State of California
Department of Fish and Wildlife

South Fork Eel River Salmonid Abundance Monitoring Project 2023-2024

California Coastal Salmonid Monitoring Program Annual Report prepared in partial fulfillment of CDFW Fisheries Restoration Grant Program
Grantee Agreement Number: CMP-23R1001

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October 7 2024

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ABSTRACT

The South Fork Eel River Salmonid Abundance Monitoring Project was initiated in 2010 to estimate Coho Salmon redd abundance in the South Fork Eel River (SFER) and inform conservation strategies for the state and federally endangered Species Act(s) threatened Southern Oregon Northern California Coast (SONCC) Coho Salmon. Additionally, the SFER project conducts redd monitoring of California Coastal (CC) Chinook salmon[3] and Northern California (NC) steelhead[3]. From November 21, 2023 to February 27, 2024, a total of 160 spawning ground surveys were conducted over 33 spatially balanced and randomly selected reaches in the SFER watershed. Each reach was surveyed an average of 3.4 times, and the average interval between surveys over all reaches was 22.1 days. During 2023-2024 SFER monitoring, surveyors observed 95 live Coho Salmon, two live Chinook Salmon, four live steelhead, 32 Coho Salmon carcasses, 14 Chinook Salmon carcass, and 23 unidentified salmonid carcasses. A total of 140 redds were detected, of which 51 redds were observed to be associated with a specific salmonid species while in the field. The remaining 89 redds were assigned a species using a k-Nearest Neighbors algorithm. The number of redds observed in randomly selected sample reaches was expanded to estimate the number of redds constructed across the entire SFER sample frame. Redd abundance estimates for the 2023-2024 spawning season in the SFER, including 95% confidence intervals, were 718 (231 - 1205) Coho Salmon redds, 105 (17 - 195) Chinook Salmon redds[4], and 106 (31 - 182) steelhead redds[3].

[3] The SFER Adult Salmonid Redd Abundance Monitoring Project does not survey the entire spatial extent of potential Chinook and steelhead trout spawning areas and does not survey the entire temporal breadth of potential steelhead spawning in the S.F. Eel River. The project's sample frame of potential reaches and annual survey start and end dates are specifically designed to cover the spatial and temporal extent of S.F. Eel River Coho Salmon spawning. Chinook and steelhead redd abundance estimates provided in this report are not derived from a survey design intended to estimate the total S.F. Eel redd abundance for these species.

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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 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 to delist the species (CDFW 2004, NMFS 2014). Long-term population monitoring is an essential component of these recovery plans as the key metric 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 North Coast area, adult salmonid population abundance are recommended to be monitored via 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 specie(s) 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 are 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 (SFER) flows through Mendocino and Humboldt Counties and is a significant tributary within the Eel River, California's third largest watershed (Figure 2). The SFER'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 mouth at the Pacific Ocean, near the town of Loleta, CA. The SFER 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 SFER is approximately 105 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 SFER 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 SFER 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 Salmon were counted at the Benbow Dam, located at River Mile 40 (Taylor, 1978) (Figure 1). However, Pacific salmon runs in SFER have markedly declined since the mid-twentieth century. In 1994, a status review of SFER Coho Salmon estimated the returning population at approximately 1,320 adults (Brown et al. 1994).

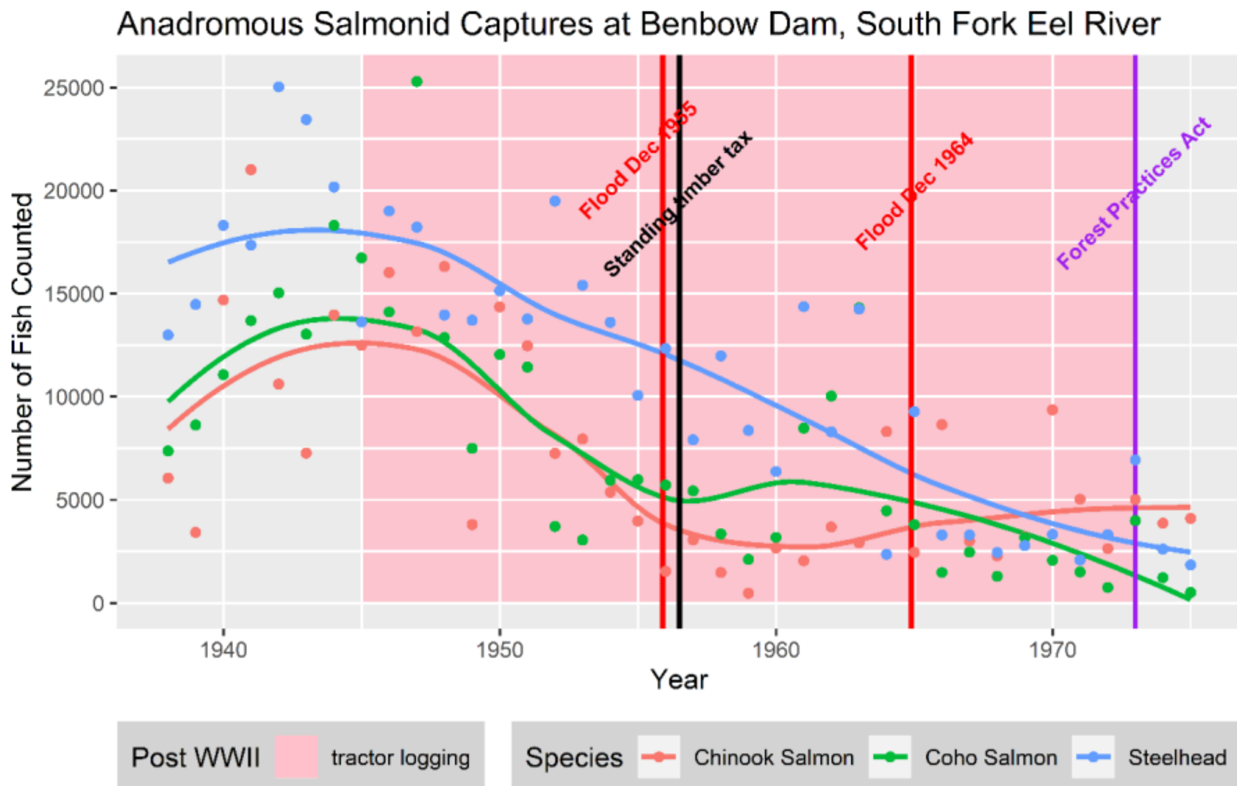

Figure 1. Counts and smoothed trend line of adult salmonids at Benbow Dam (river mile 40), SFER, 1938 - 1976. Shaded area indicates the period of increased post WWII tractor logging, and vertical lines indicate timing of major flood occurrences, and forest management legislation (SFER SHaRP Collaborative 2021).

SFER 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 SFER 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 SFER Watershed. This report presents the results of the 2023-2024 spawning survey season, the 2023 year of the project. Previous annual reports for years 2010 through 2022 are available in the CDFW Document Library: https://nrm.dfg.ca.gov/documents/.

