UC Coho Salmon and Steelhead Monitoring Report

Summer 2020

Prepared by:

Zac Reinstein, Andrew McClary, Mariska Obedzinski, and Andrew Bartshire

California Sea Grant at University of California
March 2021, Windsor, CA.

1. Contents

Suggested reference: California Sea Grant. 2021. UC Coho Salmon and Steelhead Monitoring Report: Summer 2020. Windsor, CA.

2. Background

In 2004, the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) began releasing juvenile coho salmon (*Oncorhynchus kisutch*) into tributaries of the Russian River with the goal of reestablishing populations that were on the brink of extirpation from the watershed. Our group, California Sea Grant at University of California (UC), worked with local, state and federal resource managers to design and implement a coho salmon monitoring program to track the survival and abundance of hatchery-released fish. Since the first Broodstock Program releases, we (UC) have been closely monitoring smolt abundance, adult returns, survival, and spatial distribution of coho populations in four 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, UC has developed many partnerships in salmon and steelhead (*O. mykiss)* recovery efforts, 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, 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 40 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 public resource agencies, non-profit organizations, and hundreds of private landowners who have granted us access to the streams that flow through their properties.

In this seasonal monitoring report, we provide preliminary results from our summer and fall Broodstock Program and CMP snorkel surveys, including relative abundance and spatial distribution of juvenile salmonids in Russian River tributaries. Additional information and previous reports can be found on our website.

3. Juvenile Presence and Distribution

3.1. Goals and objectives

Summer snorkel surveys were conducted in Russian River tributaries to document the relative abundance and spatial distribution of juvenile coho salmon and steelhead during the summer of 2020. These data were used to determine whether successful spawning occurred the previous winter and to track trends in relative abundance and occupancy over time.

3.2. Methods

3.2.1. Sampling reaches

Overall, we snorkeled a total of 75 reaches, 74 of which were classified as juvenile coho salmon habitat, and one reach in upper Dutch Bill Creek that was classified as steelhead only. For Broodstock Program monitoring, we surveyed juvenile salmonid reaches of Willow, Dutch Bill, Green Valley, and Mill creeks (Figure 1). For CMP monitoring, a spatially-balanced random sample of juvenile coho salmon 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) was selected using a generalized random tessellation stratified (GRTS) approach as outlined in Fish Bulletin 180 (Adams et al. 2011) (Figure 1). A total of 50 reaches were selected for estimating juvenile coho occupancy according to the GRTS draw order. This sampling rate (53% of all juvenile coho reaches) was lower than in previous years (average of 71% over the previous 5 years) due to logistical constraints resulting from the Covid-19 pandemic. Snorkeling surveys were conducted on an additional 24 reaches in order to maintain long-term relative abundance data sets on specific streams, but results from those reaches were not included from the occupancy estimates.

3.2.2. Field methods

Sampling was based on modifications of protocols in Garwood and Ricker (2014). On each snorkel survey, salmonids were counted in every other pool within the reach, with the first pool (one or two) determined randomly. Pools were defined as habitat units with a depth of greater than one foot in an area at least as long as the maximum wetted width and a surface area of greater than three square meters. Pool cover data was collected on all survey pools and classified into five categories ranging from 'no cover' to 'excellent cover', based on the number of available features (undercut banks and boulders, woody debris, overhanging vegetation, bubble curtains, aquatic vegetation and canopy) from Garwood and Ricker (2017). A GPS point was collected at the downstream end of each pool snorkeled.

For reaches that were included in the occupancy estimate, a second snorkeling pass was completed the following day in which every other pool that was snorkeled during the first pass was snorkeled a second time in order to determine snorkel efficiency.

---

[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.

During each survey, snorkeler(s) moved from the downstream end of each pool (pool tail crest) to the upstream end, surveying as much of the pool as water depth allowed. Dive lights were used to inspect shaded and covered areas. In order to minimize disturbance of fish and sediment, snorkelers avoided sudden or loud movements. Double counting was minimized by only counting fish once they were downstream of the observer. Snorkelers recorded a rating that described the certainty of their count in each pool. In larger pools requiring two snorkelers, two lanes were agreed upon and each snorkeler moved upstream through the lane at the same rate. Final counts for the pool were the sum of both lane counts. All observed salmonids were identified to species (coho salmon, Chinook salmon, steelhead) and age class (young-of-year (yoy) or parr (≥ age-1)), based on size and physical characteristics. Presence of non-salmonid species was 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. Spatial data was downloaded, error checked, and stored in an ArcGIS geodatabase for map production.

3.2.3. Metrics

3.2.3.1. Relative abundance

First-pass counts were used to document the minimum number of coho salmon and steelhead yoy and parr observed in each reach. Because only half of the pools were snorkeled, minimum counts were doubled for an expanded minimum count. Expanded minimum counts did not incorporate variation among pools or detection efficiency; therefore, they should only be considered approximate estimates of abundance useful for relative comparisons.

3.2.3.2. Spatial distribution

Multiscale occupancy models were used to estimate the probability of juvenile coho salmon occupancy at the sample reach scale (ψ) and conditional occupancy at the sample pool scale (θ), given presence in the reach (Garwood and Larson 2014; Nichols et al. 2008). Detection probability (p) at the pool scale was accounted for using the repeated dive pass data in the occupancy models. The proportion of area occupied (PAO) was then estimated by multiplying the reach- and pool-scale occupancy parameters (ψ*θ).

3.3. Results

Between May 11 and August 6, 2020, UC and Sonoma Water biologists surveyed a total of 75 reaches representing 212.0 km (131.7 mi) of stream and 43 tributaries. All juvenile coho salmon rearing reaches of Willow, Dutch Bill, Green Valley, and Mill creeks were surveyed for Broodstock Program monitoring, and 50 reaches within the Russian River sample frame that were considered to contain juvenile coho habitat (53% of coho reaches) were included in the occupancy estimate for CMP monitoring. Since there is no way of visually distinguishing hatchery- and natural-origin juvenile coho salmon, we excluded one reach in Yellowjacket Creek due to remote streamside incubator (RSI) releases prior to snorkel surveys.

One reach on Dutch Bill Creek was classified as only containing steelhead habitat and was also excluded from the coho salmon occupancy estimate.

We observed 8,346 coho salmon yoy during the summer of 2020, with an expanded minimum count of 16,606 (Table 1), and we observed 12,774 steelhead yoy, with an expanded minimum count of 25,550 (Table 2). In streams where snorkel surveys were conducted before spring stocking occurred, all coho salmon yoy were presumed to be of natural-origin. Coho salmon yoy were observed in 50 of the 74 juvenile coho salmon *reaches* surveyed and in 31 of the 43 juvenile coho salmon *streams* snorkeled (68% and 72%, respectively) (Table 1, Figure 2). Steelhead yoy were observed in 72 of the 75 steelhead reaches and 37 of the 43 steelhead streams surveyed (96% and 86%, respectively) (Table 2). Natural-origin coho salmon counts were highest in Green Valley Creek, with the second highest counts in Dutch Bill Creek (Table 1). High numbers of coho salmon were also observed in Pena Creek and its tributary Woods Creek (Table 1). For the first time in seven years of conducting snorkel surveys, natural origin coho were observed in Pechaco Creek (Pena watershed) and Bearpen Creek (Austin watershed) (Table 1).

Based on results of the multiscale occupancy model, we estimate that the probability of coho yoy occupying a given reach within the basinwide Russian River coho stratum (ψ) in 2020 was 0.64 (0.50 - 0.76, 95% CI), and the conditional probability of coho yoy occupying a pool within a reach, given that the reach was occupied (θ), was 0.59 (0.54 – 0.63, 95% CI). The proportion of the coho stratum occupied (PAO) was 0.38. This was the highest PAO observed over the last five years (Table 3).

