Russian River Coho Salmon and Steelhead Monitoring Report: Winter 2018/19

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Sea Grant California

Russian River Coho Salmon Monitoring Program

University of California

Contents

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I. 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: Dutch Bill, Green Valley, Mill, and Willow 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) (http://www.cohopartnership.org), an effort to improve stream flow and water supply reliability to water-users in five 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 all 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 at http://ca-sgep.ucsd.edu/russianrivercoho.

II. PIT Tag Monitoring

Goals and Objectives

Passive integrated transponder (PIT) tags and PIT tag detection systems (antennas and transceivers) are used to document status and trends of Russian River salmonid populations at both stream-specific and basinwide scales. From September 15, 2018, through March 1, 2019, 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.

Methods

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 (Table 1). For winter 2018/19 monitoring purposes, the Broodstock Program documented the number and percentage of PIT-tagged coho salmon by stream and release group for cohorts 2016 and 2017 (fish returning during the winter of 2018/19 as age-3 or age-2 adults, respectively) (Table 2). In addition, approximately half of all natural-origin coho salmon smolts captured in downstream migrant traps during the springs of 2017 and 2018 were PIT tagged in Willow, Green Valley, and Mill creeks (California Sea Grant 2017), (California Sea Grant 2018).

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 baseflow conditions. During storm events, stream depths exceeded maximum read range depths, so if PIT-tagged fish were travelling in the water column above the maximum read depth, they would not be detected on the antennas. The paired arrays were used to estimate antenna efficiency and account for undetected fish. From September 15, 2018 through March 1, 2019, 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%

[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 Creek.

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

Cohort (Hatch Year)	Tributary	Release Group	Total Coho Salmon Released	PIT-Tagged Coho Salmon Released	Percent PIT-tagged Coho Salmon Released
2016	Willow Creek	fall	15,273	2,291	15%
2016	Willow Creek	presmolt	7,961	1,199	15%
2016	Sheephouse Creek	fall	3,084	465	15%
2016	Freezeout Creek	fall	3,083	462	15%
2016	Austin Creek	fall	3,996	604	15%
2016	Gilliam Creek	spring	4,080	604	15%
2016	Thompson Creek	spring	2,073	304	15%
2016	Gray Creek	spring	4,097	608	15%
2016	Devil Creek	spring	4,095	607	15%
2016	Dutch Bill Creek	spring	1,016	1,016	100%
2016	Dutch Bill Creek	fall	9,911	1,494	15%
2016	Dutch Bill Creek	smolt	6,063	914	15%
2016	Green Valley Creek	spring	452	452	100%
2016	Green Valley Creek	fall	6,168	929	15%
2016	Green Valley Creek	presmolt	8,443	1,274	15%
2016	Green Valley Creek	smolt	6,064	913	15%
2016	Purrington Creek	fall	3,090	461	15%
2016	Mark West Creek	fall	15,061	2,291	15%
2016	Mark West Creek	smolt	10,150	1,542	15%
2016	Porter Creek	fall	6,096	913	15%
2016	Dry Creek	fall	1,244	1,244	100%
2016	Dry Creek	smolt	10,152	1,540	15%
2016	Mill Creek	spring	510	510	100%
2016	Mill Creek	fall	16,094	2,384	15%
2016	Mill Creek	smolt	6,079	915	15%
2016	Palmer Creek	spring	4,048	610	15%
2017	Willow Creek	fall	10,075	2,010	20%
2017	Willow Creek	smolt	8,876	1,797	20%
2017	Sheephouse Creek	fall	3,029	608	20%
2017	Freezeout Creek	fall	3,035	610	20%
2017	RR Mainstem	smolt	10,103	2,040	20%
2017	Austin Creek	fall	9,048	1,806	20%
2017	Gilliam Creek	fall	3,042	610	20%
2017	Gray Creek	fall	3,040	608	20%
2017	Devil Creek	fall	3,043	611	20%
2017	Dutch Bill Creek	spring	995	995	100%
2017	Dutch Bill Creek	fall	7,077	1,410	20%
2017	Dutch Bill Creek	smolt	5,258	1,055	20%
2017	Green Valley Creek	spring	454	454	100%
2017	Green Valley Creek	fall	8,069	1,610	20%
2017	Green Valley Creek	smolt	14,066	2,859	20%
2017	Redwood Creek (Atasc	fall	3,041	609	20%
2017	Purrington Creek	fall	3,041	610	20%
2017	Porter Creek	fall	6,062	1,728	29%
2017	Dry Creek	fall	2,977	2,977	100%
2017	Dry Creek	smolt	10,105	2,039	20%
2017	Mill Creek	spring	1,006	1,006	100%
2017	Mill Creek	fall	10,063	2,007	20%
2017	Mill Creek	smolt	5,312	1,104	21%
2017	Palmer Creek	fall	3,032	610	20%

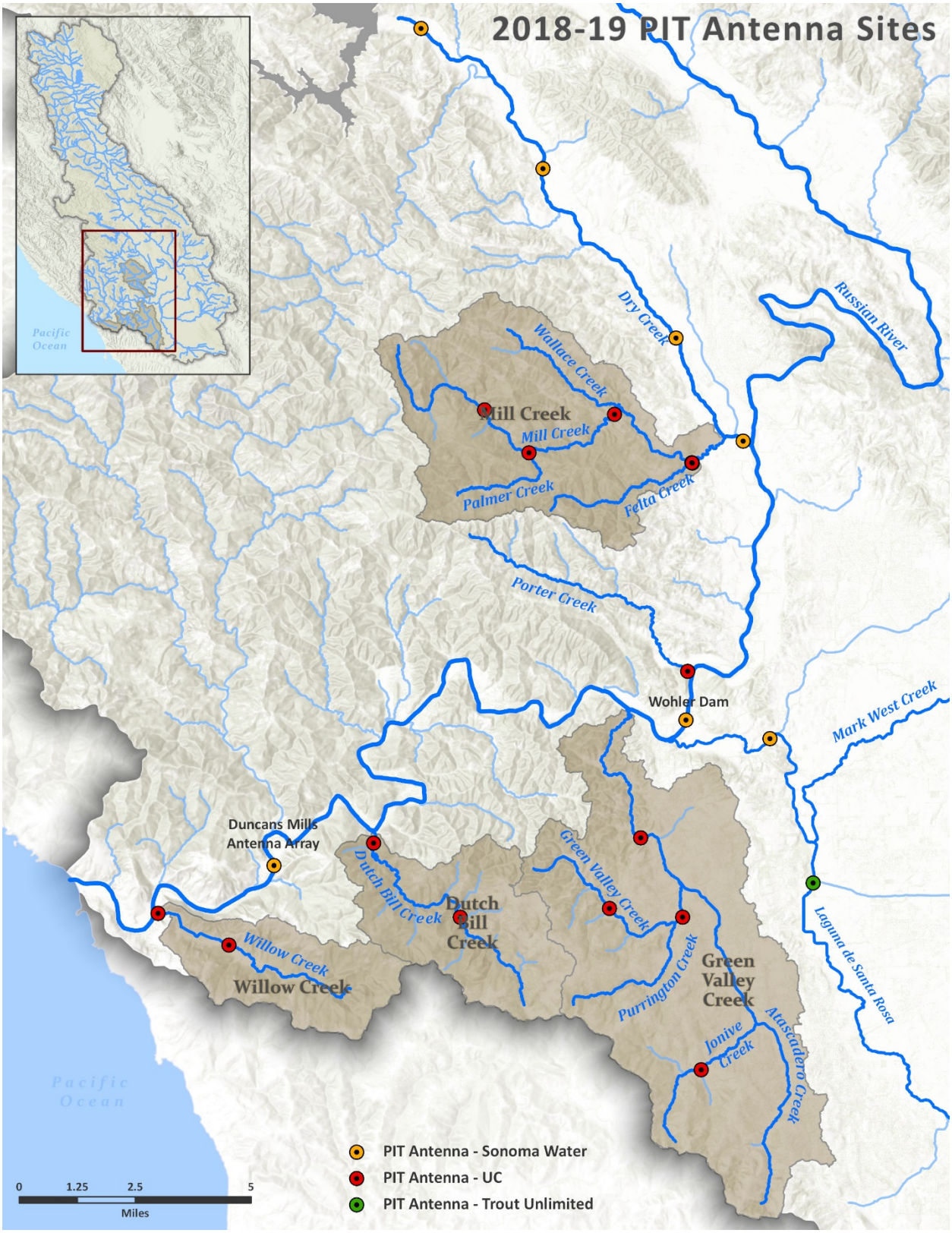

Figure 1. Passive Integrated Transponder (PIT) antenna locations in the Russian River watershed, winter 2018/19.

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

Data Analysis

First, all records of two- and three-year-old PIT-tagged coho salmon detected on antenna arrays between September 15, 2018 and March 1, 2019 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.

Adult Return Timing Relative to Flow Conditions:

The first detection of each returning PIT-tagged hatchery adult coho salmon between September 15, 2018 and March 1, 2019 was plotted with streamflow or stage data from the nearest available streamflow gage at each antenna site.

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 either released from the hatchery into each respective stream or 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 estimate the total number of hatchery coho salmon adults returning to the Russian River mainstem at Duncans Mills, a similar calculation approach was used; however, 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 had no means of estimating adults returning to those streams during the winter of 2018/19 so any returns to those creeks are not included in the basinwide estimate.

Smolt to Adult Return (SAR) Ratio:

In each of the four Broodstock Program streams, the sum of the estimated number of two-year old hatchery adults returning during the winter of 2017/18 and three-year old adults returning during the winter of 2018/19 was divided by the estimated number of smolts migrating from each stream between March 1 and June 30 of 2017 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.

Results

Adult Return Timing Relative to Flow Conditions

Total precipitation during the between September 15, 2018 and March 1, 2019 was above the 10-year average (Figure 3) and was characterized by moderate rain events in November and December, larger events in January and flood events from mid to late February. The majority of the adults returning to the Russian River passed the Duncans Mills antenna array in mid to late November 2018 with a few adults returning prior to that in October and a few returning later, with the last adult detection in early

February 2018 (Figure 4). The Duncans Mills antenna array became in operational from February 13 through March 1, 2019 following a significant flood event. Adult coho salmon detections on the tributary antennas spanned from mid-November through mid-January and appeared to coincide with storm events (Figure 5). Adult detection timing in the four Broodstock Program streams was similar among streams with a slightly higher proportion of detections later in the Mill Creek system (Figure 6 - Figure 9). In Willow Creek there were more and earlier detections at the antenna array at the mouth (river km 0.41) than at the upstream array that marks the beginning of spawning habitat (river km 3.69) (Figure 6).

Adult Return Estimates

The estimated numbers of adult hatchery coho salmon returning to Willow, Dutch Bill, Green Valley, and Mill creeks were 78 (27 to the upper reaches), 49, 26, and 93, respectively (Table 3 - Table 7), and the estimated number returning to the Russian River Basin was 642 (Table 8). In all four Broodstock Program streams, the majority of the adult returns were age-3. Straying was documented in each stream, although in Willow Creek, the only adults observed returning to the spawning habitat above the upper antenna array were from Willow Creek releases (Table 3 - Table 7). One age-3 natural-origin adult that was tagged as a smolt in Willow Creek in 2017 was detected at the Duncans Mills array. This was the only natural-origin PIT-tagged fish documented to return in winter 2018/19.

Estimated adult returns during the winter of 2018/19 were generally higher than most years of data collection (with the exception of Green Valley Creek), though not the highest on record (Figure 10 - Figure 14). The proportion of age-2 adults returning was much lower than in most years in Green Valley and Mill creeks (0% and 5%, respectively), but higher than average in Willow and Dutch Bill creeks (75% and 45 %, respectively) (Figure 10 - Figure 13). The proportion of age-2 returns at the Duncans Mills antenna array was 17%, the second lowest recorded in the last seven winters (Figure 15).

Smolt to Adult Return (SAR) Ratio

Overall, SAR ratios were low, and ranged from 0.4% in Willow Creek to 1.5% in Mill Creek (Figure 16 - Figure 19). In Willow Creek, the 2018/19 SAR ratio was lower than those previously recorded, in Dutch Bill and Green Valley creeks, ratios were similar to stream-specific averages and in Mill Creek, the ratio was higher than average (Table 9).

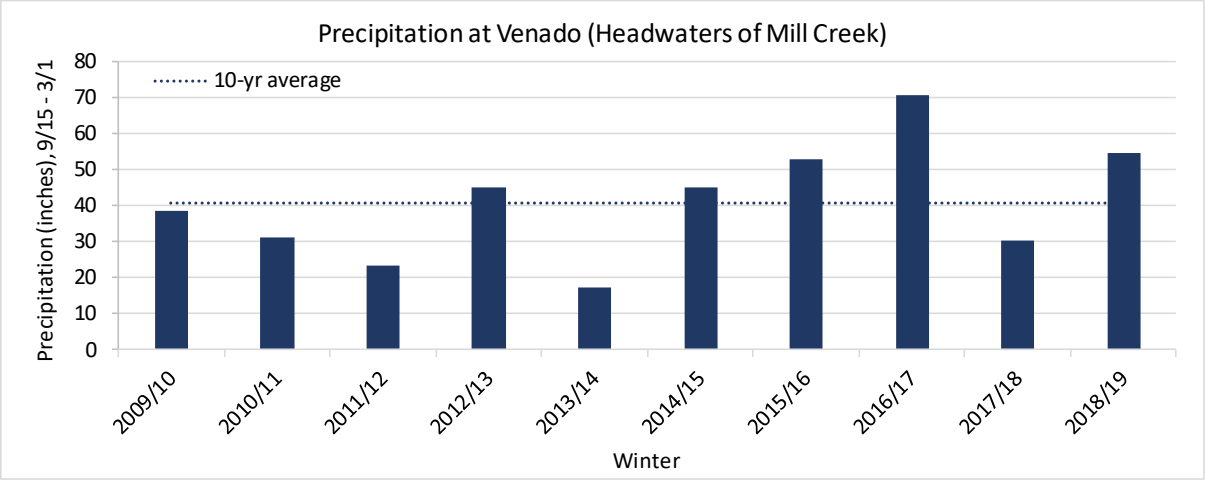

Figure 3. Precipitation at Venado gage near Mill Creek headwaters. Data downloaded from NOAA website: www.ncdc.noaa.gov/cdo-web.

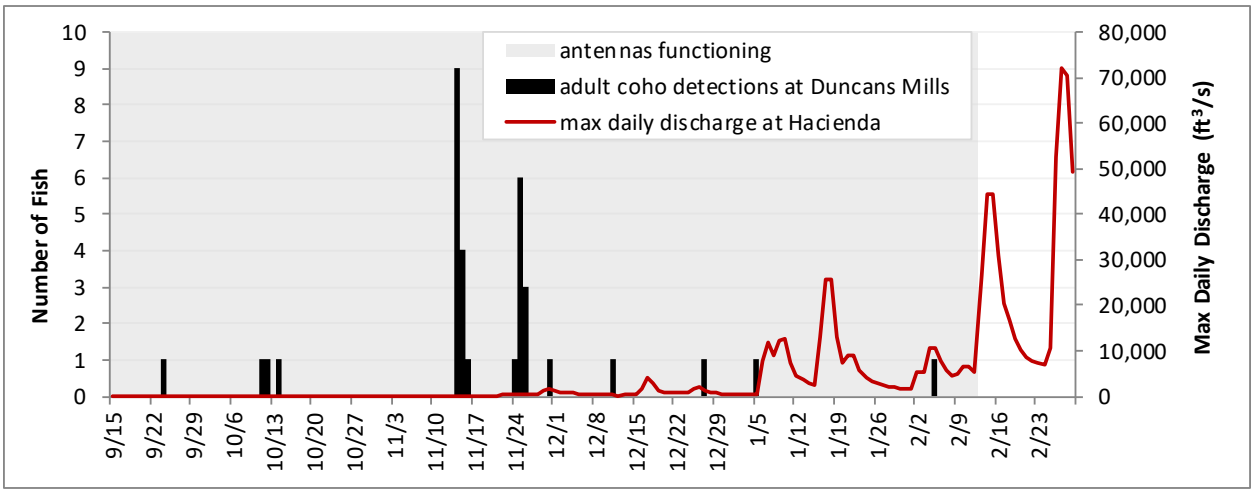

Figure 4. Detections of PIT-tagged coho salmon adults passing upstream of the Duncans Mills antenna array, September 15, 2018 - March 1, 2019. Discharge data was downloaded from USGS website: http://waterdata.usgs.gov.

