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Results of regional spawning ground surveys and estimates of total salmonid redd construction in Redwood Creek, Humboldt County California, 2015-2016.

Prepared by

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Abstract

Field staff conducted spawning ground surveys in 24 reaches within the Redwood Creek watershed between November 16, 2015 and March 28, 2016. Individual stream reaches were surveyed an average of 5.1 times at an average return interval of 23 days. We observed 389 Chinook salmon, 89 coho salmon, 59 steelhead trout, and 40 unidentified live fish. A total of 125 Chinook salmon, 32 coho salmon, 0 steelhead trout, and 41 unidentified carcasses were found. We identified 704 individual redds of which 173 were assigned to a species. Redwood Creek redd abundance estimates of Chinook salmon, coho salmon, and steelhead trout with 95% confidence intervals are 740 (427, 1200), 206 (146,313), and 283 (132,488) respectively.

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1 INTRODUCTION

1.1 Background

Pacific Salmon (*Oncorhynchus sp.*) have experienced marked decline in abundance over the last 60 years. Due to this decline, coho salmon (*Oncorhynchus kisutch*) in the Southern Oregon and Northern California Coasts (SONCC) Evolutionary Significant Unit (ESU) were federally listed as threatened pursuant to the Endangered Species Act (ESA) in 1997 (NMFS 1997). This federal listing status was reviewed and reaffirmed in 2005 (NMFS 2005) and is currently under another review. The California Fish and Game Commission found coho salmon populations within the SONCC warranted listing as threatened species under the California Endangered Species Act (CESA) (CDFG 2002). All California steelhead (*O. mykiss*) south of the Klamath River are Federally ESA listed (NMFS 2006) and coastal Chinook salmon (*O. tshawytscha*) south of the Klamath River to the Russian River are federally ESA listed (NMFS 1999). In 2004 the California Department of Fish and Game developed a recovery strategy for coho salmon populations within California (CDFG 2004). This recovery strategy is intended to direct management and restoration actions needed to recover the species, and provides basin by basin threat assessments and attempts to prioritize management and restoration actions needed to recover the species. The Federal government requires that listed species have recovery plans developed that require objective, measurable criteria which when met, would result in the species being removed from the listing (16 USC 1531, Endangered Species Act 1973). Recovery of salmon and steelhead listed under the Federal and California ESAs can be measured in part on the increase in abundance of spawning adults (Good et al. 2005). Delisting will depend on abundance thresholds and the connectivity of populations to one another (Spence et al. 2008, Williams et al. 2008).

The California Department of Fish and Wildlife and the National Oceanic and Atmospheric Administration ~ Fisheries recognize four key parameters for assessing the long term viability of salmonid populations. These viable salmonid population (VSP) parameters are population size, population growth rate (productivity), population spatial structure, and life history diversity (McElhany et al. 2000). Monitoring these population parameters is essential to evaluating the success of recovery efforts.

To address data needs for viability assessment, the California Department of Fish and Wildlife (CDFW) and the National Oceanic and Atmospheric Administration ~ Fisheries (NOAA~Fisheries) cooperatively developed the draft Coastal California Salmonid Monitoring Plan (CMP)(Adams et al. 2011). Two complimentary tasks are considered high priority in the northern monitoring area and form the foundation of the CMP approach. The first task consists of probabilistic sampling of stream reaches within a defined region using spawning ground surveys (SGS) to establish the regional status and trends of adult salmonid abundance. The second task develops intensively monitored Life Cycle monitoring Stations (LCS) nested within the regional sample frame of the SGS.

Prairie Creek is a LCS nested within the larger Redwood Creek watershed (Figures 1-3). The nesting of the SGS within the LCS investigates the relationship between SGS observations and adult escapement.

This report summarizes the results of yearly abundance and survival monitoring efforts from November 2015 to March 2016, as well as integrates all years of project data to make inference on population trajectories.

