Coho Salmon and Steelhead Monitoring Report

Winter 2023/2024

Prepared by:

Mariska Obedzinski, Gregg Horton, Andrew Bartshire, and Aaron Johnson

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Contents

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1. Background

In 2004, the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) began releasing juvenile coho salmon raised at the US Army Corps of Engineer's (USACE) Don Clausen Fish Hatchery into tributaries of the Russian River with the goal of reestablishing populations that were on the brink of extirpation from the watershed. California Sea Grant at University of California (CSG) worked with local, state, and federal resource managers to design and implement a coho salmon monitoring program to track the survival and abundance of hatchery-released fish. Since the first Broodstock Program releases, CSG has been closely monitoring smolt abundance, adult returns, survival, and spatial distribution of coho salmon populations in four life cycle monitoring (LCM) subwatersheds: Willow, Dutch Bill, Green Valley, and Mill creeks. Data collected from this effort are provided to the Broodstock Program for use in evaluating the success of hatchery releases and adaptively managing future releases.

In 2013, CSG began partnering with Sonoma Water (SW) and California Department of Fish and Wildlife (CDFW) to implement the California Monitoring Plan (CMP) in the Russian River watershed. The CMP is a statewide effort to document status and trends of anadromous salmonid populations to inform recovery, conservation, and management activities. This work complements the Broodstock Program monitoring by incorporating a basinwide monitoring component that includes surveys in over 40 streams and expanding the species monitored to include steelhead and Chinook salmon.

In 2023, CSG began transitioning away from field data collection and subcontracted with SW to conduct field activities associated with Broodstock Program monitoring. Beginning in summer of 2023, all field data has been collected by SW.

The intention of our monitoring is to provide science-based information to stakeholders involved in salmon and steelhead recovery. Our work would not be possible without the support of our partners, including public resource agencies and non-profit organizations, along with hundreds of private landowners who have granted us access to the streams that flow through their properties.

In this seasonal monitoring report, we provide results from our fall and winter field season, including results from coho salmon monitoring at passive integrated transponder (PIT) tag detection sites located throughout the watershed and from spawning surveys conducted through both Broodstock Program and CMP monitoring efforts. Additional information and previous reports can be found on our website.

2. PIT tag monitoring

2.1. Goals and objectives

PIT tags and PIT detection systems (antennas and transceivers) were used to document the status and trends of Russian River coho salmon populations at both stream-specific and basinwide scales. From September 15, 2023, through March 1, 2024, our goal was to collect PIT tag data at multiple sites to document adult coho salmon return timing, estimate the number of returning coho salmon adults, and estimate coho salmon smolt to adult return (SAR) ratios in four LCM subwatersheds (Willow, Dutch Bill, Green Valley, and Mill creeks). Except for SAR ratios, we were able to estimate these metrics for the

Russian River basin as well. It was not possible to estimate SAR ratios at the basin scale because we do not have the ability to estimate the number of smolts leaving the entire Russian River basin each year.

2.2. Methods

2.2.1. PIT tagging

Beginning in 2007, a portion of juvenile coho salmon released from Don Clausen Fish Hatchery into the Mill Creek subwatershed were implanted with 12.5 mm full duplex (FDX) PIT tags. Coho salmon destined for tagging were randomly selected from holding tanks, and for all fish ≥ 56 mm and ≥ 2.0 g, a small incision was made on the ventral side of the fish using a scalpel, and a tag was then inserted into the body cavity. Over the next few years, PIT-tagged coho salmon were released into an increasing number of Russian River tributaries (Table 1). In 2013, the Broodstock Program began PIT tagging a percentage of all coho salmon released into the Russian River watershed. Since then, the hatchery has continued to PIT-tag a proportion of all releases each year.

During the winter of 2023/24, we anticipated the return of PIT-tagged adults from cohorts 2021 (age-3 returns) and 2022 (age-2 returns) that had been released as juveniles into multiple streams (Table 2). In addition, we anticipated the return of adults that we had previously tagged as juveniles at our smolt traps. In spring of 2022, approximately half of all natural-origin coho salmon smolts captured in downstream migrant traps were PIT tagged in Willow and Green Valley creeks, and in spring of 2023, approximately half were tagged at downstream migrant traps in all four LCM streams (California Sea Grant 2022; California Sea Grant and Sonoma Water 2023). To increase the sample size for estimating smolt to adult return (SAR) ratios, we also PIT-tagged approximately one third of all non-PIT-tagged hatchery smolts captured in during the springs of 2022 (Mill, Green Valley and Willow creeks) and 2023 (all four LCM streams). Another potential source of PIT-tagged adult returns was natural-origin coho salmon tagged as young-of-year in 2022 during CMP electrofishing surveys in the following creeks: Willow (125), Dutch Bill (290), Purrington (47), Dry (68), Mill (13), and Palmer (49).

2.2.2. Field methods

As part of the Broodstock Program monitoring effort, CSG operated stationary PIT tag detection systems in stream channels near the mouths of Willow, Dutch Bill, Green Valley and Mill creeks (Figure 1). Multiplexing transceivers were placed in waterproof boxes on the stream bank and powered using AC power with DC conversion systems (Willow, Dutch Bill, and Mill creeks) or solar power (Green Valley Creek). Sixteen by two-and-a-half foot antennas, housed in four-inch PVC, were placed flat on top of the streambed and secured with duck bill anchors. The antennas were placed in paired (upstream and downstream), channel-spanning arrays (e.g., Figure 2) so that detection efficiency could be estimated and the movement direction of individuals could be determined. Based on test tag trials at the time of installation, read-range in the water column above the antennas ranged from 10” to 24” during base flow conditions. During high water storm events, stream depths likely exceeded maximum read range depths, so if PIT-tagged fish were travelling in the water column above the maximum read range depth, they may not have been detected on the antennas. The paired arrays were used to estimate antenna efficiency in order to account for undetected fish. From September 15, 2023 through March 1, 2024, PIT tag detection systems were visited every other week to download data and check antenna status. More frequent visits were made during storm events. Additional antenna arrays were operated throughout the watershed by CSG and SW, including a 10-antenna array located in the mainstem of the Russian River near Duncans Mills (see EST-10.46, Figure 1).

Table 1. Number and percent of PIT-tagged coho salmon released into Russian River tributaries by cohort.

Cohort (Hatch year)	Tributaries[1] stocked with coho salmon	Tributaries[1] stocked with PIT-tagged coho salmon	Number coho salmon released into Russian River tributaries	Number PIT-tagged coho salmon released	Percent of Russian River releases PIT-tagged
2007	DRY, DUT, GIL, GRA, GRE, MIL, PAL, SHE	MIL, PAL	71,159	7,456	10%
2008	DRY, DUT, GIL, GRA, GRE, MIL, PAL, SHE	MIL, PAL	91,483	11,284	12%
2009	DRY, DUT, GIL, GRA, GRE, MIL, PAL, SHE	MIL, PAL, GRE	81,231	8,819	11%
2010	DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, GRP, MIL, PAL, POR, PUR, THO, SHE	DRY, DUT, GRE, GRP, MIL, PAL	155,388	16,767	11%
2011	ANG, BLA, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, GRP, MAR, MIL, PAL, PEN, POR, PUR, THO, SHE, WIL	ANG, BLA, DEV, DRY, DUT, GIL, GRA, GRE, GRP, MIL, PAL, PEN, PUR, THO, WIL	160,397	18,769	12%
2012	BLA, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, GRP, MAR, MIL, PAL, PEN, POR, PUR, THO, SHE, WIL	BLA, DEV, DRY, DUT, GIL, GRA, GRE, GRP, MIL, PAL, PEN, PUR, THO, WIL	182,370	30,934	17%
2013	AUS, BLA, DEV, DRY, DUT, FRE, GIL, GRA, GRE, GRP, MAR, MIL, PAL, PEN, POR, PUR, SHE, THO, WIL		171,846	34,536	20%
2014	AUS, BLA, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, GRP, MAR, MIL, PAL, PEN, POR, PUR, SHE, THO, WIL		235,327	39,556	17%
2015	DRY, DUT, GIL, GRA, GRE, MIL, WIL		70,510	22,620	32%
2016	AUS, DEV, DRY, DUT, FRE, GIL, GRA, GRE, MAR, MIL, PAL, PUR, SHE, THO, WIL		158,379	26,546	17%
2017	AUS, DEV, DRY, DUT, FRE, GIL, GRA, GRE, MAI, MIL, PAL, PUR, RCA, SHE, WIL		133,853	31,773	24%
2018	AUS, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, SHE, WIL		134,014	27,823	21%
2019	AUS, DEV, DRY, DUT, EAU, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, WIL		194,277	31,094	16%
2020	AUS, DEV, DRY, DUT, EAU, GIL, GRA, GRE, KID, MAR, MAI, POR, PUR, RCA, WIL, YEL	AUS, DEV, DRY, DUT, EAU, GIL, GRA, GRE, KID, MAR, MAI, POR, PUR, RCA, WIL	196,276	26,805	13%
2021	AUS, DRY, DUT, EAU, FRE, GRA, GRE, MAR, MIL, PAL, POR, PUR, RCA, SHE, WIL, MAI, KID, YEL	AUS, DRY, DUT, EAU, FRE, GRA, GRE, MAR, MIL, PAL, POR, PUR, RCA, SHE, WIL, MAI, KID	215,022	29,730	14%
2022	MAI, WIL, AUS, KID, EAU, GRA, DUT, GRE, PUR, MAR, DRY,MIL, YEL	MAI, WIL, AUS, KID, EAU, GRA, DUT, GRE, PUR, MAR, DRY,MIL	118,498	28,403	24%

[1]Stream Codes: ANG: Angel Creek, AUS: Austin Creek, BLA: Black Rock Creek, DEV: Devil Creek, DRY: Dry Creek, DUT: Dutch Bill Creek, EAU: East Austin Creek, FRE: Freezeout Creek, GIL: Gilliam Creek, GRA: Gray Creek, GRE: Green Valley Creek, GRP: Grape Creek, KID: Kidd Creek, MAI: Russian River Mainstem, MAR: Mark West Creek, MIL: Mill Creek, PAL: Palmer Creek, PEN: Pena Creek, POR: Porter Creek, PUR: Purrington Creek, RCA: Redwood Creek (Atascadero), SHE: Sheephouse Creek, THO: Thompson Creek, WIL: Willow Creek, YEL: Yellow Jacket Creek.

Table 2. Number and percent of PIT-tagged juvenile coho salmon released into Russian River tributaries by stream and release group, cohorts 2020 and 2021.

Cohort (Hatch year)	Tributary	Release group	Total coho salmon released	PIT-tagged coho salmon released	Percent PIT-tagged coho salmon released
2021	Russian River	smolt	59,152	9,002	15%
2021	Willow Creek	fall	4,033	610	15%
2021	Sheephouse Creek	fall	1,498	230	15%
2021	Freezeout Creek	fall	1,520	230	15%
2021	Austin Creek	fall	8,053	1,215	15%
2021	Kidd Creek	fall	3,003	459	15%
2021	East Austin Creek	fall	11,022	1,679	15%
2021	Gray Creek	fall	3,840	609	16%
2021	Dutch Bill Creek	fall	11,930	1,811	15%
2021	Green Valley Creek	fall	11,467	1,722	15%
2021	Redwood Creek (Atascadero)	fall	2,000	305	15%
2021	Purrington Creek	fall	2,041	302	15%
2021	Mark West Creek	fall	7,991	1,210	15%
2021	Porter Creek	fall	3,045	459	15%
2021	Dry Creek	spring	30,584	4,526	15%
2021	Dry Creek	fall	20,185	3,073	15%
2021	Dry Creek	smolt	240	0	0%
2021	Dry Creek	adult	1	1	100%
2021	Mill Creek	fall	12,210	1,827	15%
2021	Palmer Creek	fall	3,050	460	15%
2021	Yellowjacket Creek	RSI	18,157	0	0%
2022	Russian River	smolt	32,518	8,483	26%
2022	Willow Creek	presmolt	3,018	775	26%
2022	Austin Creek	fall	7,533	1,949	26%
2022	Kidd Creek	fall	2,033	520	26%
2022	East Austin Creek	fall	8,207	2,078	25%
2022	Gray Creek	fall	3,044	779	26%
2022	Dutch Bill Creek	fall	6,192	1,612	26%
2022	Dutch Bill Creek	smolt	3,993	1,045	26%
2022	Green Valley Creek	smolt	24,291	6,427	26%
2022	Purrington Creek	presmolt	3,539	785	22%
2022	Mark West Creek	smolt	6,615	1,714	26%
2022	Dry Creek	presmolt	3,032	782	26%
2022	Dry Creek	smolt	400	0	0%
2022	Mill Creek	fall	4,678	1,454	31%
2022	Yellowjacket Creek	RSI	9,405	0	0%

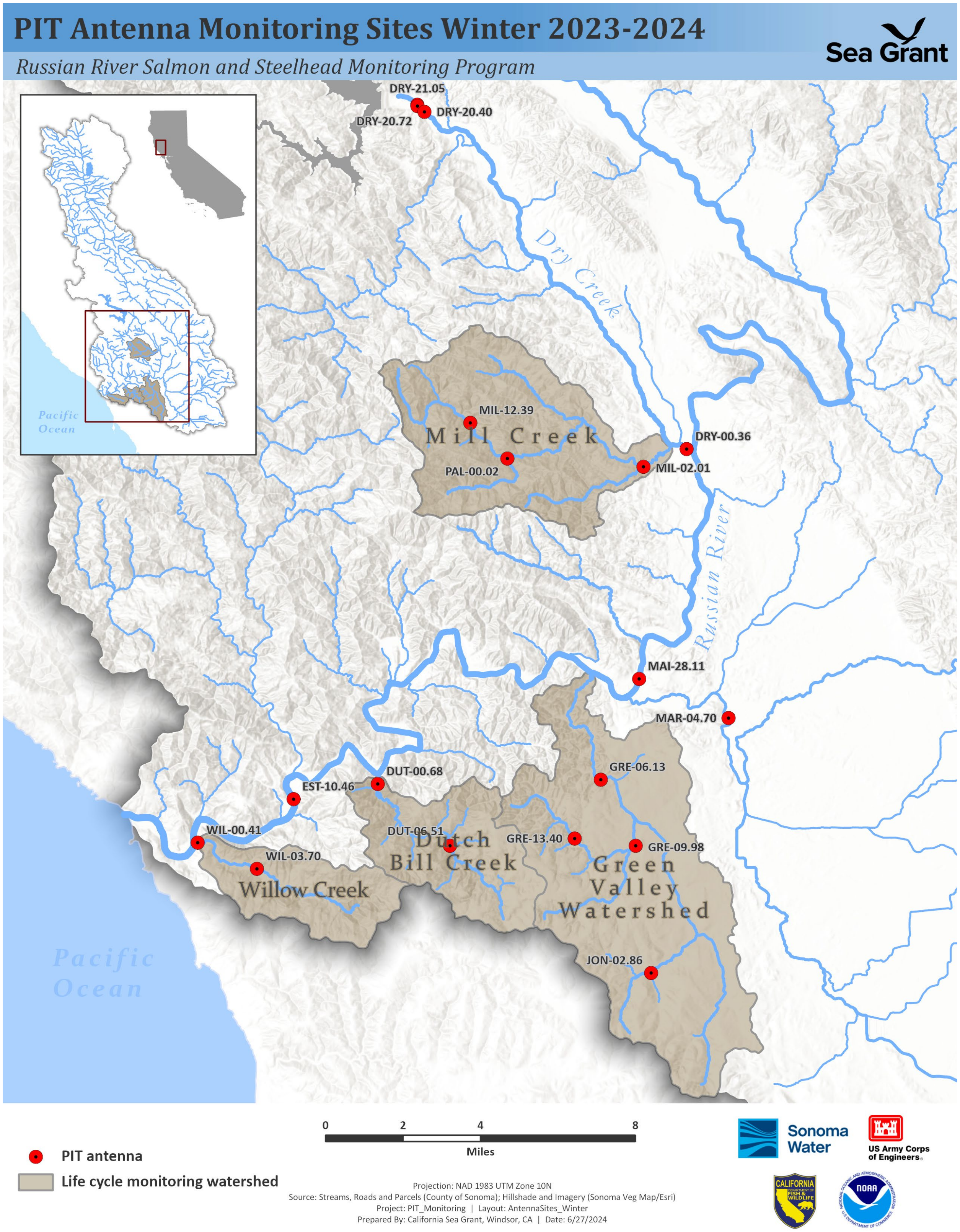


Figure 1. Passive integrated transponder (PIT) antenna locations in the Russian River watershed, winter 2023/24. Labels on antennas include a stream code (first three letters of the stream) and the distance in km from the mouth of that stream.

Figure 2. Paired flat-plate antenna array on a Russian River tributary.

2.2.3. Data analysis

First, all records of two-, three-, and four-year-old PIT-tagged coho salmon detected on antenna arrays between September 15, 2023 and March 1, 2024 were examined to determine the movement and life history patterns of fish detected on PIT antenna arrays (i.e., returning adults, age-2 emigrants, or "ghost tags") based on the duration and direction of tag movement. Individuals with a net positive upstream movement during this time frame were categorized as adult returns, which were further evaluated for their return timing relative to flow conditions, and for minimum and estimated return numbers, as described below. We presumed that two-year-olds detected moving in a downstream-only direction were juveniles and they were removed from the adult return dataset. Any tags that were moving very slowly downstream at a given antenna array (approximately one half hour or more between upper and lower arrays) and that were not previously detected emigrating as smolts, were presumed to be tags from fish that had perished (ghost tags) and these tags were also removed from the adult return dataset.

2.2.3.1. Adult return timing relative to flow conditions

The first detection of each returning PIT-tagged hatchery adult coho salmon between September 15, 2023 and March 1, 2024 was plotted with streamflow or stage data from the nearest available USGS streamflow gage at each antenna site.

2.2.3.2. Adult return minimum and estimated numbers

Estimates of the number of adult coho salmon returning to Willow, Dutch Bill, Green Valley and Mill LCM streams were calculated by 1) counting the number of unique adult PIT detections on the antenna array located furthest downstream in each LCM stream (minimum count), 2) dividing the minimum count for each stream by the proportion of PIT-tagged fish released from the hatchery into each respective LCM subwatershed or, in the case of natural-origin fish, the proportion of natural-origin fish PIT-tagged at the downstream migrant trap or during electrofishing surveys (expanded count per stream), and 3) dividing the expanded count by the estimated efficiency of the paired antenna array (estimated count per stream). The efficiency of the antenna array in each LCM stream was estimated by first estimating the efficiency of both the lower and upper antennas within each array. This was calculated by dividing the number of detections on both upstream and downstream antenna(s) by all detections on the upper or lower antenna(s) (e.g., to calculate the efficiency of the lower antenna(s) in an array, we divided the number of detections on both upstream and downstream antenna(s) by all of the detections on the upper antenna(s)). To estimate the efficiency of the entire array (i.e., combined efficiency of the upper and lower antennas in an array) we used the formula $p^* = 1-((1-p_1) \times (1-p_2))$, where p_1 = antenna efficiency of the upper antenna(s) in an array and p_2 = antenna efficiency of the lower antenna(s) in an array, and p^* = combined efficiency of all antennas in an array.

Individual data recorded at the time of tagging was used to estimate the number of returns by release group (age and season of release). To avoid the potential for duplication in our expansions of hatchery fish, we did not expand the number of hatchery adults that were previously tagged at the downstream migrant traps. Similarly, to avoid duplication of our expansions of natural-origin fish, for a given cohort and LCM stream, we did not expand natural-origin adults that were tagged electrofishing unless no natural-origin adults were detected that had been previously PIT tagged at the downstream migrant trap.

In most winters, to estimate the total number of hatchery coho salmon adults returning to the Russian River mainstem at Duncans Mills, a similar calculation approach was used as described for the LCM streams; however, the efficiency of the Duncans Mills antenna array was estimated by dividing the total number of unique PIT detections of adults at both Duncans Mills and at antenna arrays upstream of Duncans Mills by the total number of PIT-tagged adults detected on arrays upstream of Duncans Mills. Once Duncans Mills antenna efficiency was estimated, we then 1) counted the number of unique adult PIT detections at Duncans Mills (minimum count), 2) divided the minimum count by the proportion of PIT-tagged fish released from the hatchery (expanded count), and 3) divided the expanded count by the estimated efficiency of the Duncans Mills antenna array (estimated count). Because Willow Creek enters the Russian River downstream of Duncans Mills, an estimate of adults that entered Willow Creek (but were not detected on or upstream of Duncans Mills) was added to the estimate of adults migrating past Duncans Mills. Freezeout and Sheephouse creeks also enter the river downstream of Duncans Mills; however, we have no means of estimating PIT-tagged adults returning to those streams so returns to those creeks were not included in the basinwide estimate.

During the winters of 2020/21 and 2022/23, low antenna efficiencies at the Duncans Mills antenna array prevented us from using the adult estimation approach used in most years (described above). As an alternative, we first summed the number of unique adult PIT detections on any antenna that was operated in the watershed during the winter of 2020/21 or 2022/23, then divided the number of unique individuals from each release group by the proportion tagged for that release group, and finally summed the total expanded counts for each release group. This method did not account for PIT antenna efficiency and therefore may be biased low.

2.2.3.3. Smolt to adult return (SAR) ratios

In each of the four LCM subwatersheds, the sum of the estimated number of two-year old hatchery adults returning during the winter of 2022/23 and three-year old adults returning during the winter of 2023/24 was divided by the estimated number of smolts migrating from each stream between March 1 and June 30 of 2022 to derive a SAR ratio. The SAR ratio includes the probability of surviving the riverine, estuarine, and ocean environments from when the fish left the tributary as smolts until they returned to the tributary as adults. Detections of coho salmon adults from any adult releases were excluded from SAR calculations.