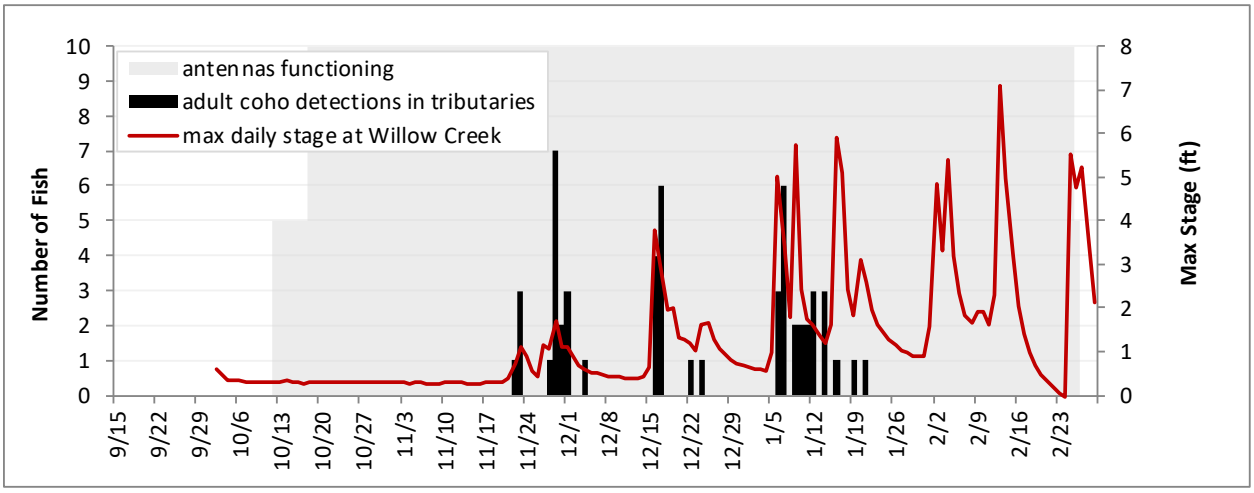

Figure 5. Detections of PIT-tagged coho salmon adults entering tributaries of the Russian River between September 15, 2018 - March 1, 2019. Stage data was collected by CSG.

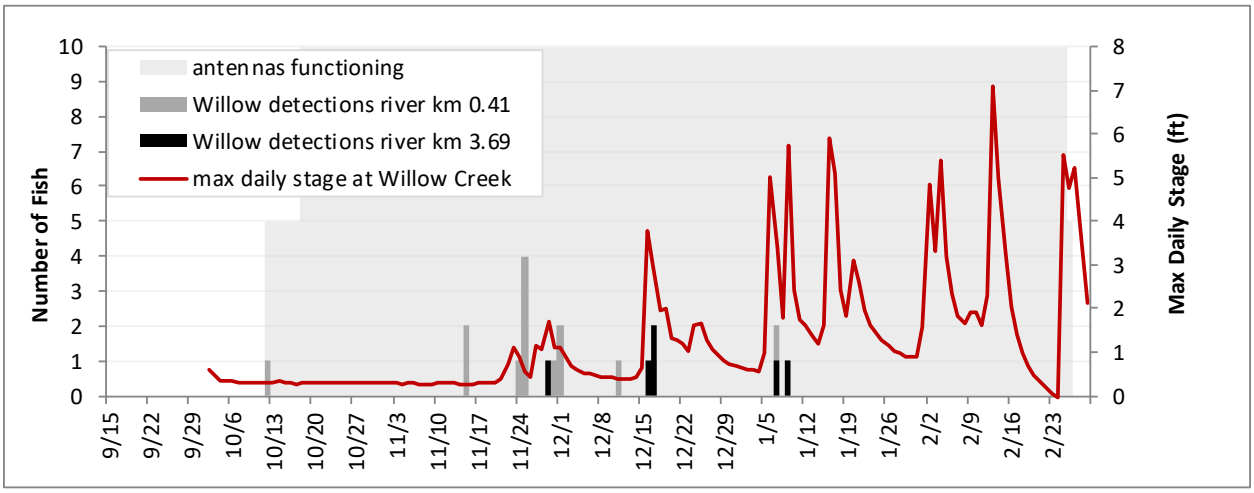

Figure 6. Detections of PIT-tagged coho salmon adults entering Willow Creek between September 15, 2018 - March 1, 2019. Stage data was collected by CSG.

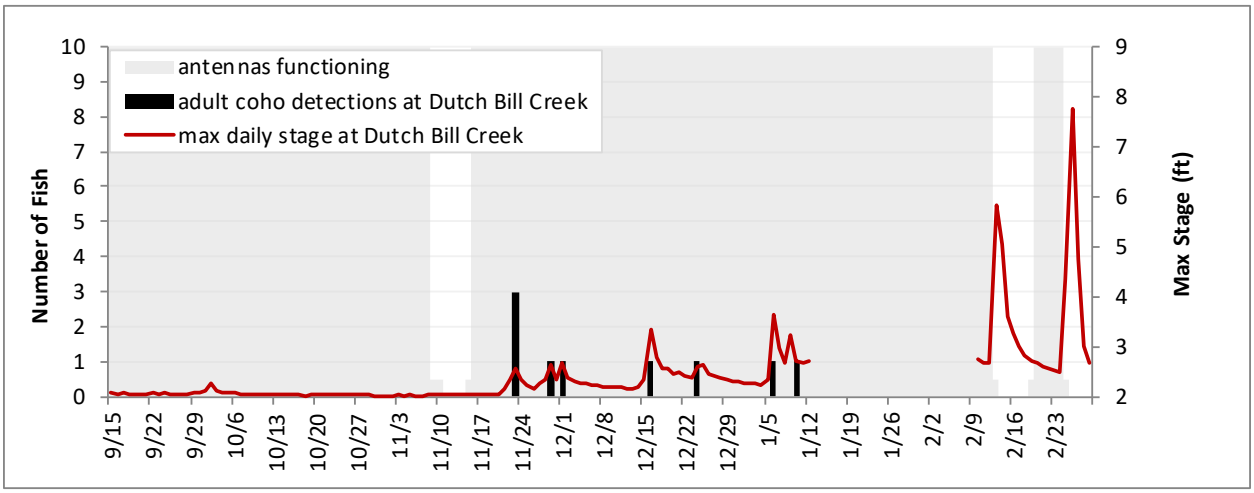

Figure 7. Detections of PIT-tagged coho salmon adults passing upstream of the Dutch Bill Creek antenna array, September 15, 2018 - March 1, 2019. Stage data was provided by Trout Unlimited.

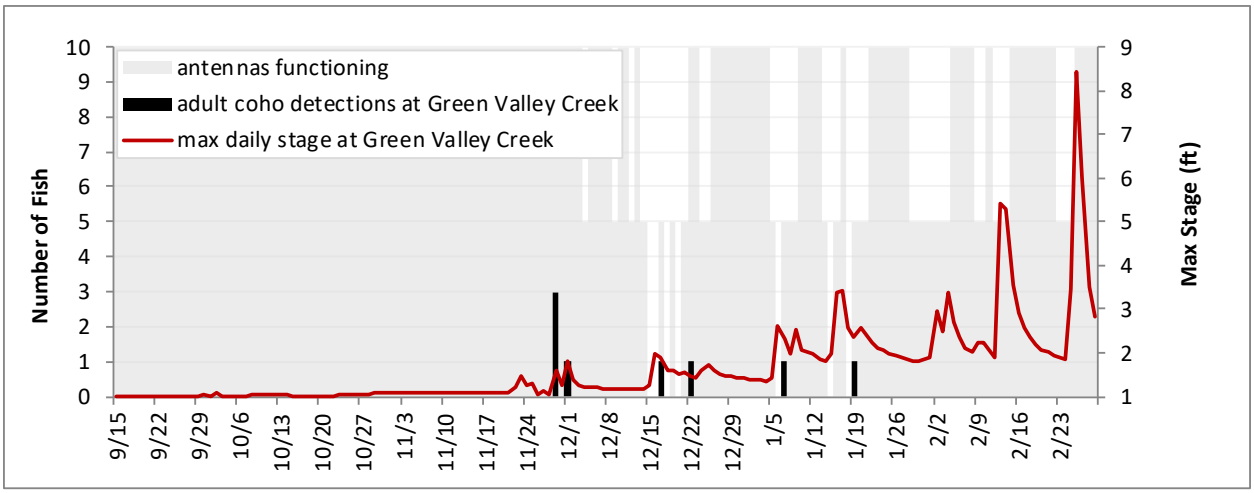

Figure 8. Detections of PIT-tagged coho salmon adults passing upstream of the Green Valley Creek antenna array, September 15, 2018 - March 1, 2019. Stage data was provided by Trout Unlimited.

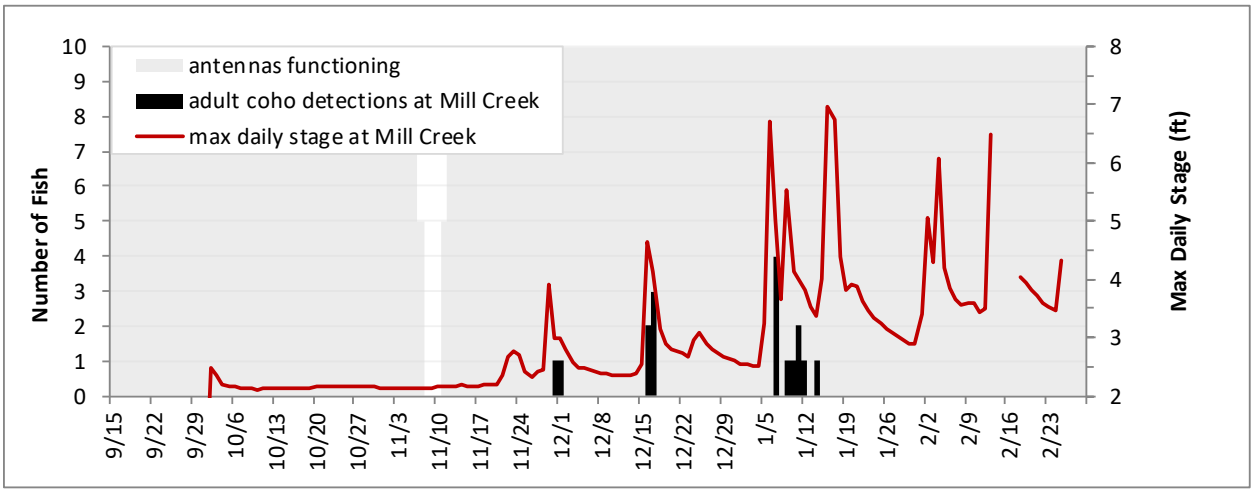

Figure 9. Detections of PIT-tagged coho salmon adults passing upstream of the Mill Creek antenna array, September 15, 2018 - March 1, 2019. Stage data was provided by Trout Unlimited.

Table 3. Minimum, expanded, and estimated counts of adult coho salmon returning to Willow Creek (array at mouth; river km 0.41) between September 15, 2018 and March 1, 2019. 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	Dry Creek	hatchery	smolt	1	15%	6.6	0.93	7.1
	Green Valley Creek	hatchery	fall	1	15%	6.6	0.93	7.1
		hatchery	spring	1	100%	1.0	0.93	1.1
		hatchery	smolt	2	15%	13.3	93%	14.2
	Willow Creek	hatchery	fall	3	15%	20.0	93%	21.4
2	Willow Creek	hatchery	fall	4	20%	20.0	93%	21.5
	Devil Creek	hatchery	fall	1	20%	5.0	93%	5.3
						Estimated hatchery adult returns (age-3):		50.9
						Estimated hachery adult returns (age-2):		26.8
						Total estimated adult returns:		**78**

Table 4. 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, 2018 and March 1, 2019. 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	1	15%	6.7	100%	6.7
2	Willow Creek	hatchery	fall	4	20%	20.0	100%	20.0
						Estimated hatchery adult returns (age-3):		6.7
						Estimated hachery adult returns (age-2):		20.0
						Total estimated adult returns:		**27**

Table 5. Minimum, expanded, and estimated counts of adult coho salmon returning to Dutch Bill Creek between September 15, 2018 and March 1, 2019. 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	1	15%	6.6	100%	6.6
	Gray Creek	hatchery	spring	1	15%	6.7	100%	6.7
	Green Valley Creek	hatchery	smlt	1	15%	6.6	100%	6.6
	Willow Creek	hatchery	fall	1	15%	6.7	100%	6.7
2	Austin Creek	hatchery	fall	2	15%	13.2	100%	13.2
	Dry Creek	hatchery	fall	2	100%	2.0	100%	2.0
	Dutch Bill Creek	hatchery	fall	1	15%	6.6	100%	6.6
							Estimated hatchery adult returns (age-3):	26.7
							Estimated hatchery adult returns (age-2):	21.9
							Total estimated adult returns:	**49**

Table 6. Minimum, expanded, and estimated counts of adult coho salmon returning to Green Valley Creek between September 15, 2018 and March 1, 2019. 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	smolt	1	15%	6.6	83%	7.9
	Green Valley Creek	hatchery	presmolt	1	15%	6.6	83%	8.0
	Green Valley Creek	hatchery	spring	1	100%	1.0	83%	1.2
	Green Valley Creek	hatchery	smolt	1	100%	1.0	83%	1.2
	Mill Creek	hatchery	smolt	1	15%	6.6	83%	8.0
							Estimated hatchery adult returns (age-3):	26
							Total estimated adult returns:	**26**

Table 7. Minimum, expanded, and estimated counts of adult coho salmon returning to Mill Creek between September 15, 2018 and March 1, 2019. 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	smolt	5	15%	33.0	100%	33.0
	Green Valley Creek	hatchery	presmolt	3	15%	19.9	100%	19.9
		hatchery	smolt	2	100%	2.0	100%	2.0
	Mill Creek	hatchery	fall	2	15%	13.5	100%	13.5
		hatchery	smolt	1	15%	6.6	100%	6.6
	Palmer Creek	hatchery	spring	1	15%	6.6	100%	6.6
	Willow Creek	hatchery	presmolt	1	15%	6.6	100%	6.6
2	Mill Creek	hatchery	fall	1	20%	5.0	100%	5.0
							Estimated hatchery adult returns (age-3):	88.3
							Estimated hatchery adult returns (age-2):	5.0
							Total estimated adult returns:	**93**

Table 8. Minimum, expanded, and estimated counts of hatchery adult coho salmon returning to the Russian River mainstem at Duncans Mills between September 15, 2018 and March 1, 2019. 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	Release Group	Minimum Count	Percent PIT-tagged	Expanded Count	Estimated Antenna Efficiency	Estimated Count
3	Dry Creek	fall	2	100%	2.0	29%	6.9
		smolt	2	15%	13.2	29%	45.2
	Dutch Bill Creek	smolt	1	15%	6.6	29%	22.7
	Freezeout Creek	fall	1	15%	6.7	29%	22.9
	Gray Creek	spring	1	15%	6.7	29%	23.1
	Green Valley Creek	fall	1	15%	6.6	29%	22.8
		presmolt	2	15%	13.3	29%	45.4
		smolt	3	15%	19.9	29%	68.3
	Mark West Creek	fall	2	15%	13.1	29%	45.1
		smolt	1	15%	6.6	29%	22.6
	Mill Creek	fall	2	15%	13.5	29%	46.3
		smolt	1	15%	6.6	29%	22.8
	Palmer Creek	spring	1	15%	6.6	29%	22.8
		fall	2	15%	13.4	29%	45.8
	Willow Creek	fall	1	15%	6.7	29%	22.9
		presmolt	2	15%	13.3	29%	45.5
2	Austin Creek	fall	2	20%	10.0	29%	34.4
	Dry Creek	fall	2	100%	2.0	29%	6.9
	Palmer Creek	fall	1	20%	5.0	29%	17.0
	Willow Creek	fall	1	20%	5.0	29%	17.2

