Pacific States Marine Fisheries Commission

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Results of regional spawning ground surveys and estimates of total salmonid redd construction in the South Fork Eel River, Humboldt County California, 2015.

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ABSTRACT

During year six (2015/2016) of the South Fork Eel River Adult Salmonid Redd Abundance Monitoring Project, 190 spawning ground surveys were conducted over 40 spatially balanced, randomly selected reaches in the South Fork Eel River watershed from November 18th, 2015 to March 3rd, 2016. Each reach was surveyed an average of 4.5 times, and the average interval between surveys over all reaches was 26 days. Over the 2015/2016 survey season crews observed 26 live coho salmon, 45 live Chinook salmon, 29 live steelhead, and 23 unidentified salmonids. Crews encountered five coho salmon carcasses, 14 Chinook carcasses, two steelhead carcasses, and five unidentified salmonid carcasses. A total of 339 redds were observed, 11 of which were assigned a species in the field. The remaining 328 redds were assigned a species using a k-Nearest Neighbors algorithm. The number of redds observed in sample reaches was expanded to estimate the number of redds constructed across the entire South Fork Eel River sample frame. Redd abundance estimates for the 2015/2016 spawning season in the South Fork Eel River, including 95% confidence intervals, were 416 (117, 715) coho salmon redds, 418 (76, 892) Chinook salmon redds, and 1125 (686, 1563) steelhead redds. Improved and updated estimates of total redd abundance are presented for survey years 2010-2014.

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1 INTRODUCTION

1.1 BACKGROUND

Coho salmon (*Oncorhynchus kisutch*) in the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) were listed as threatened under the federal Endangered Species Act in 1997 (62 FR 24588); and their listing was reaffirmed in 2005 (70 FR 37160). The SONNC coho salmon ESU was also listed as threatened under the California Endangered Species Act in 2002 (CDFG 2002). Both the California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) have developed recovery plans for coho salmon outlining recovery goals, prioritizing recovery actions, and offering criteria that must be met in order to delist the species (CDFW 2004, NMFS 2014). Long-term population monitoring is an essential component of these recovery plans, as metrics are needed to assess recovery actions and track the species' progress towards recovery.

The 2011, CDFW "*Fish Bulletin 180 California Coastal Salmonid Monitoring Plan*" (CMP) established the approach for monitoring ESA/CESA listed anadromous salmonid population(s) status and trend in California. In the CMP's Northern California area, adult salmonid population abundance will be monitored using extensive spawning ground surveys to estimate total redd escapement within a survey area/sample frame. Each year spawning ground surveys are conducted on a random and spatially balanced sample of survey reaches, drawn from a survey frame encompassing all potential spawning habitat available to anadromous salmonid species within the designated study area. Georeferenced live salmonids, salmonid carcasses, and redd observation data are collected in each reach. The number of redds per salmonid species identified by observation and data analysis within the sample reaches is then expanded to estimate total redd escapement for the entire sample frame (Adams et al. 2011).

1.2 STUDY AREA

The South Fork Eel River flows through Humboldt and Mendocino counties and is a significant tributary within California's third largest watershed (see Figure 1). The South Fork Eel River's confluence with the Eel River is located approximately three miles north of the town of Weott, CA and approximately 40 river miles upstream from the Eel River's confluence with the Pacific Ocean, near the town of Loleta, CA. The South Fork Eel River Basin is the second largest sub-basin in the Eel River watershed and covers approximately 690 square miles, 19% of the Eel River Basin. The South Fork Eel River is approximately 100 miles long and the basin contains a total of 683 miles of perennial blue line streams according to the USGS 7.5 Minute U.S. Geological Survey (USGS) Quadrangle maps (CDFW 2014). The predominant land uses throughout the basin are timber harvest, livestock grazing, and dispersed rural development. In 1998, the South Fork Eel River was listed as an impaired water body by the federal

Environmental Protection Agency due to high levels of sedimentation and high water temperature (CDFW 2014).

Historically, the South Fork Eel River was the most productive major tributary of the Eel River Basin for anadromous salmonids, supporting runs of coho salmon, Chinook salmon (*O. tshawytscha*), and steelhead/rainbow trout (*O. mykiss*). In 1947, a high of 25,289 returning adult coho were counted at the Benbow Dam (Taylor, 1978). However, Pacific salmon runs in the South Fork Eel River have markedly declined since the mid-twentieth century. In 1994, a status review of the South Fork Eel River coho salmon estimated the returning population at approximately 1,320 adults (Brown et al. 1994).

The South Fork Eel River coho salmon are considered a core population under the federal SONCC Coho Recovery Plan and as such constitute an important demographic for long-term SONCC coho salmon ESU monitoring needs (NMFS 2014). The South Fork Eel River Adult Salmonid Redd Abundance Monitoring Project was initiated by the Pacific States Marine Fisheries Commission (PSMFC), in partnership with CDFW, in 2010 as a long-term effort to provide estimates of adult coho salmon redd abundance in the South Fork Eel River. This report presents the results of the 2015/2016 spawning survey season, the sixth year of the project. Previous annual reports for years 2010 through 2014 are available in the CDFW Document Library: https://nrm.dfg.ca.gov/documents/.