Juvenile coho salmon were observed in all four Broodstock Program monitoring streams and spatial distribution varied among streams (Table 1, Figure 3 - Figure 6). In Willow Creek, coho salmon yoy were distributed throughout the stream with the highest concentrations found in the lower 75% of the sampled reaches (Figure 3). In Dutch Bill Creek, coho salmon yoy were observed in the upper watershed with isolated clusters in the lower half (Figure 4). In Green Valley Creek, coho salmon yoy were distributed throughout the stream as well as the lower third of Purrington Creek (Figure 5). In the Mill Creek watershed, the highest densities of coho yoy were downstream of Wallace Creek, with some present in Palmer Creek (Figure 6).

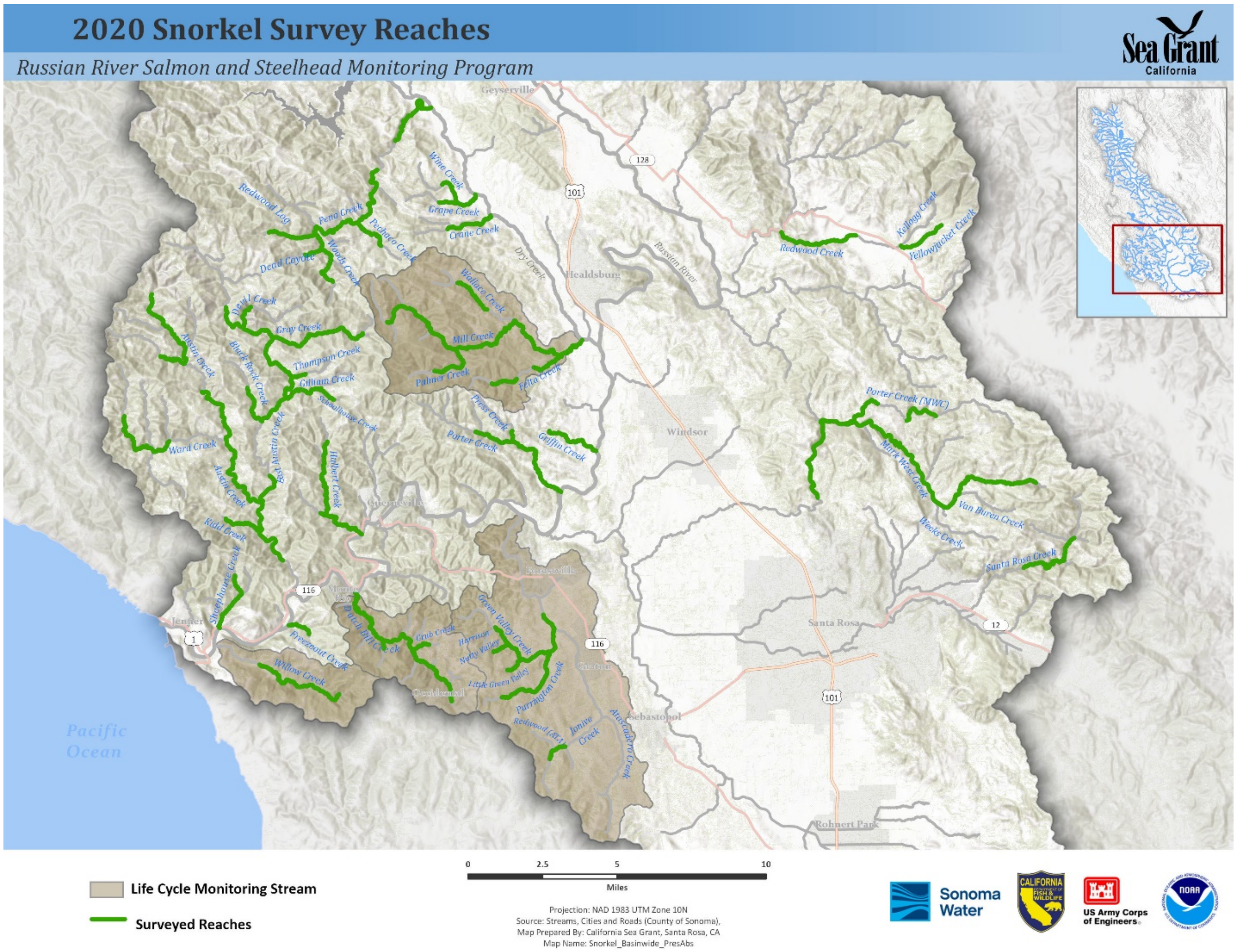

Figure 1. Reaches selected for 2020 summer juvenile snorkel surveys in the coho sample frame with lifecycle monitoring watersheds of Mill, Green Valley, Dutch Bill, and Willow creeks highlighted.

Table 1. Number of coho salmon yoy and parr observed in Russian River tributaries and expanded counts, summer 2020.

Tributary	Number of pools snorkeled	Stream length snorkeled (km)	Yoy	Expanded Yoy[1]	Parr	Expanded Parr[1]
Austin Creek	137	19.6	304	608	1	2
Bearpen Creek	14	1.9	471	942	0	0
Black Rock Creek	32	2.5	22	44	2	4
Crane Creek (Dry)	13	3.2	0	0	0	0
Dead Coyote Creek	6	1.1	47	94	0	0
Devil Creek	20	1.5	105	210	0	0
Dutch Bill Creek	133	11.4	991	1,982	31	62
East Austin Creek	103	13.1	155	310	0	0
Felta Creek	55	3.7	3	6	0	0
Freezeout Creek	26	1.5	4	8	0	0
Gilliam Creek	29	2.6	148	296	3	6
Grape Creek	43	2.6	135	270	0	0
Gray Creek	101	6.3	325	650	28	56
Green Valley Creek	86	7.0	1,528	3,056	87	174
Griffin Creek	10	3.6	2	4	0	0
Grub Creek	9	1.1	1	2	0	0
Hulbert Creek	67	8.2	0	0	1	2
Jonive Creek	21	1.5	0	0	0	0
Kidd Creek	34	2.5	34	68	2	4
Little Green Valley Creek	12	1.2	0	0	0	0
Mark West Creek	198	22.1	10	20	12	24
Mill Creek	151	16.6	697	1,394	60	120
Mission Creek	1	0.4	0	0	0	0
Nutty Valley Creek	3	1.2	2	4	9	18
Palmer Creek	42	2.9	68	136	3	6
Pechaco Creek	25	2.3	177	354	0	0
Pena Creek	77	15.1	834	1,668	29	58
Perenne Creek	9	0.5	0	0	0	0
Porter Creek	111	7.4	693	1,386	296	592
Porter Creek (MWC)	30	5.1	0	0	0	0
Press Creek	9	0.6	0	0	0	0
Purrington Creek	57	4.8	89	178	0	0
Redwood Creek	45	4.8	47	94	8	16
Santa Rosa Creek	48	4.6	0	0	0	0
Schoolhouse Creek	9	1.1	14	28	0	0
Sheephouse Creek	66	3.7	108	216	4	8
Thompson Creek	17	0.9	0	0	0	0
Wallace Creek	28	2.5	0	0	0	0
Ward Creek	48	5.0	0	0	0	0
Willow Creek	108	6.0	299	598	3	6
Wine Creek	15	1.8	235	470	0	0
Woods Creek	63	4.1	712	1,424	2	4
Yellowjacket Creek[2]	114	2.8	86	86	0	0
Total	**2,225**	**212.0**	**8,346**	**16,606**	**581**	**1,162**

[1] *Expanded count is the observed count multiplied by a factor of 2.*

[2] *Snorkel counts include yoy released as part of an RSI trial. Every pool was snorkeled as part of RSI monitoring.*

Table 2. Number of steelhead yoy and parr observed in Russian River tributaries and expanded counts, summer 2020.