Estimated adults passing Duncans Mills (age-3):	530.9
Estimated adults passing Duncans Mills (age-2):	75.4
Estimated adults returning to Willow Creek that were not detected at Duncans Mills (age-3):	14.3
Estimated adults returning to Willow Creek that were not detected at Duncans Mills (age-2):	21.4
Total estimated hatchery adult returns:	**642**

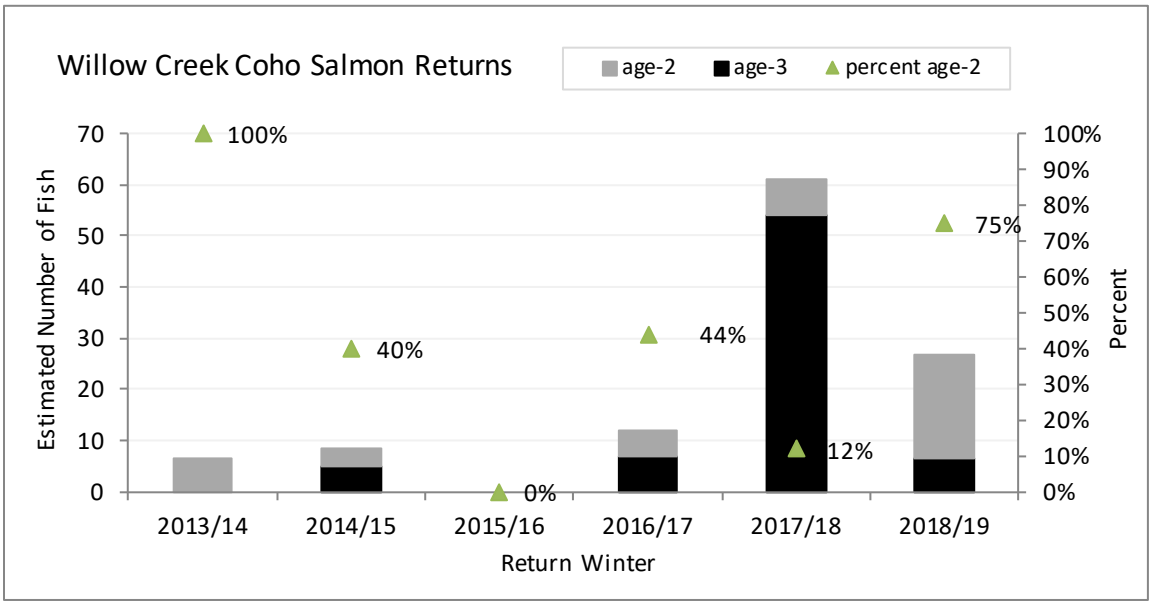

Figure 10. Estimated annual Willow Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2018/19. Note that estimates are based on returns to the upper antennas at river km 3.69 whereas in previous reports, estimates were based on detections at the Willow Creek mouth at river km 0.41.

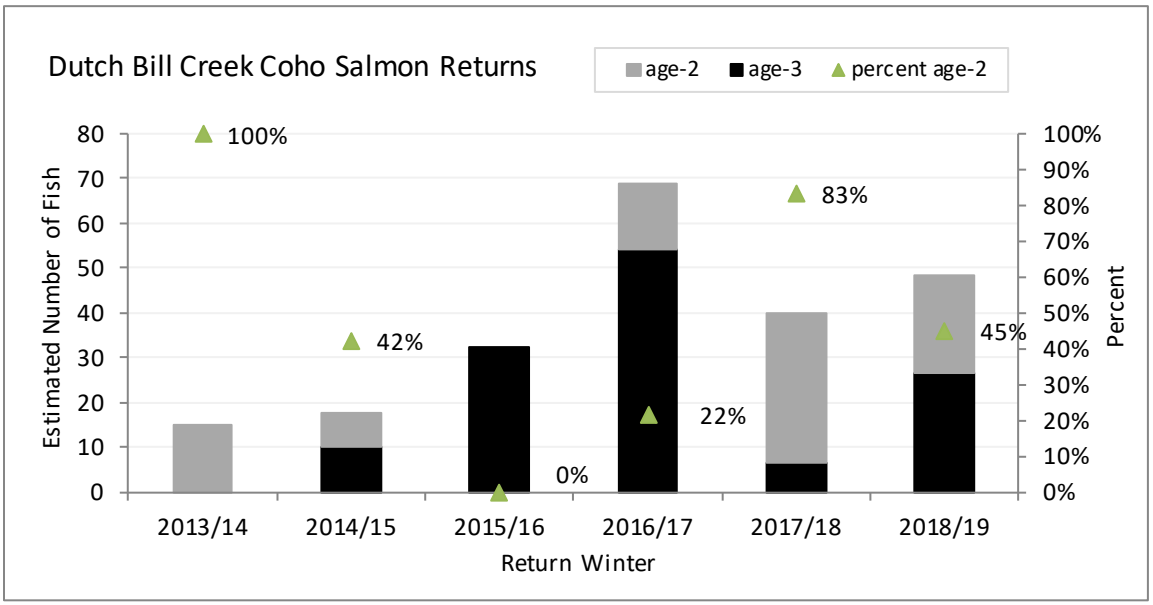

Figure 11. Estimated annual Dutch Bill Creek adult hatchery coho salmon returns by age, return seasons 2013/14 – 2018/19.

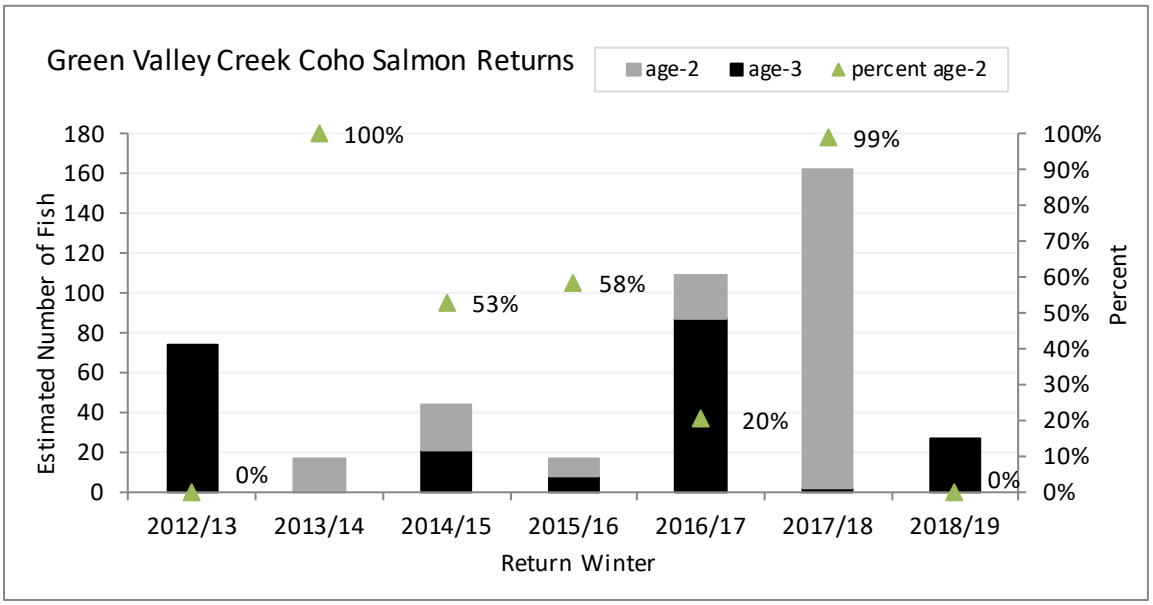

Figure 12. Estimated annual Green Valley Creek adult hatchery coho salmon returns by age, return seasons 2012/13 – 2018/19.

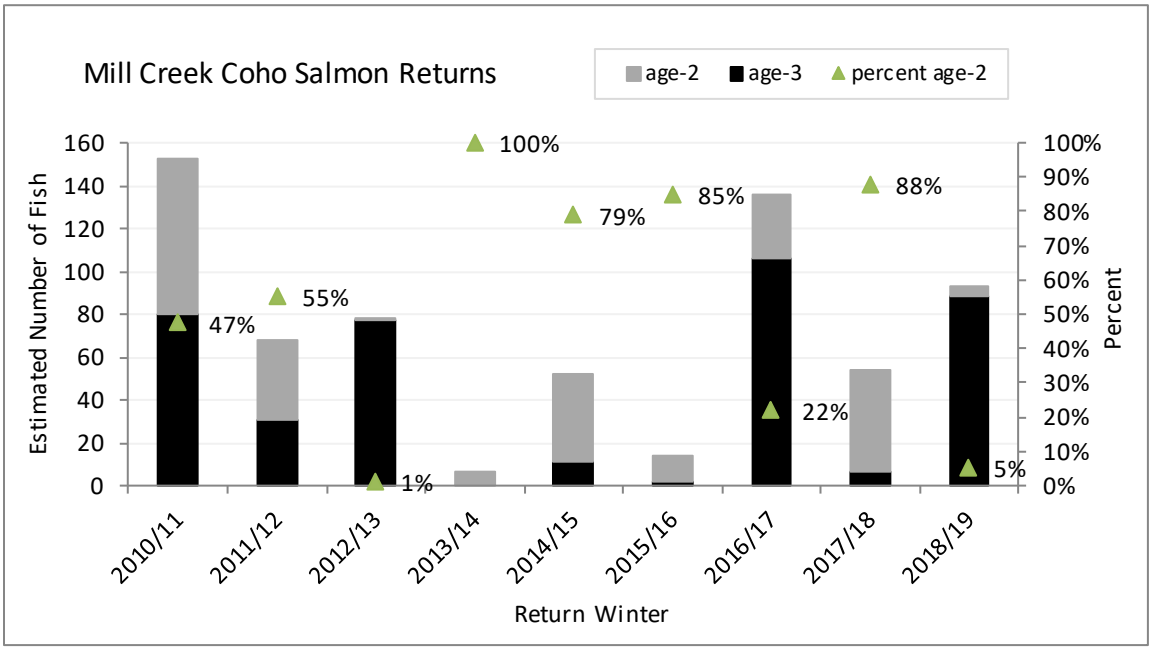

Figure 13. Estimated annual Mill Creek adult hatchery coho salmon returns by age, return seasons 2010/11 – 2018/19.

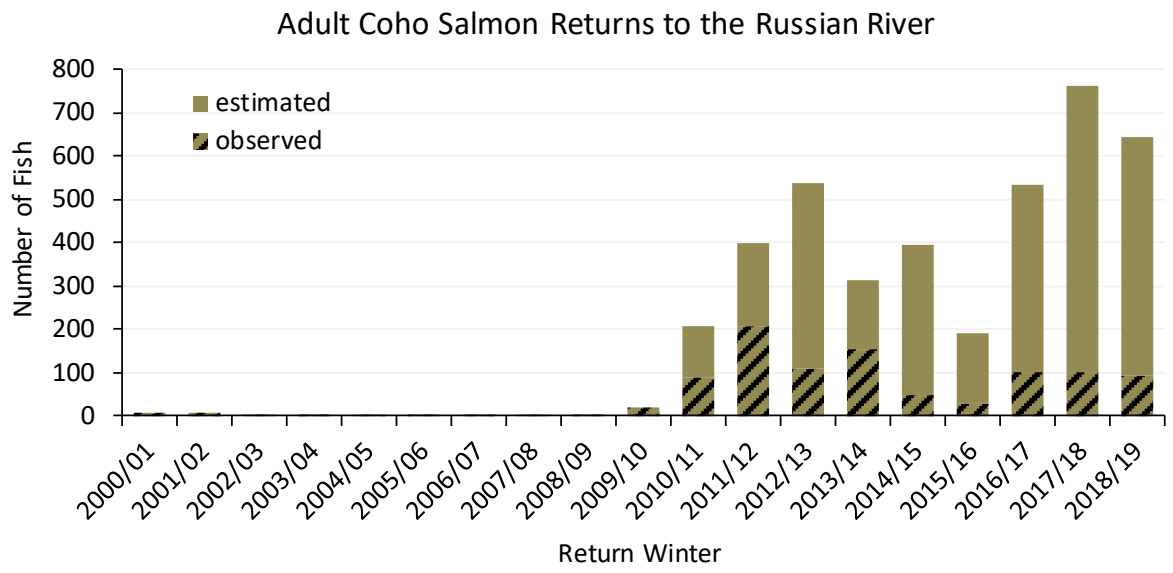

Figure 14. Estimated annual adult hatchery coho salmon returns to the Russian River, return seasons 2000/01-2018/19. Note that methods for counting/estimating the number of returning adult coho salmon were not consistent among years; prior to 2009/10, spawner surveys were the primary method, from 2009/10 – 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.

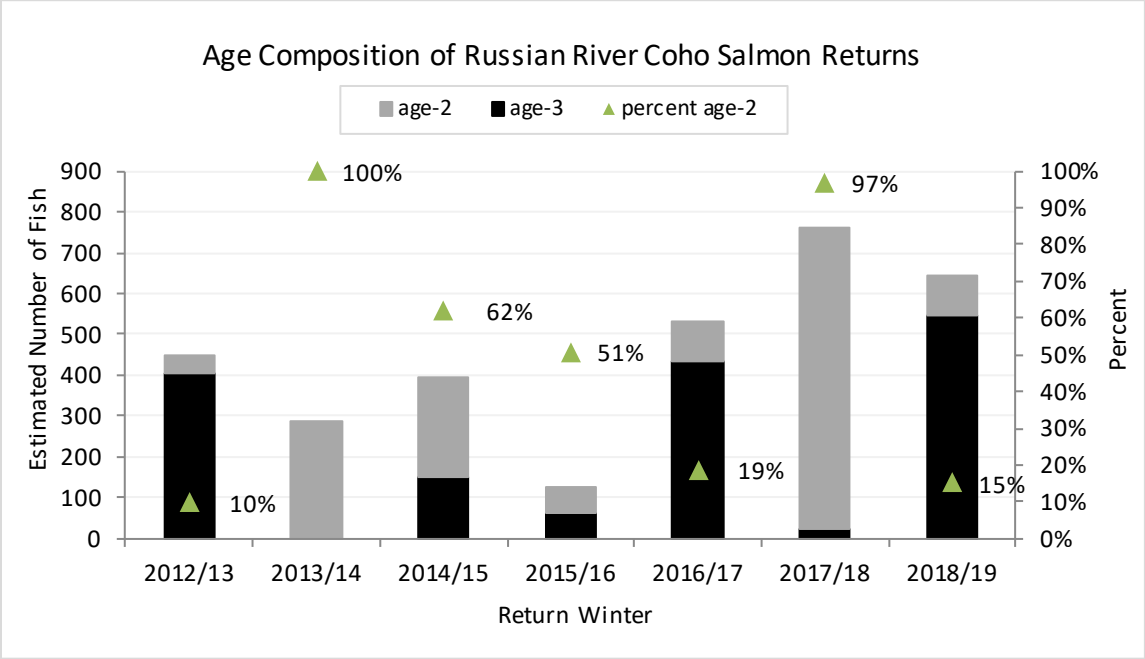

Figure 15. Estimated annual Russian River adult hatchery coho salmon returns by age, return seasons 2012/13-2018/19. Note that this figure includes only fish that we were able to age; therefore, totals will be less than adult return estimates shown in Figure 14.