1.2 Study Area

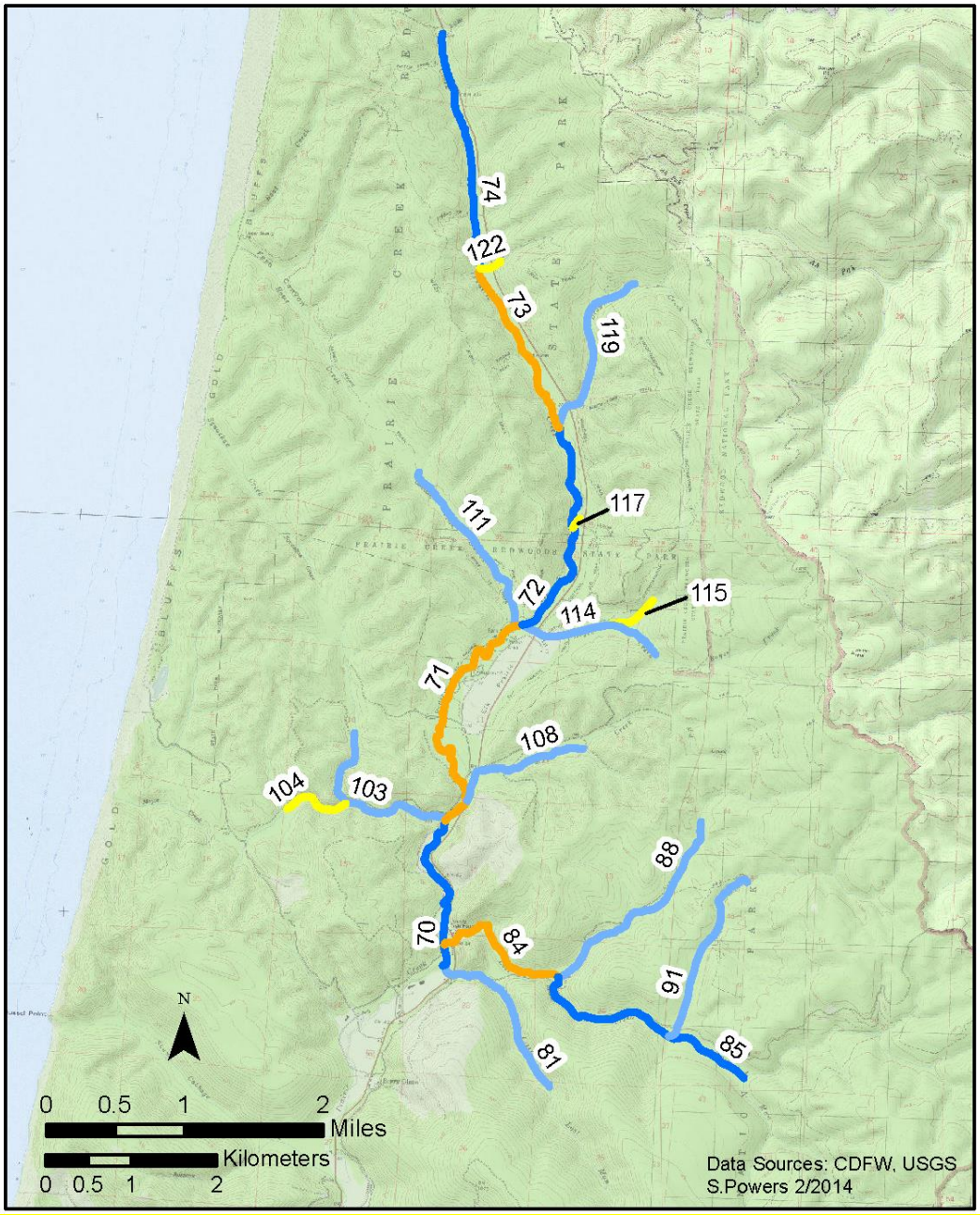

Figure 1. Prairie Creek LCS sampling frame. Reaches are depicted with alternating colors, and reach codes are presented as table references.

