Winter Steelhead Spawning Ground Surveys, 1973-2020

Salmonberry River (Nehalem Basin), Oregon

North Fork Salmonberry (Photo: James Fraser)

A STEP Project Report

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Contents

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1.Executive Summary

Redd counts of winter steelhead (*Oncorhynchus mykiss*) have been conducted on the Salmonberry River almost continuously from 1973 through 2020. Until 1994, the same three-mile reach was surveyed by the Oregon Department of Fish and Wildlife (ODFW). Beginning in 1994, multiple reaches have been surveyed, by ODFW and by a volunteer group under STEP (Salmon Trout Enhancement Program).

Redd density, expressed as redds per mile, varies widely and follows long-term cycles. The properties of these data present difficulties in statistical analysis, but all indications are that there is no discernible trend in redd density over the 47 years of observation – redd density cycles widely around a long-term mean of 24.1 redds/mile, pointing to a stable and productive population.

There is evidence that habitat damage on the main stem Salmonberry resulting from the December 2007 flood resulted in increased spawning in the North Fork, a major tributary that escaped significant flood damage.

2.Introduction

ODFW began peak redd count surveys on the 3-mile "Enright" reach of the Salmonberry in 1973. This reach has been almost continuously surveyed since then, missing only 1978. Surveys done in 1996 and 2008 were hampered by the poor conditions following the major flood events of February 1996 and December 2007. Since the mid-90's the reach has been surveyed by Walt Weber and other volunteers from Rainland Flycasters, with assistance from ODFW as needed.

In 1993 a STEP project was established to collect spawning data on other reaches in the Salmonberry. ODFW identified the additional reaches. The spring of 1993 was used for exploration and a sense of run timing; the 1993 counts were not kept. The effort was initially led by Marty and Joyce Sherman, who recruited volunteers from a number of organizations: Northwest Steelheaders, Oregon Trout, Trout Unlimited, Clark-Skamania Flyfishers, Native Fish Society, Americorps, and Sierra Club. In 1994 the team surveyed eight reaches, from early March through the end of May. Surveys have been done every year since.

A previous report covering results and methodology through 2008 can be found at the ODFW Data Clearinghouse web site, https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx ,searching on the key word "Salmonberry". The present report focuses primarily on trend analysis.

3. Spawning Distribution/Extent of Coverage

Reach descriptions and a watershed map are shown in Appendix A. The nine reaches described in Appendix A cover approximately 12 miles, or 50% of the estimated total stream miles available for spawning. There has been some adjustment of reach lengths since the previous report, due to more accurate measurements.

In addition to regular surveys of defined reaches, we have conducted periodic ad-hoc surveys to determine the extent of spawning habitat used by winter steelhead. In total, there are approximately 24 miles used for spawning in the main stem and the three largest tributaries (North Fork, South Fork, and Wolf Creek).

There are two barrier waterfalls where redds have been observed immediately below, but not above. These are in the upper main stem above Pennoyer Creek at RM 14.5 (approx.), and in a second-order tributary of Wolf Creek about 1.7 miles above Wolf Creek's confluence with the Salmonberry. There is a third barrier waterfall in Pennoyer Creek about 100 yards above its confluence with the Salmonberry. The part of Pennoyer Creek below the falls is occasionally used by steelhead. Although there are other impassable falls throughout the headwaters, it is likely that spawning is curtailed by low flows and limited gravel some distance downstream of those barriers.

4. Methods

The previous report covered field methodology in detail. For purposes of this report, the part that bears repeating is the "peak" method vs. the "cumulative" method of redd counting. Standard protocol for the ODFW Enright peak surveys has been to conduct two surveys about two weeks apart during the peak spawning period of late April – early May. All visible redds are counted in each survey, whether counted previously or not. Adult fish are also counted. Peak fish counts and peak redd counts do not necessarily coincide.

In the cumulative method of counting, which is the generally favored method, surveys are done every 10-14 days throughout the spawning season. Each redd is marked with a painted stone in the redd, and annotated flagging on a nearby tree. Each redd is counted only once. This method allows for a more accurate count of spawning activity, and a much better sense of run timing. The drawback is that it is extremely labor-intensive.