Tributary	Number of pools snorkeled	Stream length snorkeled (km)	Yoy	Expanded Yoy[1]	Parr	Expanded Parr[1]
Austin Creek	137	19.6	1,593	3,186	305	610
Bearpen Creek	14	1.9	34	68	27	54
Black Rock Creek	32	2.5	244	488	24	48
Crane Creek (Dry)	13	3.2	0	0	1	2
Dead Coyote Creek	6	1.1	1	2	1	2
Devil Creek	20	1.5	167	334	39	78
Dutch Bill Creek	133	11.4	851	1,702	152	304
East Austin Creek	103	13.1	1,582	3,164	148	296
Felta Creek	55	3.7	31	62	57	114
Freezeout Creek	26	1.5	42	84	21	42
Gilliam Creek	29	2.6	139	278	13	26
Grape Creek	43	2.6	159	318	22	44
Gray Creek	101	6.3	710	1,420	248	496
Green Valley Creek	86	7.0	453	906	94	188
Griffin Creek	10	3.6	1	2	2	4
Grub Creek	9	1.1	0	0	7	14
Hulbert Creek	67	8.2	632	1,264	113	226
Jonive Creek	21	1.5	9	18	1	2
Kidd Creek	34	2.5	130	260	82	164
Little Green Valley Creek	12	1.2	0	0	6	12
Mark West Creek	198	22.1	573	1,146	389	778
Mill Creek	151	16.6	1,864	3,728	162	324
Mission Creek	1	0.4	1	2	2	4
Nutty Valley Creek	3	1.2	0	0	0	0
Palmer Creek	42	2.9	97	194	47	94
Pechaco Creek	25	2.3	0	0	18	36
Pena Creek	77	15.1	1,141	2,282	197	394
Perenne Creek	9	0.5	4	8	1	2
Porter Creek	111	7.4	784	1,568	173	346
Porter Creek (MWC)	30	5.1	26	52	100	200
Press Creek	9	0.6	0	0	6	12
Purrington Creek	57	4.8	432	864	72	144
Redwood Creek	45	4.8	158	316	54	108
Santa Rosa Creek	48	4.6	116	232	236	472
Schoolhouse Creek	9	1.1	6	12	1	2
Sheephouse Creek	66	3.7	110	220	70	140
Thompson Creek	17	0.9	9	18	9	18
Wallace Creek	28	2.5	24	48	13	26
Ward Creek	48	5.0	487	974	189	378
Willow Creek	108	6.0	73	146	113	226
Wine Creek	15	1.8	16	32	18	36
Woods Creek	63	4.1	23	46	99	198
Yellowjacket Creek[2]	114	2.8	52	106	78	153
Total	**2,225**	**212.0**	**12,774**	**25,550**	**3,410**	**6,817**

[1] *Expanded count is the observed count multiplied by a factor of 2.*

[2] *Snorkel counts include yoy released as part of an RSI trial. Every pool was snorkeled as part of RSI monitoring.*

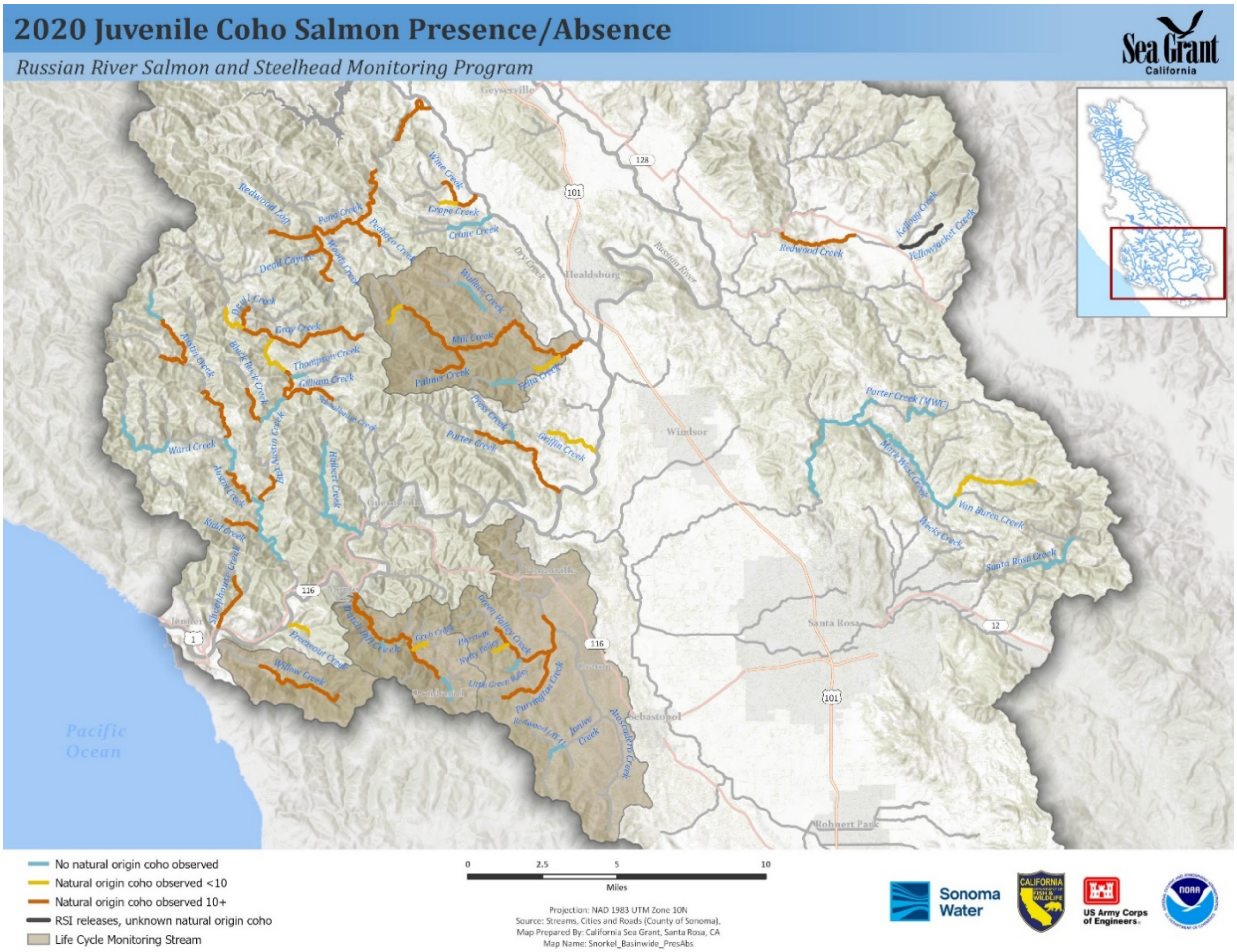

Figure 2. Natural-origin coho salmon presence by reach in surveyed Russian River tributaries, summer 2020.

Table 3. Percent of area occupied by coho salmon yoy within juvenile coho reaches of the Russian River sample frame, 2015-2020.

Year	Reaches sampled	Stream length surveyed (km)	PAO
2015	58	167	0.37
2016	72	206	0.33
2017	73	214	0.2
2018	69	205	0.25
2019	70	211	0.15
2020	50	137	0.38