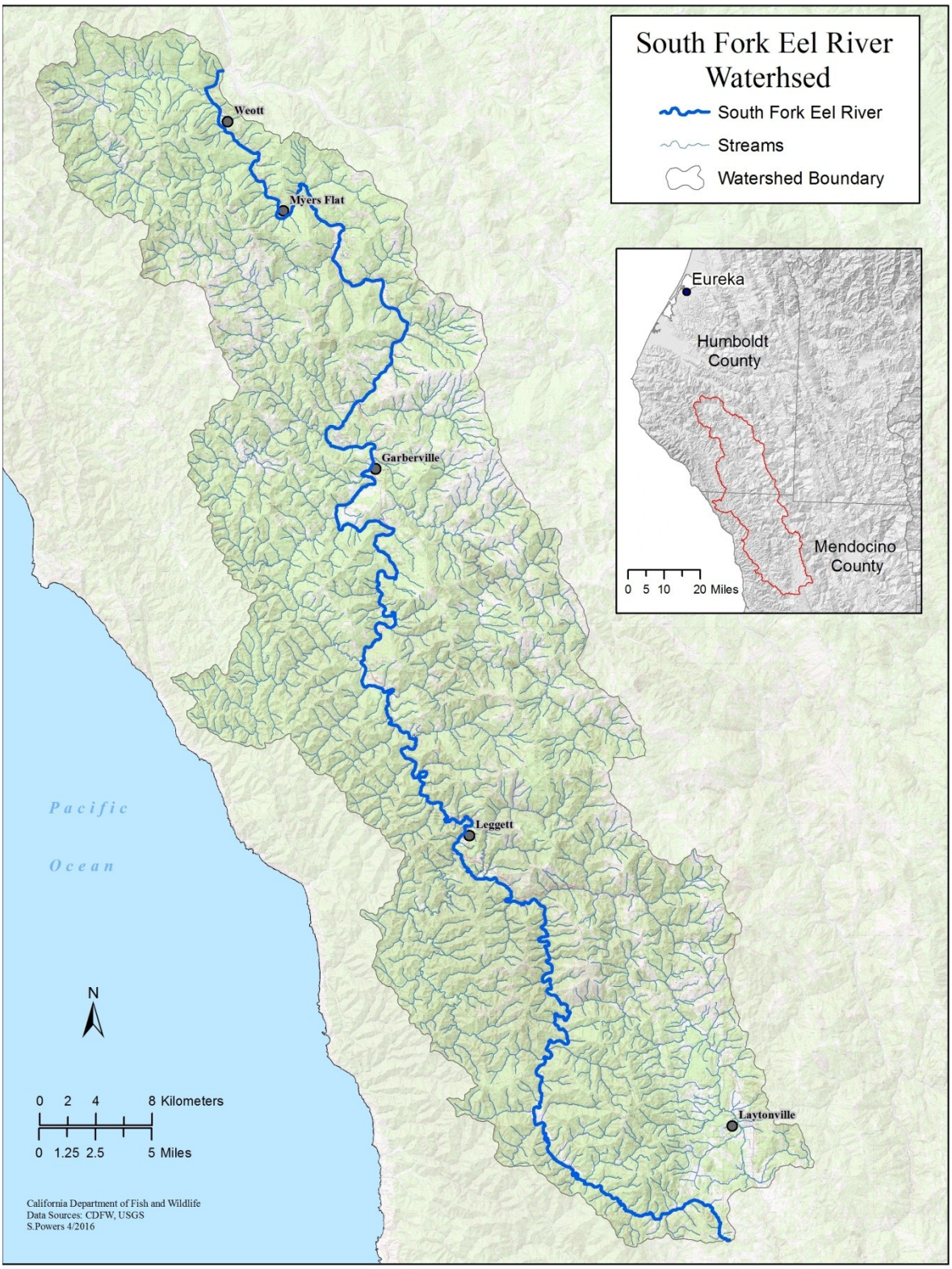

Figure 1: Map South Fork Eel River Watershed.

2 METHODS

2.1 SAMPLE FRAME

A sample frame was established for the South Fork Eel River using five parameters: (1) documented salmonid distributions, (2) stream gradient and stream size where salmonid distributions are unknown, (3) fish passage barrier data, (4) expert knowledge of salmonid distribution and migration barriers, and (5) field reconnaissance (Garwood and Ricker 2011). These data were compiled within a Geographic Information System (GIS) to develop species-specific (coho, Chinook and steelhead) spawning distributions (sample frames).

As the focus of this project is adult coho salmon, streams within the identified coho-specific sample frame were segmented into one to three kilometer sections, called reaches, with start and end points at identifiable landmarks (e.g. tributaries) and upstream extents at barriers to anadromy, both known and model-derived. All reaches were assigned a numeric identification, known as the location code, starting at the lower-most reach and moving upstream from north to south (Figures 1-3). Reaches that are less than one kilometer long (sub-reaches) are surveyed with the main reach that they flow into. All data collected in these sub-reaches are combined with that of their associated main reach (Garwood and Ricker 2011).