The STEP team conducted peak counts in 1994. In 1995 the team was asked to begin marking redds and to count only unmarked redds on subsequent visits. That protocol was followed through 2009, but turned out to be too ambitious for a group of volunteers. Initially, surveys were conducted weekly from early March to the end of May. In 1999 the team stopped surveying in March, and changed the survey interval to two weeks at the suggestion of ODFW. Dropping the March surveys was based on a combination of factors: the difficulty of recruiting enough volunteers for such a long season; the likelihood of high water conditions in March; and frequent difficult access on logging roads due to snow. The team has not always been able to find and train the volunteers needed to maintain even that reduced level of surveying activity. In some years, some reaches were surveyed only once in a season, with inconsistent timing from year to year. Since 2009 counts have been done using only the peak methodology, ideally twice per season per reach, approximately two weeks apart.

For this report, and for the data tables published to the ODFW Data Clearinghouse, I adjusted all the STEP "cumulative" counts 1995-2008 to estimated "peak" counts, using a formula based on the visibility curve developed by Susac and Jacobs (1999).

The sole exception to the use of peak counts in this report is that I used ODFW season counts for the Wolf Creek to Pennoyer Creek reach when the Corvallis research unit conducted their random redd surveys on that reach. This happened in 2005, 2010-12, and 2017 – 20. The ODFW random surveys have also been done on other reaches in other years; however, those counts generally overlapped portions of reaches that the STEP team or Rainland Flycasters had also surveyed in the same year, so using those results would constitute double counting.

5. Data Sources

Redd counts in this report are based primarily on the “Peakcounts” tab on the Excel workbook “Salmonberry STEP Spawning Survey Data.xls” on the ODFW Data Clearinghouse website, https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx . The data in that workbook relating to the Enright reach came from Walt Weber (personal communication) and the “Streamnet” database (internet link to Salmonberry data now broken).

Data from the ODFW random surveys on the Wolf Creek to Pennoyer Creek reach came from annual reports under https://odfw.forestry.oregonstate.edu/spawn/datasumm.htm .

Wilson River hydrograph data were downloaded from http://waterdata.usgs.gov/nwis/ . The Wilson occupies the watershed immediately north of the Salmonberry and, like the Salmonberry, is a relatively short system. There is no recording station on the Salmonberry.

In this data series, 1978 is missing, and I removed 1996 and 2008 due to difficulty in access for surveying as well as damage from floods tending to obscure redds, if they were present. Extremely low numbers were recorded for those years, and it was not possible to say whether that was a result of difficulty in finding redds, or indicative of population changes independent of flooding. See 7.1, Major Flood Events, for further discussion of possible flood effects.

A table with redd counts by reach, reach lengths, and redds per mile can be found in Appendix B.

6. Data Analysis Techniques

I performed data analysis using the open-source software program R (R Core Team, 2019).

Redd count data often have characteristics that make it difficult to detect trends. Foremost among these characteristics is the sizeable variation in counts between years, coupled with cycles having relatively long periods. Anadromous fish runs can exhibit wide fluctuations over time, often associated with major climate regimes such as the Pacific Interdecadal Oscillation (Mantua et al., 1997). Inter-annual variation in redd counts may reflect differing conditions: for example, a recent high-water event can obscure redds, and unusually high or low phytoplankton growth can affect redd visibility.

Another source of variability is observer error. Even though errors in the form of false identifications (additions) and missed redds (subtractions) tend to cancel each other out, there can still be considerable variation among observers when assessing “true” redd numbers versus “observed”, as pointed out by Dunham et al. (2001) and Muhlfeld et al. (2006) with regard to bull trout.

Time series data such as these often display serial correlation, a property in which an observation is dependent on previous observations. The peaks and valleys we see in the cycling of redd counts tend to not occur randomly; rather, they represent change points in a cycle. For some period, say 5 to 10 years, redd counts tend to go in one direction before changing direction. Fitting a trend line to serially correlated data points can result in overly optimistic estimates of correlation and the confidence intervals around the slope of the trend line.

