Coho Salmon and Steelhead Monitoring Report

Summer 2021

Prepared by:

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

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Contents

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1. Background

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

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

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

In this seasonal monitoring report, we provide results from our summer Broodstock Program, CMP, and National Marine Fisheries Service (NMFS) snorkel surveys, including relative abundance and spatial distribution of juvenile salmonids in Russian River tributaries. We also include spatial overlays of fish distribution with wetted habitat conditions from studies conducted in partnership with WCB, TU, GRRCD, and SRCD. Additional information and previous reports can be found on our website.

2. Juvenile Presence and Distribution

2.1. 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 2021. These data were used to determine whether successful spawning occurred the previous winter and to track spatiotemporal trends in relative abundance and occupancy.

2.2. Methods

2.2.1. Sampling reaches

We snorkeled 77 reaches, 74 of which were classified as juvenile coho salmon habitat, and three reaches, in upper Dutch Bill, East Austin, and Mark West creeks, that were classified as steelhead only (Figure 1). For Broodstock Program monitoring, we surveyed juvenile salmonid reaches of Willow, Dutch Bill, Green Valley, and Mill creeks. For CMP monitoring, we used an established spatially-balanced random sample of 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). Reaches were selected using a generalized random tessellation stratified (GRTS) approach as outlined in Fish Bulletin 180 (Adams et al. 2011). Prior to the start of the season, we contacted landowners to confirm and attempt to expand established access for selected reaches. If landowner access could not be achieved for at least three quarters of a selected reach, it was excluded from sampling. Additionally, as surveys were scheduled, communication with landowners along each reach occurred to inform them when survey efforts were taking place. A total of 63 reaches were sampled for estimating juvenile coho occupancy according to the GRTS draw order. Yellowjacket Creek was surveyed to monitor coho salmon adjacent to a remote site incubator (RSI) study conducted in partnership with NMFS, CDFW, and ACOE. Snorkeling surveys were conducted on an additional 14 reaches in order to maintain long-term relative abundance data sets on specific streams, but results from those reaches, as well as Yellowjacket Creek, were not included in the occupancy estimates.

[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.

