

Spring Chinook Salmon Spawning Surveys in the Upper Willamette River Basin in 2019

Final Report



Prepared For

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1 Introduction and Background

Normandeau Associates, Inc. and Environmental Assessment Services (EAS) were contracted by the Portland District of the U.S. Army Corps of Engineers (USACE) to provide monitoring and evaluation services (spawning surveys) for the hatchery program related to the mitigation, production, and release of spring Chinook salmon (*Oncorhynchus tshawytscha*) into the Willamette Basin (Figure 1). The upper Willamette River Evolutionarily Significant Unit (ESU) was originally listed as threatened under the Endangered Species Act in 1999 (64 FR 14308, NOAA 1999); the listing was updated in 2005 with designated critical habitat (70 FR 37159, NOAA 2005). Hatchery stocks are included in the ESU for the upper Willamette River ESU. This study provides information on the status of the spawning populations in the selected rivers and reaches of the Willamette Basin by calculating rates of prespawn mortality (PSM), determining the proportions of hatchery and natural origin fish spawning in the selected reaches, and by assessing the abundance and distribution of redds.



Figure 1. The Willamette River Basin (Source: nwp.usace.army.mil).

Upper Willamette River spring Chinook salmon spawn in the fall. After emerging, juveniles follow various life histories, with some smolting as fry and leaving their natal streams almost immediately, while others reside for more than a year before beginning downstream migration to the ocean (Schroeder et al. 2016). Adult fish return upstream to the lower Willamette River in the late winter and early spring, and then hold in the river system until spawning (Schroeder et al. 2016). According to the Oregon Department of Fish and Wildlife (ODFW), the run forecast for Willamette River spring Chinook to the Columbia River mouth was 42,490 for 2019; however, the estimated return was considerably less at 29,314 adults (JCRMS 2020). To reach the upper tributaries of the Willamette River, spring Chinook salmon must first pass the Willamette Falls Dam, which is located at river mile 26.5. Spring Chinook passage occurs at the Willamette Falls fishway between April and July, typically peaking in mid-May (JCRMS 2020). Fish passing through the Willamette Falls fishway are counted 24 hours per day year-round. According to the ODFW, in 2019 the total (adult + jack) count of spring Chinook salmon at Willamette Falls Dam was 20,617. This included 18,882 adults, of which 12,310 were clipped fish and 6,572 were unclipped fish. This was below the average total count of the previous 10 years of 38,790 (JCRMS 2020, Figure 2).

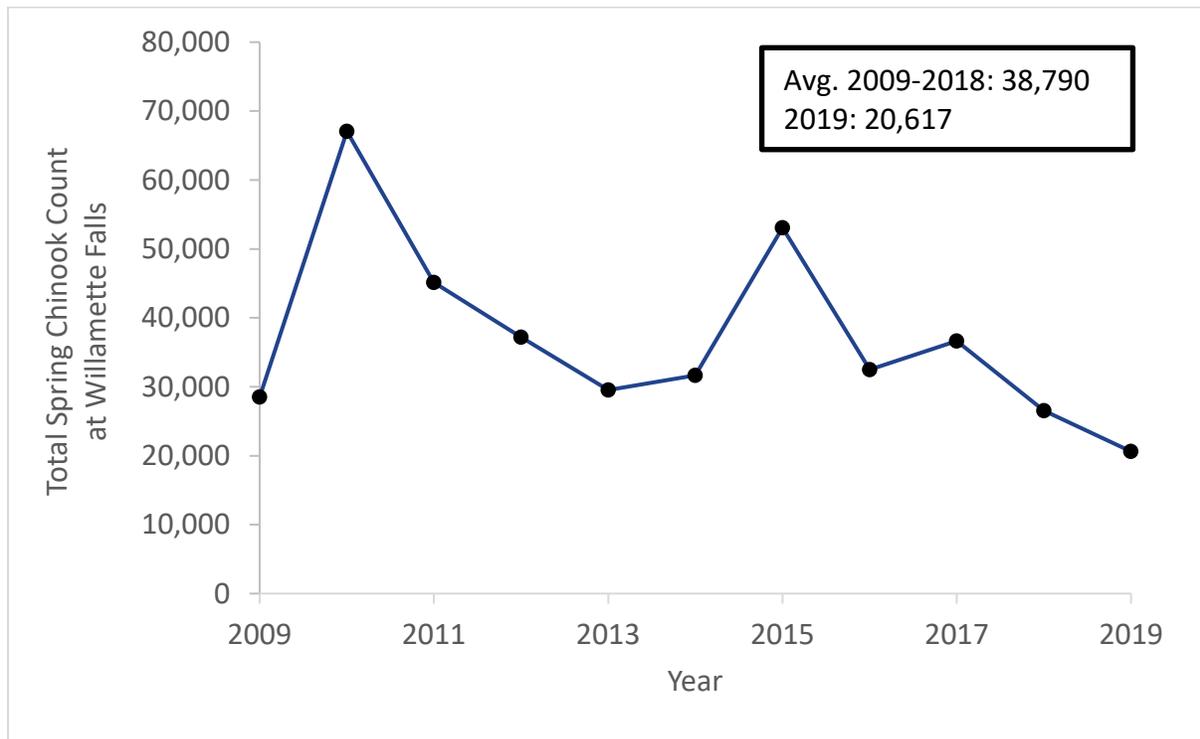


Figure 2. Counts of spring Chinook salmon (adult + jack) at Willamette Falls Dam from 2009-2019 (Source: www.dfw.state.or.us).

2 Methods

2.1 Study Area

Surveys were performed along USACE specified portions of the Santiam River, McKenzie River, Middle Fork Willamette River and selected tributaries (Figures 3, 4, and 5). Each river was divided into sections, termed “reaches”, that typically corresponded to river access points and are also consistent with the reaches surveyed during previous USACE-funded spawning surveys on the subject rivers (Table 1). This study, and the resulting data analysis, is only

relevant to the specific sections of river where surveys were conducted. These rivers vary from large, low-gradient, slow moving water in the lower sections, to Class III and IV whitewater in some of the upper reaches. Several of the river sections are located along major roadways while others are in remote areas with limited access.

Table 1. Survey reaches, ordered upstream to downstream by river.

River & Reach	River & Reach	River & Reach
McKenzie	Horse Creek	North Santiam
<i>Spawning Channel</i>	<i>Pothole Creek to Trail Bridge</i>	<i>Big Cliff Dam to Minto</i>
<i>Ollalie to Belknap</i>	<i>Trail Bridge to Separation Creek</i>	<i>Minto Dam to Packsaddle</i>
<i>Belknap to Paradise</i>	<i>Separation Creek to Road Access</i>	<i>Packsaddle to Gates Bridge</i>
<i>Paradise to McKenzie Trail</i>	<i>Road Access to Braids</i>	<i>Gates Bridge to Mill City</i>
<i>McKenzie Trail to McKenzie Bridge</i>	<i>Braids to Avenue Creek</i>	<i>Mill City to Fisherman's Bend</i>
<i>McKenzie Bridge to Hamlin</i>	<i>Avenue Creek to Horse Creek Bridge</i>	<i>Fisherman's Bend to Mehama</i>
<i>Hamlin to S.F. McKenzie</i>	<i>Horse Creek Bridge to Mouth</i>	<i>Mehama to Powerlines</i>
<i>South Fork McKenzie to Forest Glen</i>	Middle Fork Willamette	<i>Powerlines to Upper Bennett</i>
<i>Forest Glen to Rosboro Bridge</i>	<i>Dexter Dam to Pengra Landing</i>	<i>Upper Bennett (North Channel) to Stayton</i>
<i>Rosboro Bridge to Ben Kay</i>	<i>Pengra Landing to Jasper</i>	<i>Upper Bennett (South Channel) to Stayton</i>
<i>Helfrich to Leaburg Lake</i>	Fall Creek	<i>Stayton to Shelburn</i>
<i>Leaburg Dam to Leaburg Landing</i>	<i>Fall Creek Dam to Pengra Bridge</i>	<i>Shelburn to Greens Bridge</i>
<i>Leaburg Landing to Deerhorn</i>	<i>Pengra Bridge to Fall Creek Mouth</i>	<i>Greens Bridge to Mouth</i>
<i>Deerhorn to Hendricks</i>	Santiam	Little North Santiam
<i>Hendricks to Bellinger</i>	<i>Confluence to Jefferson</i>	<i>Elkhorn Bridge to Salmon Falls</i>
<i>Bellinger to Hayden Bridge</i>	<i>Jefferson to I-5 Bridge</i>	<i>Salmon Falls to Camp Cascade</i>
<i>Hayden to Armitage</i>	<i>I-5 Bridge to Mouth</i>	<i>Camp Cascade to Narrows</i>
South Fork McKenzie	South Santiam	<i>Narrows to Golf Bridge</i>
<i>Cougar to Bridge</i>	<i>Foster Dam to Pleasant Valley</i>	<i>Golf Bridge to Bear Creek Bridge</i>
<i>Bridge to Phase 2</i>	<i>Pleasant Valley to McDowell Creek</i>	<i>Bear Creek Bridge to Lomkers Bridge</i>
<i>Phase 2 to Phase 1</i>	<i>McDowell Creek to Waterloo</i>	<i>Lomkers Bridge to NF Park</i>
<i>Phase 1 to Mouth</i>	<i>Gill's Landing to Sanderson's</i>	<i>NF Park to HWY 22 Bridge</i>
Lost Creek	<i>Sanderson's to Mouth/Jefferson</i>	<i>Hwy 22 Bridge to Mouth</i>
<i>Spring to Cascade</i>		
<i>Cascade to Limberlost CG</i>		
<i>Limberlost CG to Split Point</i>		
<i>Split Pt to Hwy 126 Bridge</i>		
<i>Hwy 126 Bridge to Mouth</i>		