In this analysis I report redds per mile. Redd counts by themselves would not be appropriate, as the number of miles surveyed varies from year to year. Ratio data such as these present additional difficulties as they may violate key assumptions behind standard statistical tests (Liermann et al., 2004). For example, redds/mile data, as well as straight redd counts, have a hard bound of 0 on the lower end and are unbounded on the upper end, tending to result in skewed distributions that can complicate statistical analysis.

Notwithstanding the underlying data problems, I elected to display results with charts that display a “trend” line based on ordinary least squares regression, a common method used to evaluate possible trends. I also include a line based on a four-year centered moving average, which smooths the data and helps visualize underlying cycles. Four years represents the most common generation time for winter steelhead.

Following the suggestions of Steidl et al. (1997) and Johnson (1999), I did not test for statistical significance, instead reporting confidence intervals and other statistics such as r, the correlation coefficient, and r-squared, a measure of how close the data are to the calculated regression line. As noted, due to the nature of the data, all of these measures are probably overly optimistic; a more statistically rigorous approach might well result in lower coefficients and wider confidence intervals.

Although a 95% confidence level is generally accepted in scientific studies, it may not be appropriate for this type of highly variable data where management decisions might be based on apparent population trends; in such cases, it may be prudent to accept less precise estimates, especially considering the risks of failing to detect a declining trend (Johnson, 1999; Maxell, 1999). Accordingly, I elected to display a 90% confidence interval.

7. Results and Discussion

7.1. Major Flood Events

Data for 1996 and 2008, although collected, were removed for this analysis due to flood effects making redd counts unreliable.

There was a record flood in February 1996 (Wilson River peak 28,000 CFS, flood stage 14,000 CFS), followed by an unusual April flood event (Wilson 14,500 CFS). This combination made redd counts extremely unreliable for that year.

The December 2007 flood (Wilson River peak 26,800 CFS) caused more localized damage in the Salmonberry than the 1996 flood. Spawning habitat in the Enright reach, and most of the mainstem, was heavily damaged, with channelization, scouring, loss of pools, and gravel deposition above normal high-water levels. Kavanagh and Jones (2009), in summarizing detailed stream surveys done in the summer of 2008, stated that “deleterious long-term impacts to the Salmonberry River fish populations and instream habitat may result from an increased deposition of fine materials from scoured banks, landslides and debris avalanches into the stream.”

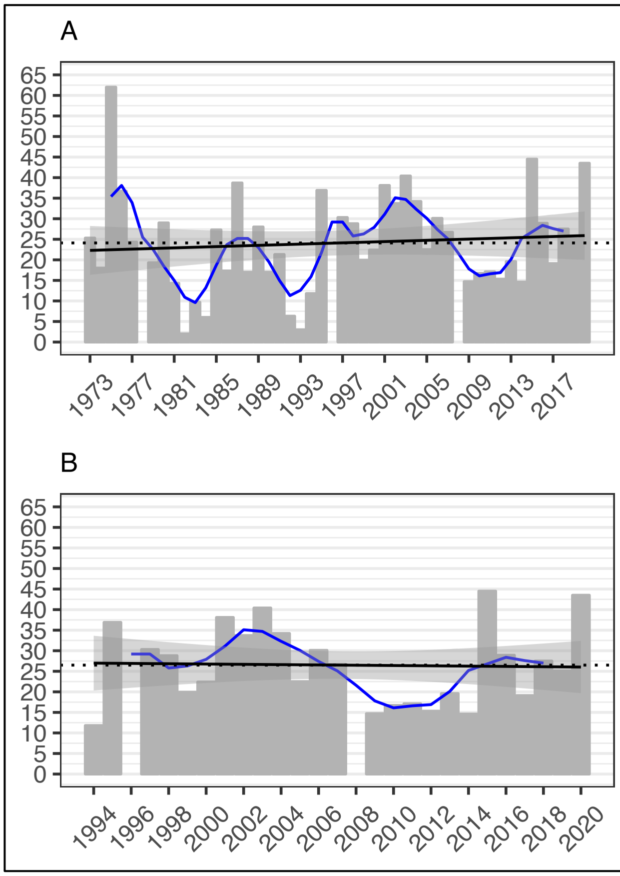
Redd densities in damaged reaches appear to track with anecdotal observations of not only the decline but also the recovery of spawning habitat, as the perched gravel deposits are recruited back into the stream channel with typical high water events.