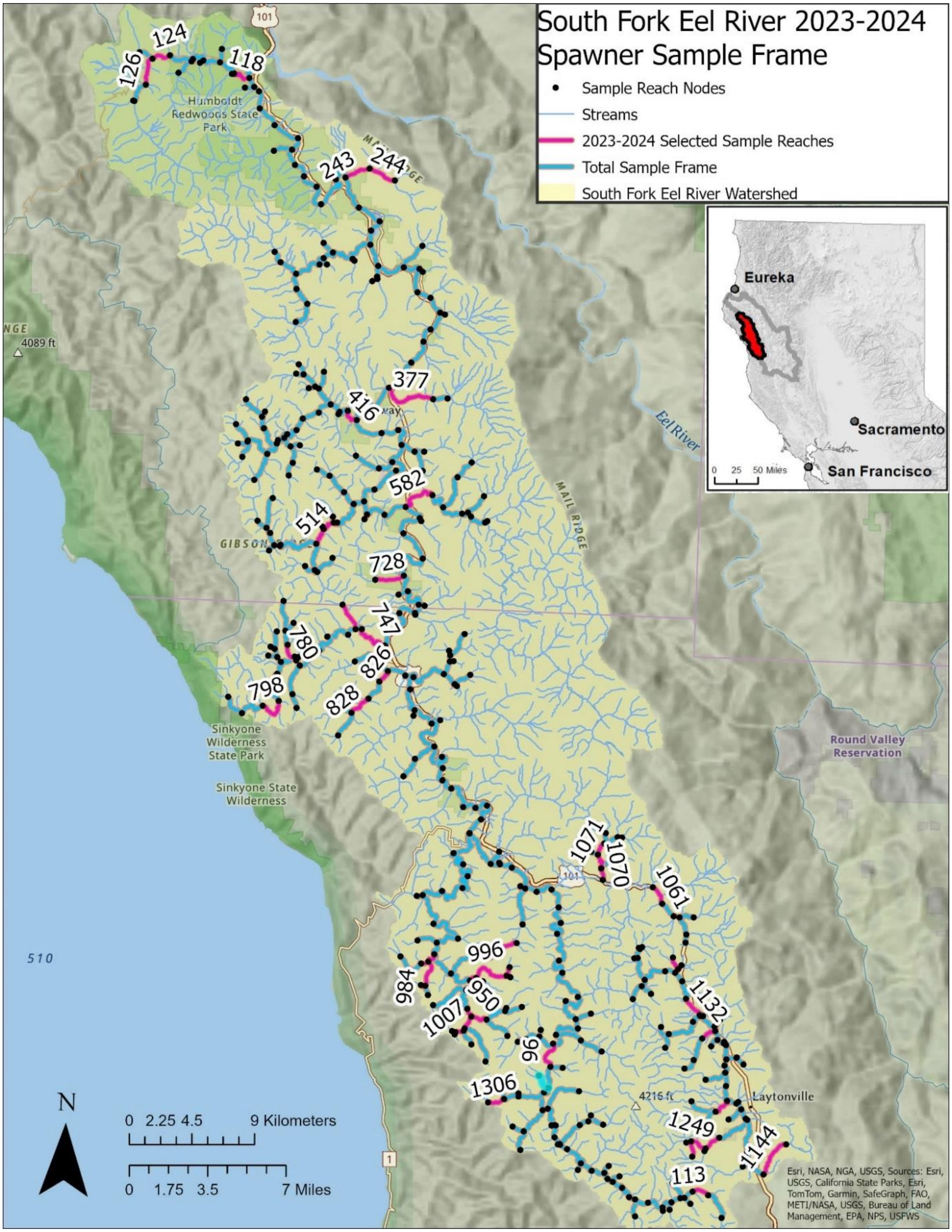

Figure 2. Map of the SFER and the reaches selected for sampling in 2023-2024. The inset map depicts the SFER (in red) within the Eel River watershed in the northern California setting.

2 METHODS

2.1 SAMPLE FRAME

A sample frame was established for SFER 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 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 (Figure 2, Figure 3). Reaches that are less than one kilometer long (sub-reaches) are surveyed together 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).

Given the focus of Coho Salmon in this project, spawning ground surveys are conducted over the spatial extent and time period deemed ideal for Coho Salmon data capture. However, the spatial extent and duration of Chinook Salmon and Steelhead spawning are greater than that of Coho Salmon in the SFER. It is likely the estimates of total redd construction for Chinook Salmon and Steelhead from these surveys are underestimates of these species in the SFER and only represent those occurring within the Coho Salmon-specific sampling frame and observation period.

2.2 SAMPLE REACH SELECTION

The SFER spawning ground surveys are conducted using a spatially balanced, random sample of stream reaches drawn from the Coho Salmon-specific sample frame of 203 potential reaches. Sample units selected by a Generalized Random Tessellation Stratified (GRTS) sampling scheme (McDonald 2003) were allocated to four panels that are assigned different visitation schedules (CDFW 2011). The four different visitation schedules for panels are as follows: one panel that will be visited every year (Panel 1), three panels that will be visited once every three years (Panels 2 through 4), 12 panels that will be visited once every 12 years (Panels 5 through 16), and 30 panels that will be visited once every 30 years (Panels 17 through 46), for the life of the project (Figure 3 for a visualization). Each panel contains multiple sample units. The panel sampled every year has ~40% of the total number of reaches visited every year. The panels sampled every 3, 12, and 30 years each have ~20% of the total annual number of reaches. Since much of the SFER is under private ownership, a reach's inclusion in the final list of sample reaches is dependent on gaining stream access permission from the relevant landowners. If permission was denied or if a landowner did not respond in time for the start of the spawning season, the reach was skipped for the year and the next stream in order was added to the survey list.

NOTE: **Panel 1 gets 40% of Annual Sample. Panel 2 thru 16 "EACH" gets 30% of Annual Sample**

VISITATION SCHEDULES

Repeat Panel	Panel ↓	YEAR 1	2	3	4	5	6	7	8	9	10	11	12
Every Year	1	15	15	15	15	15	15	15	15	15	15	15	15
Every 3 years	2	11			11			11			11		
	3		11			11			11			11	
	4			11			11			11			11
Every 12 years	5	11											
	6		11										
	7			11									
	8				11								
	9					11							
	10						11						
	11							11					
	12								11				
	13									11			
	14										11		
	15											11	
	16												11
Annual Sample		37	37	37	37	37	37	37	37	37	37	37	37
Cumulative UNIQUE Segments		37	59	81	92	103	114	125	136	147	158	169	180
Reserves Available		161	139	117	106	95	84	73	62	51	40	29	18

Figure 3. Example of a rotating panel design. In this example, 15 reaches are sampled every year, 11 reaches are sampled every 3 years, and 11 reaches are sampled every 12 years. Each season, a combined total of 37 reaches are selected for surveys.

Table 1. List of reaches in Panel 1 to be visited annually.

