

**Spring and Summer Chinook Salmon and Sockeye Salmon
Spawning Ground Surveys on the Entiat River, 1994**

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ABSTRACT

A single ground survey of spring chinook salmon *Oncorhynchus tshawytscha* spawning areas in the Entiat River from Box Canyon to Roundy Ditch and Diversion Dam, river mile (RM) 29-15, was conducted mid-September, 1994, after the peak of spawning. The survey included the index area, RM 28-21, which has been surveyed annually since 1962, and RM 29-28 and RM 21-15 which have not been surveyed in previous years. The index area was surveyed by Washington Department of Fish and Wildlife with the assistance of U.S. Fish and Wildlife Service (USFWS), and USFWS surveyed the other areas. In the index area (RM 28-21), there were 24 redds, one live, and two dead spring chinook salmon. In the entire survey area (RM 29-15), there were 34 redds, one live, and five dead spring chinook salmon. Estimates of the number of wild salmon expanded from redds counted in the index area is 84 salmon, using the estimator of 3.5 salmon per redd to account for spawning outside of the index area. The expanded estimate based on the entire count of 34 redds is 82 salmon, assuming that this survey included the entire spawning area and using the estimator of 2.4 salmon per redd. The index area count of 24 spring chinook salmon redds is the lowest count since 1962, and is 18% of the average 132 redds observed since 1962. Dam counts at Rocky Reach and Wells dams also show the lowest spring chinook salmon run recorded since the dams were completed in 1962 and 1967, respectively.

Previously summer chinook salmon *O. tshawytscha* redds had not been surveyed between RM 28-15 of the Entiat River but had been counted annually below RM 10.4, 1957-1991, by aerial surveys. In 1994, USFWS conducted multiple ground surveys for summer chinook salmon between RM 28-15, observed sections of the lower river from the road, looked for redds near RM 1, and checked areas where a few redds had been reported. There were 11 summer chinook redds counted in the survey section (RM 28-15) and four counted below RM 15. All summer chinook salmon redds were located below Brief Bridge (RM 23.4). Multiplying the total redd count of 15 by 2.4 salmon per redd gives an estimate of 36 summer chinook salmon. Since most of the area below RM 15 was not surveyed, this should be considered a low estimate. The summer chinook salmon count at Rocky Reach Dam was the highest since 1979.

There have been reports in recent years of sockeye salmon *O. nerka* in the Entiat River but none were seen during these surveys. Dam counts of sockeye salmon at Rocky Reach and Wells dams were at the lowest levels recorded since the dams were completed.

Recommendations are to continue to survey from RM 28-15 for spring and summer chinook salmon and for sockeye salmon annually on days after peak spawning or on multiple days, and to more extensively survey the area below RM 15 for summer chinook salmon. Spawning surveys in the Entiat River will be especially important in the next several years to monitor how the 1994 wildfires affect spawning distribution and salmon abundance.

INTRODUCTION

Spring chinook salmon *Oncorhynchus tshawytscha* spawning has been monitored in the Entiat River since 1962 in a seven-mile index area that has been surveyed annually on one day after the peak of spawning in mid-September by Washington Department of Fish and Wildlife (WDFW). Summer chinook salmon *O. tshawytscha* surveys in the Entiat River have been limited to aerial surveys conducted from Ardenvoir to the mouth (river mile (RM) 0-10.4), 1957-1991, by Chelan County Public Utility District. Dam counts at Rocky Reach and Wells dams are also used to monitor the salmon runs in the Entiat River area.

This was the first year (1994) that the U.S. Fish and Wildlife Service (USFWS) Mid-Columbia River Fisheries Resource Office expanded the spring chinook salmon spawning surveys to include an additional seven miles and conducted multiple summer chinook salmon surveys within a 13 mile section. Biologists also searched for sockeye salmon *O. nerka*, since they have been seen in the Entiat River in recent years.

The purposes of the USFWS surveys were to:

1. Expand current Entiat River spring chinook salmon spawning surveys to assess spawning distribution over a larger area and more accurately estimate the spawning population.
2. Assess the spawning distribution and estimate the summer chinook salmon spawning population in the Entiat River.
3. Add to spawning and population trend analysis data for spring and summer chinook salmon in the Entiat River.
4. Check for straying hatchery spring chinook salmon by retrieving coded-wire-tag data from tagged fish found in the natural stream.
5. Search for sockeye salmon and identify sockeye salmon spawning areas in the Entiat River.
6. Make recommendations for future spring and summer chinook salmon and sockeye spawning surveys in the Entiat River.