It is possible that floods affected redd counts in other years. 1978 is missing from the data; there was a flood on the Wilson River (21,500 CFS) in December 1977 that may have contributed to the missing data in the 1978 spawning season. A count of 6 redds in 1982 might have been related to high water in January (Wilson River 14,200 CFS).

Floods do not necessarily result in low redd counts, and low redd counts can occur for other reasons. In 1993 the peak Enright count was 9 redds, with no floods in the winter/spring preceding the count. There have also been higher counts following floods, such as Enright's 101 redds in 2006, which followed January flooding (Wilson River 18,100 CFS). Flooding in April 1991 (Wilson River 19,300 CFS), which came in the peak spawning month and could have made counting nearly impossible, still allowed for an Enright count of 64 redds.

7.2. System-Wide Results, 1973–2020 and 1994-2020

Figure 1 shows redd density by year for two periods (A, 1973-2020; B, 1994-2020). From 1973 through 1993, redd density is based only on the 3-mile Enright reach. Beginning in 1994, up to seven additional reaches contribute to the numbers (averaging 11 miles of surveyed reaches annually). This makes the 1994-2020 portion of the dataset more reliable (i.e., less variable) than the earlier portion. The coefficient of variation (standard deviation divided by the mean) is much higher for 1973-1993 than it is for 1994-2020 (.668 and .360, respectively). Even with that limitation, it is still useful to look at the entire period (Fig.1A).



A. All reaches, 1973–2020. Data from 1973 – 1993 are based on the Enright reach The dotted line represents the mean redd density for all years, 24.1 redds/mile. The solid black line is the least squares regression line; the blue line is the 4–year centered moving average; the 90% confidence band is shown in light grey; r = .089; rsquared = .008.

B. All reaches, 1994–2020. The dotted line represents the mean redd density for all years, 26.5 redds/mile. The solid black line is the least squares regression line; the blue line is the 4–year centered moving average; the 90% confidence band is shown in light grey; r = –.03; rsquared = .0009.

Figure 1.

Although there is a minor difference in the slope of the regression lines, with Fig. 1A suggesting a slight increasing trend and Fig. 1B suggesting an almost imperceptible decreasing trend, neither can be considered significant. The confidence bands for both regressions would allow for positive and negative slopes. What we can say at this point is that there is no apparent trend; both patterns point to a stable population that experiences wide inter-annual swings, but continues to return to the long-term mean.

In Fig. 1A, the 1975 value of 62 redds/mile recorded on the Enright reach looks like an outlier, and in that particular regression it probably causes the line to tilt closer to level than it might with a lower value. In reality, however, that value is not an outlier. After 1994, with multiple reaches surveyed each year, there have been 22 occurrences of reaches with densities exceeding 62 redds/mile. When those are combined with the results from other reaches, the average for the year comes down. This is a clear benefit to surveying multiple reaches each year. Another benefit can be seen when a shift in spawning activity occurs that may not be indicative of an overall population change (see 7.3., Shift in Reach Use).