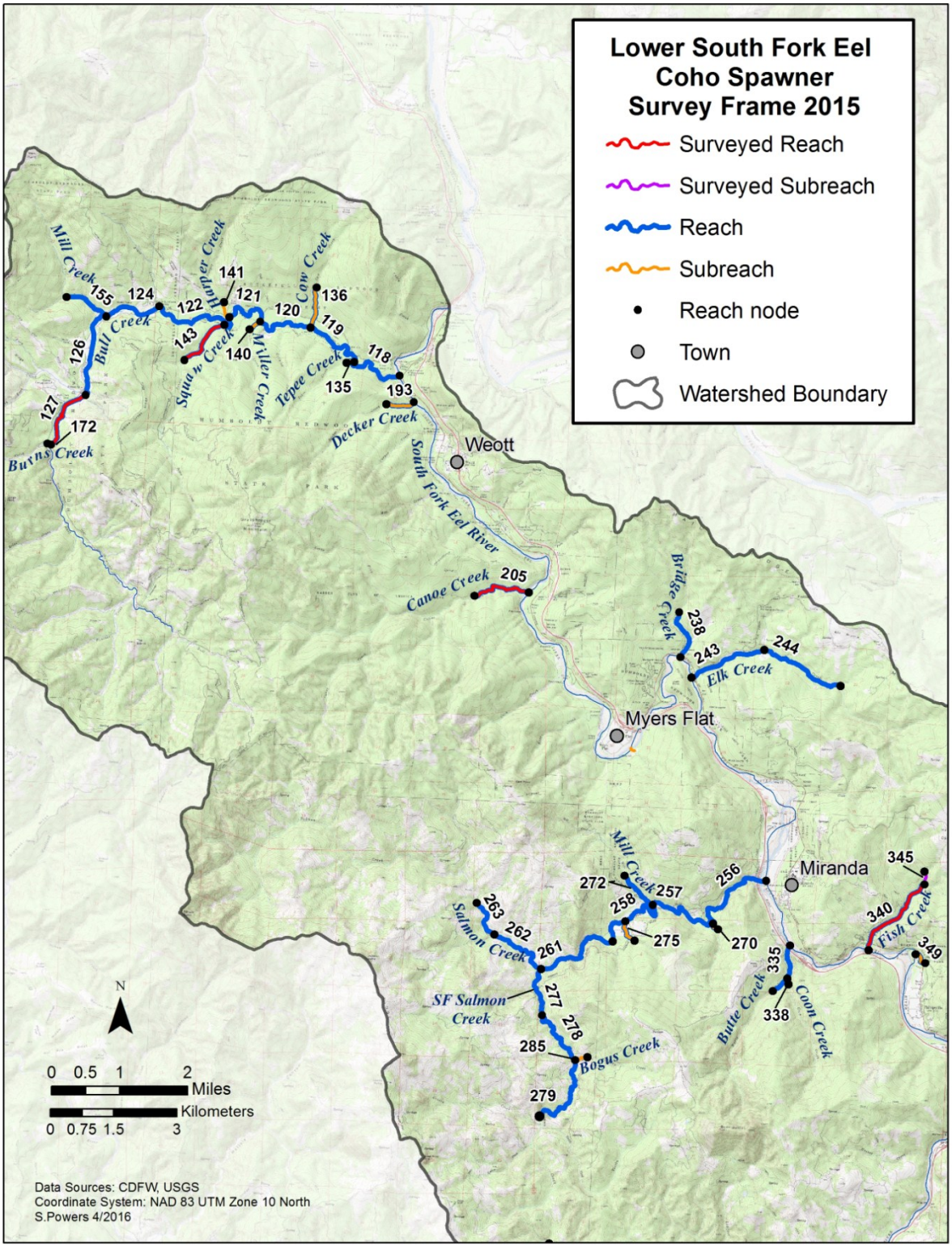

Figure 2: Map of the lower South Fork Eel River coho-specific spawner survey frame. Reaches surveyed during the 2015/2016 spawner survey season are red; associated subreaches are purple. Unsurveyed sample frame reaches are blue; associated sub-reaches are yellow. Each reach is labelled with its numeric location code.

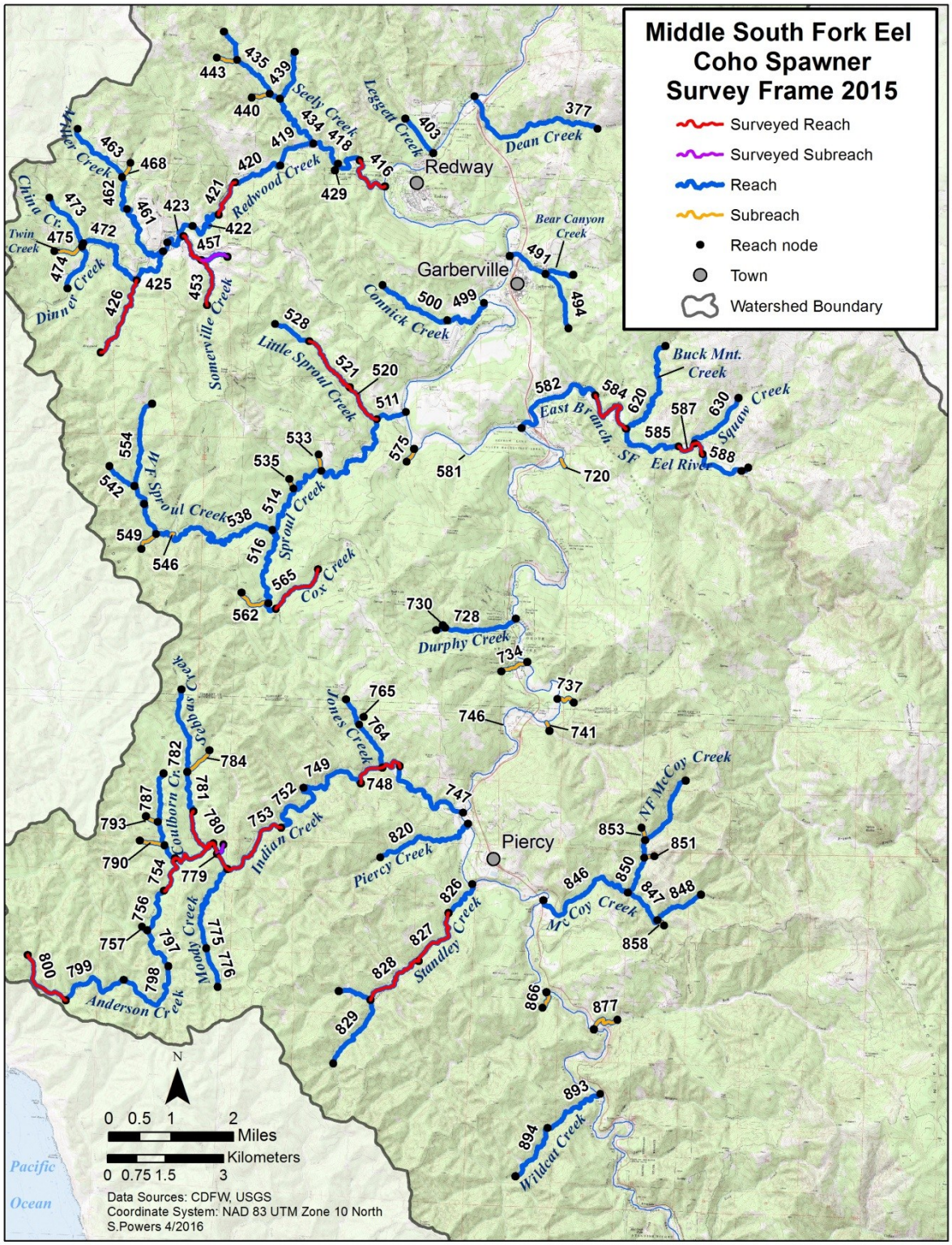

Figure 3: Map of the middle South Fork Eel River coho-specific spawner survey frame. Reaches surveyed during the 2015/2016 spawner survey season are red; associated subreaches are purple. Unsurveyed sample frame reaches are blue; associated sub-reaches are yellow. Each reach is labelled with its numeric location code.