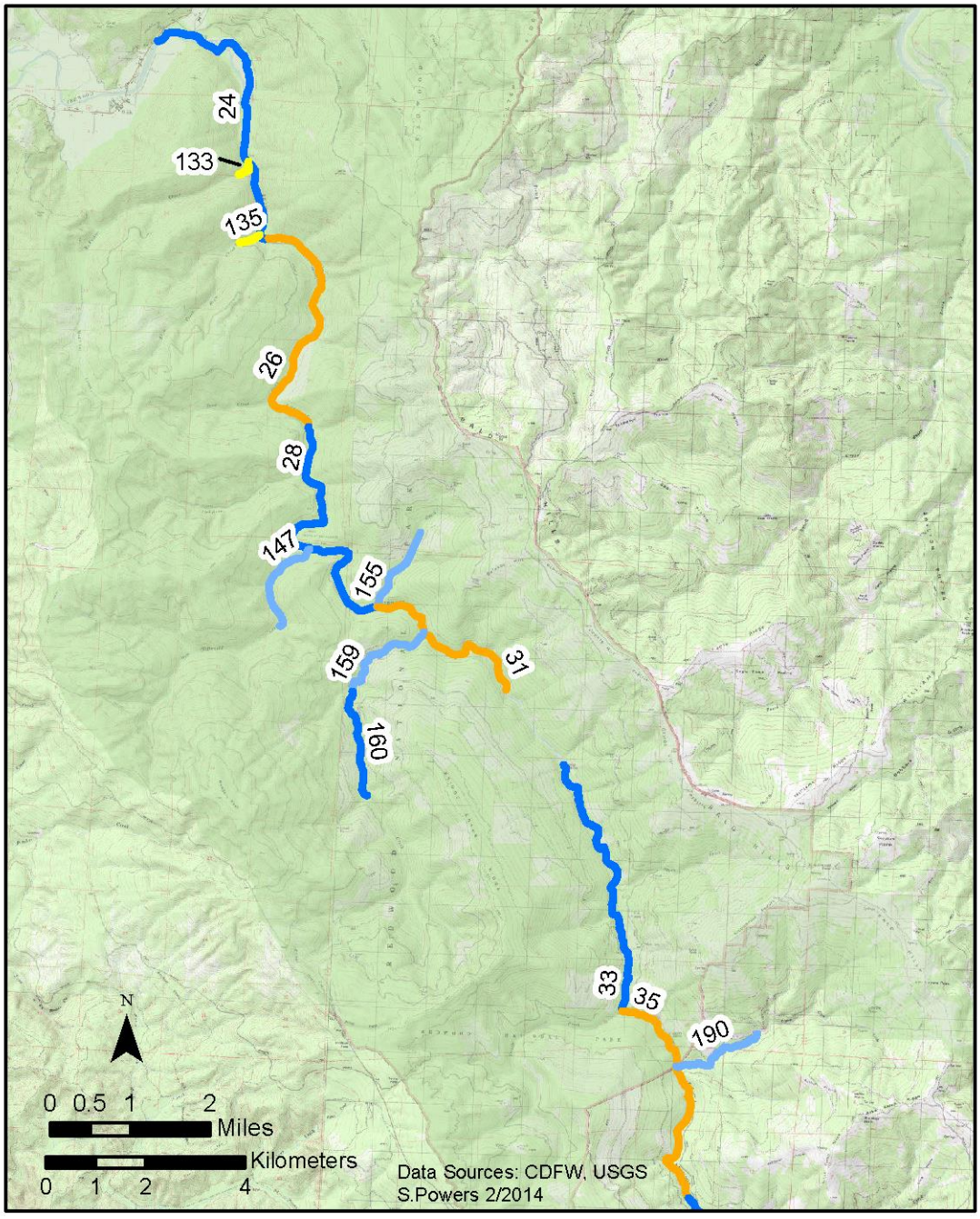

Figure 2. Lower Redwood Creek sampling frame. Reaches are depicted with alternating colors, and reach codes are presented as table references. High gradient section between reach 31 and 33 not surveyed due to unsafe conditions.

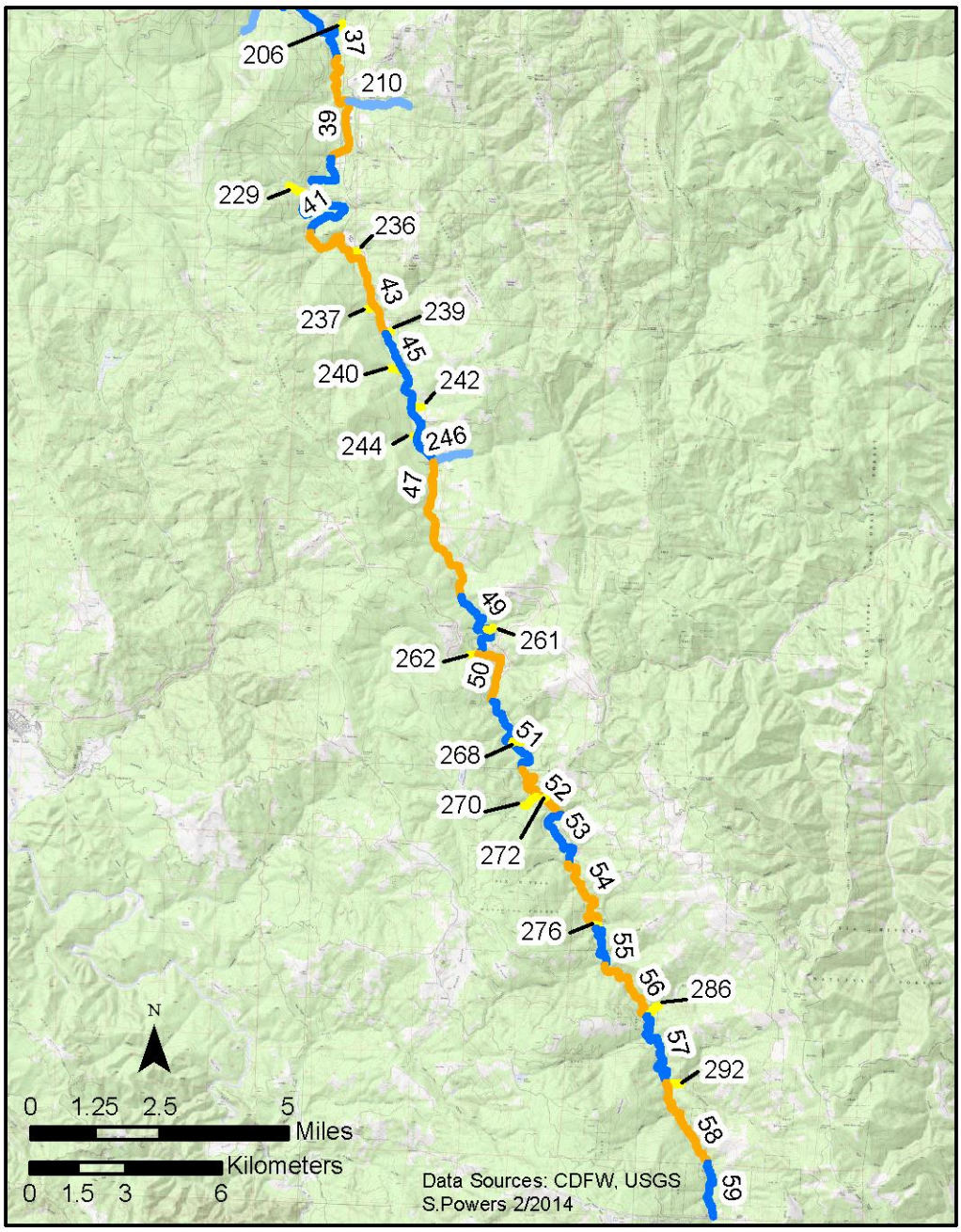

Figure 3. Upper Redwood Creek sampling frame. Reaches are depicted with alternating colors, and reach codes are presented as table references.

