Coho Salmon and Steelhead Monitoring Report

Winter 2021/22

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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 (*Oncorhynchus kisutch*) raised at the US Army Corps of Engineers (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 biologists 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 intensive monitoring watersheds: 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.

Over the last decade, CSG has developed many partnerships in salmon and steelhead (*O. mykiss)* recovery, and our program has expanded to include identification of limiting factors to survival, evaluation of habitat enhancement and streamflow improvement projects, and implementation of a statewide salmon and steelhead monitoring program. In 2010, we began documenting relationships between streamflow and juvenile coho salmon survival as part of the Russian River Coho Water Resources Partnership (Coho Partnership), an effort to improve streamflow and water supply reliability to water-users in flow-impaired Russian River tributaries. In 2013, we partnered with Sonoma Water (SW) and California Department of Fish and Wildlife (CDFW) to begin implementation of the California Coastal Monitoring Program (CMP), a statewide effort to document status and trends of anadromous salmonid populations using standardized methods and a centralized statewide database. We conduct wetted habitat surveys, in partnership with Wildlife Conservation Board, Trout Unlimited (TU), Gold Ridge Resource Conservation District, and Sonoma Resource Conservation District, during summer and fall to document sections of stream as wet, intermittent, or dry based on surface flow. These new projects, along with others, have led to the expansion of our program, which now includes over 50 Russian River tributaries.

The intention of our monitoring and research 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 update, we provide results from our fall and winter field season, including results from coho salmon monitoring at 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

Passive integrated transponder (PIT) tags and PIT tag 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, 2021, through March 1, 2022, our goal was to collect PIT tag data at multiple sites to document adult hatchery coho salmon return timing, estimate the number of returning hatchery coho salmon adults, and estimate coho salmon smolt to adult return (SAR) ratios in four Broodstock Program intensive monitoring watersheds (Willow, Dutch Bill, Green Valley, and Mill creeks). In addition, we were able to estimate these metrics for the Russian River basin, with the exception of SAR ratios since 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 watershed 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 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 tributaries and, in 2013, the Broodstock Program began PIT tagging a percentage of all coho salmon released into the Russian River watershed. The hatchery has continued to PIT-tag a proportion of all releases each year since 2013 (Table 1).

During the winter of 2021/22, we anticipated the return of PIT-tagged adults from cohorts 2019 (age-3 returns) and 2020 (age-2 returns) that had been released as juveniles into multiple streams (Table 2). In addition, we anticipated the return of fish tagged as juveniles at our smolt traps. Approximately half of all natural-origin coho salmon smolts captured in downstream migrant traps during the springs of 2020 and 2021 were PIT tagged in Willow, Green Valley, and Mill creeks (California Sea Grant 2020a; California Sea Grant 2021a). To increase the sample size for estimating smolt to adult return (SAR) ratios, we also PIT-tagged approximately one quarter of all non-PIT-tagged hatchery smolts captured in the downstream migrant traps during the springs of 2020 and 2021. Another potential source of PIT-tagged adult returns was natural-origin coho salmon tagged as juveniles in 2019 and 2020 during CMP electrofishing surveys in the Willow, Dutch Bill, Green Valley, and Mill creek watersheds and a summer survival study in Porter Creek; in 2019, a total of 295 juvenile coho salmon were PIT tagged and in 2020, a total of 1,135 were PIT-tagged.

Other adults present in the Russian River during the winter of 2021/22 originated from a Broodstock Program release of 32 adult coho salmon into a side channel of Dry Creek (Table 2, Figure 1) on February 14, 2022. All 32 adult coho salmon released at this location were marked with an external floy tag and an internal PIT tag. These adult hatchery coho salmon were considered surplus, and the Broodstock Program chose to release them in Dry Creek, where flows remained higher than in other tributary systems.

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, capable of reading FDX tags, 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 may have 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 and account for undetected fish. From September 15, 2021 through March 1, 2022, PIT tag detection systems were visited every other week to download data and check antenna status. More frequent visits (approximately daily) 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	155,442	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	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	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	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	AUS, DEV, DRY, DUT, FRE, GIL, GRA, GRE, MAR, MIL, PAL, PUR, SHE, THO, WIL	158,382	26,546	17%
2017	AUS, DEV, DRY, DUT, FRE, GIL, GRA, GRE, MAI, MIL, PAL, PUR, RCA, SHE, WIL	AUS, DEV, DRY, DUT, FRE, GIL, GRA, GRE, MAI, MIL, PAL, PUR, RCA, SHE, WIL	133,849	31,773	24%
2018	AUS, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, SHE, WIL	AUS, DEV, DRY, DUT, EAU, FRE, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, SHE, WIL	133,014	27,823	21%
2019	AUS, DEV, DRY, DUT, EAU, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, WIL	AUS, DEV, DRY, DUT, EAU, GIL, GRA, GRE, MAR, MAI, MIL, PAL, POR, PUR, RCA, WIL	194,039	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	214,432	26,805	13%

[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 2019 and 2020.

Cohort (Hatch year)	Tributary	Release group	Total coho salmon released	PIT-tagged coho salmon released	Percent PIT-tagged coho salmon released
2019	Russian River	smolt	10,079	1,514	15%
2019	Willow Creek	fall	6,015	1,986	33%
2019	Austin Creek	fall	7,258	1,207	17%
2019	Austin Creek	smolt	4,577	402	9%
2019	East Austin Creek	fall	8,056	1,210	15%
2019	Gilliam Creek	spring	3,033	597	20%
2019	Gilliam Creek	fall	3,020	455	15%
2019	Gray Creek	fry	4,774	NA	NA
2019	Gray Creek	fall	3,538	530	15%
2019	Devil Creek	spring	3,048	604	20%
2019	Devil Creek	fall	3,025	454	15%
2019	Dutch Bill Creek	fall	9,081	1,360	15%
2019	Green Valley Creek	fall	11,635	1,735	15%
2019	Green Valley Creek	smolt	15,610	2,339	15%
2019	Redwood Creek (Atascadero)	spring	2,018	406	20%
2019	Redwood Creek (Atascadero)	fall	2,050	305	15%
2019	Purrington Creek	fall	4,041	605	15%
2019	Mark West Creek	spring	10,067	1,505	15%
2019	Mark West Creek	fall	12,091	1,810	15%
2019	Mark West Creek	smolt	10,551	1,589	15%
2019	Porter Creek	spring	517	517	100%
2019	Porter Creek	fall	4,532	680	15%
2019	Dry Creek	spring	10,075	2,018	20%
2019	Dry Creek	fall	10,065	1,515	15%
2019	Dry Creek	smolt	15,135	2,269	15%
2019	Dry Creek	adult	32	32	100%
2019	Mill Creek	spring	511	511	100%
2019	Mill Creek	fall	15,069	2,259	15%
2019	Palmer Creek	fall	4,536	680	15%
2020	Russian River	smolt	12,572	378	3%
2020	Willow Creek	fall	6,634	1,000	15%
2020	Austin Creek	fall	12,995	1,963	15%
2020	Kidd Creek	fall	2,542	385	15%
2020	East Austin Creek	fall	10,053	1,508	15%
2020	Gilliam Creek	spring	2,047	310	15%
2020	Gray Creek	spring	5,040	760	15%
2020	Devil Creek	spring	2,547	380	15%
2020	Dutch Bill Creek	fall	11,084	1,732	16%
2020	Dutch Bill Creek	smolt	2,543	385	15%
2020	Green Valley Creek	fall	16,150	2,428	15%
2020	Green Valley Creek	presmolt	10,079	1,521	15%
2020	Green Valley Creek	smolt	3,634	549	15%
2020	Redwood Creek (Atascadero)	spring	2,072	310	15%
2020	Redwood Creek (Atascadero)	fall	3,039	460	15%
2020	Purrington Creek	fall	2,537	385	15%
2020	Mark West Creek	fall	13,641	2,052	15%
2020	Mark West Creek	presmolt	10,080	1,520	15%
2020	Porter Creek	spring	497	497	100%
2020	Porter Creek	fall	6,095	920	15%
2020	Dry Creek	spring	10,017	1,515	15%
2020	Dry Creek	fall	30,274	4,517	15%
2020	Dry Creek	smolt	10,156	1,330	13%
2020	Yellowjacket Creek	fry	28,104	NA	NA

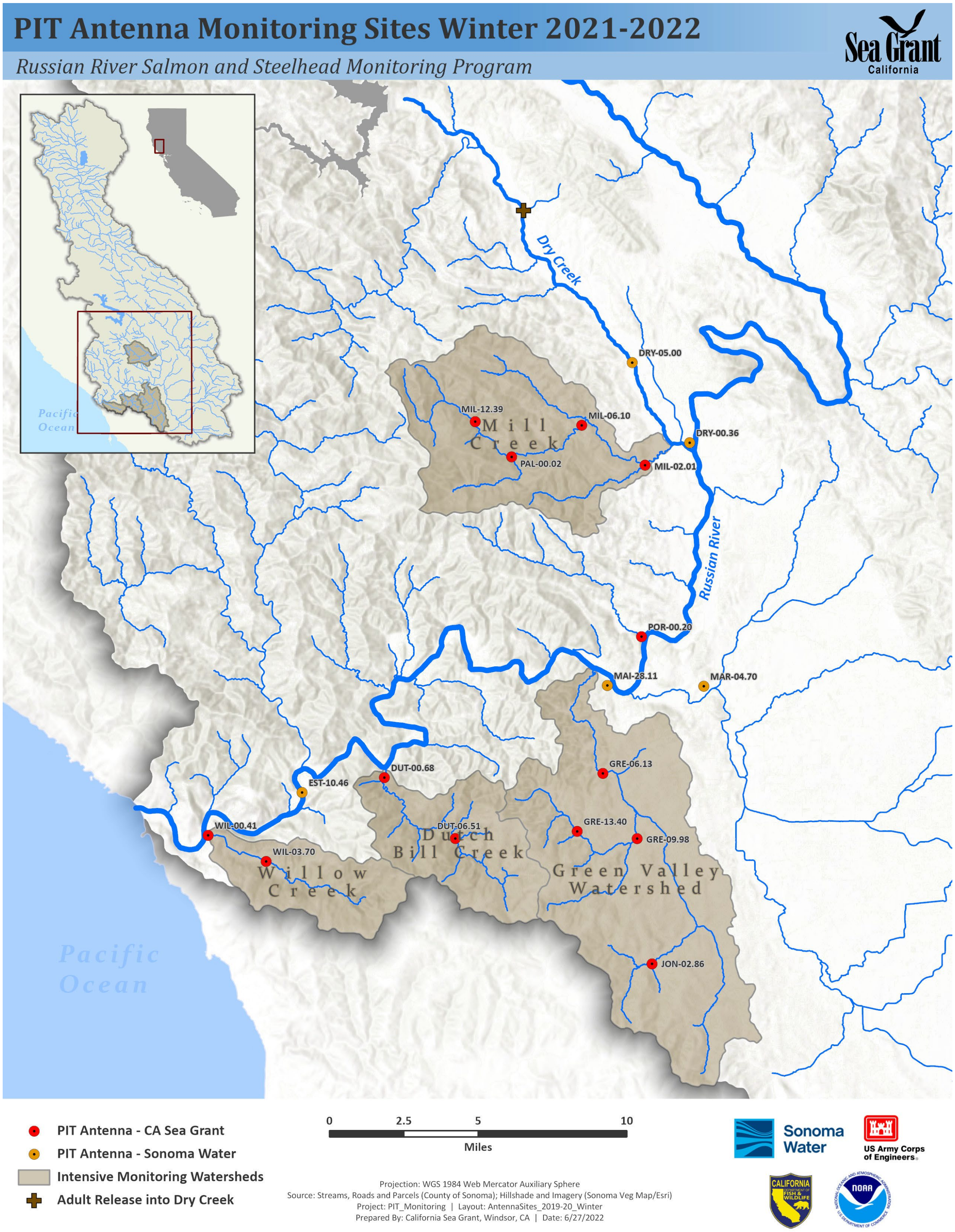


Figure 1. Passive integrated transponder (PIT) antenna and adult release location(s) in the Russian River watershed, winter 2021/22. Labels on antennas include a stream code (first three letters of a stream) and the distance in km from the mouth of the stream.

Figure 2. Paired flat-plate antenna array on Mill Creek.

2.2.3. Data analysis

First, all records of two- and three-year-old PIT-tagged coho salmon detected on antenna arrays between September 15, 2021 and March 1, 2022 were examined to determine the migratory disposition of detected fish (i.e., returning adults, age-2 outmigrants, 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 greater than one hour between upper and lower arrays) and that were not previously detected leaving 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, 2021 and March 1, 2022 was plotted with streamflow or stage data from the nearest available 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 creeks were calculated by 1) counting the number of unique adult PIT tag detections on the lower antennas of each antenna array (minimum count), 2) dividing the minimum count for each stream by the proportion of PIT-tagged fish released from the hatchery into each respective stream or, in the case of natural-origin fish, the proportion of natural-origin fish PIT-tagged at the smolt trap (expanded count per stream), and 3) dividing the expanded count by the estimated efficiency of the lower antennas of each stream array (estimated count per stream). The efficiency of the lower antennas of each paired antenna array was estimated by dividing the number of detections on both upstream and downstream antennas by all detections on the upper antennas. 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 smolt traps unless there were no other hatchery adults detected from that cohort and release stream.

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 the approach used on the Broodstock Program monitoring streams; however, the efficiency of the Duncans Mills antenna array was estimated by dividing the total number of unique PIT tag 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 tag 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.

2.2.3.3. Smolt to adult return (SAR) ratios

In each of the four Broodstock Program monitoring watersheds, the sum of the estimated number of two-year old hatchery adults returning during the winter of 2020/21 and three-year old adults returning during the winter of 2021/22 was divided by the estimated number of smolts migrating from each stream between March 1 and June 30 of 2020 to derive an 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 the February 14 adult release were excluded from SAR calculations.

3. Results

3.1.1. Adult return timing relative to flow conditions

Total precipitation between September 15, 2021 and March 1, 2022 was below the 15-year average (Figure 3) and flow patterns were notably different than the previous nine years, (e.g., Austin Creek, Figure 4). The highest streamflows were observed in October, smaller pulses of increased streamflow were observed in November and December, and flow remained low during January and February (Figure 4). PIT antenna detections of adults passing over the Duncans Mills antenna array at the head of the estuary (river km 10.46) occurred between late-October and mid-November (Figure 1, Figure 5). While a small number of adults entered the spawning tributaries coincident with the flow pulses observed in November, the majority of adults entered during storms that occurred in mid-December (Figure 6). This trend was observed in all four Broodstock Program monitoring watersheds (Figure 7 - Figure 10).

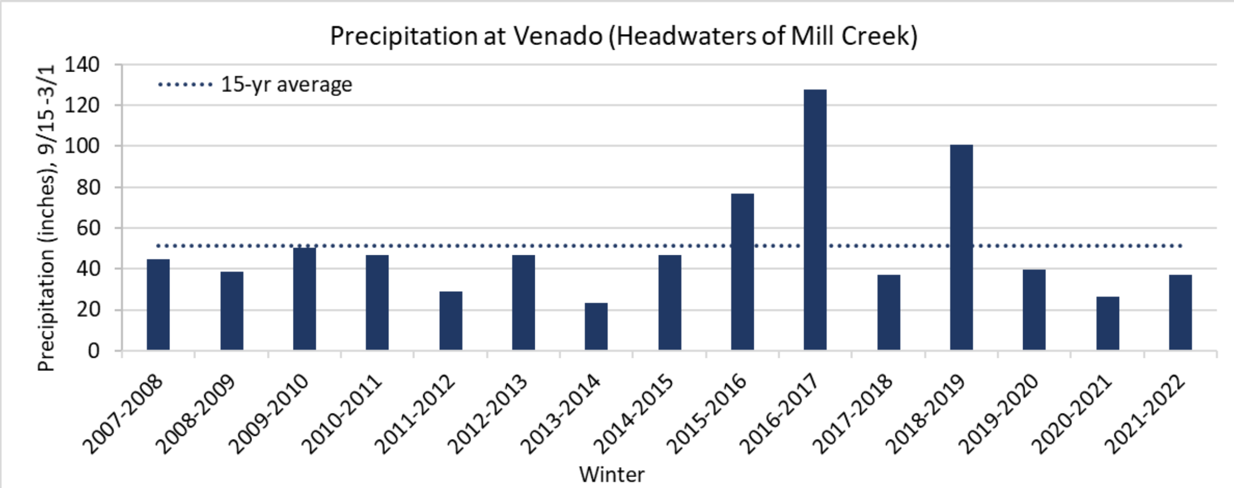


Figure 3. Precipitation at Venado gage near Mill Creek headwaters. Data were obtained from the California Data Exchange Center (https://cdec.water.ca.gov).