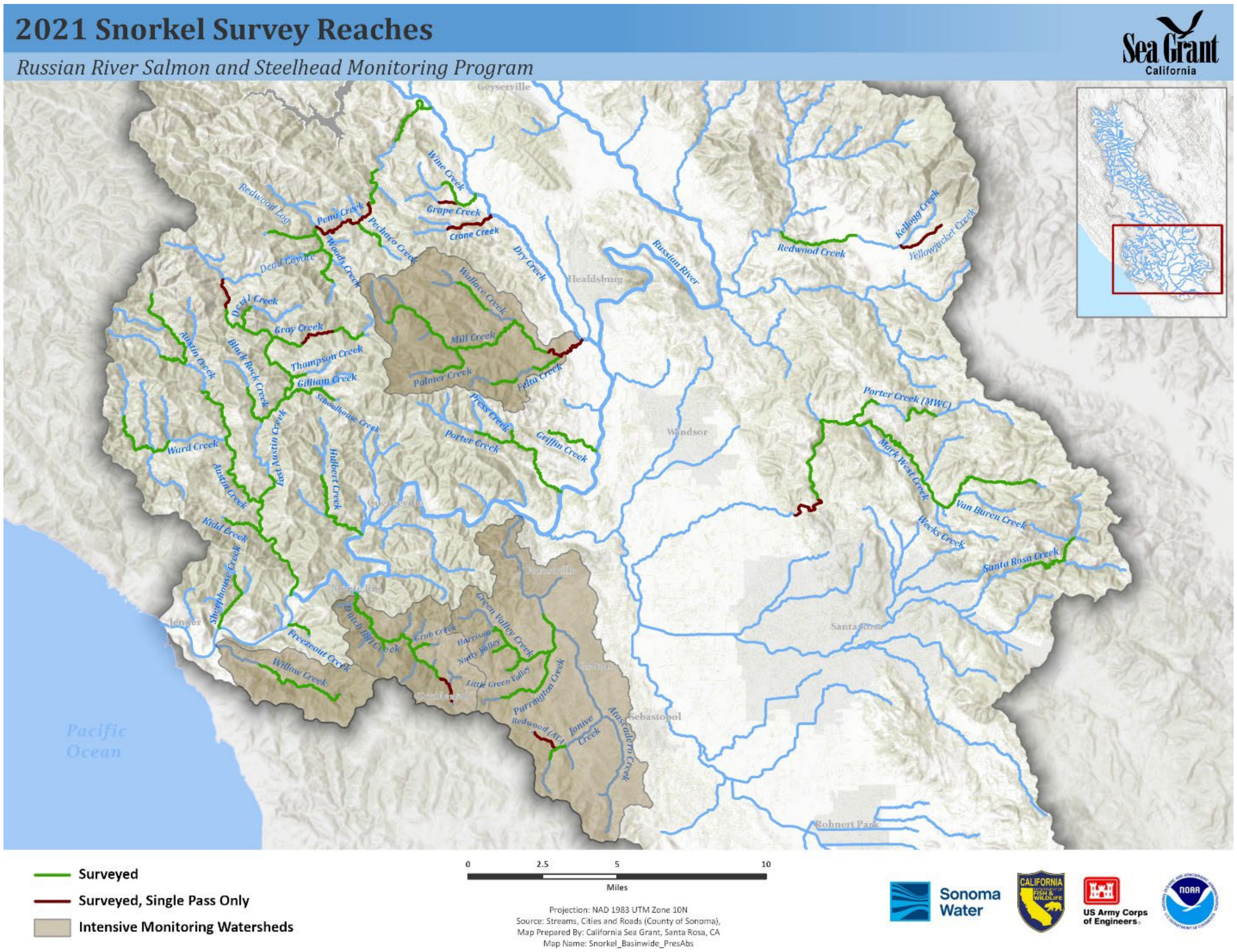

Figure 1. Reaches surveyed during 2021 summer juvenile snorkel surveys, with the four Broodstock Program intensive monitoring watersheds of Mill, Green Valley, Dutch Bill, and Willow creeks highlighted. Reaches in red were sampled with only a single pass.

2.2.2. 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 (e.g., every fourth pool) was snorkeled a second time in order to account for detection efficiency. In general, a second pass did not occur on the same day as a first pass given low streamflow and suspended sediment from the snorkeler's movements limiting visibility for a second pass. However, in cases in which both first and second passes did occur on the same day, second pass snorkelers ensured adequate visibility for detection of fish was present in pools before sampling. For reaches that were not included in the occupancy estimate, only a single pass was completed. In Yellowjacket Creek, a census survey was performed and every pool was sampled during a single pass.

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 were downloaded, error checked, and stored in an ArcGIS geodatabase for map production.

2.2.3. Metrics

2.2.3.1. 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.

2.2.3.2. 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 ($\psi * \theta$).

2.3. Results

Between May 11 and August 5, 2021, CSG and SW biologists surveyed 77 reaches representing 218 km (135.5 mi) of stream and 44 tributaries. All juvenile coho salmon rearing reaches of Willow, Dutch Bill, Green Valley, and Mill creeks were surveyed for Broodstock Program monitoring, and 63 reaches within the Russian River sample frame that were considered to contain juvenile coho habitat (66% of coho reaches) were included in the occupancy estimate for CMP monitoring. We excluded Yellowjacket Creek from the occupancy estimate because of the RSI coho salmon releases that occurred prior to snorkel surveys, since we had no way of visually distinguishing hatchery (RSI)- and natural-origin juvenile coho salmon. Other than the RSI release in Yellowjacket Creek, juvenile coho salmon were not stocked into any other tributary due to severe drought conditions. Three reaches on Dutch Bill, East Austin, and Mark West Creek were classified as only containing steelhead habitat and were also excluded from the coho salmon occupancy estimate.

We observed 3,079 coho salmon yoy during the summer of 2021, with an expanded minimum count of 5,262 (Table 1), and we observed 6,361 steelhead yoy, with an expanded minimum count of 12,717 (Table 2). In streams where snorkel surveys were conducted before fish releases from RSI and CDFW relocation efforts, all coho salmon yoy were presumed to be of natural origin. Coho salmon yoy were observed in 32 of the 74 juvenile coho salmon *reaches* surveyed and in 18 of the 44 juvenile coho salmon *streams* snorkeled (44% and 41%, respectively) (Table 1, Figure 2). Steelhead yoy were observed in 61 of the 77 steelhead reaches and 28 of the 44 steelhead streams surveyed (79% and 64%, respectively) (Table 2). Natural-origin coho salmon counts were highest in Dutch Bill Creek, with the second highest counts in Austin Creek (Table 1). Higher numbers of coho salmon were also observed in Kidd Creek (Austin Creek watershed), Green Valley Creek, and Mill Creek (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 2021 was 0.51 (0.38 - 0.64, 95% CI), and the conditional probability of coho yoy occupying a pool within a reach, given that the reach was occupied (θ), was 0.31 (0.26 – 0.36, 95% CI). The proportion of the coho stratum occupied (PAO) was 0.16. This was the second lowest PAO observed over the last seven years (Table 3).