2 METHODS

2.1 Sample Frame Construction

Sampling frames were constructed with several factors presented by Garwood and Ricker 2011 including; documented historical salmonid distributions, documented barriers to anadromy, stream gradient, and field reconnaissance. Sample frames were constructed around coho salmon and may exclude habitat which is used by Chinook salmon and steelhead trout.

Each sampling frame was further divided into streams and then into survey reaches. From each sampling frame a portion of reaches was selected to survey. Reaches were assigned numbers in a fashion that ensured that selected survey reaches were balanced spatially within each stream (Garwood and Ricker 2011). Short sub-reaches less than 1000 meters were combined with the reach into which they flowed into.

2.2 Reach Selection

Reaches were selected for sampling from each frame using a General Randomized Tessellation Stratified (GRTS) sampling algorithm (McDonald 2003). GRTS sampling ensures a randomized spatially balanced draw from each stream. We sampled 23 reaches of a total possible 38[3] reaches to achieve a sampling rate of approximately 61%.

2.3 Reach Survey Protocol

Spawning ground surveys protocol closely followed Gallagher et al. (2007). Teams of two walked upstream on small streams or boated downstream in large stream reaches. Observations include carcasses, live fish, and redds. Live and dead fish were identified to species when possible. Carcasses were marked with tags to prevent counting during subsequent surveys. All redds were flagged, measured, and assigned a unique record number. Redds were assigned a species if a fish was observed constructing, defending, or holding on a redd. Newly observed redds were aged as catergory one-new to the survey and redds recaptured on subsequent surveys received categorical ages ranging from age two as still visible and measurable, age three as still visible but not measurable, and age four redds were no longer visible (flag only).

2.4 Assigning Species to Unknown Redds

In order to assign species to unknown redds Ricker et al. (2014) applied a K-nearest neighbors (kNN) algorithm. The kNN uses distance in X-Y space and time to nearest 3 known species red or live fish to make a prediction of species based on majority vote.

[3]Frame has a total of 45 reaches. The upper 7 reaches are on property that CDFW cannot gain access to.

Each unknown redd was assigned to a species for further analysis of species specific red abundance.

We used Leave-one-out-cross-validation (LOOCV) to evaluate the KNN predictions. The LOOCV process involved removing each known redd sequentially from the data, predicting the red from the remaining data, and comparing the prediction to truth. Errors in prediction are not however propogated into the total error of within reach abundance. All kNN and LOOCV analysis were executed in program R with the "class" package (Venables and Ripley 2002) and "caret" package (Kuhn 2013).

2.5 Estimation of Within-Reach Redd Abundance

Estimation of the number of redds in each sample reach is derived by dividing the total redd count by the square root of the seasonally pooled redd survival rate. The redd survival rate is estimated as fraction of re-observed age 2 and 3 flagged redds (still visible) to age 4 (no longer visible) (Section 2.3) (Ricker et al. 2014, Schwarz et al 1993).

2.6 Estimation of Total Redd Abundance Within the Sample Frame

Total redd abundance expansion to the frame is estimated with a Simple Random Sample estimator (Adams et al. 2011). See Ricker et al. 2014 for standard error equations and calculation methods and Adams et al. 2011 for correction factors. Bootstrap re-sampling was implemented to estimate between-reach variance and within-reach variance (Ricker et al. 2014).

3 RESULTS

3.1 Reach Survey Frequency

Field staff conducted spawning ground surveys in twenty three Redwood Creek reaches between November 9, 2015 and March 30, 2016. Visitation rates to stream reaches averaged 5.1 and the average number of days between visits was 23 (Table 1).

3.2 Fish Observations

Live fish observations include 389 Chinook salmon, 89 coho salmon, 59 steelhead trout, and 40 unidentified live fish. Table 2 and Table 3 summarize and Figure 4 displays counts of live fish and carcass observations by week in Redwood Creek. Non target live fish included 17 cutthroat trout. Carcass observations include 125 Chinook salmon, 32 coho salmon, 0 steelhead trout, 1 Pacific Lamprey and 41 unidentified salmonid species.

Sex ratios of male to female live fish and carcass observations were 0.78:1, 1:0.79, and 1:0.9 for Chinook salmon, coho salmon, and steelhead trout respectively. Descriptive statistics for live fish and carcasses are presented in Table 4. Out of 198 carcass recoveries 170 were whole and measured for fork length.