Stream Name	*Drainage*	*Location Code*
SFER	Eel River	113
Bull Creek	SFER (lower)	126
Dean Creek	SFER(middle)	377
Sproul Creek	SFER (middle)	511
Sproul Creek	SFER (middle)	514
East Branch SFER	SFER (middle)	582
Anderson Creek	Indian Creek	798
Hollow Tree Creek	SFER (upper)	950.3
Foster Creek	Rattlesnake Creek	1070
Tenmile Creek	SFER	1144
Tributary to Tenmile Creek	Tenmile Creek	1168
Big Rock Creek	Tenmile Creek	1202

Little Case Creek	Tenmile Creek	1228
Tributary to Cahto Creek	Tenmile Creek	1260
Dutch Charlie Creek	SFER	1306

2.3 REACH SURVEY PROTOCOL

We conducted spawning ground surveys following the methods of ground survey and data capture outlined in Gallagher (et al. 2014) and Adams (et al. 2011). Surveys occur during the Coho Salmon and Chinook Salmon spawning season (roughly mid-November to late February/early March during an average rainfall year). This season also overlaps a portion of the Steelhead spawning season (mid-January to late April). Surveys are conducted 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. Before each survey we collected data on weather, air temperature, water temperature and turbidity. The turbidity threshold for acceptable survey conditions is 50 centimeters measured with a secchi disk. All air and water temperatures are collected in degrees Celsius. We classified weather into five categories: (1) sunny, (2) cloudy, (3) overcast, (4) rain, and (5) snow. Apple iPads were utilized as data collection devices with a Pendragon Forms data collection application. We identified live fish and carcasses to species and sex if possible and acquired latitude and longitude for every fish observation using the GPS feature in Pendragon Forms. We measured the fork length of each complete carcasses and assigned a condition code based on the level of decomposition: (1) carcass, fresh, clear eye, (2) carcass, cloudy eye, low fungus, (3) carcass, cloudy or no eye, heavy fungus, (4) carcass, skin and bones with head, (5) carcass, skin and bones no head, and (6) loose tag no fish. We marked carcasses as “captured” with a uniquely numbered jaw tag. If a carcass was recovered with a jaw tag on a subsequent survey, it was considered “re-captured”. When viable, we collected biological samples of tissue and scales. Scale and tissue samples were sent to CDFW’s Scale Library at the CDFW Arcata Office and tissue samples were delivered to the NOAA Southwest Fisheries Science Center.

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. 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, are considered unambiguously known to species. To assign a species to the redds labelled in the field as “unidentified species” we used a k-Nearest Neighbor (kNN) model to predict which species (Coho Salmon, Chinook Salmon, or steelhead) was most likely to have constructed the redd (Ricker et al. 2014). The k-Nearest Neighbors algorithm is a simple non-parametric form of machine learning where an object is classified by a majority vote of its k-nearest neighbors in Euclidean distance. Euclidean distance is a measure of distance between individuals and generalizes Pythagoras’s theorem to multiple dimensions. We use location (latitude and longitude) and date as spatial and temporal dimensions and calculated Euclidean distance (d_{ij}) between redd x_i and x_j as:

$$d_{ij} = \sum_{k=1}^{n} \sqrt{\left(x_{ik} - x_{jk}\right)^2}$$

where fish and redd attributes are represented by l. When only Julien date is used n=1. When all three attributes are used n =3.

The kNN model selects classes based on the shortest euclidean distance, and because the spatial distance is in meters, and the distance in time (number of days) are on distinctly different scales, we standardized attribute data values into z-scores by:

$$z_i = \frac{x_i - \mu}{\sigma}$$

The distance between the raw score and population mean μ is represented by z. We classified each redd by the majority vote of the three nearest neighbors (k=3) based on the previous work of Ricker and Stewart (2011) who fit used values of k from 3 to 10 and found a k of 3 was the smallest number of neighbors that produced the highest percentage correct classification rate with the fewest ties. If ties were encountered in the vote, they were mitigated by using the majority vote of the entire data set (Ricker et al. 2013). Both known species redds and live fish observations are used as known elements in the training set of data in the kNN model. We used only known species fish and redds from the current survey year in the training data set available to make redd predictions.

We used leave-one-out-cross-validation (LOOCV) of the known redds in the survey to evaluate the performance of the kNN model. LOOCV is an iterative process where each redd is removed in turn from the training data set of known species redds, the model re-fit to the data and the removed redd predicted to species. Known species redds were paired with the LOOCV prediction and confusion matrices tabulated, indexed by row of the true species of the redd and by columns of the predicted redd. From these matrices, the performances of the models are evaluated for each species by assessing their classification sensitivity, specificity, and accuracy. Values generated for these measures of model performance range from zero to one, with measures closer to one indicating better model performance. Sensitivity, or power, is the proportion of the total known redds of a particular species to the total number of redds classified as that species. High sensitivity indicates a low type ll error rate (e.g. a model is not predicting redds as species two when, in the training data set, they are known to be species one). Specificity, or confidence, is the proportion of redds that are known to be a different species, to the total number classified as different species. High specificity indicates a low type l error rate (a model is not incorrectly predicting a redd to be species two when it is known to be species one). Overall model accuracy (one minus the apparent error rate) is the proportion of the total number of predictions that are correct. Ninety-five percent confidence intervals of the accuracy rate were produced using an exact binomial test. Good classifiers have high accuracy, and both high sensitivity and high specificity (Ricker et al. 2013). All calculations are performed using the program R with the “class” package (Venables and Ripley 2002) and the “caret” package (Kuhn 2013).

2.4.2 Estimation of Within-Reach Abundance

High stream discharge and time between repeated surveys may scour or flatten redds and therefore obscure them from potential counting (Jones 2012). To account for the unseen fraction of redds constructed then subsequently obscured from view between repeated surveys, the total number of redds constructed within a survey reach is 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. We calculated redd survival 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 (Schwarz et al. 1993). This function can be defined as:

$$\check{\tau}_J = B_0 + \frac{\sum_{i=2}^{k} B_i - 1}{\sqrt{\check{S}_p}}$$

where $\widetilde{T_J}$ is the estimate of the total number of redds within a sample reach *j*; B_i is the number of new redds on the survey occasion; *k* is the total number of survey occasions; and B_0 is the number of redds observed on the first survey of the season. The numerator of the second term is then the sum of all new redds observed from the second occasion to the last occasion, divided by survival of flagged redds pooled across all survey occasions for which at least one new redd of the target species was observed (Ricker et al. 2013 and Walkey and Garwood 2015):

$$\check{S}_p = \frac{\sum_{i=1}^{k-1} R_{i+1}}{\sum_{i=1}^{k-1} M_i}$$

$\check{S}_p$is the pooled survival rate of flagged redd, *i* is the survey with k being the total number of surveys. The numerator is then the sum of recaptured redds from the second survey occasion to the last survey occasion, and the denominator is the sum of marked redds and recaptured redds that were still visible from the first occasion to the second to last occasion (Walkey and Garwood 2015, Ricker et al. 2013). A bootstrap resampling from an assumed binomial distribution is used to represent the uncertainty of the pooled seasonal redd survival term in the estimator of total number of redds within the reach. This can be defined as:

$$se(\check{T}) = N\sqrt{\left(1 - \frac{n}{N}\right)\widetilde{\Theta_b}} + \frac{1}{N_n}\left(\sum_{i=1}^{n} \theta_w\right)$$

N accounts for the total number of sample reaches in the South Fork Eel sample frame and *n* is the number of reaches sampled. $\widetilde{\theta_b}$ accounts for the between reach variance of bootstrapped replicates and $\widetilde{\theta_w}$ represents within reach variance of bootstraps replicates. This is derived from methods found in Ricker et al (2014). 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. 2013).