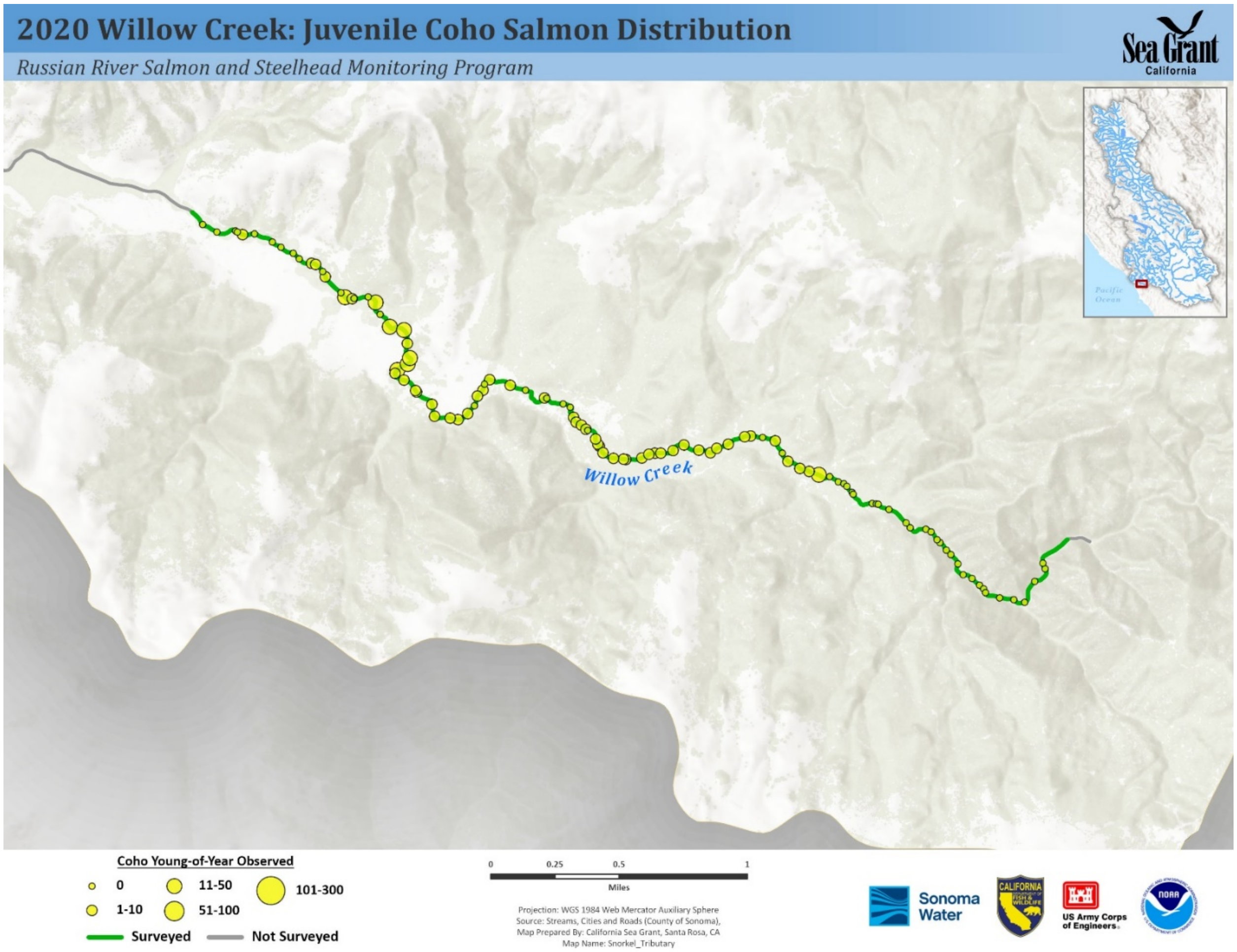

Figure 3. Density and distribution of juvenile coho salmon yoy observed in Willow Creek, 2020. Note that the smallest circle indicates no coho observations in the associated pool.

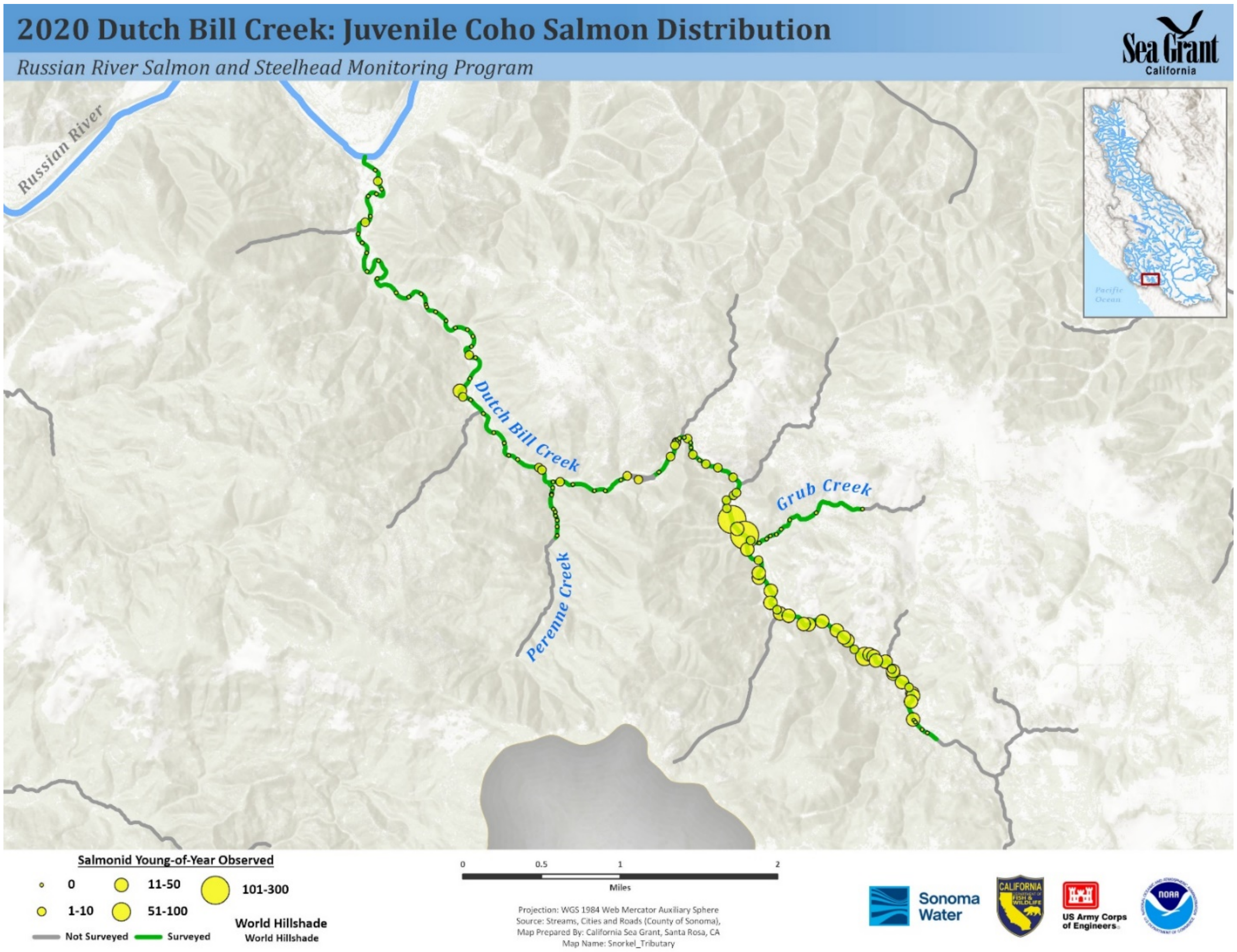

Figure 4. Density and distribution of juvenile coho salmon yoy observed in Dutch Bill Creek, 2020. Note that the smallest circle indicates no coho observations in the associated pool.

