Coho Salmon and Steelhead Monitoring Report

Winter 2020/21

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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 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 populations in four Broodstock Program release streams: Willow, Dutch Bill, Green Valley, and Mill creeks. Data collected from this effort are provided to the Broodstock Program for use in adaptively managing future releases.

Over the last decade, CSG has developed many partnerships in salmon and steelhead 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 stream flow and juvenile coho survival as part of the Russian River Coho Water Resources Partnership (Coho Partnership), an effort to improve stream flow and water supply reliability to water-users in flow-impaired Russian River tributaries. In 2013, we partnered with the Sonoma County Water Agency (Sonoma Water) 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. These new projects 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 several 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, 2020, through March 1, 2021, 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 monitoring streams (Willow, Dutch Bill, Green Valley, and Mill). In addition, we were able to estimate these metrics for the Russian River basin overall with the exception of SAR ratios 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 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 ≥ 56mm and ≥2g, a small incision was made on the ventral side of the fish using a scalpel, and the 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 2020/21, we anticipated the return of PIT-tagged adults from cohorts 2018 (age-3 returns) and 2019 (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 2019 and 2020 were PIT tagged in Willow, Green Valley, and Mill creeks (California Sea Grant 2019; California Sea Grant 2020). 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 2019 and 2020.

Other adults present in the Russian River during the winter of 2020/21 originated from a Broodstock Program release of 195 adult coho salmon into the mainstem of the Russian River at Steelhead Beach (Table 2, Figure 1) on January 7, 2021. Of the 195 adult coho salmon released at this location, 182 contained a PIT tag. These adult hatchery coho salmon were originally destined for release into Salmon Creek; however, due to low flow conditions in the Salmon Creek watershed, the Broodstock Program chose to release them in the mainstem of the Russian River where flows remained higher.

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 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, 2020 through March 1, 2021, 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 Sonoma Water, including a 10-antenna array located in the mainstem of the Russian River near Duncans Mills (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	194,007	31,062	16%

[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, 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

Table 2. Number and percent of PIT-tagged coho salmon released into Russian River tributaries by stream and release group, cohorts 2018 and 2019.

Cohort (Hatch year)	Tributary	Release group	Total coho salmon released	PIT-tagged coho salmon released	Percent PIT-tagged coho salmon released
2018	Willow Creek	fall	8,194	1,620	20%
2018	Willow Creek	presmolt	7,111	1,400	20%
2018	Sheephouse Creek	fall	3,038	610	20%
2018	Freezeout Creek	fall	2,043	410	20%
2018	Austin Creek	fall	4,157	810	19%
2018	East Austin Creek	fall	4,152	810	20%
2018	Gilliam Creek	fall	3,039	610	20%
2018	Gray Creek	fall	4,041	810	20%
2018	Devil Creek	fall	3,035	610	20%
2018	Dutch Bill Creek	fall	7,062	1,410	20%
2018	Dutch Bill Creek	smolt	5,047	1,020	20%
2018	Green Valley Creek	fall	7,063	1,410	20%
2018	Green Valley Creek	presmolt	8,054	1,600	20%
2018	Green Valley Creek	smolt	5,077	1,020	20%
2018	Redwood Creek (Atascadero)	fall	3,005	610	20%
2018	Purrington Creek	fall	3,016	610	20%
2018	Mark West Creek	presmolt	7,135	1,599	22%
2018	Porter Creek	fall	5,073	1,010	20%
2018	Dry Creek	fall	5,076	1,020	20%
2018	Dry Creek	smolt	10,118	2,040	20%
2018	Mill Creek	spring	1,010	1,010	100%
2018	Mill Creek	fall	8,164	1,620	20%
2018	Mill Creek	smolt	5,087	1,020	20%
2018	Palmer Creek	fall	5,073	1,010	20%
2018	Russian River	smolt	10,144	2,040	20%
2018	Russian River	adult	195	179	92%
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	fall	3,538	530	15%
2019	Gray Creek	rsi	4,774	0	0%
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	Mill Creek	spring	511	511	100%
2019	Mill Creek	fall	15,069	2,259	15%
2019	Palmer Creek	fall	4,536	680	15%
2019	Russian River	smolt	10,079	1,514	15%

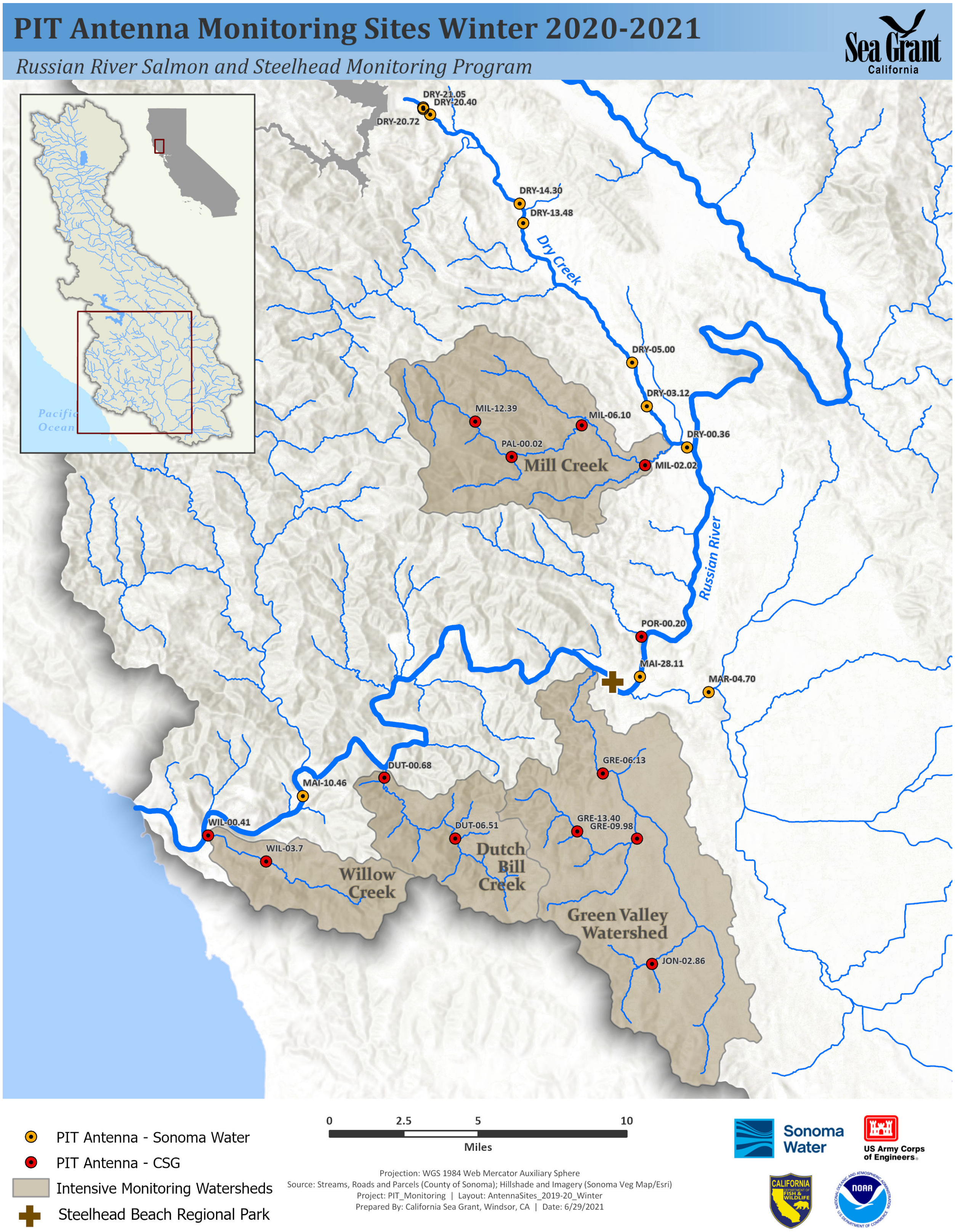


Figure 1. Passive integrated transponder (PIT) antenna locations in the Russian River watershed, winter 2020/21. Labels on antennas include a stream code (first three letters of a stream) and the distance in km from the mouth of the stream.

Figure 2. Paired flat-plate antenna array on Willow 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, 2020 and March 1, 2021 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, 2020 and March 1, 2021 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.

In years prior to winter 2020/21, 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.

During the winter of 2020/21, low antenna efficiencies at the Duncans Mills antenna array (likely caused by high salinities due to estuary closure dynamics) prevented us from using the adult estimation approach used in previous years (described above). As an alternative, we first summed the number of unique adult PIT tag detections on any antenna that was operated in the watershed during the winter of 2020/21, then divided the number of unique individuals from each release group by the proportion tagged for that release group (Table 2), 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. However, unlike the Duncans Mills antenna array, antenna efficiencies in the tributaries were generally high in winter 2020/21 because streamflow was low and we did not encounter equipment malfunctions or power outages.

2.2.3.3. Smolt to adult return (SAR) ratios

In each of the four Broodstock Program monitoring streams, the sum of the estimated number of two-year old hatchery adults returning during the winter of 2019/20 and three-year old adults returning during the winter of 2020/21 was divided by the estimated number of smolts migrating from each stream between March 1 and June 30 of 2019 to derive the 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 adults from the January 7 adult release were excluded from SAR calculations.

3. Results

3.1.1. Adult return timing relative to flow conditions

Total precipitation between September 15, 2019 and March 1, 2020 was below the 15-year average (Figure 3) and this translated into streamflow that was also well below average in Russian River tributaries, (e.g., Austin Creek, Figure 4). Although small rain events occurred in both November and December, the first significant rain event was not until late January, likely limiting adult coho access into the tributary spawning habitat. PIT antenna detections of adults passing over the Mirabel antenna array on the mainstem of the Russian River (river km 28.11) occurred between late October and the second week of January (Figure 1, Figure 5). Timing of entry into Dry Creek was very similar to the mainstem (Figure 6). In Willow Creek, adult coho were first detected at the array just upstream of the confluence with the Russian River (WIL-0.41) in November; however, they were not detected entering the spawning habitat located upstream of the upper array (WIL-3.69) until the first significant rain event at the end of January 2021 (Figure 7). The first detections of adult coho in Dutch Bill Creek also occurred at the end of January (Figure 8), whereas in Green Valley and Mill creeks, detections first occurred during a smaller rain event during the first week of January (Figure 9, Figure 10).

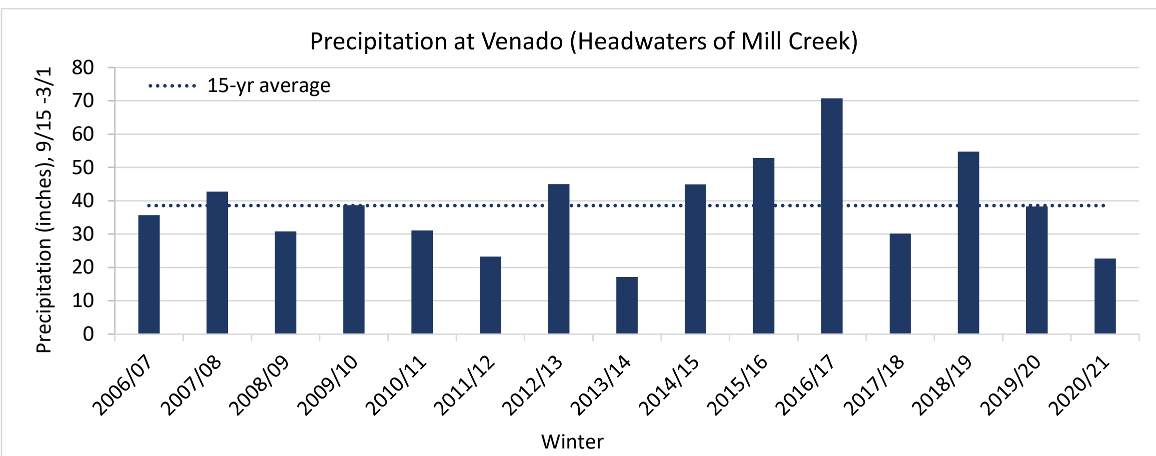


Figure 3. Precipitation at Venado gage near Mill Creek headwaters. Data was downloaded from the NOAA website.

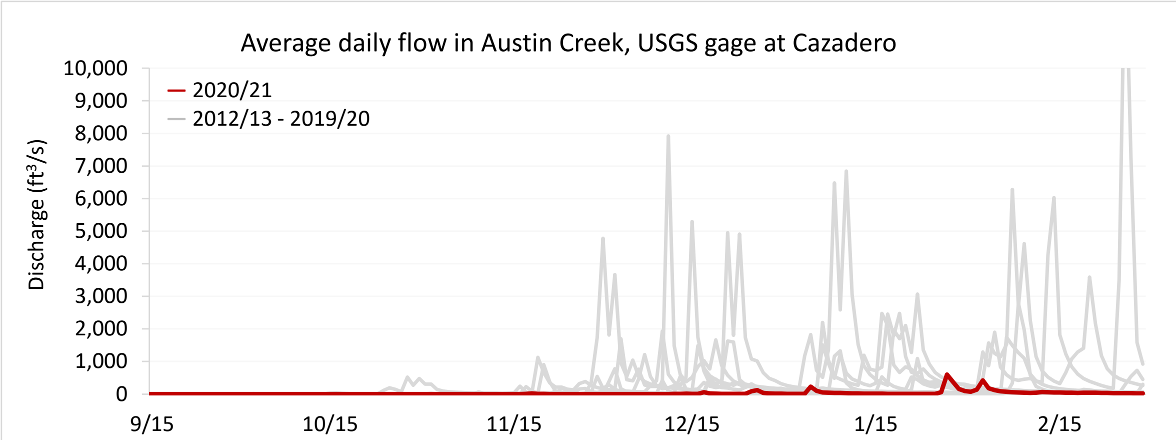


Figure 4. Winter 2020/21 streamflow in Austin Creek as compared to streamflow during the previous eight winters. Data was downloaded from the USGS website.

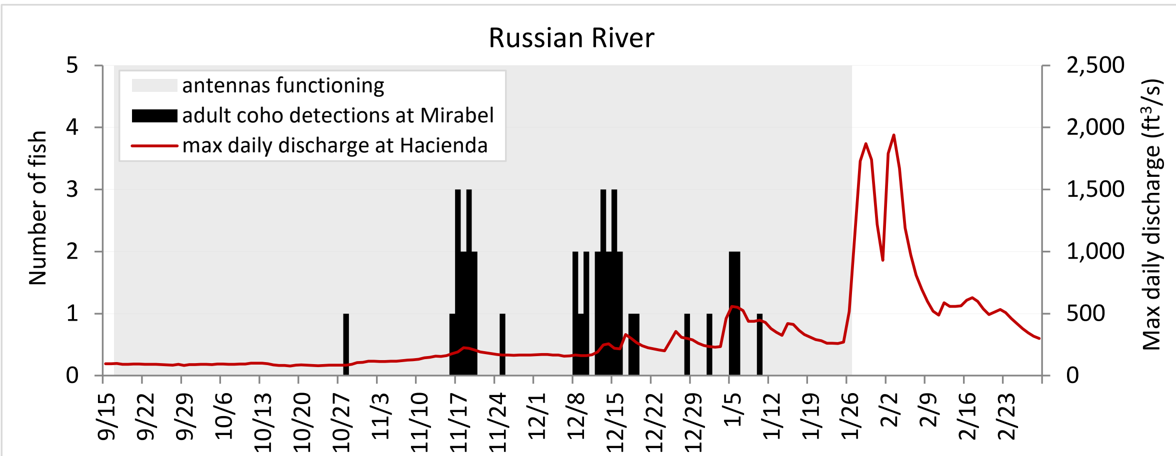


Figure 5. Detections of PIT-tagged coho salmon adults passing upstream of the Mirabel Russian River antenna array, September 15, 2020 - March 1, 2021. Adult release detections are not included. Discharge data was downloaded from USGS website: http://waterdata.usgs.gov.