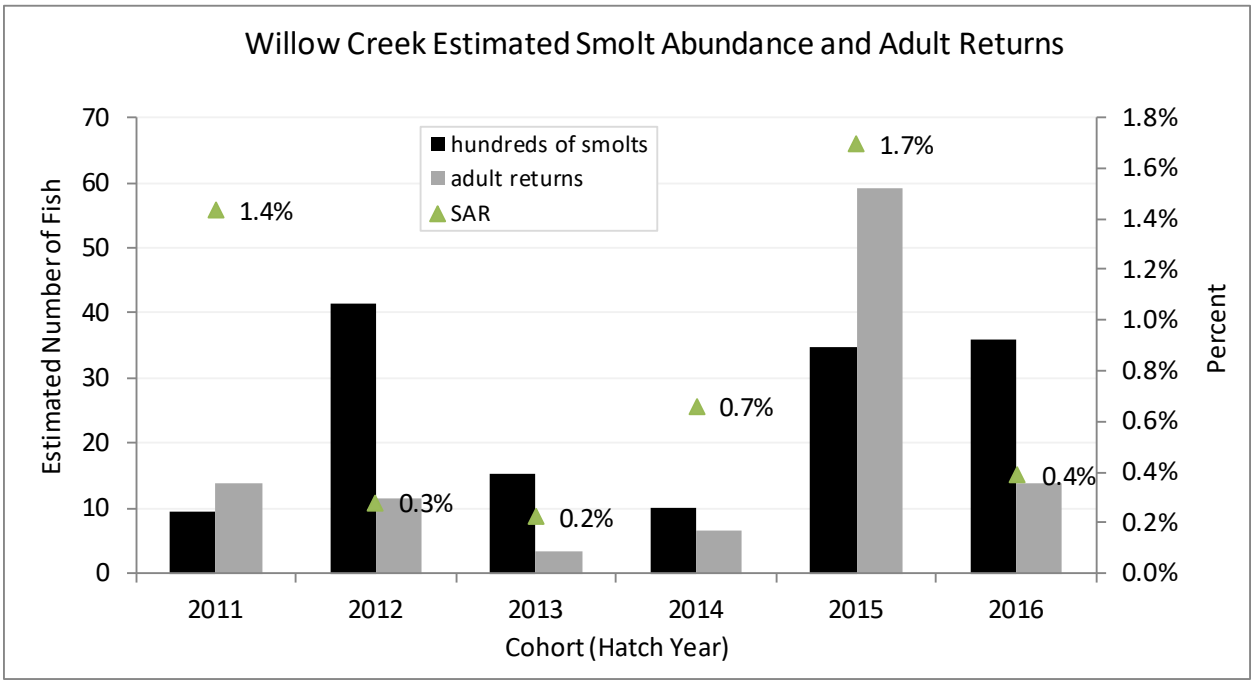

Figure 16. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Willow Creek, cohorts 2011-2016. Note that estimates are based on returns to the upper antennas at river km 3.69 whereas in previous reports, estimates were based on detections at the Willow Creek mouth at river km 0.41.

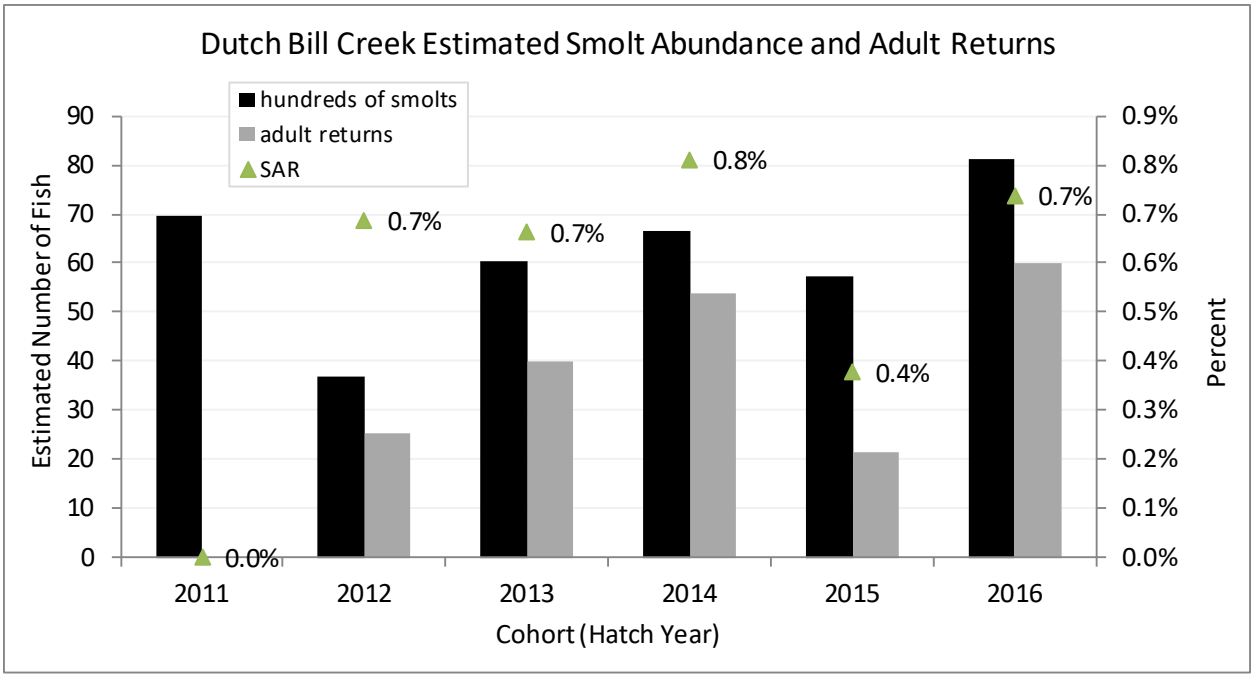

Figure 17. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Dutch Bill Creek, cohorts 2011-2016.

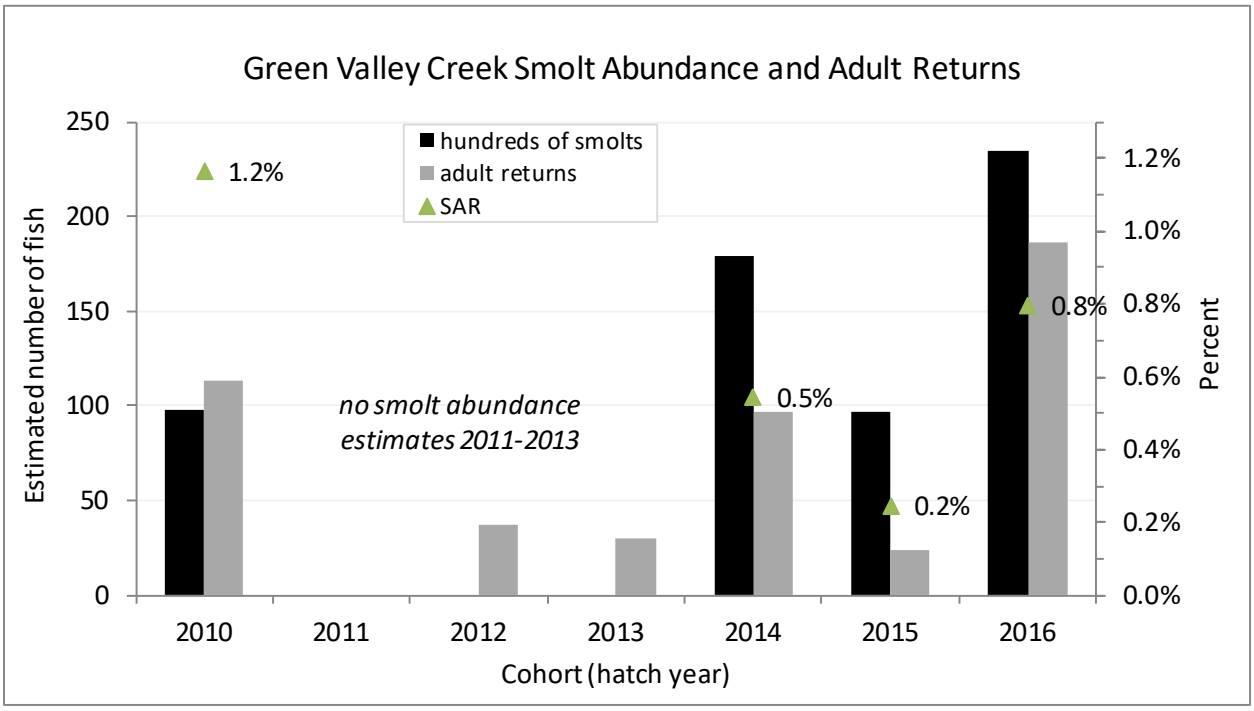

Figure 18. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Green Valley Creek, cohorts 2010-2016.

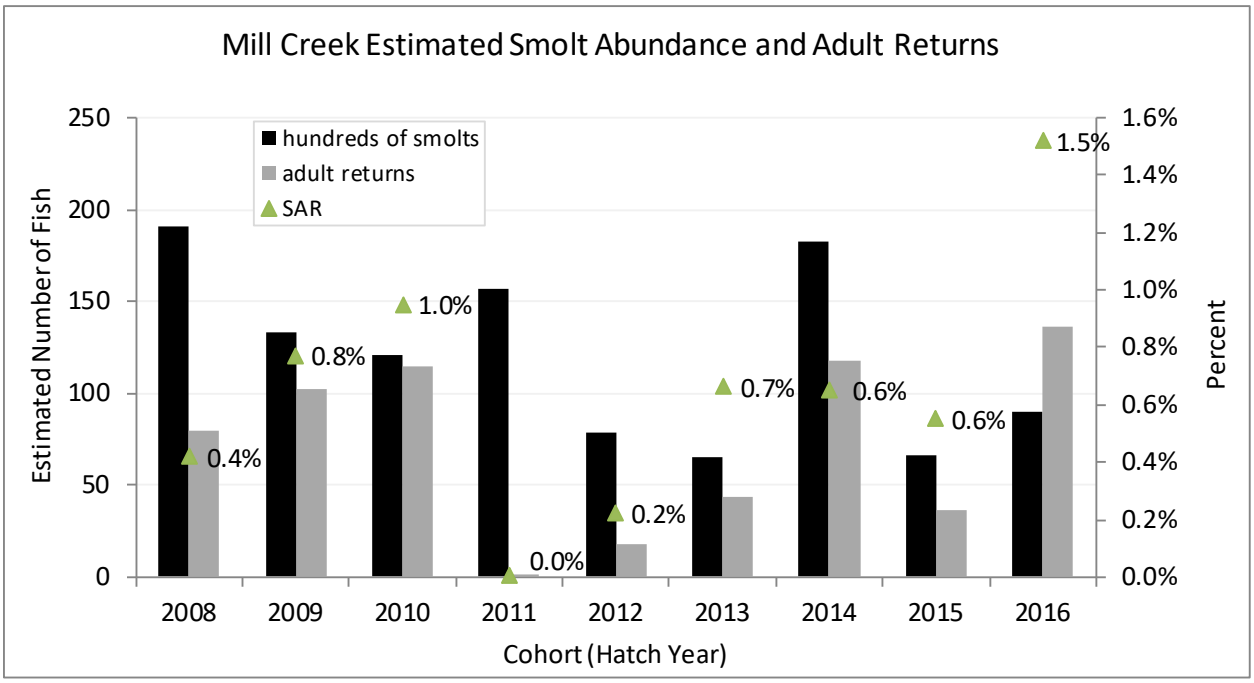

Figure 19. Estimated coho salmon smolt abundance, adult returns and smolt to adult return (SAR) ratios in Mill Creek, cohorts 2008-2016.

Table 9. Smolt to adult return (SAR) ratios estimated for Willow, Dutch Bill, Green Valley, and Mill creeks, cohorts 2008 through 2016. Note that estimates for Willow Creek are based on returns to the upper antennas at river km 3.69 whereas in previous reports, estimates were based on detections at the Willow Creek mouth at river km 0.41.

		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%
	Average	**0.8%**	**0.5%**	**0.7%**	**0.6%**

III. Spawning Surveys

Objectives

Salmonid spawner surveys were conducted in Russian River tributaries to document spatial distribution and estimate the number of redds. These data document spawning activity and adult presence in specific streams where juvenile coho salmon are released from Don Clausen Fish Hatchery and throughout other streams in the Russian River basin. For Broodstock Program monitoring, we aimed to survey all spawning reaches of Dutch Bill, Green Valley, Mill, and Willow creeks (Figure 20) in order to estimate the total number of redds in each creek. For CMP monitoring, we aimed to survey a spatially-balanced random sample of adult coho salmon and steelhead reaches in 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 20) in order to estimate the total number of coho salmon and steelhead redds in the Russian River watershed. Surveys were conducted in coordination with Sonoma Water using standardized CMP methods (Sonoma Water 2015).

Methods

Sampling framework

For Broodstock Program monitoring, we surveyed all accessible adult spawning reaches of Willow, Dutch Bill, Green Valley, and Mill creeks, for CMP *life cycle* monitoring we surveyed all accessible tributaries of Dry Creek, and for CMP *basinwide* monitoring, we used a soft stratification and generalized random tessellation stratified (GRTS) approach to survey a random, spatially-balanced selection of coho salmon and steelhead reaches within the Russian River watershed (Figure 20).

Field methods

Survey methodology for collecting information on spawning salmonids in the Russian River system was adapted from *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 individuals (live or carcasses) and redds (Figure 21). 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 (Figure 22), 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.

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. 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.

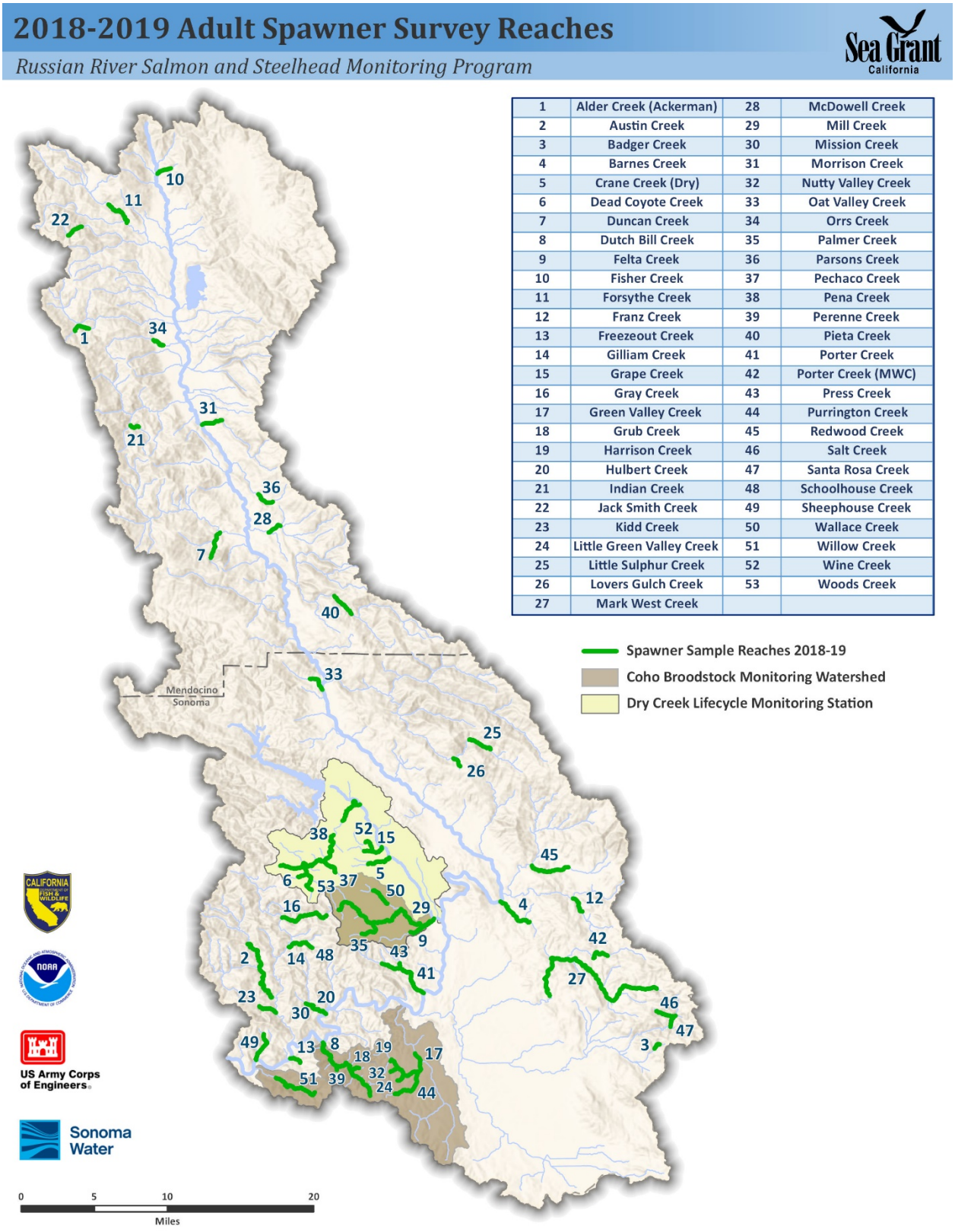

Figure 20. Broodstock Program watersheds and 2018-2019 spawner survey reaches in the Russian River.