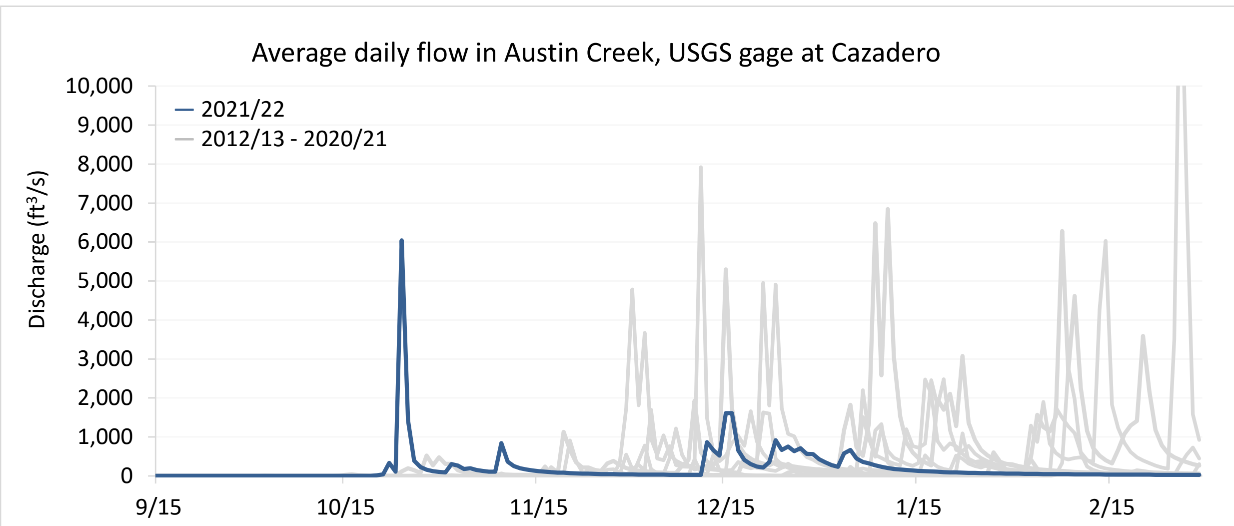


Figure 4. Winter 2021/22 streamflow in Austin Creek near Cazadero as compared to streamflow during the previous nine winters. Data were obtained from USGS (waterdata.usgs.gov).

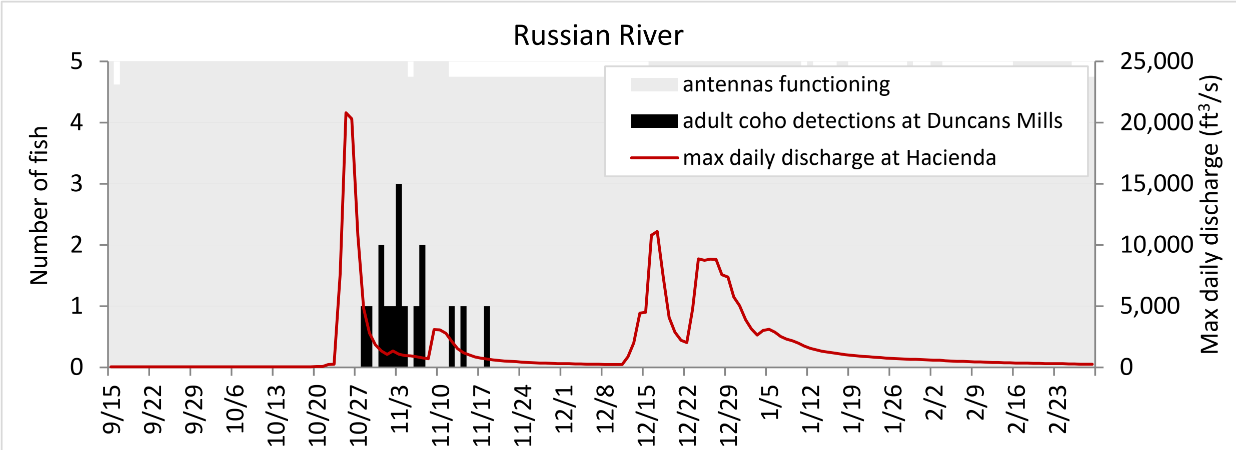


Figure 5. Detections of PIT-tagged coho salmon adults passing upstream of the Russian River antenna array at Duncans Mills (EST-10.46), September 15, 2021 - March 1, 2022. No adult release fish were detected. Discharge data were obtained from USGS (waterdata.usgs.gov).

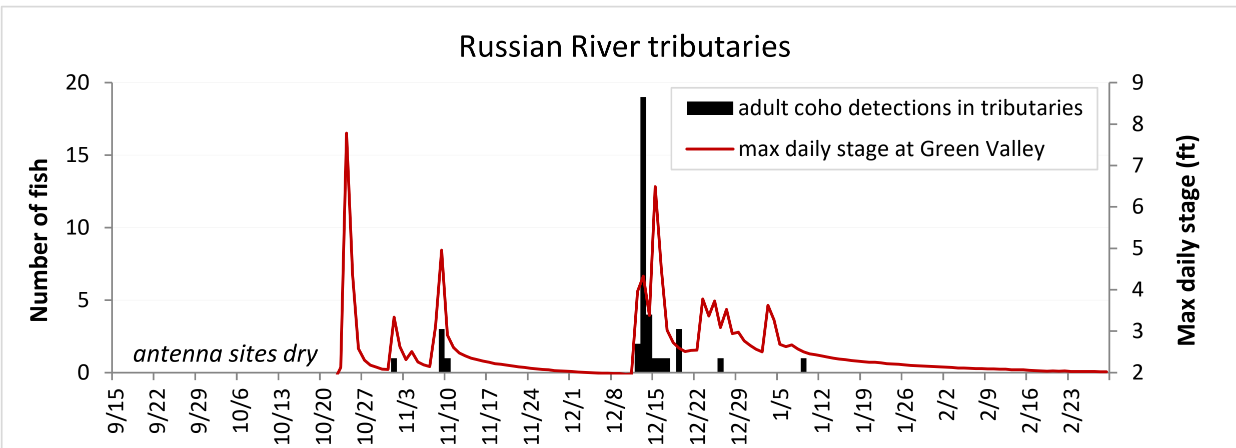


Figure 6. Detections of PIT-tagged coho salmon adults on Willow, Dutch Bill, Green Valley, Mill, Mark West, and/or Porter creek antennas, September 15, 2021 - March 1, 2022. Detections of adult release fish were excluded. Stage data were provided by Trout Unlimited.

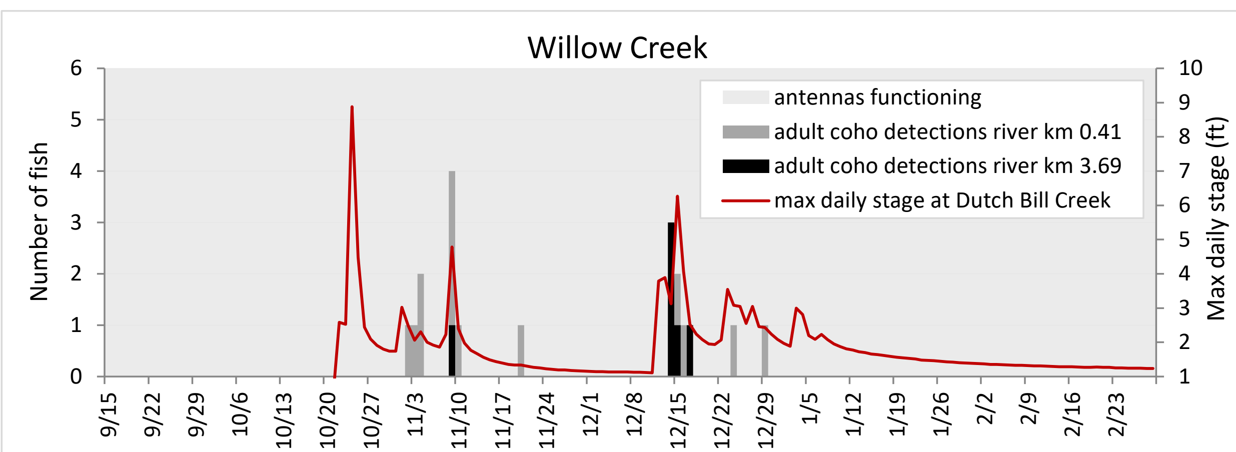


Figure 7. Detections of PIT-tagged coho salmon adults entering Willow Creek between September 15, 2021 and March 1, 2022. Stage data from Dutch Bill Creek were provided by Trout Unlimited (Willow Creek data not available).

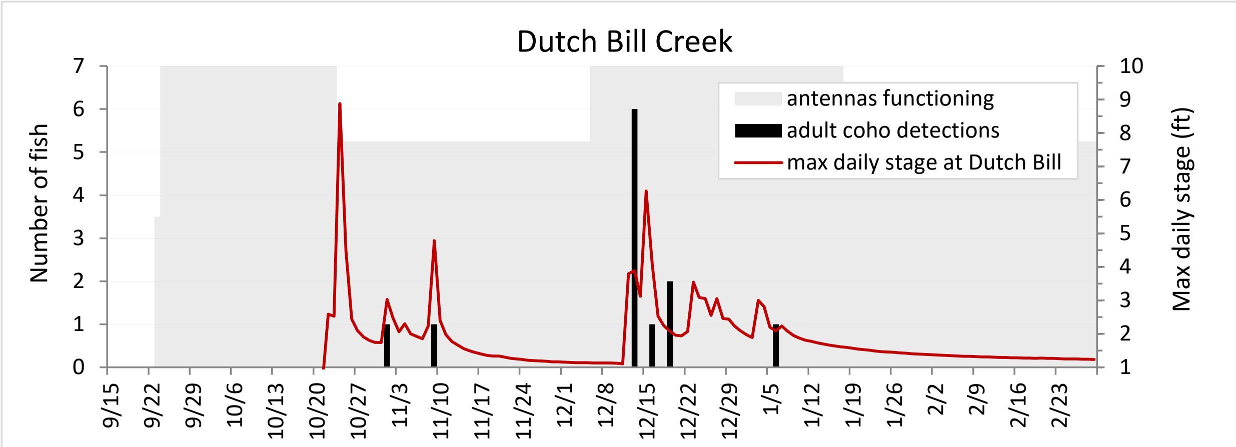


Figure 8. Detections of PIT-tagged coho salmon adults passing upstream of the Dutch Bill Creek antenna array, September 15, 2021 - March 1, 2022. Stage data were provided by Trout Unlimited.

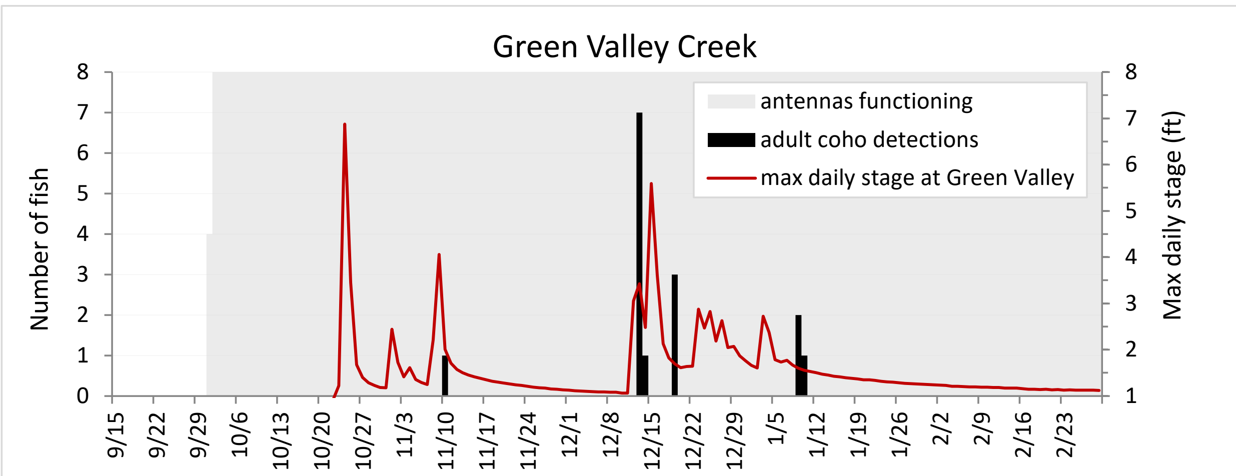


Figure 9. Detections of PIT-tagged coho salmon adults passing upstream of the Green Valley Creek antenna array, September 15, 2021 - March 1, 2022. Stage data were provided by Trout Unlimited.

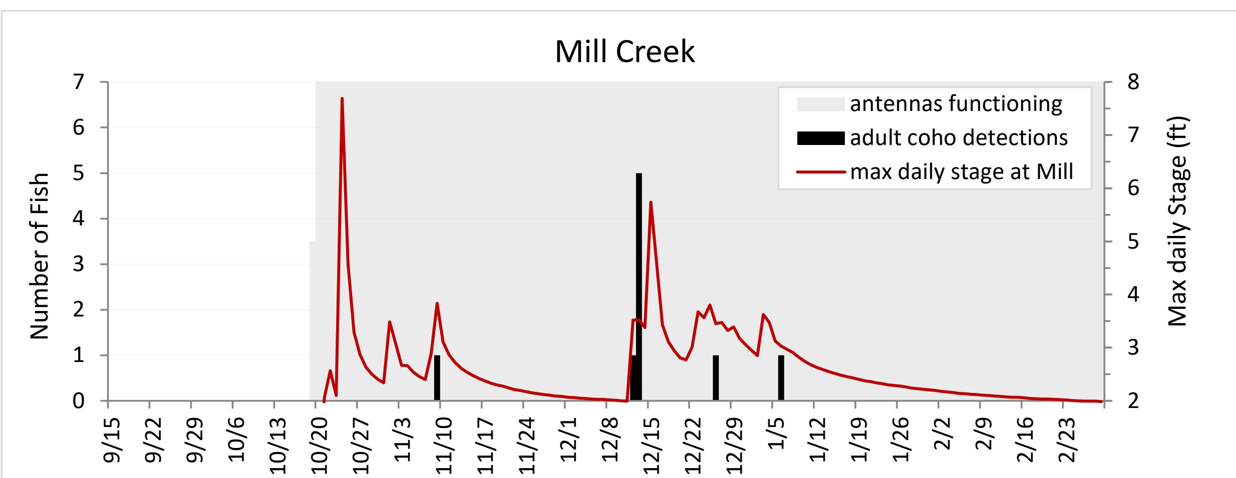


Figure 10. Detections of PIT-tagged coho salmon adults passing upstream of the Mill Creek antenna array, September 15, 2021 - March 1, 2022. Stage data were provided by Trout Unlimited.

3.1.2. Adult return estimates

Estimates of adult coho salmon returning to Willow, Dutch Bill, Green Valley, and Mill creeks were 16, 60, 89, and 60, respectively (Table 3 - Table 6), and the estimated number of hatchery coho salmon adults returning to the Russian River Basin was 484 (Table 7). The composition of release groups returning as adults to each watershed varied across watersheds. In Willow Creek, all PIT-tagged adults were age-3 and originated from either the 2019 fall release into Willow Creek or from CMP tagging of natural-origin juveniles during summer 2019 CMP electrofishing in Willow Creek (Table 3). Dutch Bill Creek age-3 and age-2 adult returns were comprised of hatchery releases from fall and smolt release groups into Dutch Bill, Willow, and Green Valley creeks and the lower Russian River (Table 4). Returns to Green Valley Creek were a mix of age-3 and age-2 adults originating from fall and/or smolt hatchery releases into Green Valley, Purrington, Austin, and Dutch Bill creeks and the Russian River (Table 5). Mill Creek adult returns also originated from a mix of streams and release groups including fall and/or smolt releases from Austin, Dry, Dutch Bill, Palmer, and Green Valley creeks and the Russian River (Table 6). Release group composition of adult coho salmon returning to the Russian River watershed included a diversity of streams and age groups with no single release group dominating the proportion of returns (Table 7).

Estimated adult returns during the winter of 2021/22 were approximately average (as observed in Willow and Mill creeks) or above-average (as observed in Green Valley Creek, Dutch Bill Creek, and Russian River) compared to previous years (Figure 11 - Figure 15). The proportion of age-2 returns was lower than most years and varied by stream from an estimated 0% in Willow Creek (Figure 11) to 25% in Dutch Bill Creek (Figure 12). The proportion of age-2 fish returning to the Russian River was 13%, which was the second lowest observed over the past ten winters (Figure 16).

Table 3. Minimum, expanded, and estimated counts of adult coho salmon returning to Willow Creek (array upstream of Third Bridge; river km 3.69) between September 15, 2021 and March 1, 2022. Minimum count: number unique PIT tag detections on lower antenna array; expanded count: minimum count/percent PIT-tagged; estimated count: expanded count/estimated antenna efficiency.

Age	Release tributary	Origin	Release group	Minimum count	Percent PIT-tagged	Expanded count	Estimated antenna efficiency	Estimated count
3	Willow Creek	hatchery	fall	5	33%	15.1	100%	15.1
	Willow Creek	natural-origin	tagged electrofishing in 2019	1	unknown	1.0	100%	1.0

Estimated hatchery adult returns (age-3):	15.1
Estimated natural-origin adult returns (age-3):	1.0
Total estimated adult returns:	**16**

Table 4. Minimum, expanded, and estimated counts of adult coho salmon returning to Dutch Bill Creek between September 15, 2021 and March 1, 2022. Minimum count: number unique PIT tag detections on lower antenna array; expanded count: minimum count/percent PIT-tagged; estimated count: expanded count/estimated antenna efficiency.

Age	Release tributary	Origin	Release group	Minimum count	Percent PIT-tagged	Expanded count	Estimated antenna efficiency	Estimated count
3	Dutch Bill Creek	hatchery	fall	3	15%	20	88%	22.9
	Green Valley Creek	hatchery	smolt	1	15%	7	88%	7.6
	Willow Creek	hatchery	fall	2	33%	6	88%	6.9
	Russian River	hatchery	smolt	1	15%	7	88%	7.6
2	Dutch Bill Creek	hatchery	fall	1	16%	6.4	88%	7.3
	Dutch Bill Creek	hatchery	smolt	1	15%	6.6	88%	7.5
							Estimated hatchery adult returns (age-3):	45.1
							Estimated hatchery adult returns (age-2):	14.9
							Total estimated adult returns:	**60**

Table 5. Minimum, expanded, and estimated counts of adult coho salmon returning to Green Valley Creek between September 15, 2021 and March 1, 2022. Minimum count: number unique PIT tag detections on upper antenna array; expanded count: minimum count/percent PIT-tagged; estimated count: expanded count/estimated antenna efficiency.

