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Freshwater Creek 2023-2024
Results of spawning ground surveys and estimates of total salmonid redds

Prepared by:
Colin Anderson*

Principle Investigator:
Seth Ricker

California Department of Fish and Wildlife
Anadromous Fisheries Resource Assessment and Monitoring Program

*Corresponding Author E-Mail: Colin.Anderson@wildlife.ca.gov

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Abstract

Field staff conducted 78 spawning ground surveys in nine reaches within the Freshwater Creek watershed between November 17, 2023, and June 25, 2024. Individual stream reaches were surveyed an average of 8.7 times at an average return interval of 16.8 days. Live fish observed include 95 Coho Salmon, six steelhead, four cutthroat trout, and four Pacific Lamprey. Carcass totals include one Chinook Salmon, 33 Coho Salmon, and 15 Pacific Lamprey. A total of 44 Coho Salmon redds, three steelhead redds, 74 unknown salmonid redds, five cutthroat trout redds, and 179 Pacific Lamprey redds were observed. We estimate 162 (123-201, 95% confidence interval) Coho Salmon redds and 14 (10-17, 95% confidence interval) steelhead trout redds within the Freshwater Creek Life Cycling Monitoring Station as the sum of a complete census of all reach estimates.

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1 INTRODUCTION

1.1 Background

Pacific Salmon (*Oncorhynchus spp.*) have experienced a 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 in 2016 (NMFS 2016). 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 as threatened (NMFS 2006), and Coastal Chinook Salmon (*O. tshawytscha*) south of the Klamath River to the Russian River are federally ESA listed as threatened (NMFS 1999). The federal listing status of both Northern California steelhead and California Coastal Chinook Salmon was reviewed and reaffirmed to be threatened in 2016 (NMFS 2016).

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 prioritize management and restoration actions needed to recover the coastal Coho Salmon population. 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 recovery criteria for each population of Coho Salmon within each diversity strata (NMFS 2014).

The California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) 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, CDFW and NMFS cooperatively developed the Coastal California Salmonid Monitoring Plan (CMP; Adams et al. 2011). One task involves using spawning ground surveys (SGS) to monitor salmonids in intensely studied Life Cycle Monitoring (LCM) stations. Long term datasets from several LCM stations provide data that drives trend analysis.

This report summarizes the results of yearly abundance and survival monitoring efforts from November 2023 to June 2024, as well as integrates all years of project data to make inference on population trajectories.

1.2 Study Area

Freshwater Creek watershed is in Humboldt County, California between the towns of Eureka to the west and Arcata to the north. Freshwater Creek is a fourth order stream with a drainage area of approximately 9227 hectares (31 sq. mi.), which drains into Humboldt Bay via the Eureka Slough.

Elevations in the watershed range from sea level at the mouth to 823 meters at the headwaters. Annual rainfall is approximately 150 cm in the headwaters and 100 cm near the mouth, with nearly 90% accumulating between October and May. Less than 10% of the annual precipitation falls between June and September. Stream discharges range from 15 ft^3/s to > 2000 ft^3/s during the rainy season and decline to 2 ft^3/s during the fall months. The Freshwater Creek LCM sampling frame contains 9 reaches (Figure 1).

The fishery resources of the basin include three species of salmonids: Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and steelhead trout (*O. mykiss*). Occasionally, Chum Salmon (*O. keta*) are observed. Other fish present in the basin include Pacific Lamprey (*Entosphenus tridentata*), Western Brook Lamprey (*Lampetra richardsoni*), cutthroat trout (*O. clarki clarki*), Prickly and Coastrange Sculpin (*Cottus asper, Cottus aleuticus*), Threespine Stickleback (*Gasterosteus aculeatus*), Longfin Smelt (*Spirinchus thaleichthys*), and Eulachon (*Thaleichthys pacificus*).

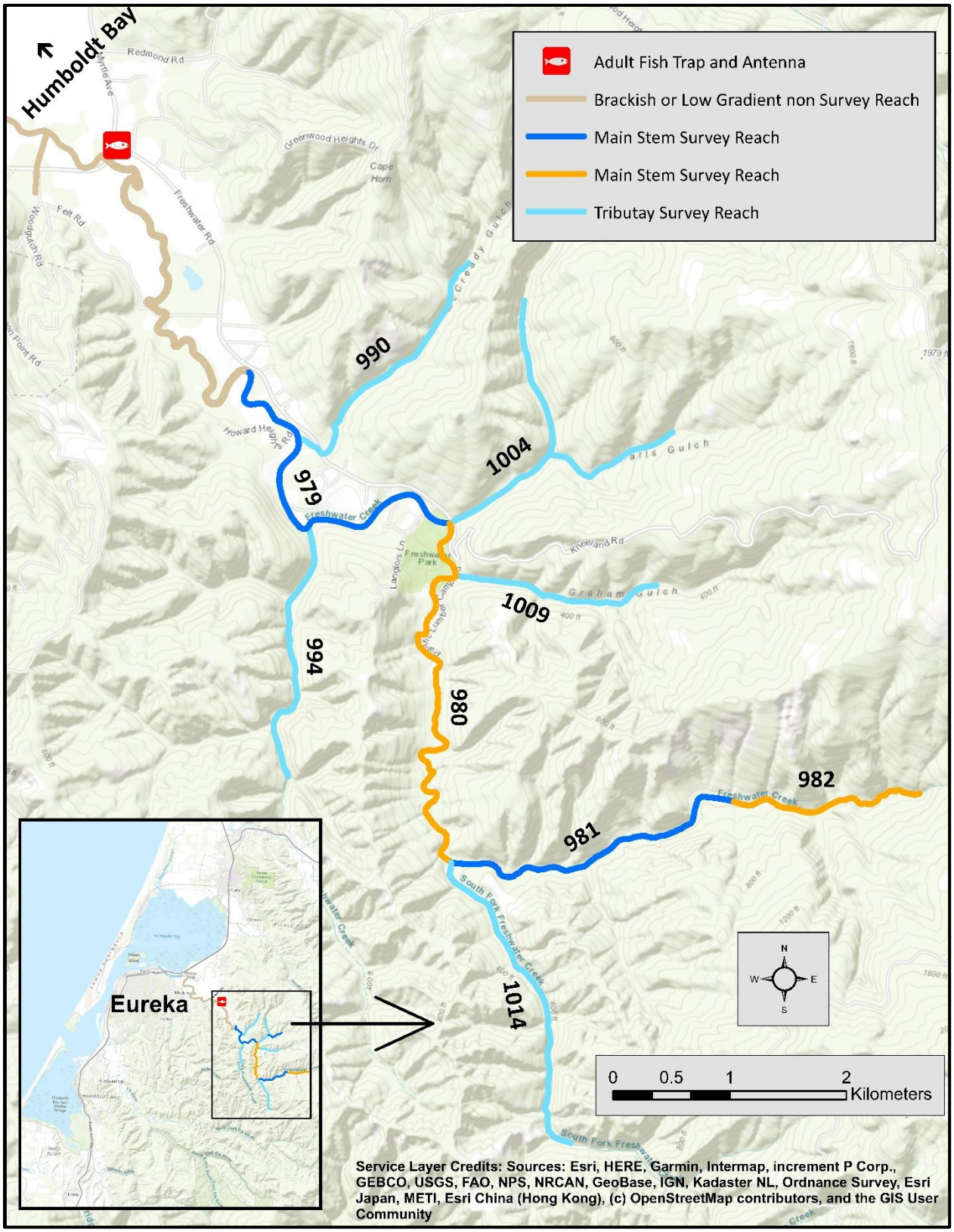

Figure 1. Freshwater Creek LCM station and sampling frame. Reach codes are presented as table references.