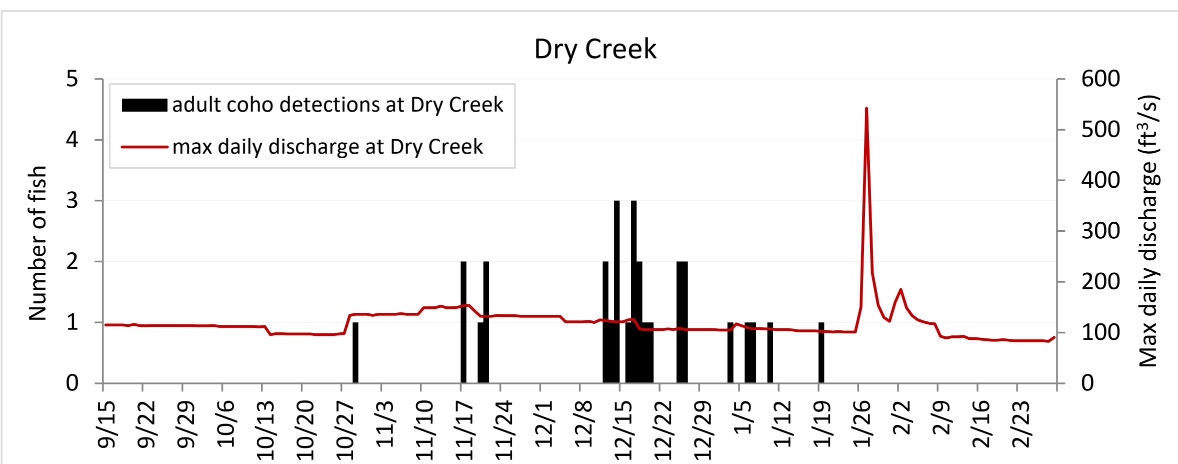


Figure 6. Detections of PIT-tagged coho salmon adults on any Dry Creek antenna, September 15, 2020 - March 1, 2021. Adult release detections are not included. Discharge data was downloaded from USGS website: http://waterdata.usgs.gov.

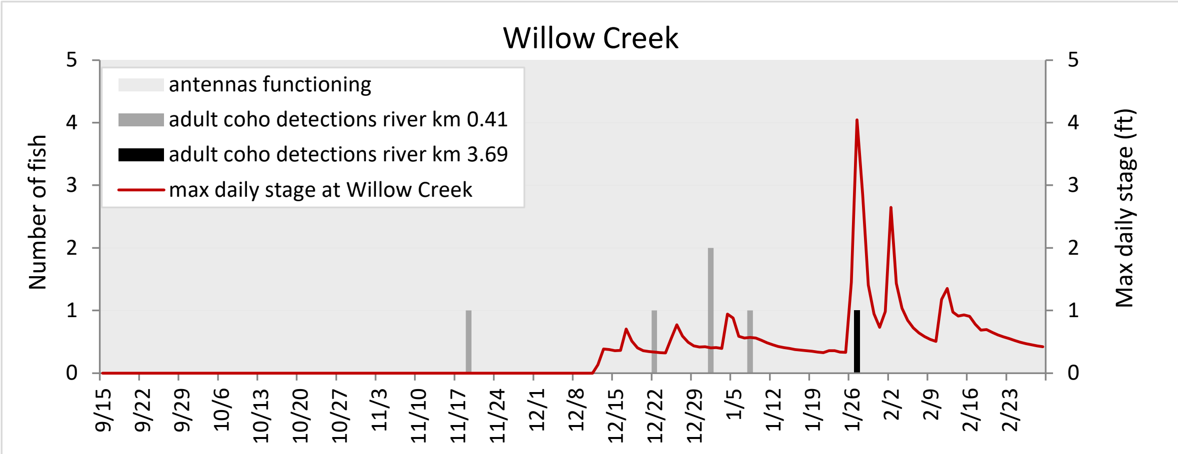


Figure 7. Detections of PIT-tagged coho salmon adults entering Willow Creek between September 15, 2020 and March 1, 2021. Stage data was collected by CSG.

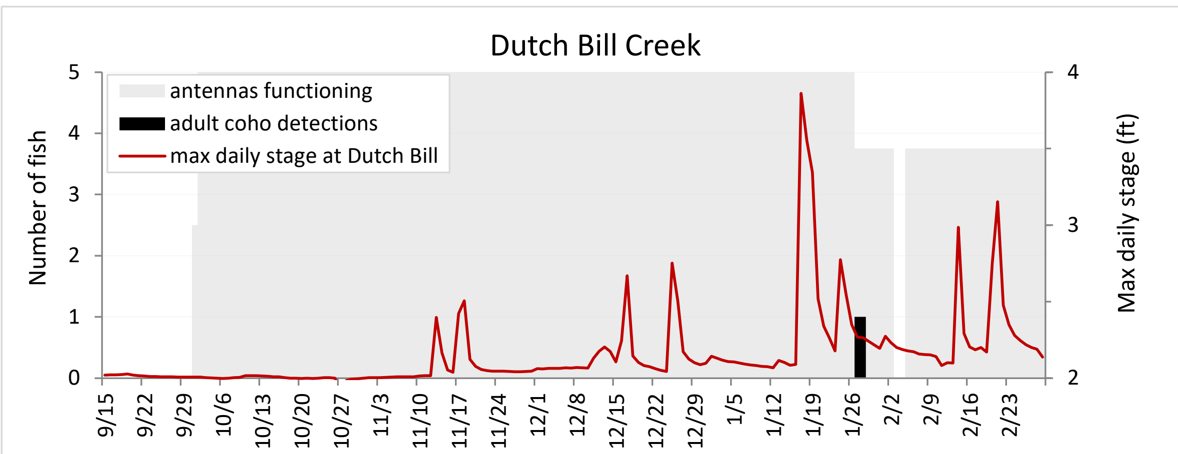


Figure 8. Detections of PIT-tagged coho salmon adults passing upstream of the Dutch Bill Creek antenna array, September 15, 2019 - March 1, 2019. Stage data was provided by Trout Unlimited.

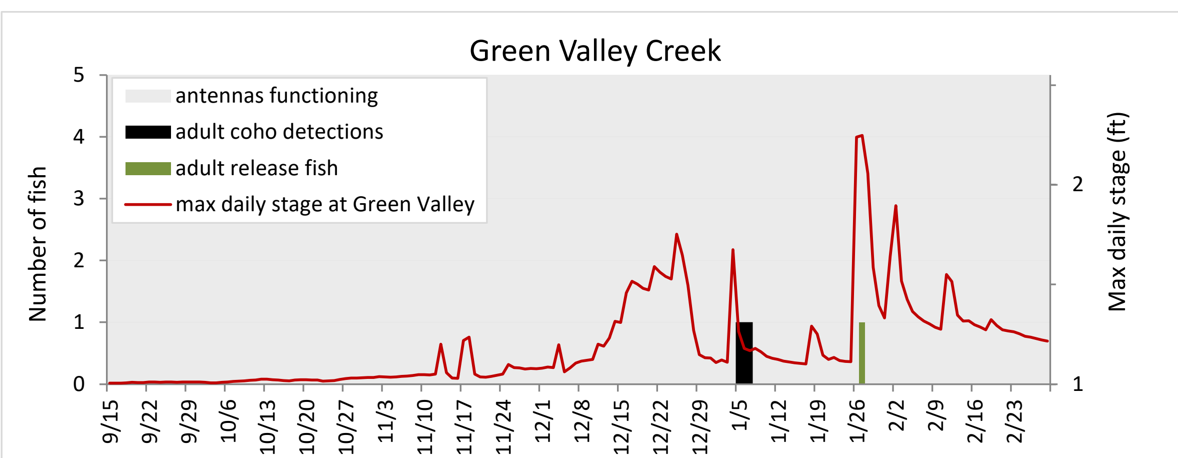


Figure 9. Detections of PIT-tagged coho salmon adults passing upstream of the Green Valley Creek antenna array, September 15, 2020 - March 1, 2021. Stage data was provided by Trout Unlimited.

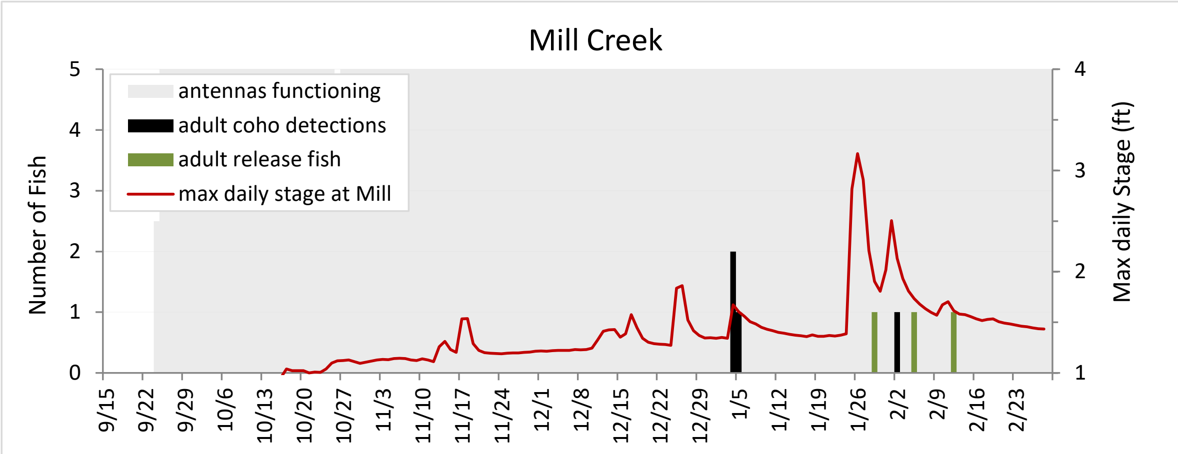


Figure 10. Detections of PIT-tagged coho salmon adults passing upstream of the Mill Creek antenna array, September 15, 2020 - March 1, 2021. Stage data was provided by Trout Unlimited.

3.1.2. Adult return estimates

The estimated numbers of adult coho salmon returning to Willow, Dutch Bill, Green Valley, and Mill creeks were 3, 11, 19, and 16, respectively (Table 3- Table 6), and the estimated number returning to the Russian River Basin was 214 (Table 7). The composition of release groups returning as adults to each stream varied by stream. In Willow Creek, only one age-two PIT-tagged adult was detected entering the spawning habitat and this fish originated from a fall release into Willow Creek (Table 4). The composition of PIT tagged fish entering Green Valley Creek was similar in that it was primarily comprised of fish released as juveniles into Green Valley Creek (Table 5). The only two PIT-tagged adults detected entering Dutch Bill Creek originated from Mark West and Russian River releases (Table 4), and in Mill Creek, adults originated from Dry Creek, Russian River, Green Valley Creek and Willow Creek releases (Table 6). One natural-origin (wild) age-3 adult that was tagged as a smolt in Green Valley Creek in 2019 was detected passing over the Mill Creek antenna array. Release group composition of adult coho 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 2020/21 were extremely low compared to previous years in all four monitoring streams as well as in the mainstem Russian River (Figure 11 - Figure 16). The proportion of age-2 returns varied by stream from an estimated 6% in Mill Creek (Figure 14) to 100% in Willow Creek (Figure 11), though low sample size does not allow for any meaningful comparison. The proportion of age-2 fish returning to the Russian River was an intermediary 45% (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, 2020 and March 1, 2021. 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
2	Willow Creek	hatchery	fall	1	33%	3.0	unknown	3.0
							Estimated hachery adult returns (age-2):	3.0
							Total estimated adult returns:	**3**

Table 4. Minimum, expanded, and estimated counts of adult coho salmon returning to Dutch Bill Creek between September 15, 2020 and March 1, 2021. 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	Mark West Creek	hatchery	presmolt	1	22%	4.5	unknown	4.5
2	Russian River	hatchery	smolt	1	15%	6.7	unknown	6.7
							Estimated hatchery adult returns (age-3):	4.5
							Estimated hatchery adult returns (age-2):	6.7
							Total estimated adult returns:	**11**

Table 5. Minimum, expanded, and estimated counts of adult coho salmon returning to Green Valley Creek between September 15, 2020 and March 1, 2021. 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	Green Valley Creek	hatchery	fall	1	20%	5.0	100%	5.0
	Russian River	hatchery	adult	1	98%	1.0	100%	1.0
2	Green Valley Creek	hatchery	smolt	2	15%	13.3	100%	13.3
							Estimated hatchery adult returns (age-3):	6
							Estimated hatchery adult returns (age-2):	13
							Total estimated adult returns:	**19**

Table 6. Minimum, expanded, and estimated counts of adult coho salmon returning to Mill Creek between September 15, 2020 and March 1, 2021. 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	Dry Creek	hatchery	fall	1	20%	5.0	100%	5.0
	Green Valley Creek	hatchery	smolt	1	20%	5.0	100%	5.0
	Russian River	hatchery	adult	3	98%	3.0	100%	3.0
	Green Valley Creek	wild	tagged at Green Valley Creek smolt trap	1	55%	1.8	100%	1.8
2	Willow Creek	hatchery	tagged at Willow Creek smolt trap	1	NA[1]			1.0
							Estimated hatchery adult returns (age-3):	13.0
							Estimated wild adult returns (age-3):	1.8
							Estimated hatchery adult returns (age-2):	1.0
							Total estimated adult returns:	**16**

[1] Expansions were not made due to potential for duplication (see *Data Analysis* section).

Table 7. Minimum and expanded counts of hatchery adult coho salmon returning to any Russian River antenna site between September 15, 2020 and March 1, 2021. Minimum count= number unique PIT tag detections on any Russian River watershed antenna array; expanded count= minimum count/percent PIT-tagged.

Age	Release tributary	Release group	Minimum count	Percent PIT-tagged	Expanded count
3	Dry Creek	fall	1	20%	5.0
	Dry Creek	smolt	5	20%	24.9
	Green Valley Creek	fall	1	20%	5.0
	Green Valley Creek	presmolt	1	20%	5.0
	Green Valley Creek	smolt	3	20%	15.0
	Mark West Creek	presmolt	5	22%	22.4
	Mill Creek	smolt	1	20%	5.0
	Porter Creek	fall	1	20%	5.0
	Purrington Creek	fall	2	20%	9.9
	Redwood Creek (Atascadero)	fall	1	20%	4.9
	Russian River	smolt	1	20%	5.0
	Willow Creek	presmolt	2	19%	10.3
	Green Valley Creek	wild fish tagged at smolt trap	2	55%	NA
	Willow Creek	wild fish tagged at smolt trap	3	60%	NA
2	Dry Creek	spring	1	20%	5.0
	Gray Creek	fall	1	15%	6.7
	Green Valley Creek	smolt	4	15%	26.7
	Mark West Creek	smolt	3	15%	19.9
	Russian River	smolt	3	15%	20.0
	Willow Creek	fall	6	33%	18.2
	Willow Creek	hatchery fish tagged at smolt trap	2	36%	NA
				Total minimum count:	***49***
				Expanded hatchery adult returns (age-3):	*117.5*
				Expanded hatchery adult returns (age-2):	*96.4*
				Total estimated hatchery adult returns:	***214***

[1] Wild fish were only tagged as smolts in Willow, Green Valley and Mill creeks; therefore, we were unable to estimate wild returns to the entire Russian River watershed.

[2] Expansions were not made due to potential for duplication (see *Data Analysis* section).