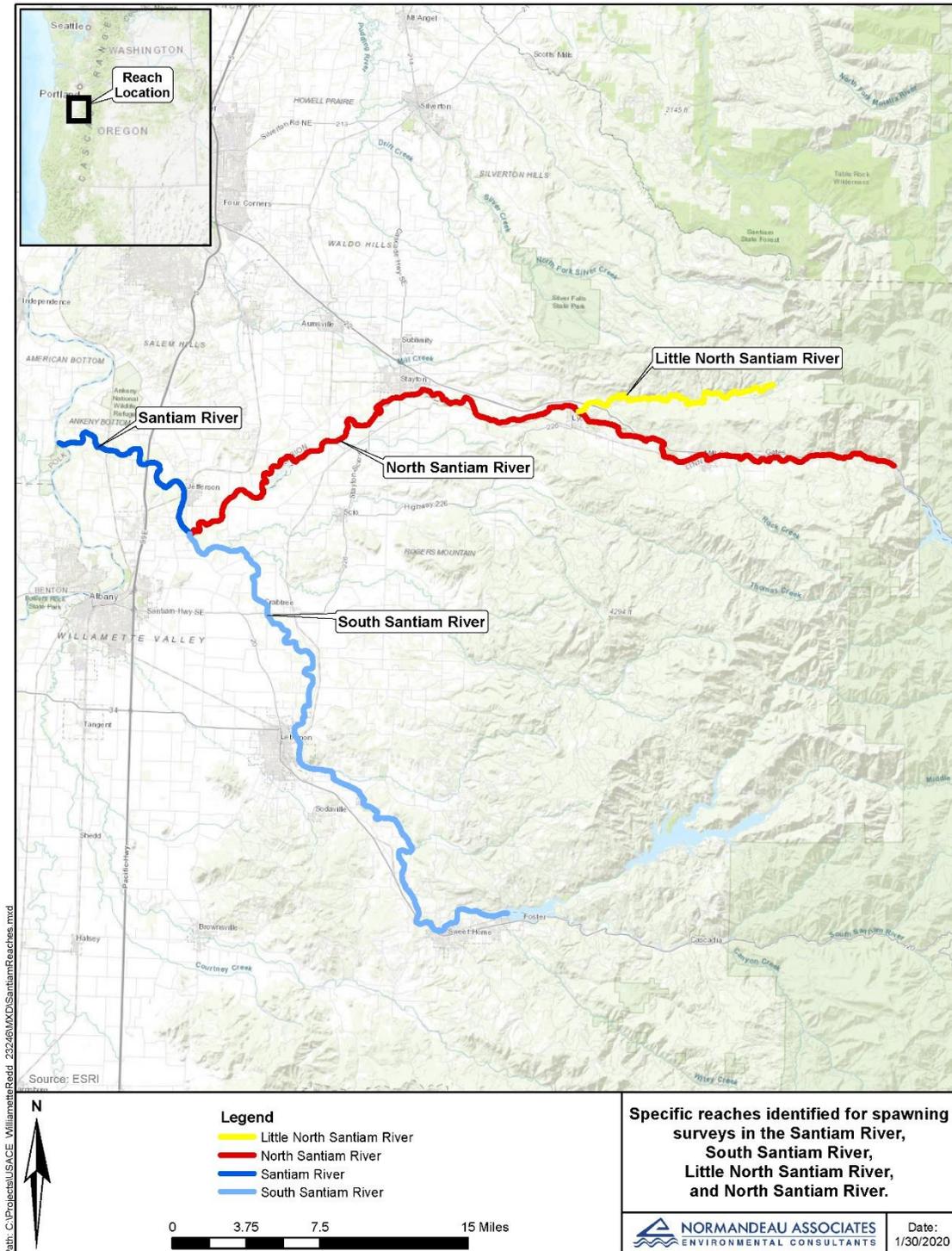


Figure 3. Specific reaches identified for spawning surveys in the Santiam River, South Santiam River, Little North Santiam River, and North Santiam River.

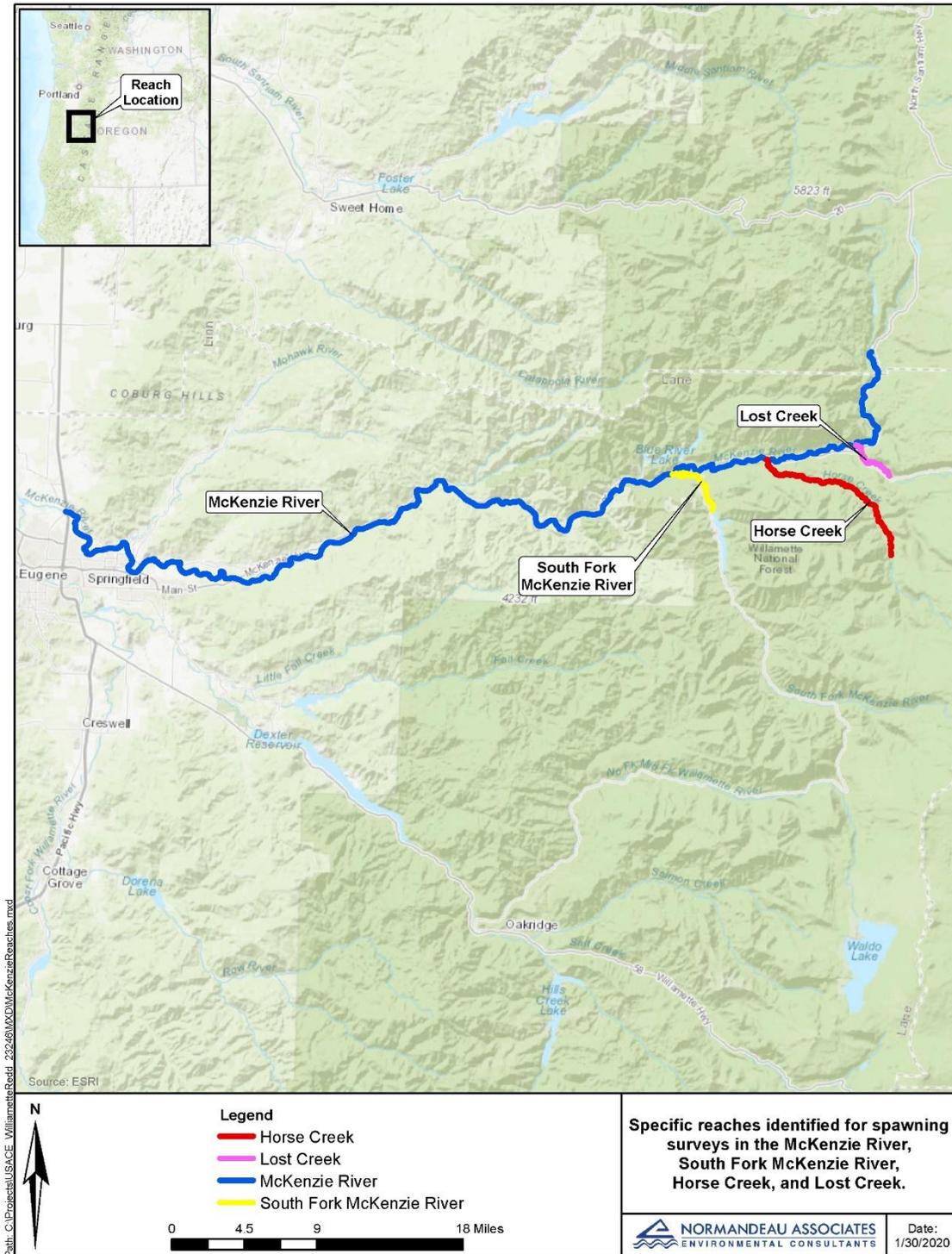


Figure 4. Specific reaches identified for spawning surveys in the McKenzie River, South Fork McKenzie River, Horse Creek, and Lost Creek.