2.3. Results

2.3.1. Adult return timing relative to flow conditions

Total precipitation between October 1, 2023 and March 1, 2024 was slightly above the 20-year average (Figure 3). The first significant storm event that reconnected the coho spawning tributaries occurred during the second half of December followed by multiple storms throughout the remainder of the coho spawning window that typically ends in March (e.g., Austin Creek, Figure 4).

PIT-tagged adult coho salmon were first detected entering the estuary (Duncans Mills PIT antenna array; EST-10.46, Figure 1) in early October, prior to the first large storm event that increased streamflow, and detections of new individuals continued through mid-February (Figure 5). Detections further upstream in the mainstem at Mirabel (MAI-28.11, Figure 1) were recorded in October through early December before the antennas were removed just prior to the first significant storm event of the water year (Figure 6). Detections at the mouth of Dry Creek (DRY-000.36, Figure 1) were recorded between late October and mid-February (Figure 7). The first detections of PIT-tagged coho adults did not occur in the LCM tributaries or Mark West Creek until the first significant storm event in mid-December (Figure 8 - Figure 12). In these tributaries, a large pulse of fish occurred during this storm event, though detections of new fish continued through late January in Willow and Dutch Bill creeks and into February in Green Valley and Mill creeks.

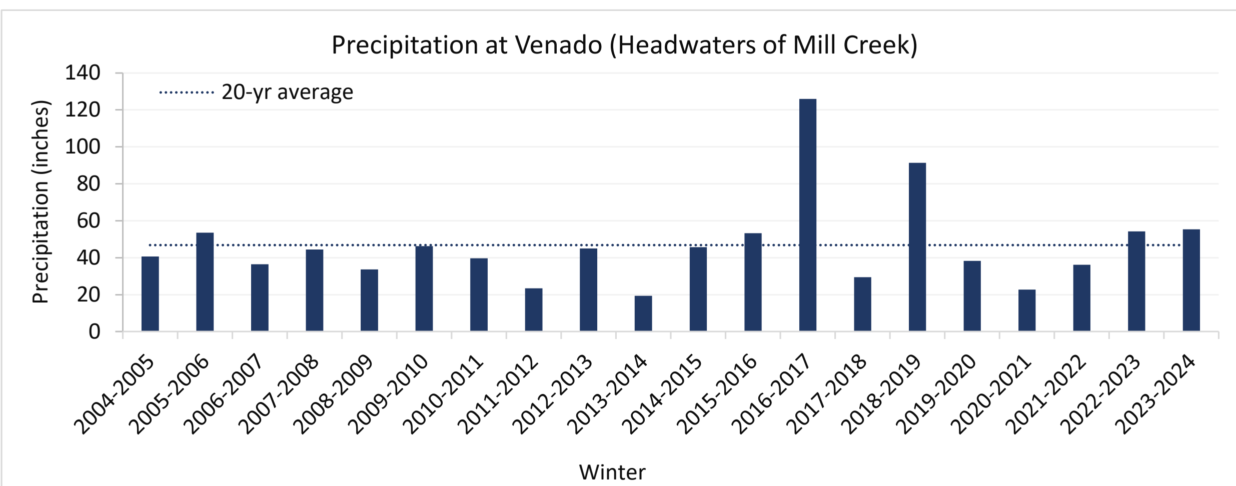


Figure 3. October – February precipitation at Venado gage near Mill Creek headwaters. Data were obtained from the California Data Exchange Center (https://cdec.water.ca.gov).

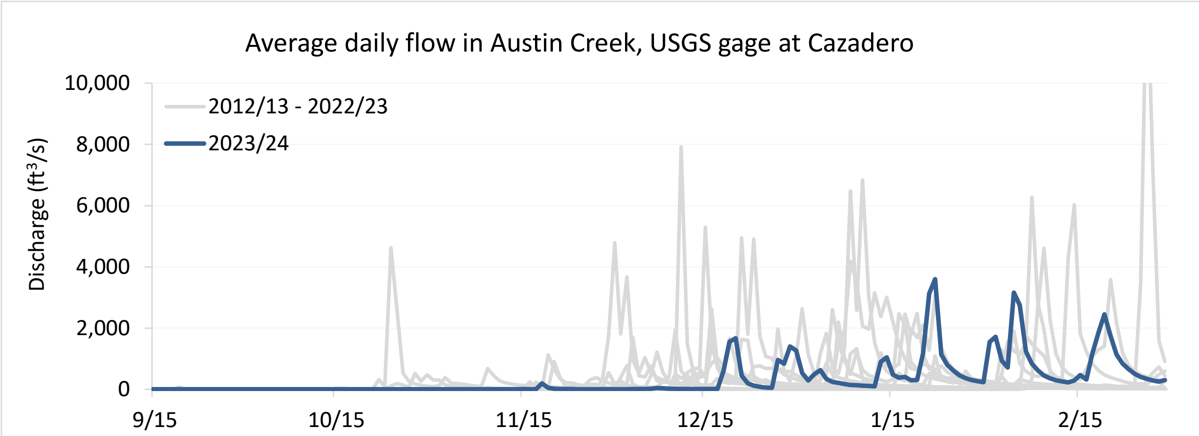


Figure 4. Winter 2023/24 streamflow in Austin Creek near Cazadero as compared to streamflow during the previous 11 winters. Data were obtained from USGS (waterdata.usgs.gov).

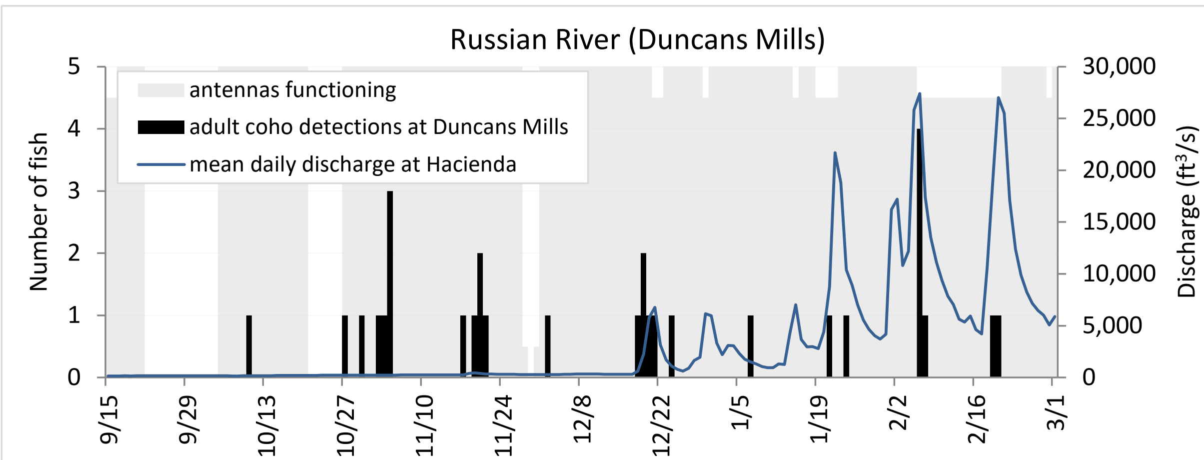


Figure 5. Detections of PIT-tagged coho salmon adults passing upstream of the Russian River antenna array at Duncans Mills (EST-10.46), September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Hacienda Bridge (11467000, waterdata.usgs.gov).

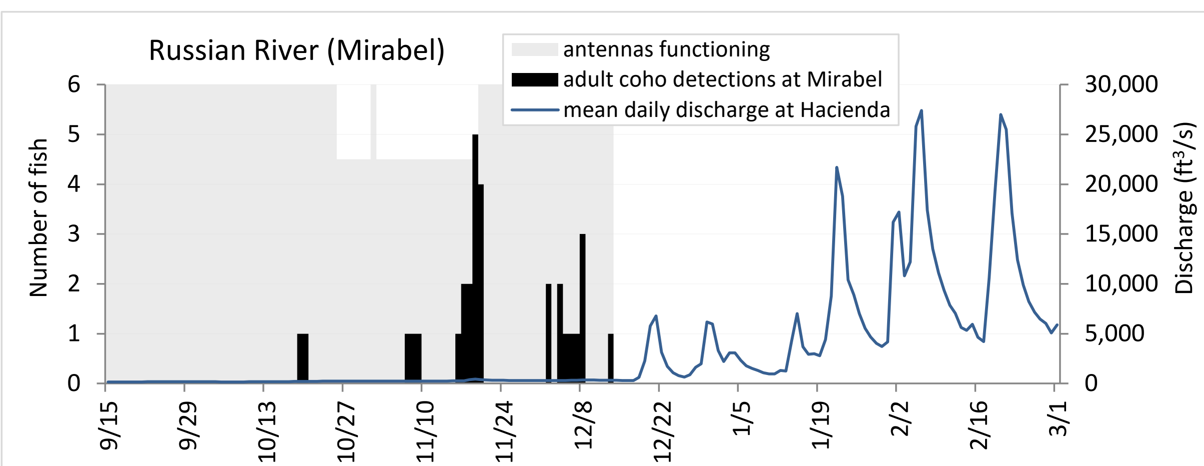


Figure 6. Detections of PIT-tagged coho salmon adults passing upstream of the Russian River antenna array at Mirabel (MAI-28.11), September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Hacienda Bridge (11467000, waterdata.usgs.gov). The antennas were removed for the season on 12/13/23.

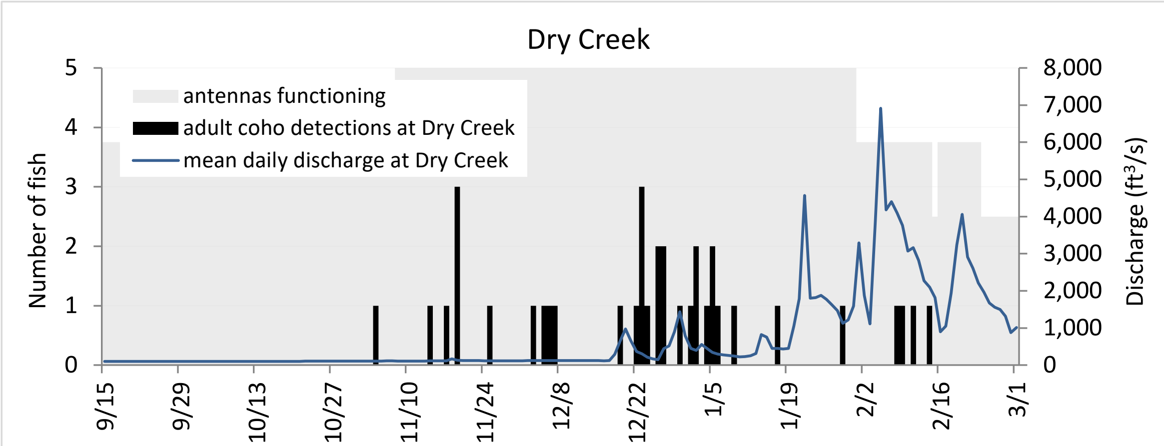


Figure 7. Detections of PIT-tagged coho salmon adults passing upstream of the Dry Creek antenna array (DRY-000.36), September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Dry Creek mouth (11465350, waterdata.usgs.gov).

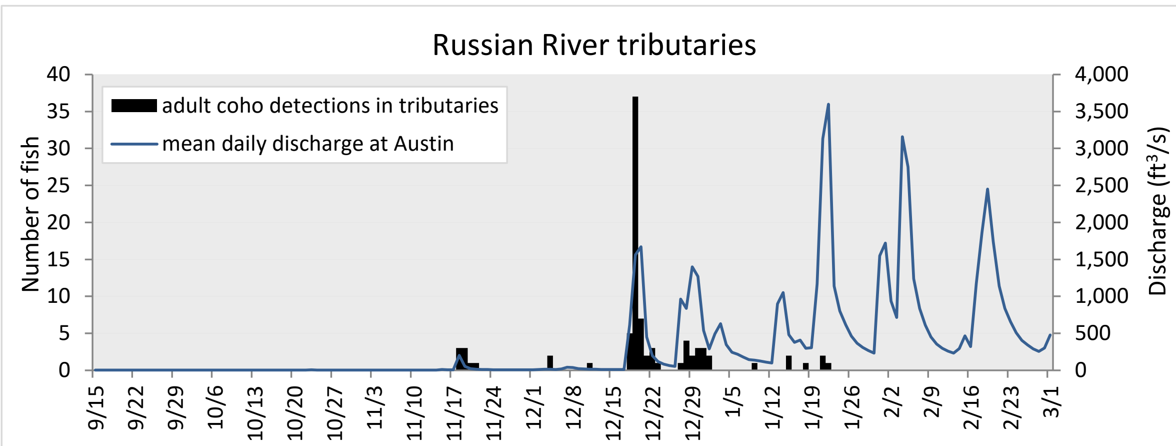


Figure 8. Detections of PIT-tagged coho salmon adults on Willow, Dutch Bill, Green Valley, Mill, and/or Mark West Creek antennas, September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Austin Creek (11467200, waterdata.usgs.gov).

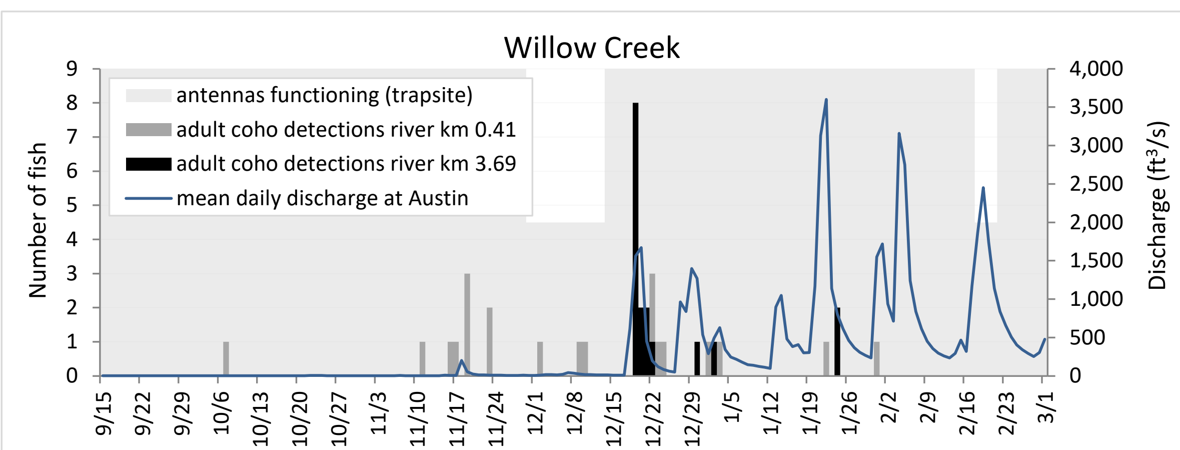


Figure 9. Detections of PIT-tagged coho salmon adults on Willow Creek between September 15, 2023 and March 1, 2024. Discharge data were obtained from the USGS gage at Austin Creek (11467200, waterdata.usgs.gov).

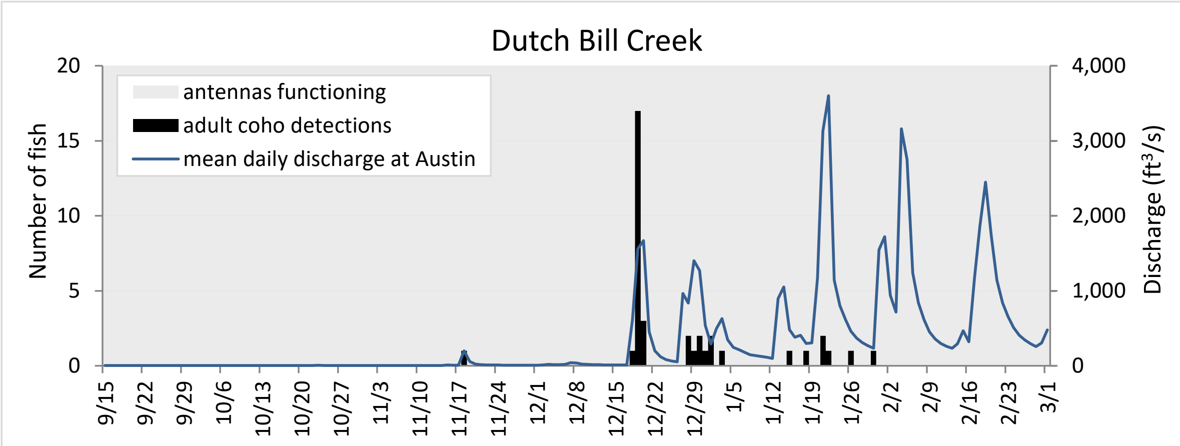


Figure 10. Detections of PIT-tagged coho salmon adults passing upstream of the Dutch Bill Creek antenna array, September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Austin Creek (11467200, waterdata.usgs.gov).

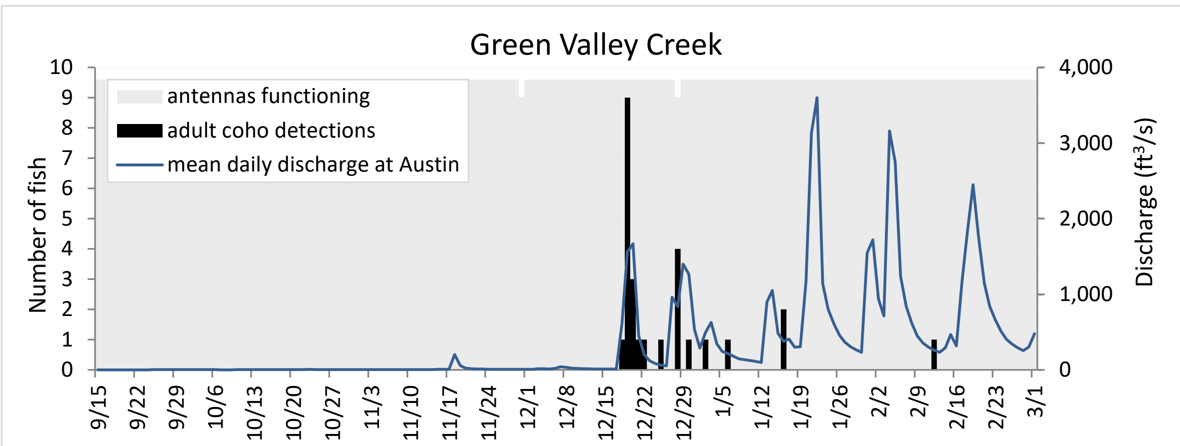


Figure 11. Detections of PIT-tagged coho salmon adults passing upstream of the Green Valley Creek antenna array, September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Austin Creek (11467200, waterdata.usgs.gov).

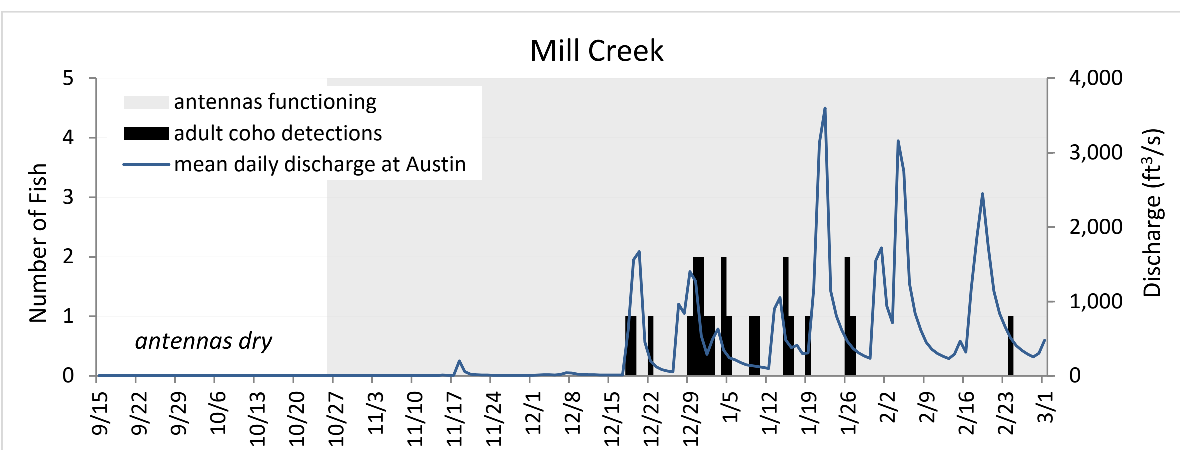


Figure 12. Detections of PIT-tagged coho salmon adults passing upstream of the Mill Creek antenna array, September 15, 2023 - March 1, 2024. Discharge data were obtained from the USGS gage at Austin Creek (11467200, waterdata.usgs.gov).

2.3.2. Adult return estimates and smolt to adult return (SAR) ratios

A total of 124 unique PIT-tagged adult coho salmon were detected on PIT antennas in the Russian River watershed during the winter of 2023/24 and were comprised of fish originating from hatchery and natural-origin, age-3 and age-2 age classes, and multiple release groups: spring, fall, presmolt and smolt hatchery releases, as well as natural-origin fish tagged as yoy during electrofishing surveys or as smolts at downstream migrant traps (Table 3). PIT-tagged adult coho salmon were detected entering each of the LCM subwatersheds (17 in Willow, 37 in Dutch Bill, 26 in Green Valley and 19 in Mill) (Table 4). Although composition of adult returns to each LCM included fish that originated from that LCM, all four streams also had a high proportion of returns of fish originating from several other Russian River tributaries and from mainstem Russian River releases. Age composition to LCM streams consisted of a combination of age-3 and age-2 adults except in Willow Creek, where only age-2 adults were detected. Natural-origin fish were detected in all four LCM streams.