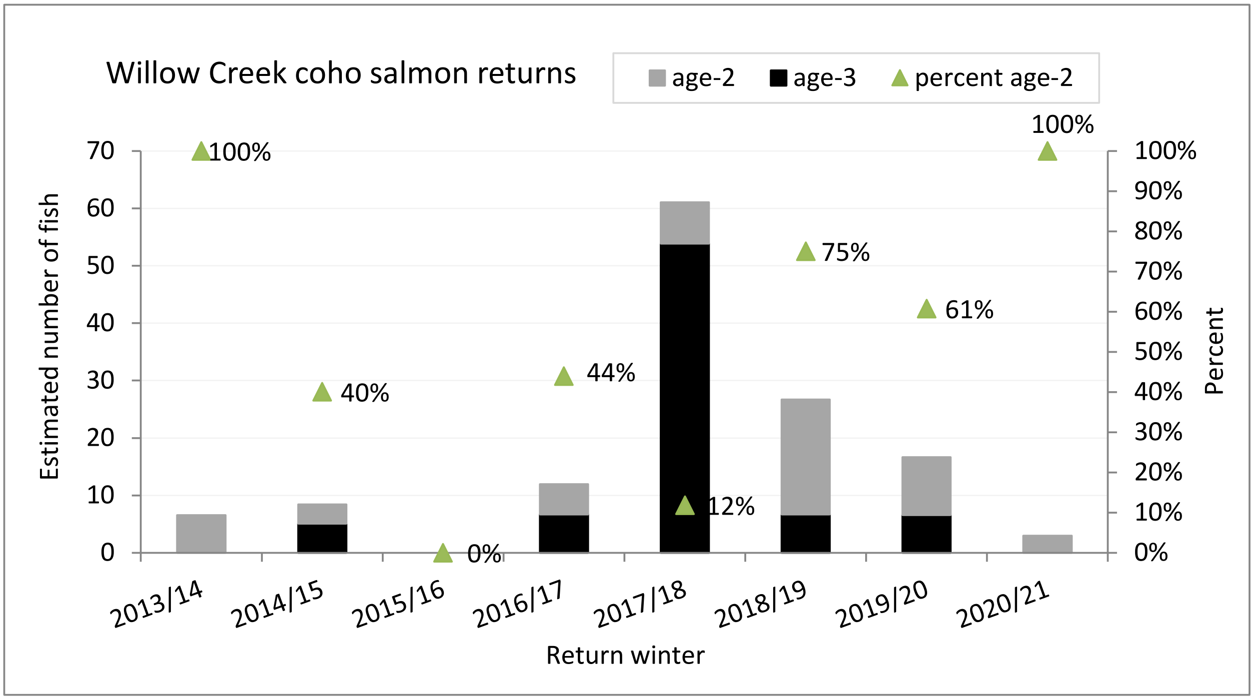


Figure 11. Estimated annual Willow Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2020/21. Note that estimates are based on returns to the upper antennas at river km 3.69.

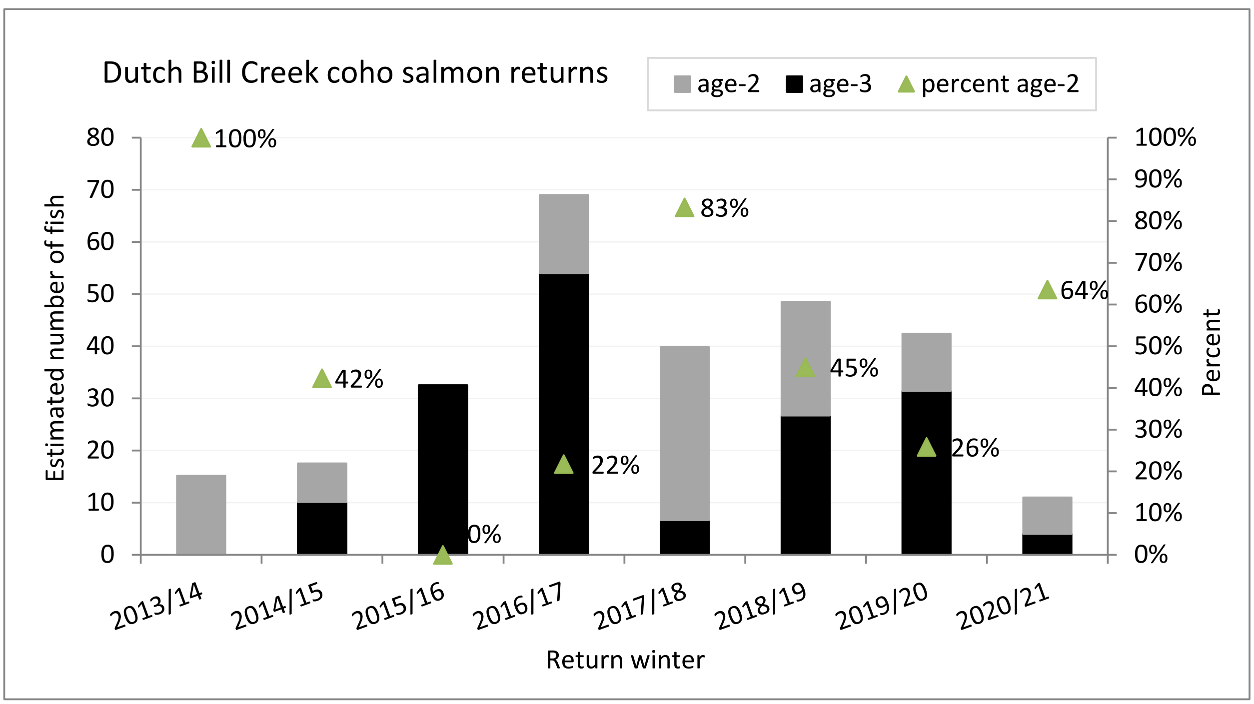


Figure 12. Estimated annual Dutch Bill Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2020/21.

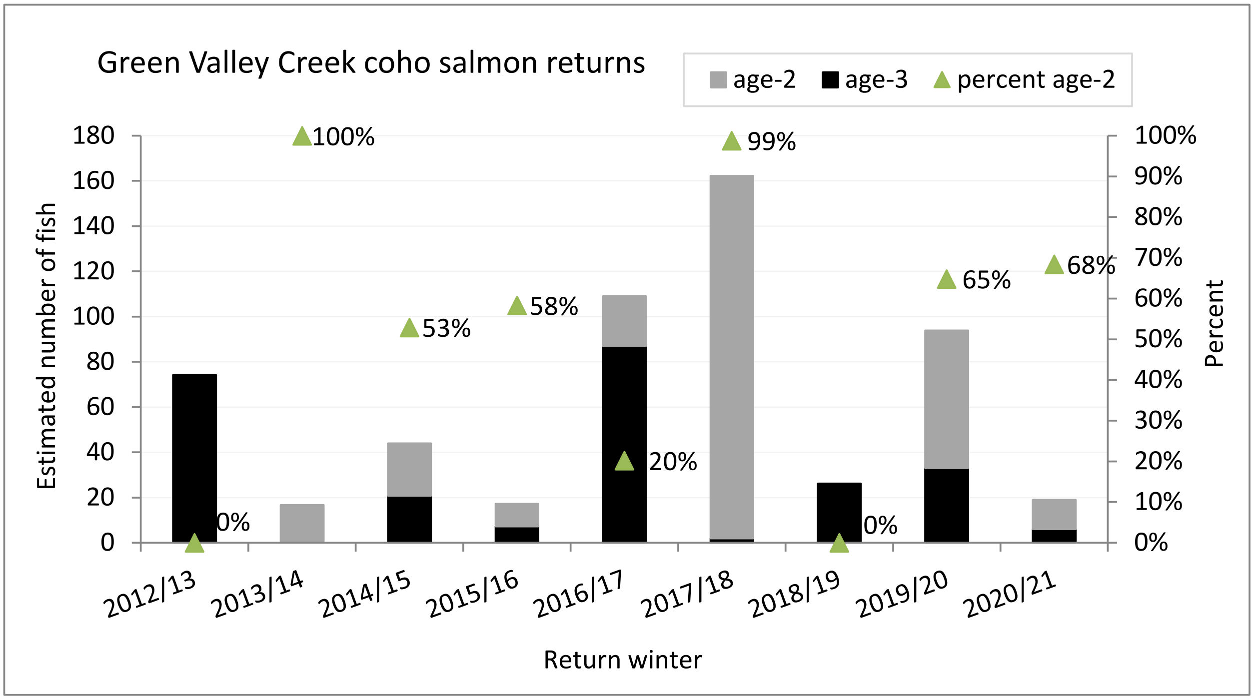


Figure 13. Estimated annual Green Valley Creek adult hatchery coho salmon returns by age, return seasons 2012/13 – 2020/21.

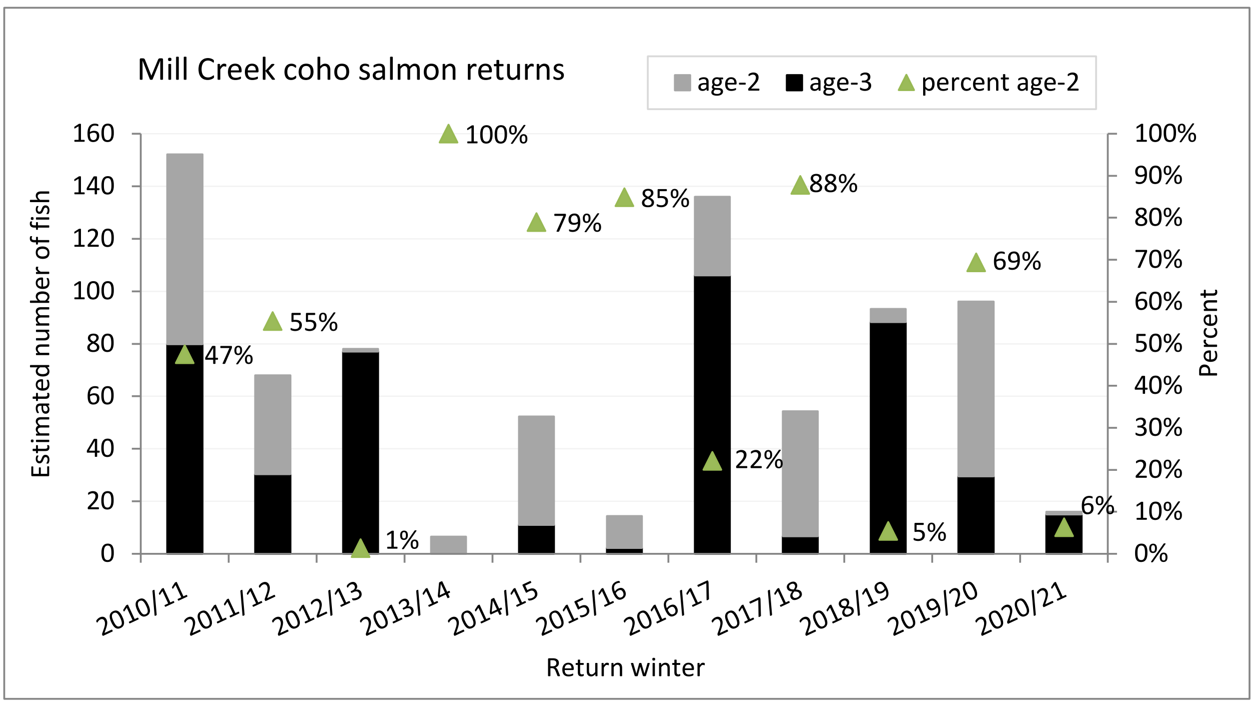


Figure 14. Estimated annual Mill Creek adult hatchery coho salmon returns by age, return seasons 2010/11 – 2020/21.

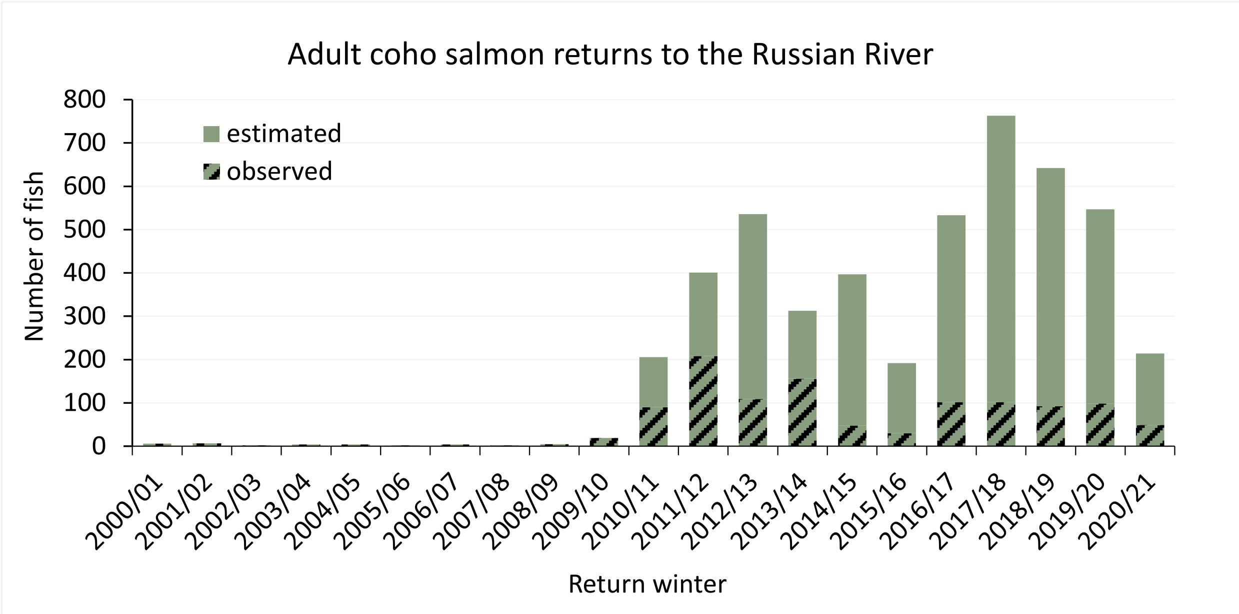


Figure 15. Estimated annual adult hatchery coho salmon returns to the Russian River, return winters 2000/01 through 2020/21. Note that methods for counting/estimating the number of returning adult coho salmon were not consistent among years; prior to 2009/10, spawner surveys were the primary method, 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.

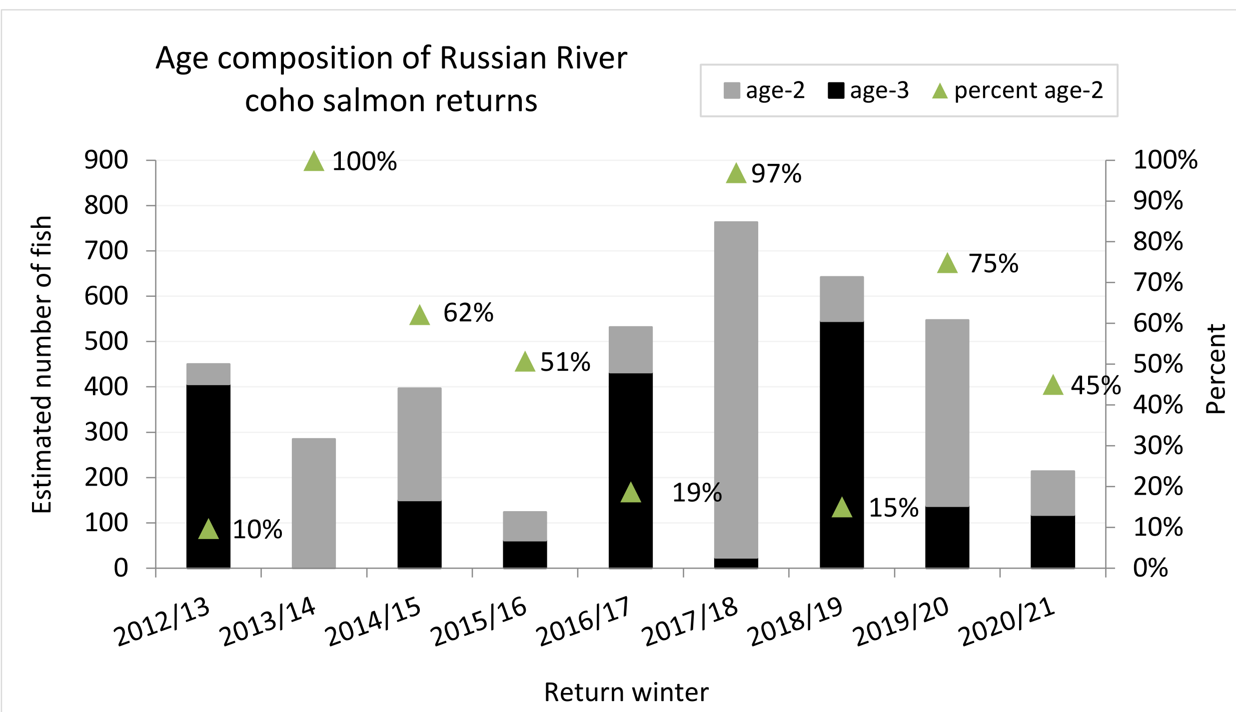


Figure 16. Estimated annual Russian River adult hatchery coho salmon returns by age, return seasons 2012/13-2019/20. Note that this figure includes only fish that we were able to age; therefore, totals will be less than adult return estimates shown in Figure 15.