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). It is defined as:

$$\check{T} = N\left(\frac{\sum_{j=1}^{n}\check{\tau}_j}{n}\right)$$

N is the number of reaches in the sample frame, *n* represents surveyed reaches, $\check{T}_j$ is the estimate of the total number of redds in a sample reach.

3 RESULTS

We completed 160 spawning ground surveys (125 main reach surveys and 35 sub-reach surveys) from November 21, 2023 to February 27, 2024 over 33 of the 37 selected stream reaches within the SFER Watershed (Table 2). Due to weather, personnel, and housing challenges in this season, four of the selected reaches were not surveyed. We surveyed each reach between one and seven times over the survey season. The average number of visits per reach was 3.4. The average interval between surveys over all reaches was 22.1 days. The period from December 12 to December 15 had the greatest number of surveys occur with 16. The most frequently surveyed reach was Sproul Creek with seven surveys total. The least frequently visited streams were Jones and Michaels Creek with one survey completed. South Fork Redwood Creek holds the lowest value for average time between surveys with 11.2 days. The highest value for survey intervals is South Fork Eel River reach 96 with 49 days between surveys. Note that this site was only surveyed twice during the sampling time frame. The high intervals between surveys can be attributed to the high water year in 2023-2024 (Figure 4), lack of field housing at the CCC center in Legget to begin the season, and other personnel constraints. The greatest discharge value recorded at the South Fork Eel USGS Miranda Gage during the season was 35,000 Cubic Feet per Second (cfs) on January 14 (Figure 3). The lowest recorded discharge value of 54.5 cfs was recorded on November 30 (Figure 3).

Table 2. Survey frequency by reach. Reaches are listed by location code (location codes listed in parentheses are subreaches). Mean indicates the average number of days between surveys, Max is the maximum number of days between surveys, and N is the total number of surveys. Subreaches with a different number of surveys and mean days between surveys from the main reach are indicated with parentheses.

Stream	Location Code	N (surveys)	Mean (days)	Max (days)
South Fork Eel River	96	2	49	49
South Fork Eel River	113	4	25	34
Bull Creek	118 (135)	3	11.5	14
Bull Creek	124	3	12.5	14
Bull Creek	126	3	12.5	14
Elk Creek	243	5	22.8	40
Elk Creek	244	6	18.2	27
Dean Creek	377	4	29.7	49
Redwood Creek	416	4	30	60
Sproul Creek	511	6	19.6	28
Sproul Creek	514 (533,535)	7	16.3	26
EB SF Eel River	582	3	38	63

Stream	Location Code	N (surveys)	Mean (days)	Max (days)
Durphy Creek	728	6	16.2	27
Indian Creek	747	6	18.2	24
Jones Creek	764	1*	-	-
Sebbas Creek	780	0	-	-
Anderson Creek	798	2	15	15
Standley Creek	826	0	-	-
Standley Creek	828	0	-	-
Hollow Tree Creek	950.3	2	21	21
Redwood Creek	981	5	13.3	18
SF Redwood Creek	984 (986)	6 (1*)	11.2	15
Bond Creek	992	0	-	-
Michaels Creek	996 (1000)	1 (0)*	-	-
Huckleberry Creek	1007 (1010)	4 (2)	21 (50)	29 (50)
Rattlesnake Creek	1061	3	35.5	49
Foster Creek	1070 (1075, 1076)	2 (1*,2)	14	14
Foster Creek	1071 (1078)	2	14	14
Tenmile Creek	1132 (1196)	3	35.5	49
Tenmile Creek	1144	4	22	31
Unnamed Reach	1168 (1169)	4	27	38
Big Rock Creek	1202	4	29.3	47
Little Case Creek	1228	5	15	23
Cahto Creek	1248 (1254)	3	29	22
Cahto Creek	1249	2	35	35
Little Charlie	1301	4	14.7	15
Dutch Charlie Creek	1306	6	12.6	19
	Mean	3.4 (2.9)	22.1 (24.7)	29.8 (30.1)
	Total	125 (35)		

* Reaches only visited once did not have intervals and were therefore not included in mean and max days