Estimates of adult coho salmon returning to Willow, Dutch Bill, Green Valley, and Mill creeks were 51, 129, 81, and 66, respectively, and the estimated number of hatchery coho salmon adults returning to the Russian River at Duncans Mills was 825 (Table 5). Adult return estimates during the winter of 2023/24 were average (Green Valley and Mill) or above average (Willow and Dutch Bill) compared to previous years, and in Dutch Bill Creek was the highest on record (Figure 13 - Figure 16). Estimated hatchery returns the mainstem at Duncans Mills were also the highest on record since Broodstock Program monitoring began (Figure 17). The proportion of age-2 returns was high, ranging from 74% on Dutch Bill Creek (Figure 14) to 100% on Willow Creek (Figure 13), and 59% to the Russian River watershed (Figure 18).

Estimated SAR ratios were 0 for Willow Creek, 1.5% for Dutch Bill Creek, 0.2% for Green Valley Creek and 0.3% for Mill Creek (Figure 19 - Figure 22, Table 6). These rates were higher than average in Dutch Bill Creek and lower than average in the other three LCM streams (Table 6).

Table 3. Detections of unique PIT-tagged coho salmon adults on any Russian River watershed PIT antenna array during winter 2023/24.

Origin	Age	Release or tagging tributary	Release group	PIT-tagged individuals detected
hatchery	3	Dry Creek	spring	2
			fall	1
		Dutch Bill Creek	fall	3
		East Austin Creek	fall	1
		Kidd Creek	fall	1
		Mark West Creek	fall	2
		Mill Creek	fall	4
		Russian River	smolt	6
	2	Austin Creek	fall	1
		Dry Creek	presmolt	4
		Dutch Bill Creek	fall	7
			smolt	5
		East Austin Creek	fall	1
		Gray Creek	fall	1
		Green Valley Creek	smolt	13
		Kidd Creek	fall	2
		Mark West Creek	smolt	14
		Mill Creek	fall	2
		Purrington Creek	presmolt	3
		Russian River	smolt	15
		Willow Creek	presmolt	9
		Dutch Bill Creek	tagged at downstream migrant trap	1
		Green Valley Creek	tagged at downstream migrant trap	2
natural	2	Dutch Bill Creek	tagged electrofishing	2
			tagged at downstream migrant trap	1
		Green Valley Creek	tagged at downstream migrant trap	10
		Mill Creek	tagged at downstream migrant trap	2
		Palmer Creek	tagged electrofishing	1
		Willow Creek	tagged electrofishing	4
			tagged at downstream migrant trap	4
			Total unique individuals detected:	**124**

Table 4. Detections of unique PIT-tagged coho salmon adults in each of the four LCM subwatersheds during winter 2023/24. Note that individual fish may have been detected in more than one LCM subwatershed.

Detection Tributary	Age	Origin	Release or tagging tributary	Release group	Minimum count	Total PIT-tagged individuals detected
Willow Creek	2	hatchery	Dutch Bill Creek	fall	1	17
			Kidd Creek	fall	1	
			Russian River	smolt	2	
			Willow Creek	presmolt	8	
		natural	Willow Creek	tagged electrofishing	2	
				tagged at downstream migrant trap	3	
Dutch Bill Creek	3	hatchery	Dutch Bill Creek	fall	2	37
			Mark West Creek	fall	1	
			Russian River	smolt	2	
	2	hatchery	Austin Creek	fall	1	
			Dry Creek	presmolt	1	
			Dutch Bill Creek	fall	7	
				smolt	3	
			Gray Creek	fall	1	
			Kidd Creek	fall	2	
			Russian River	smolt	4	
			Willow Creek	presmolt	4	
			Dutch Bill Creek	tagged at downstream migrant trap	1	
			Green Valley Creek	tagged at downstream migrant trap	1	
		natural	Dutch Bill Creek	tagged electrofishing	2	
				tagged at downstream migrant trap	1	
			Green Valley Creek	tagged at downstream migrant trap	1	
			Willow Creek	tagged electrofishing	1	
				tagged at downstream migrant trap	2	
Green Valley Creek	3	hatchery	Russian River	smolt	1	26
	2	hatchery	Dutch Bill Creek	smolt	2	
			Green Valley Creek	smolt	5	
			Mark West Creek	smolt	2	
			Purrington Creek	presmolt	2	
			Russian River	smolt	1	
			Willow Creek	presmolt	2	
			Green Valley Creek	tagged at downstream migrant trap	1	
		natural	Green Valley Creek	tagged at downstream migrant trap	9	
			Willow Creek	tagged at downstream migrant trap	1	
Mill Creek	3	hatchery	Dry Creek	fall	1	19
			Russian River	smolt	1	
	2	hatchery	Dry Creek	presmolt	2	
			Dutch Bill Creek	smolt	1	
			Mark West Creek	smolt	2	
			Mill Creek	fall	2	
			Purrington Creek	presmolt	1	
			Russian River	smolt	3	
			Willow Creek	presmolt	1	
			Green Valley Creek	tagged at downstream migrant trap	1	
		natural	Dutch Bill Creek	tagged at downstream migrant trap	1	
			Green Valley Creek	tagged at downstream migrant trap	3	

Table 5. Estimated efficiency of paired PIT antenna arrays and estimated number of adult coho salmon returns to four LCM subwatersheds during winter 2023/24.

Tributary	Efficiency of antenna array	NOR age-3	NOR age-2	HOR age-3	HOR age-2	Total returns
Willow Creek	100%	0	5	0	46	51
Dutch Bill Creek	99%	0	7	34	89	129
Green Valley Creek	96%	0	16	7	58	81
Mill Creek	100%	0	7	13	46	66
Russian River at Duncans Mills	14%	NA	NA	337	488	825

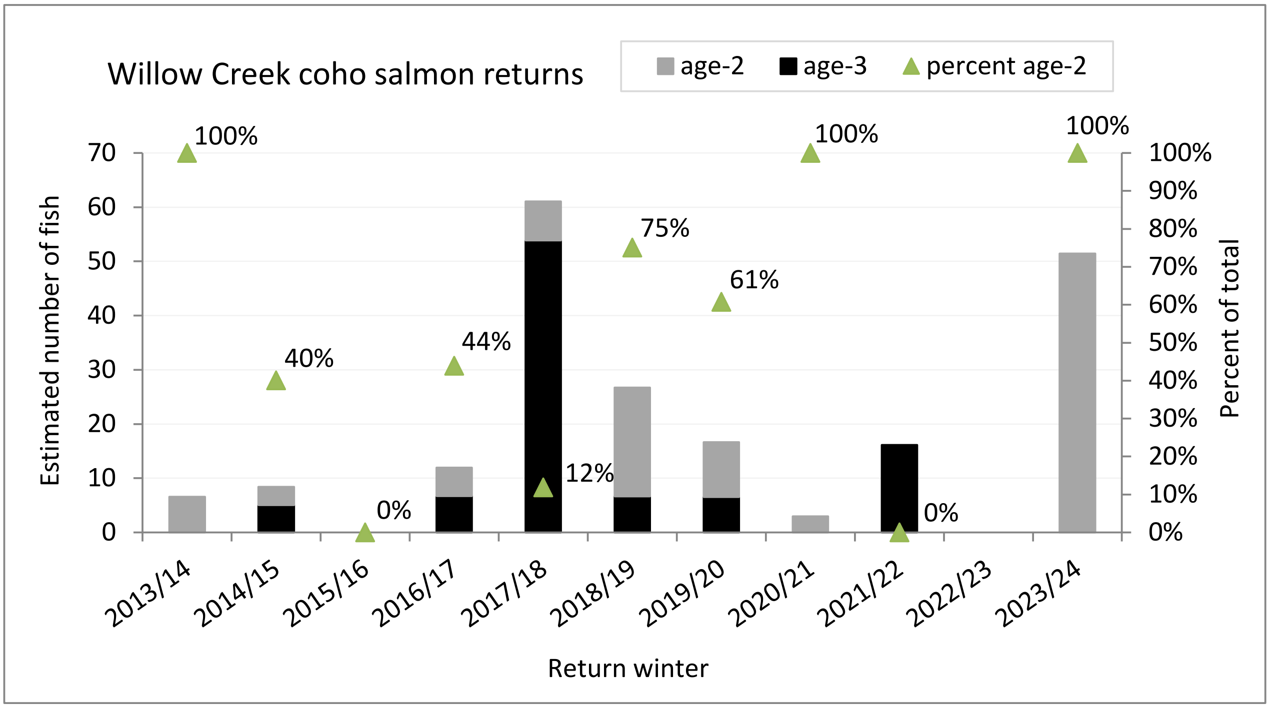


Figure 13. Estimated annual adult coho salmon returns to Willow Creek by age, return seasons 2013/14 – 2023/24. Note that estimates are based on returns to the upper antennas at river km 3.70.

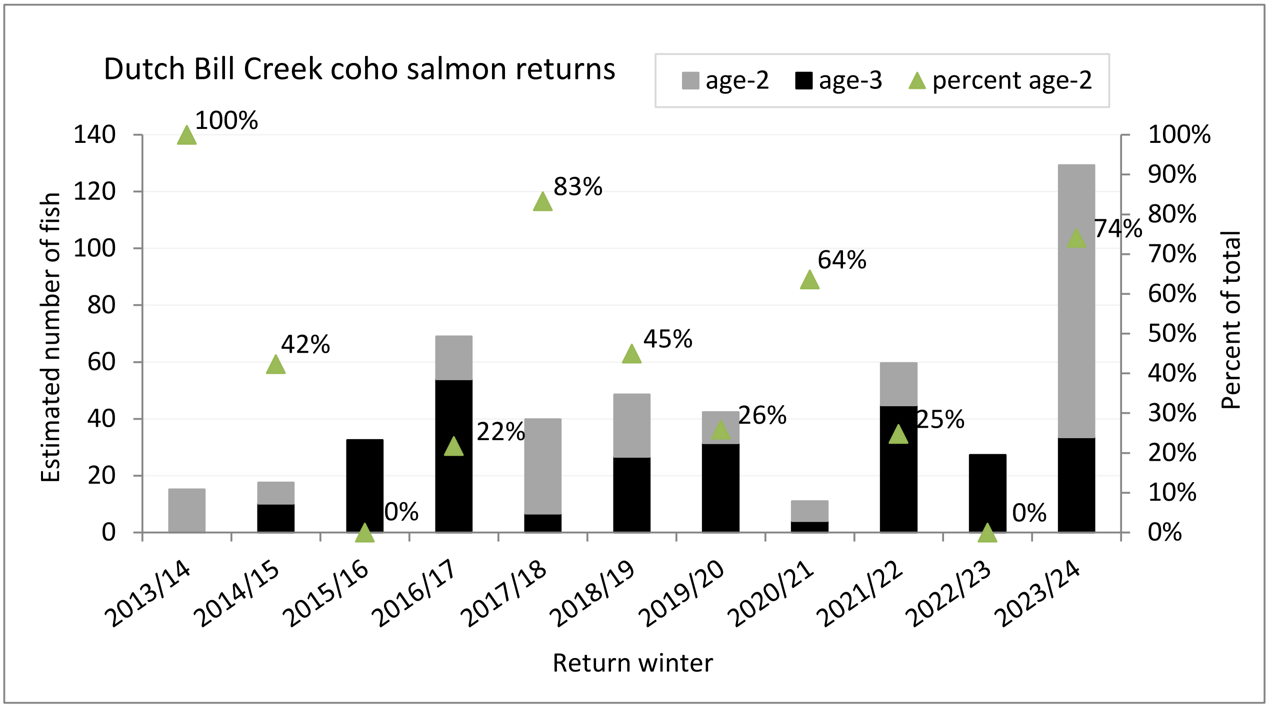


Figure 14. Estimated annual adult coho salmon returns to Dutch Bill Creek by age, return seasons 2013/14 – 2023/24.

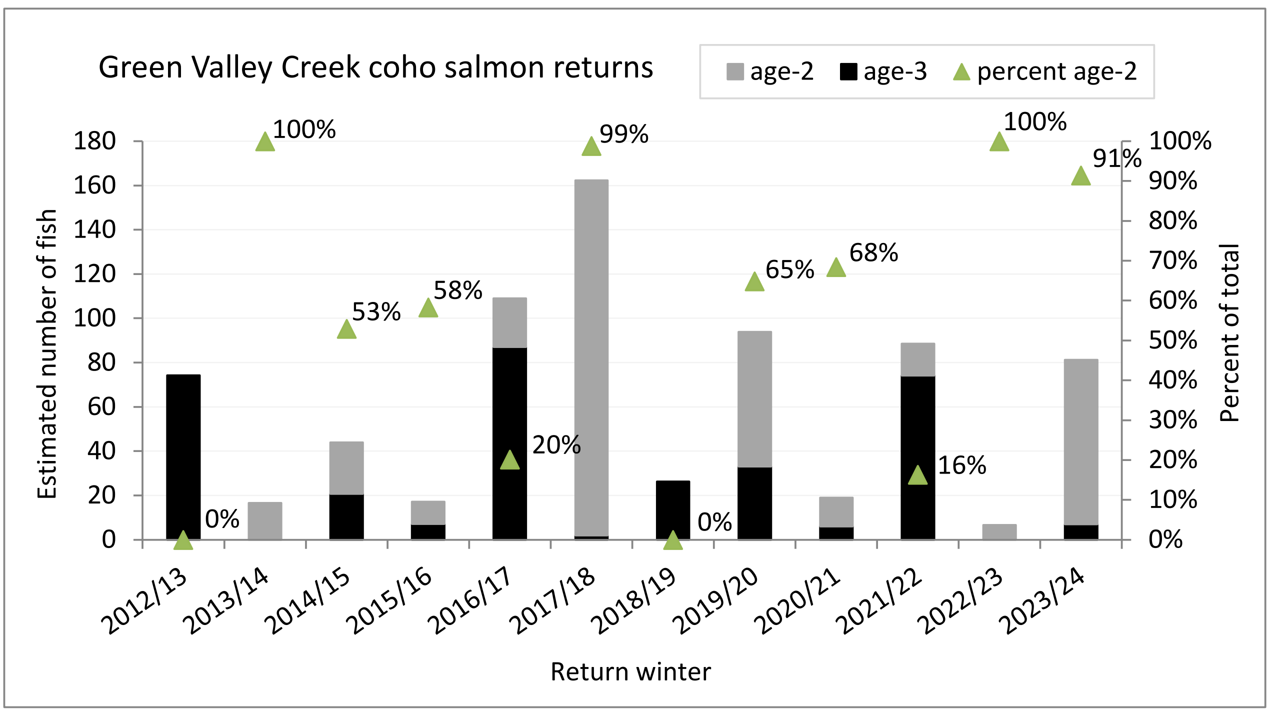


Figure 15. Estimated annual adult coho salmon returns to Green Valley Creek by age, return seasons 2012/13 – 2023/24.

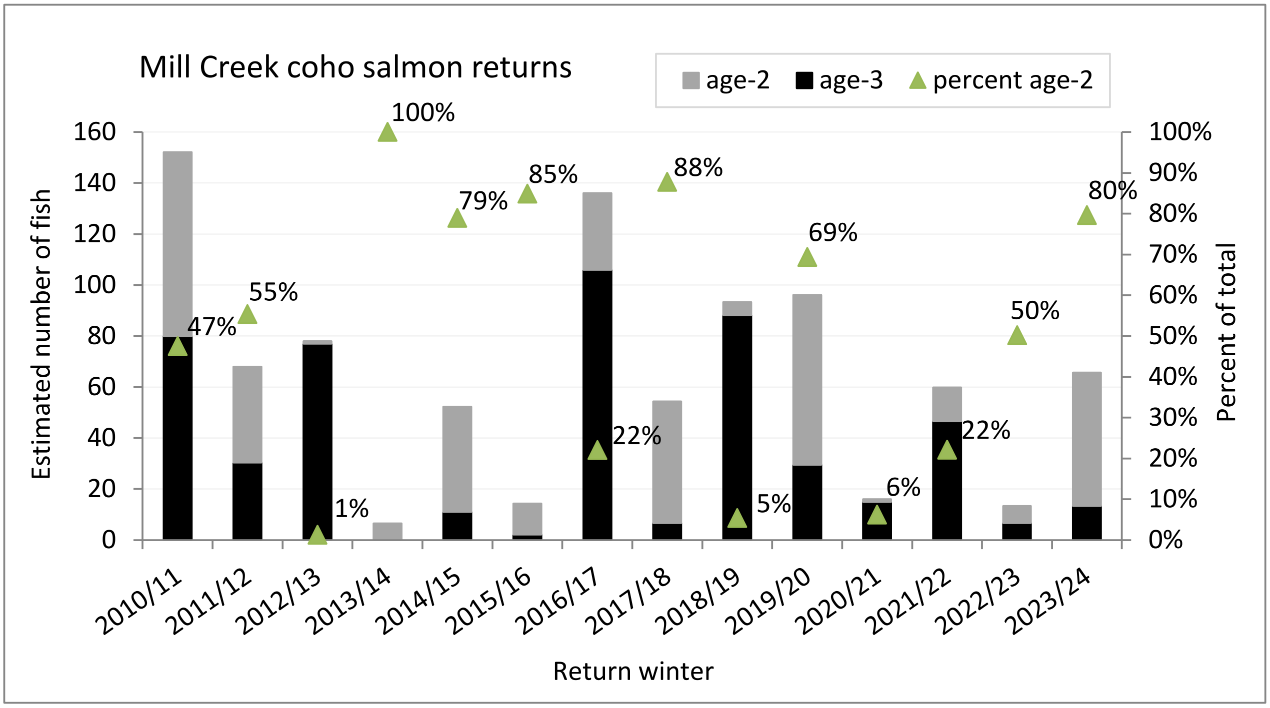


Figure 16. Estimated annual adult coho salmon returns to Mill Creek by age, return seasons 2010/11 – 2023/24.

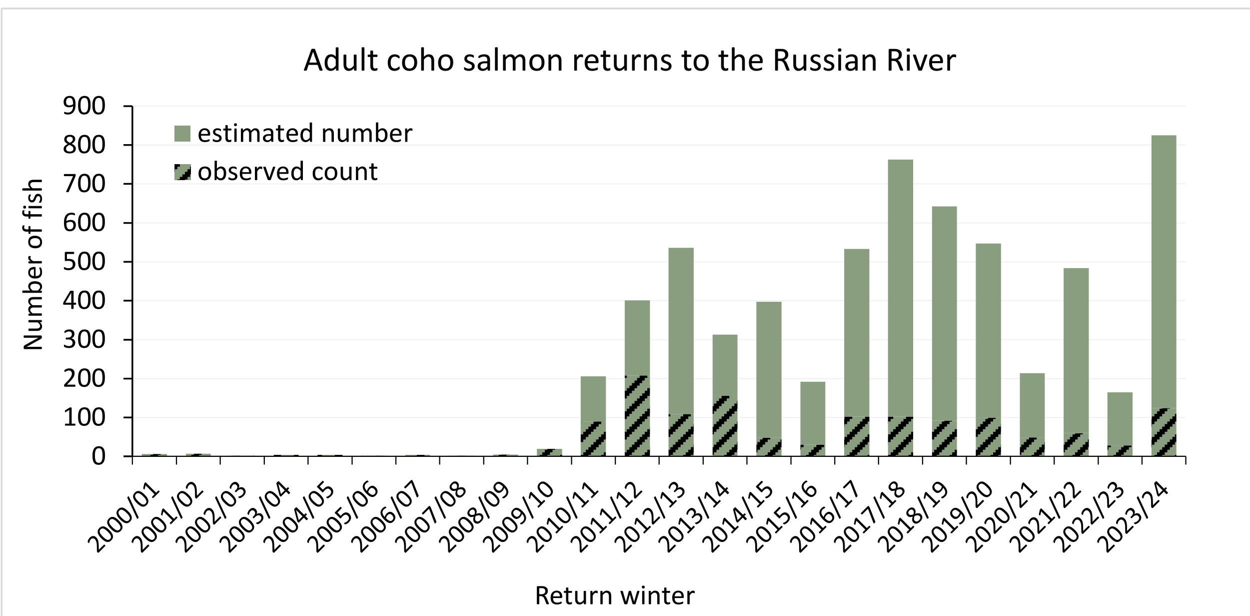


Figure 17. Estimated annual adult hatchery coho salmon returns to the Russian River, return winters 2000/01 through 2023/24. Note that methods for counting/estimating the number of returning adult coho salmon were not consistent among years; prior to 2009/10, spawner surveys were the primary method, from 2009/10 – 2011/12 methods included spawner surveys, video monitoring and PIT detection systems, and beginning in 2012/13, with the installation of the Duncans Mills antenna array, PIT detection systems were the primary method used.