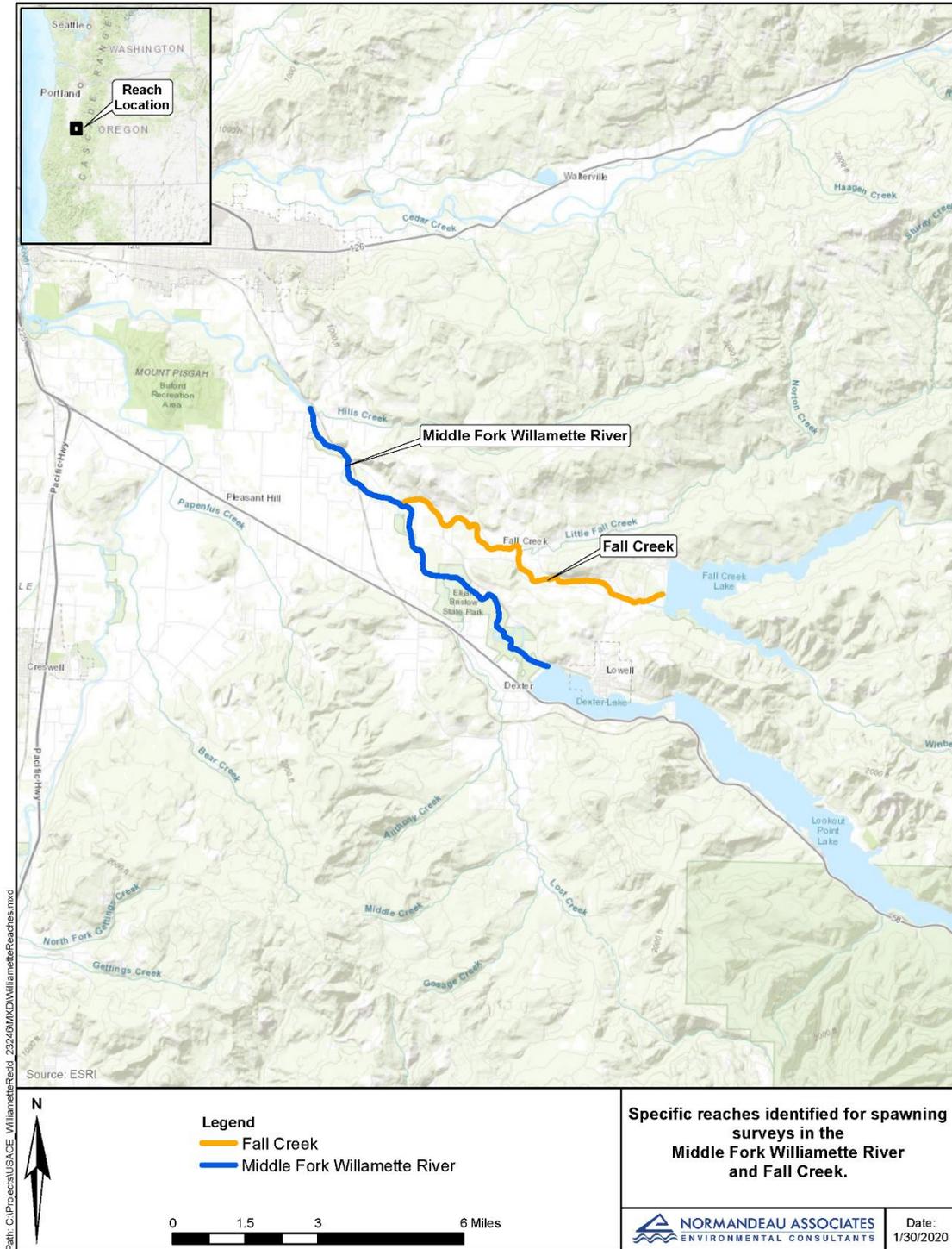


Figure 5. Specific reaches identified for spawning surveys in the Middle Fork Willamette River and Fall Creek.

2.2 Carcass and Redd Surveys

Prior to beginning field work, all crew members received training in safety procedures, carcass recovery, sample collection methods, and redd counting. Eight of the ten surveyors conducting surveys in 2019 also conducted surveys in 2018 on this project. A balanced survey design was

utilized where each reach was surveyed every 14 days, except for some of the upper reaches early in the season and some of the lowest reaches late in the season where carcasses and redds were not expected at those times. The level of effort (i.e. number of survey crews) increased over the season due to the increasing number of surveys that were required on Horse and Lost Creeks. Crews always consisted of at least two members; however, an additional crew member was added for survey areas with extensive side channels or when abundant carcasses were expected. Some reaches were surveyed by two crews of at least two crew members during peak spawning in anticipation of large carcass numbers, to facilitate completing surveys during daylight hours. USACE staff regularly conducted quality assurance assessments of field work during the season to ensure crews were performing work according to the approved study protocols.

2.2.1 Boat-based Stream Surveys

Crews utilized rafts and inflatable kayaks to navigate the survey reaches. Cataracts fitted with customized viewing towers (tower boats) were used to increase the area surveyors could effectively see. These tower rafts were used on reaches with Class II and lower rapids and in areas that were wide enough to accommodate the large boats. On reaches where tower boats could not be safely utilized, smaller rafts fitted with fishing frames were used (see cover image). Inflatable kayaks were used in the smallest creeks or in areas with large rapids, long portages, or where increased maneuverability was needed for safe navigation. All reaches were inspected for side channels; those reaches that contained side channels with spawning habit were walked by boat crew members or floated separately with an inflatable kayak. During peak spawning in areas of high redd density, two survey crews were used with each focusing on one side of the river to improve carcass recovery and to count redds along both shorelines. Expert boaters were needed to safely navigate the Class III and IV rapids present in several of the reaches.

2.2.2 Walking Stream Surveys

Walking surveys were conducted in reaches where woody debris or very low water prevented boating, including the Little North Santiam, Lost Creek, and the upper two reaches of Horse Creek. Two-person crews walked the entire stretch of the designated survey reaches and searched for redds and carcasses. The two-person crews separated to survey side channels, when present, to maximize carcass recovery rates and to ensure thorough redd counts.

2.2.3 Carcass Collection

Carcass surveys were used to estimate the abundance and distribution of both hatchery and natural origin spring Chinook salmon adults. Surveys were conducted according to the approved study plan and schedule (Normandeau and EAS 2019). At the beginning of each survey, field staff recorded the date, reach, and river being surveyed, along with water temperature (°C) and a GPS start location; a GPS position was also recorded at the end of the survey. When a carcass was processed, field staff recorded the time and assigned a unique fish ID for that carcass. Surveyors examined carcasses for adipose fin clips, measured fork length (cm) for size distributions, determined sex, and visually estimated the proportion of eggs remaining in female fish to be used for estimating PSM. Otoliths were collected in the field from carcasses without adipose fin-clips and carcasses with the adipose area missing due to scavenging or decay. Otoliths were then analyzed to differentiate hatchery fish with unclipped/regenerated adipose fins from naturally-produced fish; this determination was done in the lab by ODFW due to the presence of thermal markers on the otoliths of hatchery fish (Volk et al. 1999).

All carcasses were scanned for coded wire tags (CWT) using either a T-Wand or Blue Wand detector manufactured by Northwest Marine Technologies (NMT). CWT detectors were tested

daily using a test tag provided by NMT to ensure that detectors were functioning properly. Collected snouts were also scanned with a NWT V-Detector to confirm CWT presence after returning from the field. The snouts of fish containing CWTs were collected and the CWTs were later removed and read by ODFW. All CWT data was entered into the Regional Mark Information System (RMIS) database (<http://www.rmipc.org/>) by ODFW. CWT database queries were used to determine rates of hatchery straying, and scales taken from CWT fish with known ages were used to create an index to compare with other scale samples. Scales were collected from all carcasses, except where scale loss prevented collection, to determine age and were read by ODFW according to their standard operating procedure (Clemens et al. 2013). Finally, a tissue sample from the dorsal fin of each carcass was taken and stored for future genetic analysis. When all the samples and measurements were recorded, the tail was removed from the carcass to mark that it had been surveyed and the carcass was placed back in the stream. All data was collected, entered into an electronic database, and reviewed according to the approved study plan and quality assurance plan (Normandeau and EAS 2019).

2.2.4 Calculating Prespawn Mortality

Crews began conducting carcass surveys early in the season prior to the initiation of spawning, to improve estimates of PSM (Bowerman et al. 2016). Prespawn mortality was only calculated using data collected from female carcasses due to the uncertainty with determining spawning status of males (Bowerman et al. 2016). Female fish were examined to determine the percentage of eggs retained. For example, a fully spawned fish (i.e., no eggs present) would be recorded as 0% egg retention, while a fish that died prior to initiating spawning would be recorded as 100% egg retention. For consistency with previous survey efforts funded by USACE, fish with greater than 50% egg retention were recorded as PSM (Sharpe et al. 2017). Crews were unable to determine egg retention rates on some carcasses due to scavenging or decay and marked those carcasses as “unknown”. PSM rates were calculated by dividing the number of PSM females (fish with >50% egg loss) by the total number of females collected (i.e. excluding fish with “unknown” levels of egg retention). Consistent with previous USACE-funded survey efforts, PSM was categorized as low (<20%), medium (20-50%) and high (>50%). Fisher’s Exact Test was used to determine whether there was a significant difference in the rates of PSM between hatchery and natural origin fish, as was indicated by Bowerman et al. (2017), who found that PSM was greater in hatchery fish than natural origin fish in the Willamette Basin.

2.2.5 Redd Counting

All crew members received training in redd identification and enumeration from experienced EAS staff. Our most experienced surveyor also conducted data validation with all crews and completed concurrent counts to ensure crews were accurately enumerating redds. Once initiation of spawning was observed, survey crews began counting the total number of redds by reach and taking GPS points at locations of redds while also collecting and processing carcasses. Redds were counted every 14 days through the end of the survey season, and the highest counts by date on each reach were summed to determine peak redd counts by river. Crews took GPS points at spawning areas on all redd surveys, but not at each individual redd. Each spawning area was given a GPS point and associated redd count. Surveys were conducted according to the methods outlined in the standard operating procedure for the project, and generally follow the protocols provided by Johnson et al. 2007. Spawning area maps were generated from the GPS data using a Geographic Information System (GIS).

2.2.6 Calculating Proportion Hatchery Origin Spawners

All hatchery fish in the Willamette Basin receive an adipose fin clip to distinguish them from natural origin fish and some fish also receive a CWT to indicate their age and hatchery of origin. All hatchery fish are also put through a process of temperature cycles to induce thermal marks on their otoliths which can be read in the laboratory to distinguish hatchery fish from natural origin fish. The otoliths of unclipped fish along with “unknown” clip status were collected and analyzed for thermal marks to identify and classify unclipped hatchery fish. These unclipped hatchery fish were added to the clipped hatchery fish and divided by the total number (hatchery + natural origin) of carcasses collected to calculate the proportion of hatchery origin spawners (pHOS).

