan, J.W. 1983. Overview of artificial and natural propogation of coho salmon on the mid-Columbia River. USFWS Report No. FRI/FAO-84-4

Mullan, J.W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880s–1982: A reiew and synthesis. USFWS USFWS Biological Report 86(12)

Mullan, J.W. 1987. Status and propogation of Chinook salmon in the Mid-Columbia River through 1985. USFWS Biological Report 89(3)

Mullan, J.W. 1990. Status of Chinook salmon stocks in the mid-Columbia. Pages 45–55 *in* D.L. Park, editors. Status and future of spring Chinook salmon in the Columbia River Basin-conservation and enhancement. US Dept. Commerce, NOAA Tech. Memo. NMFS F/NWC-187.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, and J.D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. USFWS Monograph.

Nelson, M.C., B. Kelly-Ringel, R.D. Nelle. 2008. Review of Bull Trout redd observations in the Entiat River, 1994–2008. U.S. Fish and Wildlife Service, Leavenworth, WA

NMFS. 2013. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion: Entiat National Fish Hatchery Summer Chinook Hatchery Program. NMFS Consultation Number: NWR-2012-00841

Quinn, T. P., A. P. Hendry and L.A. Wetzel. 1995. The Influence of Life History Trade-Offs and the Size of Incubation Gravels on Egg Size Variation in Sockeye Salmon (Oncorhynchus nerka).*Oikos, 74*(3), 425–438.

UCSRB. 2007. Upper Columbia spring Chinook Salmon and steelhead recovery plan.

USBF. 1934/1935/1936. Entiat River physical stream survey report. US Bureau of Fisheries

USDA. 1979. Enitat: cooperative river basin study. US Department of Agriculture

Utter, F.M. 2005. Population genetics, conservation and evolution in salmonids and other widely cultured fishes: some perspectives over six decades. Rev. Fish Biol. Fish. 14:125–144.

Waples, R.S. 2004. Salmonid insights into effective population size. In: Hendry, A. and Stearns, S. (eds) Evolution Illuminated: salmon and their relatives. Pages 295–314.

APPENDIX A- Entiat River Survey Reach Descriptions

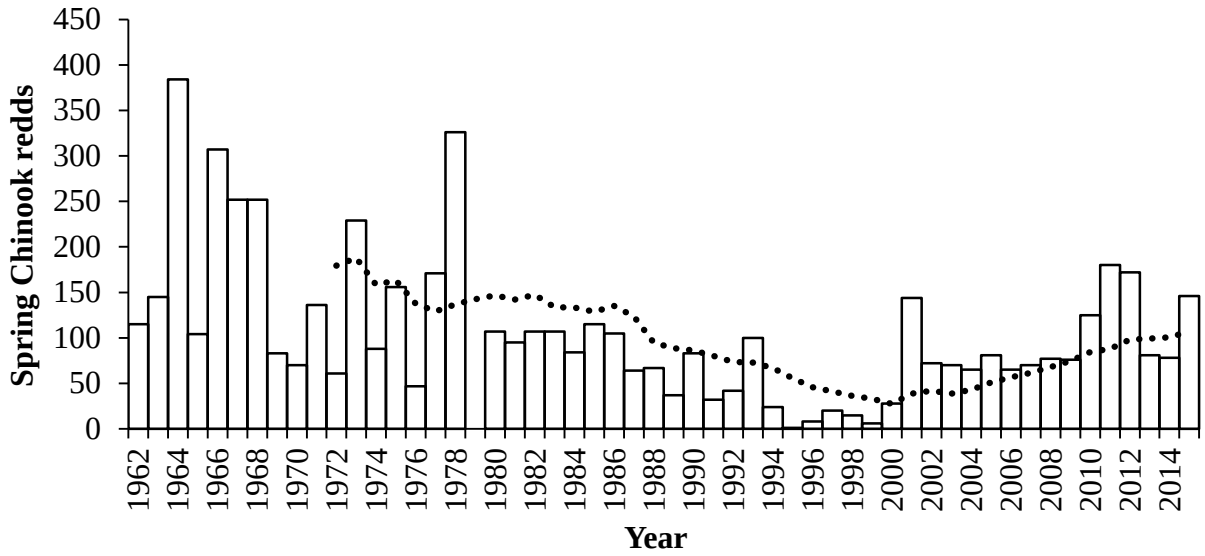
Reach	River Kilometer	Surveyed Kilometers	Description
1	41.5–45.2	3.7	Forest Service boundary to Fox Creek camp ground
2	37.7–41.5	3.8	Fox Creek camp ground to Brief Bridge
3	34.3–37.7	3.4	Brief Bridge to Kelsey Lane Bridge
4	30.1–34.3	4.2	Kelsey Lane Bridge to Stormy Creek preserve
5	26.1–30.1	4.0	Stormy 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 1994–2015 (USFWS).