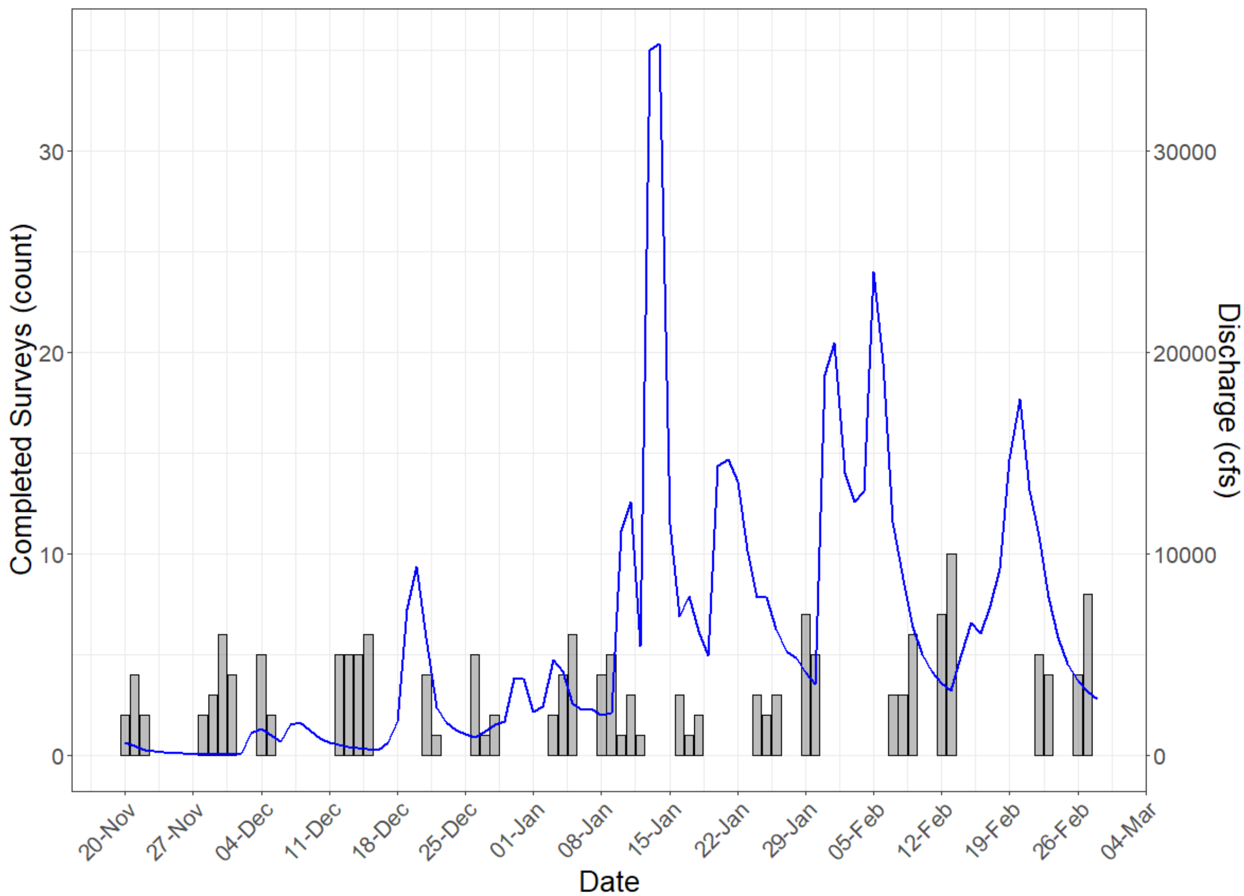

Figure 4. Daily spawning ground surveys completed in the SFER compared to discharge (in cubic feet per second, cfs) measured at the USGS gauging station near Miranda, CA between November 20th 2023 and February 27th 2024. Discharge values shown were recorded at midnight.

3.1 SAMPLE FRAME CHANGES AND STATUS

No changes to the sample frame were made this season and the frame has remained static for the majority of this project's history.

3.2 SURVEY STATISTICS

Survey crews conducted a total of 125 and 35 spawning ground surveys of main and sub-reaches, respectively, from November 20th, 2023 to February 27th, 2024 over the 33 stream reaches and 12 sub-reaches within the SFER watershed. Each reach was visited between one and seven times over the survey season (average number of visits per reach and sub-reach was 3.4 and 2.9 respectively). The average interval between surveys over all reaches was 22.1 days while the average interval between surveys over all subreaches was 24.7 (Table 2). Figure 4 presents the discharge measured at the SFER USGS gauging station near Miranda, CA relative to the number of surveys completed per day over the survey season. Frequent heavy precipitation events beginning in late December and continuing throughout the rest of the season created narrow windows in which surveyors could conduct surveys. Coupled with high flows, a lack of new fish observations in late February caused an early end to the spawning ground survey season.

3.3 FISH OBSERVATIONS

A total of 95 live Coho Salmon, two Chinook Salmon, and four steelhead were observed over the survey period. 32 Coho Salmon carcasses, 14 Chinook Salmon carcass, and 23 unidentified carcasses were counted. Peak Coho observations occurred from the week beginning on January 1st to the week of January 8th (Figure 6).Peak Chinook observations occurred during the week ending on December 28th. It is important to note that only two chinook were observed during this spawning season. Table 3 summarizes live fish, redds, and carcasses observations by location code. Figure 5 depicts counts of live fish, redds, and carcass summarized for each week of the 2023 season.

3.4 REDD OBSERVATIONS

Surveyors identified 51 known Coho Salmon redds and 89 unidentified redds (Table 3 and Figure 5). Cross validation of the 51 known redds resulted in the kNN model correctly assigning a species to 51 (100%) of the known redds. The Knn predictor was successful in identifying all 89 (100%) unidentified redds.

3.5 TOTAL REDD ABUNDANCE

Sufficient redd flag marking and re-observation data was available to apply the within-reach estimation model in 6 of the 23 randomly selected 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 17 reaches where no reach level expansion was available. The total redd abundance estimate for Coho Salmon for the 2023-2024 SFER spawning season, with 95% confidence intervals, are 718 (273, 1206). The total redd abundance estimates for Chinook Salmon and steelhead are 105 (17, 195) and 106 (31, 182), respectively (Table 4).

Table 3. Counts of observed live fish, redds, and carcasses by location code.

Location Code	Live Chinook	Known Chinook Redds	Chinook Carcass	Live Coho	Known Coho Redds	Coho Carcass	Live Steelhead	Known Steelhead Redds	Steelhead Carcass	Unk. Live Fish	Unk. Redds	Unk. Carcass	Total Live Fish	Total Redds	Total Carcass
96	-	-	-	-	-	2	-	-	-	-	2	-	0	2	2
113	-	-	-	-	-	-	1	-	-	-	1	-	1	1	0
118	1	-	1	-	-	-	-	-	-	-	-	-	1	0	1
124	-	-	-	-	-	-	-	-	-	-	1	-	0	1	0
126	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
243	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
244	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
377	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
416	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
511	-	-	-	-	-	1	-	-	-	-	7	3	0	7	4
514	-	-	6	-	1	2	-	-	-	-	8	-	0	9	8
582	-	-	3	-	-	-	-	-	-	-	1	-	0	1	3
728	-	-	-	1	-	-	-	-	-	-	5	-	1	5	0
747	1	-	2	-	-	2	-	-	-	-	1	-	1	1	4
764	-	-	-	-	-	-	-	-	-	-	2	-	0	2	0
798	-	-	-	-	-	1	2	-	-	-	3	8	2	3	9
950.3	-	-	-	24	9	3	-	-	-	-	7	1	24	16	4
981	-	-	-	8	10	5	-	-	-	-	5	5	8	15	10
984	-	-	-	17	11	11	1	-	-	-	15	5	18	26	16
996	-	-	-	1	-	-	-	-	-	-	1	-	1	1	0
1007	-	-	-	26	5	2	-	-	-	-	4	-	26	9	2
1061	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
1070	-	-	-	-	-	-	-	-	-	-	3	-	0	3	0
1071	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
1132	-	-	1	-	-	-	-	-	-	-	5	-	0	5	1
1144	-	-	-	-	-	-	-	-	-	-	1	-	0	1	0
1168	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
1202	-	-	-	-	-	-	-	-	-	-	1	1	0	1	1
1228	-	-	-	-	-	-	-	-	-	-	1	-	0	1	0

1248	-	-	-	-	-	-	-	-	-	-	3	-	0	3	0
1249	-	-	-	-	1	-	-	-	-	-	3	-	1	4	0
1301	-	-	-	-	-	2	-	-	-	-	-	-	0	0	2
1306	-	-	-	17	14	1	-	-	-	-	9	-	17	20	1
Total	**2**	**0**	**14**	**95**	**51**	**32**	**4**	**0**	**0**	**0**	**89**	**23**	**101**	**140**	**69**