3.1.3. Smolt to adult return (SAR) ratios

SAR ratios were estimated at 0.5% in Willow, Dutch Bill, and Green Valley creeks (Figure 17 - Figure 19, Table 8). In Mill Creek, the SAR ratio was estimated at 3.4 % (Figure 20, Table 8), though this is likely biased high due to the fact that returning adults originated from release groups other than Mill Creek (Table 6).

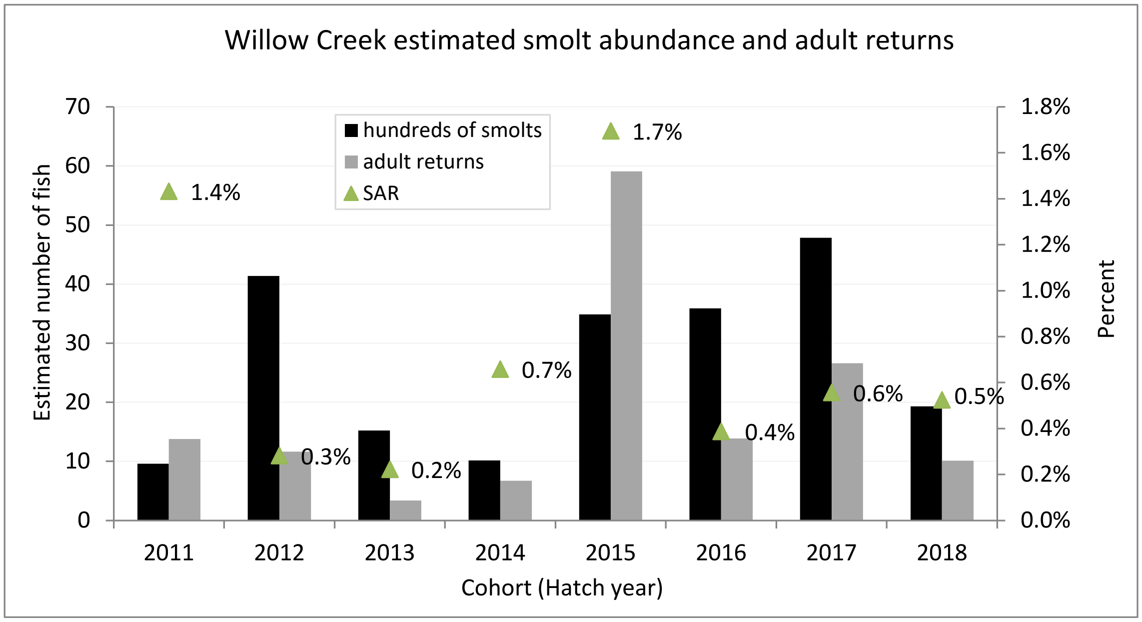


Figure 17. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Willow Creek, cohorts 2011-2018. Note that estimates are based on returns to the upper antennas at river km 3.69.

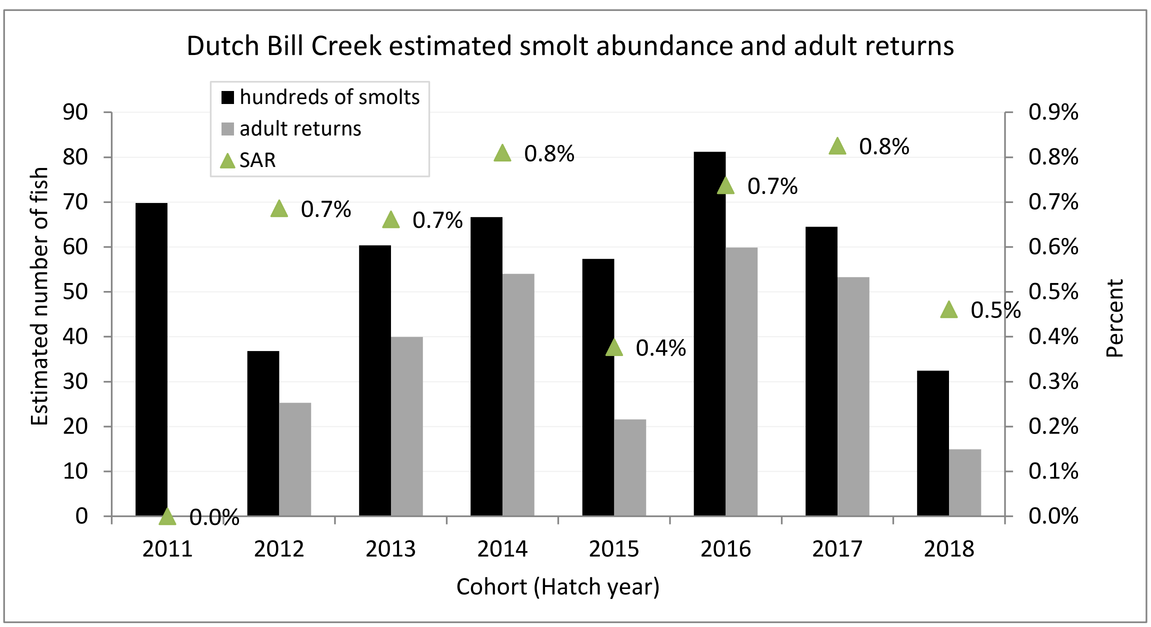


Figure 18. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Dutch Bill Creek, cohorts 2011-2018.

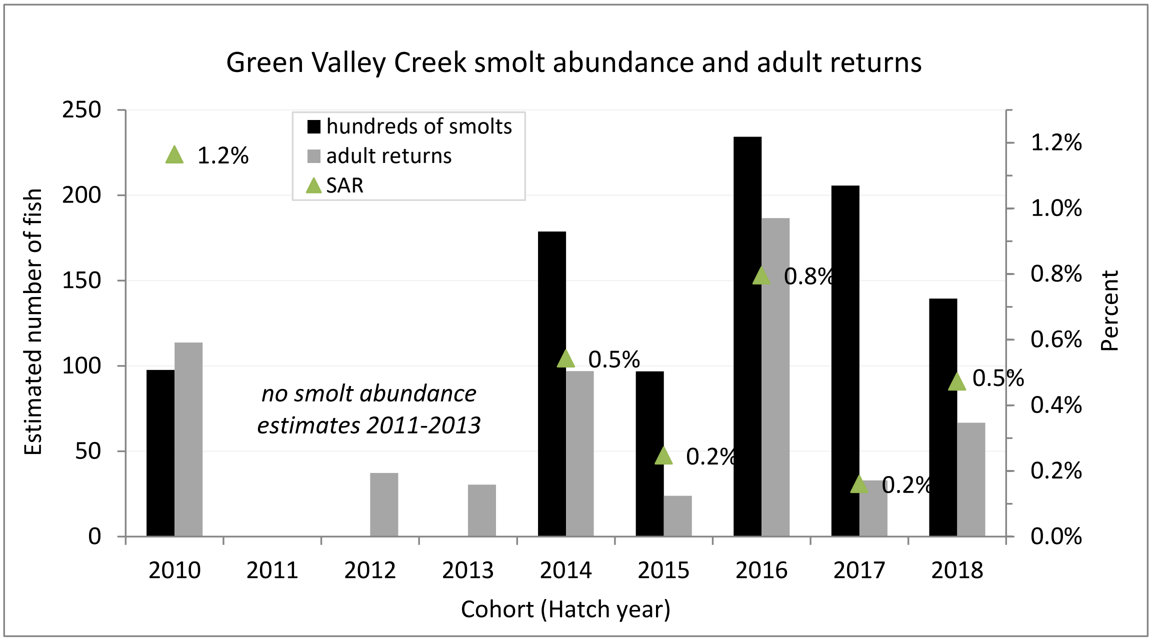


Figure 19. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Green Valley Creek, cohorts 2010-2018. Note that adult release fish returning to Green Valley Creek were excluded from SAR calculations.

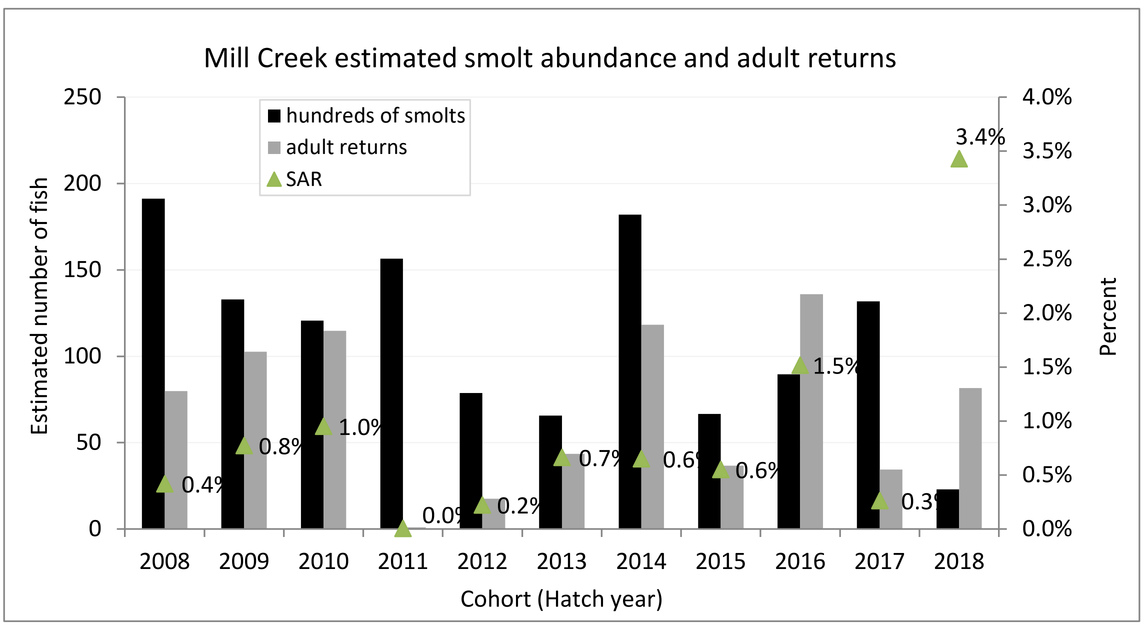


Figure 20. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Mill Creek, cohorts 2008-2018. Note that adult release fish returning to Mill Creek were excluded from SAR calculations.

Table 8. Smolt to adult return (SAR) ratios estimated for Willow, Dutch Bill, Green Valley, and Mill creeks, cohorts 2008 through 2018.

		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	0.7%	0.8%	0.5%	0.6%
2015	2017/18	1.7%	0.4%	0.2%	0.6%
2016	2018/19	0.4%	0.7%	0.8%	1.5%
2017	2019/20	0.6%	0.8%	0.2%	0.3%
2018	2020/21	0.5%	0.5%	0.5%	3.4%
	Average	**0.7%**	**0.5%**	**0.6%**	**0.9%**

3.1.4. Adult release

A total of 139 unique coho originating from the January 7, 2021 adult release on the mainstem Russian River at Steelhead Beach were detected on PIT antennas in the Russian River watershed, representing 76% of 182 PIT-tagged adults that were released. Adult release fish were detected in one stream downstream of the release site (Green Valley Creek) and in three locations/streams upstream of the release site (mainstem at Mirabel, Dry Creek and Mill Creek) (Figure 21). The greatest number of individuals (91) were detected in Mark West Creek, the tributary that is within closest proximity to Steelhead Beach (Figure 1). The majority of the fish were first detected within one week of release; however, a few individuals were detected over a month after the release (Figure 22).

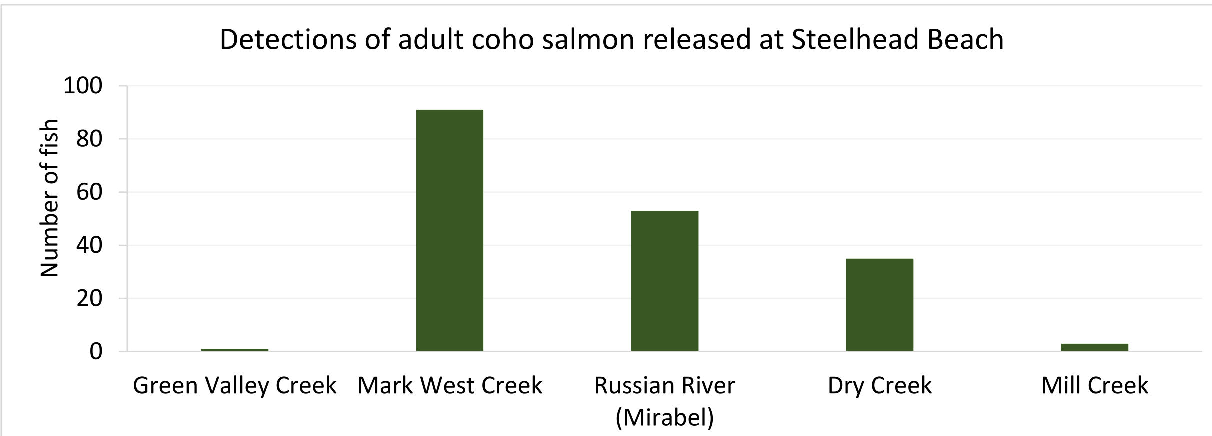


Figure 21. Detections of PIT-tagged adult coho salmon released at Steelhead Beach on January 7, 2021. Note that some individuals were detected at multiple sites.

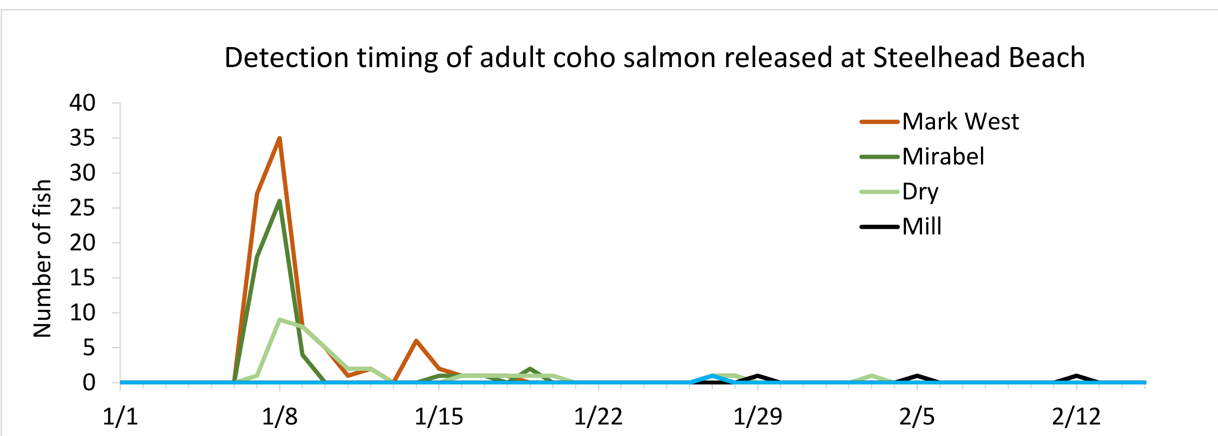


Figure 22. Detection timing of PIT-tagged adult coho salmon released at Steelhead Beach on January 7, 2021.