Figure 21. A spawner crew member measures a redd in Pena Creek.

Figure 22. An adult coho salmon carcass observed in Porter Creek during 2018/19 spawner surveys.

Results

Surveys began when streams reconnected to the Russian River mainstem and became accessible to adult salmon in early December, 2018 and continued through mid-April, 2019. During this time, CSG and Sonoma Water biologists completed a total of 517 salmonid spawning surveys on 70 reaches in 53 streams within the Russian River basin. A total of 516 salmonid redds were observed: 85 coho salmon redds, 381 steelhead redds, four Chinook salmon redds, and 46 redds of unknown salmonid species origin (Table 10, Figure 23, Figure 24). In addition, coho salmon adults (live and/or carcasses) were observed in Sheephouse, Freezeout, and Felta creeks where no confirmed coho redds were observed (Figure 23). Of the 32 coho salmon streams surveyed during the winter of 2018/19, coho salmon redds and/or adults were observed in 18 (56%) and steelhead redds and/or adults were observed in 38 of the 53 steelhead streams surveyed (72%) (Table 10, Figure 23, Figure 24). Chinook redds were only observed in Pena Creek (Table 10).

Over all streams combined, timing of redds varied by species, with the only Chinook salmon redd observations in December, coho salmon observations peaking in late December, and steelhead observations peaking in March (Figure 25). Steelhead redds were observed over the widest timeframe, ranging from early December through the end of the survey season in mid-April (Figure 25). Although our goal was to survey each reach every 10-14 days, high flows and turbidity frequently prohibited us from surveying immediately after storm events (Figure 26), therefore redd observations should be considered minimum counts (Table 10, Figure 25).

Coho salmon redd estimates in Broodstock Program monitoring streams ranged from four in Willow Creek to 47 in Green Valley Creek, and steelhead redd estimates ranged from three in Willow Creek to 52 in Mill Creek (Table 11). 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 0.55 in Green Valley Creek to 6.75 in Willow Creek (Table 11).

When compared with previous years, coho salmon redd estimates were average in Willow and Dutch Bill creeks, above average in Mill Creek, and the highest recorded in Green Valley Creek (Figure 27). Steelhead redd estimates were low in Willow Creek, high in Mill Creek, and the highest recorded in Dutch Bill and Green Valley creeks (Figure 28). At the basinwide scale, redd estimates for coho salmon were approximately average, while estimates for steelhead redds were the highest observed over the last five winters (Figure 29).

In all of the creeks surveyed, we recovered only seven intact coho salmon carcasses (Table 12). The proportion of natural-origin adult coho salmon carcasses recovered ranged from 0.0 in Willow and Dutch Bill Creeks to 0.5 in Green Valley and Mill creeks; however, the sample size was too small to make any inferences about the proportion of natural-origin fish returning to the Russian River watershed during the winter of 2018/19.

Redd distribution varied by stream (Figure 30 - Figure 33). In Willow Creek, the coho salmon redds were concentrated in the middle sections of our surveyable reaches, with only one steelhead redd and one salmonid species redd observed in the upper extent of the survey reach (Figure 30). In Dutch Bill Creek, a few coho salmon and steelhead redds were observed in the middle of the survey reach, with one steelhead redd observed near the mouth, and two other steelhead redds observed high up in the system (Figure 31). In the Green Valley Creek watershed, coho salmon and steelhead redds were observed throughout Green Valley Creek with a few coho salmon redds and several steelhead redds distributed throughout Purrington Creek (Figure 32). In the Mill Creek watershed, there was a cluster of coho salmon redds near the confluence with Felta Creek; a few near the Wallace Creek confluence and a few others high up in the system (Figure 33). Steelhead redds were distributed throughout the Mill Creek watershed (Figure 33).

Table 10. Total salmonid redds observed by species during 2018/19 spawner surveys in Russian River tributaries.

Tributary	Length of Stream Surveyed (km)	Coho Salmon	Steelhead	Chinook Salmon	Unknown Salmonid	Total
Alder Creek (Ackerman)*	2.1	0	1	0	0	1
Austin Creek	8.9	4	3	0	0	7
Badger Creek*	0.9	0	0	0	0	0
Barnes Creek*	5.0	0	4	0	0	4
Crane Creek (Dry)	3.2	0	1	0	0	1
Dead Coyote Creek	1.1	0	2	0	0	2
Duncan Creek*	3.3	0	0	0	0	0
Dutch Bill Creek	11.4	4	8	0	0	12
Felta Creek	2.0	0	8	0	1	9
Fisher Creek*	1.8	0	0	0	0	0
Forsythe Creek*	3.7	0	0	0	0	0
Franz Creek*	2.2	0	2	0	0	2
Freezeout Creek	1.5	0	3	0	1	4
Gilliam Creek	2.6	0	5	0	2	7
Grape Creek	2.6	2	18	0	0	20
Gray Creek	6.3	1	12	0	1	14
Green Valley Creek	7.0	21	19	0	5	45
Grub Creek*	1.1	0	0	0	0	0
Harrison Creek	0.2	1	0	0	0	1
Hulbert Creek	3.2	0	4	0	0	4
Indian Creek*	1.1	0	0	0	0	0
Jack Smith Creek*	1.9	0	0	0	0	0
Kidd Creek	2.5	2	2	0	1	5
Little Green Valley Creek	1.2	0	0	0	0	0
Little Sulphur Creek*	2.9	0	4	0	0	4
Lovers Gulch Creek*	1.4	0	0	0	0	0
Mark West Creek	22.1	7	30	0	3	40
Mcdowell Creek*	1.7	0	1	0	0	1
Mill Creek	16.6	15	25	0	4	44
Mission Creek	0.4	0	1	0	0	1
Morrison Creek*	2.4	0	6	0	2	8
Nutty Valley Creek	1.2	0	0	0	0	0
Oat Valley Creek*	2.3	0	24	0	0	24
Orrs Creek*	1.7	0	4	0	0	4
Palmer Creek	2.9	0	2	0	1	3
Parsons Creek*	2.2	0	0	0	0	0
Pechaco Creek*	2.3	0	12	0	1	13
Pena Creek	15.1	6	80	4	12	102
Perenne Creek*	0.5	0	0	0	0	0
Pieta Creek*	3.0	0	2	0	0	2
Porter Creek	7.4	8	12	0	3	23
Porter Creek (MWC)	2.4	0	3	0	0	3
Press Creek	0.6	0	0	0	0	0
Purrington Creek	4.8	3	15	0	2	20
Redwood Creek	4.8	0	0	0	0	0
Salt Creek*	2.4	0	0	0	0	0
Santa Rosa Creek	1.6	0	8	0	1	9
Schoolhouse Creek	1.1	0	0	0	0	0
Sheephouse Creek	3.7	0	3	0	0	3
Wallace Creek	2.5	0	7	0	0	7
Willow Creek	6.0	5	1	0	1	7
Wine Creek	1.8	4	11	0	3	18
Woods Creek	4.1	2	38	0	2	42
Total	198.7	85	381	4	46	516

*Steelhead only tributary

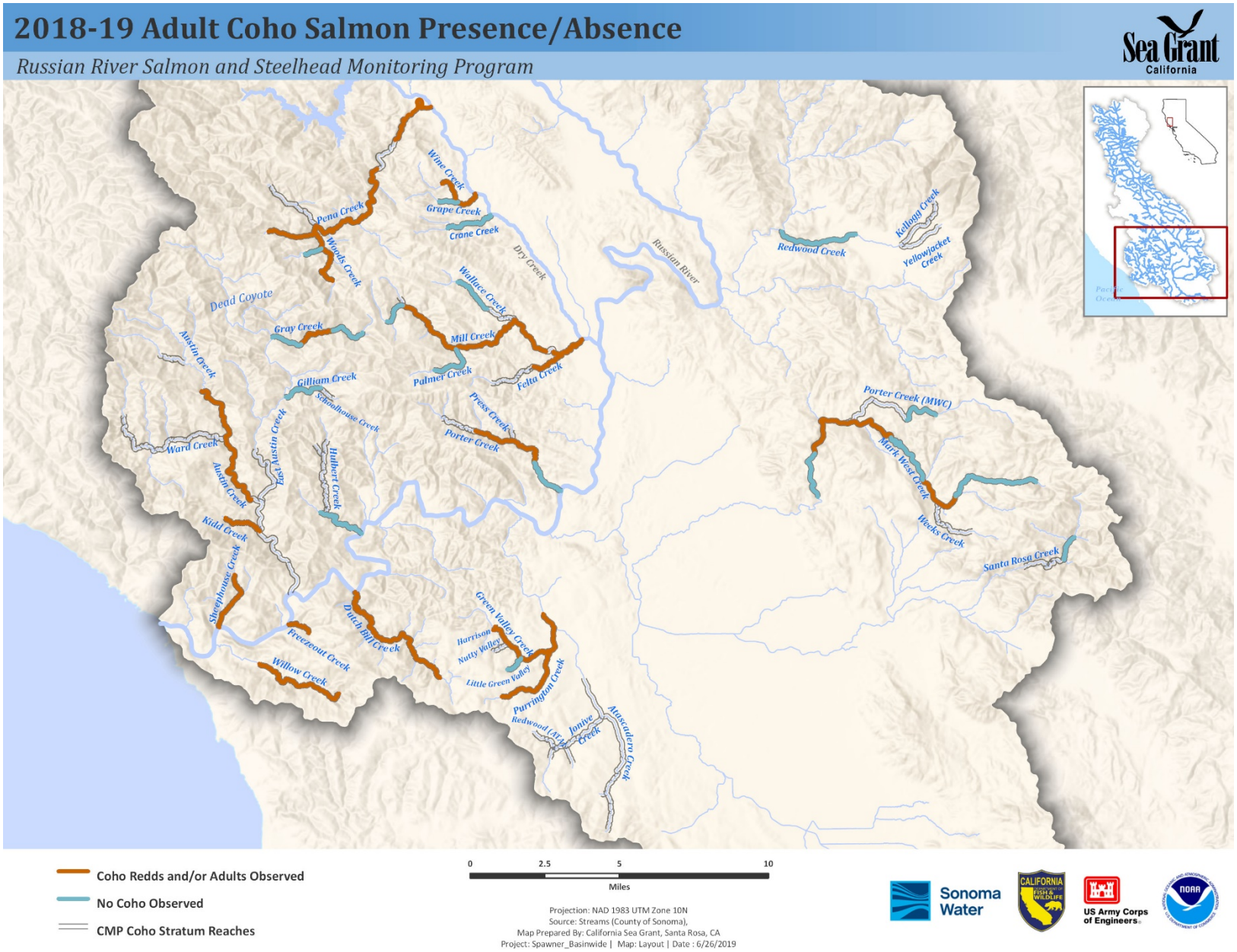

Figure 23. Spawner survey reaches where coho salmon redds and/or coho salmon adults were observed, winter 2018/19.

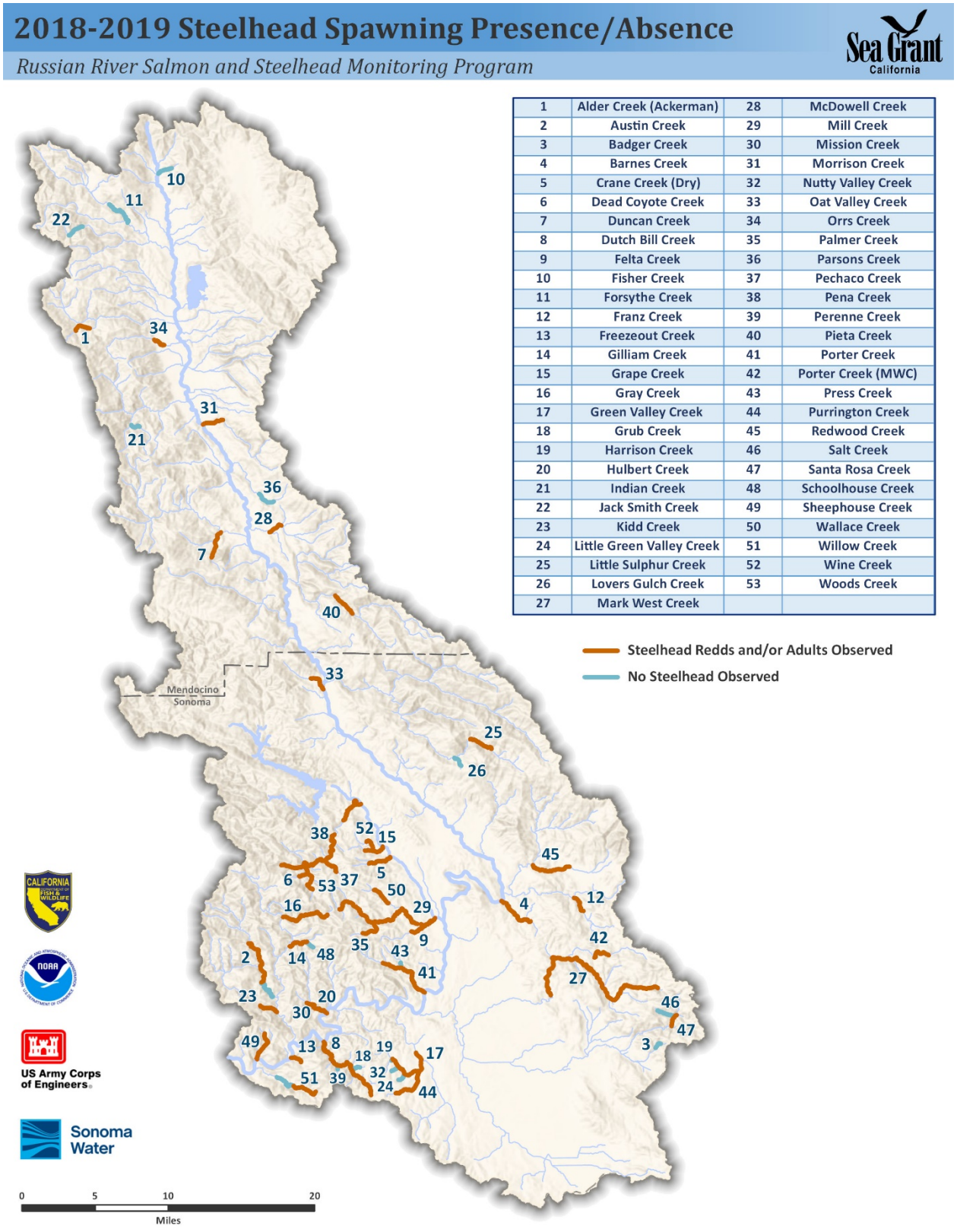

Figure 24. Spawner survey reaches where steelhead redds and/or live steelhead adults were observed, winter 2018/19.