Table 1. Summary of spawning ground survey statistics of the mean number of days between reach surveys and the maximum number of days between surveys.

Location Code	StreamName	Mean	Max	N
103/104	Prairie Creek	17.83	29	6
108	Prairie Creek	20.33	27	3
111	Prairie Creek	15.14	28	7
114/115	Prairie Creek	16.66	30	6
119	Prairie Creek	20.16	30	6
70	Prairie Creek	19.71	38	7
71	Prairie Creek	16.87	28	8
72	Prairie Creek	14.87	29	8
73	Prairie Creek	15	25	8
74	Prairie Creek	17.71	26	7
81	Prairie Creek	20.66	45	6
84	Prairie Creek	20.5	30	6
85	Prairie Creek	20.5	30	6
88	Prairie Creek	30	58	3
91	Prairie Creek	28.33	56	3
26	Redwood Creek	26.2	74	5
28	Redwood Creek	25.6	73	5
31	Redwood Creek	26.4	73	5
37	Redwood Creek	43.5	77	2
47	Redwood Creek	23.33	37	3
49	Redwood Creek	17.5	35	2
50	Redwood Creek	18.5	37	2
210	Redwood Creek	69	68	2

Table 2. Live fish observations by calendar week.

Week Beginning	Chinook	coho	steelhead	unidentified	Total
2015-11-09	0	0	1	0	1
2015-11-16	1	0	1	2	4
2015-11-23	0	0	0	0	0
2015-11-30	268	0	1	6	275
2015-12-07	86	0	0	8	94
2015-12-14	159	6	1	1	167
2015-12-21	16	0	0	0	16
2015-12-28	46	26	1	7	80
2016-01-04	51	25	1	18	95
*2016-01-11	0	0	0	0	0
*2016-01-18	0	0	0	0	0
2016-01-25	1	30	4	5	40
2016-02-01	0	3	2	0	5
2016-02-08	0	1	13	3	17
2016-02-15	0	0	2	1	3
2016-02-22	0	0	28	2	30
2016-02-29	0	0	0	0	0
2016-03-07	0	0	0	0	0
2016-03-14	0	0	12	0	12
2016-03-21	0	0	3	0	3
2016-03-28	0	0	2	1	3
Total	628	91	72	54	845

*No surveys conducted during this week.

Table 3. Carcass observations by calendar week.

Week Beginning	Chinook	coho	steelhead	unidentified	Total
2015-11-09	0	0	0	0	0
2015-11-16	0	0	0	0	0
2015-11-23	0	0	0	0	0
2015-11-30	5	0	0	0	5
2015-12-07	1	0	0	0	1
2015-12-14	5	0	0	0	5
2015-12-21	2	0	0	0	2
2015-12-28	25	0	0	1	26
2016-01-04	66	2	0	6	74
*2016-01-11	0	0	0	0	0
*2016-01-18	0	0	0	0	0
2016-01-25	15	23	0	15	53
2016-02-01	0	3	0	2	5
2016-02-08	3	0	0	3	6
2016-02-15	0	0	0	0	0
2016-02-22	3	4	0	14	21
2016-02-29	0	0	0	0	0
2016-03-07	0	0	0	0	0
2016-03-14	0	0	0	0	0
2016-03-21	0	0	0	0	0
2016-03-28	0	0	0	0	0
Total	125	32	0	41	198

*No surveys conducted during this week.