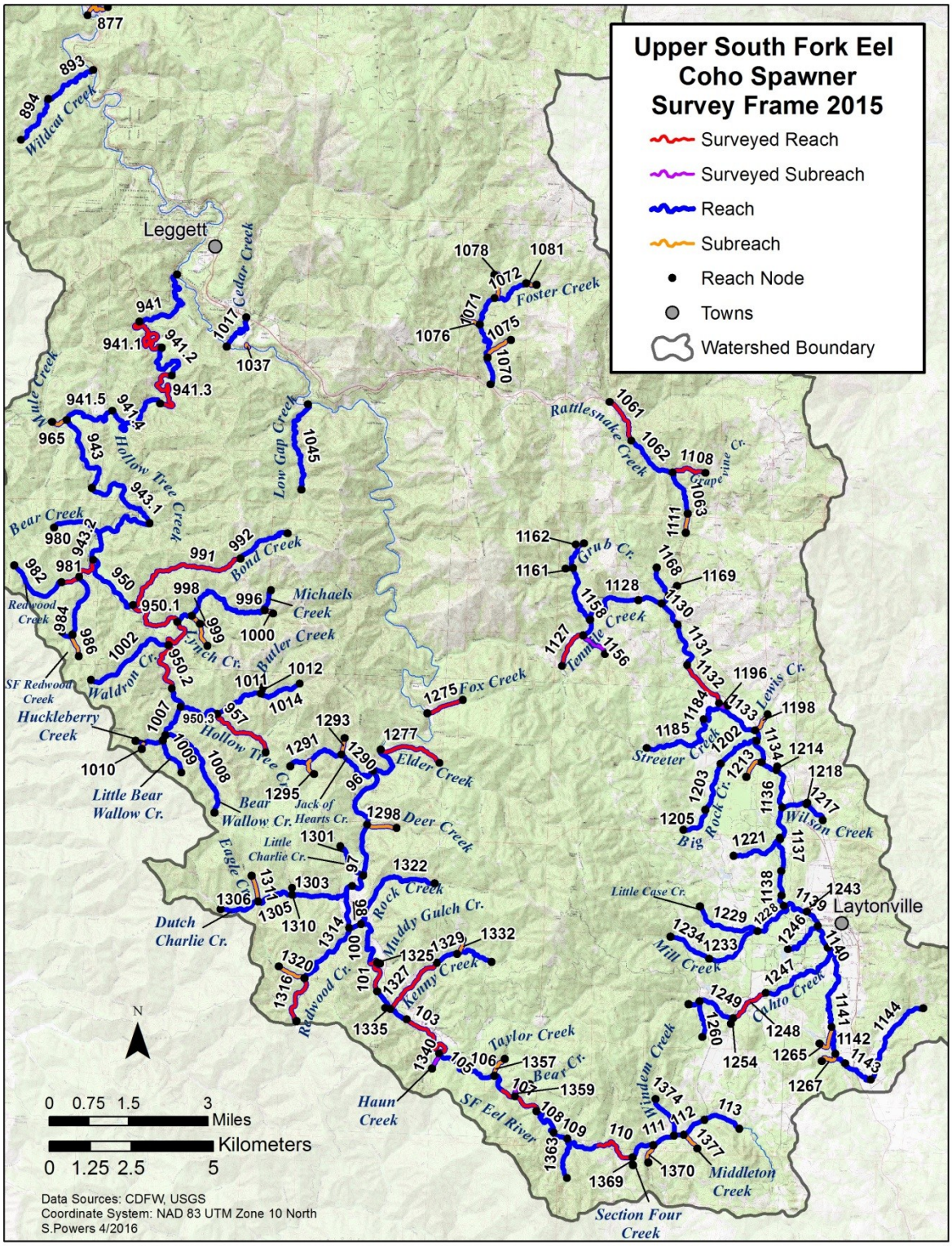

Figure 4: Map of the upper South Fork Eel River coho-specific spawner survey frame. Reaches surveyed during the 2015/2016 spawner survey season are red; associated subreaches are purple. Unsurveyed sample frame reaches are blue; associated sub-reaches are yellow. Each reach is labelled with its numeric location code.

2.2 SAMPLE REACH SELECTION

Spawning ground surveys were conducted periodically on a spatially balanced, random sample of 40 stream reaches drawn from the coho-specific sample frame of 207 potential reaches (Table 1). A General Randomized Tessellation Stratified (GRTS) routine (McDonald 2003) was used to create a randomized reordering of the survey frame from which the 40 reaches were drawn. Since much of the South Fork Eel River is under private ownership, a reach's inclusion on the list of 40 sample reaches is dependent on stream access permission from the relevant landowners. If permission was denied or if the landowner did not respond in time for the start of the spawning season, the reach was skipped for the year and the next stream was drawn from the list.

2.3 REACH SURVEY PROTOCOL

Spawning ground surveys were conducted following the methods of ground survey and data capture outlined in Gallagher et al. 2014 and Adams et al. 2011. The surveys were conducted over the coho and Chinook spawning season (roughly mid-November to late February/early March during an average rainfall year) by a two-person team, either by foot in smaller streams, or by inflatable kayak in larger streams. Each reach is intended to be surveyed once every 7 to 14 days, or as weather, flow, and turbidity conditions allow.

Live fish and carcasses were identified to species and sex if possible and X-Y coordinates acquired with a handheld GPS unit. Carcasses were assigned a condition code ranging from 1 to 5 based on freshness, measured to fork length when possible, and marked as "captured" using a uniquely numbered jaw tag. If a carcass was recovered with a jaw tag on a subsequent survey it was considered "re-captured".

Redds were attributed a species if an identifiable fish was observed actively digging or guarding the redd. If no fish was observed on the redd, its species was left as unidentified. The location of all newly observed redds was geo-referenced by acquiring X-Y coordinates with a handheld GPS unit, and marked with flagging labelled with that redd's unique record number. All new redds encountered were assigned an age of (1) new since last survey. On subsequent surveys, encountered flags were matched with their associated redds, which were then re-assigned a new age of (2) still visible and measurable, (3) visible, but not measurable, (4) not visible, or (5) unknown due to poor visibility. If a new redd was unattended or an old redd was not previously measured, physical measurements were taken, including length and width of pot and tailspill, substrate size of pot and tailspill, and depth of the pot relative to the surrounding substrate.

2.4 ESTIMATION OF TOTAL REDD ABUNDANCE WITHIN SURVEY FRAME

The redd data collected over the course of the spawning season was expanded to estimate total coho salmon redd abundance over the entire survey frame using the steps outlined in Ricker et al.

2014. In order to estimate total redd abundance; (1) all redds were assigned a species, (2) within-reach redd abundance was estimated, and (3) within-reach redd abundance was expanded to estimate total redd abundance across the entire survey frame.

2.4.1 ASSIGNING SPECIES TO REDDS

Only redds directly associated with a live fish, building or guarding them, were considered unambiguously known to species. In order to assign a species to the redds labelled in the field as "unidentified species," a k-Nearest Neighbor (kNN) model was used to predict which species (coho, Chinook, or steelhead) was most likely to have constructed the redd (Ricker et al. 2013). Both known species redds and live fish observations were used as known elements in the training set of data in the kNN model. The standardized z-scores of X and Y coordinates, and julian date of observation were used as feature attributes and each redd was classified by the majority vote of the three nearest neighbors (known redds and live fish) in Euclidean distance. Leave-one-out-cross-validation (LOOCV) of the known redds in the survey was then used to evaluate the performance of the kNN model. All calculations were performed using the program R with the "class" package (Venables and Ripley 2002) and the "caret" package (Kuhn 2013). Only known species fish and redds from the current survey year were chosen for use in the training data available to make predictions.