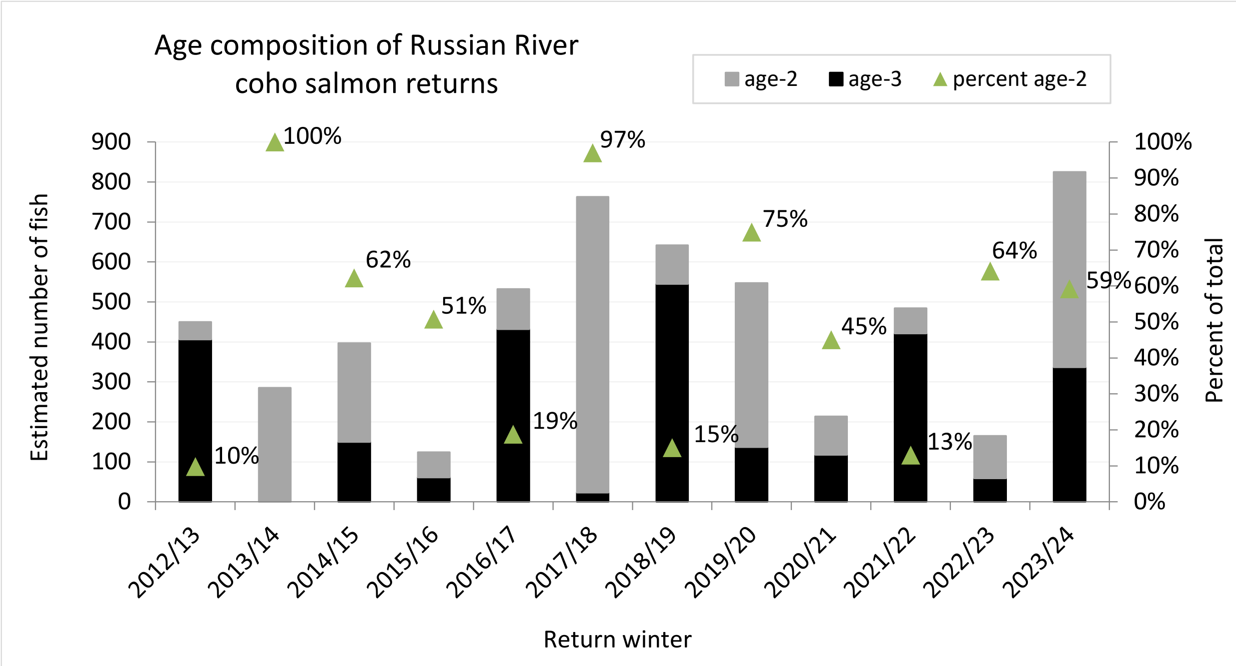


Figure 18. Estimated annual adult hatchery coho salmon returns to the Russian River by age, return seasons 2012/13-2023/24. Note that this figure includes only fish that we were able to age; therefore, totals will be less than adult return estimates shown in Figure 17.

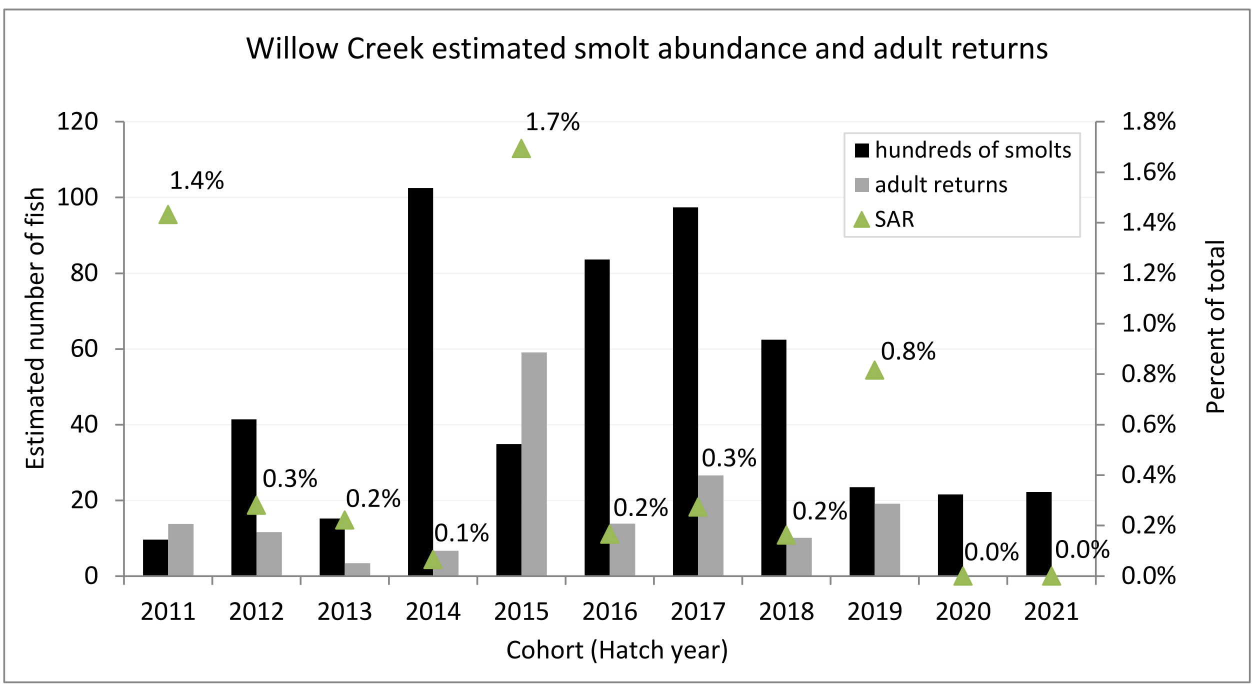


Figure 19. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Willow Creek, cohorts 2011-2021. Note that estimates are based on returns to the upper antennas at river km 3.70.

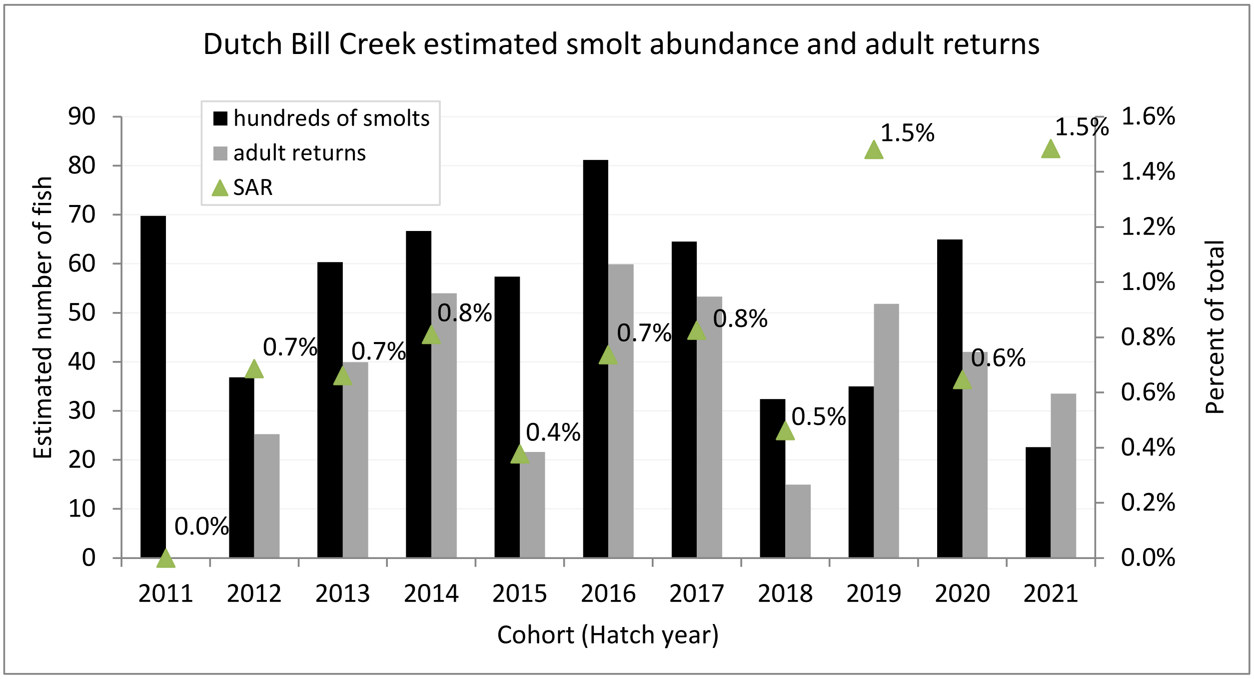


Figure 20. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Dutch Bill Creek, cohorts 2011-2021.

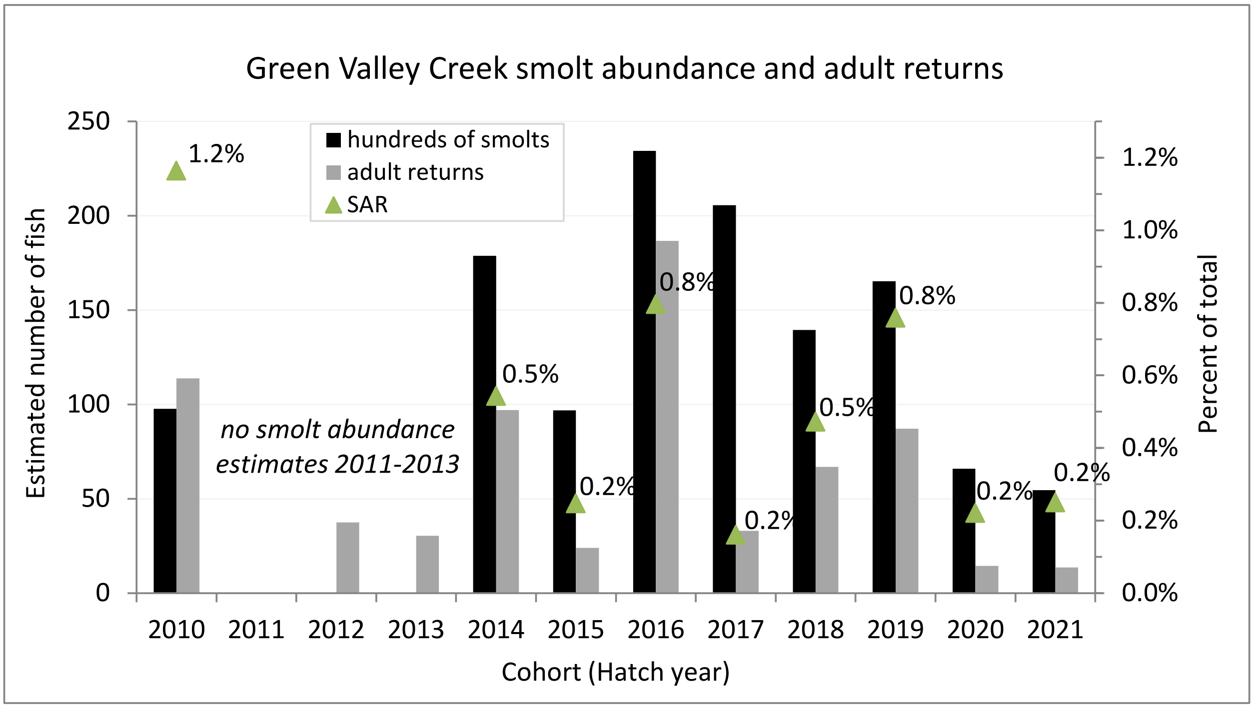


Figure 21. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Green Valley Creek, cohorts 2010-2021.

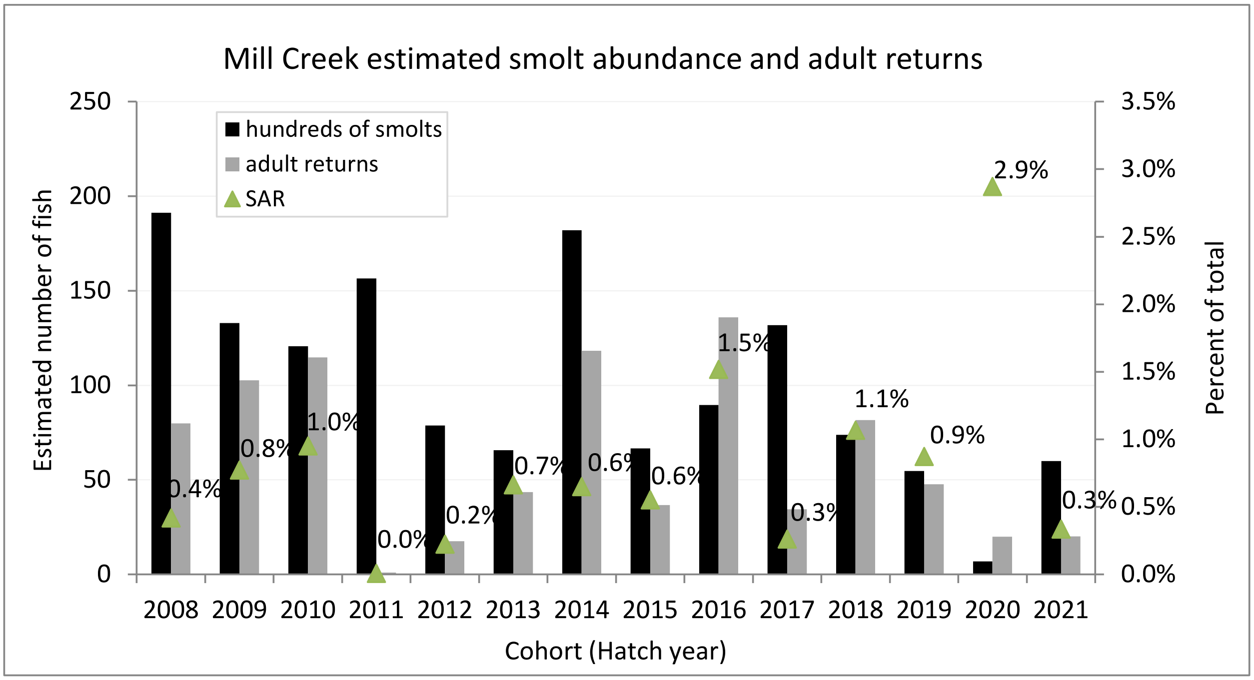


Figure 22. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Mill Creek, cohorts 2008-2021. Note that adult release fish returning to Mill Creek were excluded from SAR calculations.

Table 6. Smolt to adult return (SAR) ratios estimated for Willow, Dutch Bill, Green Valley, and Mill creeks, cohorts 2008 through 2021.

		Smolt to adult return (SAR) ratio			
Cohort (Hatch year)	**Age-3 return winter**	**Willow (River km 3.69)**	**Dutch Bill (River km 0.68)**	**Green Valley (River km 6.13)**	**Mill (River km 2.01)**
2008	2010/11	*NA*	*NA*	*NA*	0.4%
2009	2011/12	*NA*	*NA*	*NA*	0.8%
2010	2012/13	*NA*	0.2%	1.2%	1.0%
2011	2013/14	1.4%	0.0%	*NA*	0.0%
2012	2014/15	0.3%	0.7%	*NA*	0.2%
2013	2015/16	0.2%	0.7%	*NA*	0.7%
2014	2016/17	0.1%	0.8%	0.5%	0.6%
2015	2017/18	1.7%	0.4%	0.2%	0.6%
2016	2018/19	0.2%	0.7%	0.8%	1.5%
2017	2019/20	0.3%	0.8%	0.2%	0.3%
2018	2020/21	0.2%	0.5%	0.5%	1.1%
2019	2021/22	0.8%	1.5%	0.8%	0.9%
2020	2022/23	0.0%	0.6%	0.2%	2.9%
2021	2023/24	0.0%	1.5%	0.2%	0.3%
	Average	**0.5%**	**0.6%**	**0.5%**	**0.8%**

3. Spawner surveys

3.1. Goals and objectives

The overarching goal of spawner surveys in the Russian River watershed during the winter of 2023/24 was to document the occurrence of coho salmon and steelhead spawning. Broodstock Program monitoring objectives were to estimate the spatial distribution and abundance of coho salmon redds in LCM subwatersheds (Willow, Dutch Bill, Green Valley, and Mill). CMP objectives included estimation of the spatial distribution and abundance of coho salmon and steelhead redds in LCM subwatersheds and in a random, spatially-balanced sample of streams in the Russian River watershed containing coho salmon and steelhead habitat (hereafter, basinwide monitoring). Surveys were conducted using standardized CMP methods (Adams et al. 2011; Sonoma County Water Agency and California Sea Grant 2015) to ensure that data collected for different projects was compatible and could be summarized together.

3.2. Methods

3.2.1. Sampling framework and survey reaches

For stream-specific estimates of redd abundance, we surveyed all accessible adult salmonid spawning reaches of Willow, Dutch Bill, Green Valley, and Mill creeks (LCMs). For basinwide estimates, we used a generalized random tessellation stratified (GRTS) approach with soft stratification to survey a random, spatially-balanced selection of reaches that contain coho salmon habitat (Figure 23) within the Russian River sample frame (a sample frame of stream reaches identified by the Russian River CMP Technical Advisory Committee[1] as having coho salmon, steelhead, and/or Chinook salmon habitat). Although one of the goals of CMP basinwide monitoring is to survey a sample of reaches that represents the full extent of steelhead habitat throughout the Russian River watershed (including streams in the upper basin that do not contain coho salmon habitat), sampling in most winters (including 2023/24) was confined to reaches that contain both coho salmon and steelhead habitat (i.e., the lower part of the basin; e.g., Figure 23). Resulting basinwide steelhead redd estimates in this report therefore reflect trends in steelhead abundance only in the part of the watershed that contains coho salmon habitat.

3.2.2. Field methods

Survey methodology for collecting information on spawning salmonids in the Russian River watershed was adapted from the Coastal Northern California Salmonid Spawning Survey Protocol (Gallagher and Knechtle 2005). We attempted to survey each reach at an interval of 10-14 days throughout the spawning season. Two person crews hiked reaches in a downstream to upstream direction looking for adult salmon (live or carcasses, e.g. Figure 24) and redds. Redds were identified to species based on presence of identifiable adult fish or from observed redd morphology. Measurements were taken on all redds including pot length, width and depth; tailspill length, width and depth; and substrate size. In response to widespread stream drying observed in the 2020/21 and 2021/22 seasons, we also began categorically documenting the surface flow condition over observed redds (fully wet, partially dry or fully dry). All observed salmonids were identified to species (coho salmon, Chinook salmon, and steelhead), or as unknown salmonids if we could not identify the redd to species. Species, certainty of species identification, life stage, sex, certainty of sex, and fork length were recorded for all observed

[1] A body of fisheries experts, including members of the Statewide CMP Technical Team, tasked with providing guidance and technical advice related to CMP implementation in the Russian River.

fish. When a carcass was encountered, scans for coded wire tags (CWT) and PIT tags were performed. A genetics sample, scale sample, and the head (for otolith and CWT extraction) were also retrieved from all salmonid carcasses. Geospatial coordinates were recorded for all redd and fish observations. Trimble TDC600 tablets were used for data entry and, upon returning from the field, data files were downloaded, error checked, and transferred into a SQL database.

3.2.3. Redd and adult return estimates

For redds of unknown species or redds with low certainty of identification, redd measurement data was used to estimate redd species following the Gallagher and Gallagher (2005) redd species determination method. In instances where we were unable to collect redd measurements, we used a nonparametric K-nearest neighbor algorithm (KNN, (Ricker et al. 2014a)) to estimate species. The estimated number of unique redds was then summed for each surveyed reach. To account for redds missed by observers due to survey timing, the number of redds observed within each reach was expanded based upon the average observational “life span” of redds observed in that same reach (Ricker et al. 2014b).

For LCM subwatershed estimates we conducted census surveys; therefore, redd estimates from all reaches within each subwatershed were summed. An exception was the Mill Creek subwatershed where the redd estimate was expanded to account for sections of stream that we were unable to sample due to lack of landowner access. The expansion in Mill Creek was made by calculating an average redd per stream length in surveyed reaches and multiplying that ratio by the length of stream that was not surveyed. This total was then added to the sum of redds in the surveyed reaches of Mill Creek. For basinwide estimates, we calculated an average redd density per reach and multiplied that density by the total number of adult coho salmon reaches within the Russian River sample frame that contained coho salmon and steelhead habitat.

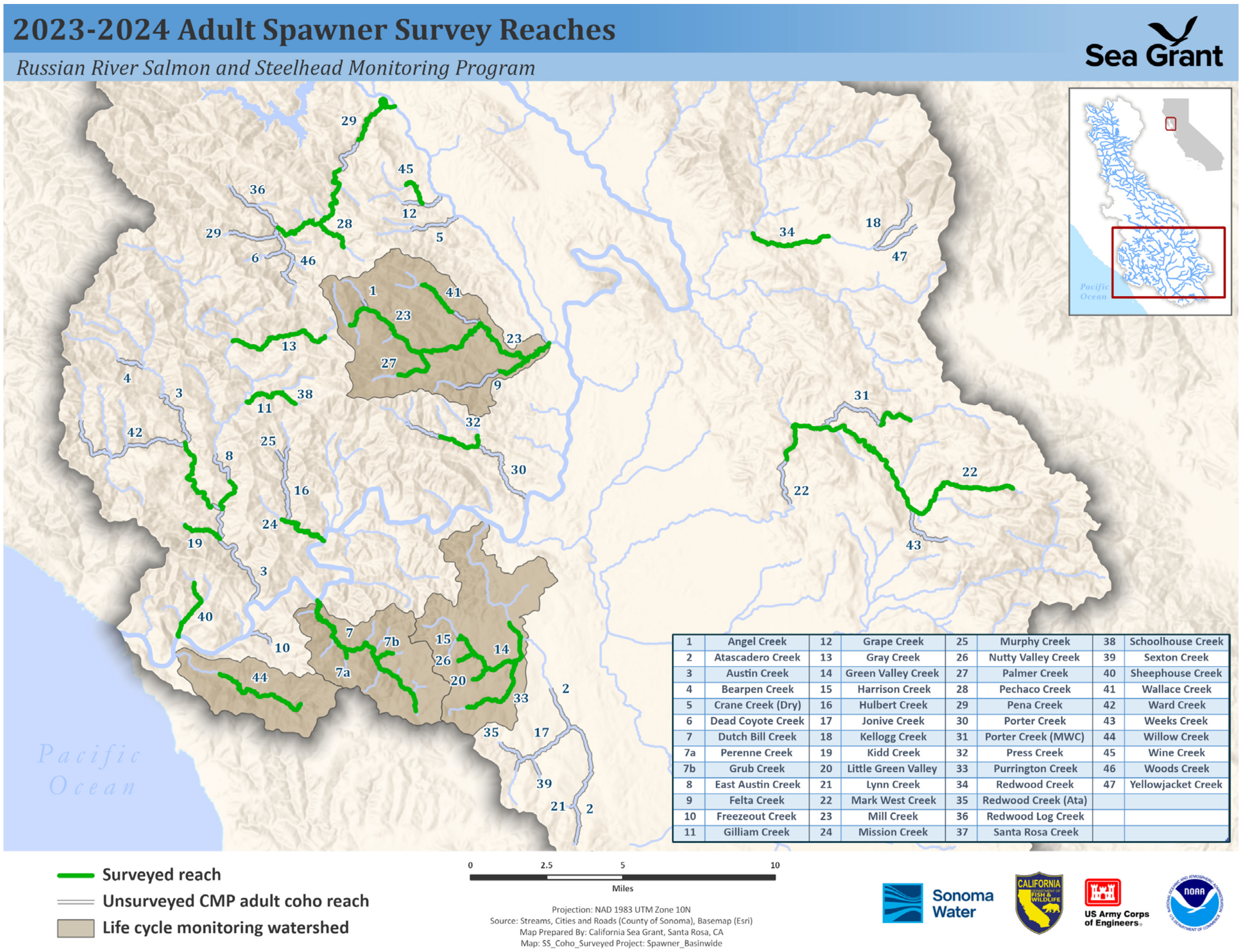


Figure 23. Intensively monitored life cycle monitoring (LCM) subwatersheds and 2023/2024 spawner survey reaches sampled in the Russian River watershed that contain spawning habitat for both coho salmon and steelhead.