Juvenile coho salmon were observed in all four Broodstock Program intensive monitoring watersheds and spatial distribution varied among streams (Table 1, Figure 3 - Figure 6). In Willow Creek, coho salmon yoy were distributed in smaller numbers in the middle of the surveyed section (Figure 3). In Dutch Bill Creek, coho salmon yoy were observed in the middle surveyed section, and no salmonids were present in the upper watershed (Figure 4). In Green Valley Creek, coho salmon yoy were distributed in the lower and highest survey sections, 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 Felta Creek, with less than five coho observed in Palmer Creek (Figure 6).

A large number of coho salmon parr was observed during the summer 2021 snorkel surveys. In Dutch Bill Creek, we observed 393 parr compared to a five-year average of 16, in Willow Creek we observed 129 compared to the five-year average of 38, and in Green Valley Creek we observed 417 compared to the five-year average of 85. Of interest, these parr were distributed across multiple pools in each stream indicating little movement (or aggregation) over the spring or subsequent movement back upstream following attempts to emigrate.

Table 1. Number of coho salmon yoy and parr observed in Russian River tributaries and expanded counts, summer 2021.

Tributary	Number of pools snorkeled	Stream length snorkeled (km)	Yoy	Expanded Yoy[1]	Parr	Expanded Parr[1]
Austin Creek	131	22.0	573	1,146	3	6
Bearpen Creek	13	1.9	14	28	0	0
Black Rock Creek	11	2.5	0	0	0	0
Crane Creek (Dry)	26	3.2	1	2	0	0
Dead Coyote Creek	6	1.1	0	0	0	0
Devil Creek	9	1.5	0	0	1	2
Dutch Bill Creek	97	11.4	592	1,184	393	786
East Austin Creek	122	14.9	51	102	5	10
Felta Creek	47	3.7	0	0	0	0
Freezeout Creek	14	1.5	6	12	0	0
Gilliam Creek	29	2.6	71	142	0	0
Grape Creek	12	2.6	0	0	0	0
Gray Creek	78	6.3	0	0	2	4
Green Valley Creek	90	7.0	163	326	296	592
Griffin Creek	8	3.6	0	0	0	0
Grub Creek	10	1.1	0	0	0	0
Harrison Creek	3	0.2	0	0	1	2
Hulbert Creek	33	6.1	0	0	0	0
Jonive Creek	21	1.5	0	0	0	0
Kidd Creek	27	2.5	349	698	43	86
Little Green Valley Creek	11	1.2	0	0	1	2
Mark West Creek	186	25.0	23	46	8	16
Mill Creek	129	16.6	160	320	7	14
Nutty Valley Creek	2	1.2	0	0	9	18
Palmer Creek	37	2.9	1	2	0	0
Pechaco Creek	19	2.3	0	0	0	0
Pena Creek	82	15.1	81	162	0	0
Perenne Creek	8	0.5	0	0	0	0
Porter Creek	66	7.4	0	0	120	240
Porter Creek (MWC)	19	5.1	0	0	0	0
Press Creek	9	0.6	0	0	0	0
Purrington Creek	73	4.8	22	44	5	10
Redwood Creek	41	4.8	46	92	0	0
Redwood Creek (Atascadero)	20	1.9	0	0	94	188
Santa Rosa Creek	60	4.6	0	0	0	0
Schoolhouse Creek	3	1.1	0	0	0	0
Sheephouse Creek	28	3.7	7	14	18	36
Thompson Creek	9	0.9	0	0	0	0
Wallace Creek	22	2.5	0	0	0	0
Ward Creek	50	5.0	0	0	0	0
Willow Creek[3]	58	6.0	23	46	126	252
Wine Creek	3	1.8	0	0	0	0
Woods Creek	53	4.1	0	0	0	0
Yellowjacket Creek[2]	124	2.8	896	896	15	15
Total	**1,899**	**219.1**	**3,079**	**5,262**	**1,147**	**2,279**

[1] *Expanded count is the observed count multiplied by a factor of 2.*
[2] *Snorkel counts include yoy released from RSI. Every pool was snorkeled in Yellowjacket Creek to evaluate coho RSI releases.*
[3] *Classified as yoy based on fork length however field crews reported they were likely small parr due to appearance.*

Table 2. Number of steelhead yoy and parr observed in Russian River tributaries and expanded counts, summer 2021.