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 streams 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 aimed to generate basinwide estimates of coho salmon and steelhead redds in the entire Russian River watershed. Surveys were conducted in coordination with Sonoma Water using standardized CMP methods (Sonoma Water 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 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) (Figure 23).

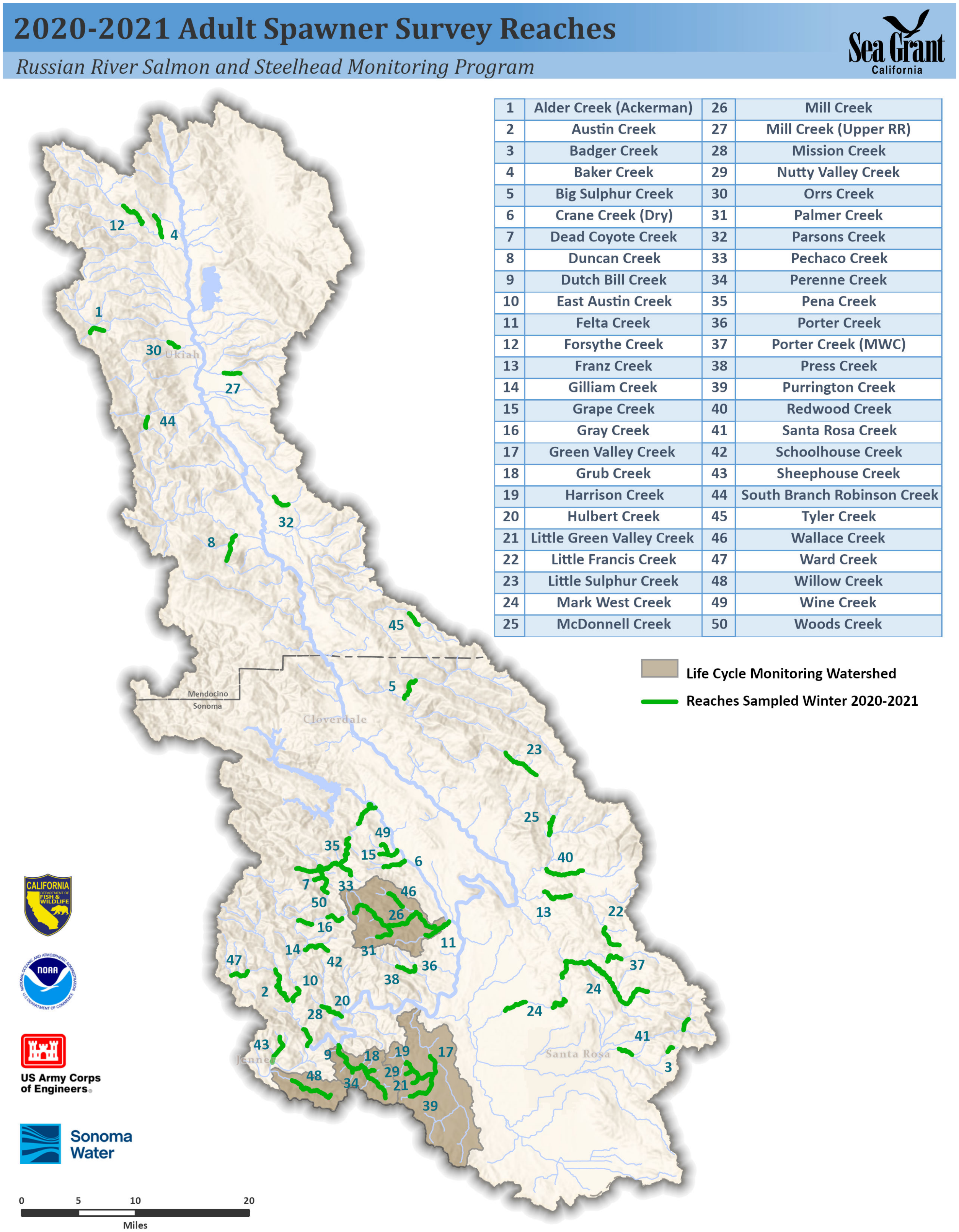
4.2.2. Field methods

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 from downstream to upstream looking for adult salmon (live or carcasses) and redds (Figure 24). 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. 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 observations. Presence of non-salmonid species was also documented at the reach scale. Allegro field computers were used for data entry and, upon returning from the field, data files were downloaded, error checked, and transferred into a SQL database.

[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.

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 assign redd species following Gallagher and Gallagher's redd species determination method (Gallagher and Gallagher 2005). The total number of unique redds was then summed for each surveyed reach. Within each reach, to account for redds missed by observers, the number of redds observed was expanded based upon the average observational "life span" of redds observed in that same reach (Ricker et al. 2014). In reaches where redds were obscured quickly due to storms or algae (leading to a higher probability of missing redds), expansion rates were higher than in reaches where redds remained visible for longer periods of time. 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.



1	Alder Creek (Ackerman)	26	Mill Creek
2	Austin Creek	27	Mill Creek (Upper RR)
3	Badger Creek	28	Mission Creek
4	Baker Creek	29	Nutty Valley Creek
5	Big Sulphur Creek	30	Orrs Creek
6	Crane Creek (Dry)	31	Palmer Creek
7	Dead Coyote Creek	32	Parsons Creek
8	Duncan Creek	33	Pechaco Creek
9	Dutch Bill Creek	34	Perenne Creek
10	East Austin Creek	35	Pena Creek
11	Felta Creek	36	Porter Creek
12	Forsythe Creek	37	Porter Creek (MWC)
13	Franz Creek	38	Press Creek
14	Gilliam Creek	39	Purrington Creek
15	Grape Creek	40	Redwood Creek
16	Gray Creek	41	Santa Rosa Creek
17	Green Valley Creek	42	Schoolhouse Creek
18	Grub Creek	43	Sheephouse Creek
19	Harrison Creek	44	South Branch Robinson Creek
20	Hulbert Creek	45	Tyler Creek
21	Little Green Valley Creek	46	Wallace Creek
22	Little Francis Creek	47	Ward Creek
23	Little Sulphur Creek	48	Willow Creek
24	Mark West Creek	49	Wine Creek
25	McDonnell Creek	50	Woods Creek

Figure 23. Broodstock Program watersheds and 2020/21 spawner survey reaches in the Russian River.

Figure 24. Adult steelhead digging a redd in a Russian River tributary. Photo taken by Keane Flynn, Sonoma Water.

4.3. Results

4.3.1. Redd estimates and spawning distribution

We began surveys on December 29, 2020 following the first rain events of the season and continued through mid-April 2021, and were able to meet our goal of surveying each reach approximately every 10-14 days. Over the winter season, CSG and Sonoma Water biologists completed a total of 532 salmonid spawning surveys on 66 reaches in 50 streams within the Russian River basin. A total of 303 salmonid redds were observed: 35 coho salmon redds, 227 steelhead redds, zero Chinook salmon redds, and 41 redds of unknown salmonid species origin (Table 9). In addition, one live coho salmon adult was observed in Willow Creek where no confirmed coho salmon redds were observed and one live steelhead adult was observed in Crane Creek where no steelhead redds were observed. During the winter of 2020/21, coho salmon redds and/or adults were observed in eight of 33 coho salmon streams surveyed (24%), and steelhead redds and/or adults were observed in 25 of the 50 steelhead streams surveyed (50%) (Table 9, Figure 25, Figure 26).

Over all streams combined, timing of redd construction varied by species, with coho salmon redd observations beginning at the end of December and ending in March, and steelhead observations showing a peak in early February and a smaller peak in late March (Figure 27). Steelhead redds were observed over a broader timeframe, ranging from early January through the end of the survey season in mid-April. It is possible that steelhead continued to spawn after mid-April, but as our surveys were discontinued at that time, we were unable to record any additional redds.

Coho salmon redd estimates in Broodstock Program monitoring streams ranged from zero in Willow Creek to 24 in Dutch Bill Creek, and steelhead redd estimates ranged from zero in Willow Creek to 56 in Dutch Bill Creek (Table 10). When coho salmon redd estimates were compared with adult estimates generated using PIT tag detection systems, adult spawner to redd ratios were calculated for each stream, and ranged from 0.5 in Dutch Bill Creek to 9.5 in Green Valley Creek.

When compared with previous years, coho salmon redd estimates were low in Willow and Green Valley creeks, high in Dutch Bill Creek, and within a comparable range in Mill Creek (Figure 28). A similar pattern was observed for steelhead redds (Figure 29). At the basinwide scale, redd estimates for coho salmon were similar to previous years, while estimates for steelhead redds were low compared to the previous two years, which were also representative of the entire steelhead frame (Figure 30).

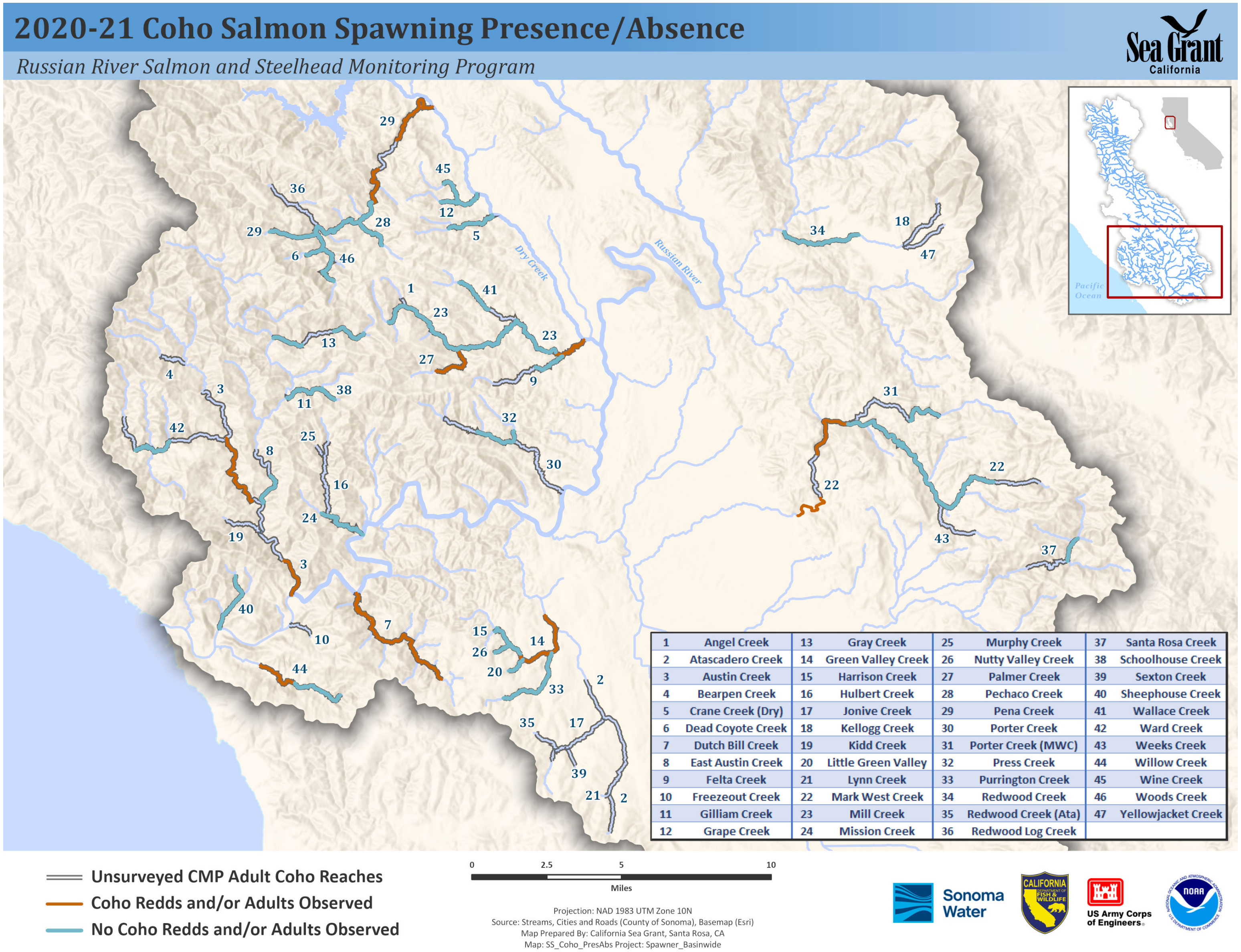
In the four Broodstock Program streams, we recovered only three intact coho salmon carcasses (Table 11). The average proportion of natural-origin adult coho salmon carcasses across all four streams was 33%; however, the small sample size makes it difficult to make any inferences about the proportion of natural-origin fish returning to the Russian River watershed during the winter of 2020/21.

Redd distribution varied by stream (Figure 31 - Figure 34). Zero coho salmon or steelhead redds were observed in Willow Creek (Figure 31), while redd abundance was high in Dutch Bill and Mill creeks (Figure 32, Figure 34). In Dutch Bill Creek, spawning was documented throughout the extent of the stream, with the highest redd densities closest to the confluence with the Russian River (Figure 32). In the Green Valley Creek watershed, only one coho salmon redd was documented in middle reaches of Green Valley Creek and seven steelhead redds were documented in Purrington Creek (Figure 33). In the Mill Creek watershed, only two coho redds were observed, one in lower Mill Creek and a second in Palmer Creek (Figure 34). Steelhead redds were observed in multiple regions of Mill Creek as well as lower Palmer Creek.

Table 9. Salmonid redds observed by species during winter 2020/21 in Russian River tributaries.