2 METHODS

2.1 Sample Frame Construction

Sampling frames were constructed based on several factors including documented historical salmonid distributions, documented barriers to anadromy, stream gradient, and field reconnaissance (Garwood and Ricker 2011). Sample frames were constructed with a focus on Coho Salmon and may exclude habitat which is used by Chinook Salmon and steelhead trout.

Each sampling frame was further divided 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 they flowed into. If a sub-reach flowed into a boundary between reaches, it was included with the downstream reach.

2.2 Reach Survey Protocol

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

Speciation of Lamprey redds was determined by surveyors and based largely on redd shape and size of pot and tail-spill dimensions. For more details on Freshwater Creek Pacific Lamprey surveys see Anderson et al. (2020) and Stillwater Sciences (2016). Four reaches, 979, 980, 981, and 1004, were surveyed in the late spring for Pacific Lamprey redds (Figure 1).

2.3 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 the nearest three known species redd or live fish to make a prediction of species based on majority vote. Each unknown redd was assigned to a species for further analysis of species-specific redd 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 redd from the remaining data, and comparing the prediction to truth. In this analysis, errors in prediction are not propagated into the total error of within reach abundance. All kNN and LOOCV analysis were executed in program R (R Core Team 2018) with the "class" package (Venables and Ripley 2002) and "caret" package (Kuhn 2013).

2.4 Estimation of Within-Reach Redd Abundance

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

2.5 Estimation of Total Redd Abundance Within Freshwater Creek LCM

Total redd abundance expansion to the frame was 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 78 spawning ground surveys in nine reaches between November 17, 2023, and June 25, 2024. Visitation rates to stream reaches averaged 8.7 times during the spawning season and the number of days between visits averaged 16.8 days (Table 1).

3.2 Fish Observations

Live anadromous salmonid observations include 95 Coho Salmon, six steelhead trout, and eight unidentified adults. (Table 2, Figure 2). Additional live fish observed during surveys include four cutthroat trout, and four Pacific Lamprey. Anadromous salmonid carcass observations include one Chinook Salmon, and 33 Coho Salmon. (Table 3, Figure 3). Additional carcasses include 15 Pacific Lamprey.

Sex ratios of male to female live Coho Salmon and carcass observations were 1:0.51, and 1:0.42. Descriptive statistics for live fish and carcasses are presented in Table 4. Out of 33 Coho Salmon carcass recoveries, 21 were whole fish. When possible, sex was determined, and fork length was measured.

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. Freshwater Creek basin spawner survey dates between December 2023 and July 2024.

Reach Code	Stream Reach Name	N	Mean	Max
979*	Freshwater Creek Lower Main Stem	12	19.7	42
980*	Freshwater Creek Middle Main Stem	11	14.9	42
981*	Freshwater Creek Upper Main Stem A	11	20.6	44
982	Freshwater Creek Upper Main Stem B	NS	NS	NS
990	McCready Gulch	2	51	51
994	Little Freshwater Creek	8	13.9	24
1004*	Cloney Gulch	8	22.9	43
1009	Graham Gulch	7	12.5	15
1014	South Fork	9	11.5	15

*Denotes reaches in which surveys continued through June to capture the entire spawning run. NS equals not surveyed.

Table 2. Live fish observations by calendar week.

Week Beginning	Chinook	Coho	steelhead	unidentified	Pacific Lamprey	Total
2023-11-13	0	0	0	0	0	0
2023-11-20	0	0	0	0	0	0
2023-11-27	0	0	0	0	0	0
*2023-12-04	-	-	-	-	-	-
2023-12-11	0	3	0	0	0	3
2023-12-18	0	6	0	1	0	7
2023-12-25	0	29	0	1	0	30
2024-01-01	0	9	0	0	0	9
*2024-01-08	-	-	-	-	-	-
2024-01-15	0	42	0	1	0	43
2024-01-22	0	2	0	0	0	2
2024-01-29	0	1	0	0	0	1
2024-02-05	0	0	3	0	0	3
2024-02-12	0	1	0	4	0	5
2024-02-19	0	0	0	0	0	0
2024-02-26	0	2	1	1	0	4
*2024-03-04	-	-	-	-	-	-
*2024-03-11	-	-	-	-	-	-
2024-03-18	0	0	0	0	0	0
*2024-03-25	-	-	-	-	-	-
*2024-04-01	-	-	-	-	-	-
2024-04-08	0	0	2	0	1	3
*2024-04-15	-	-	-	-	-	-
*2024-04-22	-	-	-	-	-	-
*2024-04-29	-	-	-	-	-	-
*2024-05-06	-	-	-	-	-	-
*2024-05-13	-	-	-	-	-	-
2024-05-20	0	0	0	0	3	3
*2024-05-27	-	-	-	-	-	-
*2024-06-03	-	-	-	-	-	-
*2024-06-10	-	-	-	-	-	-
2024-06-17	0	0	0	0	0	0
2024-06-24	0	0	0	0	0	0
Total	0	95	6	8	4	113

*No surveys conducted during this week.

Table 3. Carcass observations by calendar week.

Week Beginning	Chinook	Coho	steelhead	unidentified	Pacific Lamprey	Total
2023-11-13						
2023-11-20	0	0	0	0	0	0
2023-11-27	0	0	0	0	0	0
*2023-12-04	-	-	-	-	-	-
2023-12-11	0	0	0	0	0	0
2023-12-18	0	0	0	0	0	0
2023-12-25	0	4	0	0	0	4
2024-01-01	0	0	0	0	0	0
*2024-01-08	-	-	-	-	-	-
2024-01-15	1	9	0	0	0	10
2024-01-22	0	4	0	0	0	4
2024-01-29	0	7	0	2	0	9
2024-02-05	0	2	0	1	0	3
2024-02-12	0	5	0	3	0	8
2024-02-19	0	0	0	0	0	0
2024-02-26	0	0	0	1	0	1
*2024-03-04	-	-	-	-	-	-
*2024-03-11	-	-	-	-	-	-
2024-03-18	0	0	0	0	0	0
*2024-03-25	-	-	-	-	-	-
*2024-04-01	-	-	-	-	-	-
2024-04-08	0	0	0	0	1	1
*2024-04-15	-	-	-	-	-	-
*2024-04-22	-	-	-	-	-	-
*2024-04-29	-	-	-	-	-	-
*2024-05-06	-	-	-	-	-	-
*2024-05-13	-	-	-	-	-	-
2024-05-20	0	0	0	0	11	11
*2024-05-27	-	-	-	-	-	-
*2024-06-03	-	-	-	-	-	-
*2024-06-10	-	-	-	-	-	-
2024-06-17	0	0	0	0	1	1
2024-06-24	0	0	0	0	2	2
Total	1	33	0	2	15	51

*No surveys conducted during this week.