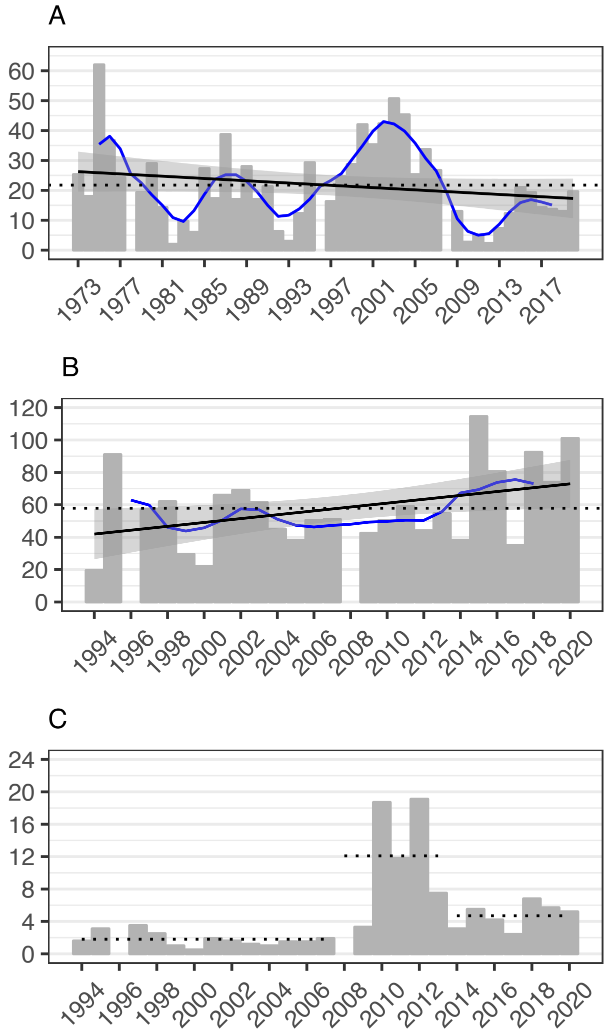
A major difficulty with using a linear model with these data is that the correlation coefficients (r, a measure of the strength of the relationship between year and redd density) for these two series are extremely low at .089 and -.03, meaning there is almost no correlation. The r^2 values, at .008 and .0009, indicate that the linear models explain less than 1% of the variation in redd density. Clearly, a simple linear regression using year as the explanatory variable does not provide a good fit to the data. A model that might explain more of the variability in the data from year to year would also include factors in the Pacific that affect smolt-to- adult survival (e.g. the Pacific Decadal Oscillation and/or its forcing factors); there are also conditions affecting the fresh water life cycle (e.g., summer water temperatures, summer water supply, and scouring floods), which in turn might interact with population density dependence phenomena and affect egg-to-smolt survival.

7.3. Shift in Reach Use – Enright to North Fork

Figure 2, panel A shows a decline in redd density for the Enright reach. Although there have been low numbers recorded prior to 2008, it does appear than low redd counts since then are related to physical habitat changes discussed in Section 7.1. There was an abrupt drop in redd density after the flood.

Following the 2007 flood, the North Fork did not display the obvious physical habitat changes seen on the mainstem. Figure 2, panel B shows an increase in redd density for the North Fork, driven by large increases in recent years. In contrast to the Enright reach, redd density in the North Fork changed little from the few years before the 2007 flood to the few years after.

Figure 2, panel C shows the ratio of North Fork redd density to Enright redd density over three periods. The boundary for the first period is clear: 2007 was the last spawning season prior to the December 2007 flood. The other two periods have somewhat arbitrary boundaries, but the overall pattern would not change significantly even if boundaries were to shift slightly right or left.



A. Enright Reach, 1973–2020. The dotted line represents the mean redd density for all years, 21.7 redds/mile. The solid black line is the least squares regression line; the blue line is the 4–year centered moving average; the 90% confidence band is shown in light grey; r = –.196; rsquared = .0386.

B. North Fork, 1994–2020, with the mean redd density for all years (21.7 redds/mile), least squares regression line, 4–year centered moving average, and 90% confidence band; r = –.392; rsquared = .154.

C. Relative redd density, North Fork:Enright. The dotted lines show the North Fork:Enright ratios for 3 periods: before the December 2007 flood, 2009–2013, 2014–2020.