Age	Release tributary	Origin	Release group	Minimum count	Percent PIT-tagged	Expanded count	Estimated antenna efficiency	Estimated count
3	Austin Creek	hatchery	smolt	1	15%	6.6	90%	7.4
	Green Valley Creek	hatchery	fall	1	15%	6.7	90%	7.5
	Green Valley Creek	hatchery	smolt	5	15%	33.4	90%	37.1
	Purrington Creek	hatchery	fall	1	15%	6.7	90%	7.4
	Russian River	hatchery	smolt	2	15%	13.3	90%	14.8
2	Dutch Bill Creek	hatchery	fall	1	16%	6.4	90%	7.1
	Green Valley Creek	hatchery	fall	1	15%	6.7	90%	7.4
							Estimated hatchery adult returns (age-3):	74.1
							Estimated hatchery adult returns (age-2):	14.5
							Total estimated adult returns:	**89**

Table 6. Minimum, expanded, and estimated counts of adult coho salmon returning to Mill Creek between September 15, 2021 and March 1, 2022. Minimum count: number unique PIT tag detections on upper antenna array; expanded count: minimum count/percent PIT-tagged; estimated count: expanded count/estimated antenna efficiency.

Age	Release tributary	Origin	Release group	Minimum count	Percent PIT-tagged	Expanded count	Estimated antenna efficiency	Estimated count
3	Austin Creek	hatchery	smolt	1	15%	6.63	100%	6.6
	Dry Creek	hatchery	smolt	1	15%	6.67	100%	6.7
	Dutch Bill Creek	hatchery	fall	1	15%	6.68	100%	6.7
	Palmer Creek	hatchery	fall	1	15%	6.67	100%	6.7
	Russian River	hatchery	smolt	3	15%	19.97	100%	20.0
2	Green Valley Creek	hatchery	fall	1	15%	6.65	100%	6.7
	Russian River	hatchery	smolt	1	15%	6.60	100%	6.6
							Estimated hatchery adult returns (age-3):	46.6
							Estimated hatchery adult returns (age-2):	13.3
							Total estimated adult returns:	**60**

Table 7. Minimum, expanded, and estimated counts of hatchery adult coho salmon returning to the Russian River mainstem at Duncans Mills between September 15, 2021 and March 1, 2022. Minimum count: number unique PIT tag detections at Duncans Mills antenna array; expanded count: minimum count/percent PIT-tagged; estimated count: expanded count/estimated antenna efficiency. Note that Willow Creek fish that were not detected at Duncans Mills were added to the estimated total passing Duncans Mills to estimate the total number of adult hatchery coho salmon returning to the Russian River.

Age	Release tributary	Origin	Release group	Minimum count	Percent PIT-tagged	Expanded count	Estimated antenna efficiency	Estimated count
3	Austin Creek	hatchery	smolt	1	15%	6.6	21%	31.5
	Dry Creek	hatchery	fall	1	15%	6.6	21%	31.6
	Dutch Bill Creek	hatchery	fall	1	15%	6.7	21%	31.7
	East Austin Creek	hatchery	fall	1	15%	6.7	21%	31.6
	Gray Creek	hatchery	fall	2	15%	13.4	21%	63.4
	Green Valley Creek	hatchery	smolt	1	15%	6.7	21%	31.7
	Palmer Creek	hatchery	fall	1	15%	6.7	21%	31.7
	Purrington Creek	hatchery	fall	1	15%	6.7	21%	31.7
	Russian River	hatchery	smolt	3	15%	20.0	21%	94.9
	Willow Creek	hatchery	fall	1	33%	3.0	21%	14.4
	Dutch Bill Creek	natural-origin	tagged electrofishing in 2019	1	NA	NA	NA	NA
2	Kidd Creek	hatchery	fall	1	15%	6.6	21%	31.4
	Russian River	hatchery	smolt	1	15%	6.6	21%	31.3
							Estimated hatchery adults passing Duncans Mills (age-3):	394.2
							Estimated hatchery adults passing Duncans Mills (age-2):	62.7
							Estimated hatchery adults returning to Willow Creek that were not detected at Duncans Mills (age-3):	27.3
							Total estimated hatchery adult returns:	**484**

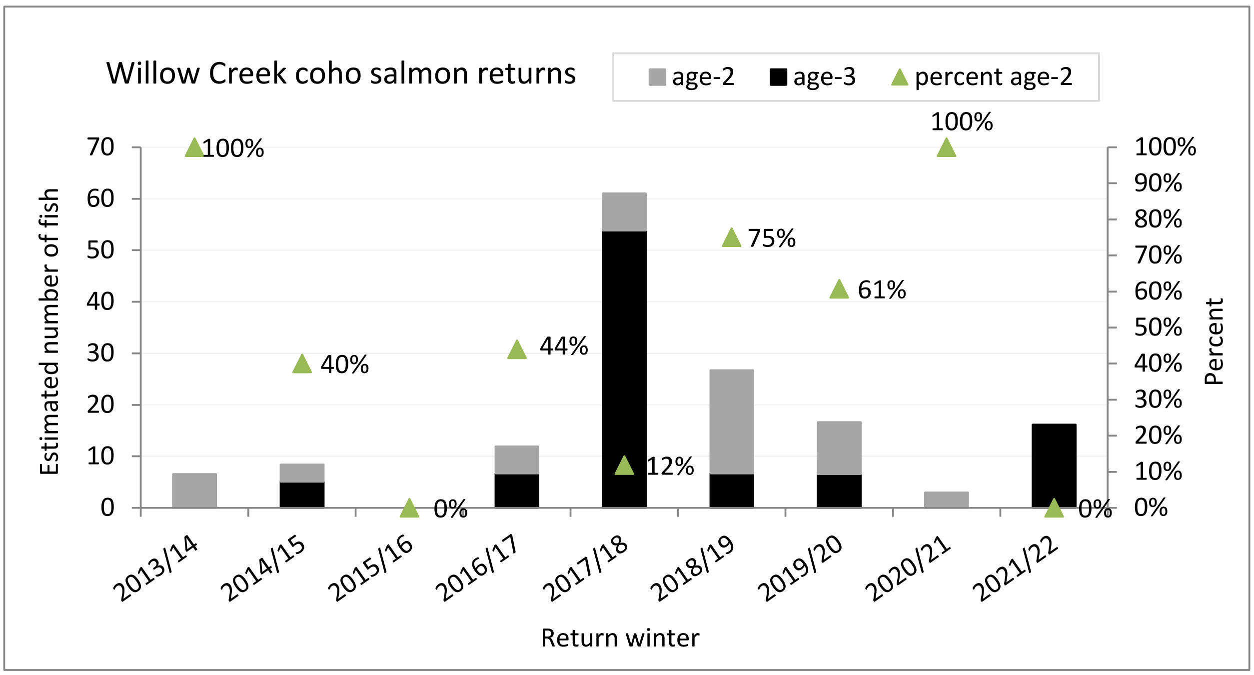


Figure 11. Estimated annual Willow Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2021/22. Note that estimates are based on returns to the upper antennas at river km 3.69.

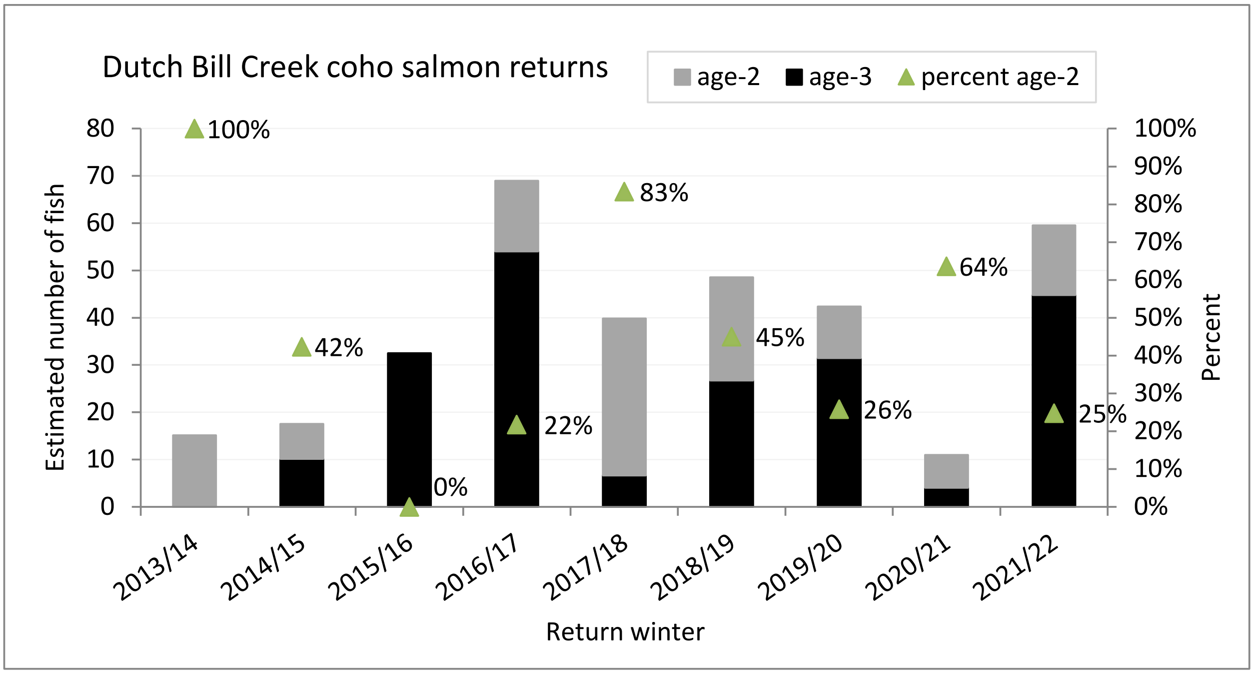


Figure 12. Estimated annual Dutch Bill Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2021/22.

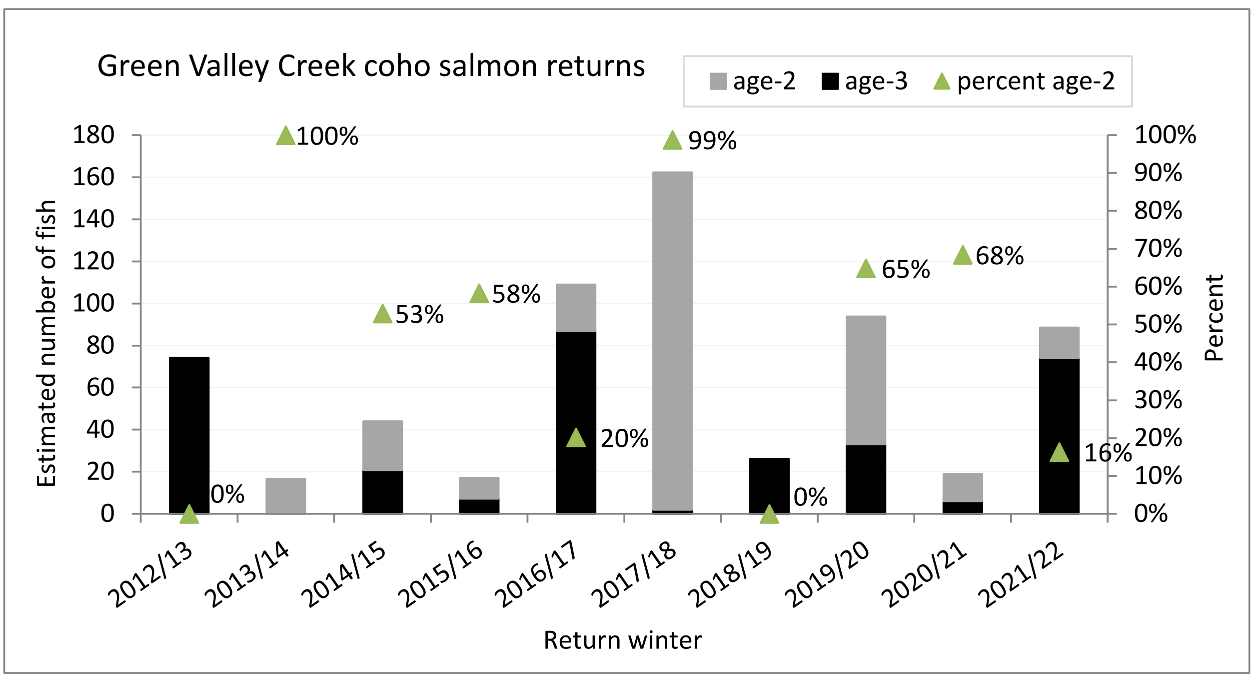


Figure 13. Estimated annual Green Valley Creek adult hatchery coho salmon returns by age, return seasons 2012/13 – 2021/22.

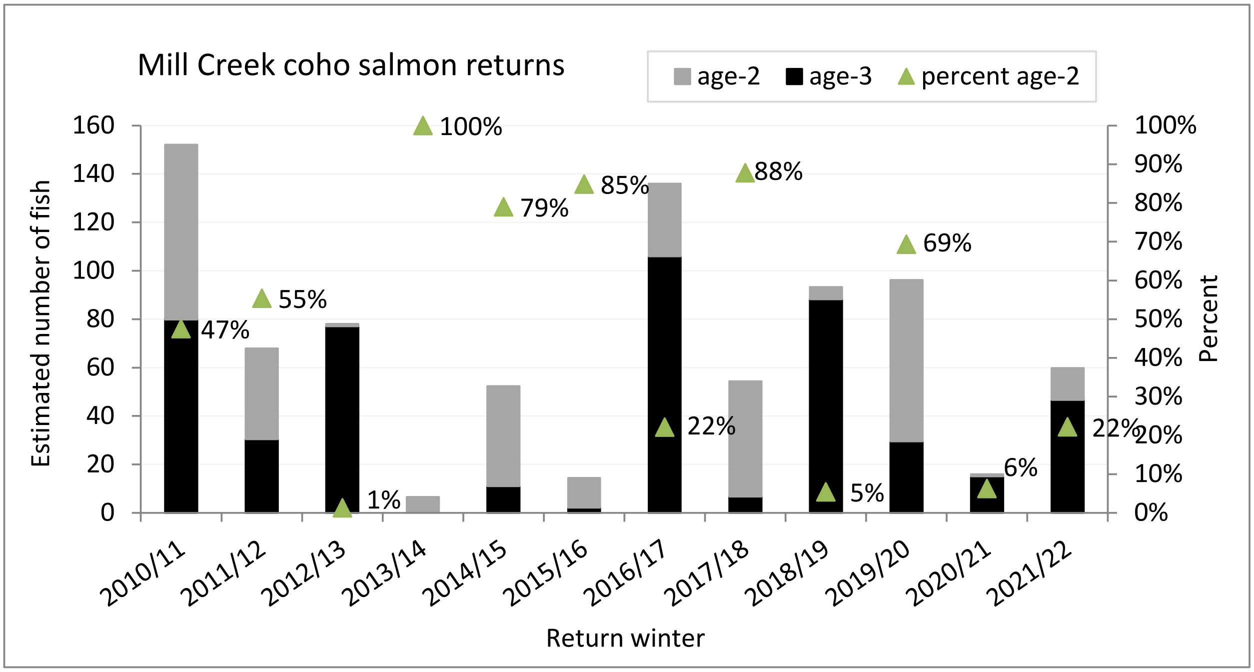


Figure 14. Estimated annual Mill Creek adult hatchery coho salmon returns by age, return seasons 2010/11 – 2021/22.

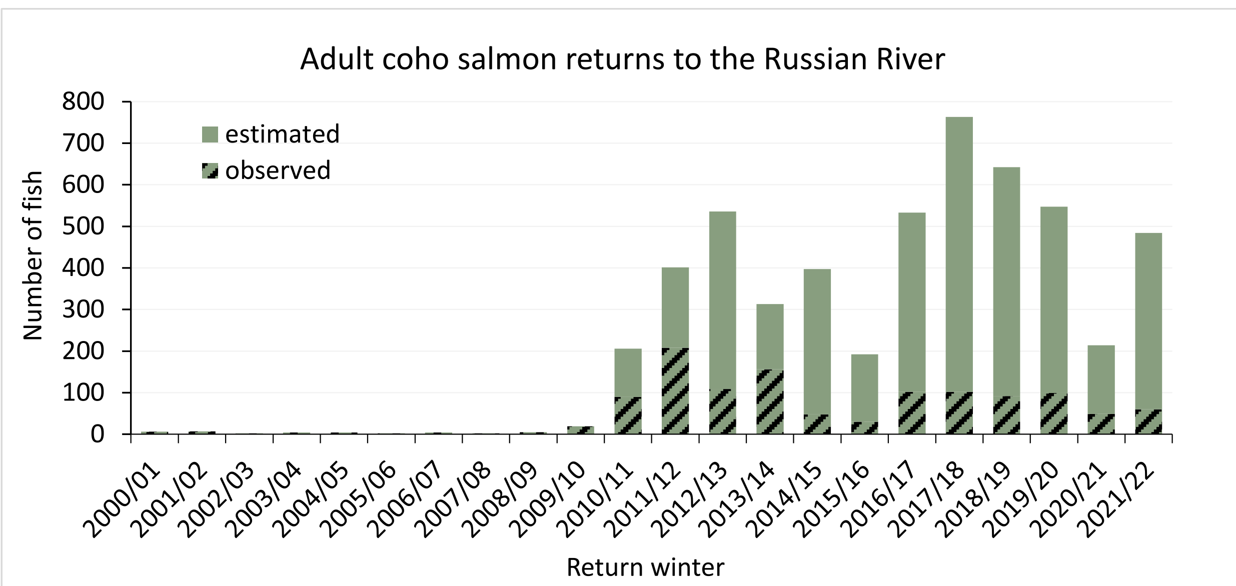


Figure 15. Estimated annual adult hatchery coho salmon returns to the Russian River, return winters 2000/01 through 2021/22. Note that methods for counting/estimating the number of returning adult coho salmon were not consistent among years; prior to 2009/10, spawner surveys were the primary method, from 2009/10 – 2011/12 methods included spawner surveys, video monitoring and PIT tag detection systems, and beginning in 2012/13, with the installation of the Duncans Mills antenna array, PIT tag detection systems were the primary method used.