STUDY AREA

The Entiat River enters the Columbia River 484 miles and 8 dams above the Pacific Ocean. The Entiat River is 52 miles long and begins as meltwater from glaciers and snow (Figure 1). Base flow is 385 ft³/s (Mullan et al. 1992), and its major tributaries are the North Fork and Mad rivers. This study only considered the river below RM 29, where Box Canyon effectively blocks upstream movement of fish. Spawning surveys concentrated between Fox Creek Campground and Roundy Ditch and Diversion Dam (RM 28 -15), because this reach contains most of the areas suitable for spawning. At RM 15 there is a terminal moraine formed by a valley glacier during the Pleistocene. Above the moraine, the valley is U-shaped and below it is V-shaped from stream cutting. Stream gradient below Box Canyon (RM 29) to RM 26 is steep, and gravel is only found in small pockets. From RM 26 to RM 15, the gradient lessens and gravel is numerous

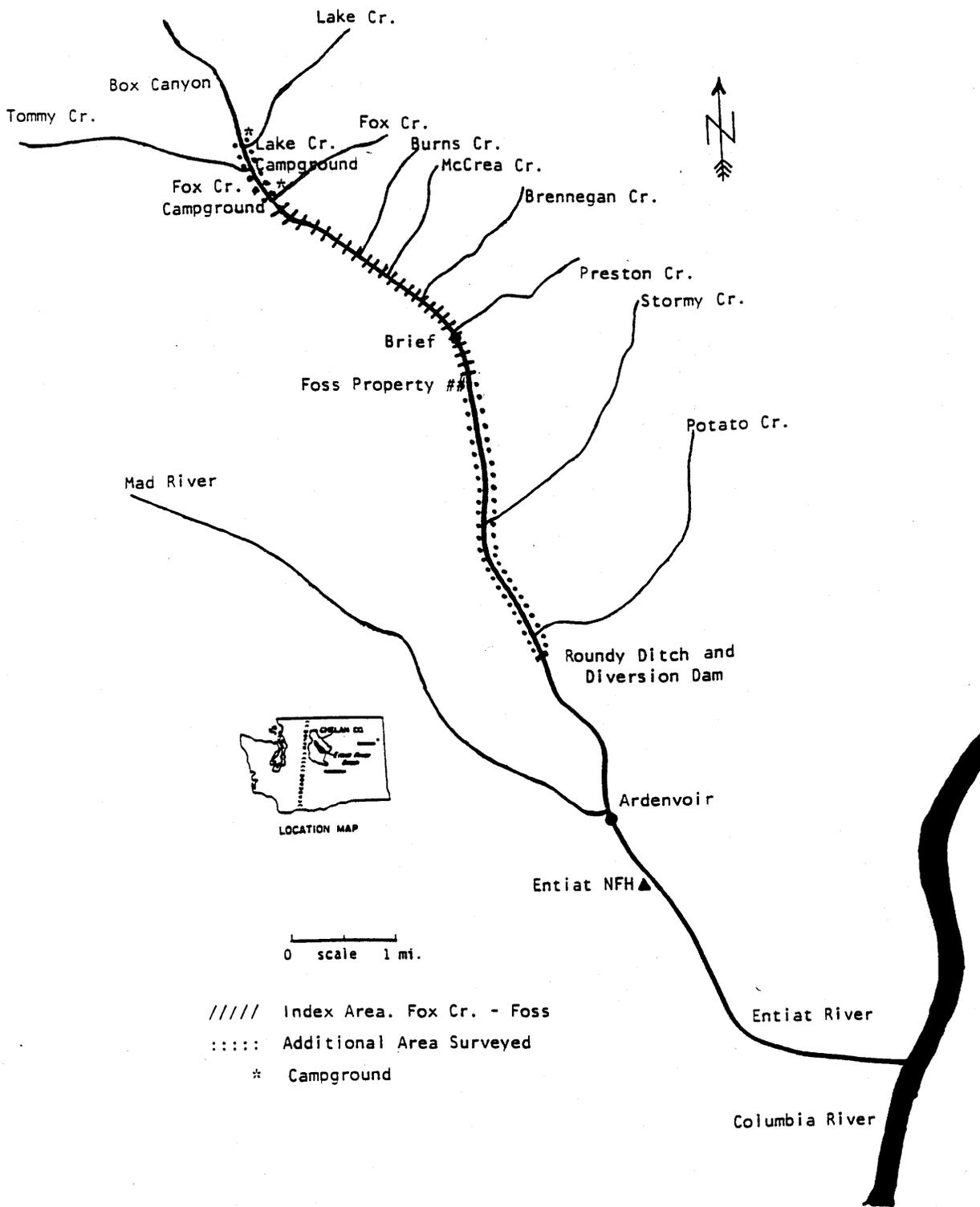


Figure 1. Map of the Entiat River.

throughout this reach. Between RM 15 and RM 2, the river gradient steepens and substrate is mostly cobble and boulder. Below RM 2, the river gradient decreases. There are some gravel areas around RM 1, and large deposits of silt and sand exist near the mouth (Figure 2). River miles and major landmarks are given in Appendix 1. Since all surveys were conducted by moving downstream, river descriptions start upstream and move downstream.