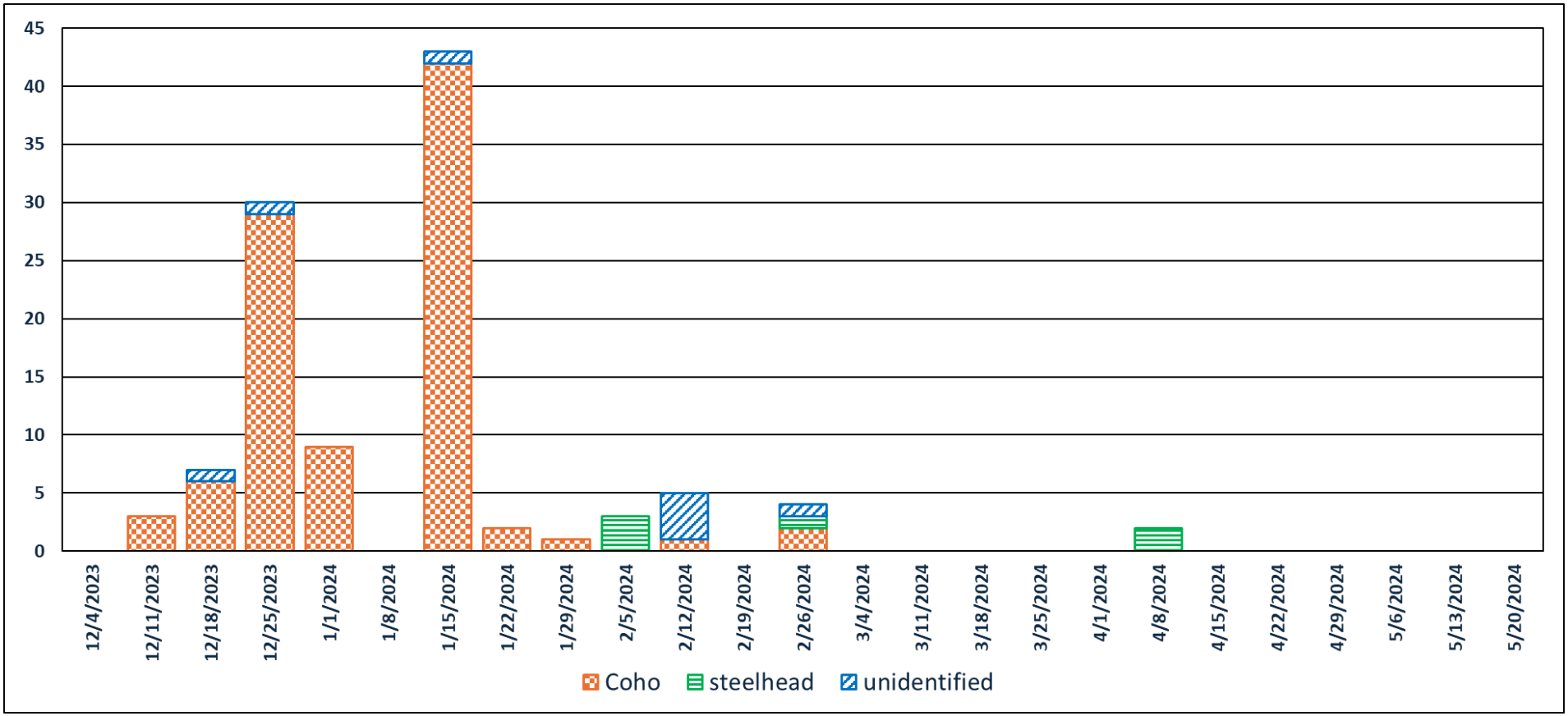

Figure 2. Stacked bar plot of live anadromous salmonids observations by week in Freshwater Creek basin December 2023 through May 2024.

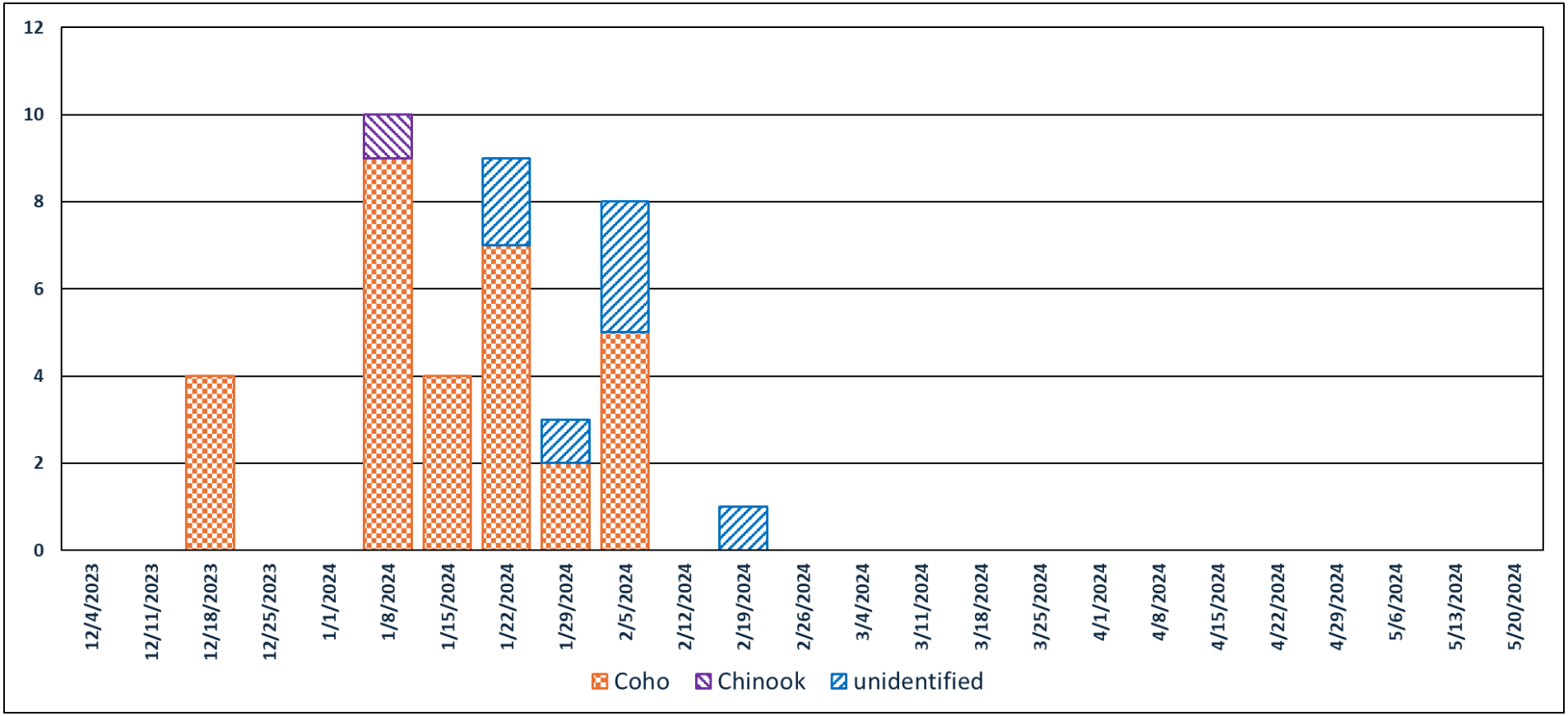

Figure 3. Stacked bar plot of anadromous salmonid carcass observations by week in Freshwater Creek basin December 2023 through May 2024.

Table 4. Descriptive statistics of number (N) live fish (L) and carcass (C) observations. Length measurements (cm) are described by mean, median, minimum, maximum, and standard deviation statistics.

Species	Sex	N L	N C	Mean L	Mean C	Median L	Median C	Min L	Min C	Max L	Max C	SD L	SD C
Coho	F	30	5	62	60	60	60	55	54	65	64	2.8	4.2
Coho	M	54	10	56	53	55	57	35	35	70	69	10.2	13.1
Coho	Unk	3	6	62	62	60	60	55	59	70	70	58.3	4.1
Chinook	F	-	1	-	95	-	95	-	95	-	95	-	-
Steelhead	F	2	-	58	-	58	-	55	-	60	-	3.5	-
Steelhead	M	1	-	60	-	60	-	60	-	60	-	-	-
Steelhead	U	3	-	42	-	40	-	35	-	50	-	7.6	-

3.3 Redd Observations

Out of 121 salmonid redds observed, occupancy was 36%. A total of 45 redds were identified as Coho Salmon redds, three as a steelhead redds, and 73 as unknown salmonid redds (Figure 4). A total of 179 Pacific Lamprey redds were identified.