2.2.7 Calculating Spawner Abundance

The peak count expansion method was used to estimate spawner abundance, consistent with previous USACE-funded survey efforts in the upper Willamette Basin (Sharpe et al. 2017). This calculation utilizes the peak redd counts, by reach, multiplied by 2.5, assuming each redd was constructed by one female that spawned with 1.5 males.

2.2.8 Spawner Abundance Estimates by Origin

Spawner abundance estimates were multiplied by pHOS calculations to determine spawner abundance estimates for hatchery origin and natural origin fish. This calculation was done after combining data from the 10 rivers (Table 1) into the following seven basin sections: 1) Middle Fork Willamette and Fall Creek below Fall Creek Dam; 2) McKenzie above Leaburg Dam including surveyed tributaries (South Fork McKenzie, Horse Creek, and Lost Creek); 3) McKenzie below Leaburg Dam; 4) North Santiam below Minto Dam and Little North Santiam; 5) North Santiam above Minto Dam; 6) South Santiam; and 7) the mainstem Santiam.

3 Results

3.1 Carcass Collections

Crews began conducting carcass surveys on July 3rd. The first carcass was collected on the second day of surveys. Carcass surveys continued through October 17th, with the last carcass of the season collected on October 16th. The distribution of the 449 carcass surveys conducted and the 478 carcasses collected is shown in Table 2. Four jacks, defined as salmon with fork lengths less than 60 cm, were collected during the project. The distributions of hatchery and natural origin fish by fork length categories are shown in Table 3. Age classifications from scale analysis or CWT were applied to the field data to determine ages of fish by origin; this distribution of fish by age class is shown in Table 4. Sex ratios of fish grouped by river basins are shown in Table 5.

Table 2. Number of carcass/redd surveys and carcasses collected by river and reach.

River & Reach	Carcasses Collected	Total Carcass/Redd Surveys
McKenzie	255	134
Spawning Channel	14	4
Olallie to Belknap	0	8
Belknap to Paradise	4	8

River & Reach	Carcasses Collected	Total Carcass/Redd Surveys
McKenzie (cont)		
Paradise to McKenzie Trail	6	8
McKenzie Trail to McKenzie Bridge	4	8
McKenzie Bridge to Hamlin	19	8
Hamlin to S.F. McKenzie	0	8
S.F. McKenzie to Forest Glen	5	8
Forest Glen to Rosboro Bridge	128	12
Rosboro Bridge to Ben & Kay	29	11
Helfrich to Leaburg Lake	8	8
Leaburg Dam to Leaburg Landing	20	12
Leaburg Landing to Deerhorn	2	8
Deerhorn to Hendricks	15	8
Hendricks to Bellinger	1	5
Bellinger to Hayden Bridge	0	5
Hayden to Armitage	0	5
S.F. McKenzie	27	28
Cougar Dam to Bridge	12	8
Bridge to Phase 2	0	6
Phase 2 to Phase 1	4	7
Phase 1 to Mouth	11	7
Lost Creek	1	20
Spring to Cascade	0	4
Cascade to Limberlost CG	0	4
Limberlost CG to Split Pt	0	4
Split Pt to Hwy 126 Bridge	1	4
Hwy 126 Bridge to Mouth	0	4
Horse Creek	37	28
Pothole Creek to Trail Bridge	2	4
Trail Bridge to Separation Creek	0	4
Separation Creek to Road Access	1	4
Road Access to Braids	2	4
Braids to Avenue Creek	3	4
Avenue Creek to Horse Creek Bridge	13	4
Horse Creek Bridge to Mouth	16	4
Middle Fork Willamette	12	16
Dexter Dam to Pengra Landing	11	8
Pengra Landing to Jasper	1	8
Fall Creek	0	16
Fall Creek Dam to Pengra Bridge	0	8
Pengra Bridge to Fall Creek Mouth	0	8

River & Reach	Carcasses Collected	Total Carcass/Redd Surveys
Santiam	1	15
Confluence to Jefferson	0	5
Jefferson to I-5 Bridge	0	5
I-5 Bridge to Mouth	1	5
S. Santiam	65	40
Foster Dam to Pleasant Valley	62	12
Pleasant Valley to McDowell Creek	3	8
McDowell Creek to Waterloo	0	8
Gill's Landing/Lebanon to Sanderson's	0	6
Sanderson's to Mouth/Jefferson	0	6
N. Santiam	80	101
Big Cliff Dam to Minto Dam	55	8
Minto Dam to Packsaddle	5	8
Packsaddle to Gates Bridge	11	8
Gates Bridge to Mill City	1	8
Mill City to Fisherman's Bend	2	8
Fisherman's Bend to Mehama	1	8
Mehama to Powerlines	1	8
Powerlines to Upper Bennett	1	8
Upper Bennett (North Channel) to Stayton	1	8
Upper Bennett (South Channel) to Stayton	2	8
Stayton to Shelburn	0	8
Shelburn to Greens Bridge	0	8
Greens Bridge to Mouth	0	5
Little N. Santiam	0	51
Elkhorn Bridge to Salmon Falls	0	6
Salmon Falls to Camp Cascade	0	6
Camp Cascade to Narrows	0	6
Narrows to Golf Bridge	0	6
Golf Bridge to Bear Creek Bridge	0	6
Bear Creek Bridge to Lomkers Bridge	0	6
Lomkers Bridge to NF Park	0	5
NF Park to HWY 22 Bridge	0	5
Hwy 22 Bridge to Mouth	0	5
Totals	478	449

Table 3. Counts and proportions of hatchery (H) and natural (N) origin fish, by size and river based on carcass counts.

FL (cm)	McKenzie				S.F. McKenzie				Lost Creek			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
<60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
60-69	14	0.13	6	0.04	1	0.10	0	0.00	0	0.00	0	0.00
70-79	58	0.54	42	0.29	5	0.50	6	0.35	0	0.00	0	0.00
80-89	33	0.31	75	0.51	4	0.40	8	0.47	0	1.00	1	1.00
90-99	3	0.03	20	0.14	0	0.00	3	0.18	0	0.00	0	0.00
≥100	0	0.00	4	0.03	0	0.00	0	0.00	0	0.00	0	0.00
n	108	-	147	-	10	-	17	-	0	-	1	-
Mean FL	77.0	-	82.9	-	77.2	-	81.5	-	0.0	-	80.0	-
Std Error FL	0.6	-	0.6	-	2.0	-	1.6	-	n/a	-	n/a	-

FL (cm)	Horse Creek				M.F. Willamette				Santiam			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
<60	0	0.00	0	0.00	1	0.11	0	0.00	0	0.00	0	0.00
60-69	0	0.00	3	0.09	3	0.33	2	0.67	0	0.00	0	0.00
70-79	3	1.00	14	0.42	5	0.56	0	0.00	1	1.00	0	0.00
80-89	0	0.00	14	0.42	0	0.00	1	0.33	0	0.00	0	0.00
90-99	0	0.00	2	0.06	0	0.00	0	0.00	0	0.00	0	0.00
≥100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
n	3	-	33	-	9	-	3	-	1	-	0	-
Mean FL	73.7	-	78.3	-	67.7	-	73.7	-	71.0	-	0.0	-
Std Error FL	1.8	-	1.1	-	2.2	-	7.7	-	n/a	-	n/a	-

FL (cm)	S. Santiam				N. Santiam				All River			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
<60	1	0.03	1	0.03	1	0.11	0	0.00	3	0.02	1	<0.01
60-69	1	0.03	1	0.03	0	0.00	11	0.16	19	0.11	23	0.08
70-79	20	0.56	6	0.21	2	0.22	35	0.51	94	0.53	103	0.34
80-89	12	0.33	16	0.55	5	0.56	22	0.32	54	0.31	137	0.46
90-99	2	0.06	5	0.17	1	0.11	1	0.01	6	0.03	31	0.10
≥100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	0.01
n	36	-	29	-	9	-	69	-	176	-	299	-
Mean FL	78.2	-	82.3	-	78.6	-	76.4	-	76.8	-	80.7	-
Std Error FL	1.1	-	1.7	-	2.8	-	0.8	-	0.5	-	0.5	-

Note: fish of unknown length or origin excluded from calculations (1 from Horse Creek, 2 from N. Santiam), no carcasses were collected in Fall Creek or the Little North Santiam.

Table 4. Counts and proportions of hatchery (H) and natural (N) origin fish, by age and river based on carcass counts.