CHINOOK AND SOCKEYE SALMON POPULATIONS

The Entiat River historically supported excellent chinook salmon runs that ascended the river in May and June and were thought to be spring chinook salmon (Craig and Suomela 1941). Construction of dams around the turn of the century near the mouth of the Entiat River completely cut salmon off from their spawning grounds, and salmon runs were essentially extinct by 1939 when Grand Coulee Dam was built (Craig and Suomela 1941). As part of the Grand Coulee Fish Maintenance Project mitigation effort, all ascending adult salmon from upriver stocks were trapped at Rock Island Dam from 1939 to 1943 and were relocated to upstream tributary streams below Grand Coulee Dam, including the Entiat River, and to hatcheries, including Leavenworth, Entiat and Winthrop National Fish Hatcheries (NFH) (Fish and Hanavan 1948). The goals of these efforts were to rebuild salmon runs in the tributary streams and mitigate for lost production above Grand Coulee Dam.

Spring Chinook Salmon

After Grand Coulee Dam was built, little effort was made to reestablish wild spring chinook salmon runs in the Entiat River. Entiat NFH released just over 1 million sub-yearling and less than 50,000 yearling spring chinook salmon in 1942 and 1944 that were offspring of the upriver stocks collected at Rock Island Dam and of McKenzie River fish (Mullan 1987). No spring chinook salmon were released from Entiat NFH from 1945 to 1975. Despite this, a wild spring chinook salmon run was observed as early as 1956 and 1957, spawning in the area above Stormy Creek (RM 18.4) (French and Wahle 1960). Since 1962, spring chinook salmon redds have been counted in an index section between RM 28-21, where a well established spring chinook salmon run has been documented (Figure 3). Entiat NFH resumed spring chinook salmon production in 1974. Egg sources have 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). Returning Entiat River adults that voluntarily entered the hatchery were the primary broodstock in 1980 and from 1982 to present.

Summer Chinook Salmon

Although summer chinook salmon are not believed to be endemic to the Entiat River (Craig and Suomela 1941), several efforts were made to establish summer chinook salmon in the Entiat River following completion of Grand Coulee Dam. In 1939 and 1940, a total of 3,015 adult summer chinook salmon, collected at Rock Island Dam from the commingled upriver stocks, were placed in upper Entiat River spawning areas. Only an estimated 1,308 of these survived to spawn (Fish and Hanavan 1948). Entiat NFH reared and released juvenile summer chinook salmon into the

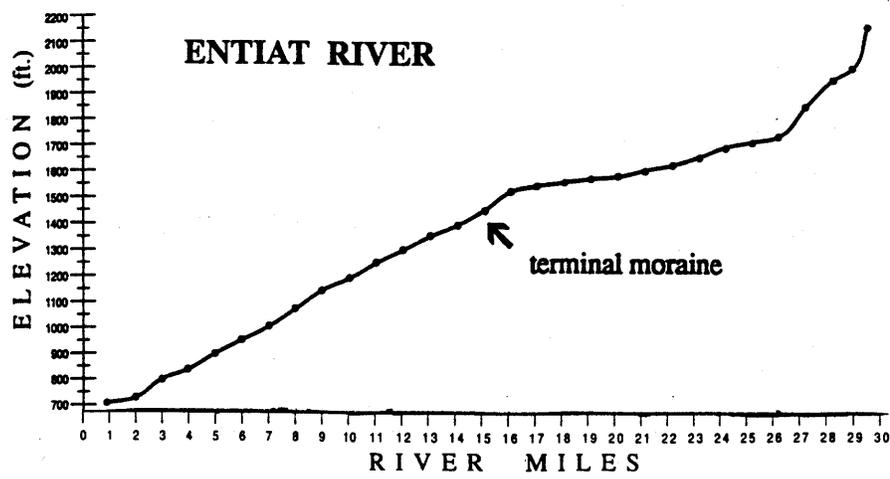


Figure 2. River gradient of the Entiat River (Mullan et al. 1992).