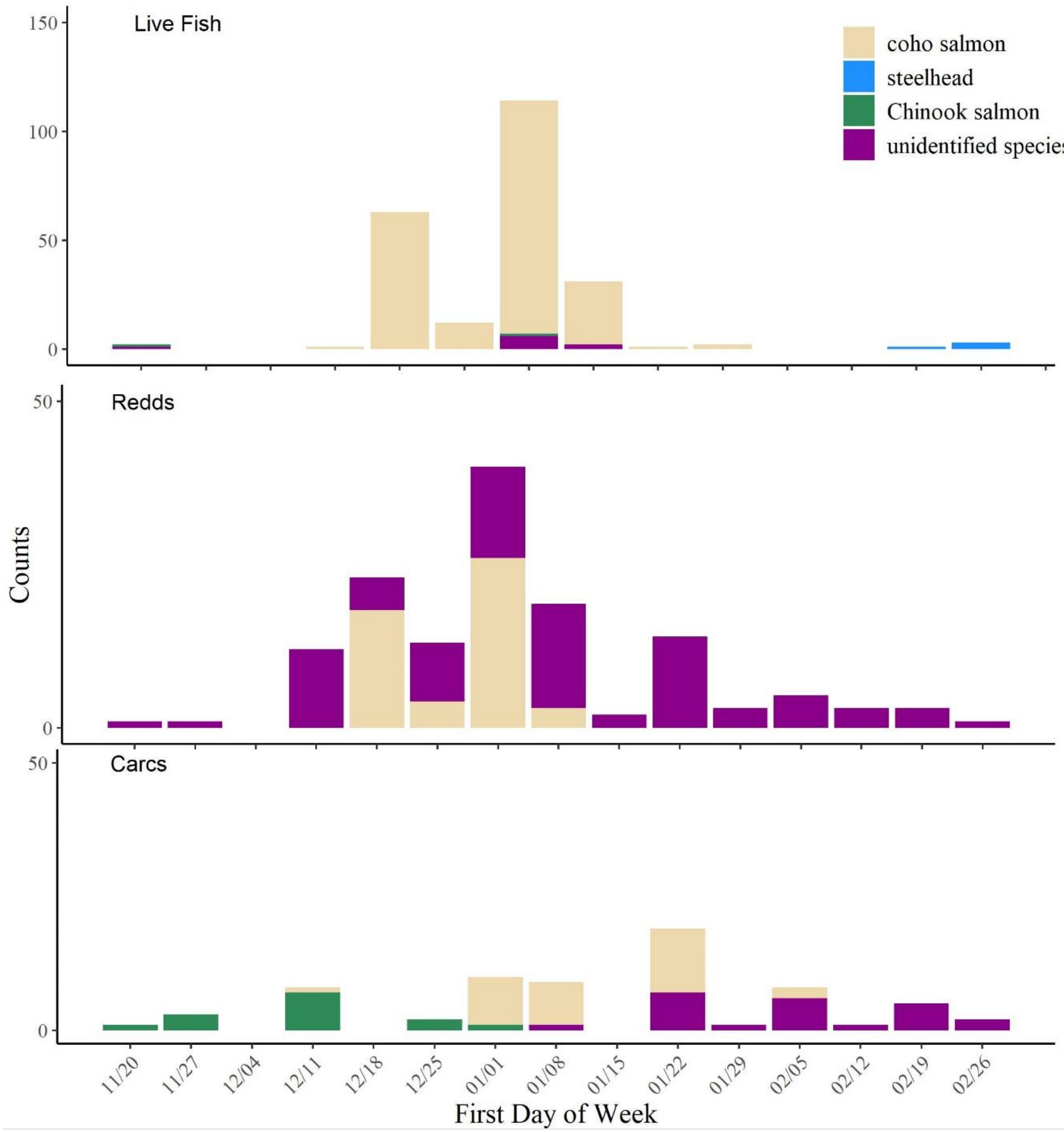

Figure 5. Live adult salmonids (top), redds (middle), and carcasses (bottom) summarized by week for the 2023 – 2024 South Fork Eel River spawning grounds survey. Dates reflect the first date of each week on the x-axis and salmonid species are grouped by color.

Table 4: Estimated total redd abundance for the SFER by species with 95% confidence intervals created using a Simple Random Sample estimator (Adams et al. 2011).

Value	Chinook	Coho	Steelhead
Estimated number of redds	105	718	106
95% Confidence Intervals	17, 195	231, 1206	31, 182

4 DISCUSSION

Fall precipitation patterns and survey effort constraints likely shaped unusually low Chinook Salmon redd estimates in the 2023-2024 season. The first significant rain events of the fall in early and mid-November, each spiking at around 650 cfs at the Miranda gauge on November 5th and November 20th, triggered the onset of spawning ground surveys (Figure 4). These rain events enabled Chinook Salmon and other adult salmonids holding in the Eel River estuary to move upstream. These initial movements were observed by a sonar camera deployed by CalTrout in the SFER; 3,855 adult salmonids moved upstream the week of November 5th-November 11th with a second large influx of 2,679 adult salmonids observed in the week of December 3rd-December 9th that coincided with a rain event on December 4th that spiked at 1500 cfs (Jason Shaffer, personal communication). Despite this large influx of adult fish, very few adult salmon were observed during spawning ground surveys of tributaries till the week of December 18th with the only observations being a few Chinook Salmon carcasses observed during this time period (Figure 5). This could be due in part to insufficient flows in tributaries, however, the presence of Chinook Salmon carcasses found on surveys at this time suggest flows were substantial enough for adult salmon to access at least some tributaries. Due to staff constraints and lack of field housing, survey efforts during this time period were primarily restricted to reaches that could be accessed within a day's drive of the Fortuna office. This constraint was a limiting factor for the reaches surveyed at this time and are likely limiting the scope of our results. Additionally, a larger magnitude flow event occurring on December 20th could have obscured previously un-observed Chinook Salmon redds before surveys could take place in many of the selected sample reaches. Most of the redds observed between mid-November and December 21 were not discernable as redds during surveys conducted after December 21. These combined factors likely reduced redd detection resulting in105 (17-195) Chinook Salmon redds estimated using the SFER spawning ground surveys; the second lowest count of Chinook Salmon since these surveys began (). Furthermore, Cal Trout's SFER sonar camera monitoring estimate of 7546 2023-2024 spawning year adult salmonids indicates the SFER redd monitoring greatly underestimated Chinook Redd abundance.

The winter precipitation pattern and personnel constraints for the 2023-2024 season made it extremely challenging to collect data. As mentioned earlier, the lack of field housing in November and December and the associated greater driving distance from the office location reduced the project's ability to survey distant portions of the watershed. Additionally, a major precipitation event occurred on December 20th with a spike at around 9000 cfs (Figure 4). Following this spike in the river conditions the SFER rarely dipped below 2000 cfs and peaked at 35000 cfs presenting challenging conditions for the rest of the spawning ground survey season (Figure 4). This resulted in the lowest number of surveys (125) completed and one of the highest average survey intervals (22.1 days) since the inception of the survey in 2010 (). Despite these difficult constraints, monitoring crews were able to survey during some of the peak spawning season for Coho Salmon between late December and early February. However, surveyors often reported an inability to survey entire reaches due to low visibility, high water, and bed movement. Despite challenges the project observed a high number of live Coho Salmon on Huckleberry Creek, Dutch Charlie Creek, Hollow Tree Creek, and Redwood Creek (Table 3). Ultimately, the efforts from this season resulted in a Coho Salmon redd estimate of 718 with a wide confidence interval of 231 and 1206.