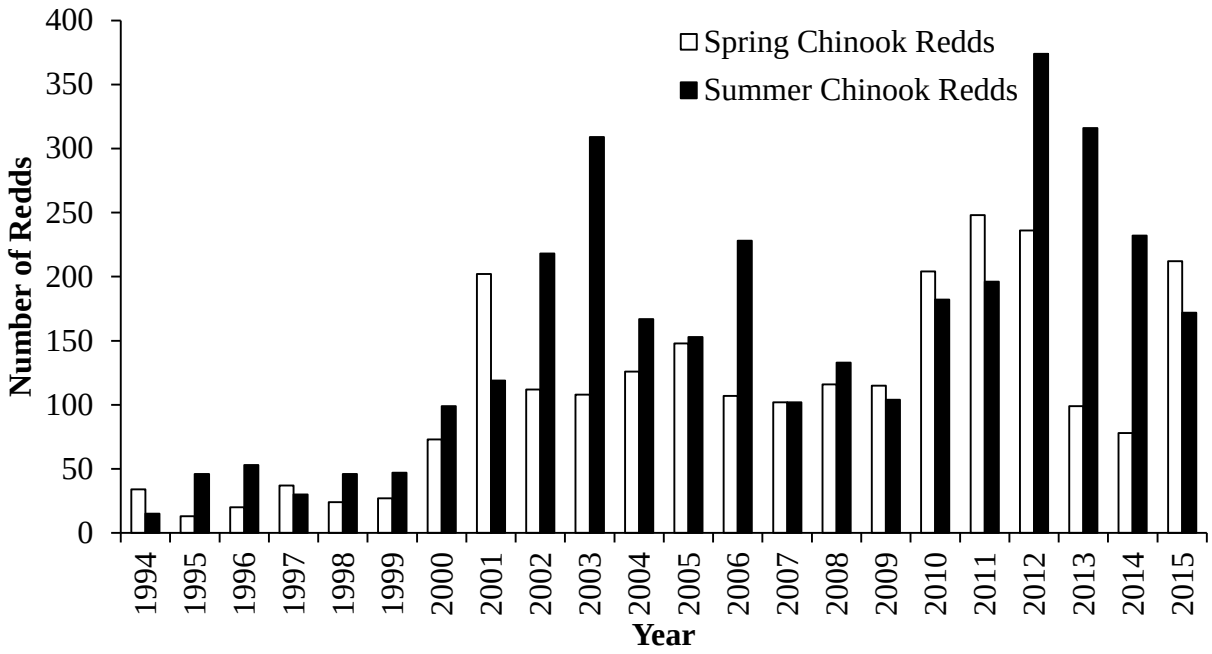
Year	Redds	Year	Redds	Year	Redds	Year	Redds
1962	115	1976	47	1990	83	2004	65
1963	145	1977	171	1991	32	2005	81
1964	384	1978	326	1992	42	2006	65
1965	104	1979	NA	1993	100	2007	70
1966	307	1980	107	1994	24	2008	77
1967	252	1981	95	1995	1	2009	76
1968	252	1982	107	1996	8	2010	125
1969	83	1983	107	1997	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		
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, 1994–2015.

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	78	232
2015	212	172



Spring and summer Chinook Salmon redd counts for the Entiat River, 1994–2015.

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	-	-

APPENDIX D- Spring and Summer Chinook Salmon Spawning Ground Survey Results in the Entiat River basin in 2015.

Reach	River Km	Date	Redds	Live Fish	Carcasses
1	41.5–45.2	7/24	0	0	0
		8/3	0	0	0
		8/7	0	0	0
		8/24	1	6	0
		8/31	5	8	0
		9/8	11	10	2
		9/14	7	1	1
		9/21	3	0	1
		Total	27	24	4
2	37.7–41.5	7/27	0	0	0
		8/3	0	0	0
		8/17	0	0	0
		8/24	3	4	0
		8/31	52	84	5
		9/8	8	6	19
		9/9	11	4	12
		9/15	2	0	30
		9/21	3	3	6
		10/5	0	0	1
		Total	79	101	73
3	34.3–37.7	7/27	0	0	0
		8/6	0	0	0
		8/17	0	0	0
		8/24	0	0	0
		8/31	19	24	0
		9/9	12	4	9
		9/16	7	1	8
		9/22	2	2	1
		Total	40	31	18
4	30.1–34.3	7/23	0	0	0
		8/4	0	0	0
		8/18	0	0	0
		8/25	0	0	1
		9/2	6	8	0
		9/10	20	21	6
		9/17	3	2	13
		9/23	2	2	2
		10/7	0	0	1
		Total	31	33	23

Spring Chinook Salmon spawning ground survey results in the Entiat River basin in 2015 (cont'd).