SPRING CHINOOK SALMON REDDS

Entiat River Index Area, 1962-1994

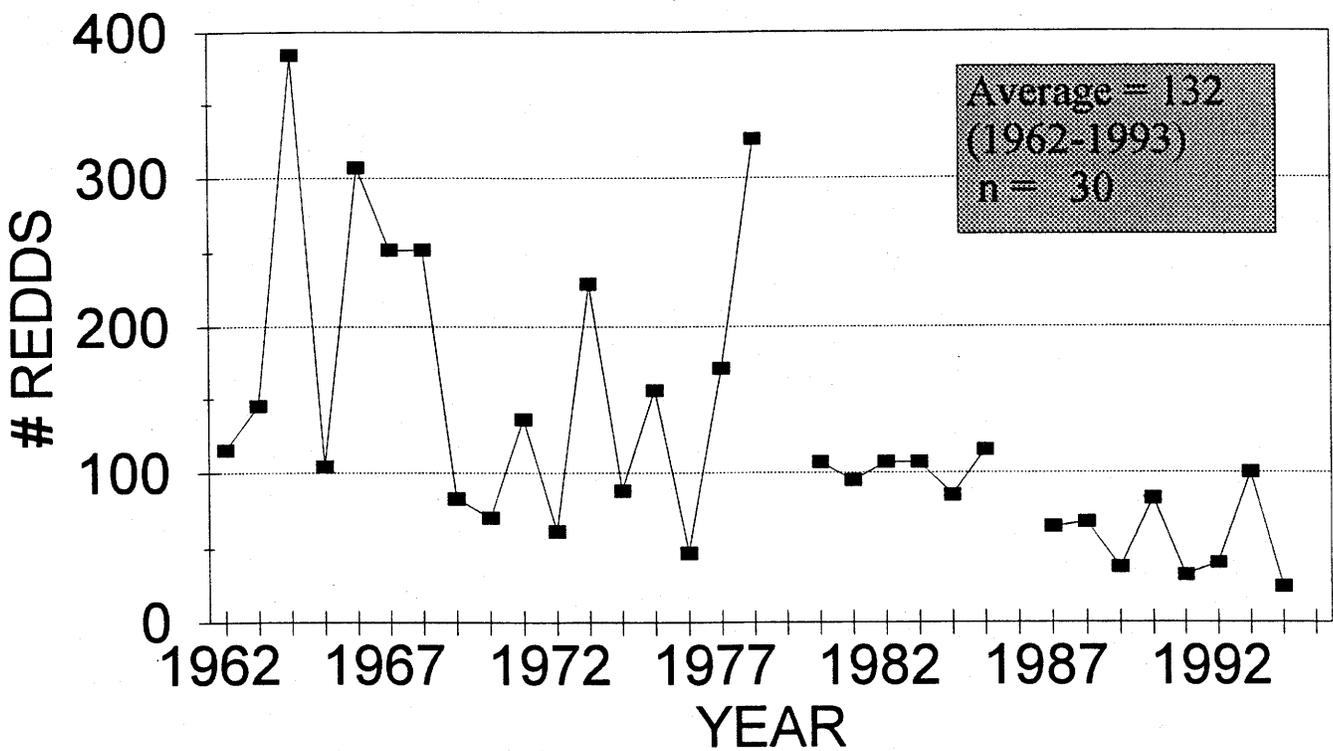


Figure 3. Spring chinook salmon redd counts from one day annual surveys in the index area, Fox Creek Campground to Foss property (RM 28-21), Entiat River, 1962-1994.

Entiat River 1941-1964 and 1976 (Mullan 1987). Egg sources included the commingled 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 Dam (1974). Summer chinook salmon spawning was monitored in the lower 10.4 miles by aerial surveys from 1957 to 1991 (Table 1). Spawning numbers were never high, with a maximum of 55 redds in 1967. The number of redds declined following the adult return of the 1964 cohort.

Sockeye Salmon

Sockeye salmon are not indigenous to the Entiat River (Craig and Suomela 1941) and have only been stocked on two occasions, in 1943 and 1944, from Lake Quinault and Lake Chelan stocks (Mullan 1986). A small run of sockeye salmon became established in the Entiat River, and Entiat NFH collected sockeye salmon from 1944 to 1963 for planting elsewhere (Mullan 1986). Sockeye salmon were observed spawning in the Entiat River from 1945 to 1955, and 75-150 were counted in incidental counts between 1969 and 1981 (Mullan 1986). Sockeye salmon were most recently observed in the Entiat River in 1993 (Phil Archibald, pers. comm.).