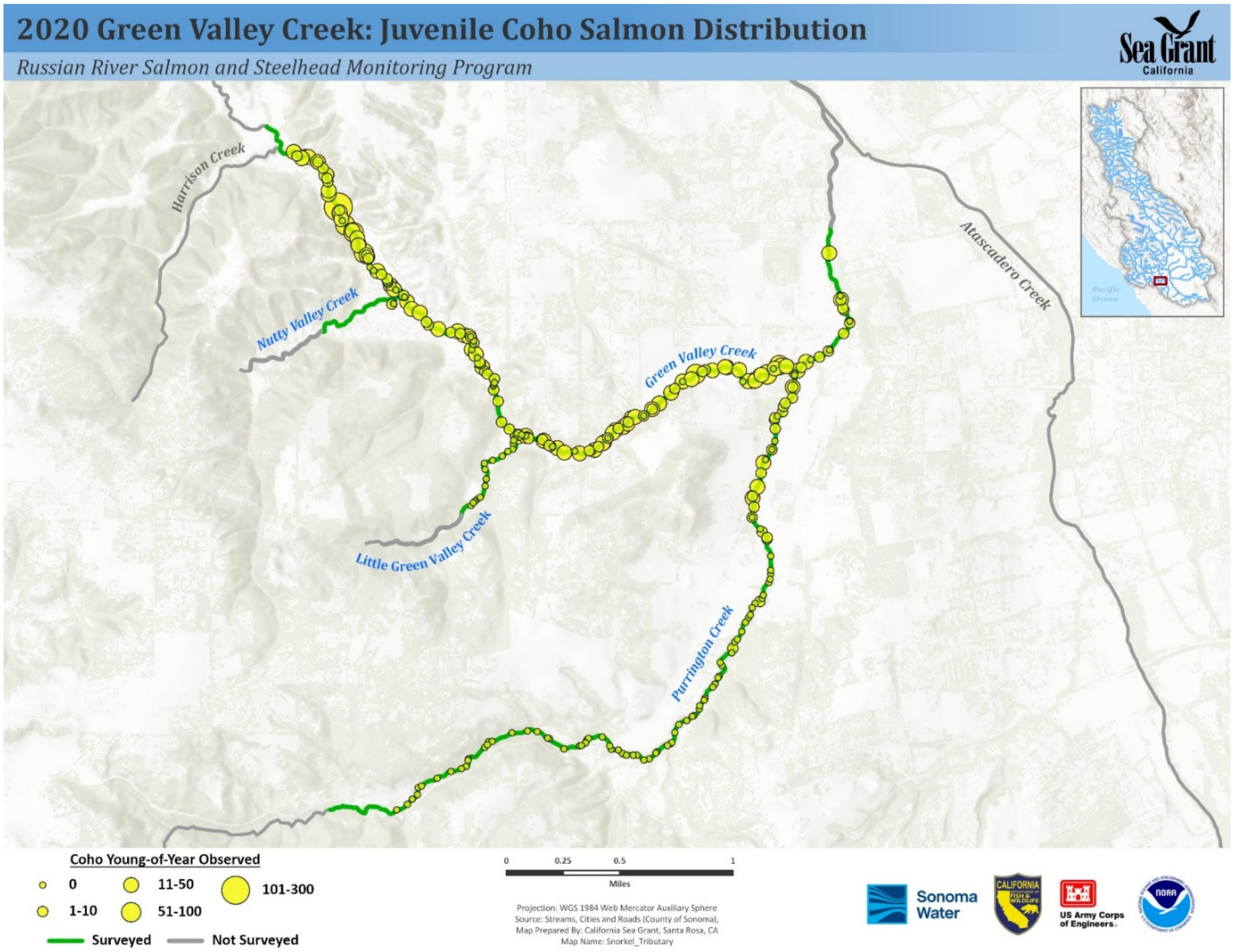

Figure 5. Density and distribution of juvenile coho salmon yoy observed in Green Valley Creek, 2020. Note that the smallest circle indicates no coho observations in the associated pool.

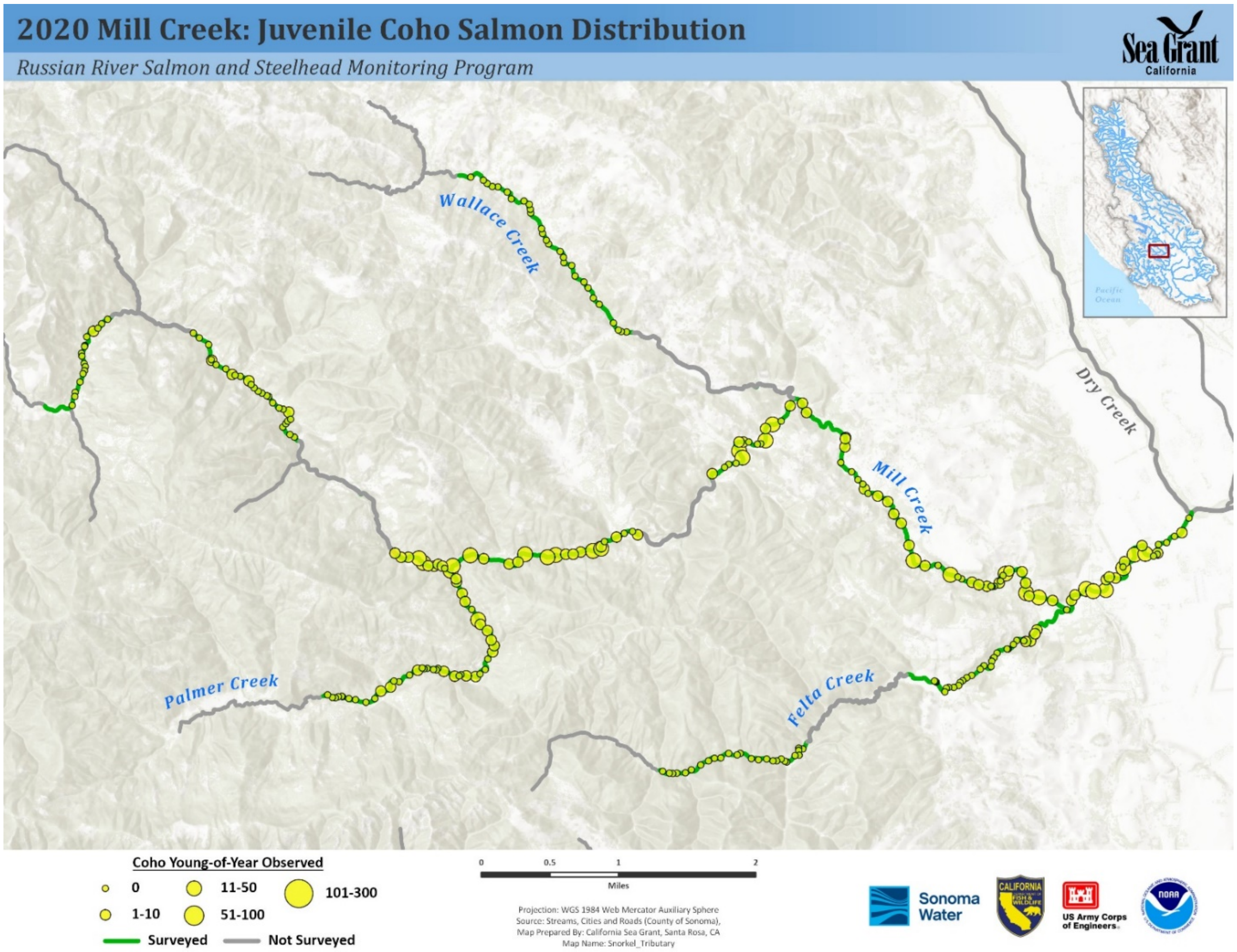

Figure 6. Density and distribution of juvenile coho salmon yoy observed in Mill Creek, 2020. Note that the smallest circle indicates no coho observations in the associated pool.

4. Discussion and recommendations

The summer of 2020 posed a new set of challenges for field monitoring due to COVID-19, extreme drought and multiple fires. Despite these constraints, we were able to accomplish our goals of documenting relative salmonid abundance and spatial distribution in the Russian River. We completed full surveys on the four Broodstock Program monitoring streams and surveyed 50 reaches for estimating juvenile coho occupancy. Although the sampling rate was reduced from 71% to 53% as compared to previous years, it was still sufficiently high for estimating coho occupancy. To maintain long-term datasets for relative abundance on many additional streams, we performed less-intensive single-pass surveys. These surveys allowed us to confirm successful spawning occurred during the winter of 2019/2020 and to compare distribution among years.

The number of coho salmon yoy observed on 2020 snorkel surveys was the highest of any year since the beginning of basinwide CMP surveys in 2015. Natural-origin juvenile coho salmon were present in all four Broodstock Program monitoring streams and in 31 of 43 juvenile coho salmon streams surveyed through the CMP Program in 2020. Ten or more coho salmon yoy were observed in 26 of the 43 coho salmon tributaries. This is a positive indication that successful spawning of adult coho salmon continued to occur in the Russian River watershed during the winter of 2019/20, and it represents a significant improvement in spatial distribution from the early 2000s when coho salmon were only known to occur in one to two streams per year. With the exception of a remote streamside incubator (RSI) release into Yellowjacket Creek, all surveys were performed prior to stocking events thus all coho salmon yoy can be presumed to be of wild origin. The origin of coho salmon parr remains unknown based on visual assessment. In reaches where coho yoy were present, all reaches had over 10 individuals, likely indicating natural-origin spawning and not immigration from other areas.