Tributary	Number of pools snorkeled	Stream length snorkeled (km)	Yoy	Expanded Yoy[1]	Parr	Expanded Parr[1]
Austin Creek	131	22.0	2043	4086	243	486
Bearpen Creek	13	1.9	310	620	5	10
Black Rock Creek	11	2.5	0	0	16	32
Crane Creek (Dry)	26	3.2	2	4	0	0
Dead Coyote Creek	6	1.1	0	0	0	0
Devil Creek	9	1.5	77	154	13	26
Dutch Bill Creek	97	11.4	423	846	15	30
East Austin Creek	122	14.9	486	972	210	420
Felta Creek	47	3.7	44	88	7	14
Freezeout Creek	14	1.5	1	2	6	12
Gilliam Creek	29	2.6	99	198	19	38
Grape Creek	12	2.6	0	0	0	0
Gray Creek	78	6.3	135	270	64	128
Green Valley Creek	90	7.0	3	6	28	56
Griffin Creek	8	3.6	0	0	0	0
Grub Creek	10	1.1	0	0	0	0
Harrison Creek	3	0.2	0	0	0	0
Hulbert Creek	33	6.1	582	1,164	4	8
Jonive Creek	21	1.5	3	6	2	4
Kidd Creek	27	2.5	20	40	28	56
Little Green Valley Creek	11	1.2	0	0	0	0
Mark West Creek	186	25.0	203	406	154	308
Mill Creek	129	16.6	274	548	61	122
Nutty Valley Creek	2	1.2	0	0	0	0
Palmer Creek	37	2.9	78	156	10	20
Pechaco Creek	19	2.3	115	230	0	0
Pena Creek	82	15.1	929	1,858	158	316
Perenne Creek	8	0.5	17	34	1	2
Porter Creek	66	7.4	66	132	7	14
Porter Creek (MWC)	19	5.1	10	20	4	8
Press Creek	9	0.6	0	0	0	0
Purrington Creek	73	4.8	124	248	73	146
Redwood Creek	41	4.8	118	236	6	12
Redwood Creek (Atascadero)	20	1.9	0	0	1	2
Santa Rosa Creek	60	4.6	205	410	531	1,062
Schoolhouse Creek	3	1.1	0	0	0	0
Sheephouse Creek	28	3.7	0	0	9	18
Thompson Creek	9	0.9	0	0	0	0
Wallace Creek	22	2.5	0	0	0	0
Ward Creek	50	5.0	12	24	35	70
Willow Creek	58	6.0	0	0	8	16
Wine Creek	3	1.8	0	0	1	2
Woods Creek	53	4.1	36	72	7	14
Yellowjacket Creek[2]	124	2.8	5	5	47	47
Total	**1,899**	**219.1**	**6,420**	**12,835**	**1,773**	**3,499**

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

[2] *Every pool was snorkeled in Yellowjacket Creek to evaluate coho RSI releases.*