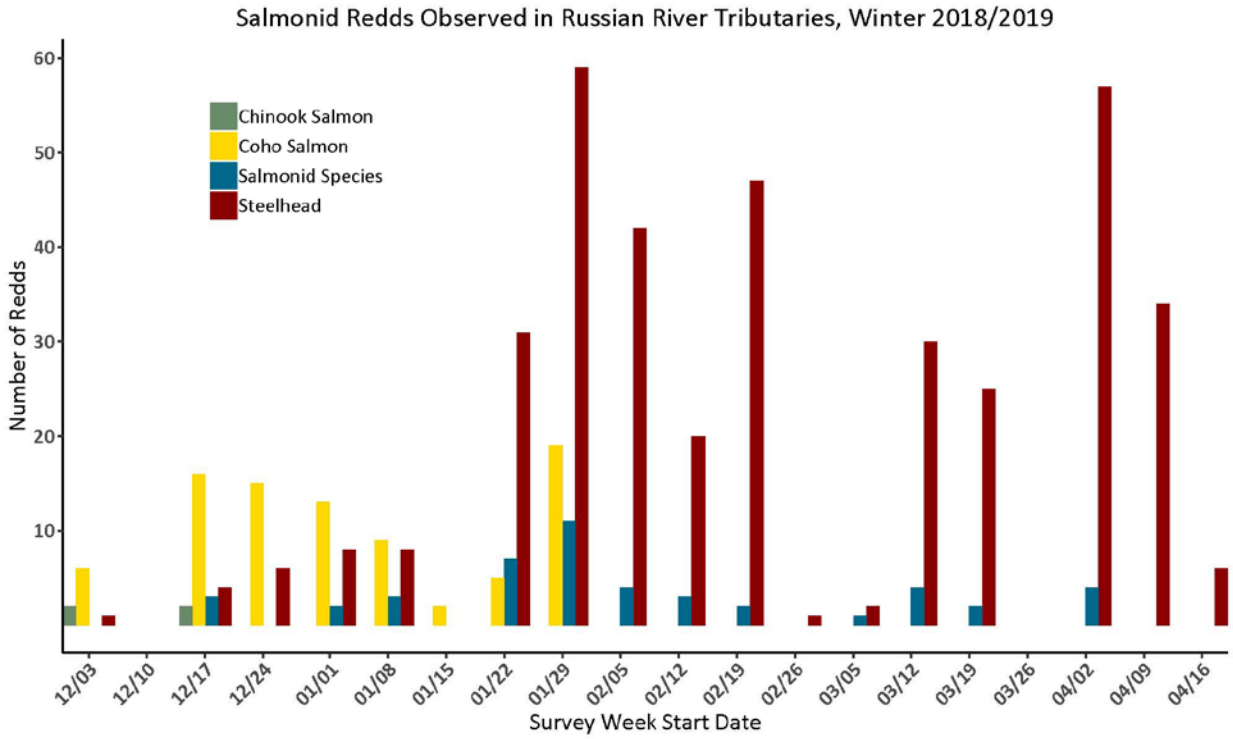

Figure 25. Number of new salmonid redds observed each week in Russian River Coastal Monitoring Program survey streams, winter 2018/19.

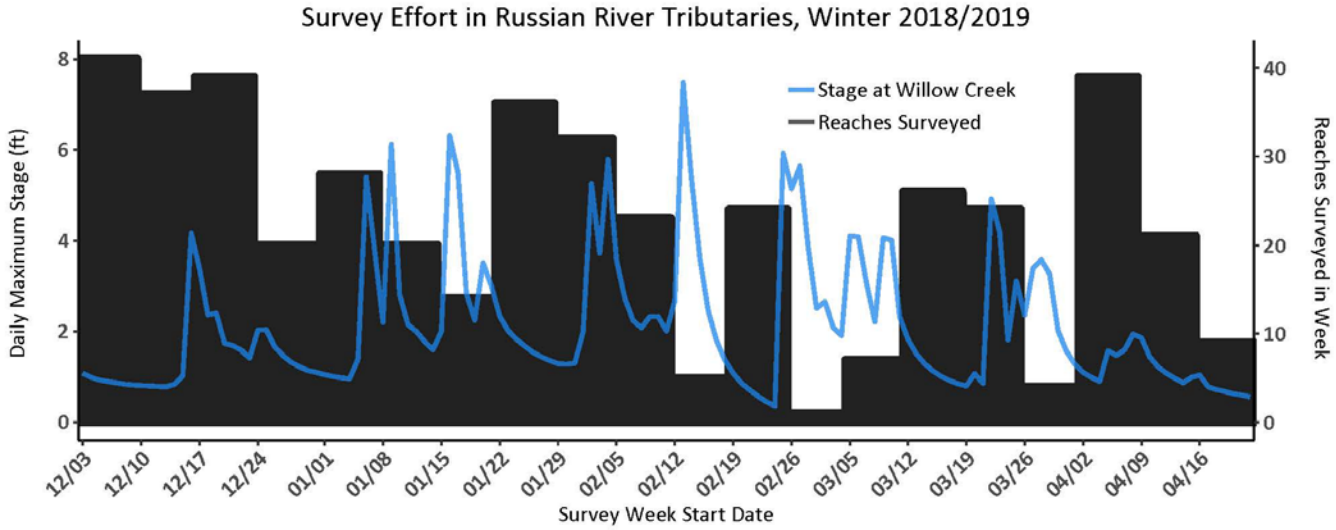

Figure 26. Number of reaches surveyed each week in Russian River Coastal Monitoring Program survey streams, winter 2018/19.

Table 11. Estimated coho salmon and steelhead redds and adults in four Russian River tributaries, winter 2018/19. Adult estimates for coho salmon were based on PIT tag data and adult to redd ratios were calculated by dividing the estimated number of adults by the estimated number of redds. Because we do not PIT tag juvenile steelhead in these streams, we were unable to estimate steelhead adult estimates or adult to redd ratios.

Tributary	Species	Estimated Redds	Estimated Adults	Adult:Redd Ratio
Willow Creek	coho salmon	4	27	6.68
Willow Creek	steelhead	3	NA	NA
Dutch Bill Creek	coho salmon	8	49	6.07
Dutch Bill Creek	steelhead	6	NA	NA
Green Valley Creek	coho salmon	47	26	0.56
Green Valley Creek	steelhead	32	NA	NA
Mill Creek	coho salmon	18	93	5.18
Mill Creek	steelhead	52	NA	NA

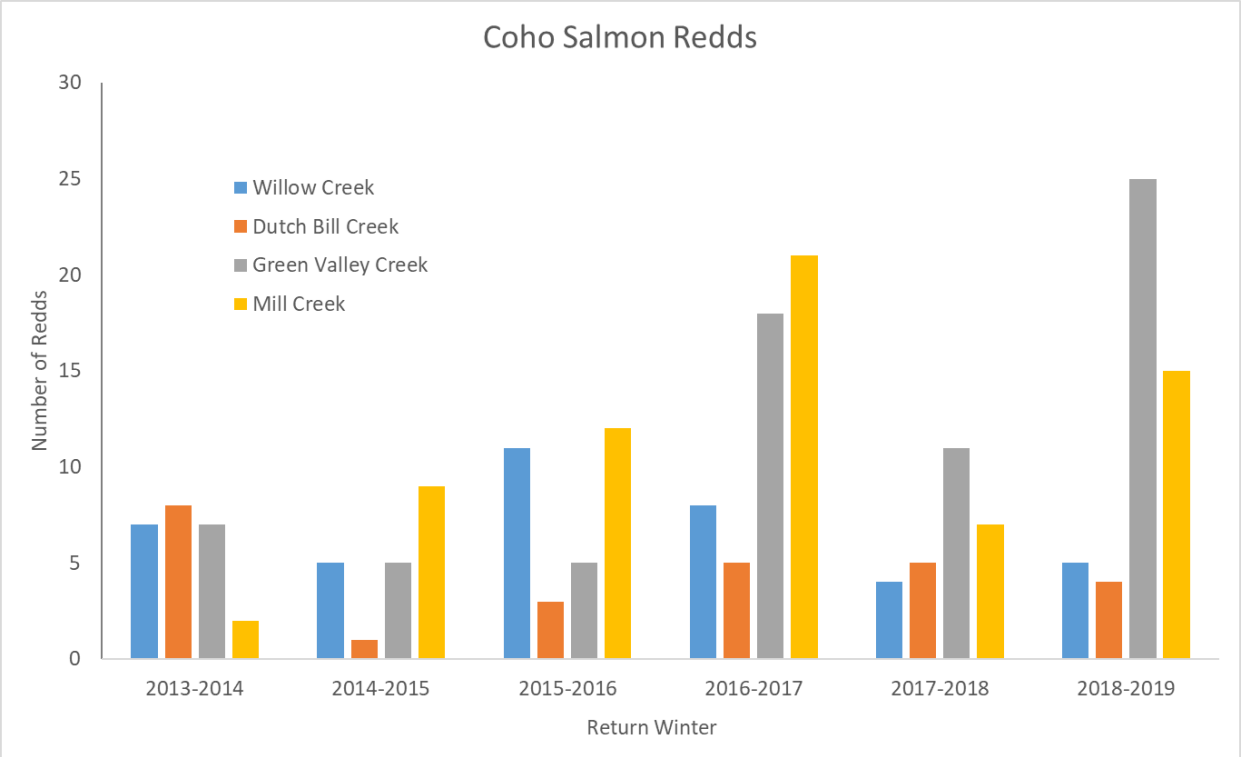

Figure 27. Observed coho salmon redds in Broodstock Program Monitoring tributaries, return winters 2013/14 2018/19.

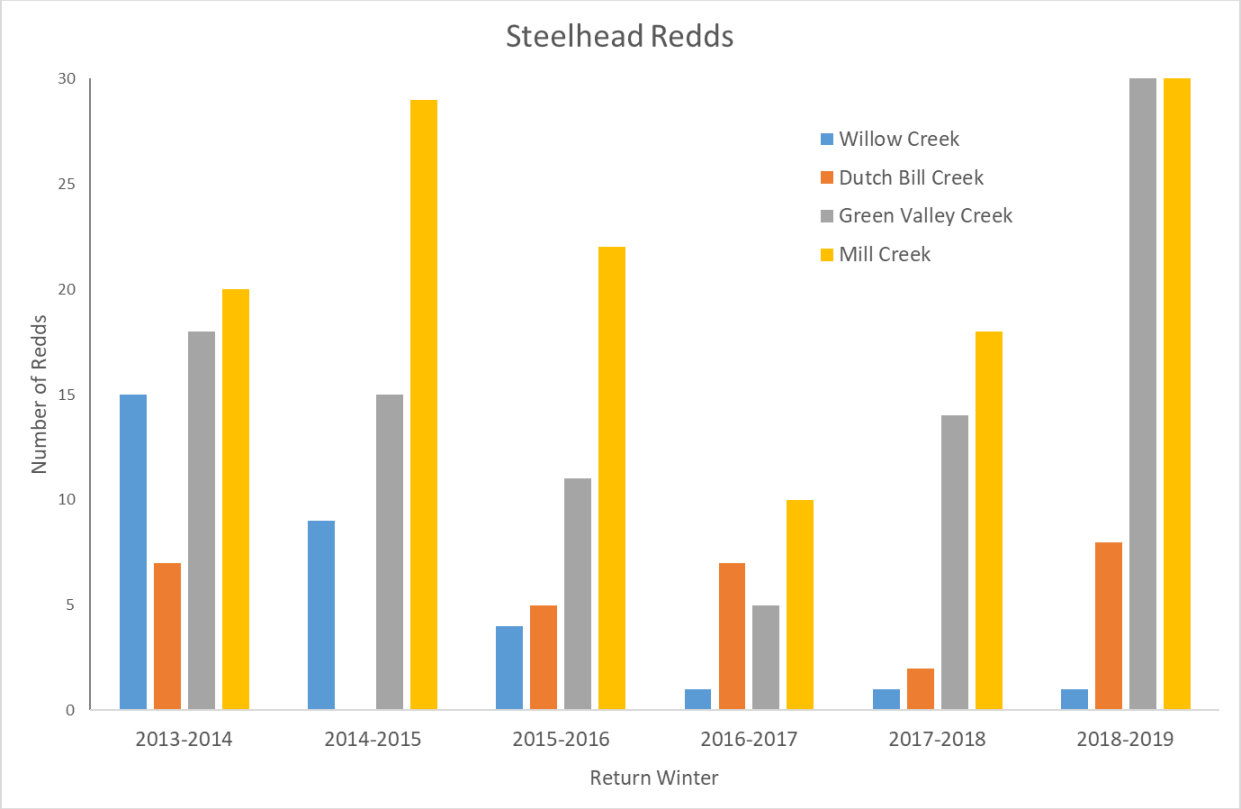

Figure 28. Steelhead redds in Broodstock Program monitoring tributaries, return winters 2013/14 - 2018/19.

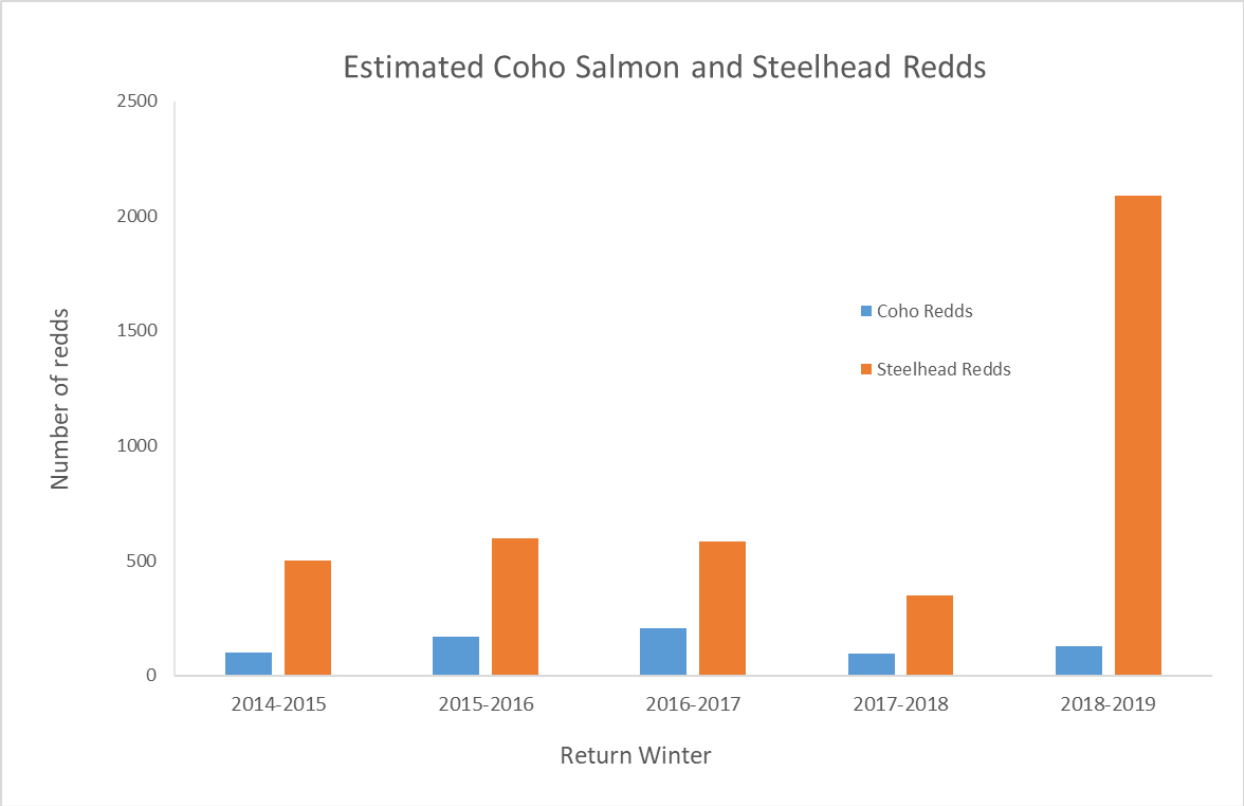

Figure 29. Estimated coho salmon and steelhead redds in the coho/steelhead stratum of the Russian River watershed, 2014/15-2018/19.

Table 12. Number of coho salmon carcasses observed relative to CWT presence/absence during 2018/19 spawner surveys in Russian River tributaries.