5	26.1–30.1	7/23	0	0	1
		8/4	0	0	0
		8/18	0	0	0
		8/26	0	0	0
		9/1	1	0	1
		9/11	11	9	2
		9/17	4	2	7
		9/23	9	5	1
		10/9	0	0	4
		Total	25	16	16
Mad River	2.4–5.6	8/13	0	0	0
		9/16	1	0	0
		9/22	9	0	3
		Total	10	0	3
Area Totals					
Index Area (R 1–3)			146	156	95
Expanded Area (R 4–5)			56	49	39
Upper River (R 1–5)			202	205	134
Mad River			10	0	3

Summer Chinook Salmon spawning ground survey results on the Entiat River in 2015.

Reach	River Km	Date	Redds	Live Fish	Carcasses
1	41.5–45.2	10/5	0		0
		10/22	0		0
		Total	0		0
2	37.7–41.5	10/5	2		0
		10/13	0		0
		10/19	3		0
		10/27	3		1
		Total	8		1
3	34.3–37.7	8/18	0		1
		9/16	0		1
		10/6	14		1
		10/13	5		2
		10/20	1		3
		10/27	0		2
			20		10
4	30.1–34.3	9/10	0		1
		10/7	12		5
		10/16	4		11
		10/22	0		5
		10/26	0		0
			16		22
5	26.1–30.1	10/9	47		15
		10/14	28		32
		10/21	6		56
		10/29	4		11
		Total	85		114
H	5.0–10.9	10/21	25		30
		Total	25		30
F	0.5–5.0	9/11			1
		10/23	14		31
		11/5	2		6
		Total	16		38
Mad River mouth		10/16	2		0
			2		0
Area Totals					
Upper River (R 1–5)			129	0	147
Lower River (H, F)			41	0	68
Entiat River basin			172	0	215

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:

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

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) by tag code (*x*);

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

APPENDIX F- Hatchery- and Natural-origin Spring Chinook Salmon Composition Data 2004–2015.

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

[1]Includes hatchery populations that were not recovered more than 2x from 2004-2014. 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 in 2014 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 2015.

PIT Tag Code	Sex	Release		Last Detection	
		Site	Date	Site	Date
3D9.1C2DF50549	M	Dworshak NFH	4/2/2013	Entiat R. ENS rkm 35.7	8/29/2015
3D9.1C2DEAC25F	M	Entiat River	11/5/2013	Entiat R. ENF rkm 40.6	9/2/2015
3D9.1C2DEE8694	M	Entiat River	10/28/2012	Entiat R. ENS rkm 35.7	9/3/2015
3D9.1C2DF89892	M	Entiat River	11/01/2012	Entiat R. ENS rkm 35.7	6/18/2015
3D9.1C2D91D61D	M	Entiat River	4/10/2013	Entiat R. ENF rkm 40.6	6/28/2015
3DD.003BDCD899	F	Wells Dam	5/26/2015	Entiat R ENM	6/7/2015
3D9.1C2D9335F1	M	Entiat River	3/06/2013	Entiat R. ENS rkm 35.7	9/12/2015
3D9.1C2D92F3B4	M	Entiat River	8/22/2012	Entiat R. ENF rkm 40.6	8/25/2015
3D9.1C2DDA4CEF	M	Entiat River	3/25/2013	Entiat R. ENS rkm 35.7	9/14/2015
3DD.007754E8CC*	M	Eastbank Outfall	8/17/2015	Mad River	9/8/2015

*****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 2015.

PIT Tag Code	Sex	Release		Last Detection	
		Site	Date	Site	Date
3D9.1C2D920DA5	M	Entiat River	4/18/2012	Entiat R. ENM	10/31/2015
3D9.1C2DD71757	M	Entiat River	9/07/2012	Entiat R. ENS rkm 35.7	9/9/2015

No PIT tags were recovered from Sockeye Salmon or Coho Salmon carcasses on the Entiat River in 2015.

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Leavenworth, WA

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