Figure 24. Adult coho salmon pair observed on Austin Creek.

3.3. Results

3.3.1. Redd estimates and spawning distribution

We began surveys on December 11, 2023, following the first rain event of the season, and continued surveying through April 29, 2024. Due to persistently high (Figure 4) and turbid flow conditions during the winter of 2023/24, we were unable to consistently maintain our goal of conducting surveys within each reach on a 10-14 day cycle, and this resulted in fewer surveys than in previous years (64 survey days as compared to the 10-year average of 76 survey days since 2014/15, Figure 25). Overall, we conducted a total of 337 surveys on 49 reaches in 30 streams within the Russian River basin. A total of 138 salmonid redds were observed: 28 coho salmon redds, 81 steelhead redds, 2 Chinook salmon redds, and 27 redds of unknown salmonid species origin (Table 7). Coho salmon redds were observed in 15 of the 30 streams surveyed (50%), and steelhead redds were observed in 15 of the 30 streams surveyed (50%) (Table 7). Of the 28 coho redds observed, 46% were observed in Mill (8) and Pena (5) subwatersheds, and of the 81 steelhead redds observed, 64% were observed in Mill (18) and Pena (33) subwatersheds. In addition to redd presence, there were 5 streams where adult coho were observed but no coho redds and 1 stream where adult steelhead were observed but no steelhead redds. Overall, adult coho and/or coho redds were observed in a total of 20 streams (Figure 26) and adult steelhead and/or steelhead redds were observed in a total of 16 streams (Figure 27).

We first observed coho salmon redds in the watershed on December 20 and we continued to observe new coho redds into late March (Figure 28). Coho salmon spawn timing peaked in early January, though redds may have been missed during a 5-day gap in surveys due to high flows in late December. Steelhead redd observations began in early January and extended into late April, peaking in mid-March which was later than the average timing of previous years (Figure 29). However, it is possible that steelhead redds were missed due to gaps in surveys in February (Figure 25). The number of observed redds per survey for coho salmon was 0.11 and the number of observed redds per survey for steelhead was 0.24 (Figure 30, Figure 31).

Coho salmon redd estimates in LCM subwatersheds ranged from 0 in Willow Creek to 14 in Mill Creek (Figure 32), and steelhead redd estimates ranged from 0 in Willow Creek to 49 in Mill Creek (Figure 33). When compared with previous years (and similar to the 2022/23 spawner season), coho salmon and steelhead redd estimates were extremely low in Willow, Dutch Bill, and Green Valley creeks, and similar in Mill Creek. At the basinwide scale, redd estimates for coho salmon were the lowest on record (67, 95% CI: ±22) and steelhead redd estimates (242, 95% CI: ±90) were the third lowest on record since basinwide surveys began in 2014/15 (Figure 34).

Only three coho salmon carcasses were recovered in LCM subwatersheds during the winter of 2023/24: one in Willow Creek; one in Purrington Creek (Green Valley subwatershed); one in Mill Creek. An additional coho carcass was recovered from Austin Creek. All four carcasses were scanned for CWT and one of those had a CWT (the Willow Creek carcass).

The distribution of salmonid redds in the four LCM subwatersheds varied by stream (Figure 35 - Figure 38). No zero redds observed in Willow Creek. In Dutch Bill Creek, two coho redds were observed in the middle reach and one coho redd was observed in Perenne Creek (Figure 36). Three steelhead redds were observed in lower-middle reaches of Dutch Bill Creek. In Green Valley Creek, we observed two coho redds upstream of the confluence with Little Green Valley Creek, two redds in or near the confluence with Harrison Creek, and two redds in Purrington Creek (Figure 37). One steelhead redd was observed in Harrison Creek. In Mill Creek, we observed multiple coho redds in the mainstem of Mill from the confluence with Felta Creek upstream to the confluence with Palmer Creek, as well as in both Felta and Palmer creeks (Figure 38). The distribution of steelhead redds in the Mill subwatershed was similar to that of coho, though concentrations of steelhead redds were higher between the confluences of Felta and Wallace creeks and also included a redd in Wallace Creek.

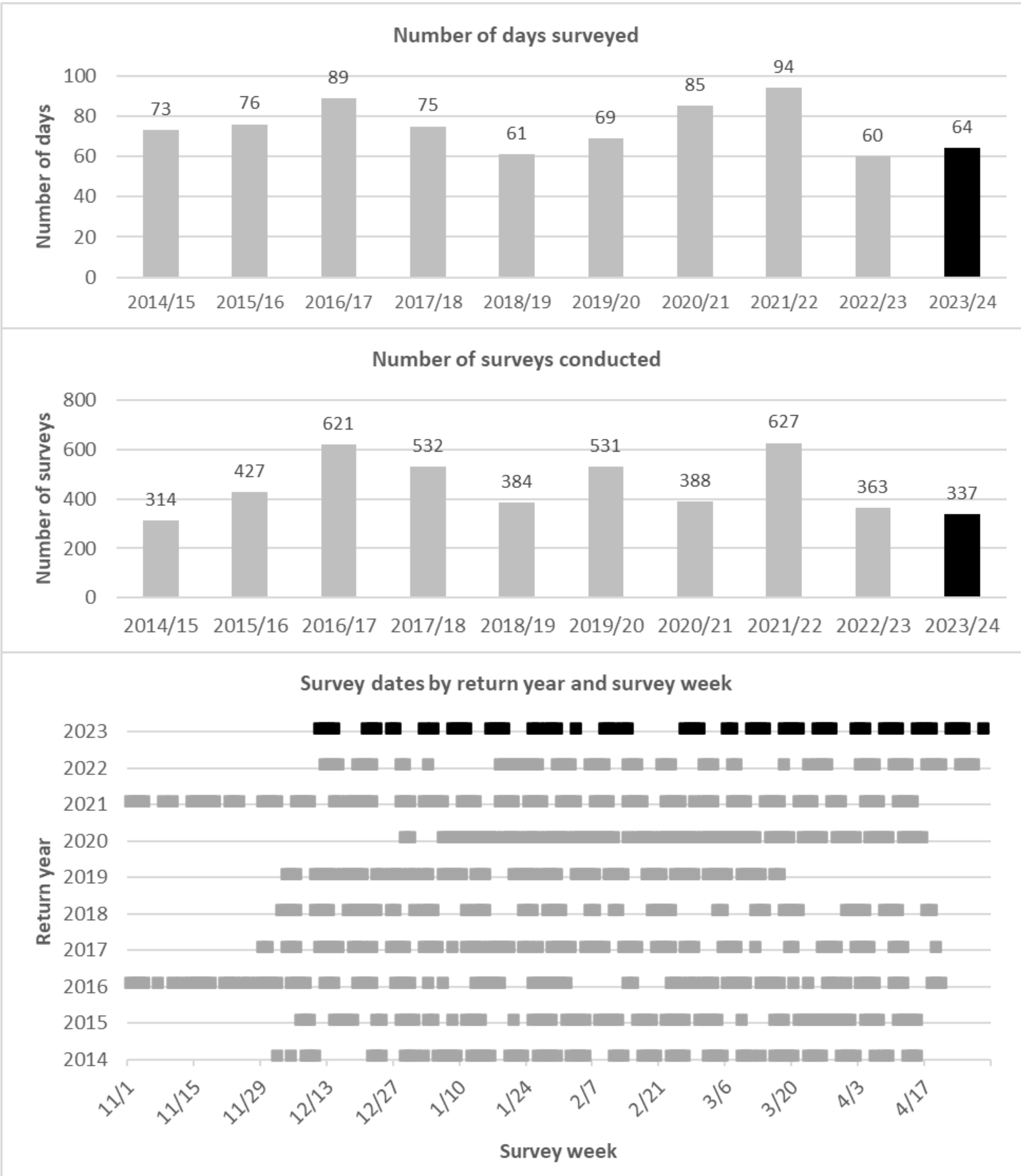


Figure 25. Historical spawner survey effort in California Monitoring Plan streams. Note, this does not include surveys that were conducted in steelhead-only reaches.

Table 7. Number of salmonid redds (and species percentage among survey streams) observed by species during winter 2023/24 in Russian River tributaries.

Tributary	Length surveyed (km)	Coho salmon	Steelhead	Chinook salmon	Salmonid sp	Total
Austin Creek	5.0	1 (3.6%)	0 (0%)	0 (0%)	0 (0%)	1 (0.7%)
Dutch Bill Creek	9.7	2 (7.1%)	3 (3.7%)	0 (0%)	0 (0%)	5 (3.6%)
East Austin Creek	2.1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Felta Creek	2.0	2 (7.1%)	1 (1.2%)	0 (0%)	1 (3.7%)	4 (2.9%)
Gilliam Creek	2.6	1 (3.6%)	3 (3.7%)	0 (0%)	1 (3.7%)	5 (3.6%)
Gray Creek	6.3	1 (3.6%)	3 (3.7%)	0 (0%)	1 (3.7%)	5 (3.6%)
Green Valley Creek	7.0	3 (10.7%)	0 (0%)	0 (0%)	3 (11.1%)	6 (4.3%)
Grub Creek	1.1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Harrison Creek	0.2	1 (3.6%)	1 (1.2%)	0 (0%)	1 (3.7%)	3 (2.2%)
Hulbert Creek	3.2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Kidd Creek	2.5	0 (0%)	2 (2.5%)	0 (0%)	0 (0%)	2 (1.4%)
Little Green Valley Creek	1.2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mark West Creek	19.2	1 (3.6%)	9 (11.1%)	0 (0%)	3 (11.1%)	13 (9.4%)
Mill Creek	16.6	5 (17.9%)	14 (17.3%)	0 (0%)	3 (11.1%)	22 (15.9%)
Mission Creek	0.4	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Nutty Valley Creek	1.2	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Palmer Creek	2.9	1 (3.6%)	2 (2.5%)	0 (0%)	1 (3.7%)	4 (2.9%)
Pechaco Creek	2.3	1 (3.6%)	2 (2.5%)	0 (0%)	0 (0%)	3 (2.2%)
Pena Creek	11.8	4 (14.3%)	31 (38.3%)	2 (100%)	10 (37.0%)	47 (34.1%)
Perenne Creek	0.5	1 (3.6%)	0 (0%)	0 (0%)	0 (0%)	1 (0.7%)
Porter Creek	2.3	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Porter Creek (MWC)	2.4	0 (0%)	1 (1.2%)	0 (0%)	0 (0%)	1 (0.7%)
Press Creek	0.6	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Purrington Creek	4.8	2 (7.1%)	0 (0%)	0 (0%)	0 (0%)	2 (1.4%)
Redwood Creek	4.8	2 (7.1%)	7 (8.6%)	0 (0%)	1 (3.7%)	10 (7.2%)
Schoolhouse Creek	1.1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Sheephouse Creek	3.7	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Wallace Creek	2.5	0 (0%)	1 (1.2%)	0 (0%)	0 (0%)	1 (0.7%)
Willow Creek	6.0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Wine Creek	1.8	0 (0%)	1 (1.2%)	0 (0%)	2 (7.4%)	3 (2.2%)
Total	**127.6**	**28 (100%)**	**81 (100%)**	**2 (100%)**	**27 (100%)**	**138 (100%)**

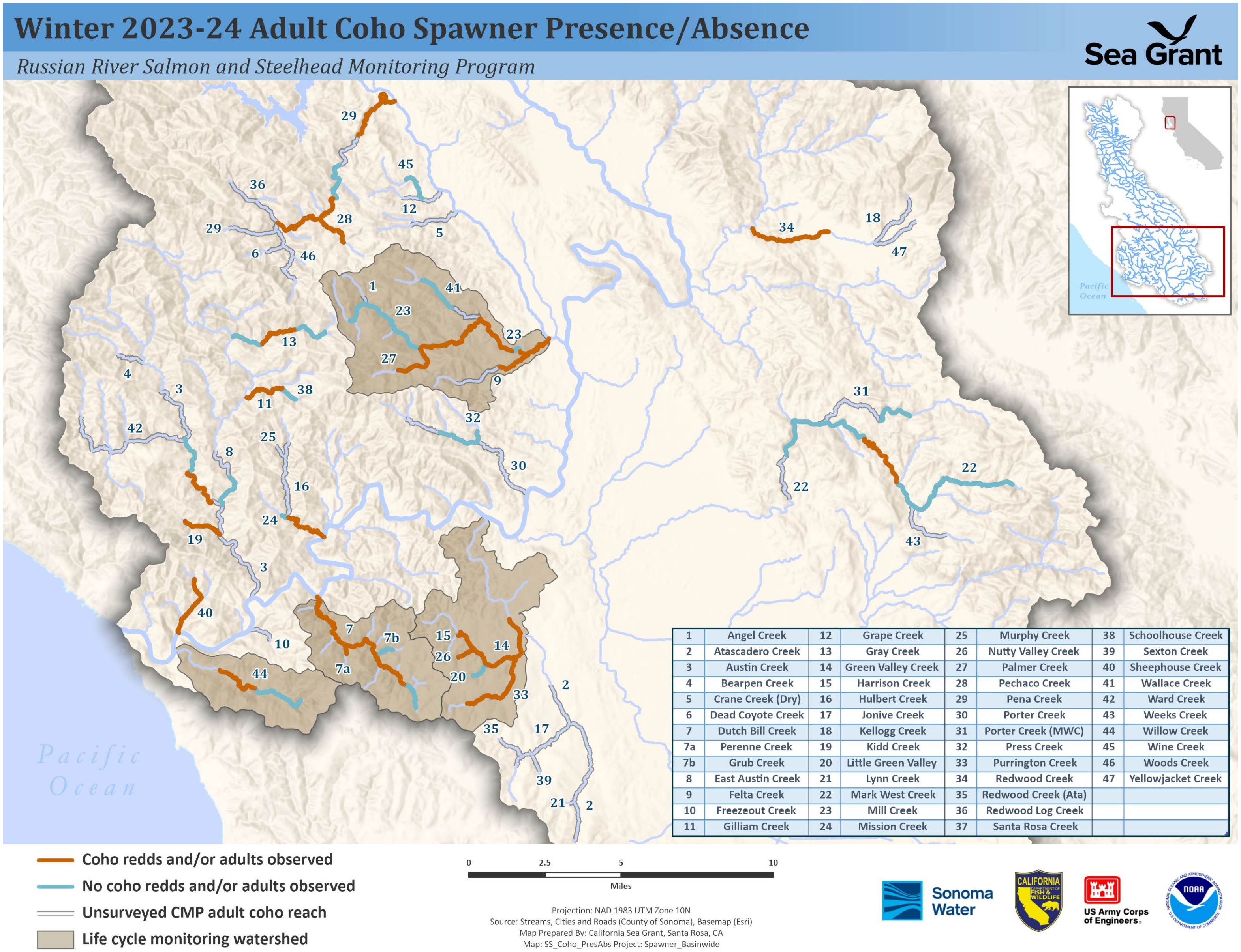


Figure 26. Coho salmon redd and/or adult presence or absence, winter 2023/24.

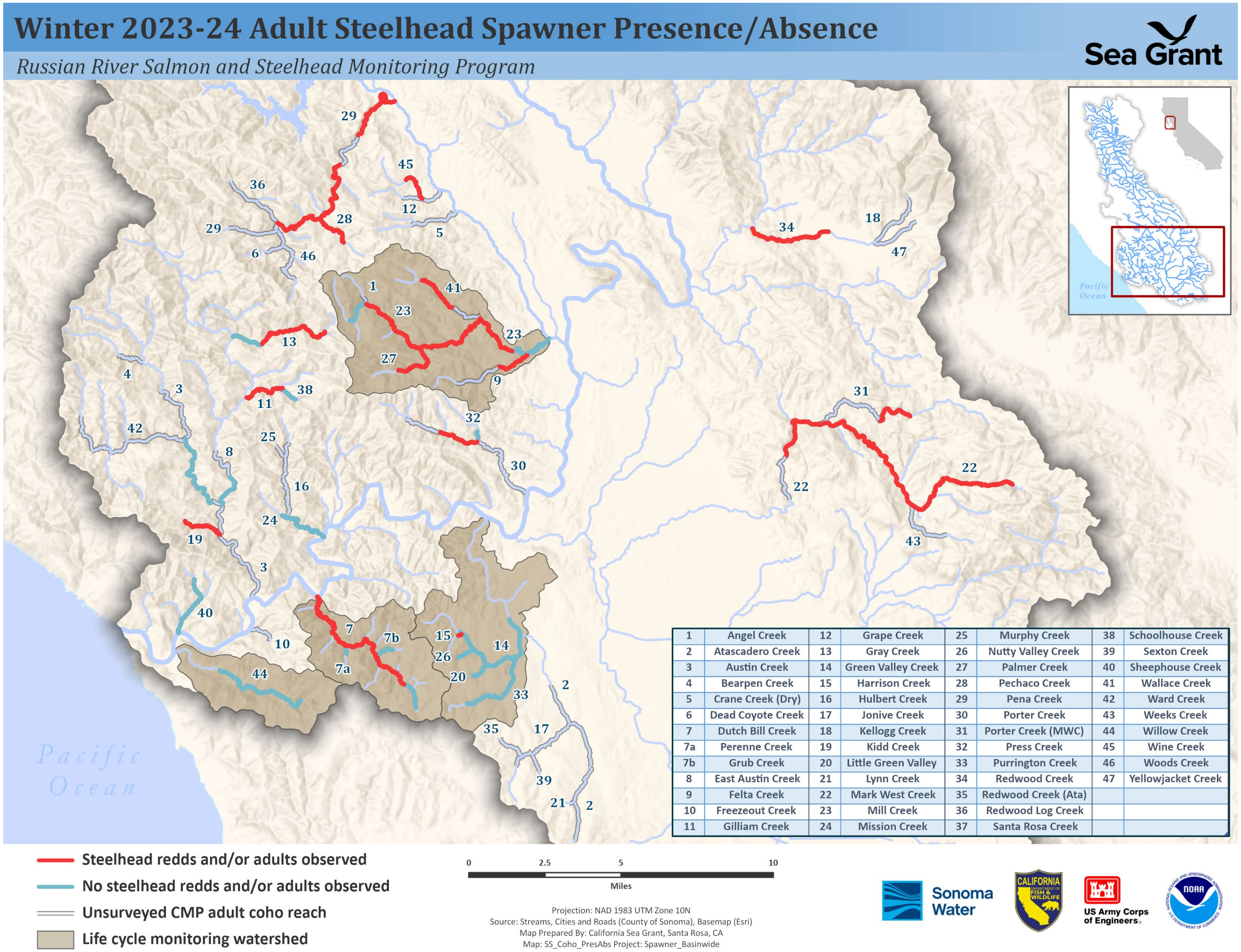


Figure 27. Steelhead redd and/or adult presence or absence, winter 2023/24.