Coho salmon PAO was the highest observed since we began conducting basinwide snorkel surveys to estimate spatial structure in 2015 (Table 3), indicating that coho were occupying more of the watershed for rearing than in previous years. Estimated coho redd abundance and adult coho returns were slightly below the five-year average in the winter of 2019/2020 (California Sea Grant 2020) therefore, it is probable that the broad spatial distribution of coho yoy was due to greater than average redd success. Low flows in the winter of 2019/2020 may have increased early life stage survival as compared to years with higher winter flows such as 2018/2019, when we observed very low PAO in the following summer despite an above average number of redds. This highlights a potential challenge for the Russian River coho salmon population in which low water years may allow higher spawning success yet result in summer conditions across much of the basin that are unsuitable for juvenile salmonids. It also provides support for the idea that land management practices designed to reduce peak flows could be highly beneficial to the coho salmon population in the Russian River in addition to efforts to increase summer flows.

Unlike coho, steelhead yoy numbers were below average in the summer of 2020. This was likely due to unfavorable flow conditions during the steelhead spawning window. The winter of 2019/20 had smaller, but more steady rainfall than typically observed. While a few larger storms occurred early in the season, which allowed coho salmon adults to return to spawning tributaries, low stream flows later in the season meant that a significant portion of spawning habitat was not available during the peak of the steelhead run. On March 1, which has generally been the peak of steelhead spawning in Russian River streams during the past seven years, 22% of survey streams were disconnected from the Russian River.

New metrics were included in the survey protocol to collect more information about habitat characteristics and to improve accuracy of salmonid counts. The new metric, 'Cover Rating', was collected throughout the season on all pass 1 pools. To validate the repeatability of this metric in the Russian River watershed, pools were resampled during pass 2 surveys during the first half of the season. Of the 785 survey pools with two passes, only 2% differed by more one category between passes and 53% were assigned the same category by both divers. With improved training planned for next season, we believe this metric can be collected even more accurately and will serve as a valuable metric of relative habitat quality.

The majority of pools in the coho sample frame were assigned a cover rating of average, meaning the habitat unit generally provides fish cover, but lacks complexity with only moderate cover features available (Figure 7). These data will be used in future efforts to map average cover values across 100m sections, which will help to uncover relationships between spawning and rearing, and help to identify potential habitat improvement project locations.

Another new metric, “Count Certainty”, was collected by field observers to record their observational confidence at the pool level during both survey passes on a scale of 1 (high confidence) to 3 (low confidence). Count certainty can be used to investigate outliers and help explain significant differences in observations between the first and second pass. According to crew comments, pool visibility appeared to be a driving factor for pools marked as low confidence. Preliminary analysis suggests that cover rating was also correlated with crew certainty with crews being less certain of their counts in pools with higher cover ratings (R = 0.22).

Along with these new metrics, one-on-one in-season feedback was provided to field crews to analyze count accuracy and discuss questions that arose about protocols. This one-on-one feedback allowed field crews to improve their skills, and ask questions. While requiring more time from managers, it is recommended to be continued in future seasons.

In addition to the challenges of COVID-19, there were a variety of environmental factors at play during the 2020 summer season. Drought conditions were observed throughout the watershed despite it being an “average” water year where 52.61 inches of precipitation were recorded at the Venado rain gage. At the completion of the snorkel season in early August, 64% of the reaches surveyed (n=49) contained pools with surface flow disconnection. Since stream drying is not evenly distributed, and field crews only snorkel every other pool unit, it is likely that the 64% value was conservative. Basinwide drying continued to occur throughout the summer months and preliminary analysis shows a close similarity to the drought year of 2015. In fall, crews performed wetted habitat surveys on the same reaches that were snorkeled during the summer and defined sections of stream as wet, intermittent, or dry based on surface flow. We performed a spatial overlay of the fish abundance and distribution data from snorkel surveys onto the fall wetted habitat maps to visualize impacts of stream drying on the fish observed during snorkel surveys (Figure 8 - Figure 11). In all four streams, a high proportion of the fish observed during snorkel surveys were exposed to dry or intermittent conditions later on in the fall, providing further evidence for a juvenile salmonid survival bottleneck that we have observed on an annual basis in many Russian River streams. In recent dry years, we have documented as much as 90% of the habitat where coho and steelhead young-of-the-year were rearing in a single stream dry or experience early intermittence. Perennial summer fish habitat is typically confined to relatively few systems, with the vast majority of streams experiencing some flow impairment in all years.

In addition to widespread drying there were two large wildfires in the lower Russian River during the summer of 2020. The Walbridge fire burned 21% of coho salmon habitat in the Russian River and the impact of that on juvenile salmonids is currently unknown. Even in areas where burn intensity may not have been high enough to cause direct mortality for fish, it is likely that there will be ongoing impacts to water quality and habitat conditions in these burn areas. Along with our partners at Sonoma Water, we plan to continue to monitor for these impacts.

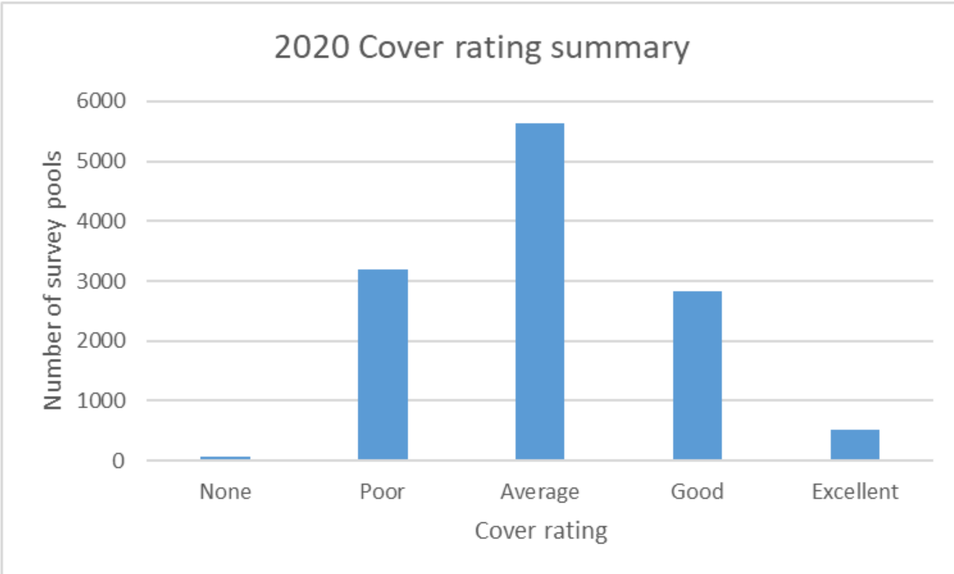

Figure 7. Distribution of cover rating values recorded for pools snorkeled in Russian River tributaries during summer 2020.