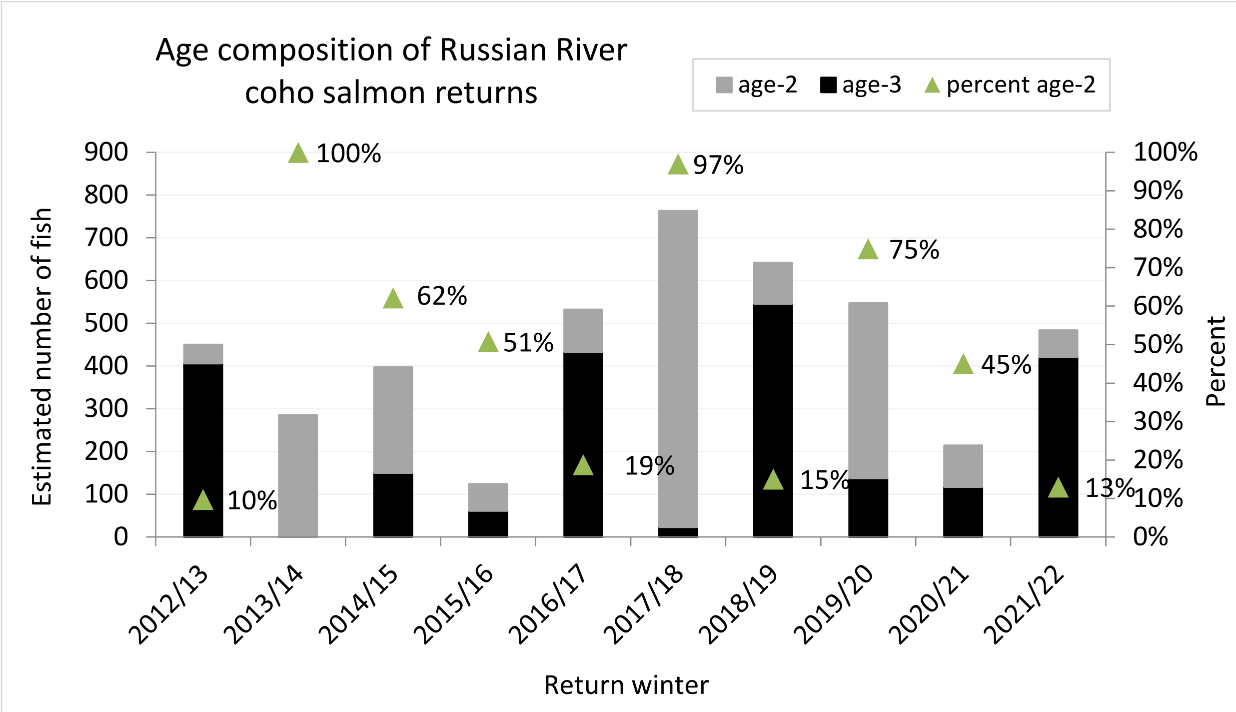


Figure 16. Estimated annual Russian River adult hatchery coho salmon returns by age, return seasons 2012/13-2021/22. Note that this figure includes only fish that we were able to age; therefore, totals will be less than adult return estimates shown in Figure 15.

3.1.3. Smolt to adult return (SAR) ratios

Estimated SAR ratios were nearly 1% in Willow, Green Valley, and Mill creeks, and over 1% in Dutch Bill Creek (Figure 17 - Figure 20, Table 8). These rates were slightly higher than rates averaged across all years of data collection (Table 8).

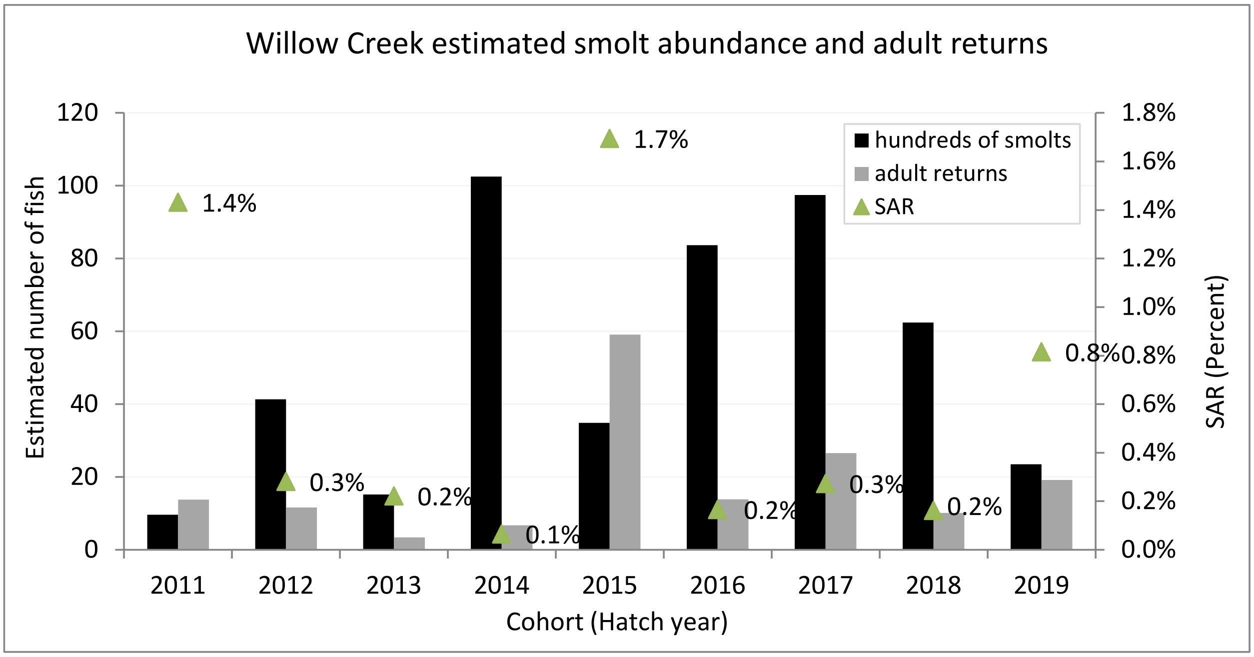


Figure 17. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Willow Creek, cohorts 2011-2019. Note that estimates are based on returns to the upper antennas at river km 3.69.

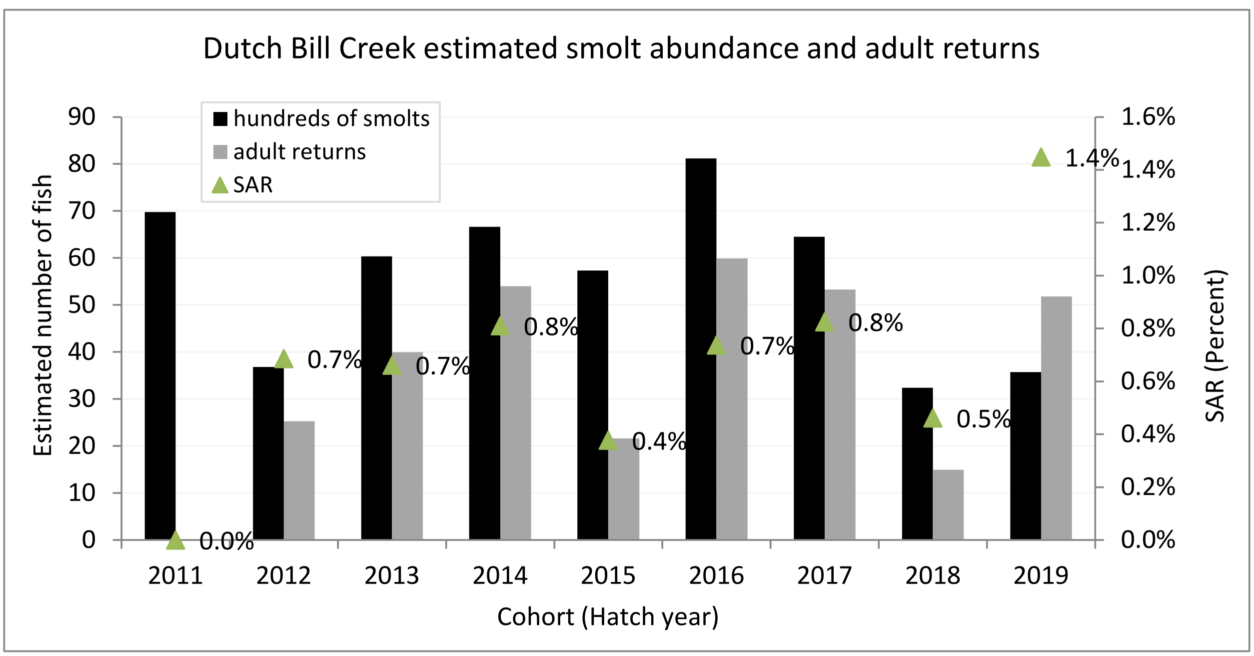


Figure 18. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Dutch Bill Creek, cohorts 2011-2019.

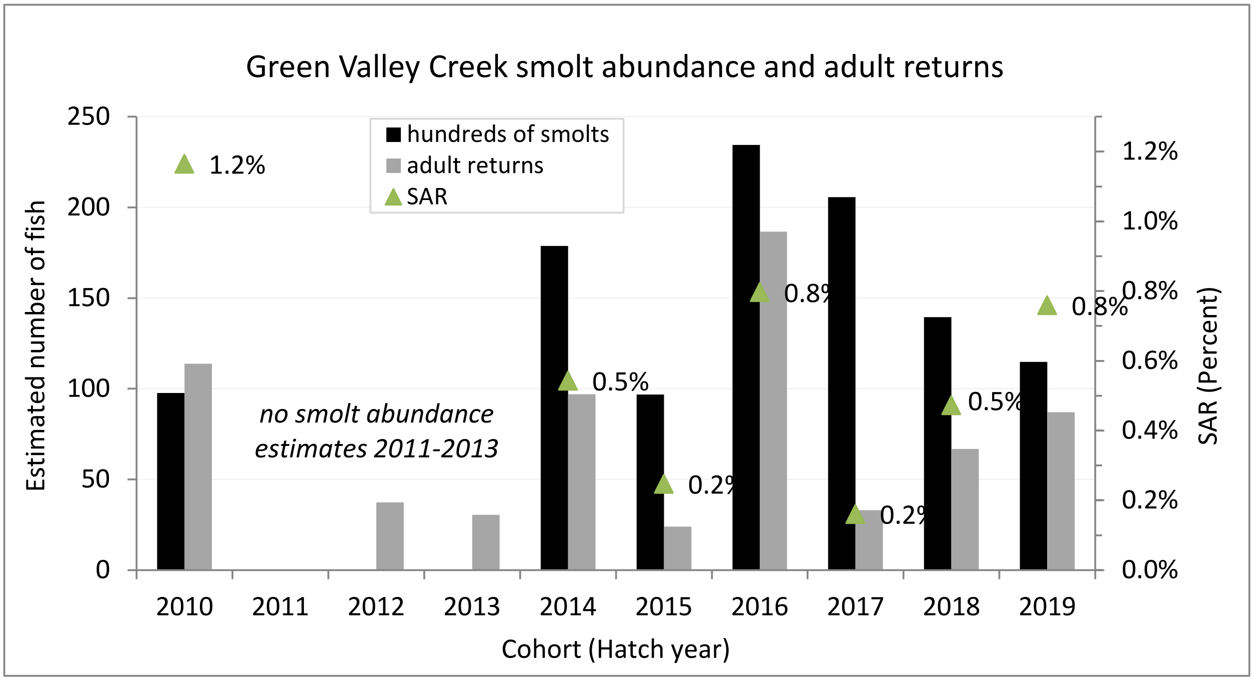


Figure 19. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Green Valley Creek, cohorts 2010-2019. Note that adult release fish returning to Green Valley Creek were excluded from SAR calculations.

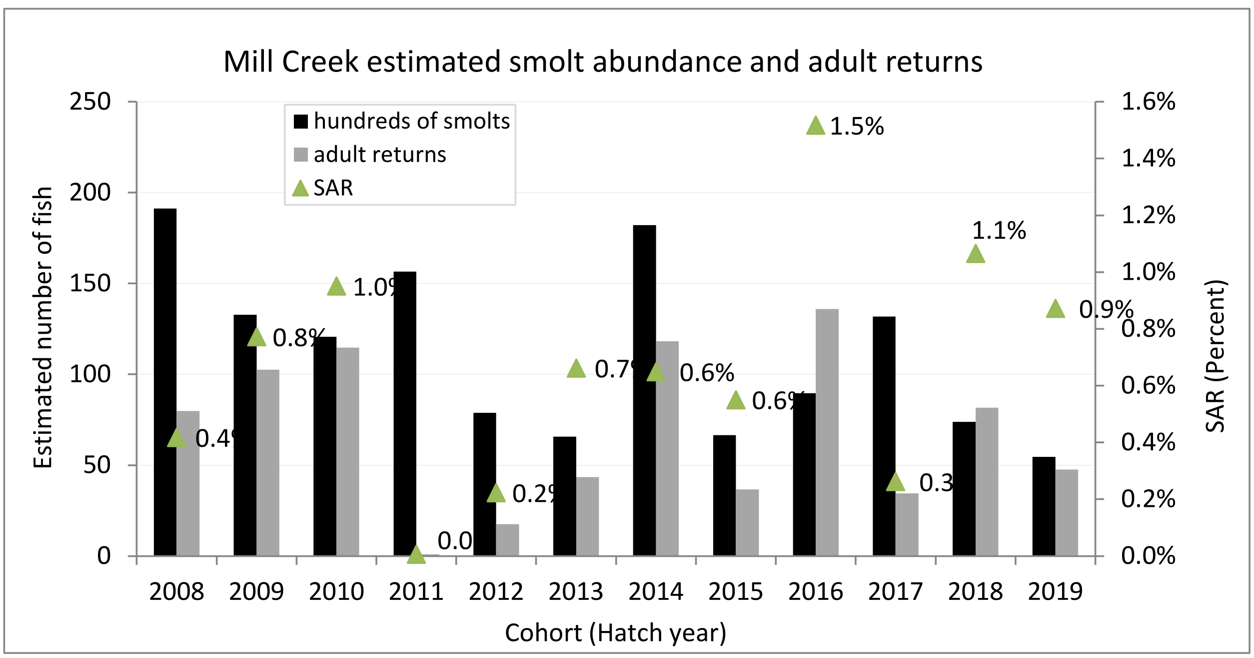


Figure 20. Estimated coho salmon smolt abundance (in hundreds), adult returns, and smolt to adult return (SAR) ratios in Mill Creek, cohorts 2008-2019. Note that adult release fish returning to Mill Creek were excluded from SAR calculations.

Table 8. Smolt to adult return (SAR) ratios estimated for Willow, Dutch Bill, Green Valley, and Mill creeks, cohorts 2008 through 2019.

		Smolt to adult return (SAR) ratio			
Cohort	**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%	1.4%	0.8%	0.9%
	Average	**0.6%**	**0.6%**	**0.6%**	**0.7%**

3.1.4. Adult release detections

Because the release of 32 PIT-tagged adult coho salmon into a Dry Creek backwater (Figure 1) occurred on February 14, 2022, we examinded PIT antenna detections of adult release fish beyond March 1 (end of typical adult coho salmon spawning in the Russian River). A total of nine unique individuals were detected following the release, between February 15 and May 10. All nine were detected at the PIT antenna at the mouth of Dry Creek (DRY-00.36). In addition being detected at the mouth of Dry Creek, one individual was also detected entering Mill Creek (MIL-02.01) on April 16, one was detected in the mainstem (MAI-28.11) and in Mark West (MAR-04.70) on April 18, one was detected in the mainstem (MAI-28.11) on April 19, and one was detected in the mainstem (MAI-28.11) on May 10.

4. Spawning surveys

4.1. Goals and objectives

Salmonid spawner surveys were conducted in Russian River tributaries to document spatial distribution and abundance of redds at both individual stream and basinwide scales. The goal for Broodstock Program monitoring was to estimate the spatial distribution and number of redds in Willow, Dutch Bill, Green Valley, and Mill creeks. These four watersheds also serve as life cycle monitoring streams for the CMP effort, which shares the goal of estimating the number of redds in each stream. In addition, the CMP effort aims to generate basinwide estimates of coho salmon and steelhead redds in the entire Russian River watershed. Unlike the sampling effort during the recent seasons 2018/19 - 2020/21, where all steelhead reaches within the CMP sample frame were surveyed, the effort this year was mostly confined to reaches within the coho salmon stratum. Surveys were conducted in coordination with SW using standardized CMP methods (Sonoma County Water Agency and Califorina Sea Grant 2015).