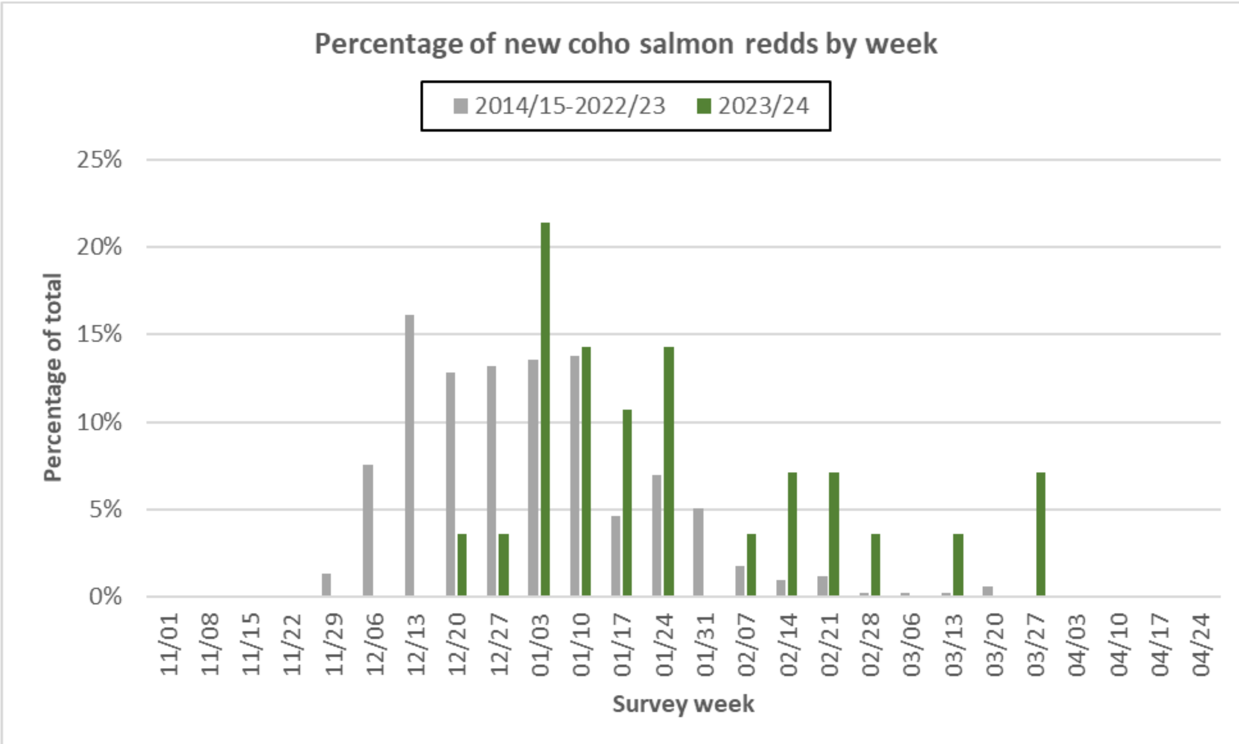


Figure 28. Number of new coho salmon redds observed each week in Russian River California Monitoring Plan survey streams, winter 2023/24 in comparison to long-term average.

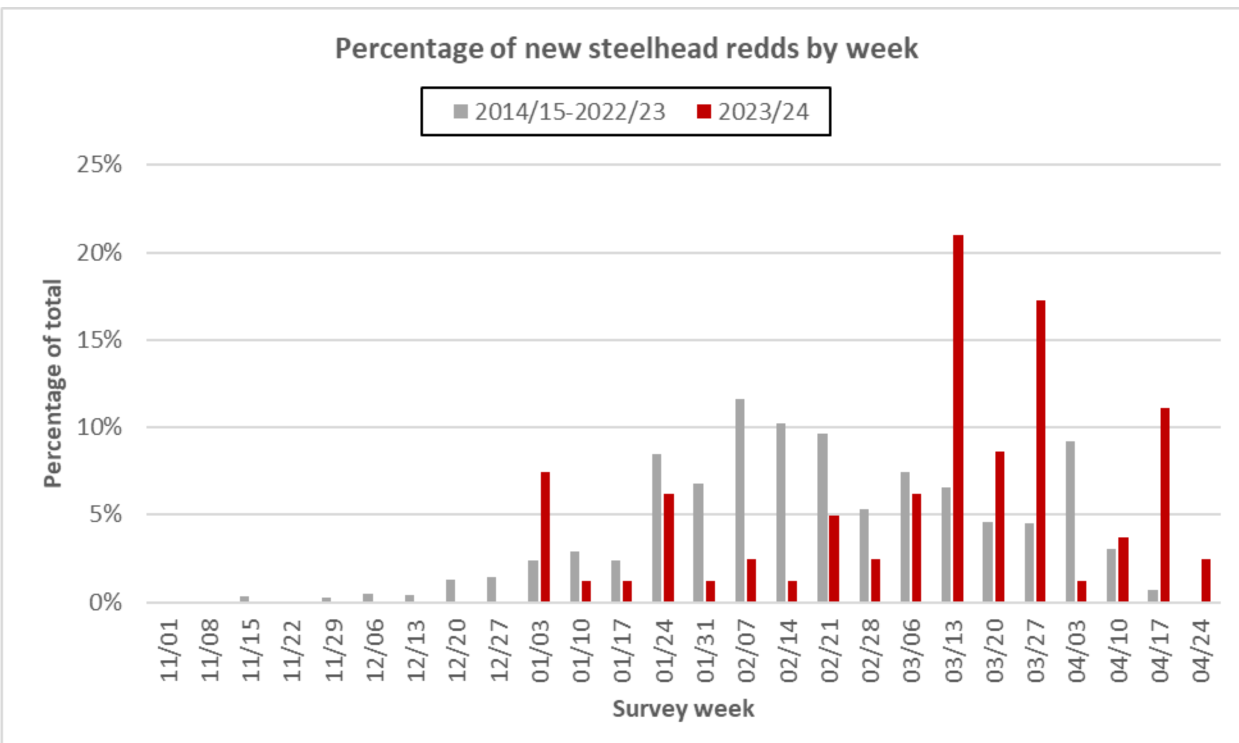


Figure 29. Number of new steelhead redds observed each week in Russian River California Monitoring Plan survey streams, winter 2023/24 in comparison to long-term average.

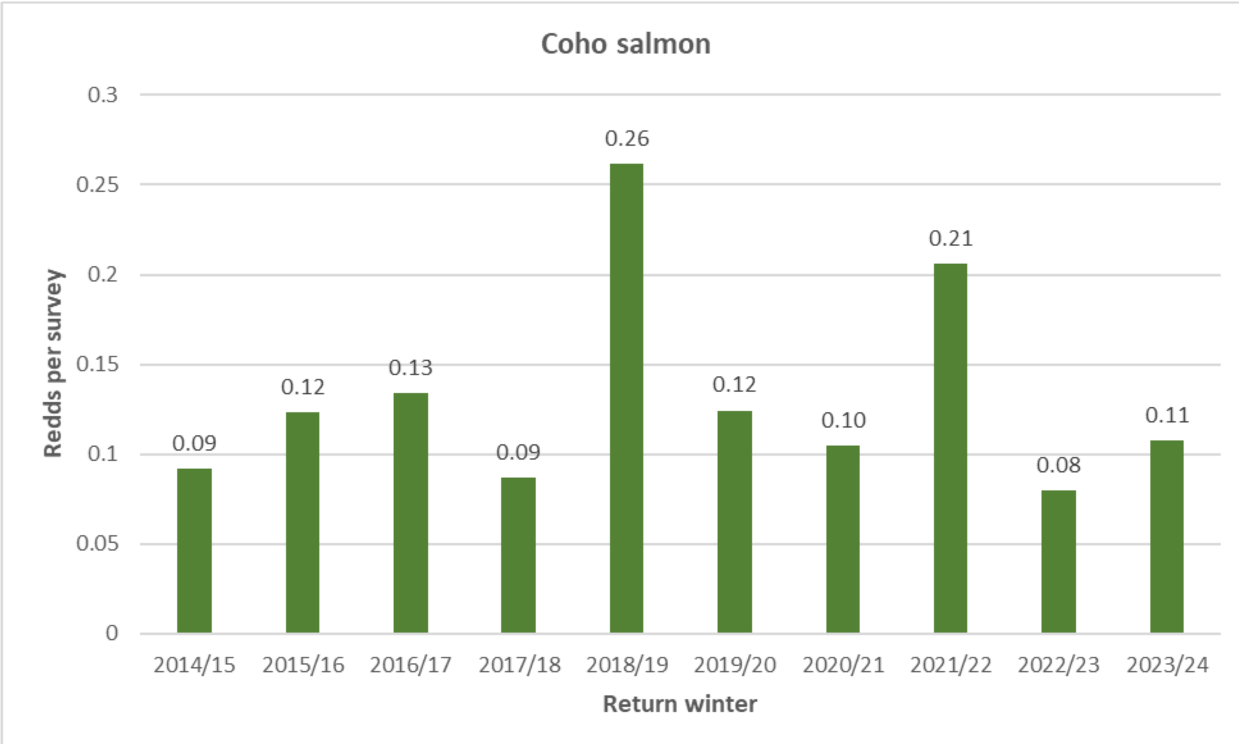


Figure 30. New coho salmon redds observed per survey in Russian River California Monitoring Plan survey streams, winter 2023/24. Note, the period covered was November 1-March 31.

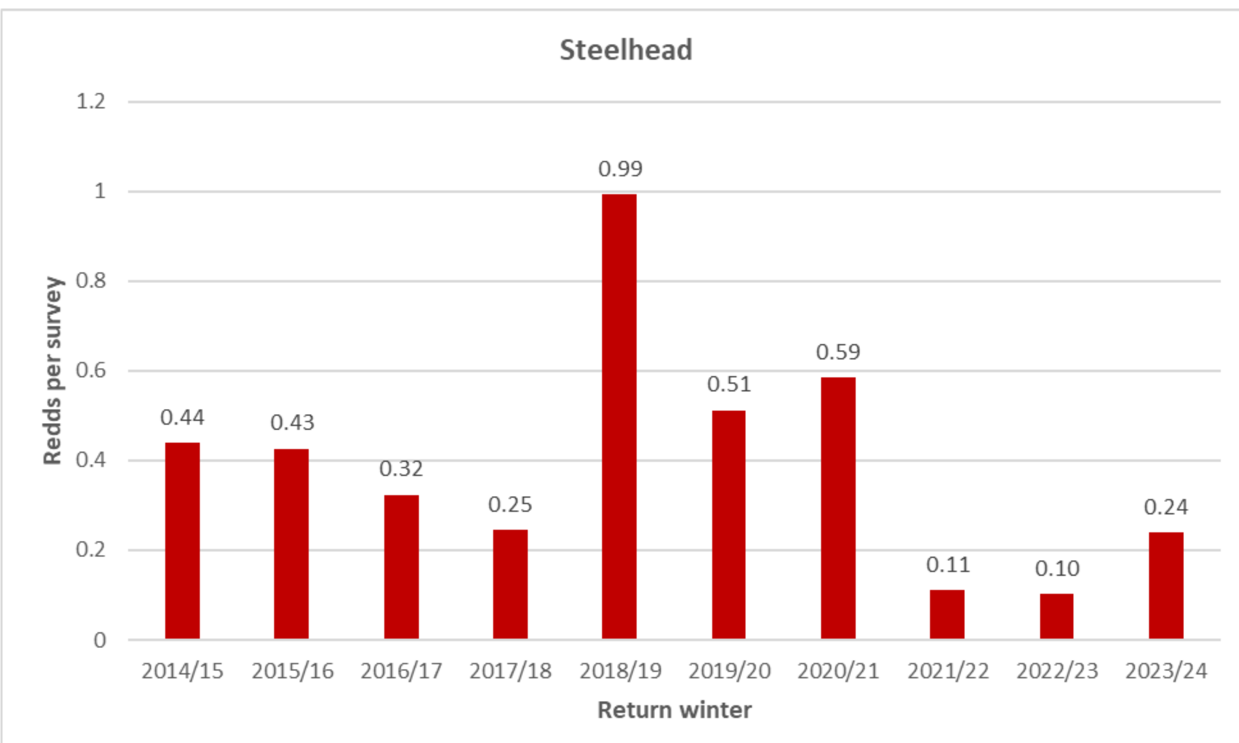
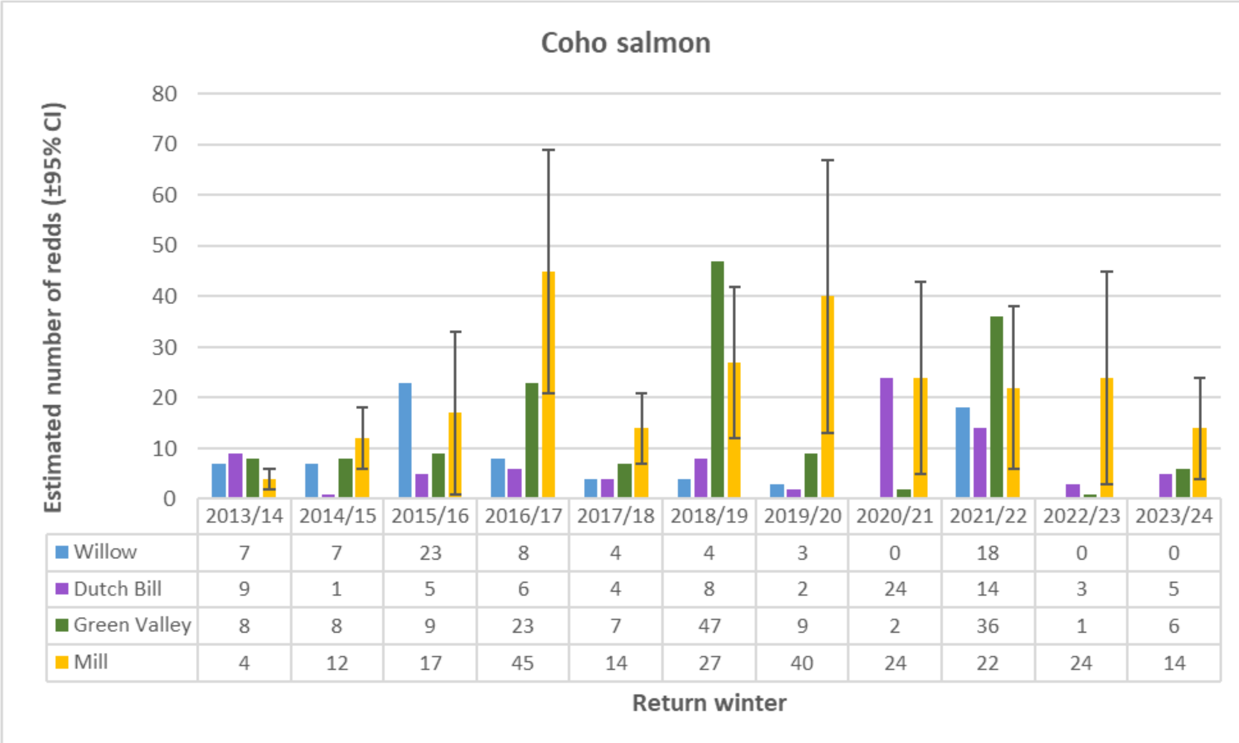
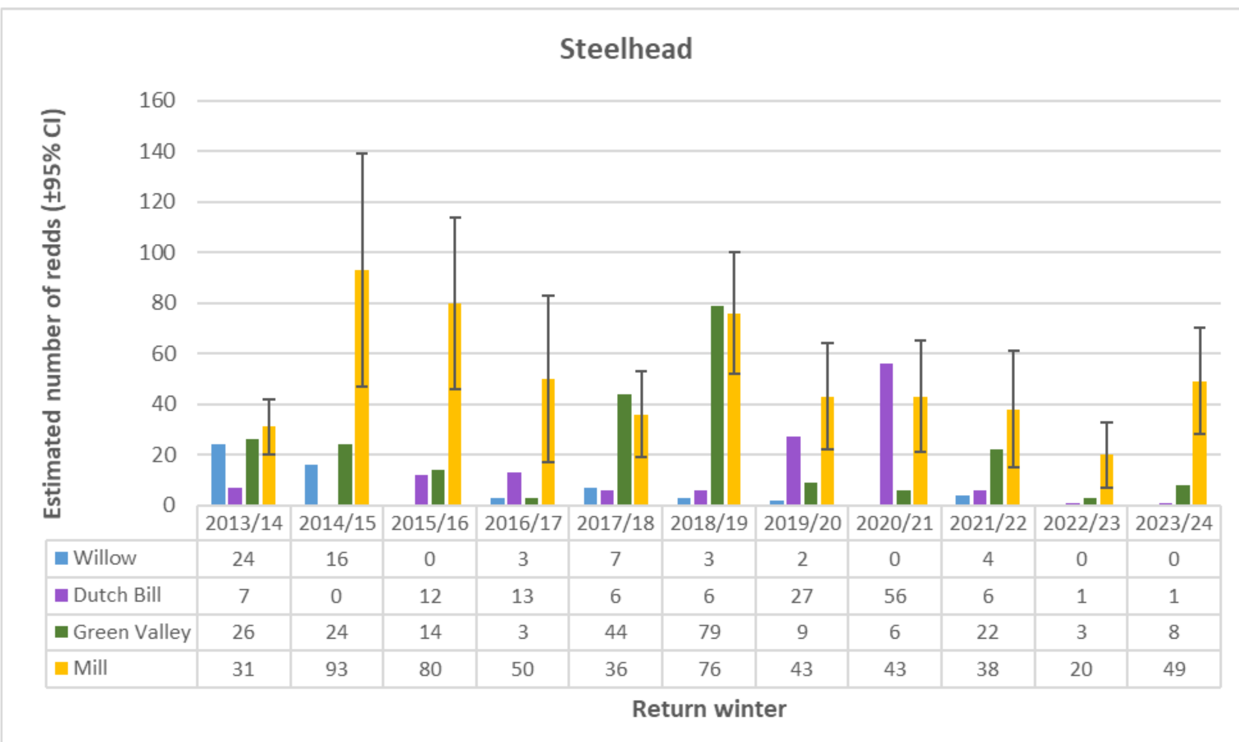


Figure 31. New steelhead redds observed per survey in Russian River California Monitoring Plan survey streams (coho stratum only), winter 2023/24. Note, the period covered is November 1-mid to end of April.



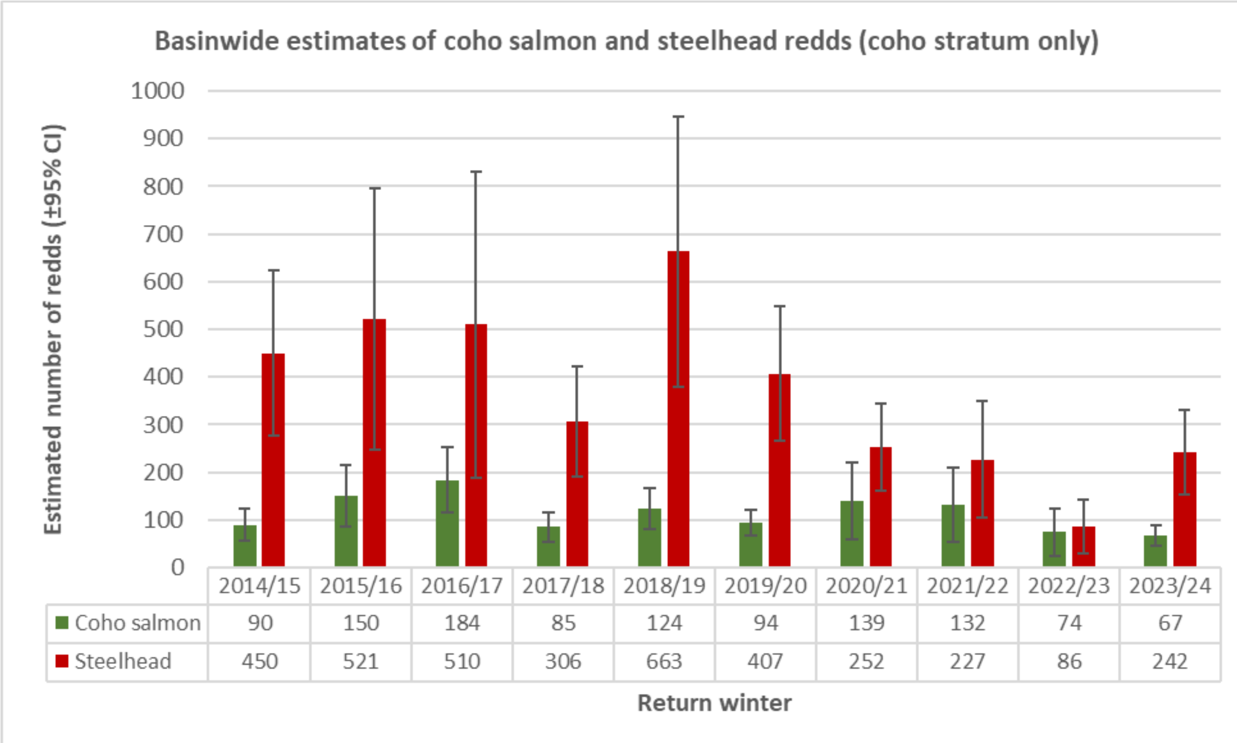
	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Willow	7	7	23	8	4	4	3	0	18	0	0
Dutch Bill	9	1	5	6	4	8	2	24	14	3	5
Green Valley	8	8	9	23	7	47	9	2	36	1	6
Mill	4	12	17	45	14	27	40	24	22	24	14

Figure 32. Estimated coho salmon redds in LCM subwatersheds, return winters 2013/14 through 2023/24. Note that Mill subwatershed has 95% CI because of incomplete coverage due to lack of landowner access.



	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Willow	24	16	0	3	7	3	2	0	4	0	0
Dutch Bill	7	0	12	13	6	6	27	56	6	1	1
Green Valley	26	24	14	3	44	79	9	6	22	3	8
Mill	31	93	80	50	36	76	43	43	38	20	49

Figure 33. Estimated steelhead redds in LCM subwatersheds, return winters 2013/14 through 2023/24. Note that Mill subwatershed has 95% CI because of incomplete coverage due to lack of landowner access.



	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Coho salmon	90	150	184	85	124	94	139	132	74	67
Steelhead	450	521	510	306	663	407	252	227	86	242

Figure 34. Basinwide estimates of coho salmon and steelhead redds in the Russian River watershed (coho stratum only), return winters 2014/15 through 2023/24.