Newly constructed redd observations for Coho Salmon peaked during the third week of January when 14 redds were counted (Table 5, Figure 5). Unknown salmonid redd observations peaked in the fourth week of February when 18 redds were counted (Table 5, Figure 5). Reach 980 (middle main stem) had the highest counts of salmonid redds with a total of 40 (Table 6). Lamprey redd observations were concentrated in May and June. The middle main stem reach 980 had the highest count of Pacific Lamprey redds with 82 observed (Table 6).

3.4 Total Redd Abundance

The total redd abundance estimate, in all nine reaches, for Coho Salmon with 95% confidence intervals is 162 (123, 201). For steelhead trout the total redd abundance estimate with 95% confidence intervals is 14 (10, 17).

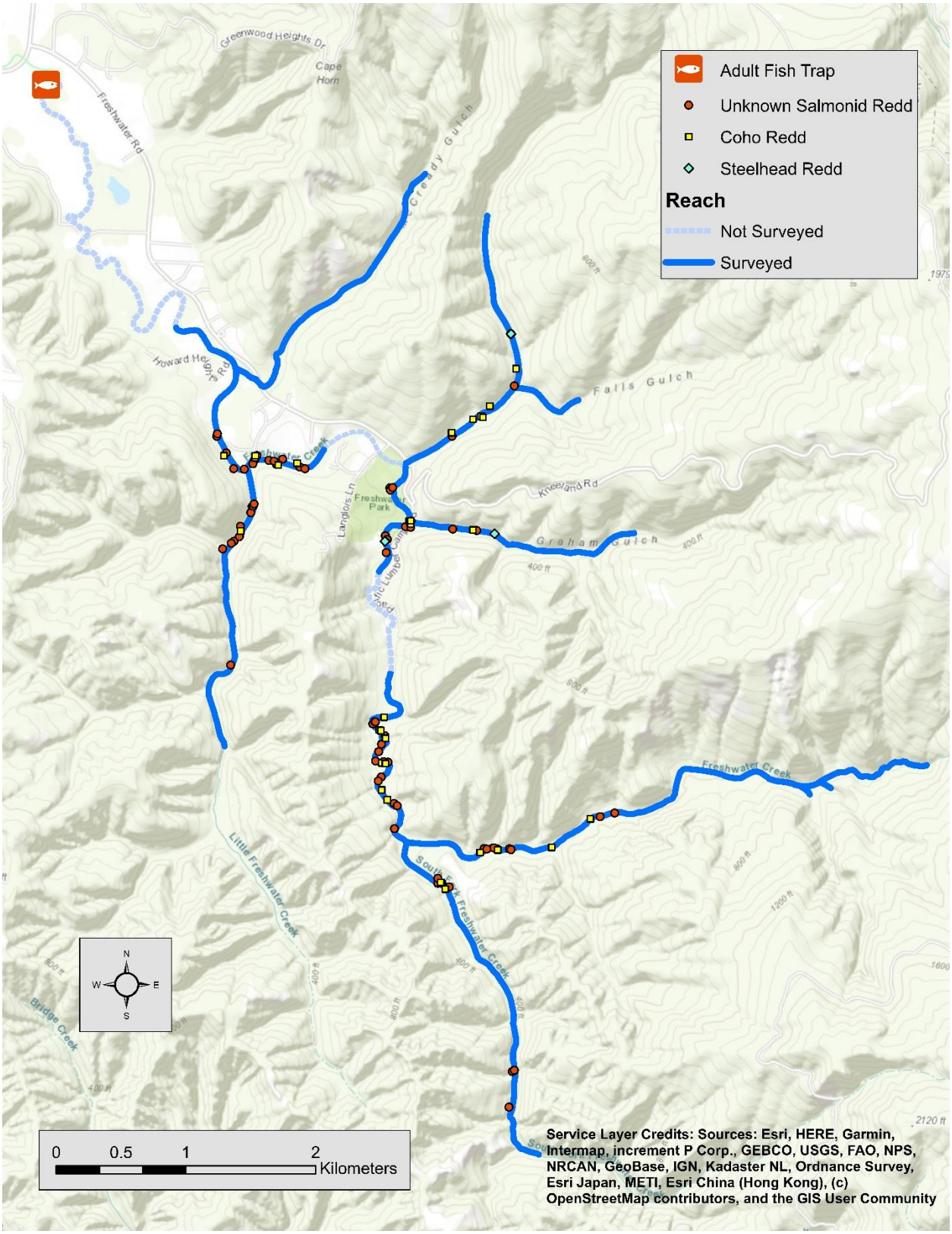

Figure 4. Anadromous salmonid redds in the Freshwater Creek Life Cycle Monitoring station winter 2023 through spring 2024.

Table 5. Counts of newly constructed redds by calendar week.

Week Beginning	Chinook	Coho	steelhead	unidentified	Pacific Lamprey	Total
2023-11-13	0	0	0	0	0	0
2023-11-20	0	0	0	0	0	0
2023-11-27	0	0	0	0	0	0
*2023-12-04	-	-	-	-	-	-
2023-12-11	0	3	0	4	0	7
2023-12-18	0	3	0	2	0	5
2023-12-25	0	11	0	9	0	20
2024-01-01	0	1	0	3	0	4
*2024-01-08	-	-	-	-	-	-
2024-01-15	0	14	0	6	0	20
2024-01-22	0	2	0	2	0	4
2024-01-29	0	2	0	7	0	9
2024-02-05	0	4	2	2	0	8
2024-02-12	0	2	0	9	0	11
2024-02-19	0	1	1	0	0	2
2024-02-26	0	1	0	18	0	19
2024-03-04	-	-	-	-	-	-
2024-03-11	-	-	-	-	-	-
2024-03-18	0	1	0	5	2	8
*2024-03-25	-	-	-	-	-	-
*2024-04-01	-	-	-	-	-	-
2024-04-08	0	0	0	3	37	40
*2024-04-15	-	-	-	-	-	-
*2024-04-22	-	-	-	-	-	-
*2024-04-29	-	-	-	-	-	-
*2024-05-06	-	-	-	-	-	-
*2024-05-13	-	-	-	-	-	-
2024-05-20	0	0	0	3	71	74
*2024-05-27	-	-	-	-	-	-
*2024-06-03	-	-	-	-	-	-
*2024-06-10	-	-	-	-	-	-
2024-06-17	0	0	0	0	13	13
2024-06-24	0	0	0	0	56	56
Total	0	45	3	73	179	300

*No surveys conducted during this week.