4.2. Methods

4.2.1. Sampling framework and survey reaches

For stream-specific estimates of redd abundance, we surveyed all accessible adult spawning reaches of Willow, Dutch Bill, Green Valley, and Mill creeks. For basinwide estimates, we used a generalized random tessellation stratified (GRTS) approach with soft stratification to survey a random, spatially-balanced selection of coho salmon and steelhead reaches (Figure 21) 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 (*O. tshawytscha*) salmon habitat).

4.2.2. 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) and redds (Figure 22). 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 2020-2021 season, we began categorically documenting the surface flow condition over observed redds. Surface flow condition over redds was categorized as 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 identification was not possible. Species, certainty of species identification, life stage, sex, certainty of sex, and fork length were recorded for all observed 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 extraction) were also retrieved from all salmonid carcasses. Geospatial coordinates were recorded for all redd and fish

[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.

observations. Presence of non-salmonid species was also documented at the reach scale. 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.

4.2.3. 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 Gallagher and Gallagher's redd species determination method (Gallagher and Gallagher 2005) with nonparametric K-nearest neighbor algorithm (KNN) used in instances where redd measurements were not available (Ricker et al. 2014a). The estimated number of unique redds was then summed for each surveyed reach. Within each reach, to account for redds missed by observers due to survey timing, the number of redds observed was expanded based upon the average observational "life span" of redds observed in that same reach (Ricker et al. 2014b). For Broodstock Program monitoring stream estimates, where census surveys were conducted, redd estimates from all tributaries and subreaches within each watershed were summed. In the Mill Creek system, the redd estimate was expanded to account for sections of stream that we were unable to sample due to lack of landowner access. This expansion was made by calculating an average redd per stream length in surveyed reaches of Mill Creek 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.

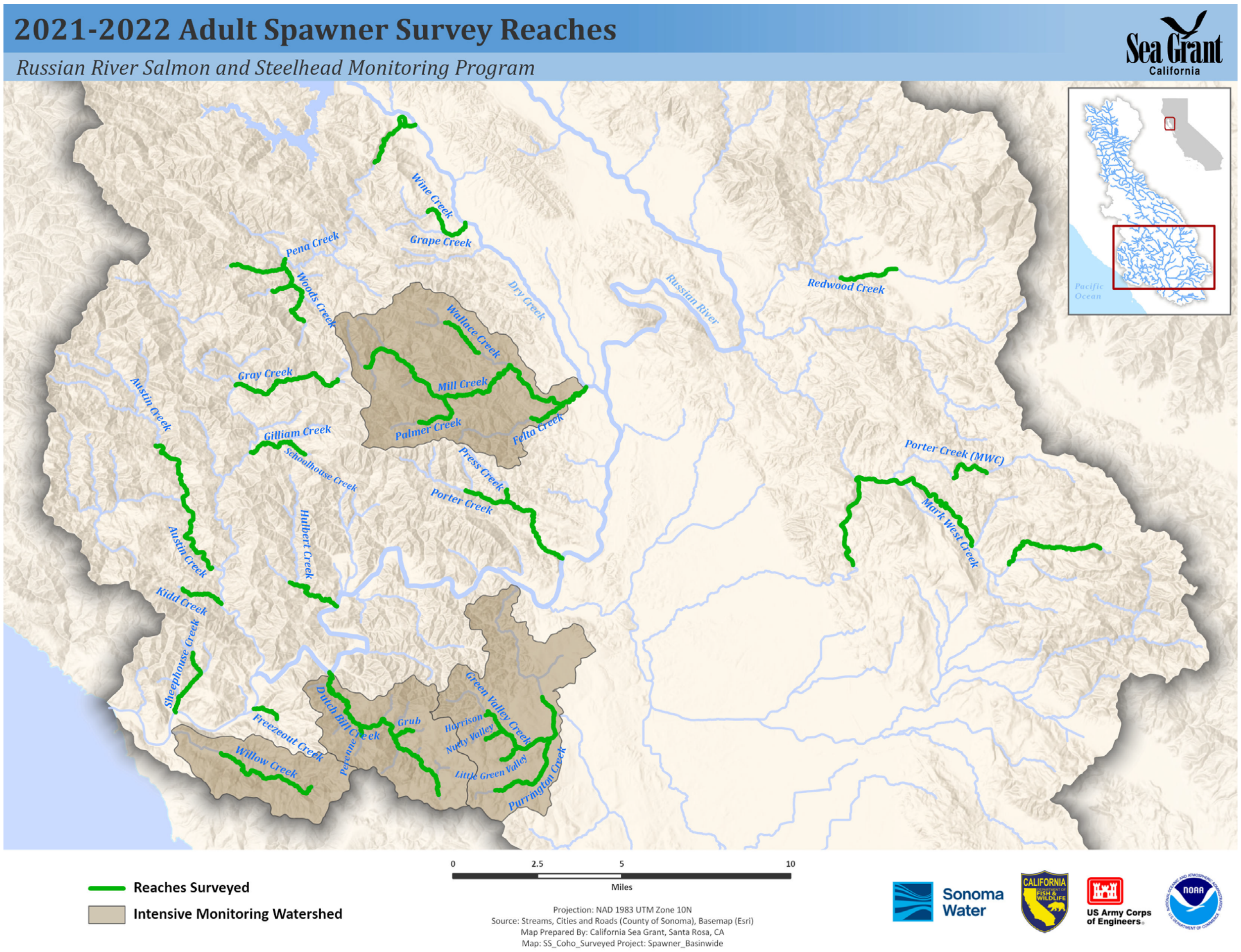


Figure 21. Broodstock Program watersheds and 2021/22 spawner survey reaches in the Russian River.

Figure 22. Adult coho salmon digging a redd in Purrington Creek, a Russian River tributary, December 19, 2021.

4.3. Results

4.3.1. Redd estimates and spawning distribution

We began surveys on November 1, 2021, following the first rain events of the season, and continued surveying through mid-April 2022. We were able to meet our goal of surveying each reach approximately every 10-14 days. Over the winter season, CSG and SW biologists completed a total of 644 salmonid spawning surveys on 44 reaches in 32 streams within the Russian River basin. A total of 259 salmonid redds were observed: 120 coho salmon redds, 70 steelhead redds, 14 Chinook salmon redds, and 55 redds of unknown salmonid species origin (Table 9). During the winter of 2021/22, coho salmon redds and/or adults were observed in 19 of 31 coho salmon streams surveyed (61%), and steelhead redds and/or adults were observed in 19 of the 31 streams that also contained coho habitat (61%) (Table 9, Figure 23, Figure 24).

Over all streams combined, timing of redd construction varied by species, with coho salmon redd observations beginning at the start of December and ending in early February, and steelhead observations occurring throughout the spawner season (Figure 25). Steelhead redd observations did not show a clear peak in frequency.

Coho salmon redd estimates in Broodstock Program monitoring watersheds ranged from 14 in Dutch Bill Creek to 36 in Green Valley Creek, and steelhead redd estimates ranged from 4 in Willow Creek to 38 in Mill Creek (Table 10).

When compared with previous years, coho salmon redd estimates were high in Willow, Dutch Bill, and Green Valley creeks, and similar to previous years in Mill Creek (Figure 26). Steelhead redd estimates were low compared to previous years in Dutch Bill Creek and approximately average in the other three Broodstock Program monitoring watersheds (Figure 27). At the basinwide scale, redd estimates for coho salmon were similar to previous years, while estimates for steelhead redds were the lowest for any season since surveys began during the 2014/15 season (Figure 28). Note that for winters 2018/19-2020/21 steelhead redd abundance was estimated for all steelhead reaches within the CMP sample frame but for all other seasons it was only estimated for the coho salmon stratum.

In the four Broodstock Program watersheds, we recovered a total of 25 coho salmon carcasses. The average proportion of natural-origin adult coho salmon carcasses across all four watersheds was 22%, with the proportion of untagged fish ranging from 71% in Willow Creek to 0% in Dutch Bill and Mill creeks (Table 11).

Coho salmon and steelhead redds were observed in all four broodstock streams and distribution of each species varied among streams (Figure 29 - Figure 32). In Willow and Dutch Bill creeks, spawning occurred throughout the surveyed reaches with the highest concentrations in the middle section for both species (Figure 29, Figure 30). In the Green Valley Creek watershed, coho salmon redds occurred throughout the watershed but densities for coho salmon were highest in the upper portion of the watershed and both steelhead and coho salmon redds were observed in Purrington Creek (Figure 31). In the Mill Creek watershed, coho salmon and steelhead redd densities were highest in the lower part of the watershed and in Felta Creek, though redds were also observed in Palmer Creek and the reach of Mill Creek immediately downstream of the confluence with Palmer Creek (Figure 32).

Table 9. Salmonid redds observed by species during winter 2021/22 in Russian River tributaries.

Tributary	Length surveyed (km)	Coho salmon	Steelhead	Chinook salmon	Salmonid	Total
Austin Creek	8.9	3	6	0	4	13
Dead Coyote Creek	1.1	2	0	0	0	2
Dutch Bill Creek	11.4	12	2	0	4	18
Felta Creek	2.0	7	1	0	3	11
Freezeout Creek	1.5	0	0	0	0	0
Gilliam Creek	2.6	0	1	0	0	1
Grape Creek	1.5	0	0	0	0	0
Gray Creek	6.3	1	1	0	0	2
Green Valley Creek	7.0	20	4	0	6	30
Grub Creek*	1.1	0	0	0	0	0
Harrison Creek	0.2	1	0	0	0	1
Hulbert Creek	3.2	1	0	0	0	1
Kidd Creek	2.5	1	1	0	1	3
Little Green Valley Creek	1.2	0	0	0	0	0
Mark West Creek	19.2	9	2	0	2	13
Mill Creek	16.6	4	19	0	2	25
Mission Creek	0.4	0	0	0	0	0
Nutty Valley Creek	1.2	4	1	0	3	8
Palmer Creek	2.9	0	2	0	1	3
Pena Creek	7.5	10	14	8	8	40
Perenne Creek	0.5	2	0	0	0	2
Porter Creek	7.4	3	1	0	3	7
Porter Creek (MWC)	2.4	0	0	0	0	0
Press Creek	0.6	0	0	0	0	0
Purrington Creek	4.8	10	5	0	4	19
Redwood Creek	3.0	0	2	0	1	3
Schoolhouse Creek	1.1	0	0	0	0	0
Sheephouse Creek	3.7	1	1	0	0	2
Wallace Creek	2.5	0	0	0	0	0
Willow Creek	6.0	17	2	0	3	22
Wine Creek	1.8	0	1	0	1	2
Woods Creek	4.1	12	4	6	7	29
Total	**136.2**	**120**	**70**	**14**	**53**	**257**

** Steelhead-only tributary*

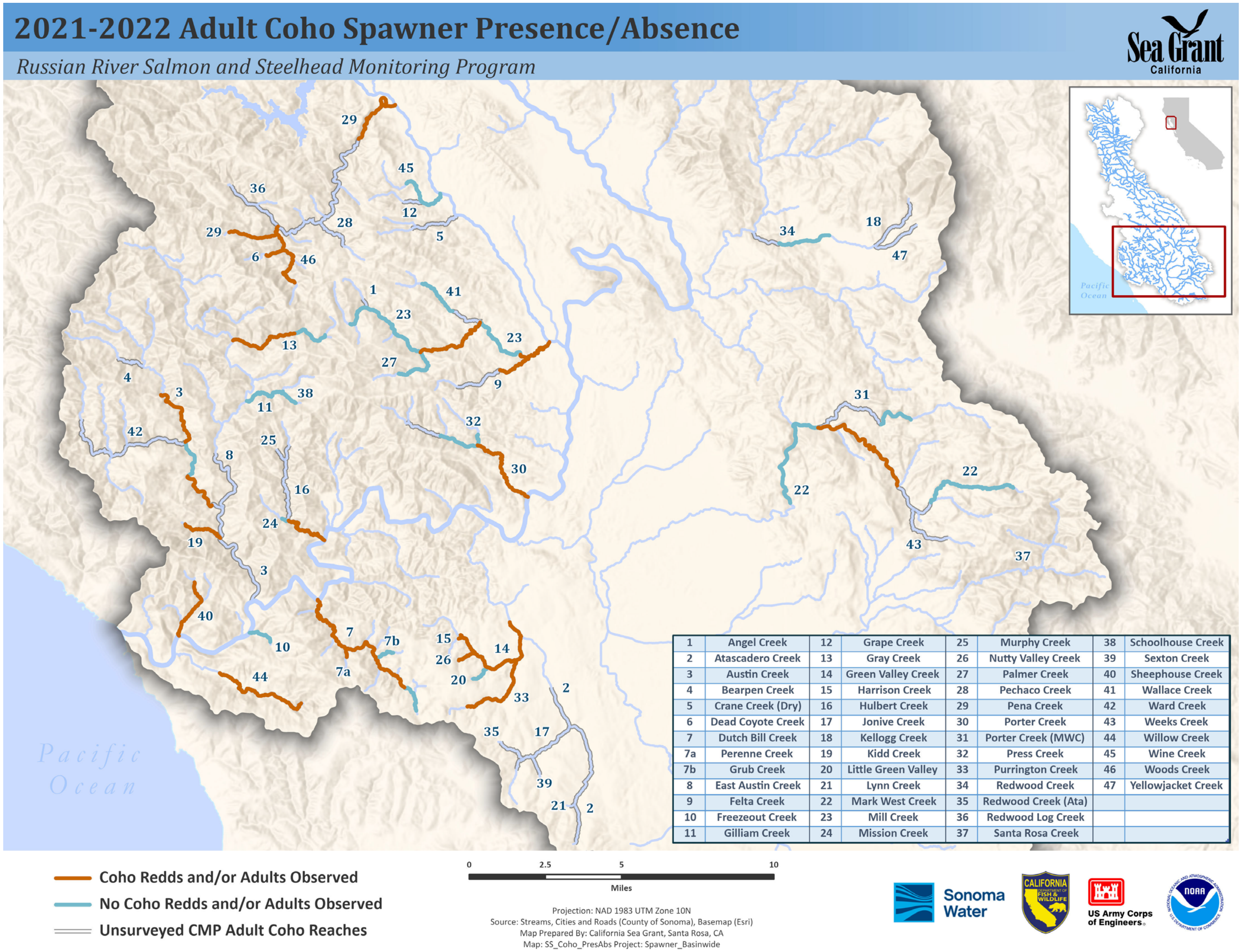
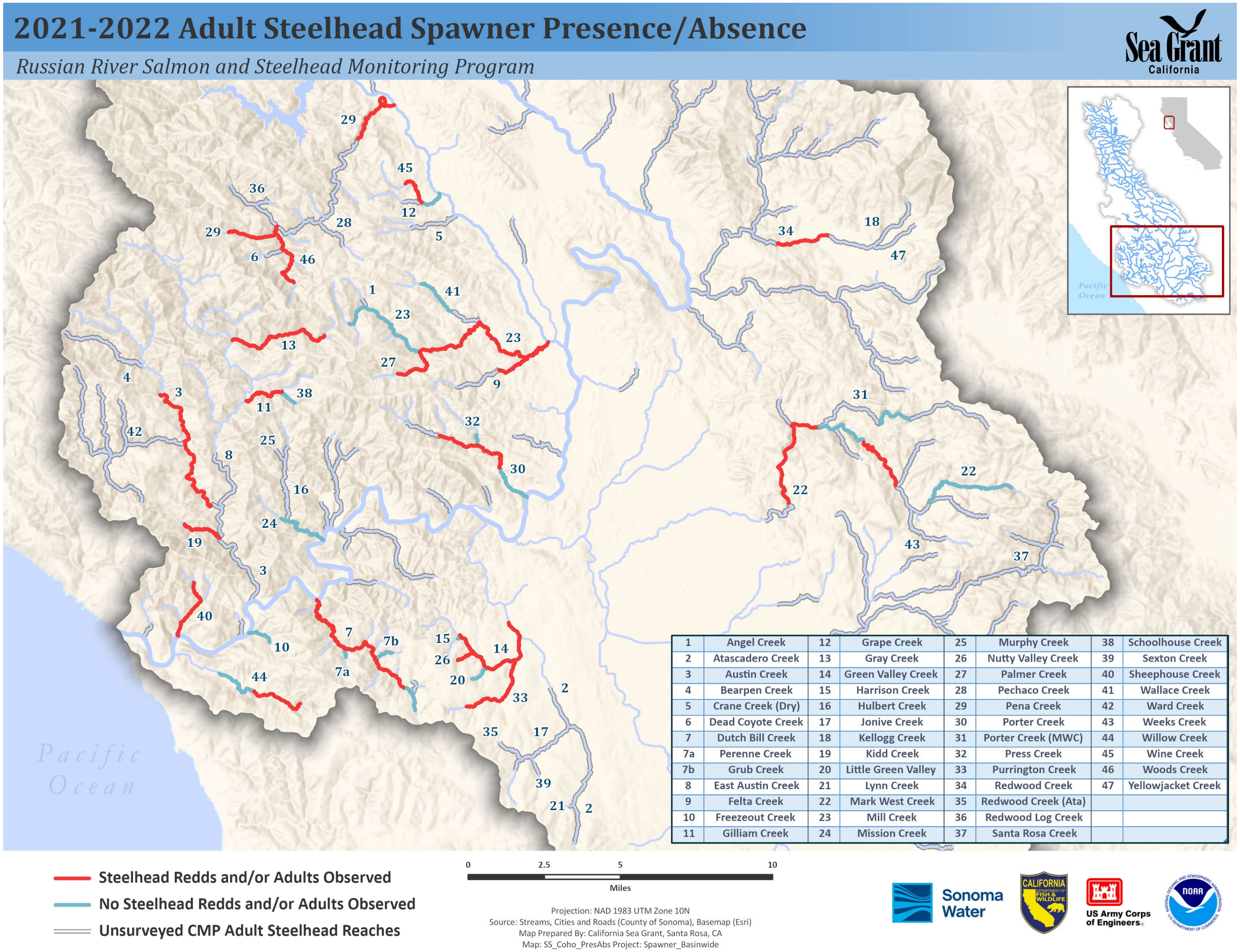


Figure 23. Coho salmon redd and/or adult presence or absence, winter 2021/22.