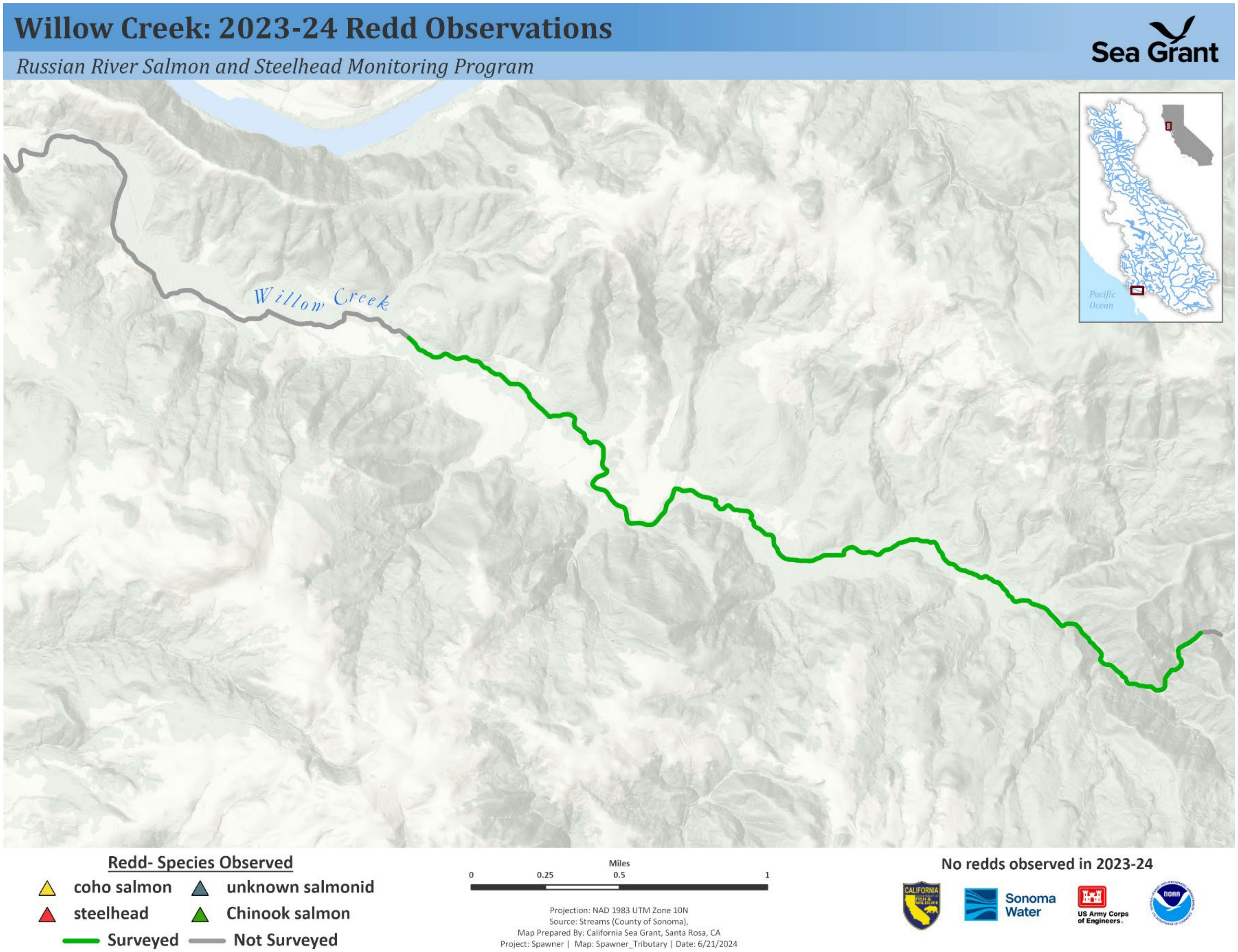


Figure 35. Distribution of salmonid redds observed in Willow Creek during winter 2023/24 (no redds were observed in Willow Creek).

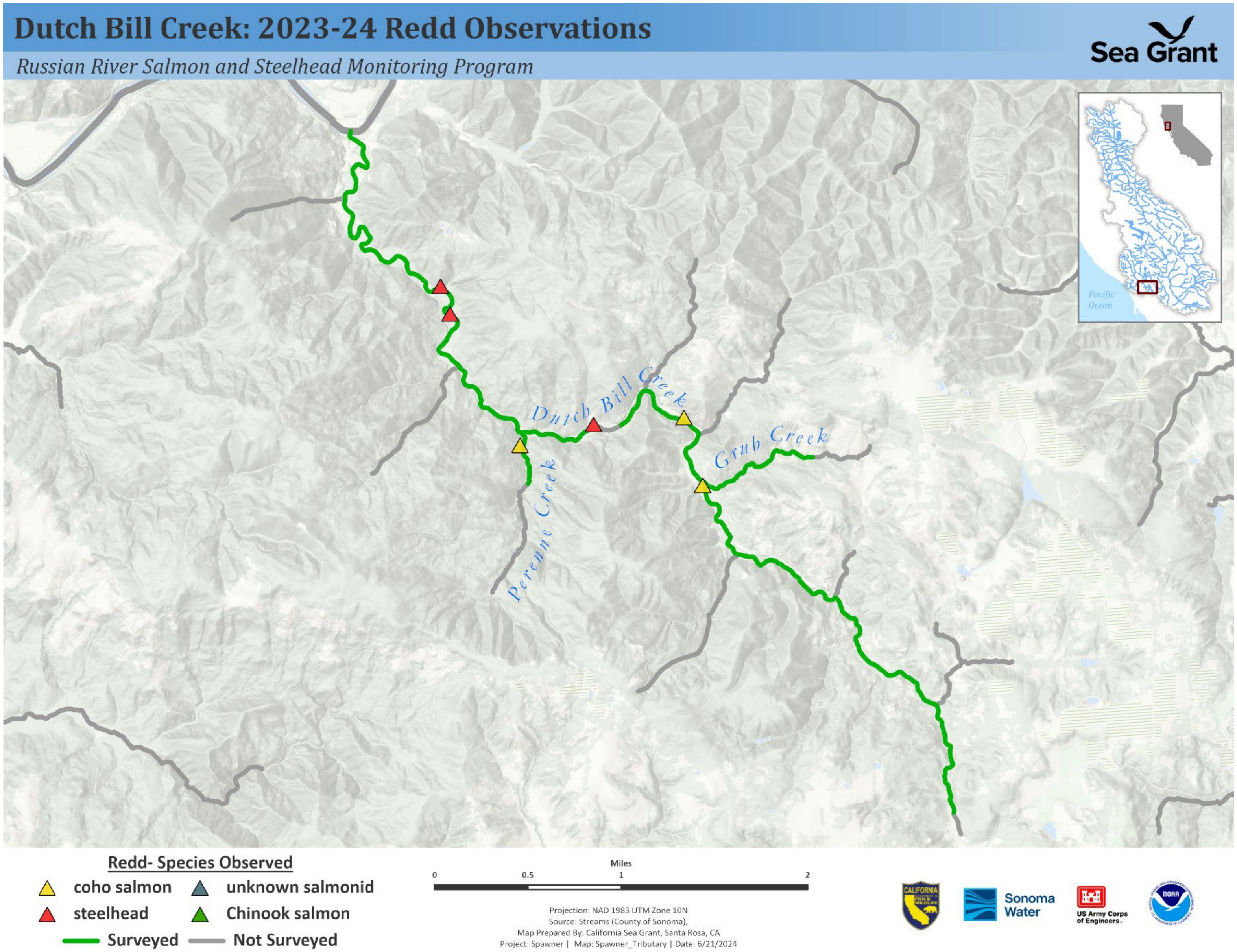


Figure 36. Distribution of salmonid redds observed in Dutch Bill Creek during winter 2023/24.

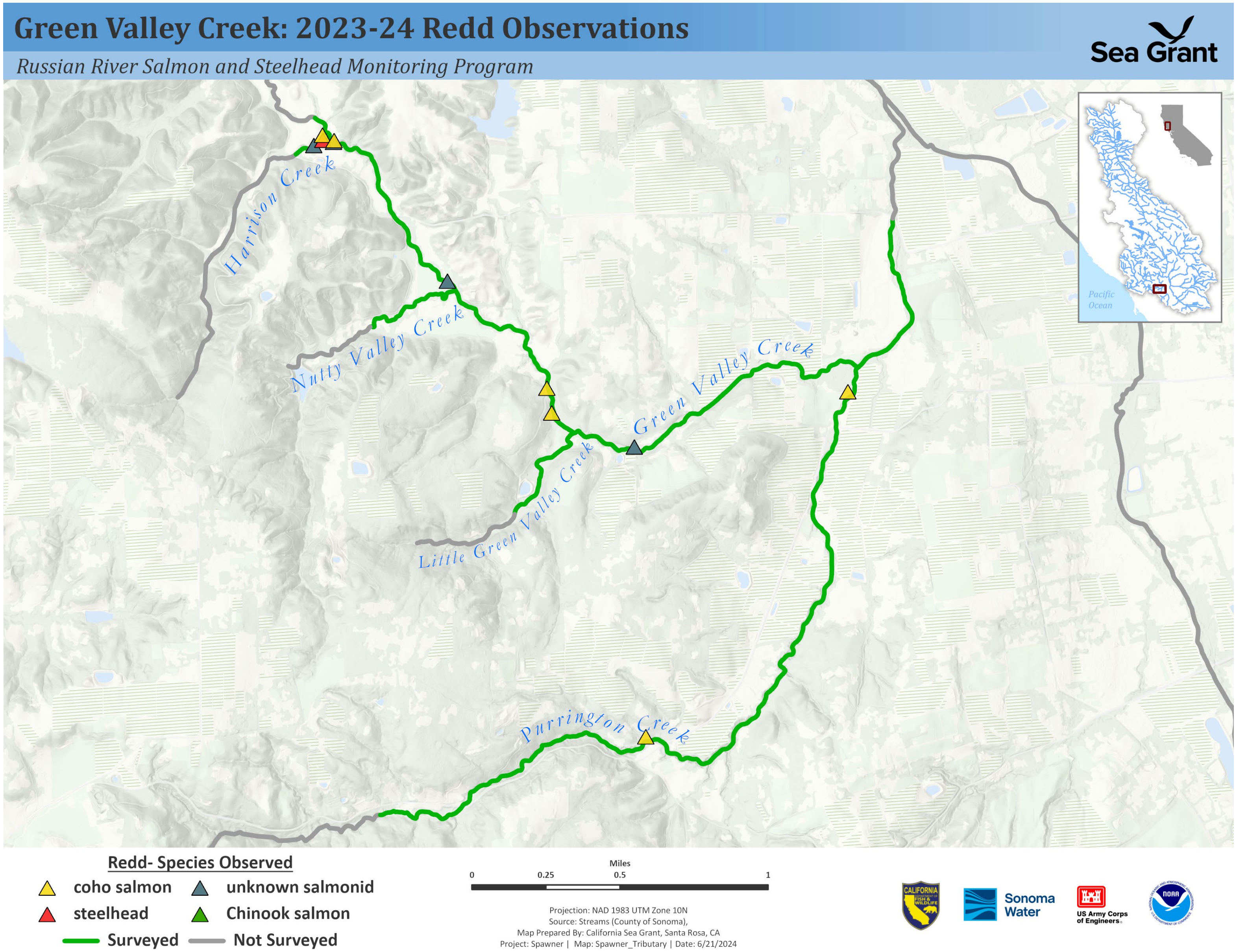


Figure 37. Distribution of salmonid redds observed in the Green Valley Creek subwatershed during winter 2023/24.

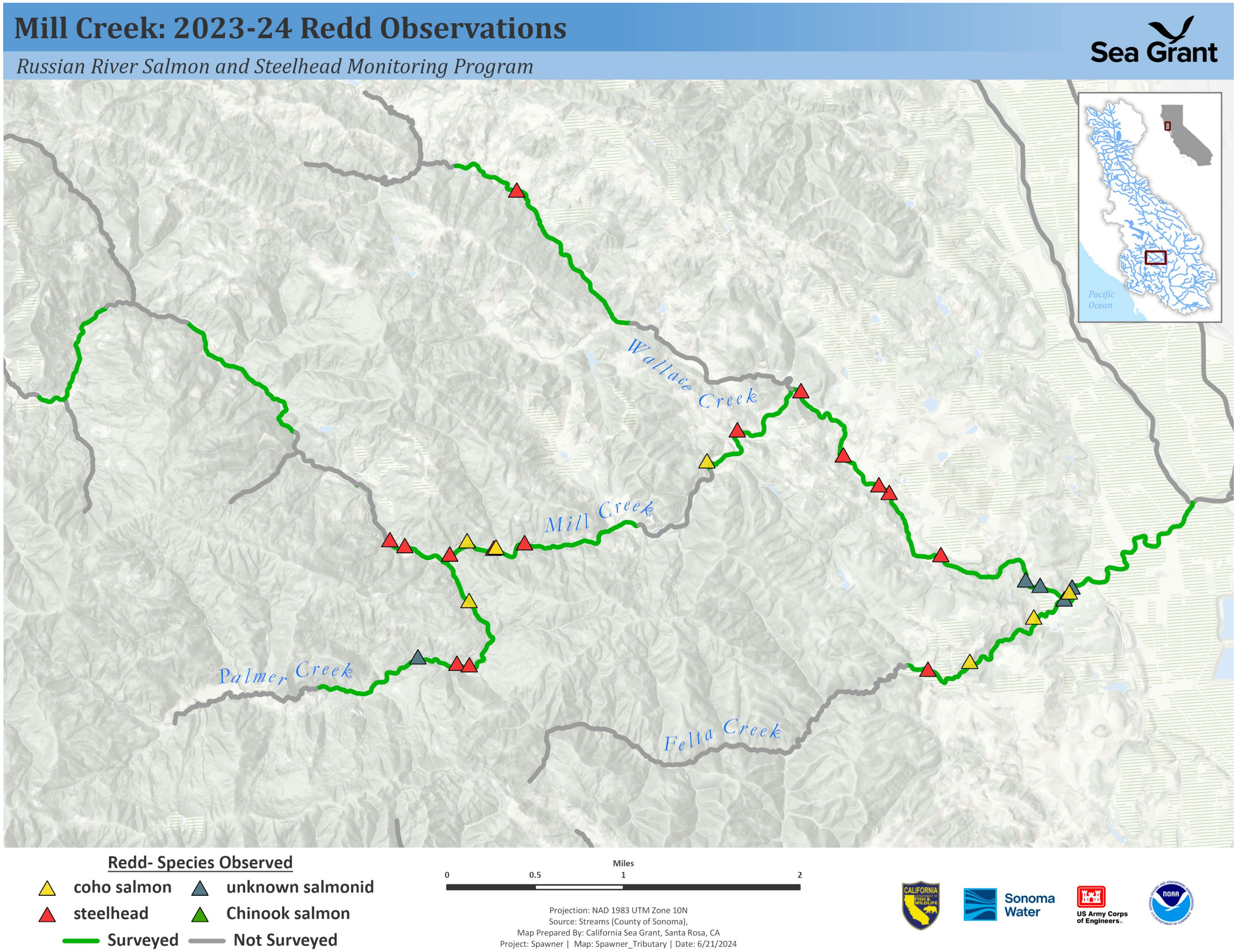


Figure 38. Distribution of salmonid redds observed in the Mill Creek subwatershed during winter 2023/24.

4. Discussion and recommendations

4.1. Adult returns

During the winter of 2023/24, the first significant rain event that provided passage for coho salmon adults to enter tributaries from the mainstem of the Russian River arrived on December 17 which was later than most years (Figure 4). Although the rain arrived later, multiple storm events occurred through the remainder of the coho spawning season (December - March). Total precipitation between October and March was slightly above the 20-year average for the region (Figure 3) which helped fish gain access to headwater portions of spawning tributaries. The high frequency of rain events but lack of extreme and flashy storm events likely provided suitable conditions for incubation and early fry survival as well.

As in most years, coho salmon entered the estuary and swam upstream in the mainstem of the river beginning in October and they began entering Dry Creek, a regulated tributary of the Russian River, in November (Figure 5 - Figure 7). Prior to the mid-December storm, adult coho were also detected on the PIT antenna array at the mouth of Willow Creek and one adult was detected at the mouth of Dutch Bill Creek (Figure 9, Figure 10). However, in the LCM streams, the majority of coho adults were not detected on the PIT antenna arrays until the mid-December storm. The majority of adult coho were detected entering the tributaries during a three-day window immediately following increased flows on December 17 (Figure 8). In Mill Creek, the distribution of adult coho detections was more evenly distributed between mid-December and late-January as compared to the other three LCM streams (Figure 9 - Figure 12).

Estimates of coho salmon adult returns to the LCM streams were average (Green Valley and Mill) to high (Willow and Dutch Bill) during the winter of 2023/24 as compared to previous years (Figure 13 - Figure 16), and were the highest on record for the mainstem of the river since the Duncans Mills PIT antenna array was installed in fall 2012 (Figure 17). While this is an encouraging result, it should be noted that the majority of the adult returns were age-2 adults, presumably male “jacks”, with the estimated percentage of age-2 fish ranging from 59% in the mainstem at Duncans Mills (Figure 18) to 100% in Willow Creek (Figure 13). This may, in part, explain the relatively low number of coho redds observed during spawner surveys (Figure 32, Figure 34). It may also indicate a strong cohort with a potentially high number of age-3 adults expected to return during the winter of 2024/25.

As in most years, there was no single release group (i.e., release life stage, release tributary, etc.) that comprised the majority of the returning adult coho salmon. Rather, we documented fish returning from spring, fall, presmolt and smolt release groups released into 12 tributaries as well as the mainstem Russian River (Table 3). Composition of adult coho salmon returns to each LCM subwatershed included fish that originated from the same LCM subwatershed, but also included a high proportion of coho that originated from other Russian River tributaries (Table 4). Similar movement patterns among subwatersheds within the Russian River basin have been observed each year since winter of 2012/13, though the level of movement among subwatersheds was greater during the winter of 2023/24 than in most years (Figure 39, Figure 40). We speculate that this may be due to high flows throughout the winter season which may have resulted in fish being able to move around more easily. Several adults were detected in more than one subwatershed. Overall, 56% of coho returning to each LCM subwatershed originated from streams other than the LCM subwatershed to which they returned. The percentage varied by LCM subwatershed, ranging from 30% in Willow Creek to 90% in Mill Creek, similar to overall percentages summarized over 12 winters (Figure 39).

We were unable to identify any clear patterns in subwatershed fidelity to LCM streams. Coho entering Willow Creek that did not originate from Willow Creek generally originated from lower river tributaries, whereas in the other three LCM subwatersheds fish originated from other coho tributaries without any particular tendency toward upper or lower river (Table 4). Interestingly, adults originating from Willow Creek entered all four LCM streams. We hypothesize that this is because as early returning adults entered the Russian River in October, the upper reaches of Willow Creek were inaccessible, resulting in fish continuing upstream to other tributaries. Subwatershed infidelity was not only characteristic of hatchery fish but was also documented for natural-origin fish, with natural-origin Willow Creek fish entering Dutch Bill and Green Valley creeks, natural-origin Green Valley fish entering Dutch Bill and Mill creeks, and natural-origin Dutch Bill fish entering Mill Creek.

The high level of movement among subwatersheds, particularly for natural-origin fish, highlights the importance of considering a suite of habitats and tributaries when thinking about population recovery. In terms of release strategies, we suggest that it is more important to release fish in locations where they have a high chance of survival rather than ensuring that they imprint on specific streams. Because we cannot predict which release strategy will result in the highest survival for a given cohort, we recommend continuing to release fish at different life stages and into different streams (i.e., bet hedging).

Smolt to adult return (SAR) ratios were lower than average in all LCM streams except Dutch Bill Creek for the 2021 cohort that emigrated as smolts during the spring of 2022 (Table 6). While it is possible that this result reflects higher estuarine and marine survival for smolts that emigrated from Dutch Bill Creek, it may also reflect the fact that adults that originated from other streams returned at a higher rate to Dutch Bill Creek (Table 4). The high level of movement among subwatersheds within the Russian River basin makes interpretation of SAR estimates difficult. Ideally, we would estimate SAR at the Russian River watershed scale; however, due to river's large size, we are unable to estimate the total number of smolts emigrating to the ocean each year. Despite these complications, it is reasonable to conclude that SAR is extremely low for the Russian River coho population, averaging less than 1% in the four LCM streams for cohorts 2008 - 2021 (Table 6).

To compare the proportion of natural-origin (NOR) to hatchery-origin (HOR) coho salmon adult returns, we compiled annual adult return data for each LCM subwatershed since year-round PIT monitoring began during the winter of 2012/13 (Table 8). Although there is evidence of NOR returns to all four LCM streams in 3 to 5 of the last 12 years, depending on stream, the numbers and proportions of NOR returns are extremely low (Table 8, Figure 41).

Another means of evaluating natural production of coho salmon is comparing the number of spawners in a given generation (*g*) to the number of NOR spawners in the next generation (*g+1*). We calculated such spawner-spawner ratios by dividing $spawner_{g+1}$ by $spawner_g$ in each of the four LCM subwatersheds for each generation in which we had data (Figure 42, Table 9). $Spawner_g$ was calculated by summing the estimated number of NOR and HOR returns for each return winter (generation *g*) and $spawner_{g+1}$ was calculated as the number of NOR returns in the next generation (generation *g+1*). To account for different ages at return for $spawner_{g+1}$ (i.e., age-2 and age-3), we summed the number of NOR returns that resulted from $spawner_g$ two and three years later. Ideally, we would observe spawner-spawner ratios of at least 1.0 (i.e., replacement) and an increasing trend over time; however, spawner-spawner ratios have not reached 1.0 in any stream or year. The overall average across streams and cohorts is extremely low (0.04, Table 9), and it has not increased over time (Figure 42). A potential issue with calculating $spawner_{g+1}$ / $spawner_g$ at the stream scale as we did here, is that it does not account for the fact that individuals can spawn in tributaries other than their stream of origin (where origin is defined as the tributary they were released into or produced from). Given our adult monitoring approach (i.e., we do not operate antennas on every tributary in the watershed), there is no ready way of fully accounting for such among-tributary movement. We therefore assumed that inter-tributary movement rates were similar among streams, which is not necessarily true (e.g., Figure 40). Regardless, this analysis does provide some perspective on the degree to which the Russian River coho salmon population are unable to complete their life cycle.