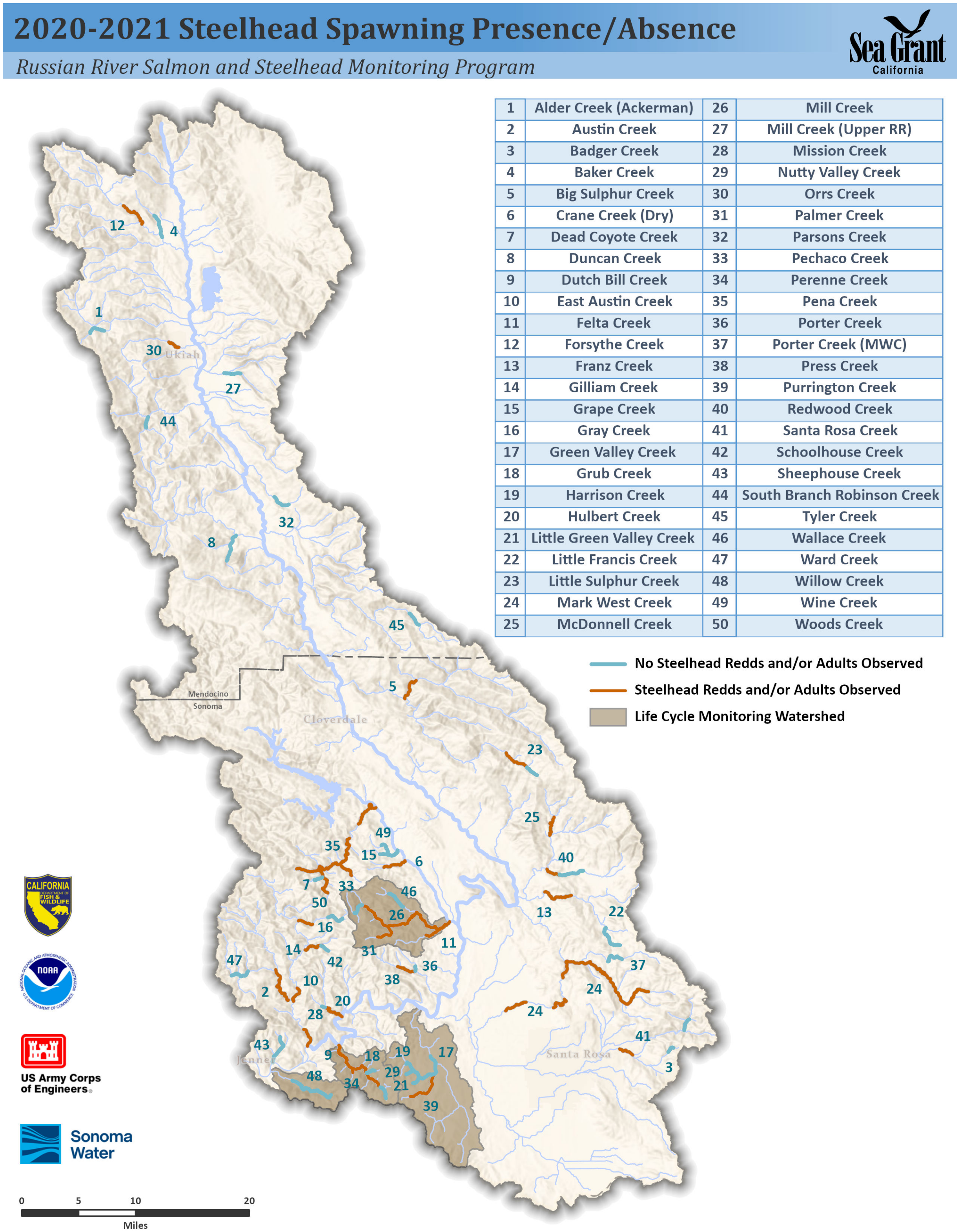
Tributary	Length surveyed (km)	Coho salmon	Steelhead	Chinook salmon	Salmonid	Total
Alder Creek (Ackerman)*	2.1	0	0	0	0	0
Austin Creek	7.4	18	43	0	2	63
Badger Creek*	0.9	0	0	0	0	0
Bakers Creek*	2.8	0	0	0	0	0
Big Sulphur Creek*	3.1	0	3	0	1	4
Crane Creek (Dry)	3.2	0	0	0	0	0
Dead Coyote Creek	1.1	0	0	0	0	0
Duncan Creek*	3.3	0	0	0	0	0
Dutch Bill Creek	11.4	10	42	0	17	69
East Austin Creek	2.1	0	3	0	0	3
Felta Creek	2.0	0	1	0	0	1
Forsythe Creek*	3.7	0	3	0	1	4
Franz Creek*	3.8	0	4	0	0	4
Gilliam Creek	2.6	0	2	0	0	2
Grape Creek	2.6	0	0	0	0	0
Gray Creek	4.1	0	2	0	1	3
Green Valley Creek	7.0	1	0	0	0	1
Grub Creek*	1.1	0	0	0	0	0
Harrison Creek	0.2	0	0	0	0	0
Hulbert Creek	3.2	0	12	0	1	13
Little Francis Creek*	3.6	0	0	0	0	0
Little Green Valley Creek	1.2	0	0	0	0	0
Little Sulphur Creek*	4.9	0	1	0	0	1
Mark West Creek	24.9	2	31	0	6	39
Mcdonnell Creek*	2.7	0	5	0	0	5
Mill Creek	16.6	1	28	0	5	34
Mill Creek (Upper RR)*	1.9	0	0	0	0	0
Mission Creek	0.4	0	0	0	0	0
Nutty Valley Creek	1.2	0	0	0	0	0
Orrs Creek*	1.7	0	1	0	0	1
Palmer Creek	2.9	1	3	0	0	4
Parsons Creek*	2.2	0	0	0	0	0
Pechaco Creek	2.3	0	2	0	0	2
Pena Creek	15.1	2	21	0	6	29
Perenne Creek*	0.5	0	1	0	0	1
Porter Creek	2.3	0	1	0	0	1
Porter Creek (MWC)	2.4	0	0	0	0	0
Press Creek	0.6	0	0	0	0	0
Purrington Creek	4.8	0	7	0	0	7
Redwood Creek	4.8	0	1	0	0	1
Santa Rosa Creek	3.4	0	6	0	1	7
Schoolhouse Creek	1.1	0	0	0	0	0
Sheephouse Creek	3.7	0	0	0	0	0
South Branch Robinson Creek*	1.4	0	0	0	0	0
Tyler Creek*	1.8	0	0	0	0	0
Wallace Creek	2.5	0	0	0	0	0
Ward Creek	2.6	0	0	0	0	0
Willow Creek	6.0	0	0	0	0	0
Wine Creek	1.8	0	0	0	0	0
Woods Creek	4.1	0	4	0	0	4
Total	**193.1**	**35**	**227**	**0**	**41**	**303**

** Steelhead-only tributary*



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

Figure 25. Spawner survey reaches where coho salmon redds and/or coho salmon adults were observed, winter 2020/21.



1	Alder Creek (Ackerman)	26	Mill Creek
2	Austin Creek	27	Mill Creek (Upper RR)
3	Badger Creek	28	Mission Creek
4	Baker Creek	29	Nutty Valley Creek
5	Big Sulphur Creek	30	Orrs Creek
6	Crane Creek (Dry)	31	Palmer Creek
7	Dead Coyote Creek	32	Parsons Creek
8	Duncan Creek	33	Pechaco Creek
9	Dutch Bill Creek	34	Perenne Creek
10	East Austin Creek	35	Pena Creek
11	Felta Creek	36	Porter Creek
12	Forsythe Creek	37	Porter Creek (MWC)
13	Franz Creek	38	Press Creek
14	Gilliam Creek	39	Purrington Creek
15	Grape Creek	40	Redwood Creek
16	Gray Creek	41	Santa Rosa Creek
17	Green Valley Creek	42	Schoolhouse Creek
18	Grub Creek	43	Sheephouse Creek
19	Harrison Creek	44	South Branch Robinson Creek
20	Hulbert Creek	45	Tyler Creek
21	Little Green Valley Creek	46	Wallace Creek
22	Little Francis Creek	47	Ward Creek
23	Little Sulphur Creek	48	Willow Creek
24	Mark West Creek	49	Wine Creek
25	McDonnell Creek	50	Woods Creek

Figure 26. Spawner survey reaches where steelhead redds and/or live steelhead adults were observed, winter 2020/21.

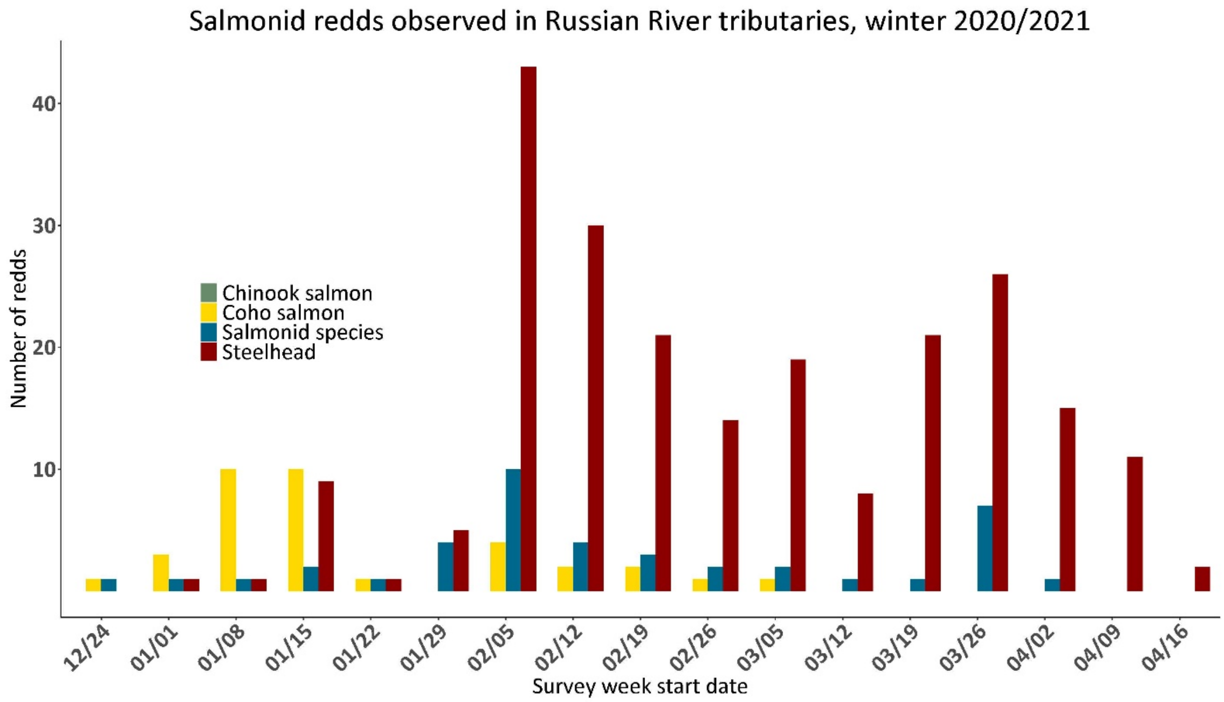


Figure 27. Number of new salmonid redds observed each week in Russian River Coastal Monitoring Program survey streams, winter 2020/21.

Table 10. Estimated coho salmon and steelhead redds and adults in four Russian River tributaries, winter 2020/21. Adult estimates for coho salmon were based on PIT tag data (Table 3 - Table 6) and adult to redd ratios were calculated by dividing the estimated number of adults by the estimated number redds. Due to lack of PIT tag data for steelhead returning in winter 2020/21, we were unable to estimate steelhead adult estimates or adult to redd ratios.

Tributary	Species	Estimated redds	Estimated adults	Adult:redd
Willow Creek	coho salmon	0	3	NA
Willow Creek	steelhead	0	NA	NA
Dutch Bill Creek	coho salmon	24	11	0.5
Dutch Bill Creek	steelhead	56	NA	NA
Green Valley Creek	coho salmon	2	19	9.5
Green Valley Creek	steelhead	6	NA	NA
Mill Creek	coho salmon	23	16	0.7
Mill Creek	steelhead	43	NA	NA

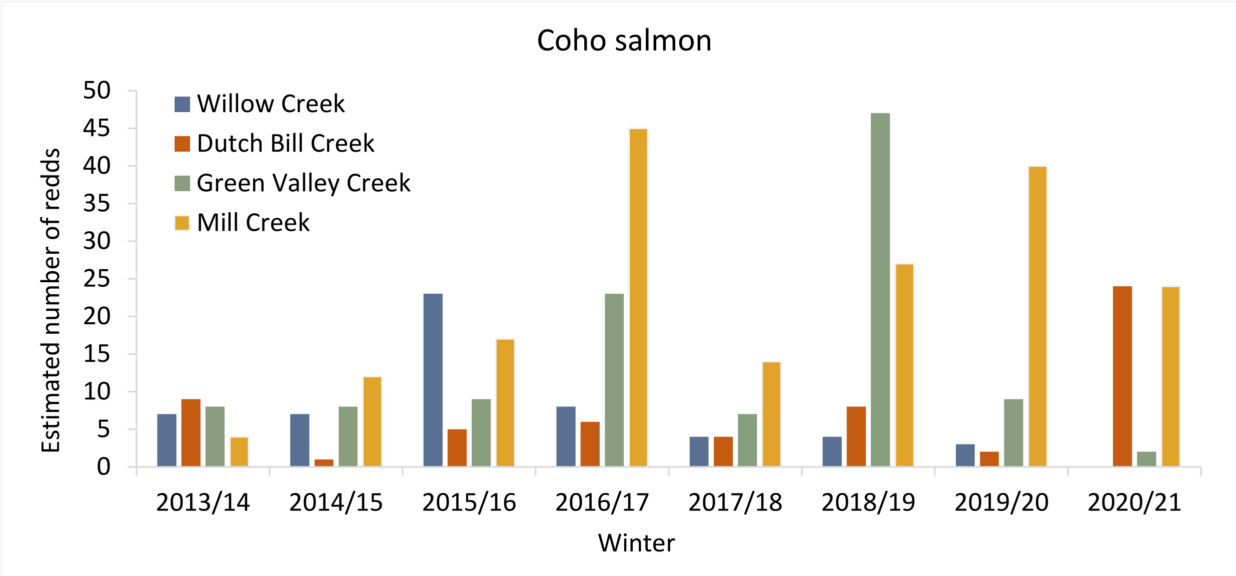


Figure 28. Estimated coho salmon redds in Broodstock Program monitoring tributaries, return winters 2013/14 through 2020/21.

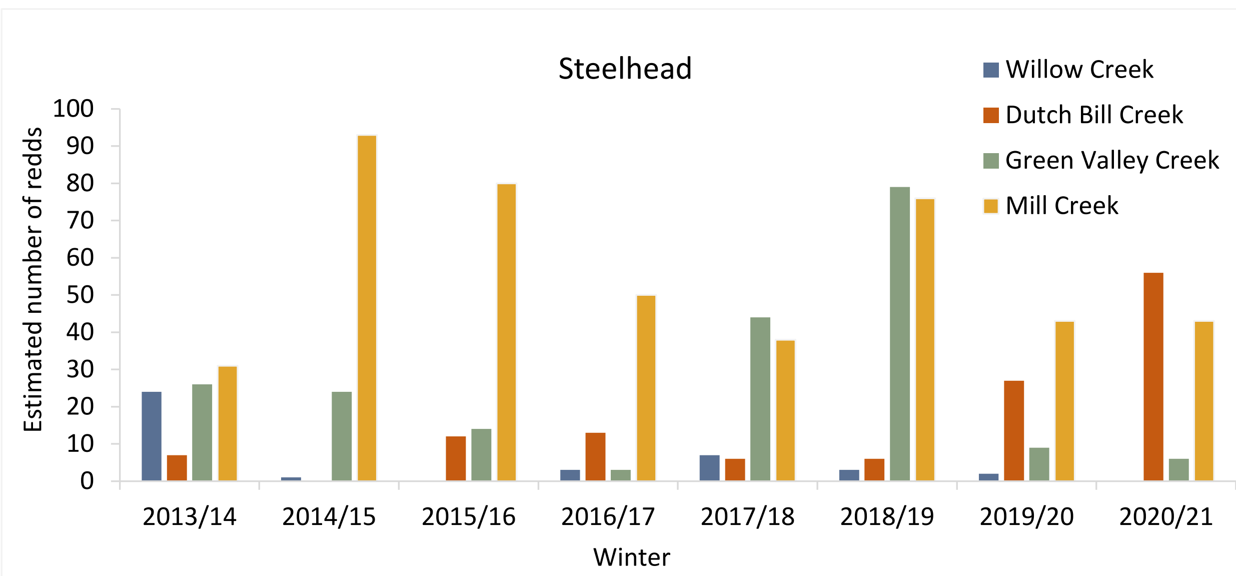


Figure 29. Estimated steelhead redds in Broodstock Program monitoring tributaries, return winters 2013/14 – 2020/21.