Age	McKenzie				S.F. McKenzie				Lost Creek			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
3	1	0.01	2	0.02	0	0.00	0	0.00	0	-	0	0.00
4	54	0.59	101	0.86	7	0.88	11	0.79	0	-	0	0.00
5	36	0.40	14	0.12	1	0.13	3	0.21	0	-	1	1.00
6	0	0.00	3	0.03	0	0.00	0	0.00	0	-	0	0.00
n	91	-	120	-	8	-	14	-	0	-	1	-
Mean Age	4.38	-	4.15	-	4.13	-	4.21	-	-	-	5.00	-
Std Error Age	0.05	-	0.04	-	0.13	-	0.11	-	-	-	0.00	-

Age	Horse Creek				M.F. Willamette				Santiam			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
3	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	-
4	2	0.67	17	0.63	7	0.78	2	0.67	0	0.00	0	-
5	1	0.33	10	0.37	2	0.22	1	0.33	1	1.00	0	-
6	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	-
n	3	-	27	-	9	-	3	-	1	-	0	-
Mean Age	4.33	-	4.37	-	4.22	-	4.33	-	5.00	-	-	-
Std Error Age	0.33	-	0.10	-	0.15	-	0.33	-	0.00	-	-	-

Age	S. Santiam				N. Santiam				All River			
	H		N		H		N		H		N	
	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.	#	Prop.
3	1	0.04	7	0.29	0	0.00	9	0.14	2	0.01	18	0.07
4	15	0.54	15	0.63	3	0.43	48	0.74	88	0.60	194	0.76
5	12	0.43	2	0.08	4	0.57	8	0.12	57	0.39	39	0.15
6	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
n	28	-	24	-	7	-	65	-	147	-	254	-
Mean Age	4.39	-	3.79	-	4.57	-	3.98	-	4.37	-	4.11	-
Std Error Age	0.11	-	0.12	-	0.20	-	0.06	-	0.04	-	0.03	-

Note: fish of unknown age or origin excluded (56 from McKenzie, 13 from S. Santiam, 8 N. Santiam), no carcasses were collected in Fall Creek or the Little North Santiam.

Table 5. Counts and proportions of male and female carcasses collected in selected river basins, including tributaries.

River Basin Counts	Female		Male		Unknown	
	Count	Proportion	Count	Proportion	Count	Proportion
McKenzie	202	0.63	115	0.36	3	0.01
Middle Fork Willamette	4	0.33	7	0.58	1	0.08
Santiam	1	1.00	0	0.00	0	0.00
South Santiam	44	0.68	21	0.32	0	0.00
North Santiam	45	0.56	31	0.39	4	0.05
Total	296	0.62	174	0.36	8	0.02

Note: unknown sex due to scavenging or decay

3.2 Prespawn Mortality

Crews collected the first carcass of the season on July 3rd, 10 weeks prior to the initiation of spawning. Across all rivers, crews determined egg retention rates for 286 female carcasses; of these, 17 fish (5.9%) were recorded as PSM (>50% egg retention), while the remaining 269 (94.1%) fish spawned successfully; ten female carcasses had unknown egg retention. Most fish either retained most of their eggs or were almost fully spawned; only one of the carcasses had between 30 and 70% egg retention. Examples of fish with various egg retention levels are shown in Figure 6. The Middle Fork Willamette had 100% PSM, but this was based on only two carcasses. In the South Santiam, 43 carcasses were collected where a low PSM (14%) was recorded. There were 156 carcasses collected in the McKenzie basin and 44 in North Santiam, and both rivers had the lowest PSM levels of basins surveyed (3% and 5%, respectively).

Results from Fisher's Exact Test showed no significant difference ($\alpha=0.05$) in the proportion of PSM for hatchery or natural origin fish for all rivers combined (0.092 and 0.036, $p=0.074$). No significant differences in PSM were noted for the South Santiam (0.156 and 0.083, $p=1.0$), the North Santiam (0.167 and 0.028, $p=0.268$), the McKenzie and its tributaries above Leaburg Dam (0.018 and 0.010, $p=1.0$), or the McKenzie below Leaburg Dam (0.111 and 0.125, $p=1.0$). PSM data by river and reach are shown in Table 6.



Figure 6. Female with 100% egg retention and intact skeins (A); female with 80% egg retention and broken skeins (B); female with 10% egg retention (C); and a fully spawned female fish with 0% egg retention (D).

Table 6. Prespawn mortality (PSM) results by river and reach based on carcass counts.

River & Reach	PSM	Spawned	Total Fish	PSM%
McKenzie	5	150	155	3%
Spawning Channel	0	10	10	0%
Belknap to Paradise	0	3	3	0%
Paradise to McKenzie Trail	0	2	2	0%
McKenzie Trail to McKenzie Bridge	0	4	4	0%
McKenzie Bridge to Hamlin	1	6	7	14%
South Fork McKenzie to Forest Glen	0	2	2	0%
Forest Glen to Rosboro	1	82	84	1%
Rosboro to Ben and Kay	0	14	14	0%
Helfrich to Leaburg Lake	0	4	4	0%
Leaburg Dam to Leaburg Landing	0	15	15	0%
Deerhorn to Hendricks	3	8	11	27%
South Fork McKenzie	1	17	18	6%
Cougar Dam to Bridge	0	7	7	0%
Phase 1 to Mouth	0	8	8	0%
Phase 2 to Phase 1	1	2	3	33%
Lost Creek	0	1	1	0%
Split Point to Hwy 126	0	1	1	0%
Horse Creek	0	23	23	0%
Pothole Creek to Trailbridge	0	1	1	0%
Separation Creek to Road Access	0	1	1	0%
Braids to Avenue Creek	0	3	3	0%
Avenue Creek to Horse Creek Bridge	0	6	6	0%
Horse Creek Bridge to Mouth	0	12	12	0%
Middle Fork Willamette	2	0	2	100%
Dexter Dam to Pengra Landing	2	0	2	100%
Santiam	1	0	1	100%
I-5 Bridge to Mouth	1	0	1	100%
South Santiam	6	38	44	14%
Foster Dam to Pleasant Valley	4	38	42	10%
Pleasant Valley to McDowell Creek	2	0	2	100%
North Santiam	2	40	42	5%
Big Cliff Dam to Minto Dam	1	27	29	3%
Minto Dam to Packsaddle	1	1	2	50%
Packsaddle to Gates Bridge	0	7	7	0%
Gates Bridge to Mill City	0	1	1	0%
Mill City to Fisherman's Bend	0	1	1	0%
Fisherman's Bend to Mehama	0	1	1	0%
Upper Bennett (South Channel) to Stayton	0	1	1	0%
Upper Bennett (North Channel) to Stayton	0	1	1	0%

Note: Reaches with no female carcasses or only female carcasses with unknown egg retention due to scavenging/decay are not shown; no carcasses were collected in Fall Creek or the Little North Santiam.

3.3 Proportion Hatchery Origin Spawners

The proportion of hatchery origin spawners was calculated to be 0.08 in Horse Creek (3 hatchery fish of 37 total) and 0.75 in the Middle Fork Willamette (9 hatchery fish of 12 total). The mainstem McKenzie River and its tributaries above Leaburg Dam had a pHOS of 0.34 (95 hatchery fish of 282 total). Above Minto Dam, where only natural origin fish were expected to be present, 2 hatchery fish out of a total of 55 were collected for a pHOS of 0.04; both fish had intact adipose fins but had hatchery thermal marks on their otoliths. The pHOS data by river and reach is shown in Table 7.

Table 7. Proportion hatchery origin spawners (pHOS) by river and reach.

River & Reach	Hatchery	Natural origin	pHOS
McKenzie	107	147	0.42
Spawning Channel	6	8	0.43
Belknap to Paradise	0	4	0.00
Paradise to McKenzie Trail	1	5	0.17
McKenzie Trail to McKenzie Bridge	0	4	0.00
McKenzie Bridge to Hamlin	4	15	0.21
South Fork McKenzie to Forest Glen	0	5	0.00
Forest Glen to Rosboro	53	75	0.41
Rosboro to Ben and Kay	12	17	0.41
Helfrich to Leaburg Lake	6	2	0.75
Leaburg Dam to Leaburg Landing	16	4	0.80
Leaburg Landing to Deerhorn	2	0	1.00
Deerhorn to Hendricks	7	8	0.47
South Fork McKenzie	10	17	0.37
Cougar Dam to Bridge	4	8	0.33
Phase 1 to Mouth	4	7	0.36
Phase 2 to Phase 1	2	2	0.50
Lost Creek	0	1	0.00
Split Point to Hwy 126	0	1	0.00
Hendricks to Bellinger	1	0	1.00
Horse Creek	3	34	0.08
Pothole Creek to Trailbridge	0	2	0.00
Separation Creek to Road Access	0	1	0.00
Road Access to Braids	0	2	0.00
Braids to Avenue Creek	0	3	0.00
Avenue Creek to Horse Creek Bridge	1	12	0.08
Horse Creek Bridge to Mouth	2	14	0.13
Middle Fork Willamette	9	3	0.75
Dexter Dam to Pengra Landing	9	2	0.82
Pengra Landing to Jasper	0	1	0.00
Santiam	1	0	1.00
I-5 Bridge to Mouth	1	0	1.00
South Santiam	36	29	0.55
Foster Dam to Pleasant Valley	35	27	0.56

River & Reach	Hatchery	Natural origin	pHOS
South Santiam (cont)			
Pleasant Valley to McDowell Creek	1	2	0.33
North Santiam	9	71	0.11
Big Cliff Dam to Minto Dam	2	53	0.04
Minto Dam to Packsaddle	3	2	0.60
Packsaddle to Gates Bridge	3	8	0.27
Gates Bridge to Mill City	1	0	1.00
Mill City to Fisherman's Bend	0	2	0.00
Fisherman's Bend to Mehama	0	1	0.00
Mehama to Powerlines	0	1	0.00
Powerlines to Upper Bennett	0	1	0.00
Upper Bennett (South Channel) to Stayton	0	2	0.00
Upper Bennett (North Channel) to Stayton	0	1	0.00

Note: Reaches with no carcasses collected are not shown; no carcasses were collected in Fall Creek or the Little North Santiam.