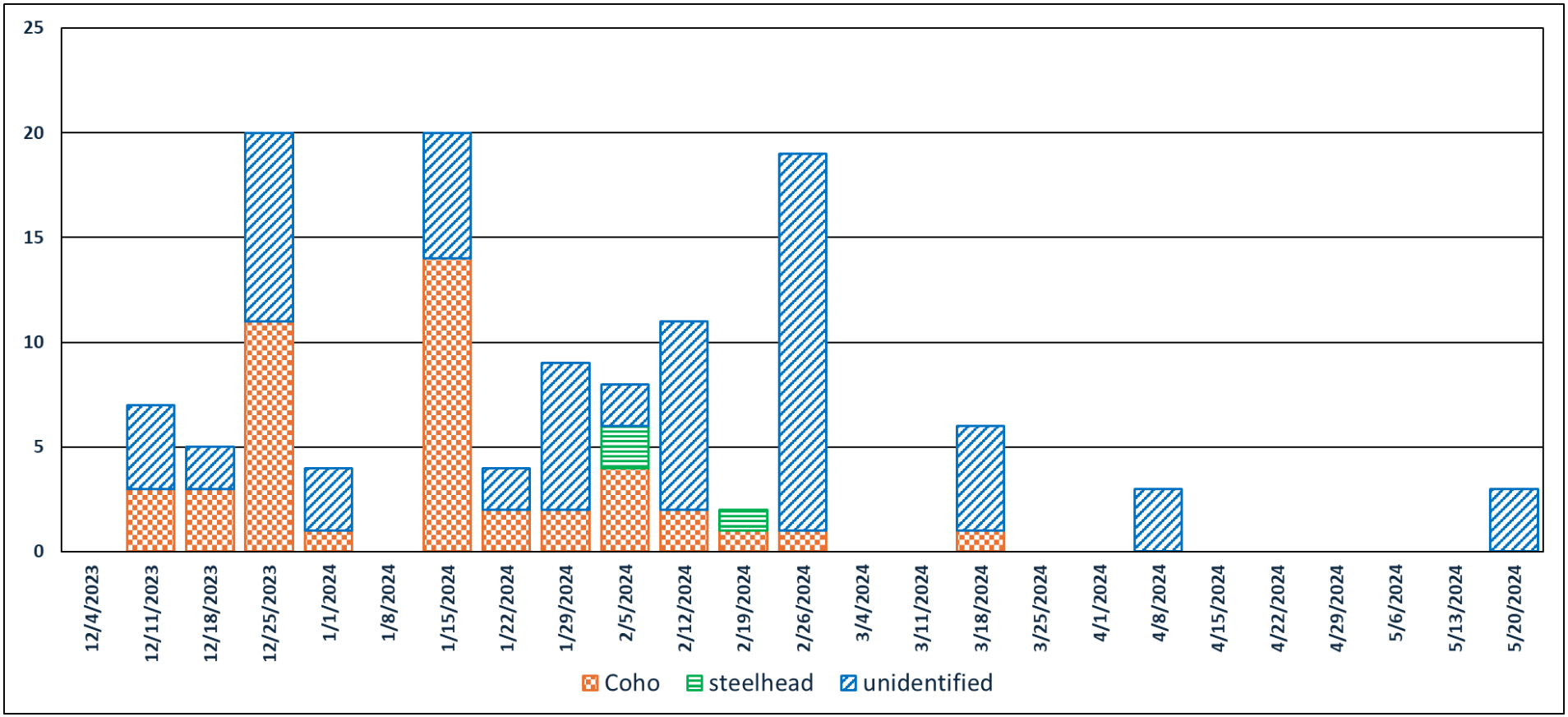

Figure 5. Stacked bar plot of anadromous salmonid redd observations by week in Freshwater Creek basin December 2023 through May 2024.

Table 6. Counts of anadromous salmonid redds within each survey reach. Survey reach numbers are labeled in Figure 1.

Location Code	Chinook	Coho	steelhead	unidentified	Salmonid Total	Pacific Lamprey
979	0	7	0	13	20	50
980	0	15	1	24	40	82
981	0	4	0	12	16	47
982	0	0	0	0	0	-
990	0	0	0	0	0	-
994	0	2	0	12	14	-
1004	0	14	1	3	18	0
1009	0	1	1	2	4	-
1014	0	2	0	7	9	-
Total	0	45	3	73	121	179

4 DISCUSSION

4.1 Between Year Comparisons

The timing of rainfall events during the Coho Salmon spawning season, December through February, restricted our ability to see due to poor visibility in the middle of the season for most of January (Figure 6). We surveyed as frequently as the protocol suggests (every ten days) even with poor visibility. December was above average for rainfall, and we experienced a 75-year flood event on January 16th. Normally surveys are delayed for 4-6 days after a significant rainfall event and sufficient survey conditions return around median daily discharge or winter base flow (Figure 6). Minimum visibility conditions to conduct redd surveys is approximately 50 cm. The mean number of days between surveys is large in 2023-2024 in some reaches due infrequent surveys during most of the steelhead spawning season (March through April).

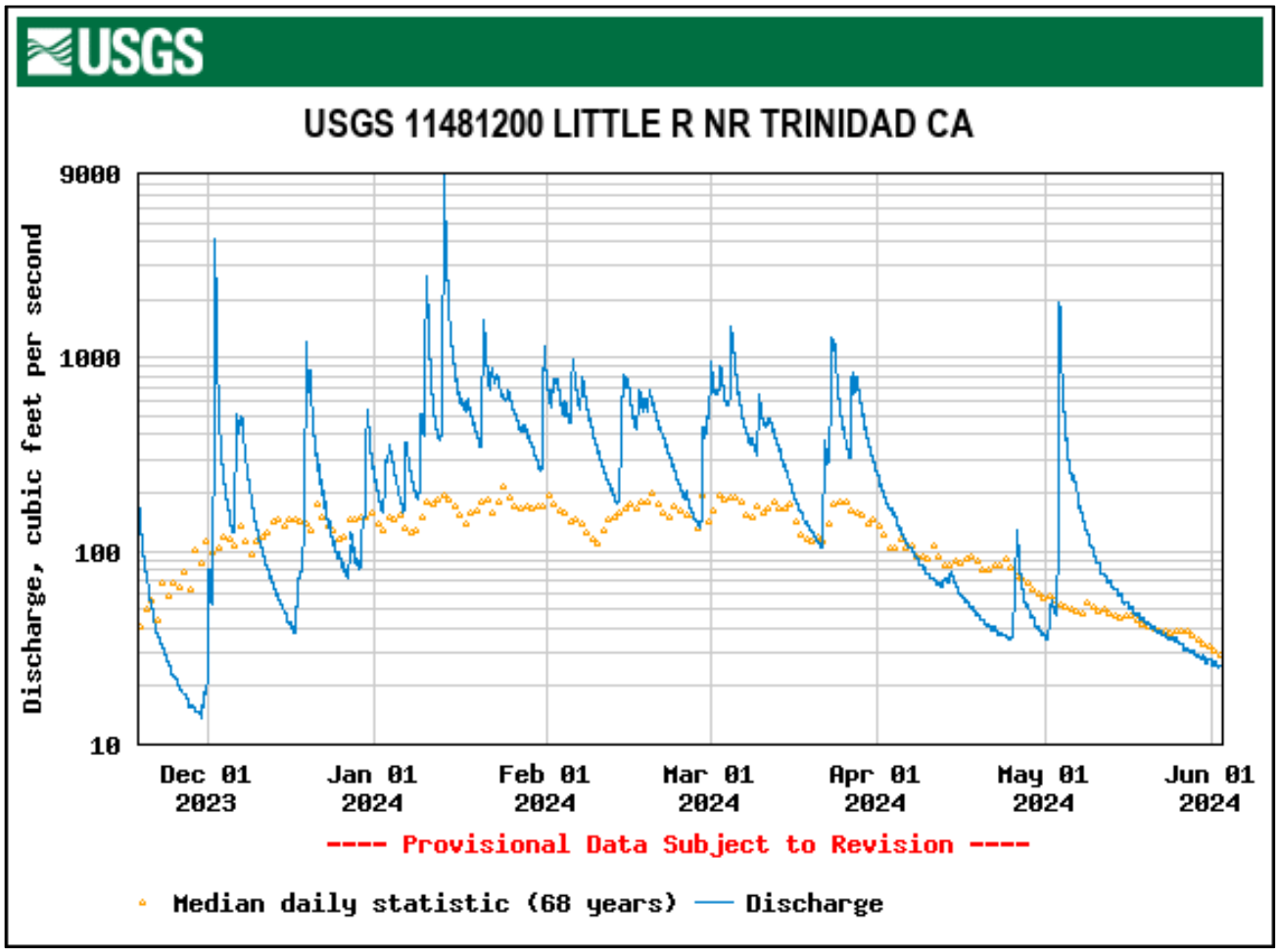

Figure 6. Mean discharge and median daily flow in cubic feet per second in Little River, used as a proxy for Freshwater Creek, December 2023 through May 2024.