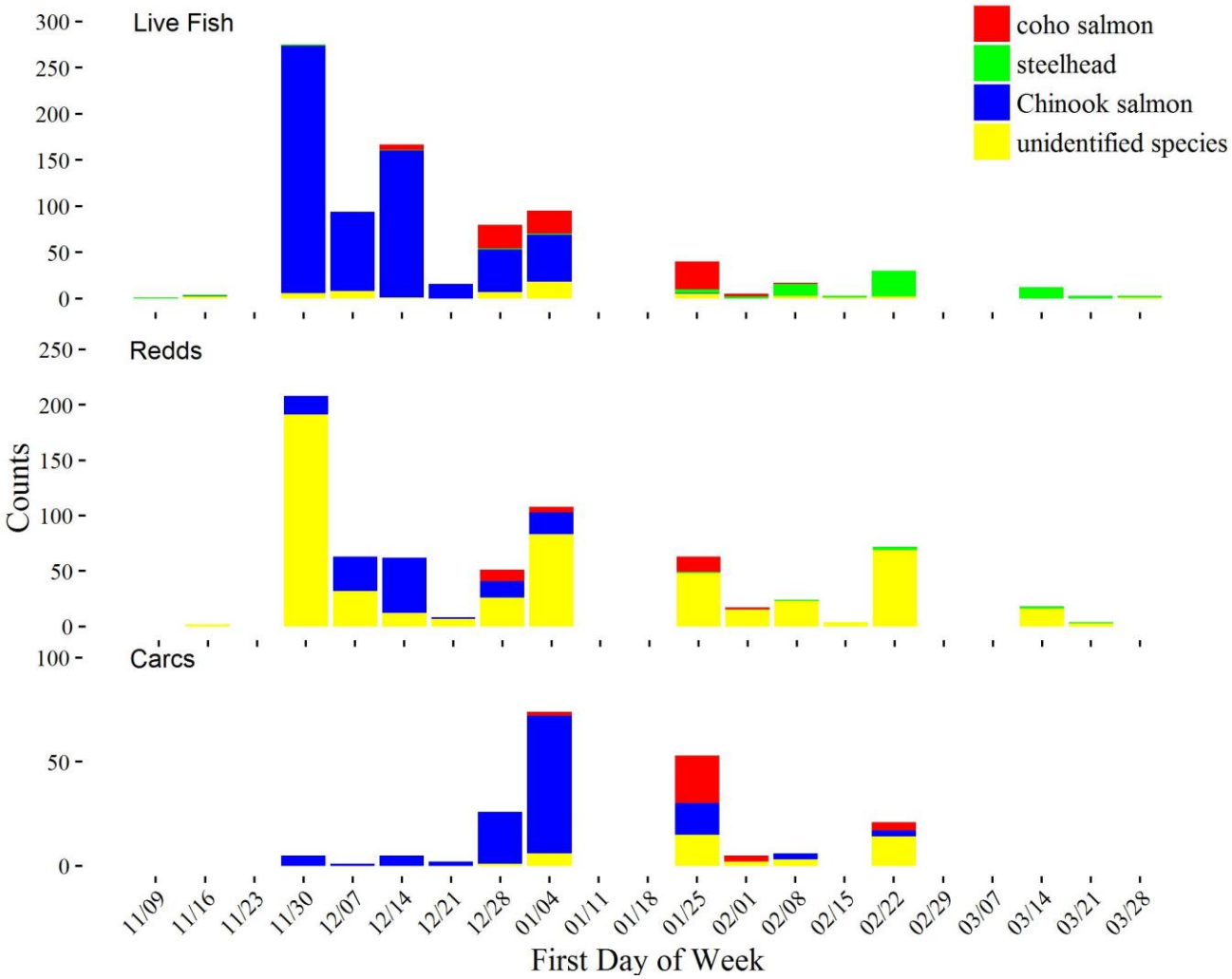

Figure 4. Stacked Bar Plot of live fish (A), individual redd, and carcass (C) observations by week.

Table 4. Descriptive statistics of live fish observations (L) and measurable carcasses (C).

Species	Sex	Mean		Median		Min		Max		SD		N	
		L	C	L	C	L	C	L	C	L	C	L	C
Chinook	F	77	84	75	85	45	63	100	99	8.5	7.4	207	58
Chinook	M	77	84	80	85	35	42	115	110	15.2	15.0	155	58
Chinook	Unk	70	87	75	88	35	78	100	101	15.7	7.1	27	12
coho	F	59	64	60	65	50	60	75	73	5.6	4.5	37	8
coho	M	60	66	60	65	45	60	75	74	7.6	4.4	45	14
coho	Unk	56	-	55	-	50	-	65	-	5.6	-	7	-
steelhead	F	64	-	65	-	55	-	75	-	7.0	-	9	-
steelhead	M	67	-	68	-	55	-	80	-	7.1	-	10	-
steelhead	Unk	59	-	60	-	35	-	75	-	8.2	-	40	-
Unknown	F	58	70	60	70	45	65	65	76	8.7	5.5	4	3
Unknown	M	70	59	70	59	70	48	70	70	-	15.6	1	2
Unknown	Unk	53	72	60	72	15	54	75	82	15.7	10.3	35	6

3.3 Redd Observations

Out of 704 redds observed 173 redds were identified to species. The known species observations compared to the LOOCV predictions are displayed in Table 5. The KNN predictions, correctly predicted redds divided by the total known redds, were 92.4% accurate.

Table 5. Confusion matrix of the known species redds in columns crossed with LOOCV redd predictions in rows.

	Chinook	coho	steelhead
Chinook	127	6	0
coho	7	25	0
steelhead	0	0	8

Newly constructed redd observations for all species peaked during the first week of December when 208 anadromous salmonid redds were counted (Table 6, Figure 4). Chinook redd observations peaked in mid-December. Coho red observations peaked in the last week of January. Steelhead redd observations peaked during the last week in February when 3 redds were tallied. Reach 31 in Redwood Creek had the highest count of redds (Table 7). Non-target species redd totals were 5 cutthroat redds (See Appendix Table 12).

Table 6. Counts of newly constructed redds by calendar week.

Week Beginning	Chinook	coho	steelhead	unidentified	Total
2015-11-09	0	0	0	0	0
2015-11-16	0	0	0	2	2
2015-11-23	0	0	0	0	0
2015-11-30	17	0	0	191	208
2015-12-07	31	0	0	32	63
2015-12-14	50	0	0	12	62
2015-12-21	1	0	0	7	8
2015-12-28	15	10	0	26	51
2016-01-04	20	5	0	83	108
*2016-01-11	0	0	0	0	0
*2016-01-18	0	0	0	0	0
2016-01-25	0	14	1	48	63
2016-02-01	0	2	0	15	17
2016-02-08	0	0	1	23	24
2016-02-15	0	0	0	4	4
2016-02-22	0	0	3	69	72
2016-02-29	0	0	0	0	0
2016-03-07	0	0	0	0	0
2016-03-14	0	0	2	16	18
2016-03-21	0	0	1	3	4
2016-03-28	0	0	0	0	0
Total	134	31	8	531	704

*No surveys conducted during this week.