The 2023 Coho Salmon cohort is a portion of the strongest SFER three year cohorts (Figure 6). However, this season observed a somewhat significant decline in the spawning population of Coho Salmon. This could be attributed to multiple monitoring accuracy factors including survey conditions, survey frequency, and selected sample reaches. This year presented "some of the worst possible conditions for spawning ground surveys since the program started" (Chris Loomis, personal communication). This is reflected in the high survey interval and lower average number of surveys per reach. The sample draw this year also contained 6 of the top 40 historically productive reaches for coho salmon of which 4 (Sproul Creek, Anderson Creek, Hollow Tree Creek, and Dutch Charlie Creek) are in the annual survey reaches (Table 1). Of these more productive reaches, Hollow Tree and Anderson Creeks were only surveyed twice during the spawning ground seasons highlighting the difficulty to maintain consistent surveys during the 2023-2024 season (Table 2). Additionally, four survey reaches (780, 826, 828, and 992) couldn't be accessed at the beginning of the season due to the lack of field housing and were not visited later due to the poor weather conditions. This ultimately reduced the sample size of surveyed reaches, and because three of the four unsurveyed reaches have had Coho Salmon redds in the past this may have further skewed our results. Due to the challenging survey conditions, lower frequency of surveys, smaller sample size, and limited surveys on historically productive reaches, the sharp cohort decline observed in this year's Coho Salmon redd estimates might not be as alarming as the data shows. Coho Salmon population distribution and relative abundance will be assessed during analysis of the juvenile spatial structure occupancy surveys conducted as a complementary component of the 2023-2024 spawner survey seasons in the summer of

2024. These surveys are completed in the same reaches as the previous winters spawning ground surveys and the counts of juvenile Coho Salmon are used to understand which reaches are occupied for rearing and where/if we missed spawning adult salmon.

The challenging survey conditions in the SFER due to high precipitation events, erosive geology of the watershed, and limited number of reaches where any spawning activity has been documented suggests an alternative approach to salmonid abundance monitoring in the SFER may be warranted. While 2023 was an exceptionally challenging year, it was not unique in the conditions it presented for surveyors. High flows and exceptionally turbid conditions frequently prevent surveys from occurring and the expansive size of the SFER watershed creates travel and reach access constraints that make it very challenging to re-visit reaches with any reasonable consistency. Figure 7 shows the average density (redds per reach) of Coho Salmon redds since the survey began in 2010. Redd distribution is patchy and concentrated in a few sub-watersheds of the SFER. Reaches in the Redwood Creek, Indian Creek, Sproul Creek, Hollow Tree Creek, and Dutch Charlie Creek watersheds consistently contain the highest numbers of adult Coho Salmon redds while other reaches in the survey frame rarely contain any adult Coho Salmon redds. For the 2024-2025 survey year, we are attempting to implement a hybrid approach that focuses spawning ground surveys on high density spawning reaches contained in the GRTS draw followed by juvenile snorkel surveys on reaches with lower historical density. This adaptive, two phase approach may be more cost effective and provide similar estimates of Coho Salmon redd abundance in the SFER and a more accurate estimate of the spatial distribution of this species.

Table 5. Summary of SFER Adult Salmonid Redd Abundance Monitoring Project redd estimates and 95% confidence intervals () for survey years 2010-2011 through 2023-2024

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)
2016-2017	40	227	20	6	465 (98, 831)	1458 (923, 1992)	54 (9, 111)
2017-2018	37	249	16.8	6.7	1,633 (793, 2473)	867 (454, 1279)	5 (1, 15)

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 *
2018-2019	38	232	19.9	4.9	990 (205, 1776)	404 (131, 676)	322 (168, 476)
2019-2020	36	317	12.4	8.9	138 (34, 243)	135 (34, 277)	607 (381, 834)
2020-2021	30 (18)**	442	8.6	10.9	1700** (616, 3897)	14** (2, 31)	232** (106, 359)
2021-2022	36	265	17	7	941 (502, 1380)	155 (44, 266)	397 (187, 607)
2022-2023	40	161	20.4	4	109 (48, 169)	132 (31, 233)	5 (4, 14)
2023-2024	37	125	22.1	3.4	718 (231, 1206)	105 (17,195)	106 (31, 182)

*The SFER Salmonid Redd Abundance Monitoring Project is focused upon the temporal extent of Coho Salmon spawn timing and spatial extent of Coho spawning distribution within the SFER. The project does not monitor the complete spatial extent of Chinook Salmon spawning in the SFER, and the Chinook redd abundance estimate is limited to redds observed within the Coho focused reach sample frame. The project does not monitor the complete spatial and temporal extent of steelhead spawning areas and spawning period in the SFER, and the steelhead redd abundance estimate is limited to redds observed within the Coho focused reach sample frame and November to February survey period.

**Due to logistical complications related to COVID-19, a limited number of random reaches could be surveyed during the 2020-2021 winter survey season. Resulting estimates reflect a smaller sample frame than other survey years.