Fig. 2

The abrupt change in ratio (from 1.8 X Enright to 12.1 X Enright) after the flood supports the notion of returning mainstem-hatched steelhead turning into the North Fork after finding severely degraded spawning habitat on the mainstem. After 2013, the ratio dropped to 4.7 X Enright. This drop could be due to a combination of the recovery of mainstem spawning areas, and an externally-driven increase in returns (an "up" cycle). Referring to panel B, note that the redd density in the North Fork has continued to increase even as the ratio drops; both Enright and the North Fork therefore are seeing substantial gains.

Some possible scenarios regarding steelhead spawning in the spring of 2008 and following years include:

> Steelhead continued to spawn in the damaged reaches, and most redds were not detectable, resulting in artificially low counts. This seems unlikely to have occurred to a significant extent, especially considering the long experience of the primary surveyor (Walt Weber) on the Enright reach.

> Steelhead sought out less damaged reaches of the Salmonberry, even though they might otherwise have spawned in the mainstem, and many of them used reaches that were not surveyed.
>
> Steelhead failed to enter the Salmonberry in significant numbers, and strayed elsewhere. This would depend on what cues the fish use to identify their natal stream, and to what extent those cues were masked. This effect would be indistinguishable from a "down" cycle.
>
> A normal "down" cycle occurred that coincided with the most severe period of flood damage. There is corroborating evidence of this in the Oregon Coast DPS, where 2009 showed the lowest wild steelhead redd estimates over a 14-year period (Jacobsen et al., 2019).

It is likely that some combination of the above occurred, such as a "down" cycle combined with steelhead movement to reaches they might not have otherwise used. The results on the North Fork appear to bear this out. In a down cycle with no flood damage, North Fork numbers would be expected to drop. Instead, they remained relatively level. With steelhead spawning shifting from the mainstem to the North Fork due to flood damage, North Fork numbers could remain level in spite of the downturn. A further indicator of this is the notable increase in redd density starting in 2015. Assuming that steelhead tend to return to their natal tributary, this is when we would expect to see a compound effect: the progeny of "mainstem" fish that turned up the North Fork to spawn returned to the North Fork, after spending at least 2 years in fresh water and 2 or more years in salt water.

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Appendix A. Reach Locations

		Start		End	
Reach	Miles	Lat.	Long.	Lat.	Long.
Mainstem-Buick Canyon Cr. to Belfort Cr.	1.0	45.7415	-123.63359	45.73305	-123.60361
Mainstem-Enright to North Fk (1973-2018)	3.0	45.72596	-123.57299	45.71726	-123.52362
Mainstem-Enright to North Fk (2019 -)	2.7	45.72435	-123.57299	45.71726	-123.52362
Mainstem-North Fork to Belding Crossing	1.8	45.71726	-123.52362	45.70612	-123.4951
Mainstem- Belding Crossing to Kinney Cr.	0.4	45.70612	-123.4951	45.70573	-123.48352
Mainstem-Kinney Cr. To Wolf Cr.	1.3	45.70573	-123.48352	45.70846	-123.45918
Mainstem-Wolf Cr. To Pennoyer Cr.	1.6	45.70846	-123.45918	45.71882	-123.4393
North Fork - Lower Reach	1.2	45.72899	-123.50751	45.73755	-123.48707
North Fork-Upper Reach	0.8	45.74595	-123.48965	45.75616	-123.48623
South Fork- mouth to Ripple Cr.	1.0	45.71398	-123.54705	45.70245	-123.55842

Table A1. Reaches contributing data to this report.