Tributary	CWT Present	CWT Not Present	Proportion Untagged (Natural Origin)
Willow Creek	0	0	0%
Dutch Bill Creek	0	0	0%
Green Valley Creek	1	1	50%
Mill Creek	1	1	50%
Other Streams	2	1	33%
All Streams	**4**	**3**	43%

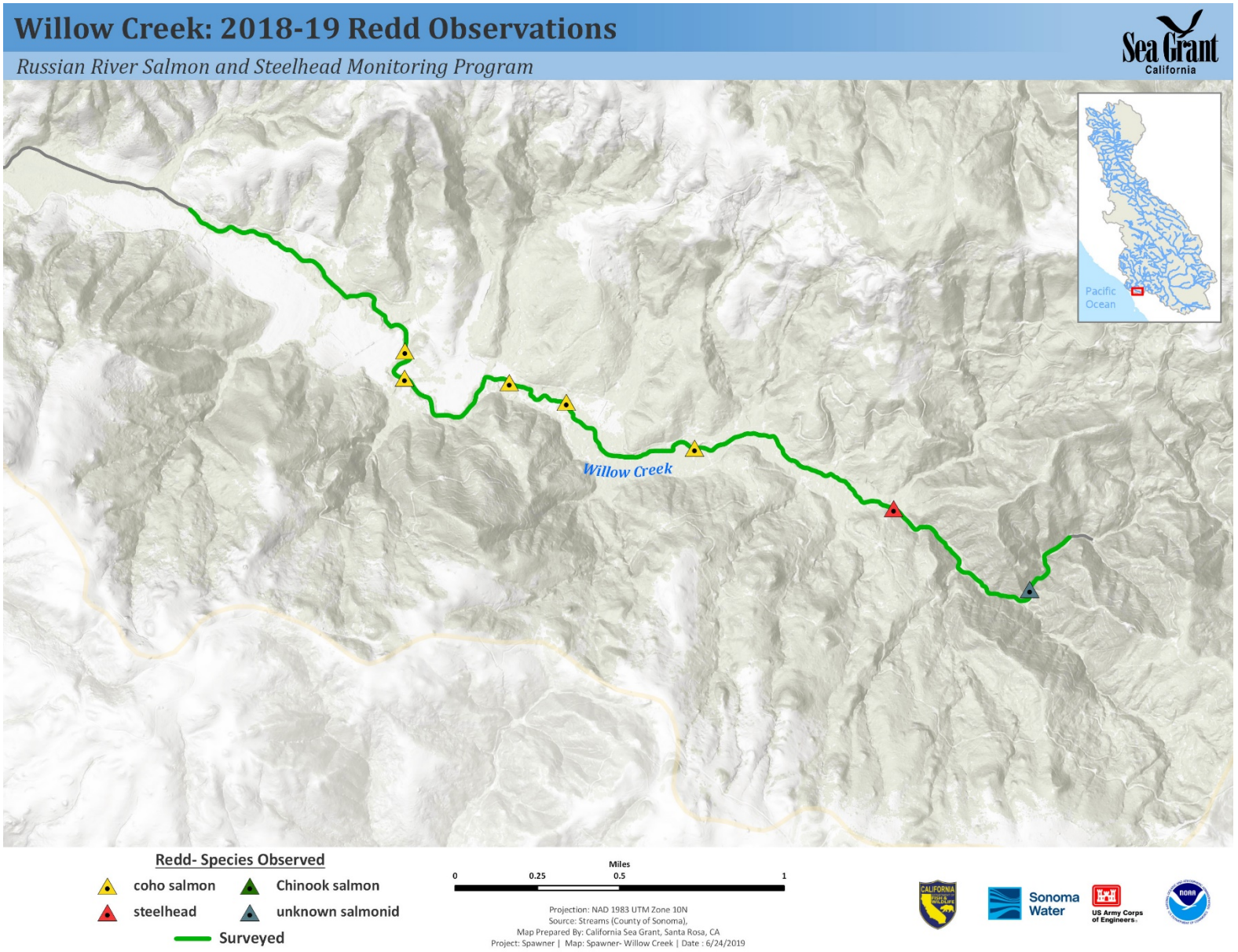

Figure 30. Salmonid redds observed in Willow Creek during winter 2018/19.

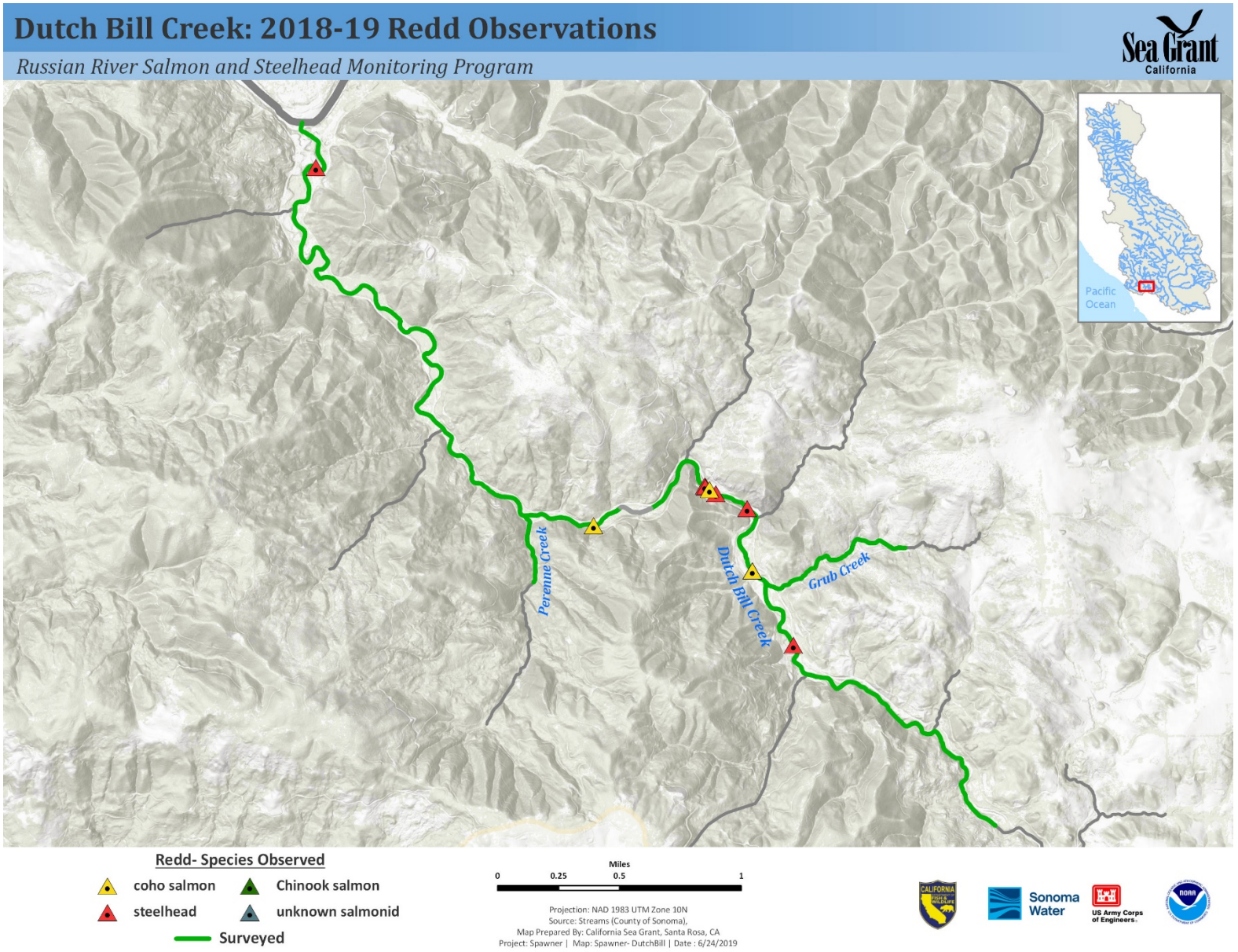

Figure 31. Salmonid redds observed in Dutch Bill Creek during winter 2018/19.

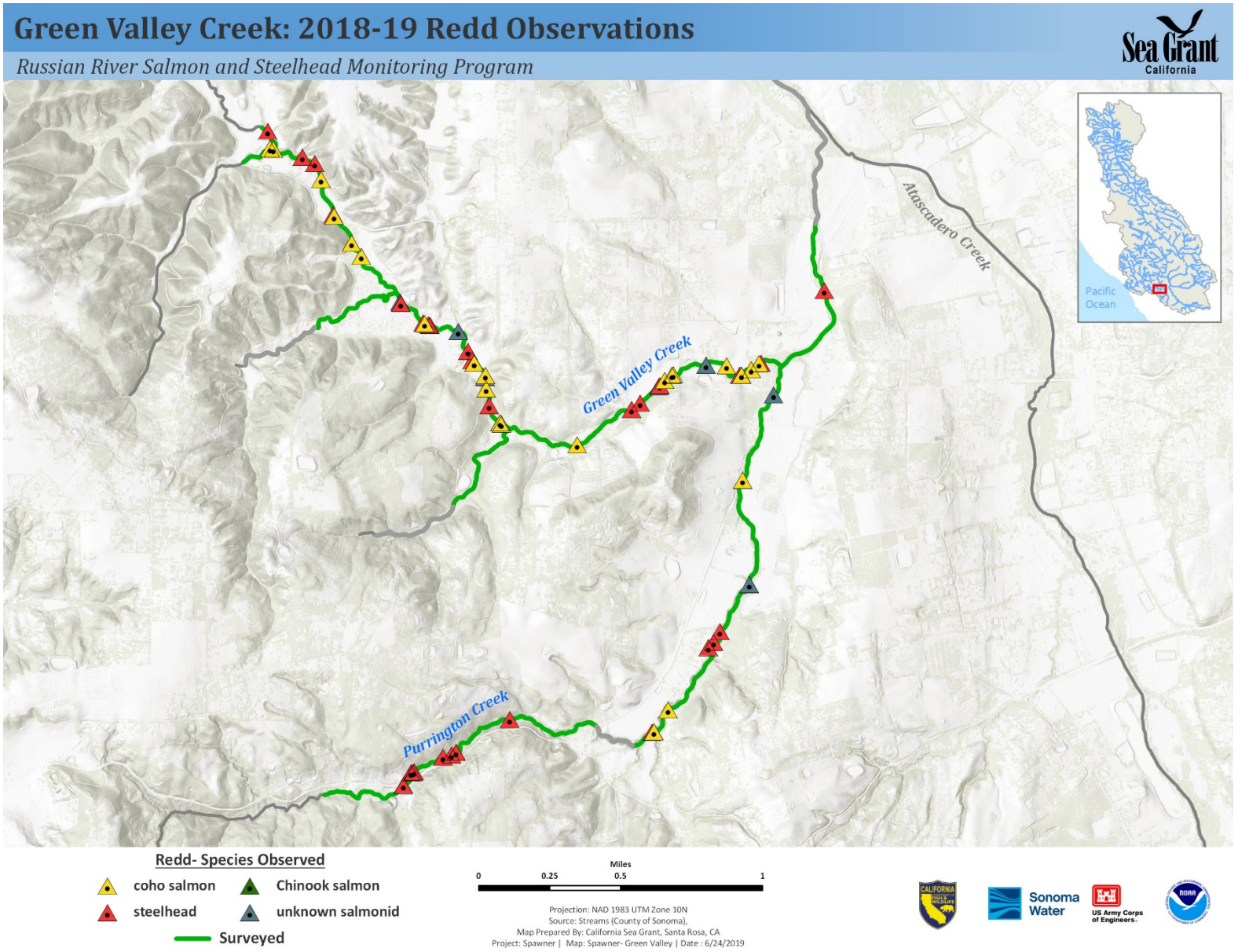

Figure 32. Salmonid redds observed in the Green Valley Creek watershed during winter 2018/19.

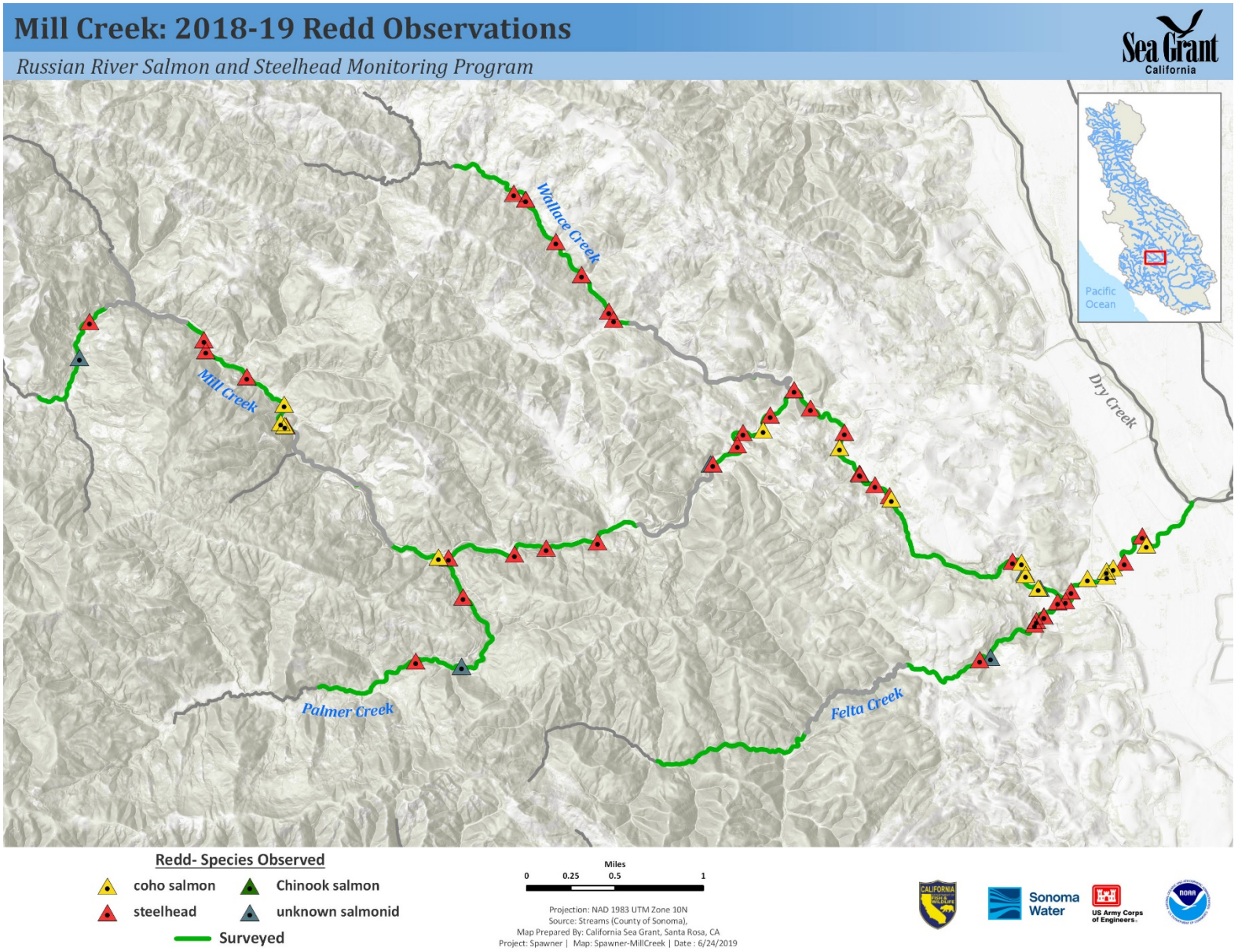

Figure 33. Salmonid redds observed in the Mill Creek watershed during winter 2018/19.

Discussion and Recommendations

The estimated number of coho salmon returning to the Russian River watershed during the winter of 2018/19 was the second highest on record since the beginning of the Broodstock Program (Figure 14). A total of 642 hatchery coho salmon adults were estimated to have passed the Duncans Mills or Willow Creek antenna arrays (Table 8), and adult coho salmon redds and/or coho salmon adults were observed in 18 of 32 coho salmon streams surveyed (Figure 23). It should be noted that the 642 fish estimate was comprised of 85% age-3 adults, marking the highest estimated return of age-3 adults since we began operating a PIT tag detection system at the head of the estuary at Duncans Mills in 2012/13 (Figure 15, Figure 1). The higher number of returning adults may be partially explained by high smolt production in spring 2017; nearly 44,000 smolts were estimated to have emigrated from the four Broodstock Program monitoring streams in 2017 which was significantly greater than the eight-year average of 27,980 (2011-2018) emigrating from those four streams.