The use of live fish in the prediction of species to field unidentified redds represents a change to the implementation of the kNN model used in past years' analysis. This change was implemented to improve the accuracy of predictions, particularly where redd locations and spawning period overlap for coho salmon and steelhead. Field observations indicate steelhead are more rarely seen building or guarding their redds, but more regularly observed proximal to the redd features, often associated with cover and/or deeper habitats. Due to few steelhead redds being unambiguously assigned to species, both the LOOCV evaluations of model performance and professional judgement indicated the model using only known redds in the training set was erroneously predicting many of the later season, steelhead sized and appearance redd features as coho salmon. The inclusion of known fish to the training set provided more observations and is believed to be more accurate at predicting species of unknown redds.

2.4.2 ESTIMATION OF WITHIN-REACH ABUNDANCE

High stream discharge, and time between repeated surveys result in scour or flatten redds and therefore obscure them from potential counting (Jones, 2012). To account for the unseen fraction of redds deposited then subsequently obscured from view between repeated surveys, the total number of redds constructed within a survey reach was estimated using a flag-based mark-recapture model. The total count of individually observed and flagged redds for a given reach is divided by the square root of the seasonally pooled redd survival rate. Redd survival is calculated as the fraction of re-observed and still identifiable flagged redds ("recaptures" assigned age 2 or

3) to the total number of flagged redds available to for potential re-observation ("marked"). Taking the square root of this fraction assumes the deposition of redds occurs at the midpoint between survey intervals (see below) (Schwarz et al. 1993). Bootstrap resampling from an assumed binomial distribution was used to represent the uncertainty of the pooled seasonal redd survival term in the estimator of total number of redds within the reach. The variance of the estimated total number of redds within a reach is calculated as the variance of the resultant bootstrap distribution (Manly 1997, Ricker et al. 2014). Additional assumptions applied to this model are:

1. Surveyors correctly identify all redds and no redds are missed during each survey.
2. Once a redd has been classified as "not visible" it does not become visible at a later occasion.
3. All redd flags are re-observed, identifiable, and recorded.
4. All marked redds have the same probability of survival, regardless of species or age and across all occasions.
5. New redds are constructed at the mid-point between survey intervals

2.4.3 ESTIMATION OF TOTAL REDD ABUNDANCE

A Simple Random Sample estimator is used to expand the number of redds in the sample reaches to an estimated total over the entire sample frame. The estimated total is calculated as the product of the total number of reaches in the sample frame and the mean number of redds of the sample reaches. The total variance is the sum of the within reach variance of the sample reaches and the between sample reach variance (Adams et al. 2011).

Table 1: Survey frequency by reach. Reaches are listed by stream name and location code (location codes listed in parentheses are subreaches). Mean indicates the average interval between visits, Max is the maximum number of days between visits, and N is the total number of visits.

Location Code	Stream Name	Mean	Max	N
101 (1325)	South Fork Eel River	13.5	14	3
103 (1340)	South Fork Eel River	22.67	41	4
107 (1359)	South Fork Eel River	18	26	4
110 (1369)	South Fork Eel River	27.5	29	3
127 (172)	Bull Creek	24.25	64	5
143	Squaw Creek	14	37	8
205	Canoe Creek	31.33	52	4
340 (345)	Fish Creek	18.8	30	6
416	Redwood Creek	42	75	3
421	Redwood Creek	32	61	4
426	Redwood Creek	13.71	21	8
453 (457)	Somerville Creek	19.4	34	6
520	Little Sproul Creek	16.5	24	7
521	Little Sproul Creek	16.5	24	7
565	Cox Creek	13	17	8
584	East Branch South Fork Eel River	32.67	59	4
587	East Branch South Fork Eel River	32.67	59	4
748	Indian Creek	30.33	40	4
753	Indian Creek	42.5	56	3
754 (779)	Indian Creek	20.5	28	5
780	Sebbas Creek	20.5	35	5
800	Anderson Creek	29.33	49	4
827	Standley Creek	40.5	55	3
828	Standley Creek	40.5	55	3
941.1	Hollow Tree Creek	45	75	3
941.3	Hollow Tree Creek	45	75	3
950.1	Hollow Tree Creek	45.5	62	3
950.2	Hollow Tree Creek	45.5	62	3
957	Hollow Tree Creek	15.17	32	7
981	Redwood Creek	11.5	16	5
991	Bond Creek	22.25	47	5
1061	Rattlesnake Creek	24.5	54	5
1108	Grapewine Creek	14.14	25	8
1127 (1156)	Ten Mile Creek	49	84	3
1132 (1196)	Ten Mile Creek	17.5	22	3
1248 (1254)	Cahto Creek	17.8	27	6
1275	Fox Creek	15.75	27	5
1277	Elder Creek	15.75	27	5
1316	Redwood Creek	15.2	21	6
1327	Kenny Creek	21	28	5
	All Reaches	**25.83**		**190**

3 RESULTS

3.1 SAMPLE FRAME CHANGES AND STATUS

Field reconnaissance of the South Fork Eel River sampling frame is now considered complete and appropriate updates transferred to the state-wide CMP Geo database in Sacramento and the luLocation table of the CMP Aquatic Survey's Survey Management Switchboard. Sample frame updates included changes to reach lengths, start stop locations, and total number of reaches. Reach additions resulted from the splitting of reaches on Hollow Tree Creek (Location Codes 943, 950) into multiple shorter reaches that better fit field protocols and reach length criteria for the CMP. Primary main reaches in the South Fork Eel headwaters region above Dutch Charlie Creek were removed from the sample frame for the 2011-12 survey season then added back in for the 2012 and future years after physical access for survey crews was deemed available and reasonable using boating survey methods. The lower most reach in Rattlesnake Creek above the canyon (Location Code 160) was removed in 2011 due to inaccessibility and surveyor safety concerns. There were additional instances of shortening reaches at the terminus at the upstream extents of distribution. Smaller sub-reaches were added and or subtracted, but the manipulation of sub-reaches did not change the total number of main reaches in the sample frame. The 2015 South Fork Eel coho salmon sampling frame is considered finalized and will remain static for the continuation of the project into future years. The finalized coho salmon sample frame consists of 204 main survey reaches (Figures 1, 2, and 3). Given this progress, the adoption of a fixed, rotating panel revisit design will be proposed to the CMP Science Team Sample Frame group for adoption and implementation.