3.4 Coded Wire Tags and Straying

A total of 29 snouts were recovered from nine reaches in 2019. Of the 29 snouts identified in the field as having a CWT, one appeared to have been a false read as no CWT was recovered. In the Middle Fork Willamette, seven snouts were collected in the Dexter to Pengra Bridge reach. In the mainstem McKenzie River below Leaburg Dam, four tags were recovered from Deerhorn to Hendricks, two from Leaburg to Deerhorn, and three Leaburg Dam to Leaburg Landing. In the McKenzie River mainstem above Leaburg Dam, two tags were recovered from Rosboro to Ben and Kay, eight were recovered in the Forest Glen to Rosboro reach. The remaining two tags recovered in the McKenzie River were in Horse Creek Bridge to Mouth reach and one in the South Fork McKenzie River from Cougar Dam to the bridge. Overall, 28 CWT's were extracted by ODFW and entered into the RMIS database.

The CWT data revealed that only a single stray was identified in 2019: this fish was released from McKenzie Hatchery but the carcass was recovered in the North Santiam between Packsaddle and Gates Bridge.

3.5 Otoliths

A total of 289 carcasses had otoliths analyzed for thermal markings, six of these were collected due to unknown adipose fin clip status. Of the 283 unclipped fish which had otolith analysis completed successfully, seven (2.5%) were determined to have been mis-clipped hatchery origin fish. Of these seven mis-clipped fish, two were found in the Big Cliff to Minto Dam reach, and one in the Minto to Packsaddle reach of the North Santiam. One mis-clipped fish was found in the McKenzie between Forest Glen and Rosboro. The remaining three were in tributaries of the McKenzie: two in Horse Creek and one in the South Fork McKenzie.

3.6 Redd Counts

Survey crews first observed fish constructing redds on September 5; the first spawned carcass with <50% egg retention was collected on September 11. Completed redds were first observed in

the South Fork McKenzie on September 11, followed by the North Santiam on September 12, Horse Creek on September 14, the McKenzie on September 18, Fall Creek and the South Santiam on September 19, Lost Creek on September 25, and in the Little North Santiam on September 26. In some reaches, the number of redds observed were the same on different survey days. In these instances, the peak date was assigned to the earlier survey date.

Peak redd counts occurred between September 18 and October 16, with most of the peak counts occurring on the final redd survey in each reach. A total of 66 reaches were surveyed in 2019 and redds were observed in 42 of the reaches. The highest redd densities were recorded in the Phase I restoration area on the South Fork McKenzie (127 redds/km), whereas the Forest Glen to Rosboro reach of the McKenzie had the highest total number of redds (465). Redd counts and redd densities by river and reach are listed in Table 8. Maps showing the location and number of redds along each river and reach are presented in Appendix A.

Table 8. Reach length, redd counts and number of redds per kilometer by river and reach.

River & Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
McKenzie	115.5	1034	9	
Spawning Channel	1.6	35	22	16-Oct-19
Ollalie to Belknap	1.6	21	13	1-Oct-19
Belknap to Paradise	5.3	23	4	1-Oct-19
Paradise to McKenzie Trail	2.4	19	8	1-Oct-19
McKenzie Trail to McKenzie Bridge	2.6	2	1	1-Oct-19
McKenzie Bridge to Hamlin	13.4	78	6	15-Oct-19
Hamlin to S.F. McKenzie	0.5	1	2	18-Sep-19
South Fork McKenzie to Forest Glen	3.9	32	8	15-Oct-19
Forest Glen to Rosboro Bridge	9.2	465	51	3-Oct-19
Rosboro Bridge to Ben Kay	10.5	119	11	3-Oct-19
Helfrich to Leaburg Lake	7.1	36	5	14-Oct-19
Leaburg Dam to Leaburg Landing	9.7	155	16	15-Oct-19
Leaburg Landing to Deerhorn	3.4	0	0	n/a
Deerhorn to Hendricks	12.2	48	4	10-Oct-19
Hendricks to Bellinger	8.8	0	0	n/a
Bellinger to Hayden	7.1	0	0	n/a
Hayden to Armitage	16.4	0	0	n/a
South Fork McKenzie	6.7	265	40	
Cougar to Bridge	3.6	49	14	25-Sep-19
Bridge to Phase 2	1.3	0	0	n/a
Phase 2 to Phase 1	0.8	89	111	9-Oct-19
Phase 1 to Mouth	1.0	127	127	2-Oct-19
Lost Creek	7.7	30	4	
Spring to Cascade	3.4	0	0	n/a
Cascade to Limberlost	0.8	5	6	26-Sep-19
Limberlost to Split Point	2.4	9	4	10-Oct-19
Split Pt to Hwy 126 Bridge	0.8	16	20	10-Oct-19

River & Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
Lost Creek (cont)				
Hwy 126 Bridge to Mouth	0.3	0	0	n/a
Horse Creek	21.7	118	5	
Pothole Creek to Trail Bridge	2.7	20	7	28-Sep-19
Trail Bridge to Separation Creek	1.8	1	1	28-Sep-19
Separation Creek to Road Access	2.4	17	7	12-Oct-19
Road Access to Braids	3.9	0	0	n/a
Braids to Avenue Creek	3.4	18	5	12-Oct-19
Avenue Creek to Horse Creek Bridge	1.9	42	22	12-Oct-19
Horse Creek Bridge to Mouth	5.6	20	4	3-Oct-19
Middle Fork Willamette	12.7	0	0	
Dexter Dam to Pengra Landing	4.3	0	0	n/a
Pengra Landing to Jasper	8.4	0	0	n/a
Fall Creek	10.4	2	<1	
Fall Creek Dam to Pengra Bridge	8	2	0	2-Oct-19
Pengra Bridge to Fall Creek Mouth	2.4	0	0	n/a
Santiam	19.5	0	0	
Confluence to Jefferson	3.4	0	0	n/a
Jefferson to I-5 Bridge	5.8	0	0	n/a
I-5 Bridge to Mouth	10.3	0	0	n/a
South Santiam	54.5	156	3	
Foster Dam to Pleasant Valley	7.2	146	20	2-Oct-19
Pleasant Valley to McDowell Creek	8.7	10	1	9-Oct-19
McDowell Creek to Waterloo	6.9	0	0	n/a
Gills Landing to Sandersons	15.6	0	0	n/a
Sandersons to Mouth/Jefferson	16.1	0	0	n/a
North Santiam	79.1	271	3	
Big Cliff Dam to Minto Dam	6.4	139	22	10-Oct-19
Minto Dam to Packsaddle	0.3	22	73	26-Sep-19
Packsaddle to Gates Bridge	4.5	22	5	11-Oct-19
Gates Bridge to Mill City	6.1	13	2	11-Oct-19
Mill City to Fisherman's Bend	3.2	0	0	n/a
Fisherman's Bend to Mehama	10.5	21	2	28-Sep-19
Mehama to Powerlines	5.6	7	1	11-Oct-19
Powerlines to Upper Bennett	5.6	9	2	11-Oct-19
Upper Bennett (North Channel) to Stayton	5.1	3	1	11-Oct-19
Upper Bennett (South Channel) to Stayton	5.1	30	6	11-Oct-19
Stayton to Shelburn	8.8	2	0	11-Oct-19
Shelburn to Greens Bridge	13.2	3	0	12-Oct-19
Greens Bridge to Mouth	4.7	0	0	n/a
Little North Santiam	28.2	11	<1	
Elkhorn Bridge to Salmon Falls	1.6	0	0	n/a
Salmon Falls to Camp Cascade	1.4	0	0	n/a

River & Reach	Reach Length (km)	# of Redds	Redds/km	Date of Final Count
Little North Santiam (cont)				
Camp Cascade to Narrows	1.9	3	2	26-Sep-19
Narrows to Golf Bridge	1.4	4	3	10-Oct-19
Golf Bridge to Bear Creek Bridge	5.5	4	1	10-Oct-19
Bear Creek to Lomkers	3.1	0	0	n/a
Lomkers Bridge to NF Park	6.4	0	0	n/a
NF Park to HWY 22 Bridge	4.5	0	0	n/a
Hwy 22 Bridge to Mouth	2.4	0	0	n/a

3.7 Spawner Abundance and Carcass Recovery Rates

Spawner abundance estimates based on redd counts are provided by river and reach in Table 9. This data was compared to the total number of carcasses collected by river and reach to determine carcass recovery rates, which is the number of carcasses collected out of the estimated spawner abundance. Spawner abundance estimates by origin were calculated for river basin sections as shown in Table 10.

Table 9. Carcass recovery rates compared to spawner abundance by river and reach.

River & Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
McKenzie	2585.0	255	9.9%
Spawning Channel	87.5	14	16.0%
Olallie to Belknap	52.5	0	no carcasses
Belknap to Paradise	57.5	4	7.0%
Paradise to McKenzie Trail	47.5	6	12.6%
McKenzie Trail to McKenzie Bridge	5.0	4	80.0%
McKenzie Bridge to Hamlin	195.0	19	9.7%
Hamlin to S.F. McKenzie	2.5	0	0.0%
South Fork McKenzie to Forest Glen	80.0	5	6.3%
Forest Glen to Rosboro Bridge	1162.5	128	11.0%
Rosboro Bridge to Ben Kay	297.5	29	9.7%
Helfrich to Leaburg Lake	90.0	8	8.9%
Leaburg Dam to Leaburg Landing	387.5	20	5.2%
Leaburg Landing to Deerhorn	0.0	2	no redds
Deerhorn to Hendricks	120.0	15	12.5%
Hendricks to Bellinger	0.0	1	no redds
Bellinger to Hayden	0.0	0	n/a
Hayden to Armitage	0.0	0	n/a
South Fork McKenzie	662.5	27	4.1%
Cougar to Bridge	122.5	12	9.8%
Bridge to Phase 2	0.0	4	no redds
Phase 2 to Phase 1	222.5	0	0.0%
Phase 1 to Mouth	317.5	11	3.5%

River & Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
Lost Creek	75.0	1	1.3%
Spring to Cascade	0.0	0	no redds
Cascade to Limberlost CG	12.5	0	no carcasses
Limberlost to Split Point	22.5	0	no carcasses
Split Pt to Hwy 126 Bridge	40.0	1	2.5%
Hwy 126 Bridge to Mouth	0.0	0	n/a
Horse Creek	295.0	37	12.5%
Pothole Creek to Trail Bridge	50.0	2	4.0%
Trail Bridge to Separation Creek	2.5	0	no carcasses
Separation Creek to Road Access	42.5	1	2.4%
Road Access to Braids	0.0	2	no redds
Braids to Avenue Creek	45.0	3	6.7%
Avenue Creek to Horse Creek Bridge	105.0	13	12.4%
Horse Creek Bridge to Mouth	50.0	16	32.0%
Middle Fork Willamette	0.0	12	no redds
Dexter Dam to Pengra Landing	0.0	11	no redds
Pengra Landing to Jasper	0.0	1	no redds
Fall Creek	5.0	0	no carcasses
Fall Creek Dam to Pengra Bridge	5.0	0	no carcasses
Pengra Bridge to Fall Creek Mouth	0.0	0	n/a
Santiam	0.0	1	no redds
Confluence to Jefferson	0.0	0	n/a
Jefferson to I-5 Bridge	0.0	0	n/a
I-5 Bridge to Mouth	0.0	1	no redds
South Santiam	390.0	65	16.7%
Foster Dam to Pleasant Valley	365.0	62	17.0%
Pleasant Valley to McDowell Creek	25.0	3	12.0%
McDowell Creek to Waterloo	0.0	0	n/a
Gills Landing to Sandersons	0.0	0	n/a
Sandersons to Mouth/Jefferson	0.0	0	n/a
North Santiam	677.5	80	11.8%
Big Cliff Dam to Minto Dam	347.5	55	15.8%
Minto Dam to Packsaddle	55.0	5	9.1%
Packsaddle to Gates Bridge	55.0	11	20.0%
Gates Bridge to Mill City	32.5	1	3.1%
Mill City to Fisherman's Bend	0.0	2	no redds
Fisherman's Bend to Mehama	52.5	1	1.9%
Mehama to Powerlines	17.5	1	5.7%
Powerlines to Upper Bennett	22.5	1	4.4%
Upper Bennett to Stayton (North Channel)	7.5	1	13.3%
Upper Bennett to Stayton (South Channel)	75.0	2	2.7%
Stayton to Shelburn	5.0	0	0.0%
Shelburn to Greens Bridge	7.5	0	0.0%
Greens Bridge to Mouth	0.0	0	n/a

River & Reach	Spawner Abundance (Redds*2.5)	Total Carcasses	Carcass Recovery Rate (Carc./Spawn.)
Little North Santiam	27.5	0	no carcasses
Elkhorn Bridge to Salmon Falls	0.0	0	n/a
Salmon Falls to Camp Cascade	0.0	0	n/a
Camp Cascade to Narrows	7.5	0	no carcasses
Narrows to Golf Bridge	10.0	0	no carcasses
Golf Bridge to Bear Creek Bridge	10.0	0	no carcasses
Bear Creek Bridge to Lomkers	0.0	0	n/a
Lomkers Bridge to NF Park	0.0	0	n/a
NF Park to HWY 22 Bridge	0.0	0	n/a
Hwy 22 Bridge to Mouth	0.0	0	n/a

Table 10. Spawner abundance estimates by origin for specified basin sections.

Basin Sections	Redd Count	Spawner Abundance (Redds*2.5)	pHOS	Spawner Abundance	
				Hatchery origin	Natural origin
McKenzie below Leaburg Dam	203	507.5	0.68	345	162
McKenzie above Leaburg Dam (including SF McKenzie, Horse Creek, and Lost Creek)	1244	3110	0.34	1057	2053
MF Willamette and Fall Creek below Fall Creek Dam	2	5	0.75	4	1
Santiam	0	0	0.00	0	0
South Santiam	156	390	0.55	215	176
North Santiam above Minto Dam	139	347.5	0.04	14	334
North Santiam below Minto Dam and Little North Santiam	143	357.5	0.28	100	257

Note: Natural and hatchery origin spawner abundance rounded to the nearest whole fish.

4 Discussion

4.1 Prespawn Mortality Estimates

We observed reduced PSM in 2019 compared to 2018 in the South Santiam (14% vs 18%, respectively), McKenzie above Leaburg Dam (3% vs 16%), McKenzie below Leaburg Dam (12% vs 14%), and in the North Santiam (5% vs 37%). PSM rates observed across all rivers in 2019 were significantly lower at 6% than the 18% observed in 2018 (Fisher's Exact: $p < 0.001$). Factors that may have resulted in the observed reduction in PSM could be the higher peak flows observed in the spring of 2019 (Figure 7), and possibly lower water temperatures in June (Figure 7). As was observed in 2018, we did not detect a difference in the proportions of PSM between hatchery and natural origin fish for all rivers.

The temporally balanced survey design conducted in 2019 should increase confidence in the estimates of PSM. Surveys began on July 3, well before the initiation of spawning, however passage at Willamette Falls peaks during mid-April and early May (JCRMS 2020). As a result, it is possible that some PSM occurred prior to the start of our surveys. Although we did collect a

carcass on our second day of surveys (July 4), the next carcass was not collected until 3 weeks later (July 24), indicating very low rates of PSM early in the survey season.

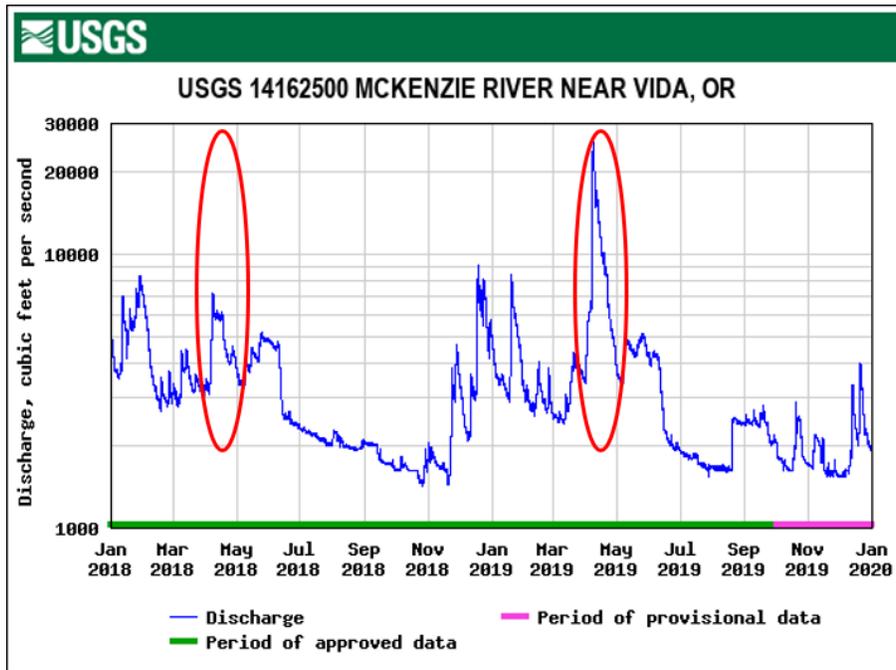


Figure 7. High peak flows were present on the McKenzie during the spring of 2019 but were absent in 2018, as indicated in red.

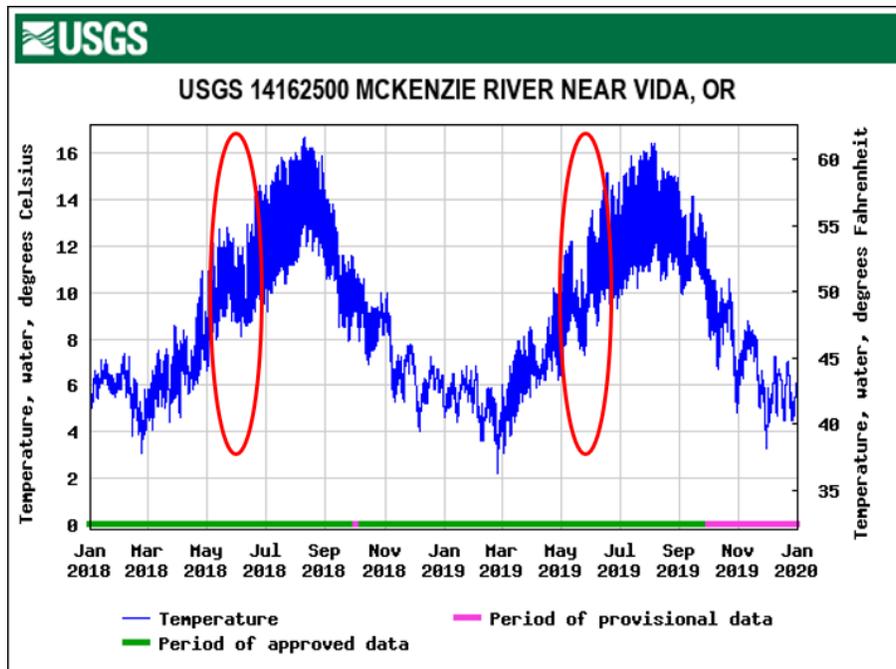


Figure 8. Lower temperatures observed on the McKenzie in June 2019 compared to June 2018, as indicated in red.