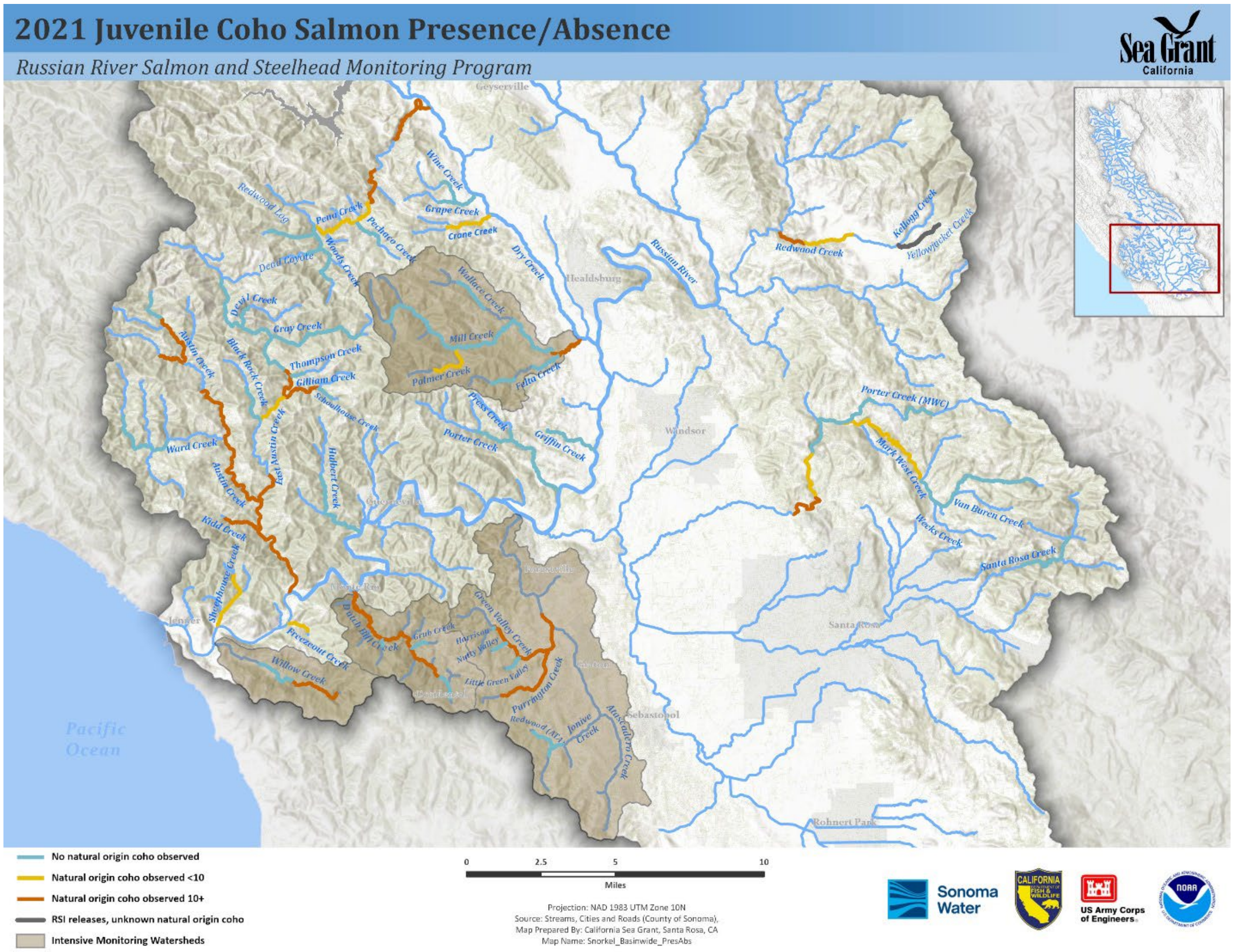

Figure 2. Natural-origin coho salmon presence by reach in surveyed Russian River tributaries, summer 2021. Note Fish in Willow Creek were classified as yoy based on fork length however field crews reported they were likely small parr due to appearance.

Table 3. Percent of area occupied by coho salmon yoy within juvenile coho reaches of the Russian River sample frame, 2015-2021.

Year	Reaches Sampled	Stream length surveyed (km)	PAO
2015	58	167	0.37
2016	72	206	0.33
2017	73	214	0.20
2018	69	205	0.25
2019	70	211	0.15
2020	51	139	0.37
2021	63	178	0.16