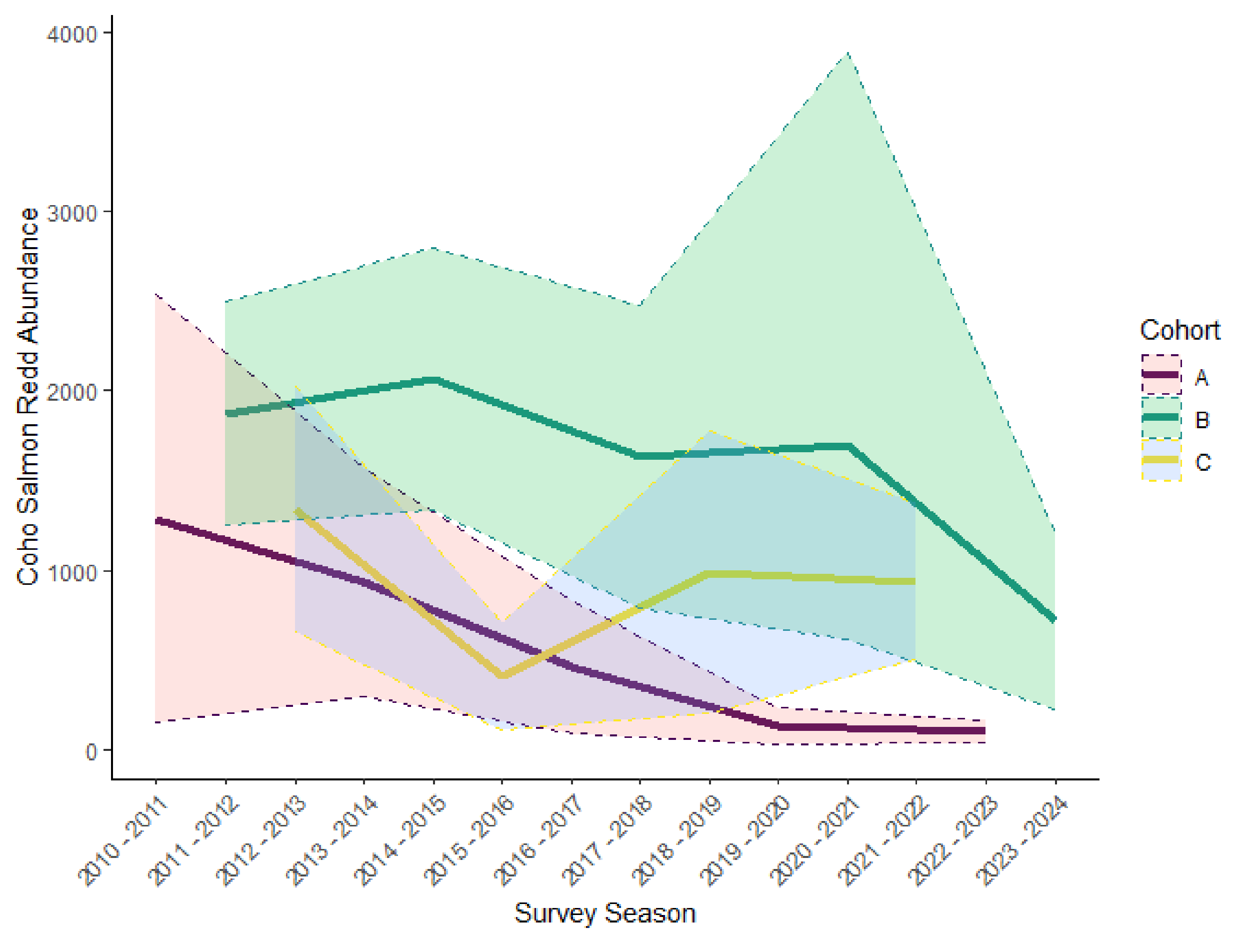

Figure 6. Coho redd abundance estimates of the SFER population from 2010 to present (lines connecting annual point estimates). Cohorts have been separated out by color and 95% confidence intervals are displayed as ribbons.

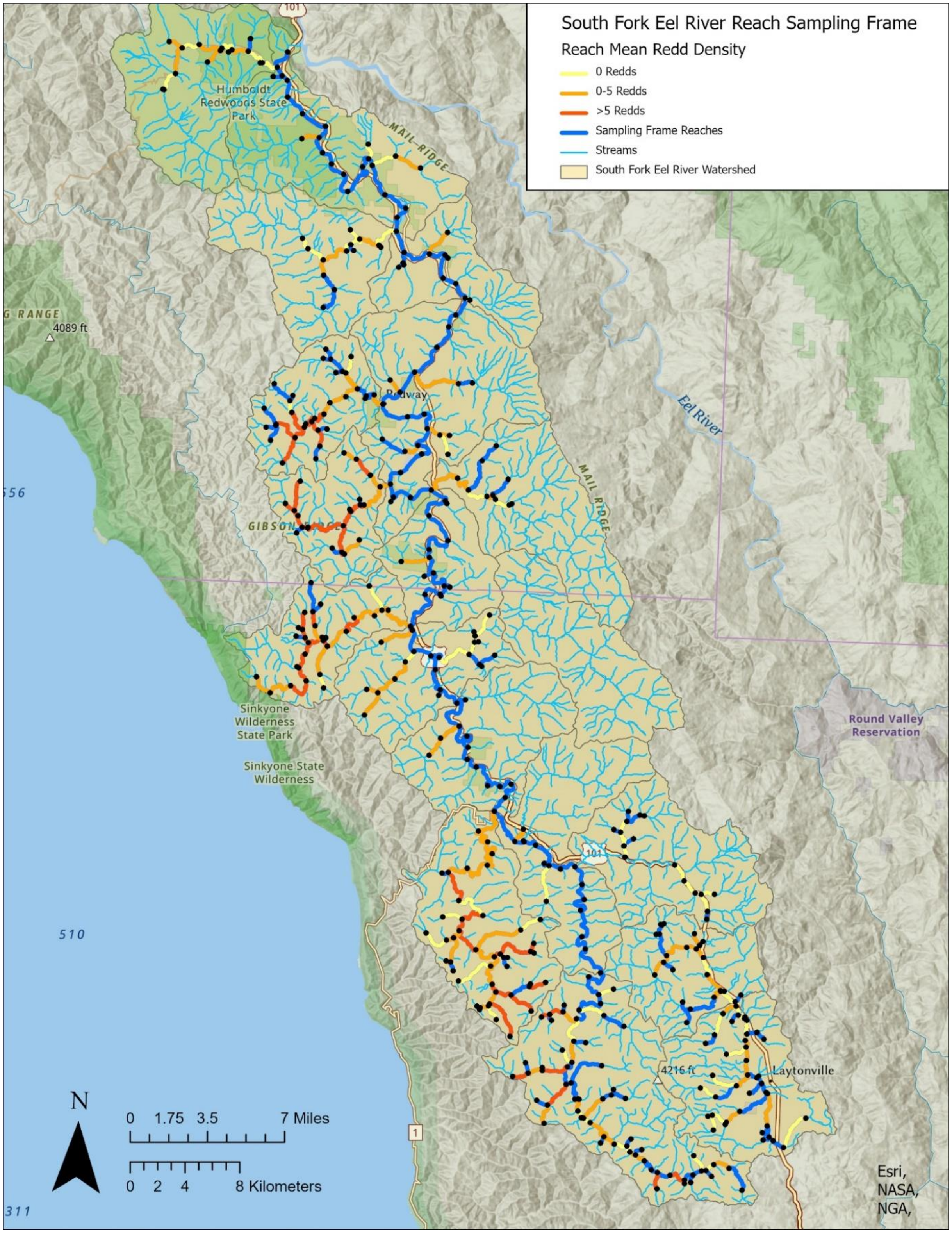

Figure 7. Historical mean densities of Coho Salmon redds in the South Fork Eel River spawning ground frame from 2010-2024. Reaches highlighted in red have historical mean spawning densities of greater than 5, reaches highlighted in orange have historical mean spawning densities of 0.1 to 5, and highlighted in yellow have never had a redd observed.

5 ACKNOWLEDGEMENTS

Funding for the 2023-2024 SFER Adult Salmonid Redd Abundance Monitoring Project was provided by the CDFW Fisheries Restoration Grant Program: Grantee Agreement CMP-23R1001.

We would like to thank our project partners: the California Conservation Corps AmeriCorps Watershed Stewards Program. Thank you to Travis Massey and Megan Berberich for leading the monitoring crews and logistics and preparation of draft report components. Thank you to the project field technicians for many slippery, soggy miles this winter: Justina Madrigal, Zachary Vegso, Zoe Burgess, Brittney Tresenrider, Dominick Davis, and Andrew Nogoski. We thank Travis Massey for his leadership as the interim field crew lead for these spawning ground surveys and without whose help these surveys would not have occurred. Also, we thank Chris Loomis and Allan Renger for editing this report.

This project was possible thanks to the many willing landowners who granted the project team access to their land and throughout the SFER Watershed.

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