1	Angel Creek	12	Grape Creek	25	Murphy Creek	38	Schoolhouse Creek
2	Atascadero Creek	13	Gray Creek	26	Nutty Valley Creek	39	Sexton Creek
3	Austin Creek	14	Green Valley Creek	27	Palmer Creek	40	Sheephouse Creek
4	Bearpen Creek	15	Harrison Creek	28	Pechaco Creek	41	Wallace Creek
5	Crane Creek (Dry)	16	Hulbert Creek	29	Pena Creek	42	Ward Creek
6	Dead Coyote Creek	17	Jonive Creek	30	Porter Creek	43	Weeks Creek
7	Dutch Bill Creek	18	Kellogg Creek	31	Porter Creek (MWC)	44	Willow Creek
7a	Perenne Creek	19	Kidd Creek	32	Press Creek	45	Wine Creek
7b	Grub Creek	20	Little Green Valley	33	Purrington Creek	46	Woods Creek
8	East Austin Creek	21	Lynn Creek	34	Redwood Creek	47	Yellowjacket Creek
9	Felta Creek	22	Mark West Creek	35	Redwood Creek (Ata)		
10	Freezeout Creek	23	Mill Creek	36	Redwood Log Creek		
11	Gilliam Creek	24	Mission Creek	37	Santa Rosa Creek		

Figure 24. Steelhead redd and/or adult presence or absence, winter 2021/22.

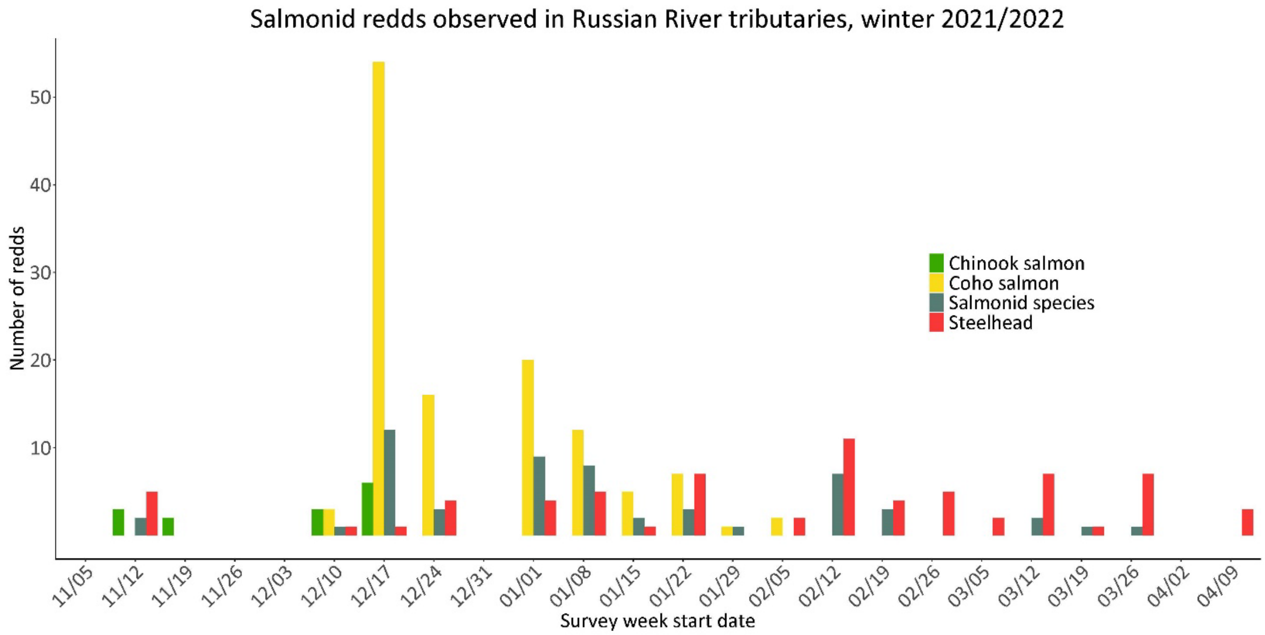


Figure 25. Number of new salmonid redds observed each week in Russian River Coastal Monitoring Program survey streams, winter 2021/22.

Table 10. Estimated coho salmon and steelhead redds and adults in four Russian River watersheds, winter 2021/22.

Tributary	Coho	Steelhead
Willow Creek	18	4
Dutch Bill Creek	14	6
Green Valley Creek	36	22
Mill Creek	22	38

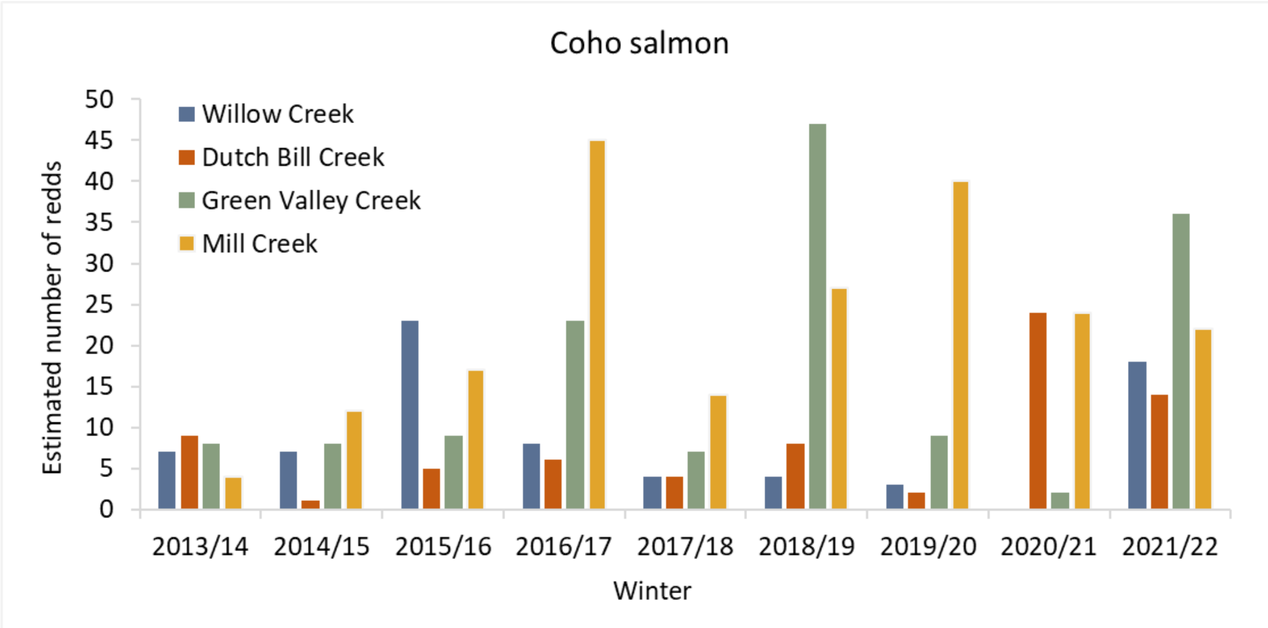


Figure 26. Estimated coho salmon redds in Broodstock Program monitoring tributaries, return winters 2013/14 through 2021/22.

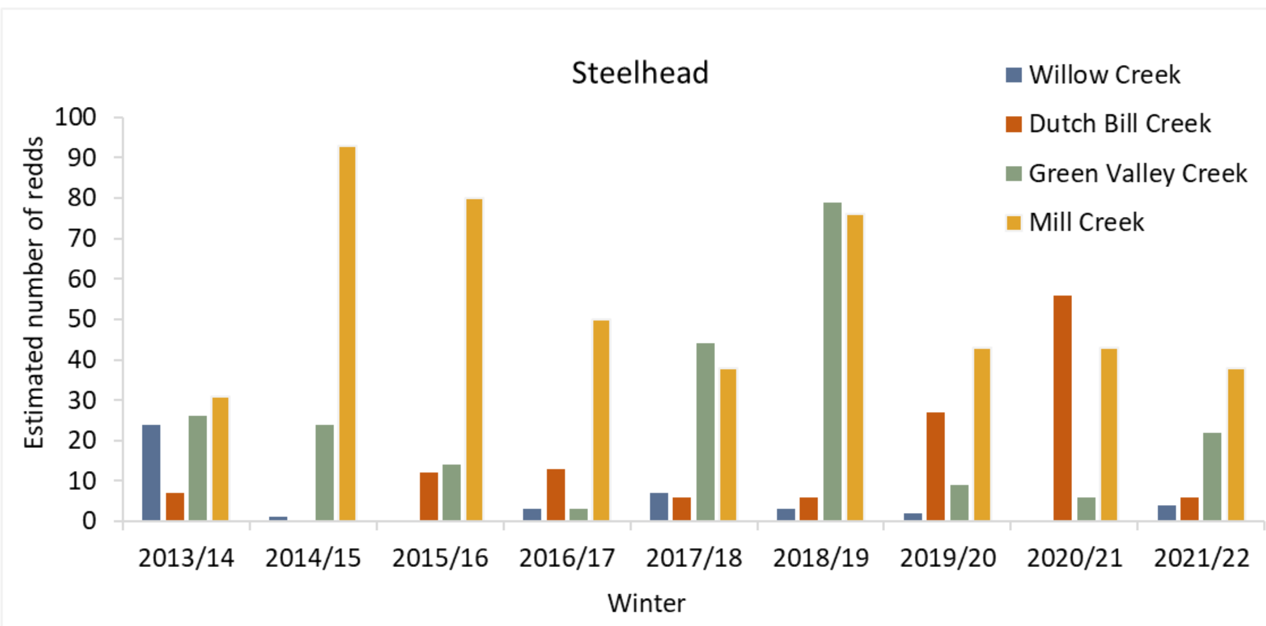


Figure 27. Estimated steelhead redds in Broodstock Program monitoring tributaries, return winters 2013/14 – 2021/22.

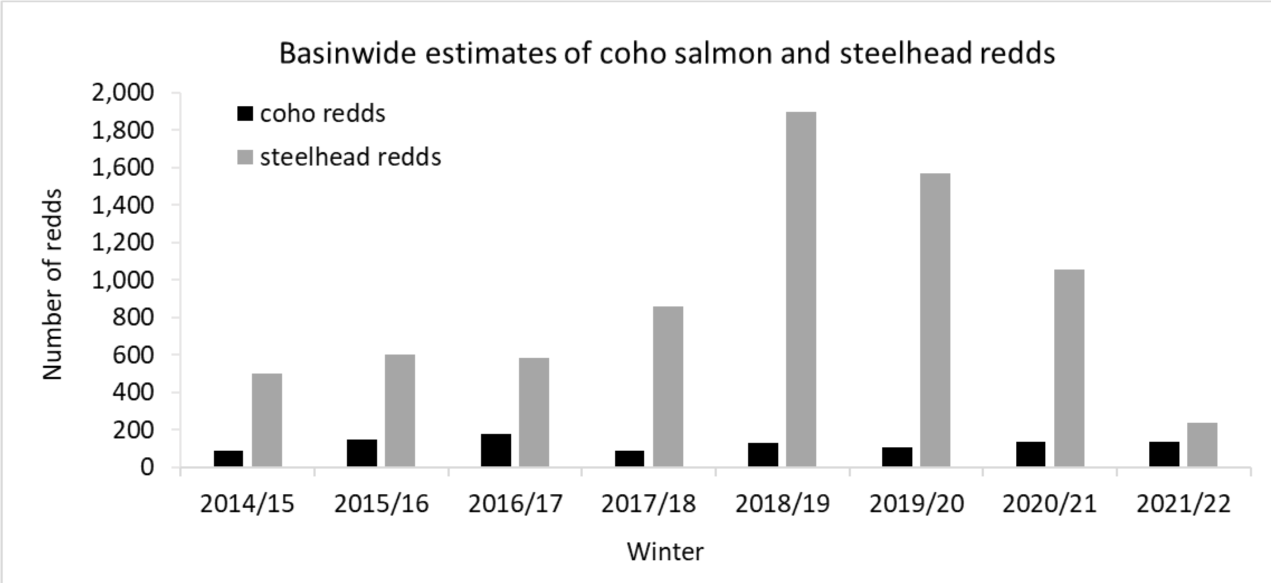


Figure 28. Basinwide estimates of coho salmon and steelhead redds in the Russian River watershed, return winters 2014/15 through 2021/22. Note that for winters 2018/19-2020/21 steelhead redd abundance was estimated for all steelhead reaches within the CMP sample frame but for all other seasons it was only estimated for the coho salmon stratum.

Table 11. Coded wire tag (CWT) observations in coho salmon carcasses recovered during spawner surveys, 2021/22.

Tributary	CWT observed	CWT not observed	Proportion untagged (presumed natural-origin)
Willow Creek	2	5	71%
Dutch Bill Creek	1	0	0%
Green Valley Creek	11	2	15%
Mill Creek	4	0	0%
		Average:	22%

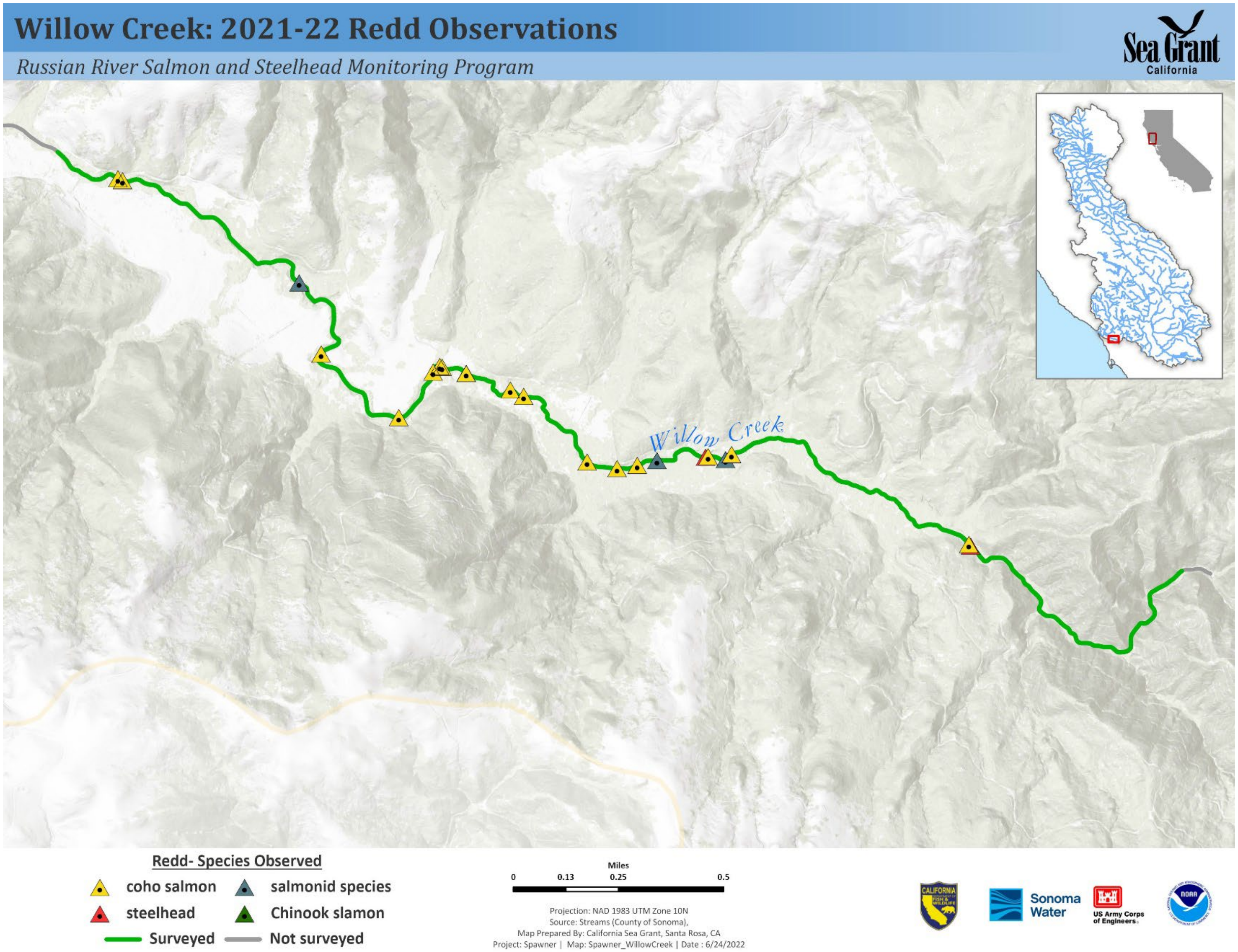


Figure 29. Salmonid redds observed in Willow Creek during winter 2021/22.