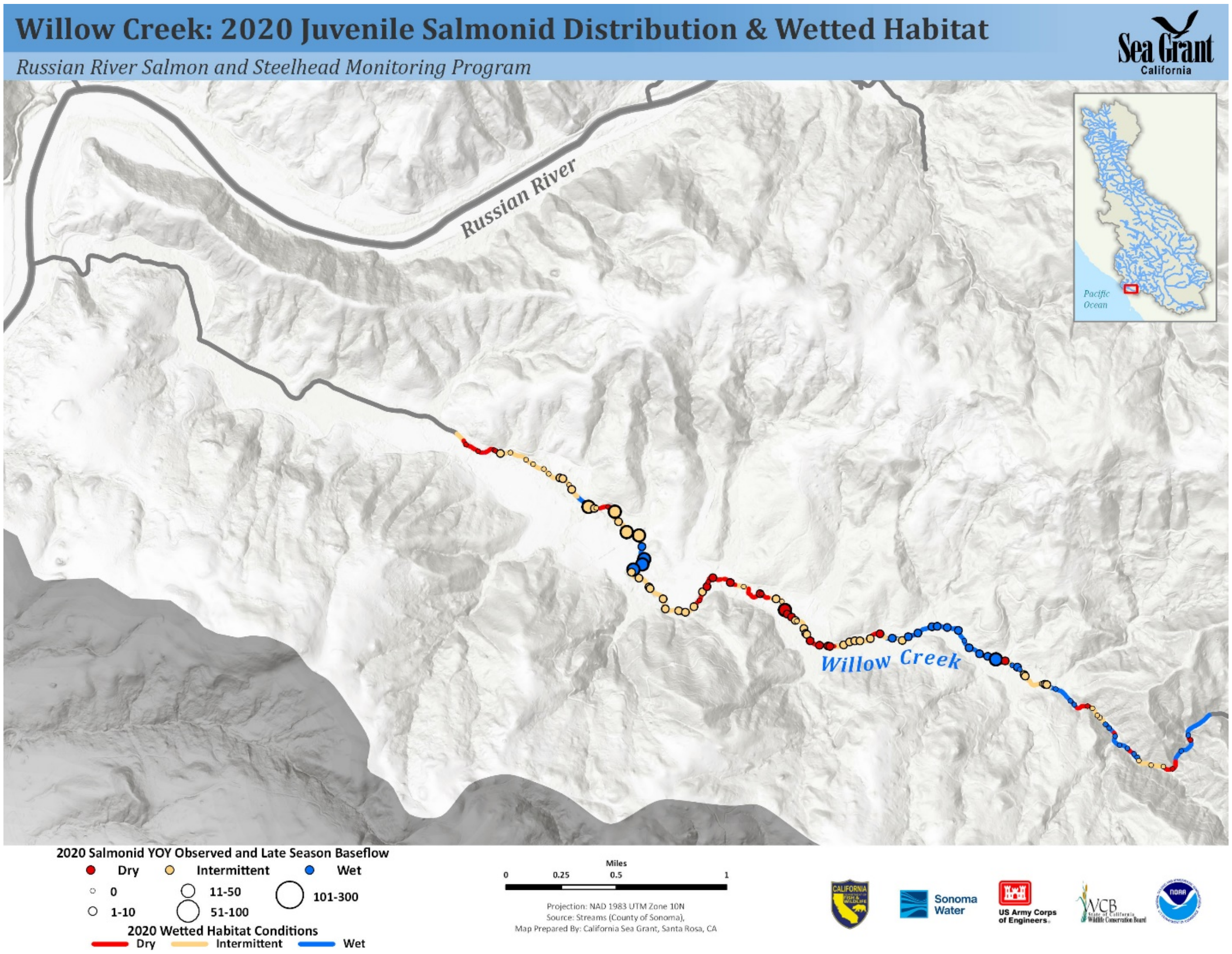

Figure 8. Willow Creek juvenile salmonid density and distribution from summer 2020 overlaid with fall 2020 wetted habitat conditions.

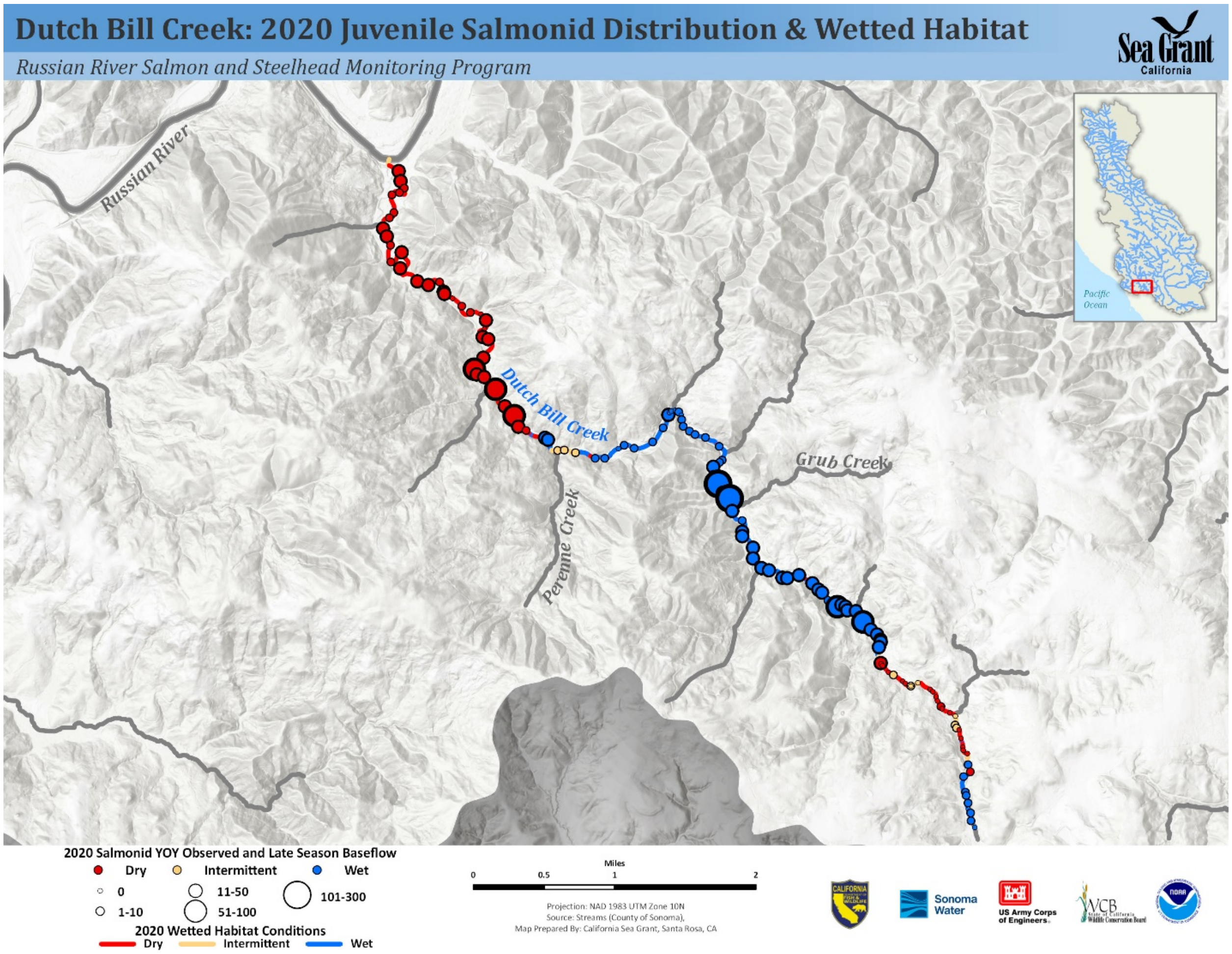

Figure 9. Dutch Bill Creek juvenile salmonid density and distribution from summer 2020 overlaid with fall 2020 wetted habitat conditions.