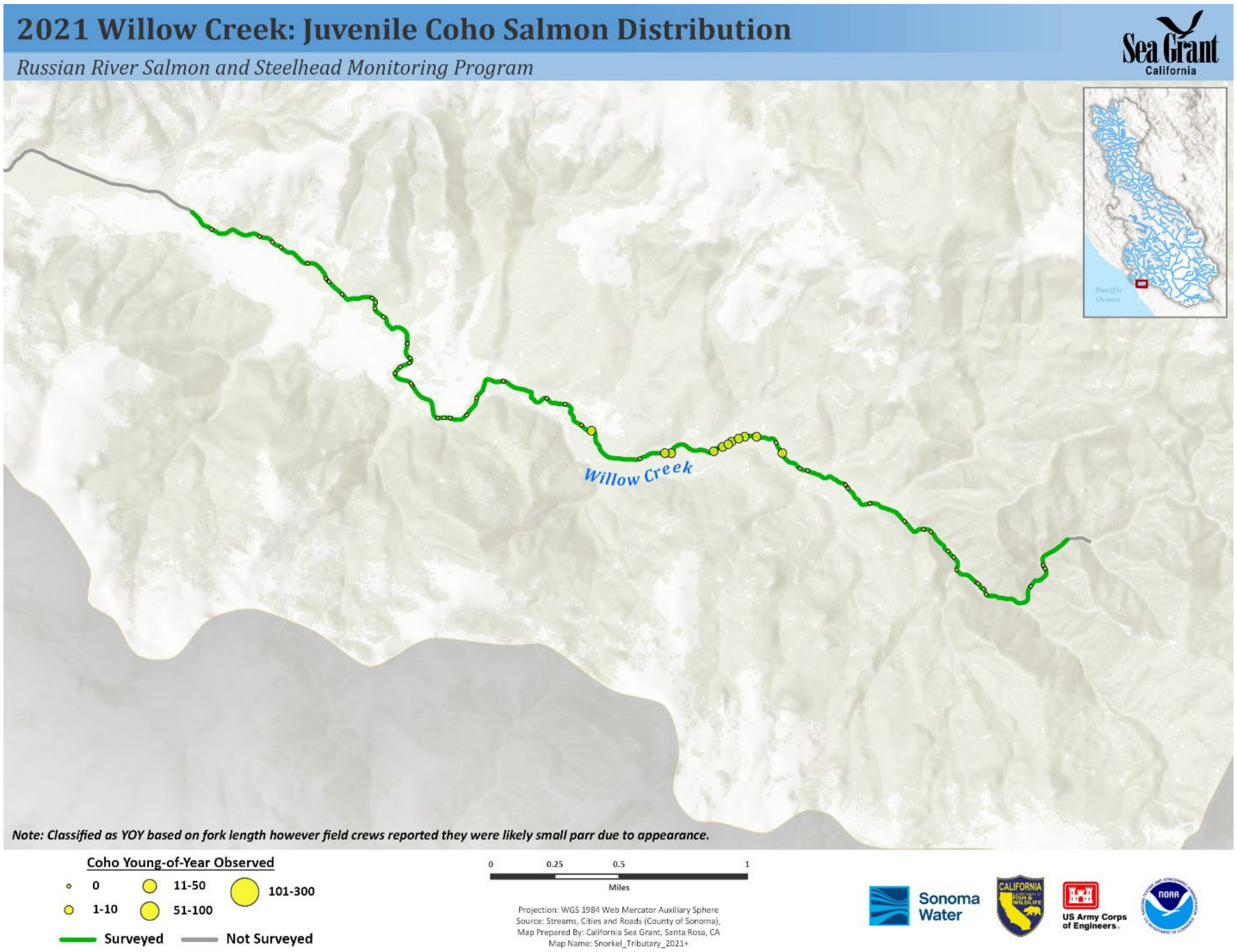

Figure 3. Density and distribution of juvenile coho salmon yoy observed in Willow Creek, 2021. Note that the smallest circle indicates no coho observations in the associated pool. The coho salmon observed were classified as yoy based on fork length however field crews reported they were likely small parr due to morphology.