The Coho Salmon redd estimate for Freshwater Creek in 2023 was below average, when compared to the last fourteen years (Table 7). The Coho Salmon redd estimate shows a slight downward trend over the last fourteen years (Figure 7). It is likely that in some years most steelhead redds were predicted to be Coho Salmon redds, such as in 2016 and 2021, thus inflating the estimated number of Coho Salmon redds.

Estimates for low density species such as Chinook Salmon in the Freshwater Creek LCM site (2011 to 2023), and steelhead, in the LCM site (2010 to 2013, 2016, 2021, and 2022) (Figure 8), continue to challenge the protocol and the ability to analyze the data with the tools available in Adams et al. (2011). In some years, steelhead estimates may also be influenced by the lack of surveys later in the season, which could capture the later spawning activity. Drought years tend to lead to conditions where clear water, and longer periods between storm events, make the counting of steelhead redds more favorable, such as in the years 2017 through 2020 (Figure 8). Extremely wet years such as 2023 create challenging survey conditions and steelhead redds may be obscured before they can be observed.

The Pacific Lamprey redd count in spring of 2024 was 179, which is close to the fourteen-year average of 175 (Figure 9). Factors contributing to the wide swing in numbers of Pacific Lamprey redds over the years, from 594 in 2016 to 42 in 2019, are still a mystery and more information is needed.

Table 7. Redd estimates with 95% confidence intervals for three species during fourteen years in Freshwater Creek Life Cycle Monitoring Station.

Year	Chinook Salmon	Coho Salmon	steelhead trout
2010-2011	12 (12,12)	231 (223,239)	4 (4,4)
2011-2012	0	420 (391,449)	7 (7,7)
2012-2013	0	244 (240,249)	13 (13,13)
2013-2014	0	127 (87,168)	2 (2,2)
2014-2015	0	453 (367,538)	72 (57,88)
2015-2016	3 (3,3)	322 (251,394)	1 (1,1)
2016-2017	0	178 (143,214)	0
2017-2018	0	181 (153,209)	110 (81,139)
2018-2019	1	406 (344,469)	83 (58,108)
2019-2020	0	153 (126,180)	81 (58,108)
2020-2021	0	210 (162,258)	59 (42,76)
2021-2022	0	378 (351,406)	0
2022-2023	0	181 (145,214)	2 (1,4)
2023-2024	0	162 (123,201)	14(10,17)
Average	1.1	260	32

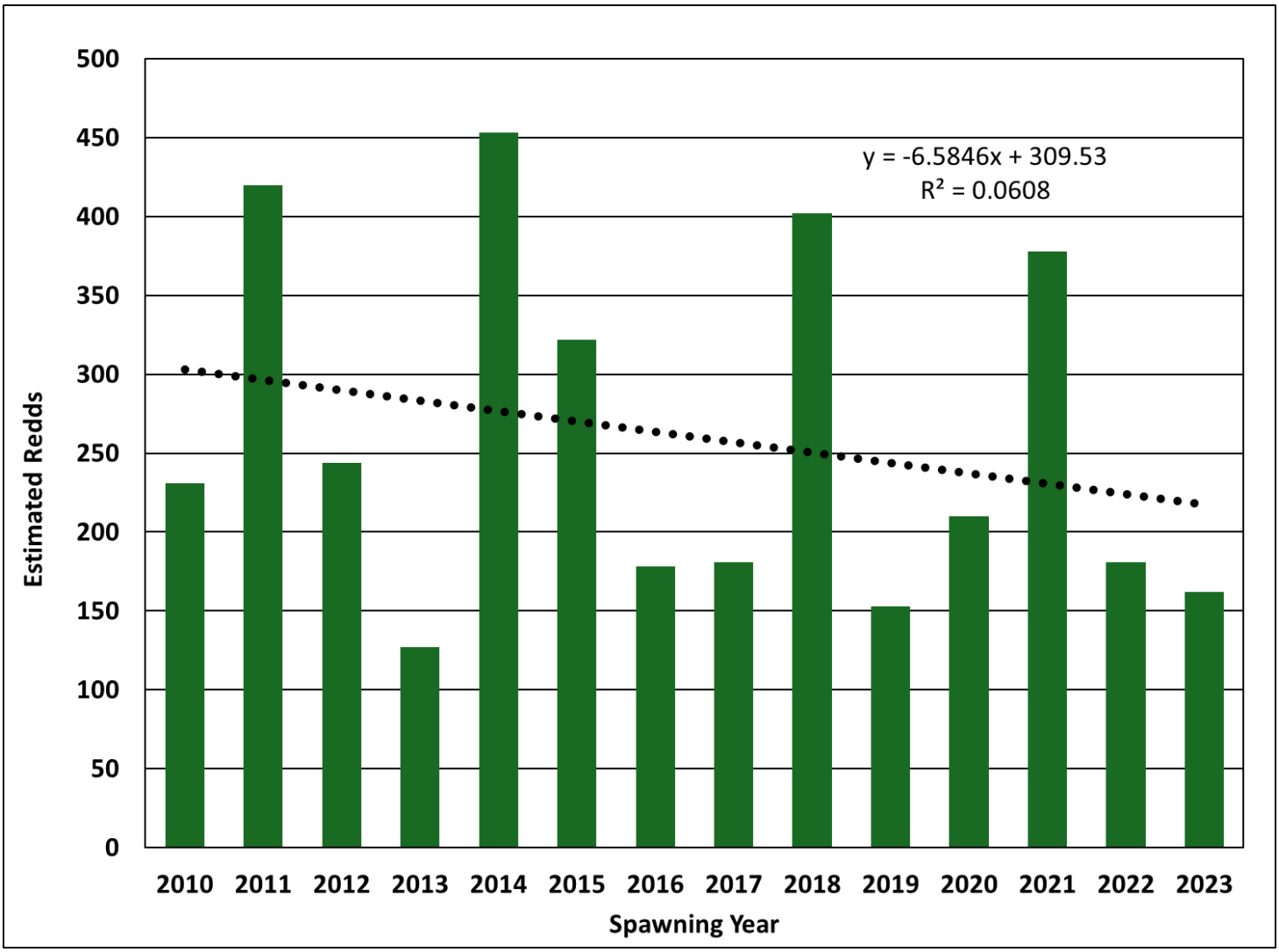

Figure 7. Estimated number of Coho Salmon redds in Freshwater Creek LCM reaches in spawning years 2010 to 2023. Year includes fall through spring (e.g. Year 2010 is fall 2010 through spring 2011). Freshwater Creek LCM contains nine census reaches.