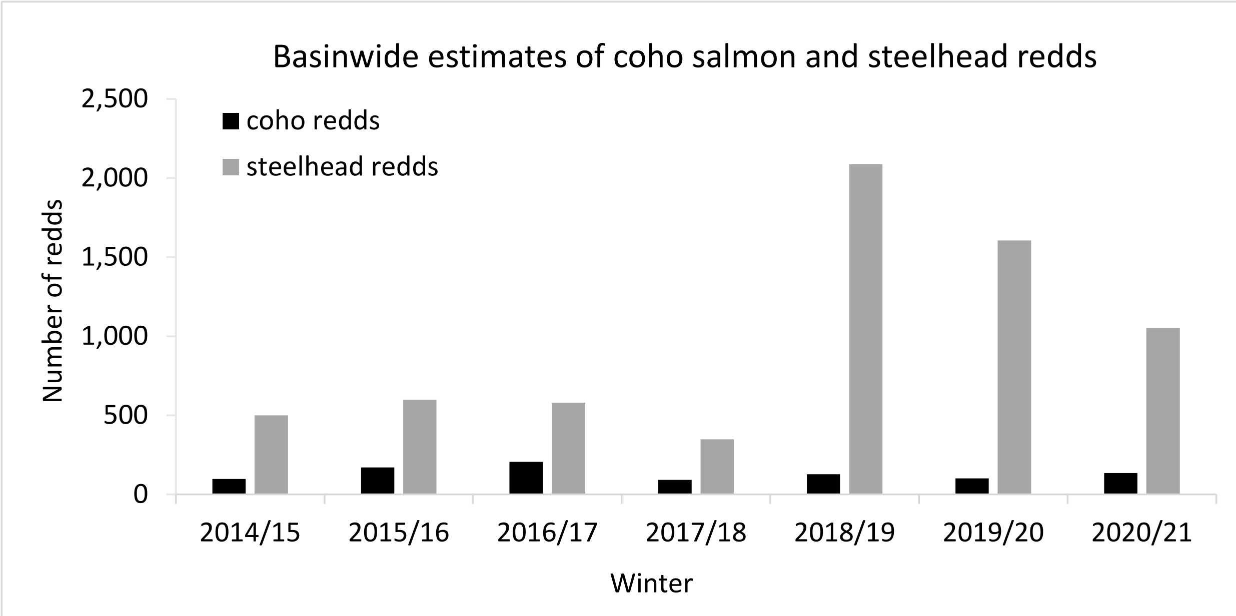


Figure 30. Basinwide estimates of coho salmon and steelhead redds in the Russian River watershed, return winters 2014/15 through 2020/21. Note that prior to winter 2018/19, steelhead redd abundance was only estimated for CMP reaches that also contained coho salmon habitat, while abundance from 2018/19 forward was estimated for all steelhead reaches within the CMP sample frame.

Table 11. Coded wire tag (CWT) presence in coho salmon carcasses recovered during spawner surveys, 2020/21.

Tributary	**CWT present**	**CWT not present**	**Proportion untagged (natural-origin)**
Willow Creek	0	0	NA
Dutch Bill Creek	1	0	0%
Green Valley Creek	1	0	0%
Mill Creek	0	1	100%
Combined	**2**	**1**	33%

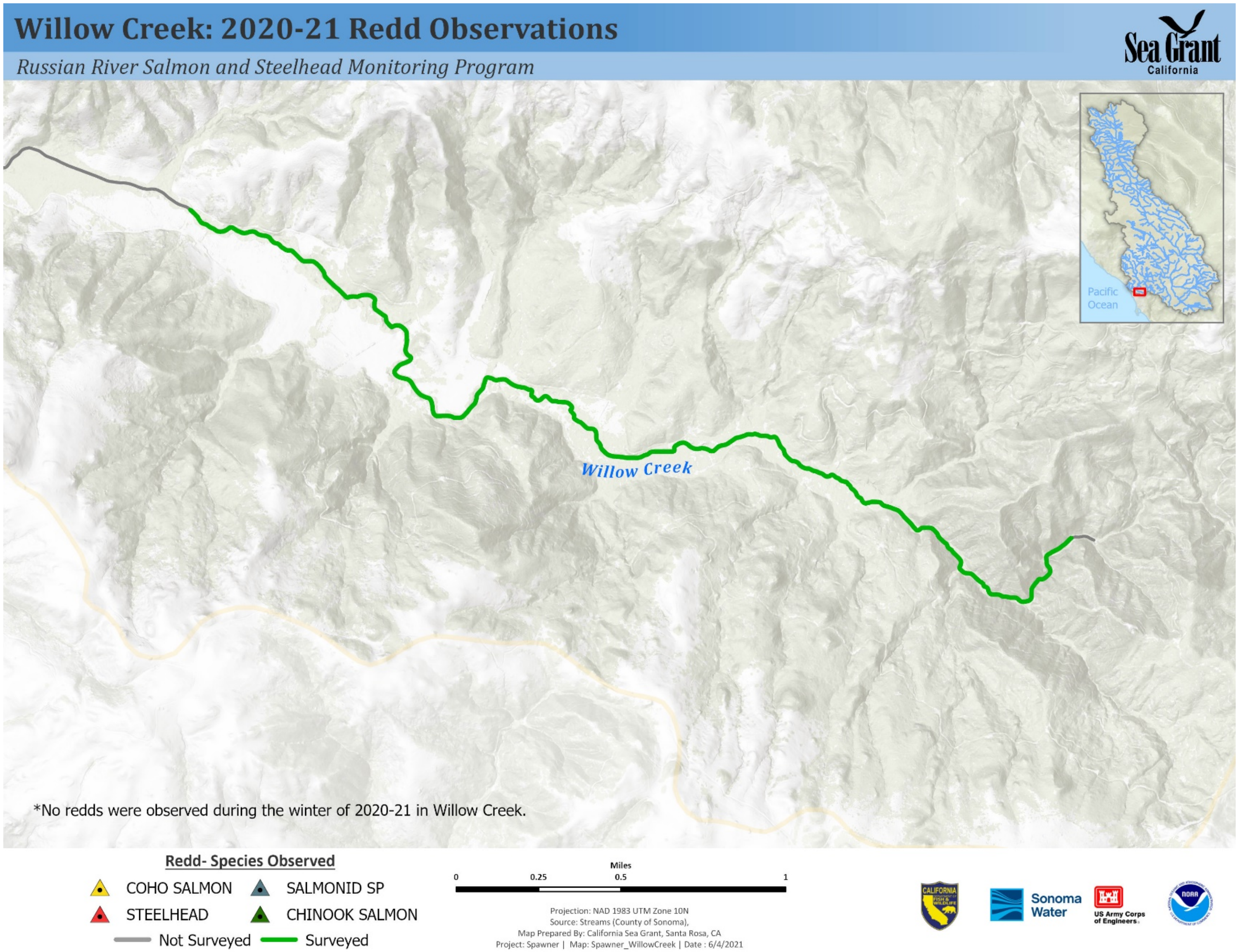


Figure 31. Salmonid redds observed in Willow Creek during winter 2020/21.

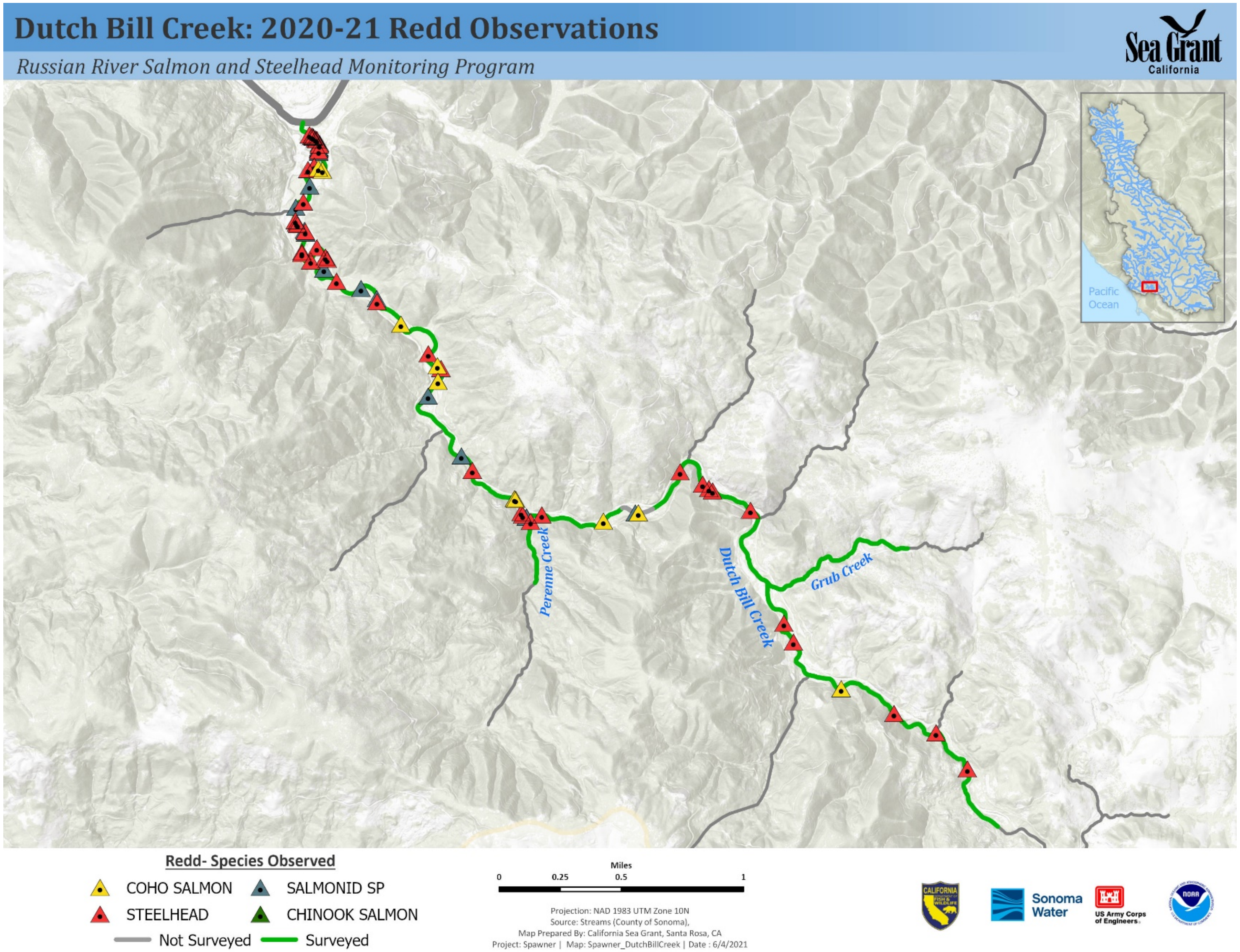


Figure 32. Salmonid redds observed in Dutch Bill Creek during winter 2020/21.

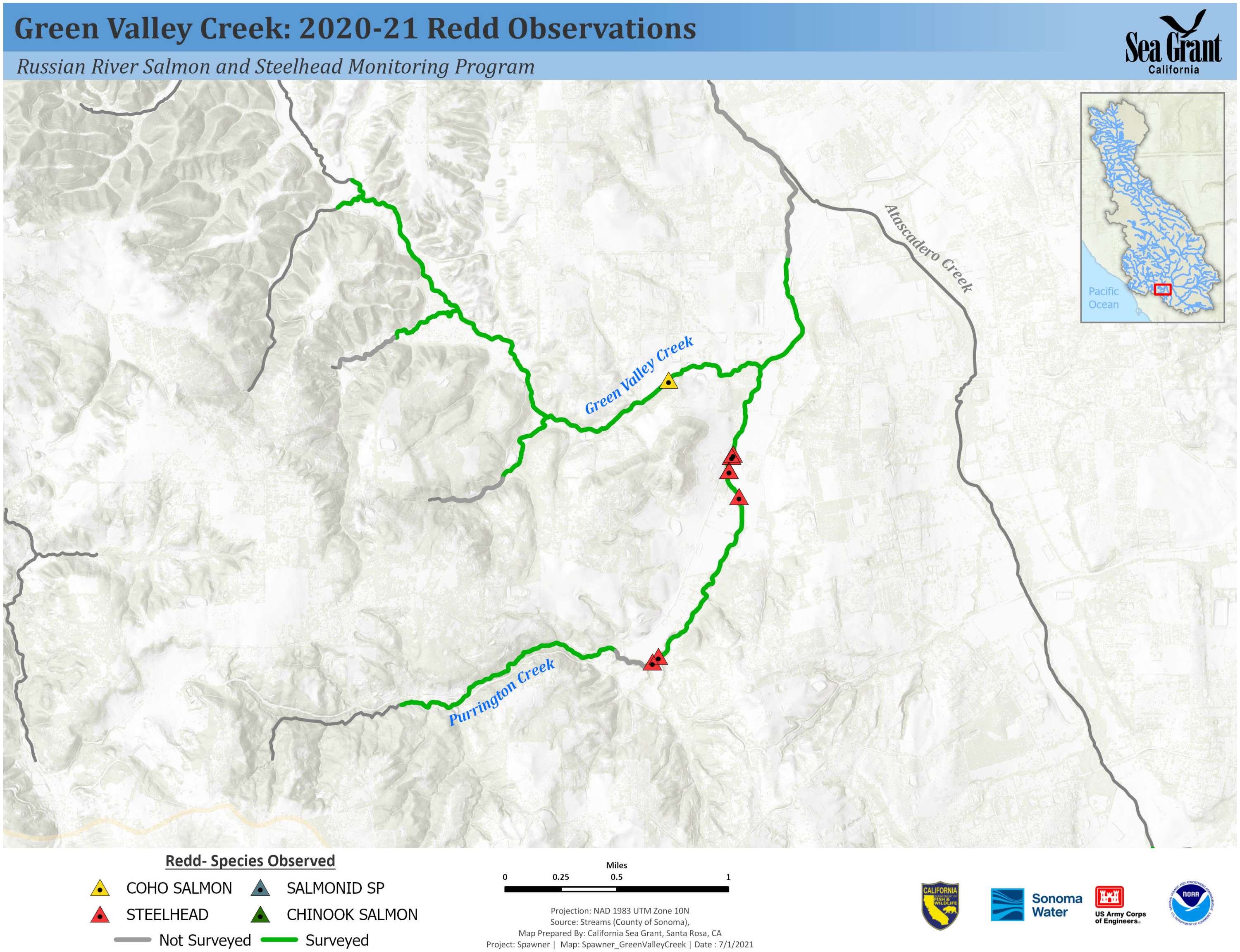


Figure 33. Salmonid redds observed in the Green Valley Creek watershed during winter 2020/21.

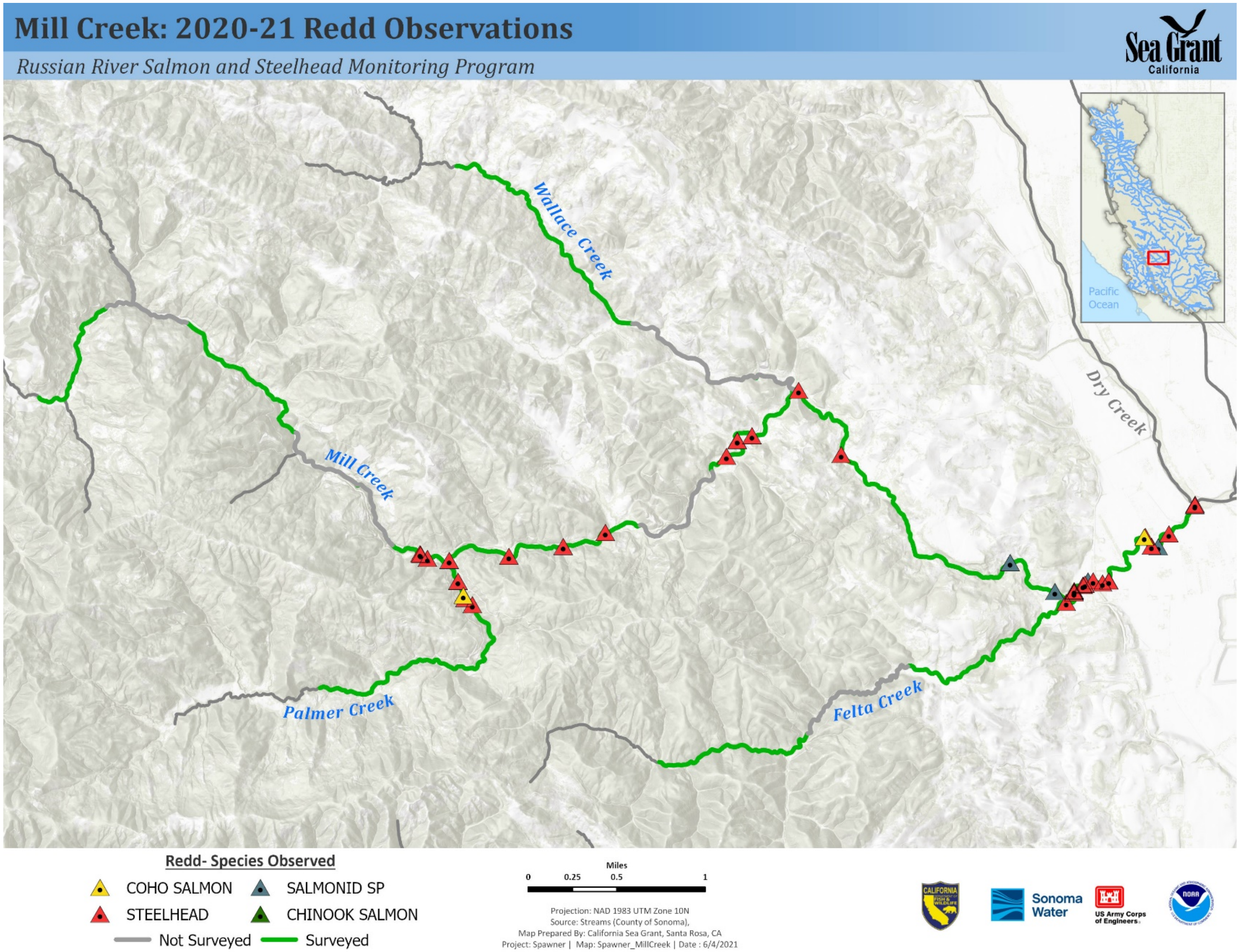


Figure 34. Salmonid redds observed in the Mill Creek watershed during winter 2020/21.