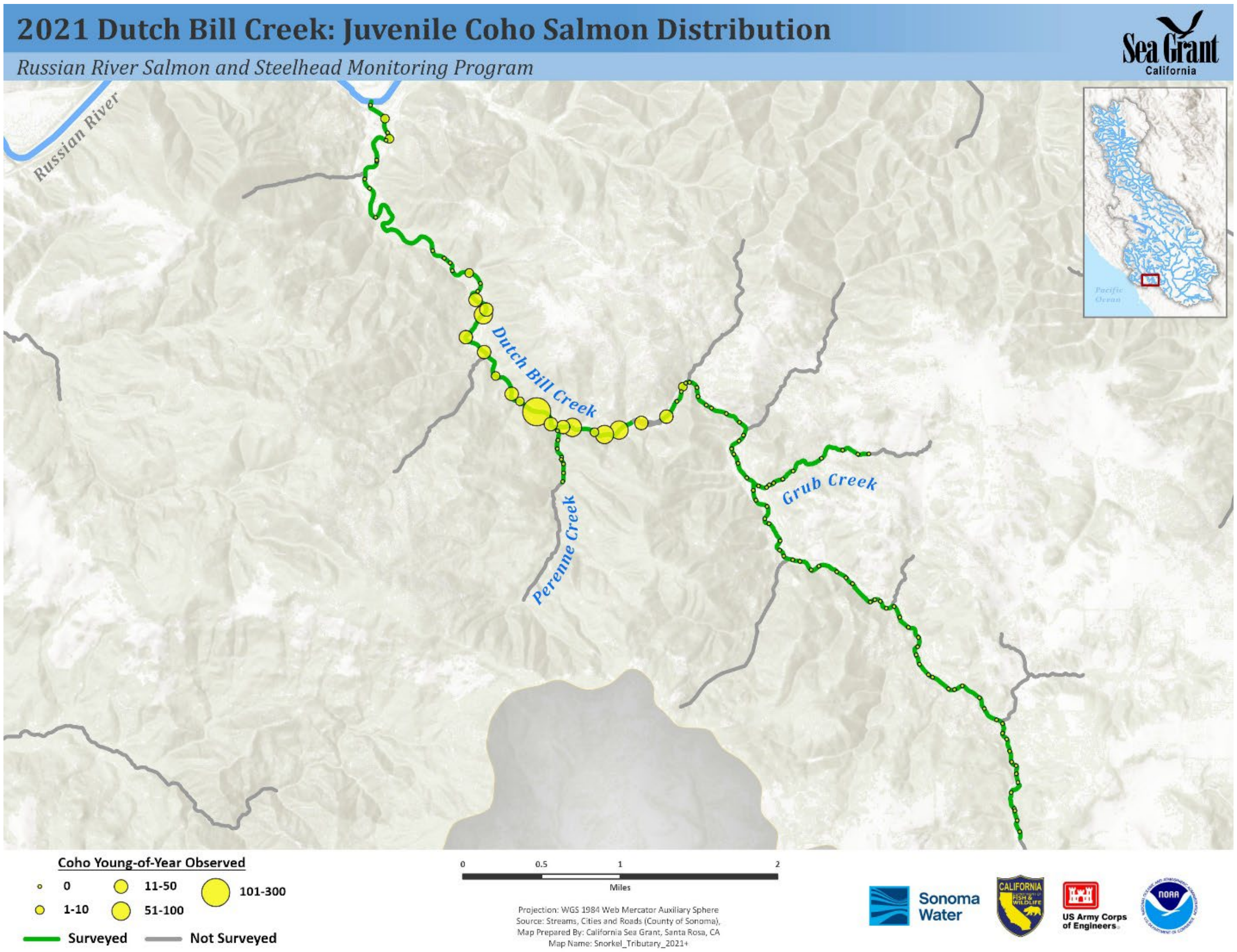

Figure 4. Density and distribution of juvenile coho salmon yoy observed in Dutch Bill Creek, 2021. Note that the smallest circle indicates no coho observations in the associated pool.

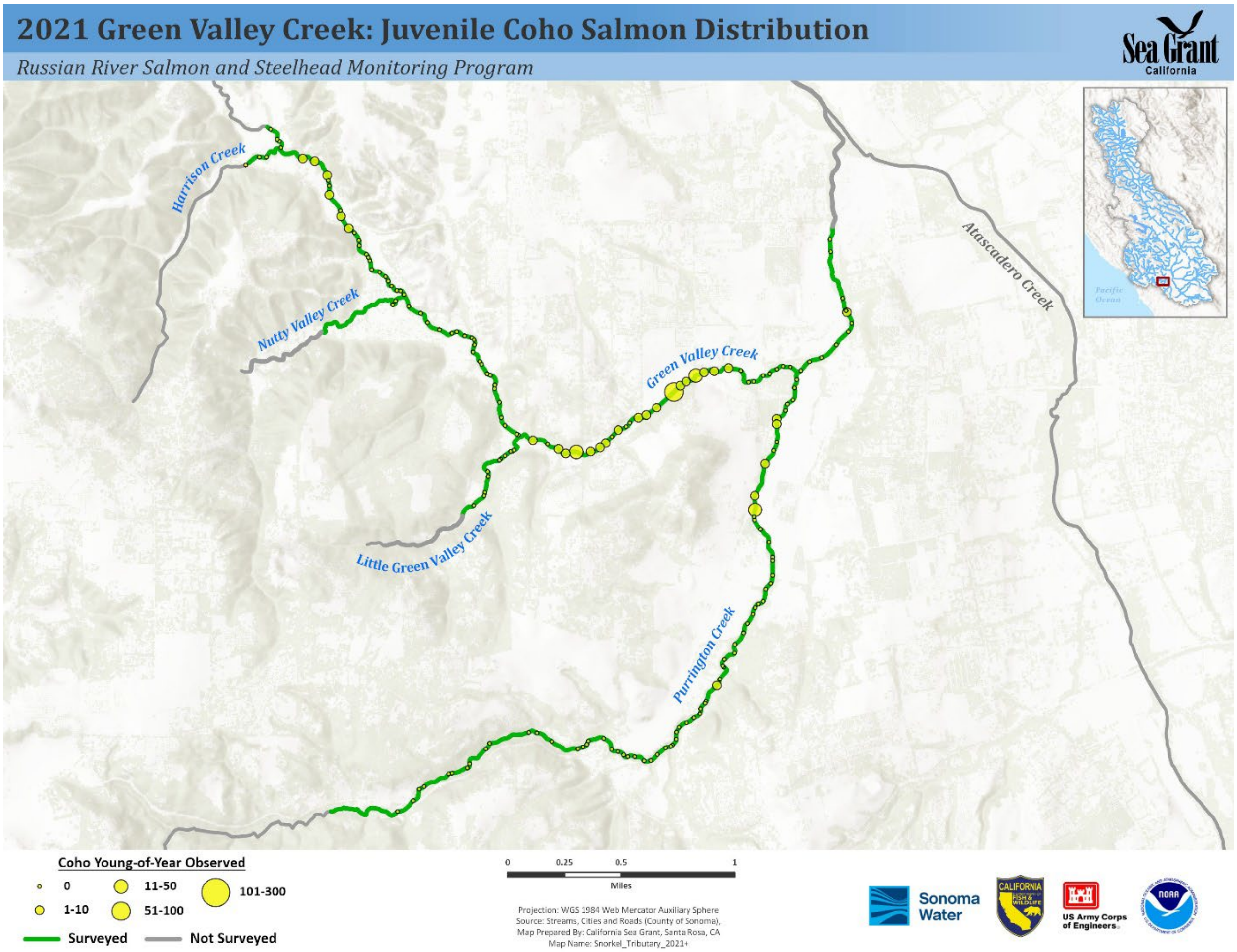

Figure 5. Density and distribution of juvenile coho salmon yoy observed in Green Valley Creek, 2021. Note that the smallest circle indicates no coho observations in the associated pool.