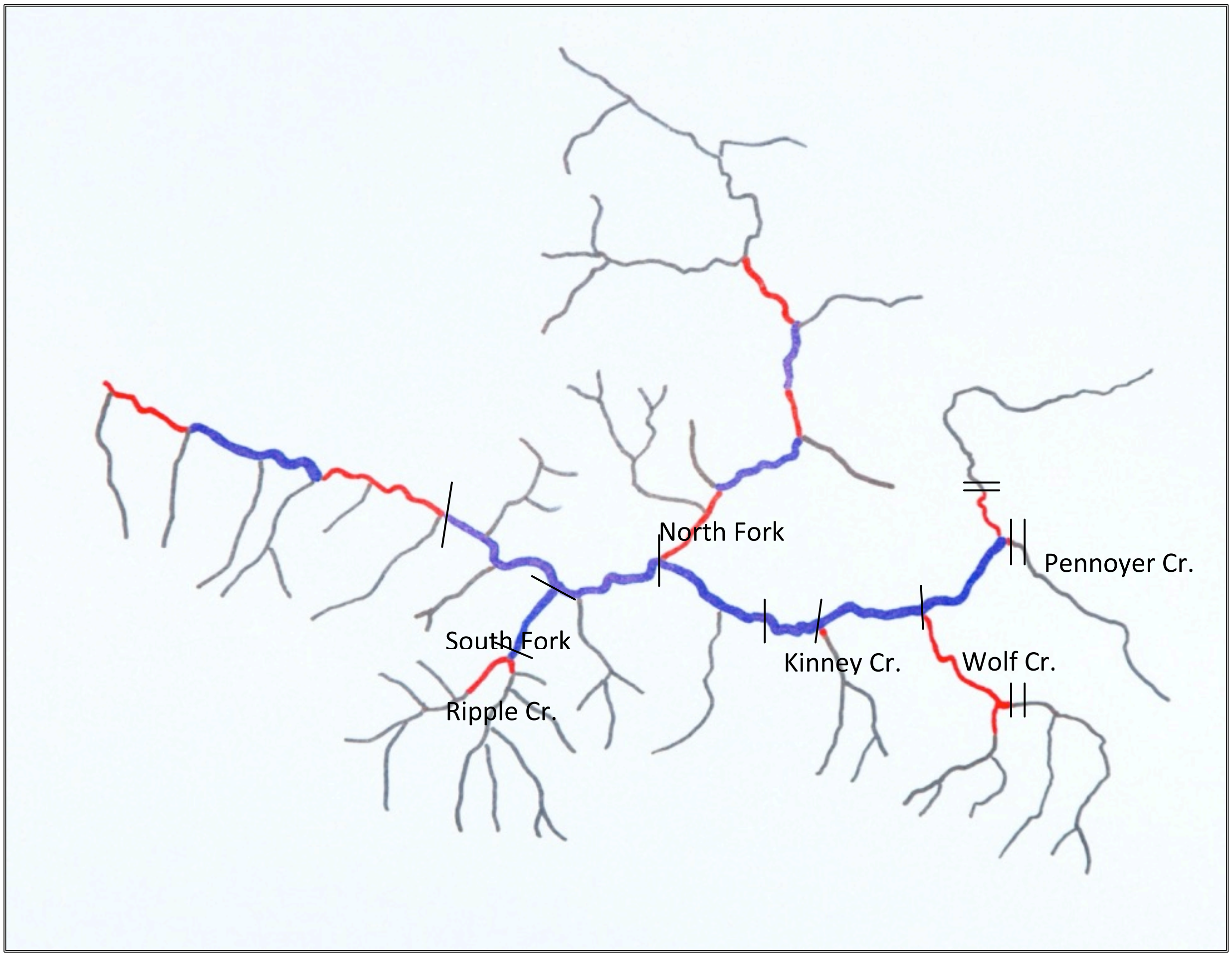

Figure A1. Salmonberry watershed map showing defined reaches (blue), with breaks for adjacent reaches indicated by single lines. Verified extent of winter steelhead spawning outside defined reaches is shown in red. Barrier waterfalls known to prevent steelhead migration are shown by double lines.