METHODS

Spring Chinook Salmon

Methods for surveying spring chinook salmon were consistent with those used historically in the index area by WDFW. The survey area was divided into several reaches, and single surveys of each reach were conducted after peak spawning in mid-September by one or two persons walking downstream and counting redds, live fish, and dead fish. Only well established redds were counted; excavations were noted but were not considered to contain eggs. Time required to complete the survey and stream temperature were recorded. Dead fish were measured to the nearest centimeter (fork length), gender identified, and scale samples taken when possible. Outside of the index area, redd locations were marked with biodegradable flagging on nearby vegetation to distinguish them from summer chinook salmon redds in subsequent surveys. Landowners were contacted by mail or in person to notify them of the spring and summer chinook salmon spawning surveys and to ask them to contact us if they had any objections to our surveying the river passing through their land.

The index area, from Fox Creek Campground to the Foss property bridge (RM 28-21), was surveyed on September 15, 1994 by WDFW with assistance from USFWS for evidence of spring chinook salmon spawning. USFWS surveyed from Foss property bridge to Roundy Ditch and Diversion Dam (RM 21-15) on September 22 and from Lake Campground to Fox Creek Campground (RM 29-28) on September 23.

We estimated the number of spring chinook salmon spawning in the Entiat River by expanding redd counts using two different estimators. The estimator of 2.4 chinook salmon adults per redd is widely used and generally accepted in the mid-Columbia basin. This estimator is used under the assumption that all redds were counted. Another estimator used by WDFW is 3.5 spring chinook

Table 1. Summer chinook salmon aerial redd counts in the Entiat River from the mouth to Ardenvoir (RM 0 -10.4), 1957-1991 (Peven 1992). (Counts not done 1992-1994.)

Year	Redds	Year	Redds
1957	8	1975	0
1958	27	1976	6
1959	12	1977	4
1960	12	1978	13
1961	8	1979	6
1962	18	1980	8
1963	5	1981	0
1964	24	1982	5
1965	17	1983	3
1966	23	1984	0
1967	55	1985	0
1968	54	1986	0
1969	41	1987	14
1970	26	1988	5
1971	18	1989	0
1972	5	1990	0
1973	24	1991	2
1974	0		

salmon adults per redd. This estimator is used to determine the number of spawning spring chinook salmon adults in the Entiat River given redd counts from only the index area (RM 28-15).

Summer Chinook Salmon

Methods were the same as for the spring chinook salmon surveys with a few differences in area surveyed and survey frequency. The area from Fox Creek campground to Roundy Ditch and Diversion Dam (RM 28-15) was divided into several reaches and each was surveyed one to three times by two surveyors. Neither salmon nor redds were seen above Brief Bridge (RM 23.4) so that area was surveyed less frequently. Redd locations were marked with biodegradable flagging on nearby vegetation, and carcasses were cut in half to prevent recounting. Since permission for access to the entire area downstream of RM 15 was not requested from landowners, surveys were limited to observing stream substrate from the road, walking in the area around RM 1, and examining a few reported redds at various locations where access was approved. The number of summer chinook salmon that spawned was estimated by expanding redd counts using the estimator of 2.4 chinook salmon per redd.

Sockeye Salmon

Sockeye salmon and their redds were searched for on all surveys.

RESULTS

Spring Chinook Salmon

Twenty-four spring chinook salmon redds, and one live and two dead spring chinook salmon were counted in the index area (RM 28-21) (Table 2). Above the index area, there were two redds in RM 29-28, and below, in RM 21-15, there were eight redds and three dead spring chinook salmon. The complete survey identified a total of 34 redds, one live, and five dead spring chinook salmon. Length and gender data for the dead salmon is given in Appendix 2. None of the dead fish had missing adipose fins to suggest hatchery origin or straying of hatchery fish into natural spawning areas; however, less than 20% of the yearlings from brood years 1989 and 1990 were marked. There were also 10 excavations, but they likely did not contain eggs. The index redd count was 71% of the total redd count. The area from RM 29 to 15 probably included most or all of the spring chinook spawning in the Entiat River, since spring chinook salmon are not known to spawn in the lower river. However, some spawning gravel exists in those areas which were not surveyed.

For the 1994 redd count, multiplication of the 24 redds by the estimator of 3.5 salmon per redd yields an estimate of 84 spring chinook salmon. Assuming all spawning areas were surveyed, the total redd count of 34 multiplied by 2.4 chinook per redd gives an estimate of 82 spring chinook salmon.