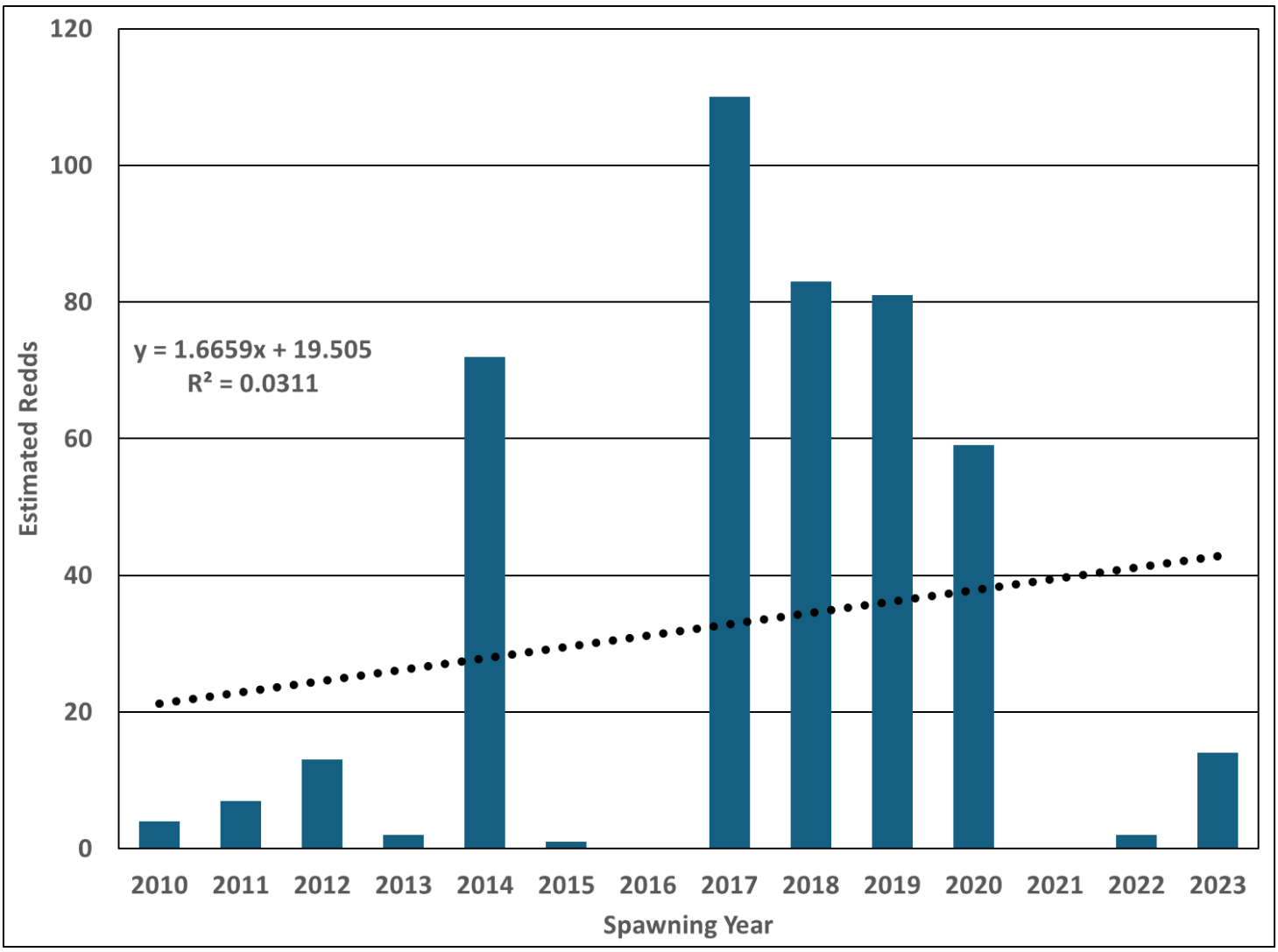

Figure 8. Estimated number of steelhead trout redds in Freshwater Creek LCM reaches in spawning years beginning in 2010 to 2023. Year includes fall through spring (e.g. Year 2010 is fall 2010 through spring 2011). Freshwater Creek LCM site contains nine census reaches, of which four are surveyed through the spring to capture the entire steelhead run.

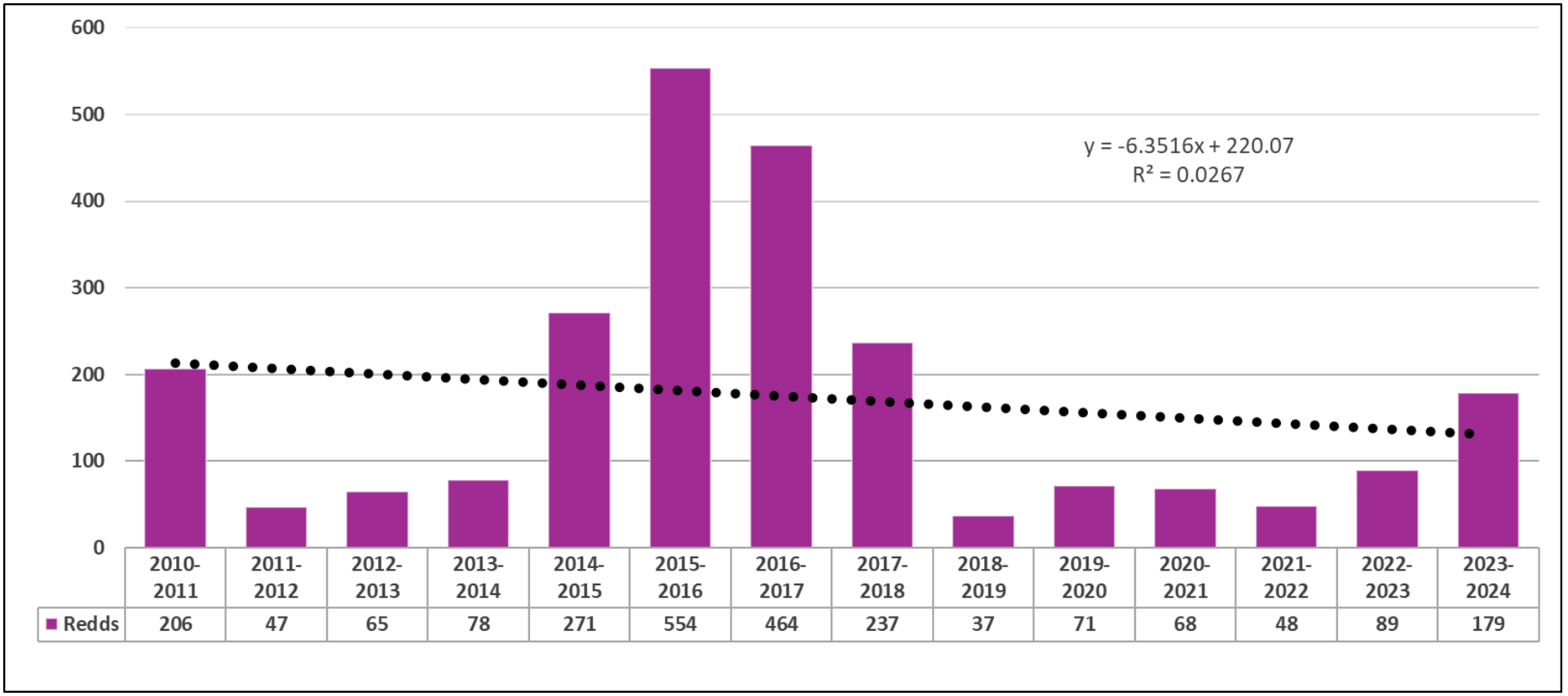

Figure 9. Time series of Pacific Lamprey redds in 4 survey reaches in Freshwater Creek. Years include winter through springtime.

4.2 Trends Throughout North Coast Life Cycle Monitoring Stations

The Northern California coast is home to three SONCC ESU LCM watersheds where SGS surveys are conducted with the same protocol (Figure 10). This consistency gives us a rare chance to compare redd trend data spatially and temporally.

Figure 11 presents Coho Salmon redd estimates over several years from three North Coast LCM stations. Estimate year represents the year that begins in fall and continues into the next year in the winter.

Although SONCC Coho Salmon in these three LCM stations may experience similar freshwater and marine conditions, the trends between watersheds are mixed at best. From 2013 to 2014 Prairie Creek showed a significant decrease in estimated redds while Freshwater Creek showed the opposite. Alternate trends in certain years suggest factors that determine adult survival may be different over space and time. More years of data may provide insight into the relationship of these three LCM stations.