3.2 SURVEY STATISTICS

Survey crews conducted a total of 190 spawning ground surveys from November 18th, 2015 to March 3rd, 2016 over the 40 randomly selected stream reaches within the South Fork Eel River watershed. Each reach was visited between three and eight times over the survey season (average number of visits per reach was 5). The average interval between surveys over all reaches was 26 days (Table 1). Figure 4 presents the discharge measured at the South Fork Eel River USGS gauging station near Miranda, CA relative to the number of surveys completed per day over the survey season.

3.3 FISH OBSERVATIONS

A total of 26 coho salmon, 45 Chinook salmon, 29 steelhead, and 23 unidentified salmonids were observed over the survey period. Five coho salmon carcasses, 14 Chinook salmon carcasses, two steelhead carcasses and five unidentified carcasses were counted. Peak coho observations occurred from the week ending on December 31st, 2015 to the week ending on January 14th, 2016. Peak Chinook observations occurred from the week ending on December 10th, 2015 to the

week ending on December 31st, 2015 (Figure 5). Table 2 summarizes live fish observations by location code. Table 3 summarizes observations of live fish and carcasses by survey week.

In addition to coho, Chinook, and steelhead, one Pacific lamprey (*Lampetra tridentate*) was observed in Indian Creek, location code 754, on February 24th, 2016. Lamprey data is not included in Table 2 or in Table 3.

3.4 REDD OBSERVATIONS

Surveyors identified five known coho salmon redds, three known Chinook redds, and three known steelhead redds (Tables 2 and 3, Figure 5). Cross validation of the eleven known redds resulted in the kNN model correctly assigning all known redds to the respective species. Three hundred thirty-three redds were not field identified to species and kNN predictions of species likely to have constructed them were made.

3.5 TOTAL REDD ABUNDANCE

Sufficient flag marking and re-observation data was available to apply the with-reach estimation model in four sample reaches where known or predicted coho salmon redds were observed. Aggregate counts of individual known and predicted redds by species were used in the remaining six reaches where no reach level expansion was available. The total redd abundance estimate for coho salmon for the 2015/2016 South Fork Eel River spawning season, with 95% confidence intervals, is 416 (109, 722). The total redd abundance estimates for Chinook salmon and steelhead is 433 (77, 917) and 1141 (698, 1585), respectively (Table 4).

Due to both the improvement of the kNN model's performance by incorporating live fish into the training set of known elements, and the adjustments to the total number of reaches in the coho salmon sampling frame, new estimates of total redd abundance were produced for all past survey seasons, updating previously reported figures (Table 5).

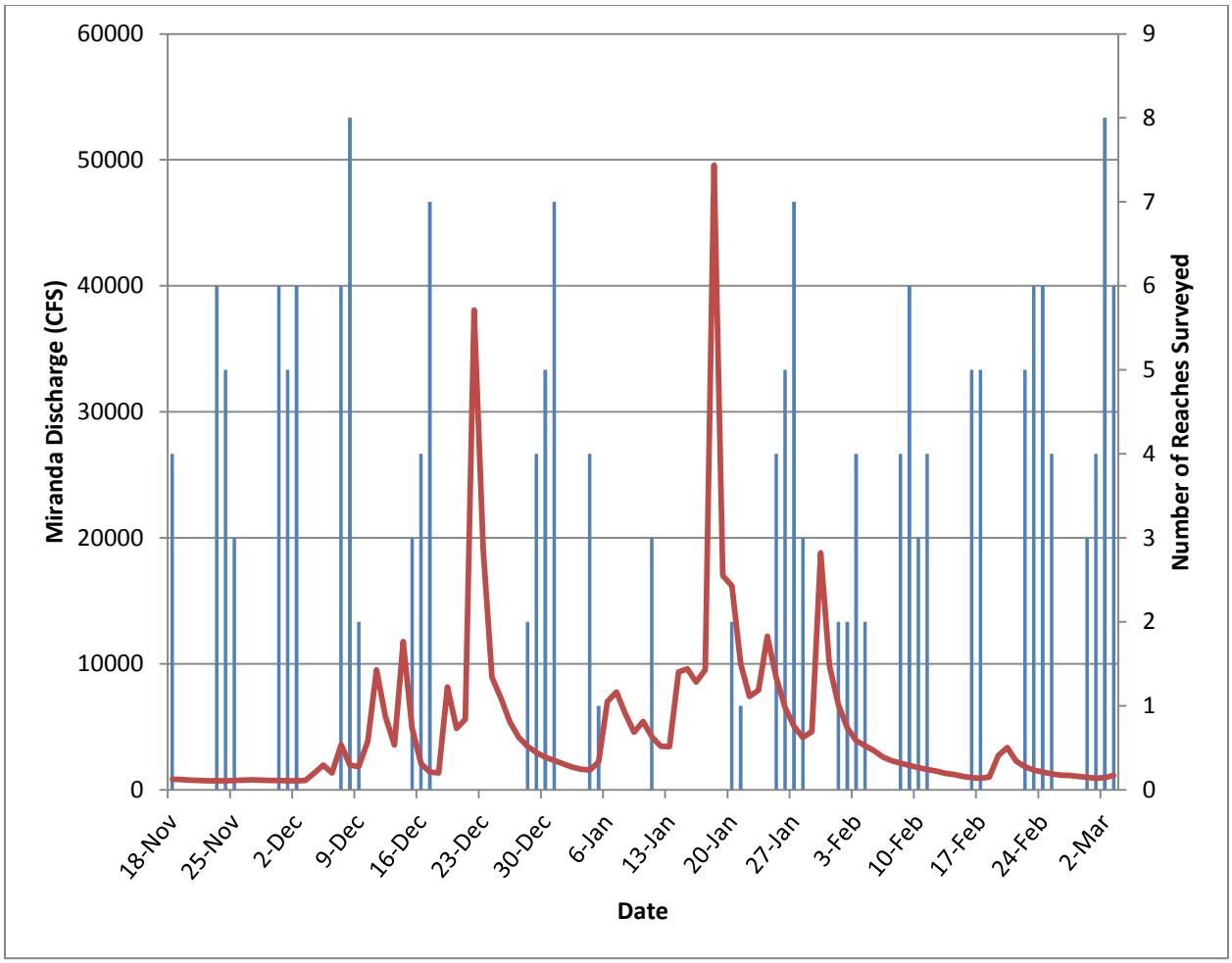

Figure 5: Discharge of the South Fork Eel River near Miranda compared to number of surveys conducted each day over the survey period, November 18th, 2015 to March 3rd, 2016. Discharge (in cubic feet per second, cfs) as recorded at midnight on each day is presented on the primary y-axis (blue line); the number of reaches surveyed per day is presented on the secondary y-axis (red line).