Summer Chinook Salmon

Eleven summer chinook salmon redds were counted in the survey section (RM 28-15), and these were all below RM 23.4. Summer chinook salmon were first seen in a group of 13 brightly colored, deep-bodied, adult chinook salmon in a large hole near RM 16.5 on the September 22 spring chinook salmon survey, and the last live summer chinook salmon were seen October 21. Only three dead summer chinook salmon were found. Length and gender data for two of these dead salmon is given in Appendix 2. Four summer chinook salmon redds were checked and reported below RM 15, two near RM 1, one near RM 4, and one near Entiat NFH. This gives a total count of 15 redds (Table 3). Multiplying this total count by the estimator of 2.4 salmon per redd gives an estimate of 36 summer chinook salmon. This estimate should be considered a minimum, since the river was not completely surveyed below RM 15.

Sockeye Salmon

No sockeye salmon were observed during any of the surveys.

Table 2. Summary of spring chinook salmon spawning surveys in the Entiat River, 1994.

Section and river miles (approximate)	Miles (approx)	Total redds	Live fish	Dead fish
Lake Creek to Fox Creek RM 28.9 - ~28	0.9	2	0	0
INDEX: Fox Creek to Big Rock RM 28 - ~26	2.0	13	0	0
INDEX: Big Rock to Brief RM ~26- 23.4	2.6	5	1	1
INDEX: Brief to Foss Property RM 23.4 - 21	2.4	6	0	1
Foss Property to "Watch for Ice" sign RM 21 - 17.5	3.5	4	0	0
"Watch for Ice" sign to Roundy Ditch and Diversion RM 17.5 - 15	2.5	4	0	3
INDEX TOTAL	7.0	24	1	2
TOTAL	13.4	34	1	5

Table 3. Summer chinook salmon spawning ground surveys on the Entiat River, 1994.

Section in river miles ^a	Date	New redds	Live fish	Dead fish	Temp. (C)	Time start	Time end
28 -23.4	10/11/94	0	0	0	8	1130	1750
25.5-23.4	11/02/94	0	0	0	6	1030	1300
23.4-17.5	10/12/94	2	7	0	8	1030	1530
	10/20/94	3	2	0	8	1120	1520
	11/03/94	0	0	0	6	1000	1430
21 -15	09/22/94	0	13	0	unk.	1025	1700
17.5-15	10/13/94	4	8	0	9	1130	1500
	10/21/94	0	2	3	8	1100	1500
	11/04/94	2	0	0	6	1030	1400
7 -0 ^b	10 / 94	3	2	0			
	11/04/94	<u>1</u>	<u>0</u>	<u>0</u>	6		
TOTALS		15	34 ^c	3			

a) River miles are approximate.

b) This reach was not completely surveyed, so these counts may be low and the distance surveyed less than the section length.

c) This is not a true total count as individual adults may have been counted more than once due to fish movement in the stream between survey days.

DISCUSSION

Wild spring chinook salmon adult returns to the Entiat River in 1994 were at low levels. The index count of 24 spring chinook salmon redds is the lowest on record and 18% of the 1962-1993 average count of 132 redds (Figure 3). Since 1980, redd counts have been depressed. Redd counts have averaged only 56 redds for 1987-1994. One reason for the low return in 1994 might be the depressed number of redds observed in 1989 (n=37) and 1990 (n=83). Also, spring chinook salmon runs throughout the Columbia River basin were depressed in 1994. The low return is likely partly attributable to conditions in the migration corridor and ocean.

Dam counts at Rocky Reach and Wells dams for spring chinook salmon were also at historical lows in 1994 (Table 4). Counts at both dams were 11% of the 15 year average (1979-1993). Wild spring chinook salmon escapement between Rocky Reach and Wells Dam is estimated at 41 (Table 5) compared to the number estimated by redd expansions of 84. Both methods of estimating the size of the wild salmon spawning population have inherent assumptions that influence their results. Dam counts suffer from possible multiple counts of fish due to fall back and failure to account for pre-spawning mortality. The date for separating the chinook run into spring and summer components is founded on historical dam counts. Therefore, it does not allow for overlap of run timing between stocks nor annual variability in run timing for each stock. On the other hand, the accuracy of redd counts can be influenced by salmon spawning outside of the survey area, including the mainstem Columbia River; observer error; or/and the use of an incorrect expansion factor to estimate the number of spawners from redd counts. Given the inherent problems with each estimation method, we believe that redd counts provide a better monitoring tool for determining trends in the Entiat River.