Appendix B. Data Table

	Total System			Mainstem						Tributaries					
Year	Total Redds	Total Miles	Total Redds/Mi	Enright Redds	Enright Miles	Enright Redds/Mi	Other MS Redds	Other MS Miles	Other MS Redds/Mi	North Fork Redds	North Fork Miles	North Fork Redds/Mi	South Fork Redds	South Fork Miles	South Fork Redds/Mi
1973	76	3.0	25.3	76	3.0	25.3									
1974	54	3.0	18	54	3.0	18									
1975	186	3.0	62	186	3.0	62									
1976	110	3.0	36.7	110	3.0	36.7									
1977	73	3.0	24.3	73	3.0	24.3									
1978															
1979	58	3.0	19.3	58	3.0	19.3									
1980	87	3.0	29	87	3.0	29									
1981	43	3.0	14.3	43	3.0	14.3									
1982	6	3.0	2	6	3.0	2									
1983	29	3.0	9.7	29	3.0	9.7									
1984	18	3.0	6	18	3.0	6									
1985	82	3.0	27.3	82	3.0	27.3									
1986	52	3.0	17.3	52	3.0	17.3									
1987	116	3.0	38.7	116	3.0	38.7									
1988	51	3.0	17	51	3.0	17									
1989	84	3.0	28	84	3.0	28									
1990	51	3.0	17	51	3.0	17									
1991	64	3.0	21.3	64	3.0	21.3									
1992	19	3.0	6.3	19	3.0	6.3									
1993	9	3.0	3	9	3.0	3									
1994	131	11.1	11.8	37	3.0	12.3	41	5.1	8.1	39	2.0	19.5	14	1.0	14
1995	408	11.1	36.9	88	3.0	29.3	123	5.1	24.3	182	2.0	91	15	1.0	15
1996															
1997	335	11.1	30.3	49	3.0	16.3	158	5.1	31.2	114	2.0	57	14	1.0	14
1998	319	11.1	28.8	74	3.0	24.7	112	5.1	22.1	124	2.0	62	9	1.0	9
1999	204	10.3	19.9	86	3.0	28.7	49	4.3	11.5	59	2.0	29.5	10	1.0	10
2000	235	10.5	22.4	126	3.0	42	51	4.5	11.3	44	2.0	22	14	1.0	14
2001	400	10.5	38.1	106	3.0	35.3	125	4.5	27.8	132	2.0	66	37	1.0	37
2002	407	12.1	33.7	127	3.0	42.3	116	6.1	19.1	138	2.0	69	26	1.0	26
2003	447	11.1	40.4	152	3.0	50.7	127	5.1	25	123	2.0	61.5	45	1.0	45
2004	365	10.7	34.2	136	3.0	45.3	99	4.7	21.2	90	2.0	45	40	1.0	40
2005	249	11.1	22.5	76	3.0	25.3	93	5.1	18.3	76	2.0	38	4	1.0	4
2006	286	9.5	30.1	101	3.0	33.7	48	3.5	13.7	101	2.0	50.5	36	1.0	36
2007	254	9.5	26.7	80	3.0	26.7	57	3.5	16.3	102	2.0	51	15	1.0	15
2008															
2009	116	7.9	14.7	39	3.0	13	21	2.7	7.8	51	1.2	42.5	5	1.0	5
2010	201	12.1	16.7	8	3.0	2.7	85	6.1	14	101	2.0	50.5	7	1.0	7
2011	189	11.1	17.1	15	3.0	5	51	5.1	10.1	118	2.0	59	5	1.0	5
2012	185	12.1	15.3	7	3.0	2.3	69	6.1	11.3	88	2.0	44	21	1.0	21
2013	237	12.1	19.6	22	3.0	7.3	106	6.1	17.5	109	2.0	54.5	0	1.0	0
2014	139	9.5	14.6	37	3.0	12.3	21	3.5	6	76	2.0	38	5	1.0	5
2015	467	10.5	44.5	63	3.0	21	166	4.5	36.9	229	2.0	114.5	9	1.0	9
2016	303	10.5	28.9	58	3.0	19.3	84	4.5	18.7	161	2.0	80.5	0	1.0	0
2017	192	10.1	19.1	43	3.0	14.3	79	5.1	15.6	70	2.0	35			
2018	304	11.1	27.5	41	3.0	13.7	78	6.1	12.9	185	2.0	92.5			
2019	295	11.8	25.1	35	2.7	13	93	6.1	15.3	148	2.0	74	19	1.0	19
2020	469	10.8	43.5	53	2.7	19.6	214	6.1	35.3	202	2.0	101			