Table 2: Counts of observed live fish and redds by location code.

Location Code	Live Chinook	Known Chinook Redds	Live Coho	Known Coho Redds	Live Steelhead	Known Steelhead Redds	Live Unidentified	Unidentified Redds
101	0	0	0	0	3	0	0	0
103	0	0	0	0	0	0	2	8
107	0	0	0	0	4	0	0	2
110	0	0	3	2	0	0	1	4
127	0	0	0	0	0	0	0	1
143	21	2	0	0	0	0	0	9
205	1	1	0	0	0	0	0	0
340	0	0	0	0	0	0	0	6
416	0	0	0	0	0	0	0	0
421	0	0	0	0	0	0	0	0
426	0	0	0	0	7	1	2	26
453	0	0	0	0	0	0	0	12
520	0	0	0	0	0	0	0	0
521	0	0	3	1	0	0	1	18
565	0	0	0	0	0	0	0	9
584	0	0	0	0	0	0	0	29
587	0	0	0	0	0	0	0	2
748	0	0	0	0	0	0	0	1
753	0	0	0	0	0	0	0	5
754	19	0	1	0	2	0	4	51
780	0	0	1	0	0	0	1	7
800	0	0	0	0	2	0	4	5
827	0	0	0	0	2	1	0	2
828	0	0	0	0	0	0	0	1
941.1	0	0	0	0	0	0	0	4
941.3	0	0	0	0	2	0	2	2
950.1	0	0	0	0	2	0	0	10
950.2	0	0	0	0	1	0	0	13
957	0	0	7	2	0	0	2	45
981	0	0	10	0	0	0	1	9
991	0	0	0	0	0	0	0	8
1061	0	0	0	0	2	1	0	2
1108	0	0	0	0	0	0	0	13
1127	1	0	0	0	0	0	0	1
1132	0	0	0	0	0	0	2	2
1248	0	0	0	0	1	0	0	15
1275	0	0	0	0	0	0	0	0
1277	0	0	0	0	0	0	0	1
1316	3	0	1	0	0	0	1	1
1327	0	0	0	0	1	0	0	5
Total	45	3	26	5	29	3	23	329

Table 3: Counts of observed live fish, carcasses and redds by week over the survey season, November 18th, 2015 to March 3rd, 2016.

Last Day of Week	Live Chinook	Live Coho	Live Steelhead	Live Unidentified	Chinook carcasses	Coho carcasses	Steelhead carcasses	Unidentified carcasses	Known Chinook Redds	Known Coho Redds	Known Steelhead Redds	Unidentified Redds
19-Nov	0	0	0	0	0	0	0	0	0	0	0	0
26-Nov	0	0	0	0	0	0	0	0	0	0	0	0
3-Dec	0	0	0	0	0	0	0	0	0	0	0	0
10-Dec	1	0	0	1	0	0	0	0	0	0	0	4
17-Dec	37	0	0	7	2	0	0	0	2	0	0	54
24-Dec	0	0	0	0	0	0	0	0	0	0	0	0
31-Dec	6	11	0	4	9	1	0	2	1	2	0	32
7-Jan	1	4	0	2	1	0	0	0	0	1	0	11
14-Jan	0	10	0	0	0	0	0	1	0	2	0	28
21-Jan	0	1	2	6	0	0	0	1	0	0	0	4
28-Jan	0	0	0	1	0	2	0	0	0	0	0	25
4-Feb	0	0	5	0	0	1	0	0	0	0	0	16
11-Feb	0	0	7	0	0	0	0	0	0	0	0	41
18-Feb	0	0	2	0	1	0	0	1	0	0	0	53
25-Feb	0	0	8	0	0	0	1	0	0	0	2	24
3-Mar	0	0	5	2	0	0	1	0	0	0	1	37
Total:	45	26	29	23	13	4	2	5	3	5	3	329

Figure 6: Stacked barplot of observed live fish, carcasses, and redds by week over the survey season, November 18th, 2015 to March 3rd, 2016.