Few summer chinook salmon spawned in the Entiat River in 1994. Although historical redd counts are not available for RM 28-15, aerial redd counts in the lower 10.4 miles, 1957-1991, indicate that summer chinook salmon numbers were never high and averaged only four redds over the last 15 years of the survey (1977-1991); in several years counts were zero (Table 1). This was the first time to our knowledge that summer chinook salmon have been extensively documented in the upper Entiat River, other than a few spot observations in recent years (Phil Archibald, pers. comm.). It is unknown if the summer chinook salmon observed are an established wild run or if they are strays from upper Columbia River stocks. Dam counts indicate that there was a large run of summer chinook salmon over Rocky Reach Dam in 1994, 7,293 fish, which exceeds the 15 year average (1979-1993) of 4,638 summer chinook (Table 4). The estimated wild escapement between Rocky Reach and Wells dams was 269 (Table 5), which greatly exceeds the estimate from the redd expansion of 36 summer chinook. Again, inherent problems with dam counts causes us to prefer using redd counts for estimating the number of summer chinook spawning in the Entiat River.

At the present depressed population numbers, chinook salmon spawning area is not limited. Numerous areas of substrate that appeared suitable for spawning were observed unused during

Table 4. Annual fish counts of spring and summer chinook salmon and sockeye salmon at Rocky Reach Dam, 1962-1994, and Wells Dam, 1967-1994.

Year	Spring Chinook		Summer Chinook		Sockeye Salmon	
	Rocky Reach	Wells	Rocky Reach	Wells	Rocky Reach	Wells
1962	3,697		9,295		9,870	
1963	4,644		5,776		37,046	
1964	6,536		10,752		32,159	
1965	2,755		15,975		31,735	
1966	6,962		19,445		129,557	
1967	5,560	1,157	15,558	12,504	109,434	113,232
1968	6,422	4,931	14,721	8,922	91,376	81,530
1969	4,400	3,599	12,996	6,846	20,374	17,352
1970	4,375	2,670	11,822	8,003	57,251	50,677
1971	4,132	3,168	10,031	5,988	49,838	48,172
1972	3,894	3,616	5,577	4,141	26,978	33,398
1973	4,344	2,937	9,683	5,052	48,856	37,178
1974	4,263	3,420	8,274	4,567	20,976	16,716
1975	3,353	2,225	15,367	8,522	26,925	22,286
1976	1,892	2,759	7,771	7,901	27,205	27,619
1977	5,948	4,211	10,593	7,527	25,648	21,973
1978	7,396	3,615	8,095	6,419	8,157	7,458
1979	2,203	1,103	8,577	10,080	28,747	22,655
1980	1,866	1,182	5,367	4,892	29,906	26,573
1981	3,529	1,935	4,668	4,276	30,649	28,234
1982	2,815	2,401	2,705	3,349	17,379	19,005
1983	3,406	2,869	2,777	2,821	26,069	27,925
1984	3,934	3,280	5,875	5,941	73,290	81,054
1985	8,718	5,257	5,937	4,456	54,077	53,170
1986	4,206	3,150	5,554	4,178	32,912	34,876
1987	3,496	2,344	4,078	3,142	41,115	39,948
1988	4,777	3,036	3,683	2,775	34,090	33,980
1989	3,229	1,740	5,654	3,333	16,176	15,895
1990	1,916	981	4,297	3,354	9,296	7,597
1991	1,303	779	3,158	2,028	27,439	27,492
1992	2,741	1,623	2,257	1,967	41,804	41,844
1993	4,249	2,444	4,980	3,603	28,318	23,038
1994	378	257	7,293	4,891	1,680	1,662

Table 5. Estimated escapement in 1994 of wild spring and summer chinook between Rocky Reach and Wells dams using the difference between dam counts reduced by the number of salmon taken at state and federal fish hatcheries.

Count	Spring chinook	Summer chinook
Rocky Reach Dam	378	7,293
Wells Dam	<u>257</u>	<u>4,891</u>
Difference	121	2,402
Entiat NFH - # Fish Taken	80	0
Wells SFH - # Fish Taken	<u>0</u>	<u>2,133</u>
Estimated wild escapement	41	269

these surveys. The 1994 Tye Creek fire, human associated activities, and potential associated floods could significantly alter salmon habitat. The fire burned upstream as far as Preston Creek (RM 23.5), and 41% of the spring chinook salmon and 100% of the summer chinook salmon redds observed this year were in or below the burn area.

No sockeye salmon were seen during these surveys, although it is possible that some ascended the Entiat River but were not detected during these surveys. It is not known if there is an established run of sockeye salmon in the Entiat River or if the individuals that have been observed in past years were strays. The numbers of sockeye salmon counted at Rocky Reach and Wells dams in 1994 were at the lowest levels on record (Table 4).