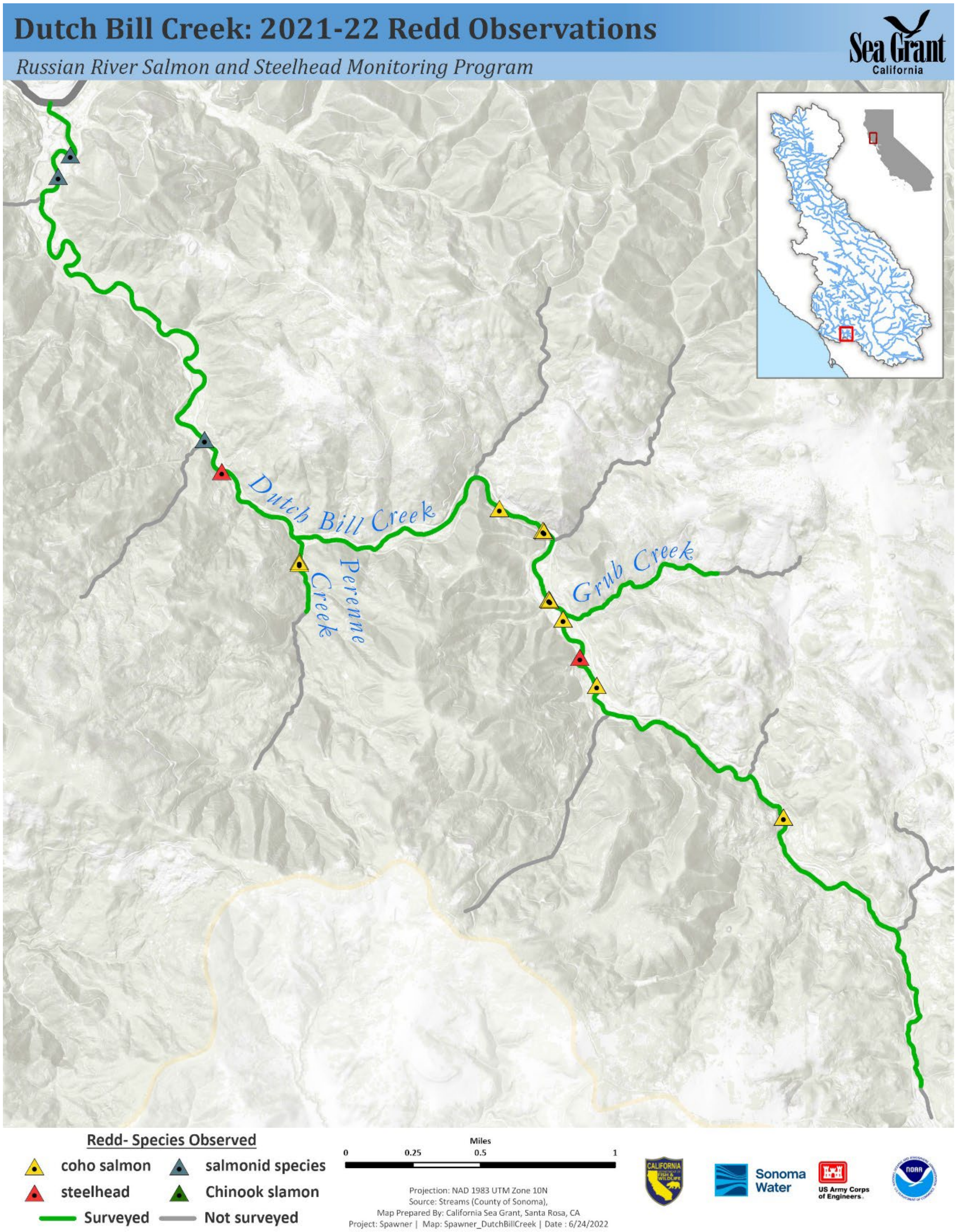


Figure 30. Salmonid redds observed in Dutch Bill Creek during winter 2021/22.

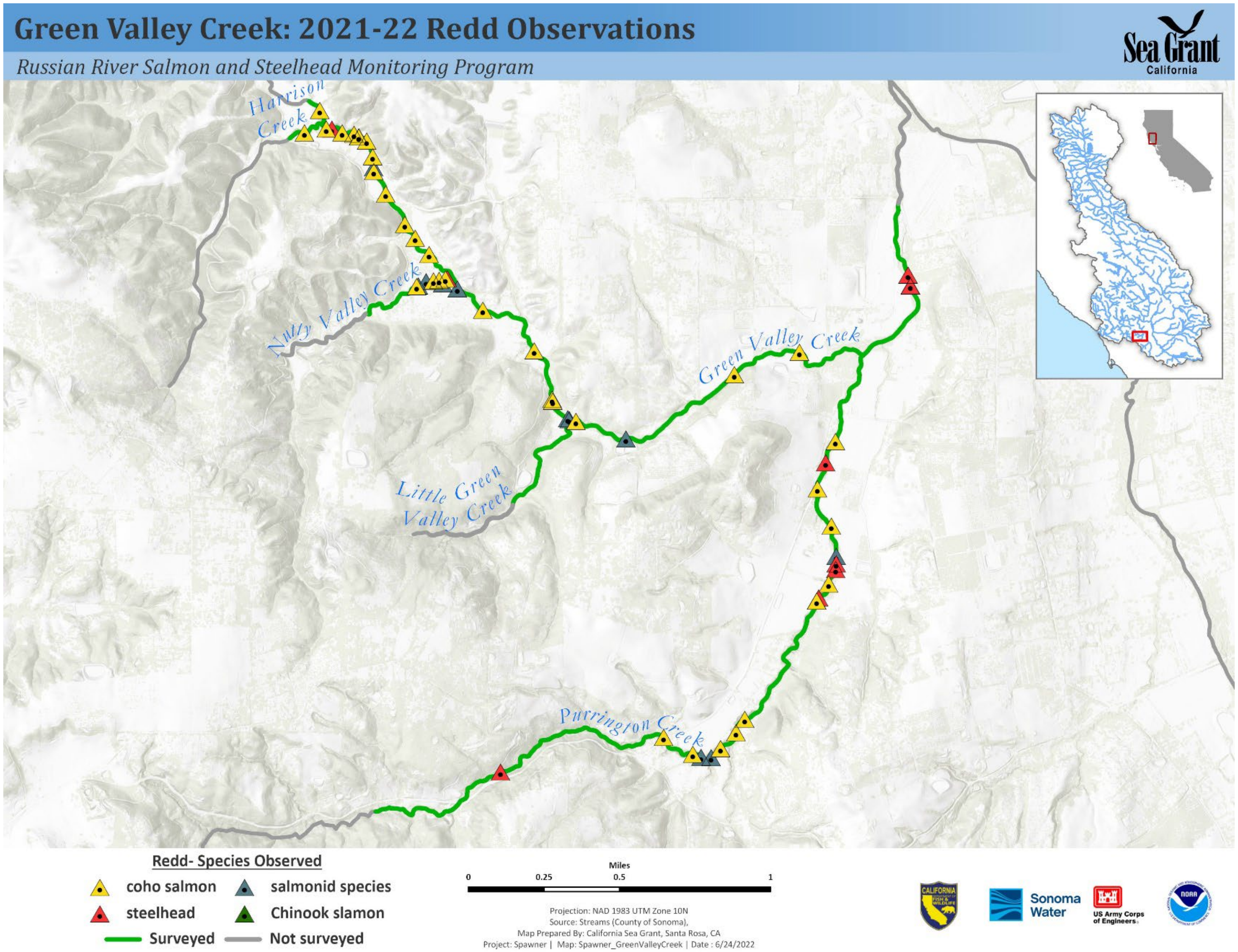


Figure 31. Salmonid redds observed in the Green Valley Creek watershed during winter 2021/22.

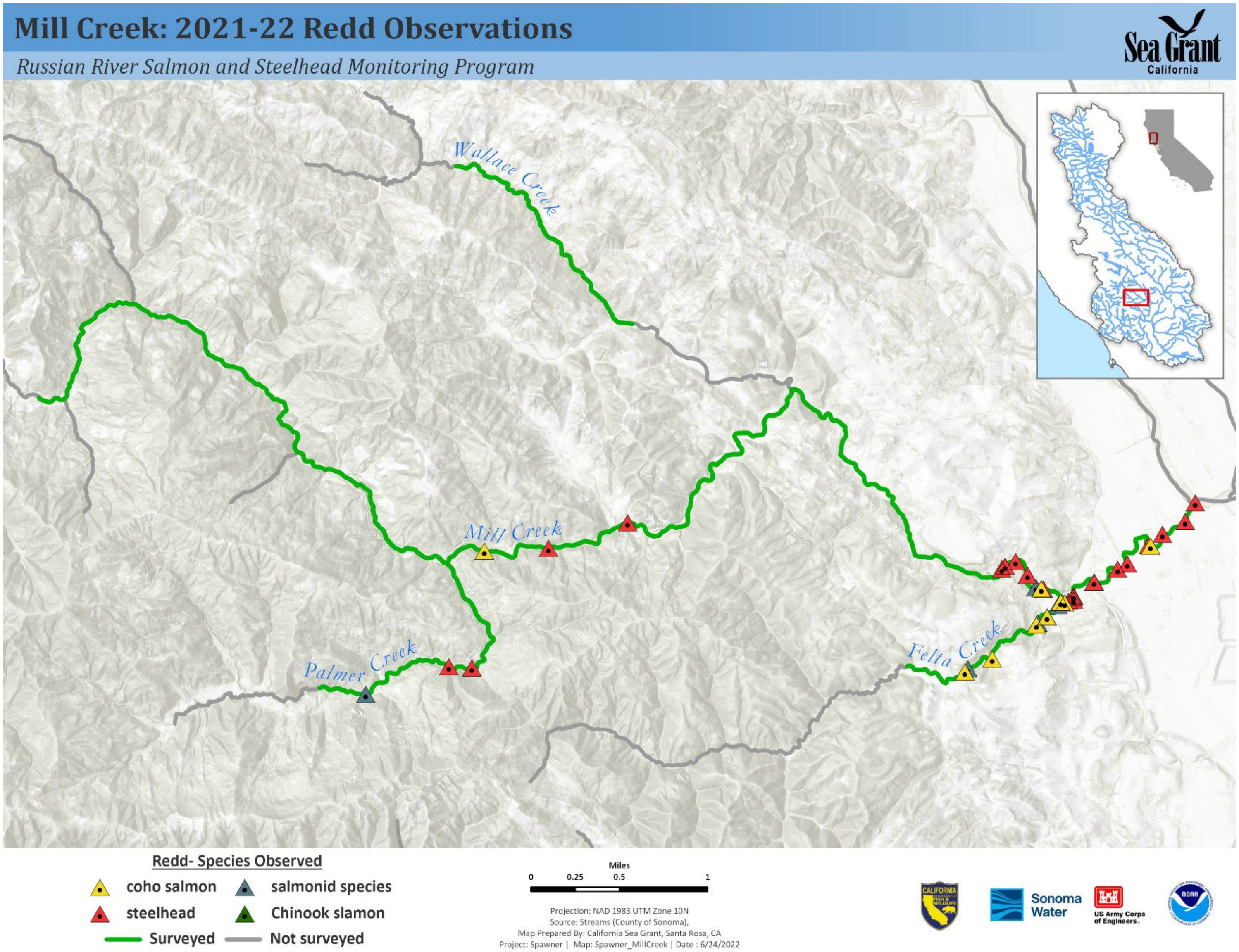


Figure 32. Salmonid redds observed in the Mill Creek watershed during winter 2021/22.

5. Discussion and recommendations

5.1. Effects of flow on adult returns

The wet season of 2021/22 began with an uncharacteristic atmospheric river event in October followed by extremely low precipitation in January and February. Total precipitation between 9/15/21 and 3/1/22 at NOAA's Venado rain gage (California Data Exchange Center, https://cdec.water.ca.gov/queryTools.html), located in the headwaters of Mill Creek, was 37 inches, which is 72% of the 15-year average and the fifth lowest over the 15-year period (Figure 3). Almost half of the season's precipitation (48%) fell in one week during the October rain event (10/17-27/2021), followed by near-average precipitation in November and December and almost no precipitation in January through March (Figure 33). These precipitation patterns resulted in high flows in the early part of the spawning season with the latter half characterized by low streamflow (Figure 4).

In most years, Russian River tributaries where coho salmon and steelhead spawn become disconnected from the mainstem of the river during the summer dry season, limiting adult fish passage until the tributaries reconnect. While adult coho salmon are often documented entering the mainstem of the river in October, the first redds observed in the tributaries coincides with the occurrence of sufficient precipitation to reconnect the tributaries, which typically occurs following storms in late November or early December. Unlike most years, the high rainfall in October of 2021 reconnected the spawning tributaries much earlier than usual, allowing adults access to spawning habitat as soon as they entered the river. Despite the earlier access, the majority of the adult coho salmon that entered the river in October and November did not migrate up into the spawning tributaries until mid-December when a second series of storms occurred (Figure 5, Figure 6). This suggests that factors other than passage (e.g., maturation or water chemistry) may also influence migration timing in Russian River coho salmon populations.

The unusual precipitation pattern impacted returning adult coho salmon and steelhead in different ways due to differences in average run timing. Based on redd observations over nine years, the majority of coho salmon spawning activity in the Russian River occurs in December and January, while steelhead spawner activity largely takes place between late January and early April (Figure 34). The high flows during the peak of coho salmon spawning likely allowed coho salmon access to more stream habitat than in most years, as evidenced by a greater number of redds observed in smaller tributaries such as Harrison, Nutty Valley, and Perenne creeks (Table 9, Figure 23) compared to previous years. Throughout the basin, adult coho salmon presence was documented in 19 of 31 coho salmon streams surveyed (61%), which is higher than the average observed over the past six years (average 49%, range 24% - 65%). The early high flows may also have contributed to a slightly higher than the average basinwide redd estimate (Figure 28) and slightly higher SAR ratios (Table 8). For steelhead, the low winter flows that occurred during all but the beginning of their migration window likely limited their access to upper reaches and smaller tributaries in the latter half of the steelhead run. This likely contributed to the low number of steelhead redds observed as compared to previous winters (Figure 23). The steelhead redd estimate for 2021/22 was less than half of the lowest estimate from the past seven years. Despite historically low steelhead redd estimates, steelhead spatial distribution within the coho salmon sample frame was only slightly lower than the average for the past five years, perhaps because the early spawners were widely distributed. Adult steelhead presence within the coho salmon sample frame was

61%, whereas in the previous five years, it averaged 63% and ranged from 50% to 82% (Table 9, Figure 23).

In addition to impeding adult steelhead access to spawning habitat, the extreme low flows in January and February likely impacted both coho salmon and steelhead spawning success by dropping to levels that exposed redds, particularly those located in smaller tributaries or along stream margins. Partial or full drying within 60 days of first observation was observed for 28 of the 109 coho salmon redds (26%) and 28 of 134 steelhead redds (21%). Although the impact of stream drying on early life stage survival is complex and influenced by hyporheic flow, temperature, dissolved oxygen, gravel composition and life stage (Becker and Neitzel 1985), it is likely that redd success was at least somewhat impaired.

The proportion of age-3 fish for the 2021-2022 spawning season was higher than average for the Russian River (Figure 16). The high number of age-3 fish is a positive indicator of population health and was somewhat surprising considering the low number of coho salmon yoy observed during snorkel surveys in 2019 and only average smolt abundance estimates from downstream migrant trapping during the 2020 season (California Sea Grant 2020a; California Sea Grant 2020b). However, the low number of age-2 adults observed in 2021-2022 is concerning and may reflect a combination of challenging summer conditions for hatch year 2020 natural-origin juveniles and poor smolt survival during the 2021 smolt migration. Snorkel counts for coho salmon yoy during the summer 2020 were the highest observed since the beginning of basinwide CMP surveys in 2015; however, widespread drying occurred in the tributaries over the summer of 2020 and likely led to extensive juvenile mortality (California Sea Grant 2020c). Additionally, smolt outmigration throughout the Russian River watershed in the spring of 2021 was impaired by low streamflow, with stream disconnection observed all four broodstock watersheds during the March–June smolt migration. Overwinter survival for 2020 fall-release fish in Broodstock Program monitoring watersheds was the lowest our program has observed, likely due to low flow impediments to migration. Smolt size and growth rates can influence age-2 return rates; however, both of these metrics for cohort 2020 coho salmon captured during downstream trapping were similar to historical averages in the Broodstock Program watersheds so this seems unlikely to be an explanation for the low age-2 return rates (California Sea Grant 2021a). Of the nine tagged age-2 adults detected returning during the 2021-2022 season, four were released as smolts in the mainstem Russian River and two were early migrants from Green Valley Creek that were detected heading downstream in mid-December 2020, providing additional evidence that outmigration challenges in spring 2021 may have limited the number of 2-year olds returning.

In response to low flow conditions in tributaries in 2020, hatchery smolt releases primarily took place in Dry Creek and the mainstem Russian River. In low flow years, Dry Creek, which has regulated flows, has often been chosen as a release location. In order to study the survival and travel time of coho salmon smolts released in Dry Creek, SW and USACE conducted an acoustic telemetry study with hatchery coho salmon released into Dry Creek during the spring of 2021. This study estimated the probability of survival to be 0.19 from the release site in Dry Creek to the lower end of the Russian River estuary, with the mortality largely concentrated in the mainstem of the Russian River. Although additional years of data are needed, these preliminary results indicate that in low flow years, mainstem survival for emigrating coho salmon smolts may be poor. Combined with disconnection in tributaries that prevented many out migrating smolts from reaching the mainstem, this could have led to significantly reduced numbers of fish available to return as jacks. None of the fish that returned as jacks were released in Dry

Creek, which suggests that in low flow years lower Russian River releases may be a preferable release strategy.