Table 7. Counts of anadromous salmonid redds within each survey reach. Species totals include unknown species predicted by kNN. Survey reach numbers are labeled in figure 1-3.

Location Code	Chinook	coho	steelhead	Total
103	0	14	5	19
*104	0	4	0	4
108	1	1	2	4
111	9	13	7	29
114	0	1	6	7
*115	0	7	6	13
119	5	2	0	7
*122	0	2	0	2
69	8	0	2	10
70	12	2	6	20
71	50	7	28	85
72	63	5	14	82
73	35	31	13	79
74	2	28	7	37
81	20	2	6	28
84	24	1	2	27
85	6	3	13	22
88	1	13	0	14
91	0	9	0	9
26	27	0	0	27
28	60	0	3	63
31	95	0	1	96
37	0	0	1	1
47	4	0	2	6
49	2	0	0	2
210	0	0	8	8
*262	3	0	0	3
Total	427	145	132	704

*Denotes Sub Reach

3.4 Total Redd Abundance

Redwood Creek redd abundance estimates of Chinook salmon, coho salmon, and steelhead trout with 95% confidence intervals was 740 (427, 1200), 206 (145,313), and 283 (132,488) respectively. Redd abundance estimates and descriptive statistics of surveyed reaches are presented in Table 8.

Table 8. Estimated number of reddsin surveyed reachesin Redwood Creek and in all reaches in the Prairie Creek Life Cycle Monitoring Station. Estimated Descriptive statistics are between sampled reaches.

	Redwood Creek			Prairie Creek		
	Chinook	coho	steelhead	Chinook	coho	steelhead
Redd Estimate	486	180	216	295	180	201
Standard Error	5.97	2.24	2.70	6.29	2.83	3.59
Variance	821.5	115.6	167.3	634.1	128.7	206.9
95% C.I.	(429,543)	(158,201)	(190,241)	(245,345)	(157,202)	(172,229)

4 DISCUSSION

This year's reach survey frequency is less than in recent years (Table 9) due to heavy rainfall in an El Nino weather cycle. Surveys were not conducted between the dates of January 9-26 when we experienced several storm events. Table 9 below includes randomly selected reaches and additional reaches surveyed in the Prairie Creek LCS.

Table 9. Reach survey frequency by year in Redwood Creek tributaries.

Year	Mean # surveys per reach	Mean # days between surveys
2010-2011	7.1	20
2011-2012	6.6	20
2012-2013	9.2	16
2013-2014	6.7	23
2014-2015	6.4	26
2015-2016	5.1	23

The timing of the rainfall events in January (Figure 5) prevented surveys from occurring as frequently as the protocol suggests (every ten days). Normally surveys are delayed for 4-6 days after a significant rainfall event. Minimum visibility conditions to conduct redd surveys is 50cm which is usually reached as streams approach median winter base flows (Figure 5). If the storm frequency is once a week only a few reaches in the frame can be surveyed between storm events. Some reaches were visited only two times during the entire spawning season (Table 1). Infrequent reach visitation could decrease the chances of observations of both carcasses and new redds.

High water during the historical peak of the coho spawning season, in January, most likely obscured redds and decreased carcass and live fish observations. Redds constructed during this period may have been obscured and were unavailable for surveyors to observe during a subsequent survey (Jones 2012). Flood events could have moved carcasses into deep pools and high onto the flood plain impeding observations. As the water visibility decreases the chances of viewing live fish decreases. All of these factors could lead to a lower estimate of redds within the Redwood Creek sample frame during an El Nino water year.