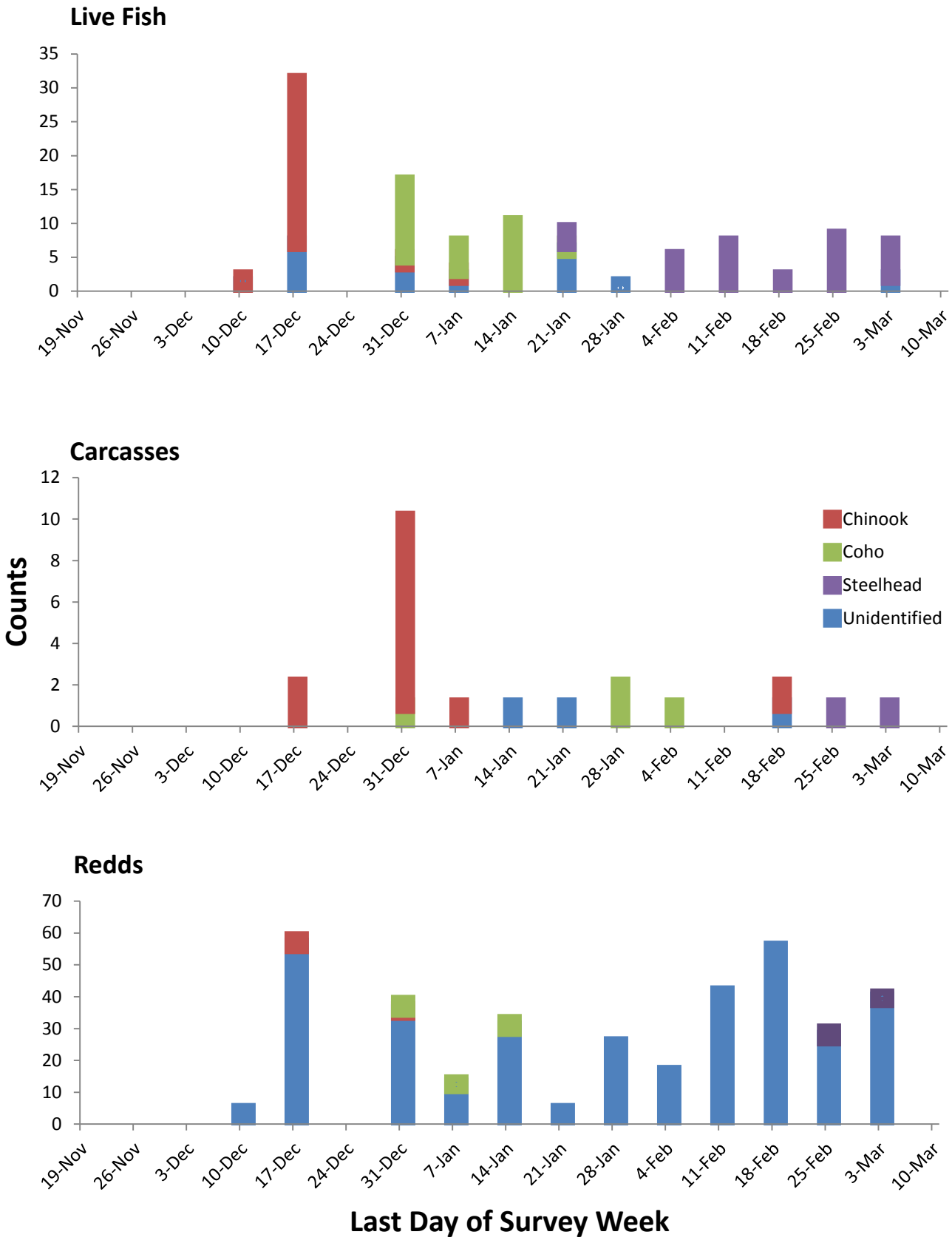

Table 4: Estimated total redd abundance by species with 95% confidence intervals.

	Chinook	Coho	Steelhead
Estimated number of redds	418	416	1125
95% Confidence Intervals	76, 892	117, 715	686, 1563

4 DISCUSSION

The South Fork Eel River Adult Salmonid Redd Abundance Monitoring Project was initiated in 2010 as a long-term effort to provide estimates of adult coho salmon redd abundance in the South Fork Eel River over time. As the primary focus of this project is coho salmon, spawning ground surveys are conducted only over the spatial extent and time period deemed ideal for coho data capture. Estimates of total redd construction for Chinook salmon and steelhead presented herein are likely underestimates because the spatial extent of Chinook salmon and steelhead spawning habitats are greater than the spatial extent of the coho salmon sampling frame, and because the duration of the steelhead spawning run extends beyond the coho spawning run. The estimates of total redd abundance for Chinook salmon and steelhead presented in this report are representative only of those occurring within the coho-specific sampling frame and within the observation period, November 18th, 2015 to March 3rd, 2016.

The first significant rain event of the season in the Eel River watershed occurred in mid-December. Heavy precipitation continued through January in the sample area causing the Eel River to reach near flood stage on multiple occasions. This heavy and consistent rainfall increased flows and turbidity such that surveys in the South Fork Eel River watershed were significantly impacted. Stream conditions prevented crews from surveying December 17 through December 28 as well as January 11 through January 20, 2016. Between the two larger storm events, persistent rainfall prevented consistent surveys in many reaches due to unsafe high flows and/or lack of instream visibility.

The South Fork Eel River is a large and complex system. As such, survey intervals and the number of visits per reach are more influenced by the unique discharge and turbidity characteristics of the individual reaches than by conditions basin wide. For example, Hollow Tree Creek and Indian Creek have low turbidity rates during storm events and tend to present a flashy behavior with quick rise and fall of stream flows, making it easier to conduct surveys within three to five days after a significant rain event. Bull Creek and East Branch South Fork Eel River are very high turbidity streams and can take weeks before conditions are clear enough to survey. Consequently, some reaches within the sample frame will be more heavily sampled during a season. Each reach was visited between three to eight times over the survey season (average number of visits per reach was 5), and the maximum number of days between visits ranged from 14 to 75 (the average survey interval was 26).

Due to significant gaps in the survey that occurred due to weather and flow the South Fork Eel 2015/2016 redd abundance estimate is likely an underestimate of actual coho and Chinook redd abundance for this spawning year. Frequent and significant flow events prevented repeat survey recapture of previously observed redds throughout the sampled reaches due to redds becoming obscured between surveys, and the lack of redd recapture and live fish observations reduced within-reach redd abundance estimates. Monitoring during the peak of steelhead spawning was less hampered by persistent high flow and allowed for regular interval surveys, fish and redd observation, and redd recapture.

Data obtained from operation of a salmonid life cycle monitoring station (LCM) in a sub-basin of the South Fork Eel River would provide a ratio of redd abundance to adult salmonid spawning escapement within the South Fork Eel watershed. An effort is underway to establish a S.F. Eel LCM in the Sproul Creek sub-basin. Until a South Fork Eel River LCM derived, or other appropriate index of annual redd/adult ratio is available, redd estimates developed from South Fork Eel surveys 2010/2011, 2011/2012, 2012/2013, 2013/2014, 2014/2015, 2015/2016, and, should be evaluated together with the achieved annual survey frequency and flow conditions that occurred in those years. Table 5 summarizes survey statistics and redd estimates for the last six years of the project.

Table 5: Summary of the prior six years of South Fork Eel River Coho Population Monitoring Project redd estimates and 95% confidence intervals. *The estimated number of salmonids redds for survey years 2010-2011 through 2014-2015 have been adjusted following new data analysis techniques. The estimates presented in this table are the most current and should be used for future analysis.

Survey Year	Number of reaches surveyed	Total Number of Surveys	Average Survey Interval	Average number of surveys per reach	Estimated number of coho redds	Estimated number of Chinook redds	Estimated number of steelhead redds
2010-2011*	31	151	21	5	1284 (159, 2543)	1829 (679, 2980)	288 (35, 255)
2011-2012*	40	204	22	5	1873 (1253, 2493)	68 (15, 148)	379 (58, 818)
2012-2013*	40	229	16	6	1340 (658, 2022)	855 (293, 1418)	761 (471, 1051)
2013-2014*	39	247	27	6	939 (304, 1574)	223 (40, 423)	1055 (359, 1751)
2014-2015*	40	248	19	6	2069 (1342, 2795)	781 (310, 1253)	967 (541, 1393)
2015-2016	40	190	26	5	416 (117, 715)	418 (76, 892)	1125 (686, 1563)

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