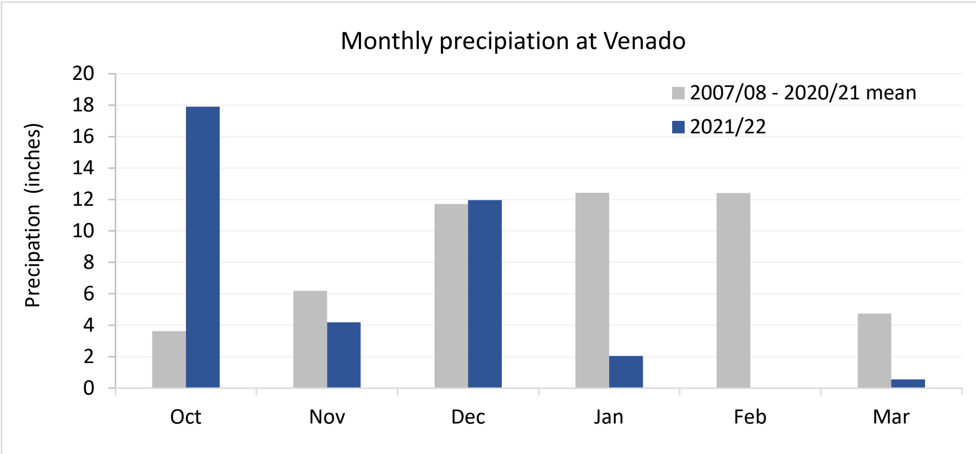


Figure 33. Monthly precipitation at Venado gage. Data were obtained from the California Data Exchange Center (https://cdec.water.ca.gov).

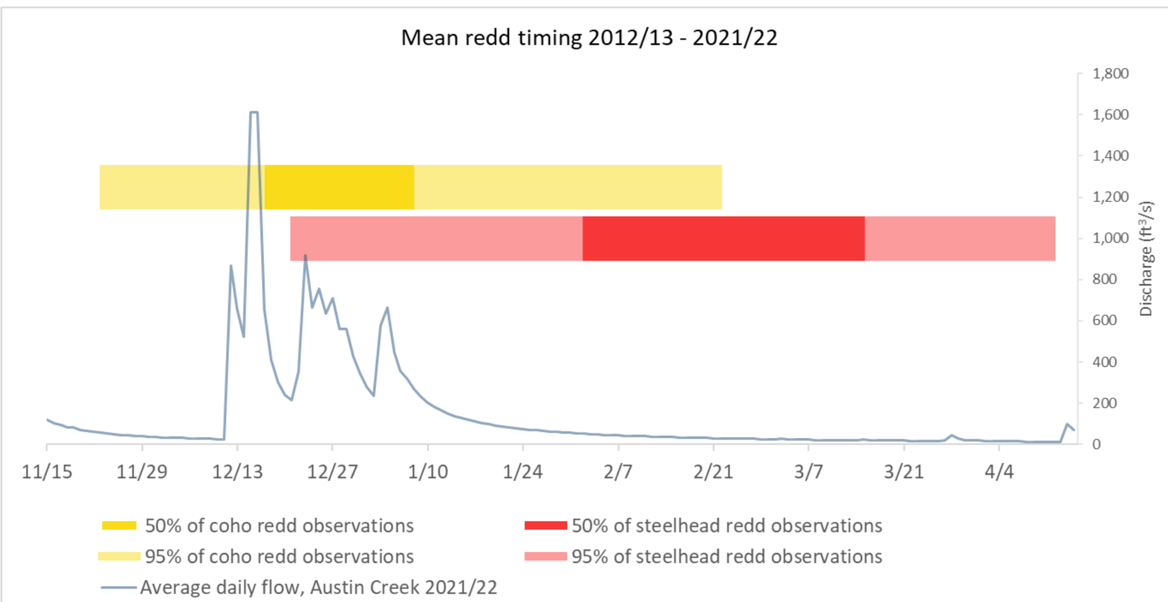


Figure 34. Timing distribution of redd observations during spawner seasons 2012/13-2021/22 and average daily streamflow for Austin Creek near Cazadero during the 2021/22 spawner season. Streamflow data were obtained from USGS (waterdata.usgs.gov).

5.2. Adult returns from pre-smolt and smolt releases

To evaluate the adult return rates of coho salmon pre-smolt and smolt releases, we summed the number of unique adult PIT tag detections on any PIT antenna operated in the Russian River watershed during subsequent return winters. We then compared those totals with the numbers of PIT-tagged pre-smolts and smolts released to calculate a minimum stock to adult return rate.

We first examined adult return rates by release timing by combining results across all streams for releases occurring in the Russian River watershed from 2009 through 2020 (cohorts 2008-2019) and using six date range bins corresponding to two week intervals between February 15 and May 31. We observed that early release timing, especially in the first half of March, resulted in higher adult return rates (Table 12, Figure 35). However, caution should be taken in drawing conclusions relative to release timing due to small sample sizes and inconsistencies in release numbers across streams and years, as well as annual differences in spring streamflow conditions.

We examined adult return rates by release location over the past decade, using data from return winters of 2012/13 through 2021/22. Over the course of 10 return winters, a total of 315 unique PIT-tagged adults were detected, representing 0.34% of the total number of PIT-tagged fish released as pre-smolts or smolts (Table 13). The percent of adults detected returning was less than 0.5% in all streams and was highest overall for the Green Valley and Mark West creek releases. Nearly half of the detected fish were adults returning as age-2 fish.

For all pre-smolt and smolt release groups, adults were detected returning to multiple Russian River tributaries (Table 14). The Russian River and Green Valley Creek release groups had detections in the greatest number of tributaries on average with some cohorts returning to up to six different tributaries in a given winter (Table 13). We also documented inter-basin movement of coho salmon from the Russian River into Walker Creek, a watershed located to the south of the Russian River where California Trout has operated PIT antennas for two winters. During the winter 2020/21, an age-3 adult from a Green Valley pre-smolt release was detected in Walker Creek, and during the winter 2021/22, an age-2 adult from a Russian River release was detected.

The Dry Creek smolt release group had the highest overall return rate to the stream of release (74%) but for that group, fish were also detected at all Russian River antenna locations (Table 14). Green Valley and Dutch Bill creeks also had relatively higher rates of fidelity, while fish from Willow and Mark West creeks were had lower overall rates. This could be an artifact of low sample size, but could also be explained by the potentially longer imprinting times on Dutch Bill and Green Valley creeks; in Dutch Bill Creek, USACE has conducted streamside tank imprinting and in Green Valley Creek, travel time of released smolts takes longer than in other creeks, naturally allowing for more imprinting time. An alternative possibility for the lower fidelity observed in fish released into Willow and Mark West creeks is that those streams likely have greater passage issues in low flow years, which could reduce the fish's ability to return to their streams of release in drier years. Investigation of return rates for specific release groups into these streams in relation to flow and fish passage would help shed light on this topic.

Interestingly, fish from all release groups, even those released into lower river tributaries, have been detected in the Dry Creek watershed (Table 14). In previous reports we have summarize data that suggests that in lower flow years, a higher proportion of lower river release fish return to Dry Creek (California Sea Grant 2021b) where flow is less of a passage impediment. Because the source of the water at the hatchery is Dry Creek, it is also likely that all fish have imprinted to some extent on Dry Creek and have a greater tendency to return there.

We do not view the fact that pre-smolt and smolt release adults are returning to multiple streams within the watershed as a problem, necessarily. In addition to olfactory imprinting, homing and straying are influenced by factors such as adult maturation processes, reproductive behavior, environmental conditions during migration, and senescence physiology (Bett and Hinch 2015; Keefer and Caudill 2014;

Peterson et al. 2016). In the Russian River watershed, causes of inter-tributary movement might include low flow passage impediments, presence of other adults, and water quality and/or habitat preferences. Such inter-tributary movement could result in increased survival and genetic exchange.

The fact that adult return rates to streams in which efforts have been made to imprint fish (Dutch Bill, Mill and Green Valley creeks) are similar to other release streams (Table 13, Table 14) suggests that smolt releases into Dry Creek or the mainstem, which are logistically simpler, may be just as effective. They also have the benefit of increasing smolt survival to the ocean and reducing predation on coho salmon and steelhead young-of-year in the smaller tributaries.

To specifically compare return rates for the Dry Creek and lower Russian River smolt release groups, we summarized data for the four cohorts in which releases were made in both locations (Table 15). We found that in years with average or low flow during the smolt migration, a higher proportion of adults returned for the lower Russian River releases, while the Dry Creek release had a higher rate of return for the cohort whose smolts migrated in higher flow conditions (Figure 36). This result aligns with recent findings from an acoustic tagging study led by SWand USACE to estimate coho salmon smolt survival through the mainstem of the Russian River (Horton et al. 2021). In 2021, the first year of this study and an extreme drought year, Horton et al. (2021) found that coho salmon survival probability from Dry Creek to the head of the estuary was only 0.19. While more years of data are needed to fully understand whether flow is the driving factor of smolt survival through the Russian River, based on this preliminary evidence, we recommend releasing smolts in the lower Russian River (as opposed to Dry Creek or other tributaries) during low flow years.

Table 12. Stock to adult return rates for coho salmon smolt and pre-smolt releases into the Russian River watershed. Releases were combined across all streams and evaluated across six date range bins to evaluate differences in release timing. Results do not account for different numbers of fish released into different tributaries each year.

	Release date range						
Cohort (hatch year)	**2/15 - 2/29**	**3/1 - 3/15**	**3/16 - 3/31**	**4/1 - 4/15**	**4/16 - 4/30**	**5/1 - 5/15**	**5/15 - 5/31**
2008			0.20%				
2009			0.30%	0.20%			
2010				0.52%	0.47%		1.06%
2011		0.03%			0.15%	0.00%	0.00%
2012		0.50%	0.63%	0.37%	0.00%	0.34%	0.25%
2013		0.23%	0.25%	0.25%	0.00%	0.33%	0.00%
2014	0.38%	0.35%	0.32%		0.43%	0.39%	1.27%
2015				0.69%	0.30%	0.07%	0.40%
2016		1.25%	0.88%	0.68%	0.33%	0.72%	0.44%
2017			0.22%	0.16%	0.16%	0.15%	0.05%
2018		0.57%	0.52%	0.38%	0.21%		
2019			0.51%	0.19%	0.10%	0.59%	
Average:	**0.38%**	**0.48%**	**0.38%**	**0.34%**	**0.26%**	**0.34%**	**0.29%**

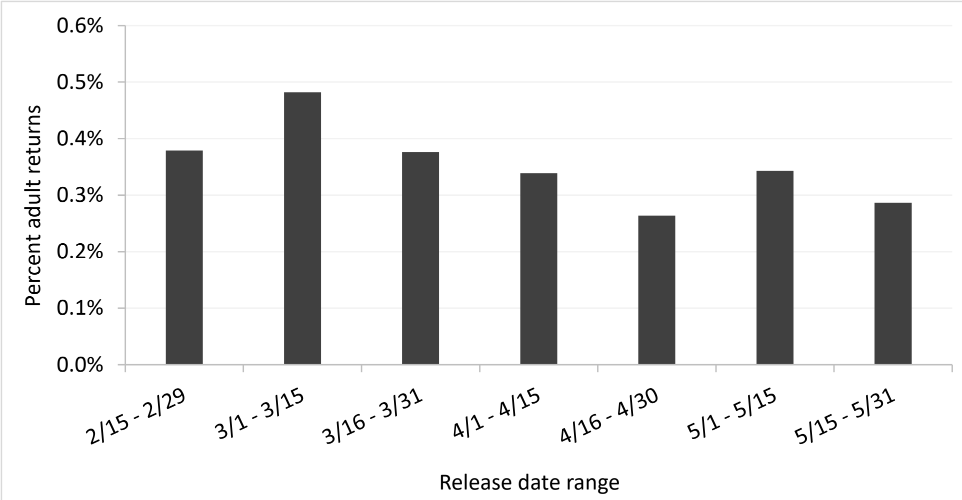


Figure 35. Percent adults returning from coho salmon pre-smolt and smolt releases into the Russian River watershed from 2009 through 2020 (cohorts 2008-2019) by release timeframe.

Table 13. Summary of adult coho salmon returns from pre-smolt and smolt releases into the Russian River, cohorts 2010 – 2020 returning during winters 2012/13 through 2021/22. Note that antenna efficiency was not accounted for and antennas were not operated on all streams in all years.

Release tributary	Number of years smolts or pre-smolts released	Number of PIT-tagged fish released	Total unique PIT-tagged adult detections (all ages)	Percent detected returning	Number of unique age-2 PIT-tagged adult detections	Percentage age-2 adult returns detected	Mean number (range) of tributaries where adults were detected annually
Willow Creek	4	6,663	11	0.17%	2	18%	2.0 (1-3)
Russian River	4	7,490	21	0.28%	9	43%	4.3 (2-6)
Austin Creek	2	2,208	6	0.27%	2	33%	1.0 (0-3)
Dutch Bill Creek	10	9,677	26	0.27%	5	19%	1.1 (0-4)
Green Valley Creek	11	20,623	92	0.45%	44	48%	3.8 (1-6)
Mark West Creek	4	6,247	27	0.43%	19	70%	2.5 (1-5)
Dry Creek	11	29,882	105	0.35%	57	54%	3.2 (1-5)
Mill Creek	8	9,292	27	0.29%	13	48%	1.8 (0-4)
	Total or mean:	**92,082**	**315**	**0.34%**	**151**	**48%**	**2.4 (0-6)**

Table 14. Number of unique PIT-tagged coho salmon adults detected in each tributary where PIT antennas were operated for at least two winters between 2012/13 and 2021/22. Note that within each year, adults were frequently detected in multiple streams, and those fish were counted once in each stream; therefore, the sum of all detections across stream sites is greater than the number of total unique fish. The percentage documented returning to the stream of release is shown in parentheses for release streams where antennas were operated.

Release stream (downstream -> upstream)	Willow Creek (mouth)	Willow Creek	Estuary (Duncans Mills)	Dutch Bill Creek	Green Valley Creek	Russian River (Mirabel)	Mark West Creek	Porter Creek	Dry Creek	Mill Creek	Grape Creek	Warm Springs Hatchery	Walker Creek (outside of Russian River)	Total unique fish
Willow Creek	4	2 (18%)	9	2	1	2		1	3	1				11
Russian River	3		6	6	4	5		1	1	6		1	1	22
Austin Creek			4		1				2	1				6
Dutch Bill Creek			18	14 (54%)		1		1	4	1		1		26
Green Valley Creek	2		3	3	51 (55%)	32	4	7	37	19		4	1	92
Mark West Creek	1		7	1		15	8 (30%)	1	8	1		2		27
Dry Creek	3	1	5	3	6	44	1	3	74 (74%)	3	6	4		100
Mill Creek			19	1	2	8		1	12	11 (42%)				26

downstream -> upstream

Years of antenna operation: Mark West: 5, Porter: 5, Grape: 3, Russian River: 9, Walker: 2, all other sites: 10.

Table 15. Number of coho salmon adult returns in relation to number of fish released for smolt releases into Dry Creek and the lower Russian River for cohorts 2017 – 2020. Note that cohort 2020 fish have only had an opportunity to return as age-2 adults so we suspect that number to increase if age-3 adults return during the winter of 2022/23.

Cohort (Hatch year)	Age-3 return winter	Release location	Total released	*Estimated adult returns* Age-2 (n)	Age-3 (n)	Total (n)	Total (%)	Spring flows during smolt migration
2017	2019/20	Dry Creek	10,105	0	10	10	0.10%	average
		Russian River	10,103	0	20	20	0.20%	
2018	2020/21	Dry Creek	10,118	45	25	70	0.69%	high
		Russian River	10,144	10	5	15	0.15%	
2019	2021/22	Dry Creek	15,135	0	13	13	0.09%	low
		Russian River	10,079	20	47	67	0.66%	
2020	2022/23	Dry Creek	10,156	0	NA	0	0.00%	low
		Russian River	12,572	33	NA	33	0.26%	

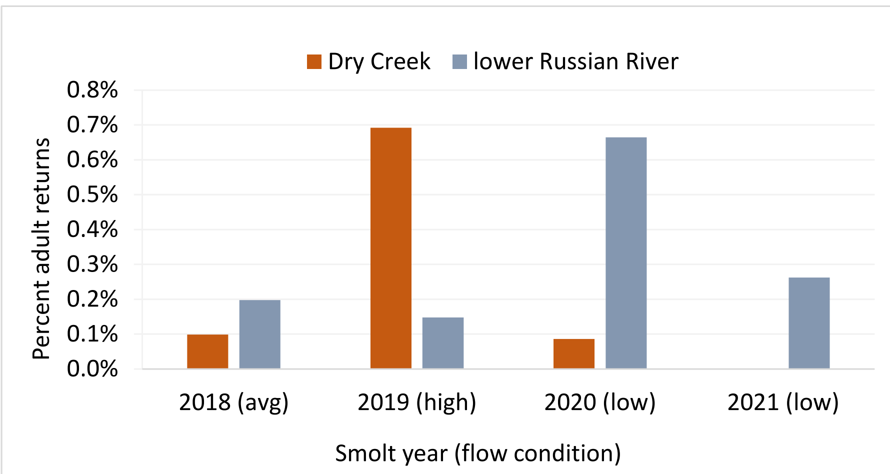


Figure 36. Comparison of coho salmon adult return rates of smolt releases into Dry Creek and the lower Russian River in low, average and high flow years.

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