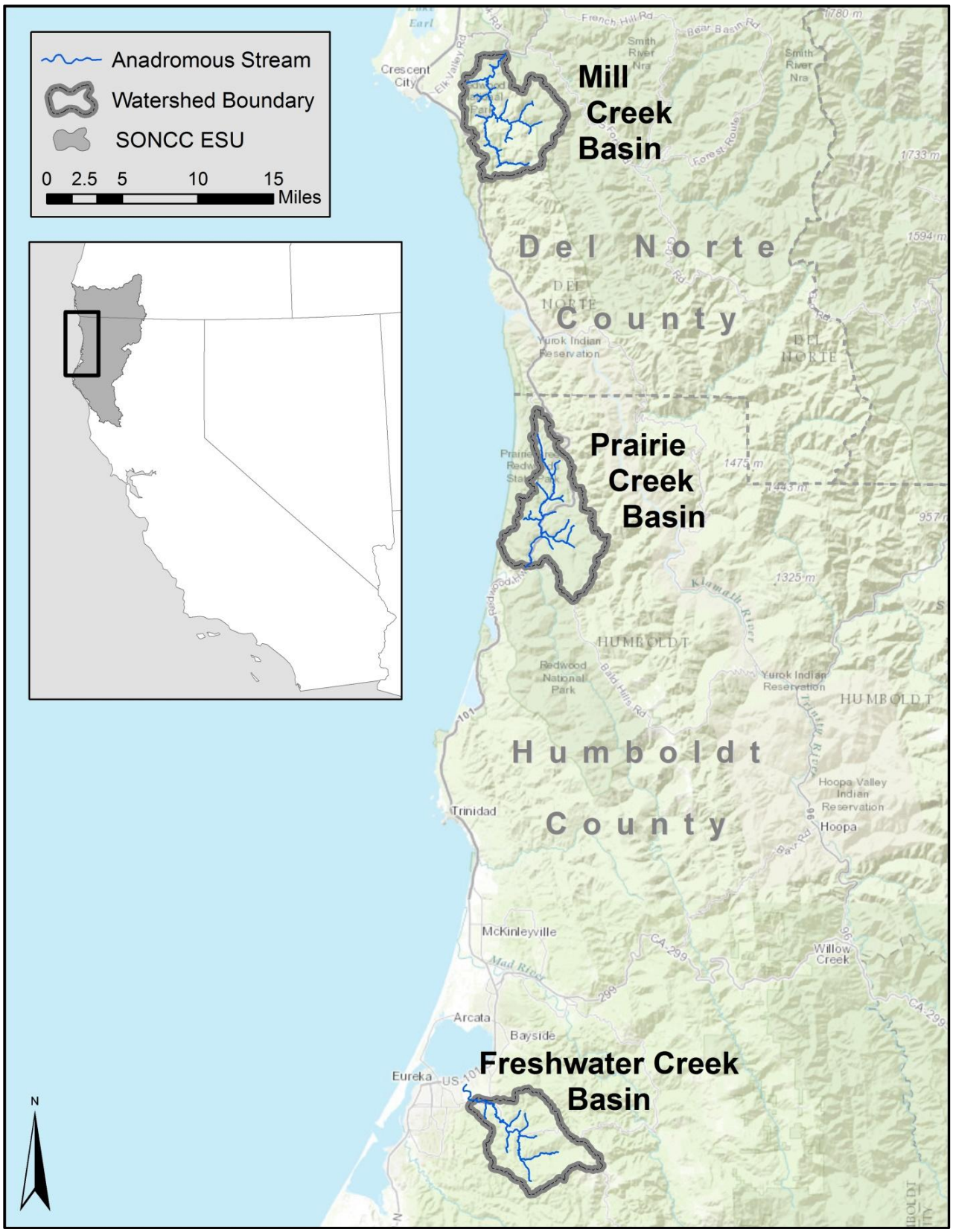

Figure 10. Northern California LCM stations. Source J. Deibner- Hanson.

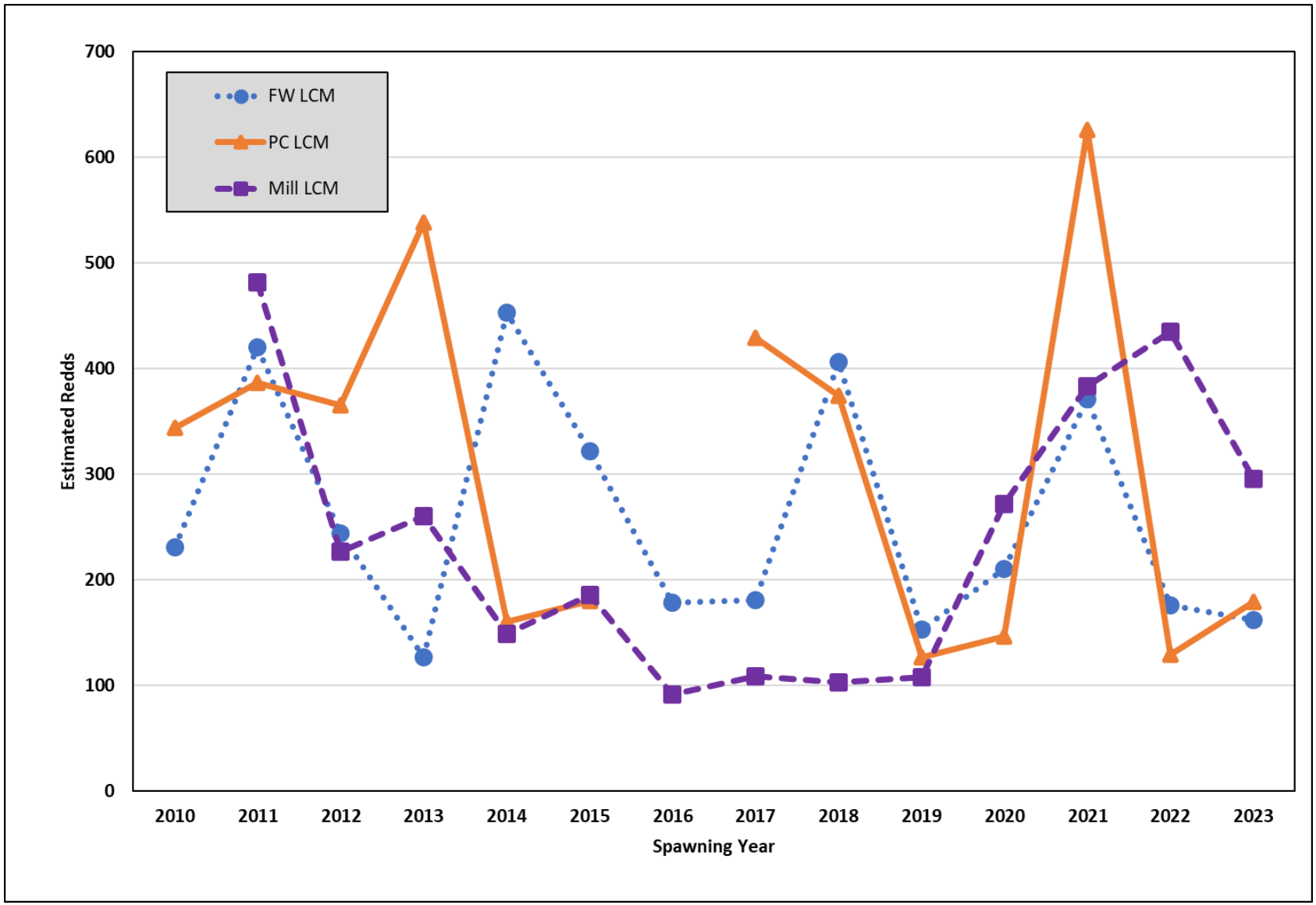

Figure 11. Coho Salmon Redd estimates from three Northern California LCM stations. Data not Available for Prairie Creek in 2016.

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