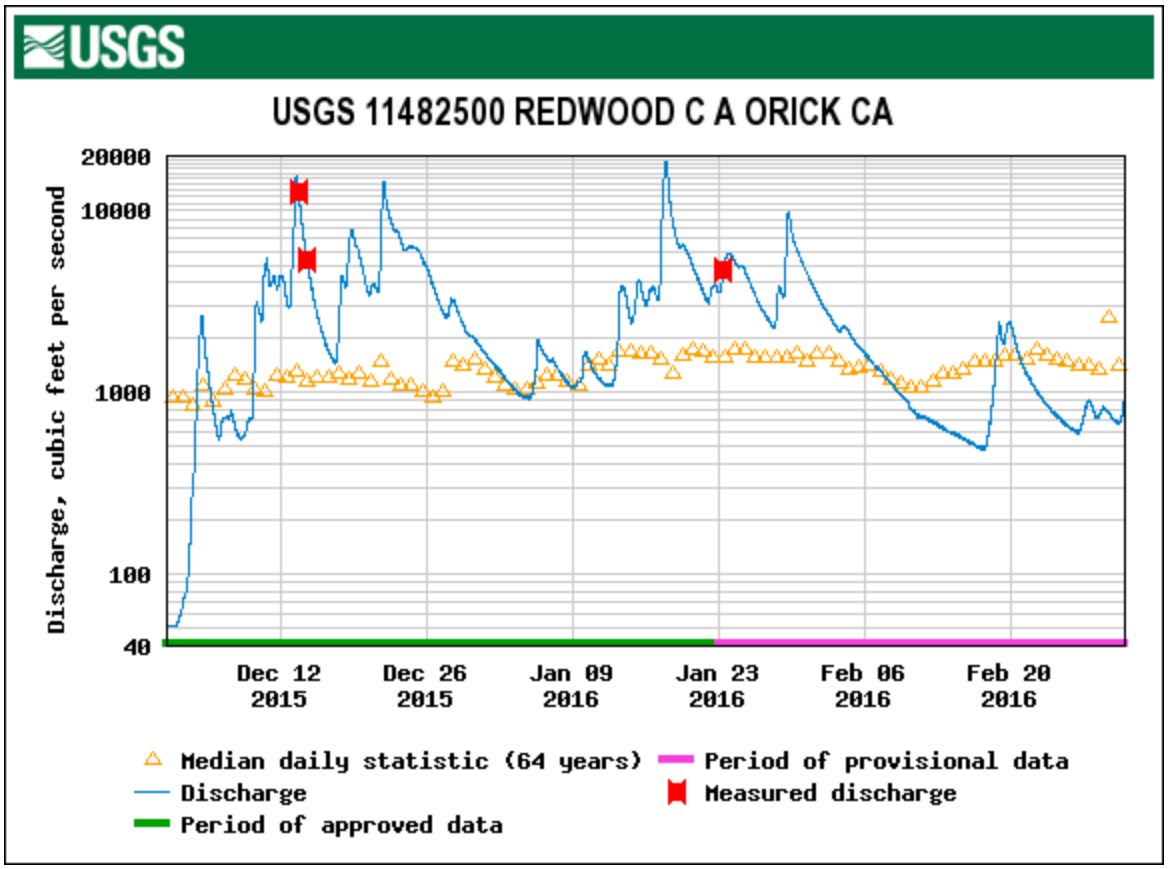

Figure 5. Discharge in Redwood Creek from December 2015 to March 2016.

Coho redd estimates in 2015 were the lowest compared to the last five years in the Redwood Creek frame and the fifth lowest out of six survey years in the Prairie Creek LCS (Table 10 and Table 11). Estimates during high rainfall years continue to challenge the protocol and the ability to analyze the data with the tools available in Adams et al. (2011). Steelhead estimates may also be influenced by water visibility and the lack of surveys later in the year which would capture the spawning activity. Steelhead spawning may occur outside of the survey time frame and estimates in this report are only for the early steelhead spawning season.

Table 10. Total redd estimates with 95% confidence intervals for three species during six years in Redwood Creek watershed.

Year	Chinook	coho	steelhead
2010-2011	783 (407,1159)	574 (328,820)	86 (43,130)
2011-2012	866 (282,1449)	540 (196,883)	50 (23,77)
2012-2013	940 (459,1422)	405 (214,597)	405 (260,551)
2013-2014	963 (320,1606)	705 (217,1192)	82 (36,128)
2014-2015	1063 (389, 1738)	297 (128,466)	335 (181,489)
2015-2016	740 (427,1200)	206 (145,313)	283 (132,488)

Table 11. Redd estimates with 95% confidence intervals for three species during six years in Prairie Creek Life Cycle Monitoring Station.

Year	Chinook	coho	steelhead
2010-2011	262 (246,278)	344 (325,363)	19 (19,19)
2011-2012	103 (96,110)	387 (373,400)	10 (10,10)
2012-2013	308 (293,324)	365 (354,377)	66 (64,69)
2013-2014	151 (147,154)	538 (517,560)	57 (56,58)
2014-2015	158 (130,187)	160 (141,178)	187 (164,210)
2015-2016	295 (245,345)	180 (176,183)	201 (172,229)

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6 APPENDIX

Table 12. Counts of newly constructed redds by calendar week for non-target species.

Week Beginning	cutthroat	Unidentified trout	Pacific Lamprey
2015-11-09	0	0	0
2015-11-16	0	0	0
2015-11-23	0	0	0
2015-11-30	0	0	0
2015-12-07	0	0	0
2015-12-14	0	0	0
2015-12-21	0	0	0
2015-12-28	0	0	0
2016-01-04	0	0	0
*2016-01-11	0	0	0
*2016-01-18	0	0	0
2016-01-25	3	0	0
2016-02-01	0	0	0
2016-02-08	0	0	0
2016-02-15	0	0	0
2016-02-22	1	0	0
2016-02-29	0	0	0
2016-03-07	0	0	0
2016-03-14	0	0	0
2016-03-21	1	0	0
2016-03-28	0	0	0
Total	5	0	0

*No surveys conducted during this week.