The winter of 2018/19 was an exceptional year for adult steelhead and steelhead redds. Basinwide redd estimates were several orders of magnitude larger than in the previous several years (Figure 29). With the late rains, suitable streamflow conditions for spawning persisted through May, and much of the steelhead spawning occurred after the February flooding events (Figure 25, Figure 26).

Adult coho salmon began entering the lower Russian River at Duncans Mills in late September 2018 with the majority entering during the month of November (Figure 4). The winter of 2018/19 was an above average rainfall winter (Figure 3), with early December rains reconnecting the tributaries to the mainstem. The December rains enabled adult coho salmon to access some of the spawning tributaries (Figure 5) and the first coho salmon redds were observed in the tributaries in early December (Figure 25). Coho salmon spawning activity continued through the end of January, lasting approximately two months.

Within the four Broodstock Program monitoring streams, estimated adult coho salmon returns during the winter of 2018/19 varied. In Willow, Dutch Bill, and Mill creeks, estimates were generally high (Figure 10, Figure 11, Figure 13), while the estimate for Green Valley Creek was lower than previous winters (Figure 12). In previous reports, the lower Willow Creek antenna site (river km 0.41) was used to estimate adult spawners entering Willow Creek. Because the lower antenna site is in a tidally influenced portion of the Russian River estuary and adult fish are sometimes detected on that antenna which are never detected at the upstream Willow Creek antenna (Table 3, Table 4), it is likely that some of the lower antenna observations could be from fish that briefly enter the Willow Creek stream mouth before continuing their migration upstream in the mainstem Russian River. To address this, we used the upstream antenna site (river km 3.69) to generate adult estimates because it better reflects adults that migrated to the spawning grounds which are almost exclusively upstream of the upper array.

Smolt to adult return (SAR) ratios were below 1% in all but Mill Creek which was estimated at 1.5% (Table 9). The overall average for the four Broodstock Programs streams over all years of data collection is 0.6%. For reference, in the Lagunitas watershed just south of the Russian River, the average SAR ratio for the last 11 cohorts (smolt years 2006-2016) was 4.3%, ranging from 1.2% to 12.9% (Eric Ettlinger, personal communication).

SAR ratios reported for the four Broodstock Program streams represent survival during smolt migration through the river and estuary, ocean residence, and adult survival back up through the estuary and river.

Because the Duncans Mills antenna array is not efficient at detecting smolts (due to high spring water depths and the fact that smolts travel up high in the water column), we are unable to disentangle survival through the river and estuary from marine survival. Because SAR ratios are so low, we recommend pursuing studies aimed at quantifying smolt survival through the riverine and estuarine environments using acoustic telemetry. If riverine or estuarine survival is low, measures might be taken to improve survival as fish migrate through these habitats.

It is notable that only one PIT-tagged natural-origin adult was detected returning to the Russian River watershed during winter 2018/19. We attribute this to the fact that there were very few natural-origin smolts emigrating from the four Broodstock Program monitoring streams in 2017. During that smolt season, we captured a total of 748 natural-origin smolts (abundance estimate was 2,805), and PIT tagged 326 of them (approximately half of all captured at the Willow, Green Valley and Mill Creek traps). Given the low number of tagged natural-origin fish, we did not anticipate many detections of adults (e.g., applying an average SAR of 0.85% for the cohort, we would have only expected three tagged natural-origin fish returning as adults and we do not have 100% detection efficiency on our antennas). It could be beneficial to increase the proportion of natural-origin fish that we PIT tag at the smolt traps as well as tag yoy in the streams to increase sample size; however, until natural production of juveniles increases, we do not anticipate observing may natural-origin returns, even if we increase tagging rates. Identifying bottlenecks to wild smolt production will be critical for long term recovery and the re-establishment of self-sustaining runs of coho salmon.

The estimated number of redds as compared to the estimated number of adult coho salmon returning to each stream varied, ranging from 0.56 to 6.68 (Table 11). Most of these values were higher than the average adult to redd ratio of 2.35 observed in Mendocino streams (Gallagher et al. 2010), while the value in Green Valley Creek was much lower. The average across the four streams in winter 2018/19 was 4.62 which was lower than the winter 2017/18 average of 13.98, likely due to the higher proportion of age-3 fish returning during winter 2018/19. We are not sure why spawner to redd ratios appear higher in Russian River tributaries than Mendocino tributaries, but it is possible that the larger size of the Russian River watershed and our sampling design may be factors. In Russian River tributaries it is common to observe adults entering more than one spawning tributary and these fish are included in the estimates for each creek they enter. This might lead to higher spawner: redd ratios than in systems where there is only one life-cycle stream and individuals are only counted when they enter the mainstem of the river. It is also possible that the Russian River population has a higher male: female sex ratio which could lead to a higher spawner to redd ratio. It could be informative to test a small proportion of broodstock fish to determine sex ratios.

Over the last few years we have observed that highly variable winter flows are impacting spawning success and this was true in 2018/19 as well. After the first precipitation event connected the streams in late-November, a period of relatively dry winter conditions persisted through mid-December. During this time, stream flows receded to the point that some streams became disconnected from the mainstem and were inaccessible to adults. In one instance, a live adult coho salmon was observed stranded in an isolated pool of a lower tributary. Following this dry spell, a series of large storms, starting in mid-January 2018 and ending with record breaking flows in late February, may have had a deleterious effect on coho salmon redds and newly hatched fish. When large spikes in streamflow occur, gravel beds can mobilize, washing out salmon redds along with the gravel. Schuett-Hames et al. (2000) inferred that scour can be a significant source of egg loss. We will learn more about the effects of the 2018/19 flooding events when we complete our summer

snorkel surveys to document juvenile numbers and distribution. We recommend that resource managers support projects and programs that are designed to improve overwinter habitat and streamflow conditions in coho streams throughout the watershed.

Since the inception of the Broodstock Program, juvenile coho salmon have been released at different life stages into different streams. We have been successful at comparing juvenile stock to smolt survival among streams and release groups (California Sea Grant 2018), but evaluating success of the different groups to the adult stage has been more challenging due to low adult return rates and thus small sample size for the different release groups. In an attempt to compare overall success of the different release groups to the adult stage, we compared the estimated number of adults returning to the lower river to the number of hatchery fish released in the watershed for four cohorts of spring, fall, presmolt and smolt release groups (Table 13). Although the percentages of adult estimates to hatchery releases were variable among years, we found that (as expected) releasing fish at later life stages resulted in higher percentages of returning adults. The presmolt releases had the highest percentage of returning adults and we therefore recommend continuing and even increasing the number of fish allocated to this release group.

To evaluate differences among release sub-basins, including the Lower Russian River, Austin Creek, Middle Mainstem, Mark West Creek, and Dry Creek sub-basins (Table 14), we compared ratios of adult estimates to hatchery releases within the spring, fall, presmolt an smolt release groups (Table 15 - Table 18). Within the spring release groups, the Dry Creek sub-basin had the highest percentage of adult returns, though this was entirely driven by a relatively successful cohort of fish released into Palmer Creek in the spring of 2016 (Table 15). Within the fall release groups, return percentages were similar among sub-basins, with overall averages ranging from 0.23% to 0.37% (Table 16). Within the presmolt release groups, Green Valley Creek had higher percentages than Willow Creek in both cohorts that these releases occurred (Table 17), and within the smolt release group the Middle Mainstem and Dry Creek sub-basins had similar average percentages (Table 18). The Lower Russian River sub-basin had a lower percentage and Mark West was higher; however, with only one cohort for those release sub-basins, we cannot draw any definitive conclusions.

Based on these results, we recommend that the Broodstock Program consider increasing the numbers of fish that are released as presmolts and smolts in the sub-basins with high percentages of returning adults while continuing to release fish into multiple sub-basins of the Russian River watershed to bet-hedge unpredictable environmental conditions that may affect access to habitat and survival of coho salmon in different ways.

Table 13. Estimated hatchery adult coho salmon returning to the Russian River (Duncans Mills or Willow Creek antenna arrays) in relation to number of hatchery fish released by release group and cohort.

Estimated returns is the sum of age-3 returns in return winter n plus the number of age-2 returns in return winter n-1.

Release Group	Cohort (Hatch Year)	Age-3 Return Winter	Number Released	Estimated Returns	Percent Returning	Average Percent Returning
Spring	2013	2015/16	27,864	16	0.06%	0.14%
	2014	2016/17	46,602	1	0.00%	
	2015	2017/18	1,822	3	0.18%	
	2016	2018/19	20,370	68	0.33%	
Fall	2013	2015/16	91,957	163	0.18%	0.29%
	2014	2016/17	113,151	165	0.15%	
	2015	2017/18	44,107	51	0.12%	
	2016	2018/19	83,100	609	0.73%	
Presmolt	2013	2015/16	0	0	NA	1.00%
	2014	2016/17	30,548	151	0.50%	
	2015	2017/18	0	0	NA	
	2016	2018/19	16,404	247	1.50%	
Smolt	2013	2015/16	52,001	126	0.24%	0.51%
	2014	2016/17	45,023	253	0.56%	
	2015	2017/18	24,581	74	0.30%	
	2016	2018/19	38,508	359	0.93%	

Table 14. Broodstock Program release sub-basins and tributaries in the Russian River.

Sub-basin	Release Tributary
Lower Russian River	Willow Creek
	Sheephouse Creek
	Freezeout Creek
Austin Creek	Austin Creek
	East Austin Creek
	Black Rock Creek
	Gilliam Creek
	Thompson Creek
	Gray Creek
	Devil Creek
Middle Mainstem	Dutch Bill Creek
	Green Valley Creek
	Redwood Creek (Atascadero)
	Purringon Creek
	Porter Creek
Mark West Creek	Mark West Creek
Dry Creek	Dry Creek
	Mill Creek
	Palmer Creek
	Grape Creek
	Pena Creek

Table 15. Estimated spring release adult coho salmon returning to the Russian River (Duncans Mills or Willow Creek antenna arrays) in relation to number of hatchery fish released by sub-basin and cohort. Estimated returns is the sum of age-3 returns in return winter n plus the number of age-2 returns in return winter n-1.

Release Sub-basin	Cohort (Hatch Year)	Age-3 Return Winter	Number Released	Estimated Returns	Percent Returning	Average Percent Returning
Lower Russian River	2013	2015/16	0	0	NA	0.00%
	2014	2016/17	15,393	0	0.00%	
	2015	2017/18	0	0	NA	
	2016	2018/19	0	0	NA	
Austin Creek	2013	2015/16	18,205	13	0.07%	0.08%
	2014	2016/17	21,485	0	0.00%	
	2015	2017/18	0	0	NA	
	2016	2018/19	14,345	23	0.16%	
Middle Mainstem	2013	2015/16	1,212	3	0.22%	0.14%
	2014	2016/17	1,514	1	0.10%	
	2015	2017/18	1,313	3	0.26%	
	2016	2018/19	1,468	0	0.00%	
Dry Creek	2013	2015/16	8,447	0	0.00%	0.25%
	2014	2016/17	8,210	0	0.00%	
	2015	2017/18	509	0	0.00%	
	2016	2018/19	4,557	45	0.99%	

Table 16. Estimated fall release adult coho salmon returning to the Russian River (Duncans Mills or Willow Creek antenna arrays) in relation to number of hatchery fish released by sub-basin and cohort. Estimated returns is the sum of age-3 returns in return winter n plus the number of age-2 returns in return winter n-1.

Release Sub-basin	Cohort (Hatch Year)	Age-3 Return Winter	Number Released	Estimated Returns	Percent Returning	Average Percent Returning
Lower Russian River	2013	2015/16	15,200	64	0.42%	0.37%
	2014	2016/17	6,117	7	0.11%	
	2015	2017/18	9,032	8	0.09%	
	2016	2018/19	21,440	184	0.86%	
Austin Creek	2013	2015/16	0	0	NA	0.24%
	2014	2016/17	20,169	19	0.09%	
	2015	2017/18	8,128	5	0.06%	
	2016	2018/19	3,996	22	0.56%	
Middle Mainstem	2013	2015/16	30,315	63	0.21%	0.34%
	2014	2016/17	35,348	42	0.12%	
	2015	2017/18	17,978	19	0.11%	
	2016	2018/19	25,265	232	0.92%	
Mark West Creek	2013	2015/16	15,143	0	0.00%	0.27%
	2014	2016/17	15,127	10	0.06%	
	2015	2017/18	0	0	NA	
	2016	2018/19	15,061	111	0.74%	
Dry Creek	2013	2015/16	31,299	36	0.11%	0.23%
	2014	2016/17	36,390	88	0.24%	
	2015	2017/18	8,969	19	0.21%	
	2016	2018/19	17,338	60	0.35%	

Table 17. Estimated presmolt release adult coho salmon returning to the Russian River (Duncans Mills or Willow Creek antenna arrays) in relation to number of hatchery fish released by sub-basin and cohort. Estimated returns is the sum of age-3 returns in return winter n plus the number of age-2 returns in return winter n-1.

Release Sub-basin	Cohort (Hatch Year)	Age-3 Return Winter	Number Released	Estimated Returns	Percent Returning	Average Percent Returning
Lower Russian River (Willow Creek)	2013	2015/16	0	0	NA	0.63%
	2014	2016/17	15,300	62	0.40%	
	2015	2017/18	0	0	NA	
	2016	2018/19	7,961	68	0.85%	
Middle Mainstem (Green Valley Creek)	2013	2015/16	0	0	NA	1.35%
	2014	2016/17	15,248	90	0.59%	
	2015	2017/18	0	0	NA	
	2016	2018/19	8,443	179	2.12%	

Table 18. Estimated smolt release adult coho salmon returning to the Russian River (Duncans Mills or Willow Creek antenna arrays) in relation to number of hatchery fish released by sub-basin and cohort. Estimated returns is the sum of age-3 returns in return winter n plus the number of age-2 returns in return winter n-1.

Release Sub-basin	Cohort (Hatch Year)	Age-3 Return Winter	Number Released	Estimated Returns	Percent Returning	Average Percent Returning
Austin Creek	2013	2015/16	10,117	36	0.35%	0.35%
	2014	2016/17	0	0	NA	
	2015	2017/18	0	0	NA	
	2016	2018/19	0	0	NA	
Middle Mainstem	2013	2015/16	12,421	18	0.15%	0.48%
	2014	2016/17	12,306	47	0.38%	
	2015	2017/18	9,882	46	0.47%	
	2016	2018/19	12,127	113	0.93%	
Mark West Creek	2013	2015/16	0	0	NA	0.88%
	2014	2016/17	0	0	NA	
	2015	2017/18	0	0	NA	
	2016	2018/19	10,150	89	0.88%	
Dry Creek	2013	2015/16	29,463	72	0.24%	0.51%
	2014	2016/17	32,717	206	0.63%	
	2015	2017/18	14,699	28	0.19%	
	2016	2018/19	16,231	157	0.97%	

IV. References

California Sea Grant. 2017. UC Coho Salmon and Steelhead Monitoring Report: Spring 2017. Unviversity of California, Santa Rosa, CA.

California Sea Grant. 2018. California Sea Grant Coho Salmon and Steelhead Monitoring Report: Spring 2018. University of California, Windsor, CA.

Gallagher, S. P., P. B. Adams, D. W. Wright, and B. W. Collins. 2010. Performance of spawner survey techniques at low abundance levels. North American Journal of Fisheries Management 30(5):1086-1097.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fisheries Management 25:284-300.

Gallagher, S. P., and M. Knechtle. 2005. Coastal Northern California salmonid spawning survey protocol. California Department of Fish and Game.

Ricker, S., K. Lindke, and C. Anderson. 2014. Results of regional spawning ground surveys and estimates of total salmonid redd construction in the Redwood Creek, Humboldt County, California, 2013. California Department of Fish and Wildlife, Humboldt County, California.

Schuett-Hames, D. E., N. P. Peterson, R. Conrad, and T. P. Quinn. 2000. Patterns of gravel scour and fill after spawning by chum salmon in a Western Washington Stream. North American Journal of Fisheries Management 20(3):610-617.

Sonoma Water, C. S. G. 2015. Implementation of California Coastal Salmonid Population Monitoring in the Russian River Watershed. Santa Rosa, CA.