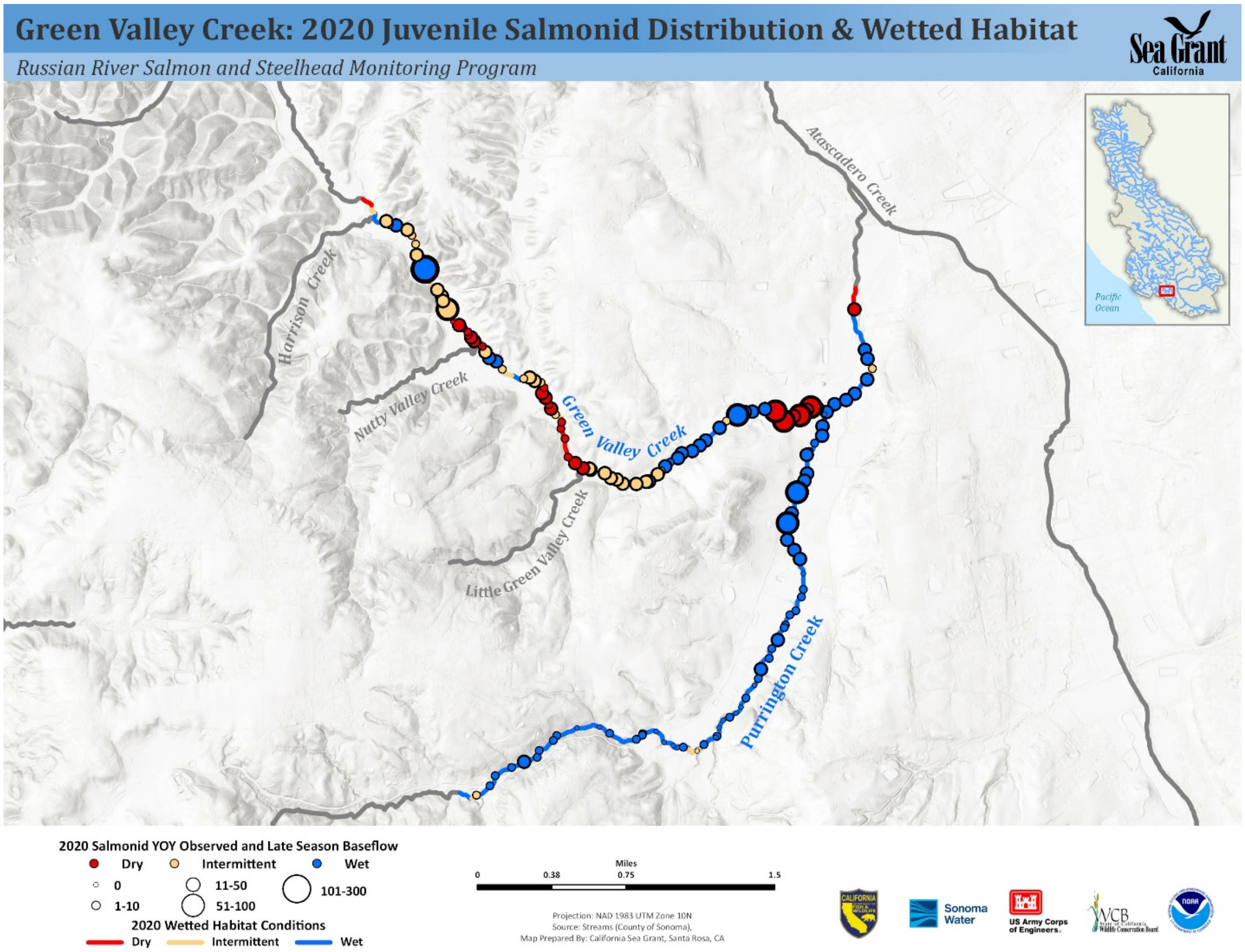

Figure 10. Green Valley Creek juvenile salmonid density and distribution from summer 2020 overlaid with fall 2020 wetted habitat conditions.

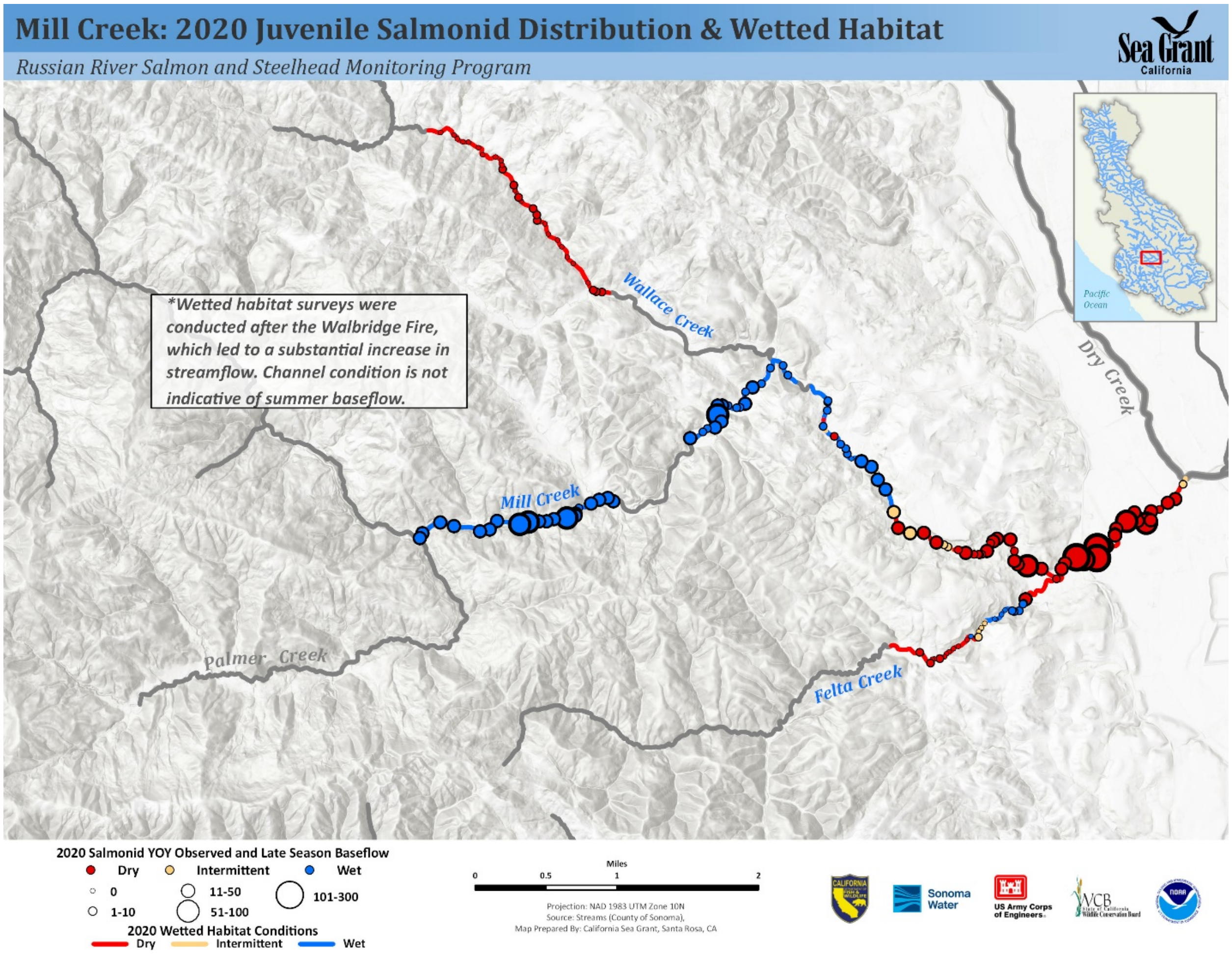

Figure 11. Mill Creek juvenile salmonid density and distribution from summer 2020 overlaid with fall 2020 wetted habitat conditions.

5. References

Adams, P. B., and coauthors. 2011. California coastal salmonid population monitoring: strategy, design, and methods. California Department of Fish and Game, California.

California Sea Grant. 2020. Russian River coho salmon and steelhead monitoring report: Winter 2019/20. University of California San Diego, Windsor, CA.

Garwood, J., and S. Ricker. 2014. 2014 Juvenile coho spatial structure monitoring protocol: Summer survey methods. California Department of Fish and Wildlife, Arcata, CA.

Garwood, J., and S. Ricker. 2017. Salmonid spatial structure monitoring survey protocol: Summer snorkel survey methods. California Department of Fish and Wildlife, Arcata, CA.

Garwood, J. M., and M. D. Larson. 2014. Reconnaissance of salmonid redd abundance and juvenile spatial structure in the Smith River with emphasis on coho salmon (*Oncorhynchus kisutch*). California Department of Fish and Wildlife, Arcata, California.

Nichols, J. D., and coauthors. 2008. Multi-scale occupancy estimation and modelling using multiple detection methods. Journal of Applied Ecology 45:1321-1329.