4.2 Carcass Recovery Rates

Carcass recovery rates ranged from lows of 0% in the Little North Santiam and 1% in Lost Creek to highs of 17% in the South Santiam and 12% in the North Santiam and Horse Creek. A variety of factors may contribute to the observed variability in carcass recovery rates including level of surveyor effort, river conditions (e.g., flow, water clarity, debris), survey timing, spawning timing, and redd count accuracy. Some rivers, Lost Creek for example, are complex, fast moving rivers which can result in lower carcass recovery rates. Alternatively, the South Santiam is characterized by slower water velocities and less stream complexity, and consequently carcass recovery rates were much higher.

ODFW survey crews also collected carcasses on the McKenzie, South Fork McKenzie, and Horse Creek in the same reaches surveyed by EAS for this project, however the methodology and level of effort for the ODFW surveys is not known. In reaches where both crews were collecting carcasses, a carcass collected by one crew would be unavailable to the other crew (both crews marked processed carcasses by removing the tail, which is necessary to avoid double-counting, but also renders carcasses unavailable for processing by the other crew). EAS staff coordinated with ODFW to attempt to stagger surveys so that crews were not surveying the same reaches on the same days; as a result, ODFW and EAS crews surveyed the same reach on the same day on only a few occasions during the season. The presence of the ODFW crew reduced the overall carcass recovery rate for this project, but the combined carcass recovery rate from the two crews was likely higher overall because the frequency of surveys was increased. An analysis of the combined datasets would be required to determine if and how the collection of carcasses by ODFW affected the results described in this report. A more complete analysis could be performed by combining the datasets from the two carcass crews in the specific rivers and reaches where ODFW conducted surveys, assuming sampling protocols are comparable.

4.3 Coded Wire Tags

Of the 29 snouts collected in the field, only a single snout did not result in an extracted CWT in 2019; the snout was either a false positive read in the field and on the V-reader, or the tag was lost. One stray from the McKenzie Hatchery was recovered in the North Santiam, producing an overall straying rate of only 3%, compared to 31% in 2018; however, these differences are based on relatively low sample sizes and may not be representative of true straying rates. A total of 16% of clipped fish were found to have a CWT in 2019, which was higher than the 2.8% collected in 2018. Also, the distribution of carcasses was very different between the two years: in 2019, 53% of carcasses were collected on the McKenzie compared to only 27% in 2018.

4.4 Scale Age Analysis

The rate of agreement between ages from scale reads and ages from the CWT data was 96%, with conflicting results from only a single fish from the Middle Fork Willamette which produced a scale age of 4 versus a CWT age of 5. This rate of agreement was a substantial improvement compared to 2018, when rates of agreement were 71% in the South Santiam and 27% in the McKenzie. CWT data was provided to the ODFW prior to scale analysis for 2019, allowing for validation of scale age estimates.

4.5 Factors Affecting Redd Counts

Factors that may influence redd counts include surveyor experience, redd life, boat type, survey timing, spawning timing, experience with habitat locations on individual reaches, frequency of redd counts (e.g. weekly, biweekly, etc.), river conditions, and frequency of early of redd construction observations. Crews regularly surveyed reaches beginning in early July and generally surveyed reaches every 14 days for the duration of the season; this allowed them to become familiar with the location of redds and relative number of live fish remaining. Eight of the ten crew members returned from the 2018 season, so those crew members were very familiar with the specific river reaches and locations of spawning habitat. The addition of some aerial photographs of spawning reaches could provide an index that would help to determine the accuracy of on-the-water visual counts in a variety of river conditions.

4.6 Flows in the Little North Santiam

Water levels in the Little North Santiam were higher in 2019 compared to 2018. The elevation of the headwaters for this basin is relatively low compared to the other drainages surveyed, which are either dam controlled or glacially fed, resulting in greater flow variability due to changing weather conditions. The increased water level likely improved passage for Chinook and the number of redd increased from two in 2018 to 11 in 2019.

4.7 South Fork McKenzie River Habitat Restoration

In 2018 and 2019, habitat restoration projects were completed by the United States Forest Service (USFS) on the South Fork McKenzie River, from the mouth upstream 0.6 miles in Phase 1 (2018) and an additional 0.5 miles in Phase 2 (2019). The South Fork McKenzie was diverted onto a historical floodplain, then the main channel was recontoured and logs were deposited in the restoration area. The amount of woody debris deposited in the habitat restoration made surveying difficult, not only because of the difficulty of navigating unstable woody debris but also the introduction of clean gravels lacking periphyton making redds less discernable.

The South Fork McKenzie was historically broken into two reaches in the survey schedule: Cougar Dam to Forest Service 19 Bridge, and Forest Service 19 bridge to the Mouth, both of which were surveyed by boat. Due to the difficulty of walking over the new logs and debris, the lower reach was split into 3 reaches in 2019; Forest Service 19 bridge to Phase 2, Phase 2, and Phase 1. Forest Service 19 bridge to Phase 2 was still surveyed by boat, whereas Phase 2 and Phase 1 reaches were surveyed by traversing the woody debris on foot (Figure 9). For safety reasons related to instream restoration work, construction of Phase 2 delayed surveying of the Bridge to Phase 2 and Phase 2 to Phase 1 reaches by three weeks.



Figure 9. Phase 1 of USFS habitat restoration, South Fork McKenzie.

4.8 South Santiam 2018 vs. 2019

In 2019 lower return numbers were observed on the South Santiam compared to 2018, with the greatest differences observed in the Foster to Pleasant Valley reach. In 2019 survey crews counted 146 redds which was down from 570 redds observed during the 2018 spawning season. Several factors may account for this reduction. According to counts performed by ODFW at the Foster Dam Facility, the numbers of adult spring Chinook were lower at the Foster Dam Fish ladder trap as well. In 2018, a total of 1425 adult spring Chinook were counted in the fish ladder trap, versus only 973 fish in 2019. The high flow event that occurred during 2019 also appeared to have redistributed gravels below Foster Dam, and some of the spawning locations used in 2018 became too shallow to be used in 2019. Finally, there was also a lower proportion of age four returning fish in this reach in 2019 compared to other rivers in the basin (Figure 10).

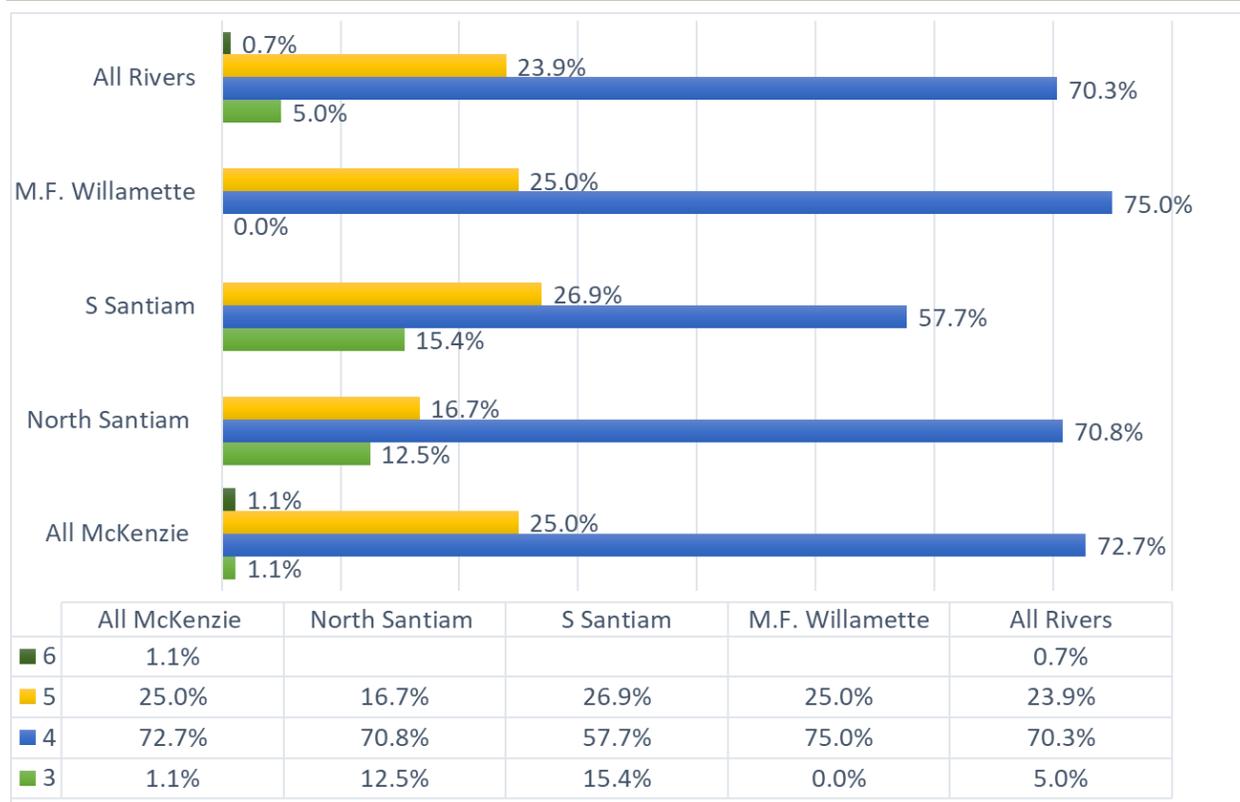


Figure 10. Age distribution of fish in 2019, showing lower proportion of age 4 fish on the South Santiam.

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Appendix A: Redd Counts and Locations