RECOMMENDATIONS

Spring Chinook Salmon

The annual one-day index area count should be continued to monitor long-term trends. The additional areas that were surveyed gave useful information about spawning numbers and distribution. These areas should be surveyed annually on at least one day to monitor the effects of the 1994 wildfires on the salmon runs and spawning distribution. Areas above the burn area could become increasingly important if areas below the burned areas are negatively impacted. It would not be possible to survey RM 29-28 in higher water, because the canyon walls force the surveyor to wade in the stream channel. This reach should be surveyed when conditions permit. When conditions are unsafe, a surveyor should walk upstream from Fox Creek campground as far as possible. The additional survey from RM 21-15 will add one long day to the survey time.

Summer Chinook Salmon

Valuable information about run size and spawning distribution of summer chinook salmon was gained by this survey, but questions remain about population trends. Summer chinook salmon spawning should continue to be monitored annually in RM 28-15 to identify trends and the effect of the 1994 forest fire on spawning numbers and distribution. The entire reach should be surveyed at least once at the end of October or early November, after most spawning is completed. Preferably the reach should be surveyed three or four times starting at the beginning of October. This would allow data collection on timing of spawning, increase counting and sampling of live and dead salmon, and would reduce the chance of not observing older redds. To complete one survey from RM 28-15 takes 3 days.

The area below RM 15 was not surveyed completely in 1994, even though summer chinook salmon were found to spawn in this section in surveys done 1957-1991. Substrate through this reach is mostly cobble - boulder, but there are pockets of gravel. It is possible that salmon spawned in this reach in areas where we did not survey. To more accurately assess the summer chinook salmon spawning population in the Entiat River, this lower reach should be completely surveyed. Ground surveys of this reach could be difficult, because stream access would have to be granted by the numerous landowners and large substrate in this reach would make wading difficult. About half of this section could be surveyed from the road. It would probably take 3-4 days to ground survey. Another option for a complete survey would be an aerial survey. Although these surveys are costly and less accurate than ground surveys, they could be merged with data from previous aerial counts to monitor long term trends.

Sockeye Salmon

Chinook salmon surveys should include observations of sockeye salmon and their spawning areas.

Temperature Monitoring

Mullan et al. (1992) suggested that summer chinook salmon in the Entiat River are limited by cold temperatures. Chinook salmon eggs incubated at temperatures below 5.8°C throughout development have high mortality rates (Combs and Burrows 1957), and these cold temperatures are common in the Entiat River in October, during the time of summer chinook salmon egg incubation (Mullan et al. 1992). To assess the affect of temperature on spawning timing and distribution and potential incubation success, it would be useful to analyze temperature data that has been recorded by Entiat NFH and Washington State Department of Ecology and to monitor water temperatures in summer chinook salmon spawning areas during spawning and incubation.

Genetics

Genetic analysis of wild and hatchery chinook salmon stocks in the Entiat River would be useful to identify the genetic relationships not only among stocks in the Entiat River but also with other chinook stocks in the mid-Columbia River basin. This could help answer some questions about stock origins.

References

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APPENDICES

Appendix 1. River mile index of the Entiat River from the mouth to Box Canyon.

River-mile	Description
0.0	Mouth of <u>Entiat River</u> at river-mile 483.7 on Columbia River
0.3	Head of Pool from Rocky Reach Dam
3.1	Entiat Valley Highway Bridge
4.5	Entiat Valley Highway Bridge
~7	Entiat National Fish Hatchery
10.4	Ardenvoir Road Bridge at ARDENVOIR
10.6	Mad River (R bank)
~15	Roundy Ditch and Diversion Dam
15.2	Potato Creek
~16.5	large hole on Bockoven's property
~17.5	"Watch for Ice" sign on Highway
18.4	Stormy Creek (L bank)
~21	Foss property
23.1	Preston Creek (L bank)
23.4	BRIEF bridge
23.9	Brennegan Creek (L bank)
25.0	McCrea Creek (L bank)
~25.5	Burns Creek
27.7	Fox Creek (L bank)
~28	Fox Creek Campground
28.6	Tommy Creek (R bank)
28.9	Lake Creek (L bank) and Lake Creek Campground
~29	Box Canyon

~ indicates that the mileage location is approximate

Appendix 2. Sex and fork lengths (cm) of dead spring and summer chinook salmon sampled in the Entiat River, 1994

Species	Sex	Fork length (cm)
Spring chinook	F	84
Spring chinook	M	70
Spring chinook	M	91
Summer chinook	M	70
Summer chinook	M	101