The observation of minimal natural production suggests that the Russian River coho salmon population continues to rely almost entirely on hatchery augmentation and that very few individuals are able to independently complete their life cycle in the natural environment. As described in previous reports and other studies, there is evidence that low streamflow is limiting survival and production of NOR fish at multiple life stages. Extensive stream drying during the summer season contributes to mortality of rearing juveniles (Obedzinski et al. 2018; Vander Vorste et al. 2020; Moidu et al. 2021). In addition, low spring flow can shorten the migration window of smolts (Kastl et al. 2022) and contribute to lower overwinter survival (California Sea Grant 2021a), while low winter flows can limit access to spawning habitat, alter migration timing, strand fish, and cause redd desiccation (California Sea Grant 2021b). Although numerous efforts are underway to increase streamflow in Russian River tributaries (e.g., see Coho Partnership website), the watershed-level changes that are needed to overcome these issues could take decades. Given the increased frequency and intensity of low flow extremes, we anticipate the continued need for hatchery supplementation if coho salmon are to persist in the Russian River watershed.

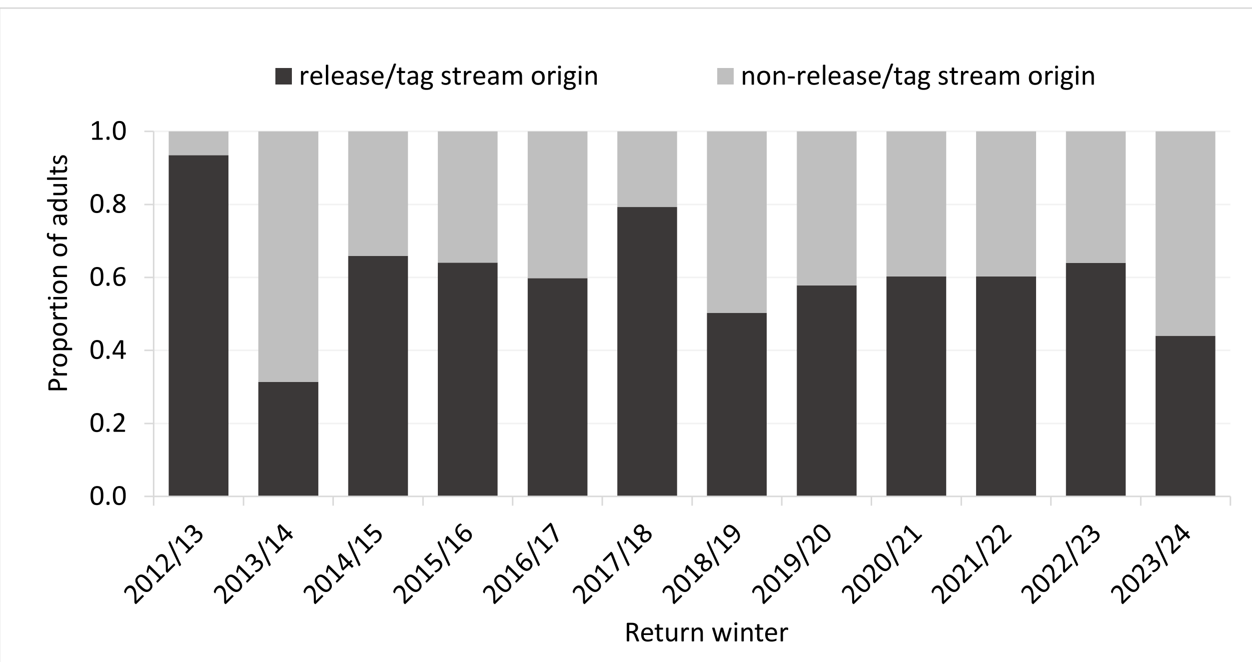


Figure 39. Composition of adult coho salmon returning to four LCM subwatersheds. Black represents the percentage of adults that returned to the stream in which they were released or tagged and gray represents the percentage that originated from a tributary other than the one to which they returned.

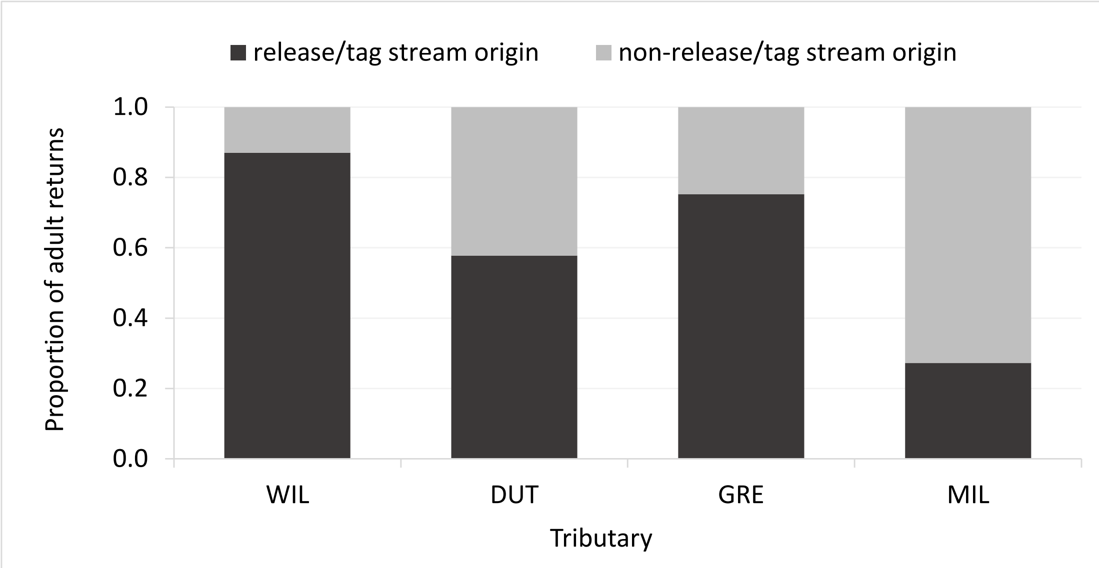


Figure 40. Composition of adult coho salmon returning to each LCM subwatershed (WIL = Willow Creek, DUT = Dutch Bill Creek, GRE = Green Valley Creek, MIL = Mill Creek). Black represents the percentage of adults that returned to the stream in which they were released or tagged and gray represents the percentage that originated from a tributary other than the one to which they returned.

Table 8. Estimated natural-origin (NOR) and hatchery-origin (HOR) coho salmon adult returns by stream and return winter.

Return winter	Willow		Dutch Bill		Green Valley		Mill	
	NOR	HOR	NOR	HOR	NOR	HOR	NOR	HOR
2012/13	0	14	0	9	0	74	0	78
2013/14	0	7	0	15	0	17	0	7
2014/15	0	8	0	18	0	44	0	52
2015/16	0	0	0	33	0	17	1	13
2016/17	2	10	2	67	2	107	4	132
2017/18	3	58	0	40	2	160	0	54
2018/19	0	27	0	49	0	26	0	93
2019/20	0	17	0	42	0	94	3	93
2020/21	0	3	0	11	0	19	2	14
2021/22	1	15	0	60	0	89	0	60
2022/23	0	0	1	26	0	7	0	13
2023/24	5	46	7	122	16	65	7	59

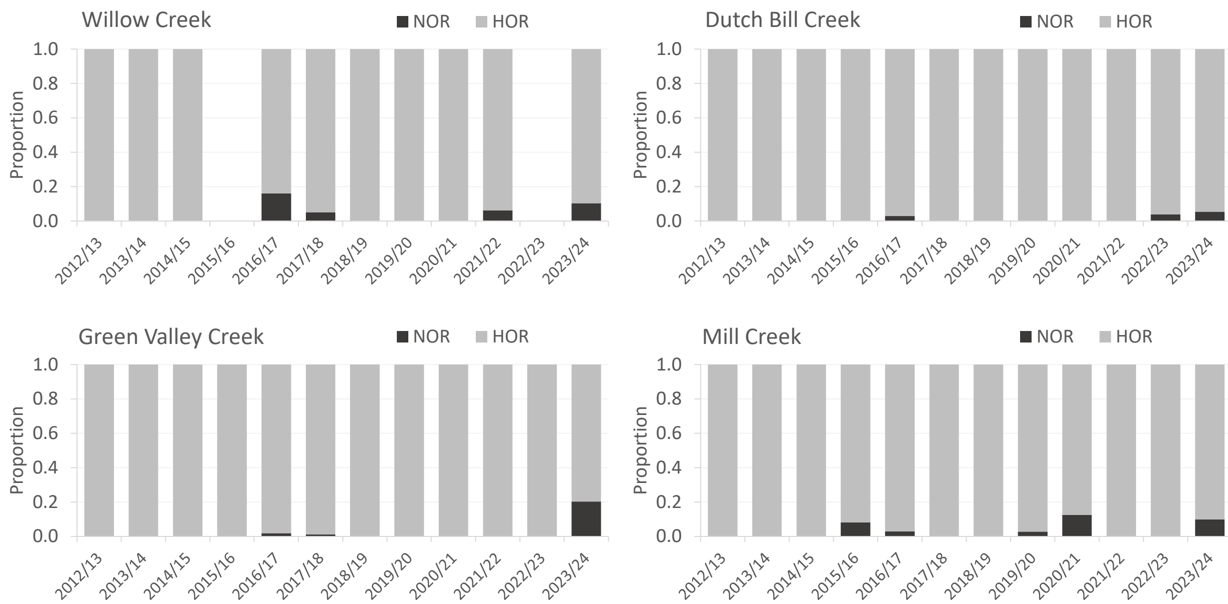


Figure 41. Annual proportion of natural-origin (NOR) and hatchery-origin (HOR) adult returns to four LCM streams, winters 2012/13 – 2023/24.

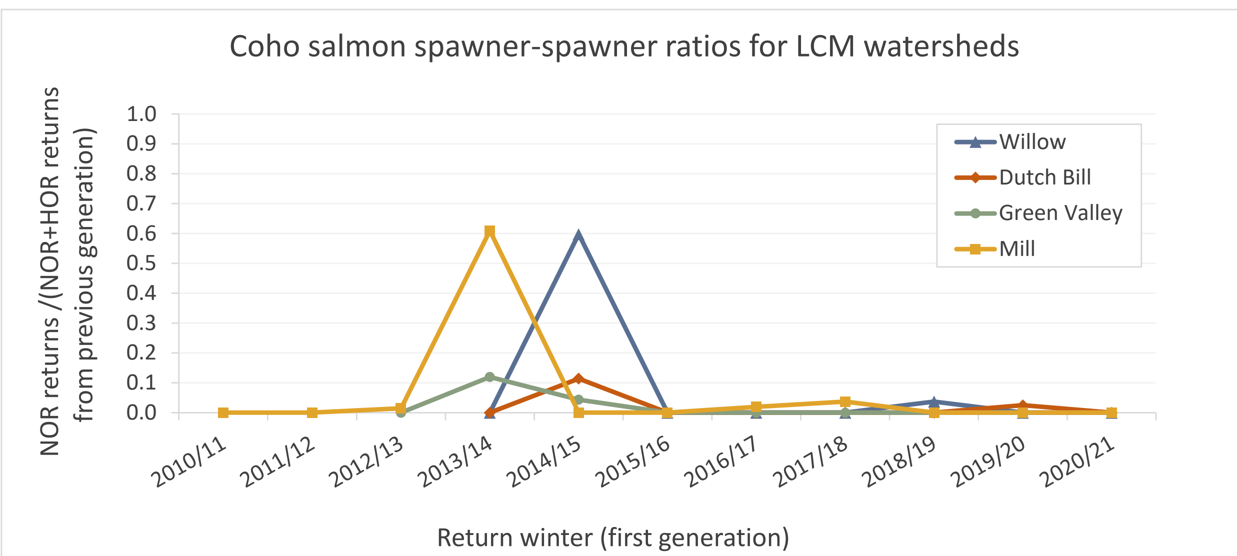


Figure 42. Coho salmon spawner-recruitment ratios in Russian River LCM streams. NOR = natural-origin, HOR = hatchery-origin.

Table 9. Coho salmon spawner-spawner ratios for LCM monitoring streams in the Russian River watershed. NOR = natural-origin, HOR = hatchery-origin.

LCM watershed	Return winter	Estimated adult returns (NOR + HOR)	Estimated NOR returns in next generation	Spawner-spawner ratio
Willow Creek	2013/14	7	0	0.00
	2014/15	8	5	0.60
	2015/16	0	0	0.00
	2016/17	12	0	0.00
	2017/18	61	0	0.00
	2018/19	27	1	0.04
	2019/20	17	0	0.00
	2020/21	3	0	0.00
Dutch Bill Creek	2013/14	15	0	0.00
	2014/15	18	2	0.11
	2015/16	33	0	0.00
	2016/17	69	0	0.00
	2017/18	40	0	0.00
	2018/19	49	0	0.00
	2019/20	42	1	0.02
	2020/21	11	0	0.00
Green Valley Creek	2012/13	74	0	0.00
	2013/14	17	2	0.12
	2014/15	44	2	0.04
	2015/16	17	0	0.00
	2016/17	109	0	0.00
	2017/18	162	0	0.00
	2018/19	26	0	0.00
	2019/20	94	0	0.00
	2020/21	19	0	0.00
Mill Creek	2010/11	152	0	0.00
	2011/12	68	0	0.00
	2012/13	78	1	0.02
	2013/14	7	4	0.61
	2014/15	52	0	0.00
	2015/16	14	0	0.00
	2016/17	136	3	0.02
	2017/18	54	2	0.04
	2018/19	93	0	0.00
	2019/20	96	0	0.00
	2020/21	16	0	0.00
			Average recruitment:	**0.04**

4.2. Abundance and distribution of redds

The timing of coho salmon and steelhead spawning in 2023/24 was relatively later than previous return seasons (Figure 28, Figure 29). This was likely due to the somewhat later onset of winter rains that persisted through late winter into early spring thus sustaining flows for a longer period than usual (Figure 43). Sustained flows also allowed fish to access upper reaches of tributaries for spawning and were perhaps at least partially responsible for the high number of observed redds in upper river tributaries. For example, in the Mill and Pena subwatersheds, combined (Figure 26), we observed 46% of the seasonal total of coho redds and 62% of the season total of steelhead redds (Table 7). The number of coho salmon and steelhead redds in Mill was also markedly higher than the other three LCM subwatersheds, accounting for over 20% of the overall estimated redd abundance for each species.

The number of coho salmon redds observed and estimated in the LCM subwatersheds as well as the basinwide estimate of coho salmon redds was lower than expected given the higher than average estimated number of adult coho returns to the Russian River basin. There are multiple factors that may have contributed to this apparent discrepancy. First, the timing and frequency of storm events during the winter of 2023/24 posed challenges for conducting spawning surveys, resulting in a lower number of surveys than in most years (Figure 25). Furthermore, the peak timing of adult coho detections in the tributaries (Dec 18-22, Figure 8) coincided with a low frequency in spawner surveys due to high and turbid waters which may have biased our redd estimates low. A second potential reason for the lower than expected redd abundance is, as mentioned previously, the fact that the majority of the adult returns were age-2 fish, presumably male “jacks” that do not construct redds.

A third potential cause of the apparent discrepancy between adult abundance and redd abundance estimates is the possibility that the basinwide adult estimate, which is based on PIT antenna detections, is biased high. This could arise because of an unequal ability to detect fish originating from different subwatersheds. For example, consider PIT tagged fish that originate from locations upstream of one or more PIT antenna arrays in their tributary of origin. During the 2022-2024 smolt and adult return periods, examples include Willow, Dutch Bill, Green Valley, Mark West and Mill creeks. For individuals originating from these streams, we have the ability to detect them during the smolt migration window (March-June) and again during the adult migration window (September-February) so we can confidently classify fish as adult returns. Because detection probabilities on tributary PIT antennas is high (often exceeding 0.9 for smolts and adults), we have high confidence in classifying adults for the majority of individuals detected that leave and return to these or other tributaries with PIT antennas. In contrast, there are fewer opportunities for detections of PIT-tagged fish originating from tributaries without PIT antennas but upstream of the Duncans Mills PIT antenna array (e.g., the Austin Creek subwatershed), or fish released into the lower mainstem Russian River upstream of the Duncans Mills array. Because the Duncans Mills array has relatively low detection efficiency for smolts, we detect few smolts at that location. When evaluating potential PIT-tagged adults, there are frequently “fish” that have few or no PIT antenna detections, which is particularly the case for fish originating from lower basin locations near Duncans Mills where the only opportunity to detect them is the Duncans Mills array. For those individuals, it can be extremely difficult to distinguish an actual live fish returning as an adult from a “ghost tag”. If ghost tags are misclassified as fish, the result will be biased-high estimates of adult returns. Unfortunately, we have no means of estimating confidence intervals or bias for our adult return estimates; however, from year-to-year we are as consistent as possible in our approach to adult classification meaning that in a relative sense the estimates are comparable among years allowing an accurate depiction of trends over time.

In general, monitoring adult salmonids in a watershed the size of the Russian is challenging and the degree of those challenges can be strongly influenced by factors such as winter storms that are outside of our control. However, some metrics are less influenced than others. To meet Coho Broodstock Program and CMP monitoring objectives, we consider adult abundance, adult run timing, redd abundance, SAR, hatchery- to natural-origin ratios, spawn timing, and spatial distribution of spawning. For the reasons described above, it can be difficult to meet all of these monitoring objectives each season. For the 2023/24 return winter, as well as several other winters since we began the monitoring described here, those challenges were prevalent. Although measures to completely alleviate those challenges are not possible, by focusing on relative abundance (e.g., year-to-year and subwatershed comparisons within years; Figure 30, Figure 31) as well as spawn timing and distribution, the monitoring approaches applied here continue to be extremely useful for evaluating performance of the Coho Broodstock Program.

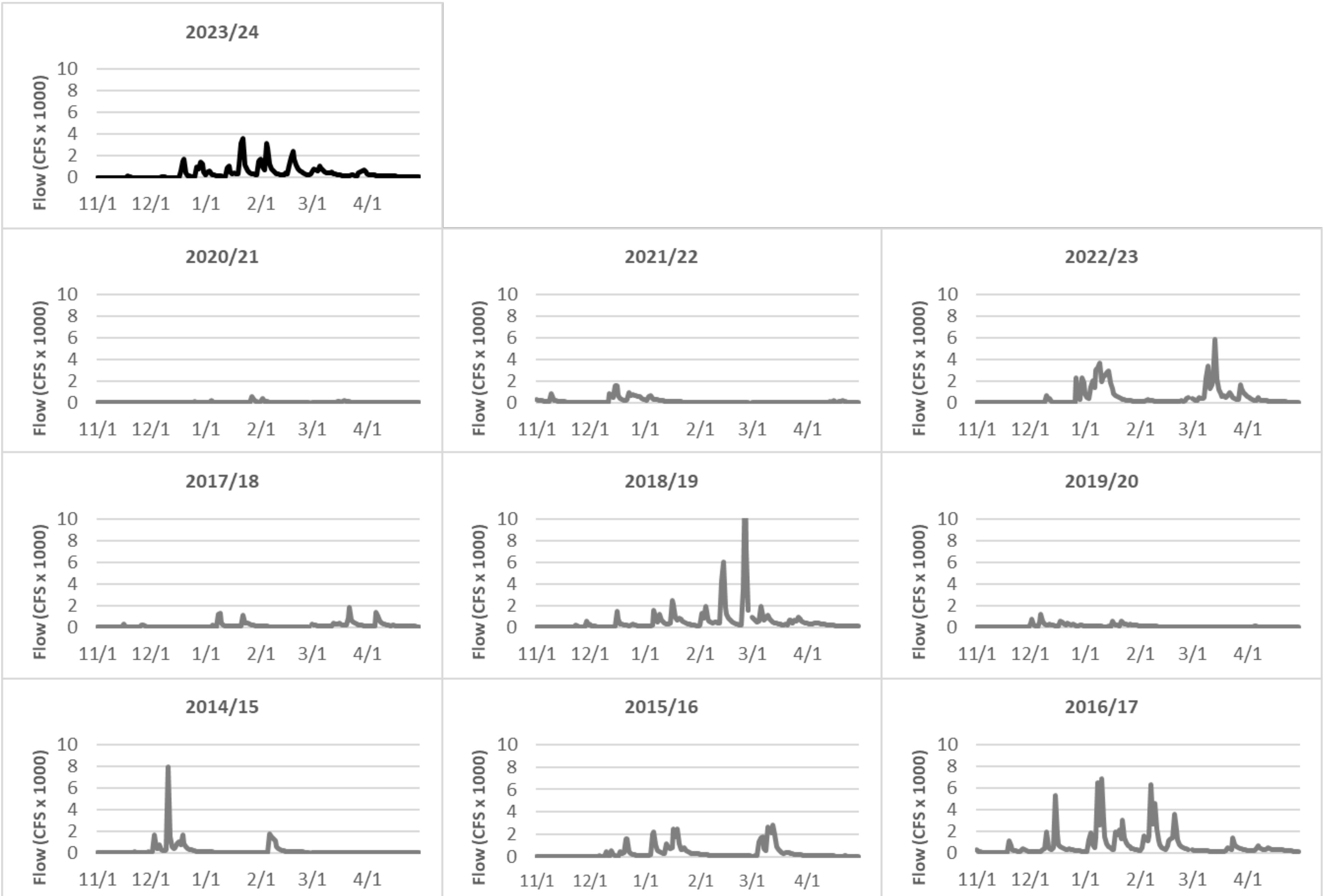


Figure 43. Average daily discharge in Austin Creek by year. Data were obtained from USGS (waterdata.usgs.gov).

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