5. Discussion and recommendations

Winter of 2020/21 was characterized by extremely low precipitation and, in turn, low streamflow. For example, total precipitation between 9/15/20 and 3/1/21 at NOAA's Venado rain gage, located in the headwaters of Mill Creek, was 22.7 inches which is less than 60% of the 15-year average and the third lowest over the 15-year period (Figure 3). Average daily streamflow in Austin Creek, an unregulated tributary of the Russian River where USGS has a long-term record of discharge, was only a fraction of what it is in most years (Figure 4), and represents a pattern we anecdotally observed in most of the streams we survey in which gages are not operated. Furthermore, the timing of precipitation in 2020/21 was delayed as compared to most years, with the first rain event that fully opened up the coho spawning tributaries not occurring until January (e.g., Figure 5 - Figure 10).

Late and limited winter precipitation appears to have affected returning salmonids in multiple ways. In most years, Russian River tributaries where coho salmon and steelhead spawn and rear become disconnected from the river during the dry summer and fall seasons, preventing fish passage. Atmospheric river events, typically beginning in late November, reconnect the streams and allow adult salmonids to access spawning habitat soon after they enter the river from the ocean. During the winter of 2020/21, the late and minimal rainfall reduced access to spawning habitat, influencing both timing of entry into the tributaries as well as spawning distribution throughout the watershed.

Adult coho salmon typically begin entering the Russian River in late September, with the peak of entry in mid-November and extending into early February (Figure 35). Migration into the tributaries usually peaks a little later, with the highest proportion of fish entering the tributaries between early December and early January. In 2020/21, adult coho salmon entry into the river began later than average, and showed peaks in mid-November and early December, coinciding with two small rain events (Figure 36). Timing of entry into the tributaries was delayed over a month as compared to average, with adults entering the smaller tributaries during rain events in early- and late-January when precipitation was sufficient to increase flows to levels that permitted passage of adult salmonids.

Over the last 10 years, we have anecdotally observed that more adult coho salmon move upriver and into Dry Creek during years of low and/or late rainfall, and we hypothesized that when fish are unable to access the lower-river tributaries in which they were released as juveniles, they continue their migration upstream into Dry Creek where flows do not limit passage. To investigate whether adult coho salmon have a tendency to migrate further upriver in years when access to lower-river tributary habitat is limited by low flow, we estimated the percentage of adult coho that originated from lower-river release tributaries (i.e., tributaries that enter the river downstream of the Mirabel antenna array (Figure 1)) that migrated upstream of Mirabel over the last three years. Streamflow varied among the three years, with the first date of small tributary access ranging from mid-November in winter 2018/19 to early-January in 2020/21. As suspected, we found a trend of a progressively higher proportion of adults migrating upstream of Mirabel and into Dry Creek with progressively later dates of tributary accessibility (Table 12).

This pattern is evident at an individual level as well. For example, of 10 PIT-tagged adult hatchery coho that originated from juvenile releases into Willow Creek, six of them were detected migrating past the Mirabel antenna array. Of those six, five were also detected in Dry Creek. We observed this for natural-origin adults as well; all three PIT-tagged natural-original coho salmon adults that returned to the basin (tagged as smolts in Willow or Green Valley Creek), were detected at Mirabel and two of the three were later detected in Dry Creek.

Atypical patterns in basinwide redd distribution may also be explained by the low flow conditions of winter 2020/21. Over half of the observed coho salmon redds were found in Austin Creek (18/35; Table 9), whereas in the previous five winters the proportion of coho salmon redds observed in Austin Creek ranged from 0% to 7%. We suspect that this is due to the fact that Austin Creek is more accessible than most tributaries during low flow conditions because of its larger size. We were also surprised by how few salmonid redds were observed in both Green Valley and Willow creeks as compared to Dutch Bill and Mill creeks (Table 9, Figure 31 - Figure 34). Willow and Green Valley creeks are lower gradient than Dutch Bill and Mill creeks, so one possible explanation is that passage in the lower gradient streams was more restricted by the lower flows during the key times when adults were attempting to enter the tributaries. Spawner survey crews reported stream disconnections between rain events on many tributaries, so access was likely patchy and highly variable among tributaries.

Throughout the basin, adult coho salmon presence was documented in eight of 33 coho salmon streams surveyed (24%) (Table 9, Figure 25), which represents less than half of the proportion observed during the previous five years (average 56%, range 50% - 68%). A reduction in steelhead spatial distribution was also observed, though it was not as extreme as that observed for coho salmon; adult steelhead presence was documented in 50% of steelhead streams surveyed, whereas in the previous five years, it averaged 65% and ranged from 56% to 74%.

As during the winter of 2019/20, we observed uncharacteristically high numbers of steelhead redds in lower Dutch Bill Creek (Figure 32), and this was likely influenced by adult releases of hatchery steelhead in the mainstem of the Russian River in the vicinity of the confluence with Dutch Bill Creek. CDFW released Floy-tagged adult steelhead at multiple Russian River sites, including at the Monte Rio boat launch, which is immediately across the river from Dutch Bill Creek. Spawner survey observations of Floy-tagged adult steelhead and steelhead redds in Dutch Bill Creek increased shortly after these releases began. In the future, we recommend PIT tagging adult steelhead that are released from the hatchery to track their movement patterns. We also suggest the consideration of new release locations that are further from critical coho salmon recovery streams.

The number of coho salmon returning to the Russian River watershed during the winter of 2020/21 was the third lowest on record since the winter of 2010/11, with an estimated 214 hatchery coho salmon adults returning to the basin, not including fish released as adults (Figure 16, Table 7). Smolt abundance for the 2018 cohort was low to average in the four Broodstock Program monitoring streams (Figure 17-Figure 20), which may, in part, have contributed to the relatively low number of adult returns.

Smolt to adult return (SAR) ratios were lower than average in three of the four streams (Table 8), suggesting that poor "marine" survival may have also contributed to the low number of adult returns. However, in a year when tributary access was limited and fish that originated from one stream were more likely to return to a different (more accessible) stream, the SAR ratios are presumably biased. For example, the SAR ratio for Mill Creek was 3.4%, yet none of the returning fish originated from Mill Creek juvenile releases (Table 6). We estimate the SAR ratios in the manner described in the methods because it is most comparable to methods used in other California streams, but with such low sample sizes, there are many possibilities for bias. Despite these confounding issues, we believe this approach has the capability of detecting significant trends in SAR over the long term.

We think that the continued observation of low SAR ratios (average of < 1% across all four streams and years; Table 8) warrants further investigation. Because we do not detect a sufficient number of PIT-tagged smolts at the Duncans Mills antenna array at the head of the estuary, our estimate of "marine" survival on a given monitoring stream encompasses survival of smolts migrating through the river and estuary, survival in the ocean, and survival of adults migrating back through the estuary and river. It would be beneficial to disentangle riverine and estuarine survival from ocean survival to help identify bottlenecks that could be addressed in the riverine/estuarine environments. Sonoma Water and the Army Corps are collaborating on a study to evaluate coho salmon smolt survival through the river using acoustic tags, and we recommend continued support for this effort as it will complement the tributary monitoring and increase our understanding of survival bottlenecks, and, in turn, help guide future coho salmon recovery efforts.

The winter of 2020/21 was the first year in which adult hatchery coho salmon were released into the mainstem of the Russian River. The adults were released on January 7, 2021 at Steelhead Beach (Figure 1), and a high proportion of these fish (76%) were later detected on PIT antenna arrays within the basin (Figure 21, Figure 22). The majority of the PIT-tagged adults were detected on the Mark West Creek antenna array which is the first tributary located upstream of the release site. A number of adults were also detected entering Dry Creek, with three adults detected in Mill Creek. Only one adult was detected on an antenna array downstream of the release site in Green Valley Creek. Because these adults potentially spawned in locations where other adult coho returned, we do not have a means of quantifying their contribution to redds and natural production which is a consideration for selection of future release sites if the program would like to evaluate spawning success of adult releases. If such evaluation is desired, some of the confounding with other releases could be reduced by stocking the fish into (or near the confluence with) tributaries that are not receiving other releases.

Overall, the winter of 2020/21 posed new flow-related challenges to salmonids, particularly coho salmon. Although we have consistently observed the impacts of low streamflow and drought on juvenile salmon rearing in tributaries throughout the summer dry season (Obedzinski et al. 2018; Vander Vorste et al. 2020), as well as the impacts of dry spring conditions on the ability of smolts to emigrate (CSG unpublished data), it is only in more recent years that we are beginning to document the impacts of winter drought. The low and late precipitation in winter of 2020/21 delayed the time that adult salmonids could access the spawning tributaries by approximately six weeks and it reduced the number of streams they could access during their spawning window. On a stream scale, coho salmon presence was reduced to approximately half of what was observed in the previous five years, and within streams it was likely even further reduced. Although we did not quantify it, field crews observed redd desiccation and adult salmonid stranding on multiple occasions.

While it is difficult to identify measures that can be taken to promote the resilience of salmon populations to large-scale climatic patterns, we continue to encourage the bet-hedging strategy that the Broodstock Program has taken of stocking coho salmon at different life stages into multiple streams. Over the many years of monitoring, we have observed that the success of specific release groups varies by stream and is related to environmental conditions that we are unable to predict at the time of release. For example, until this winter, we have always observed a high proportion of spawning activity in Green Valley Creek, but in winter 2020/21 we observed only one coho salmon redd and very few steelhead redds. In contrast, Dutch Bill Creek, where we generally observe a lower proportion of redds, had an increase in spawning activity. This is fortunate, given that juveniles have a higher probability of surviving the summer season in times of drought (Obedzinski et al. 2018; Vander Vorste et al. 2020). Because we cannot predict such environmental conditions at the time of release, it is important to continue stocking multiple streams and release groups with the hope that conditions will be suitable for at least some of the fish. Diversifying the program's strategies to include adult releases and remote stream side incubators is certainly warranted, but will require careful planning in order to evaluate each strategy's effectiveness.

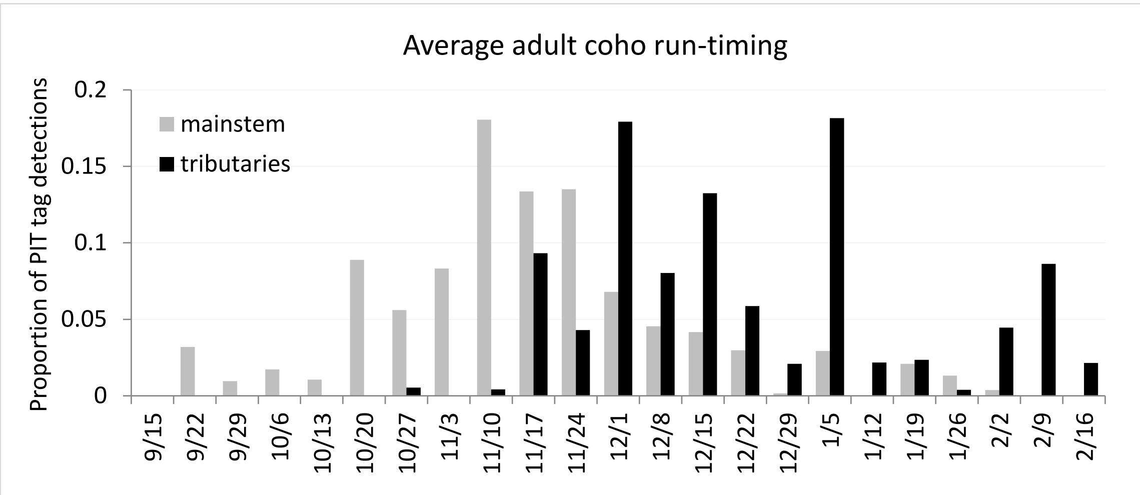


Figure 35. Average proportion of PIT tag detections at Russian River mainstem and tributary antenna arrays, winters 2012/13 through 2019/20.

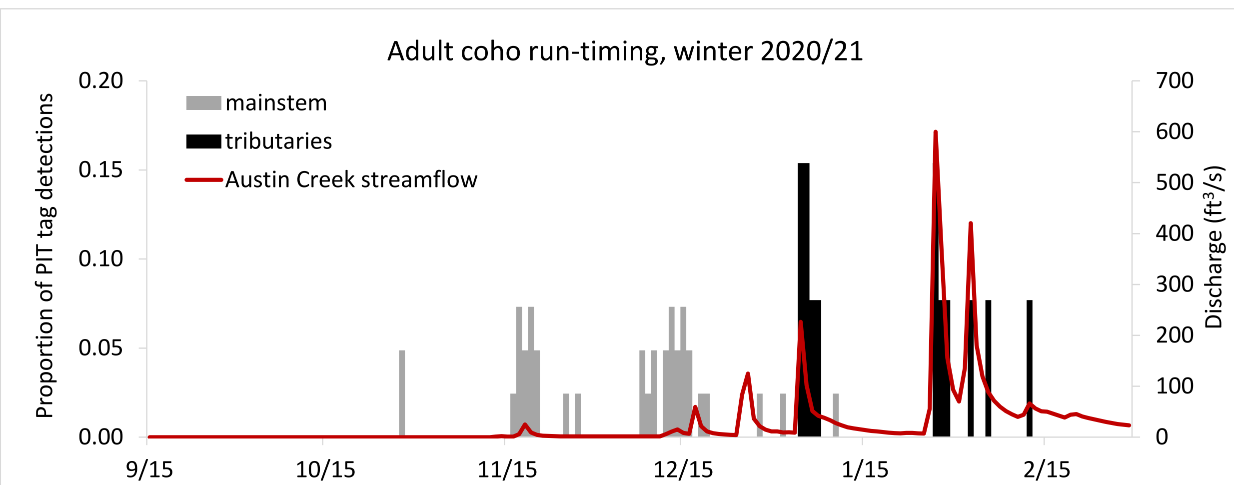


Figure 36. Proportion of PIT tag detections at Russian River mainstem and tributary antenna arrays in relation to Austin Creek streamflow, winter 2020/21.

Table 12. Percentages of adult returns from lower-river release groups migrating to upper-river reaches in relation to timing of access to spawning tributaries in the Russian River, winters 2018/19- 2020/21.

Winter	Adult returns originating from release groups downstream of Mirabel	Date of first detection in tributaries	Number (percent) detected at Mirabel	Number (percent) detected in Dry Creek
2018/19	46	11/22/2018	9 (20%)	8 (17%)
2019/20	65	12/1/2019	29 (45%)	24 (37%)
2020/21	40	1/4/2021	31 (78%)	23 (58%)

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