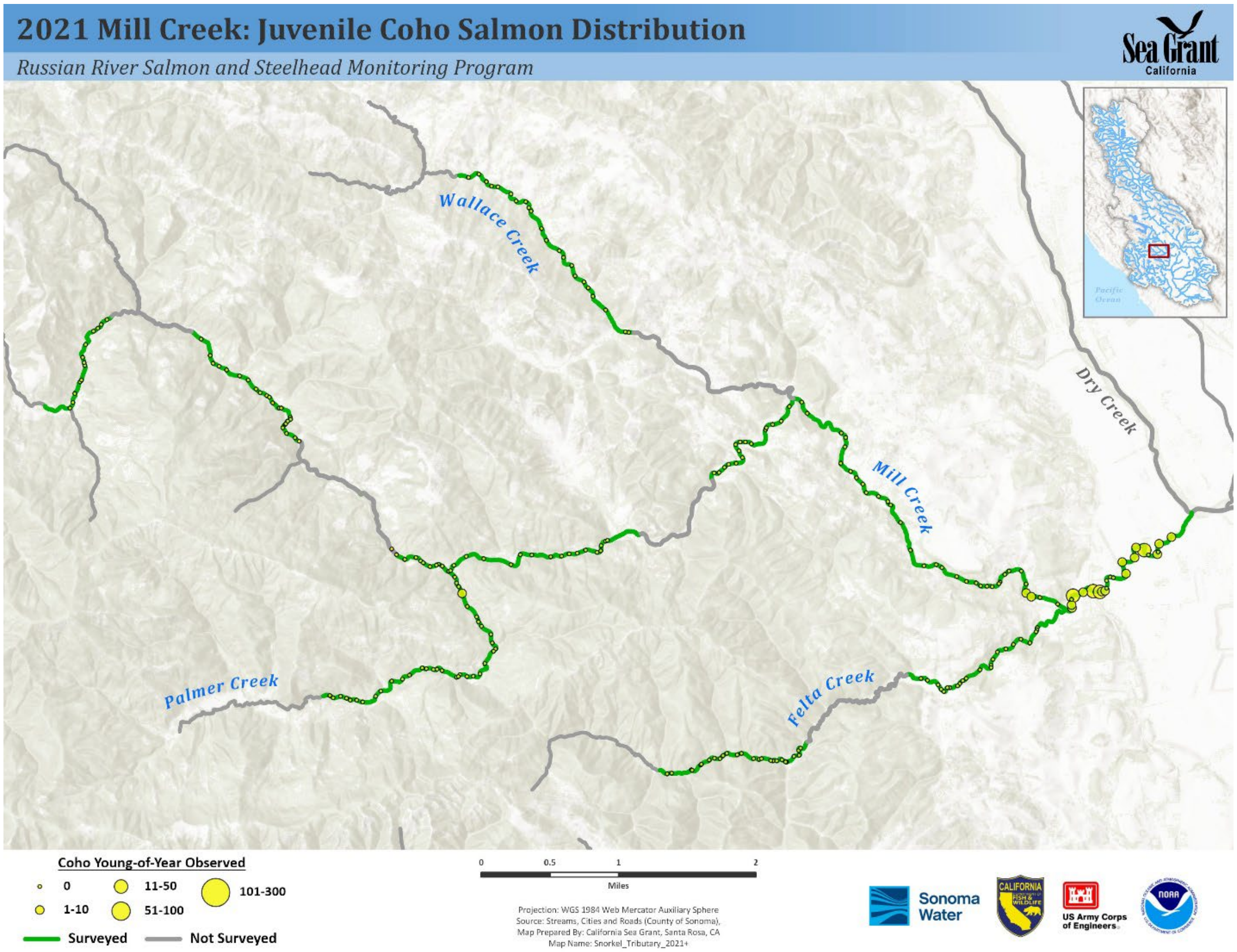

Figure 6. Density and distribution of juvenile coho salmon yoy observed in Mill Creek, 2021. Note that the smallest circle indicates no coho observations in the associated pool.

3. Discussion and recommendations

The Russian River experienced severe drought conditions in the summer of 2021, which led to large-scale spatial drying of tributary streams. We completed full surveys in the four Broodstock Program intensive monitoring watersheds and surveyed 63 reaches for estimation of juvenile coho occupancy. The sampling rate was increased from 53% in 2020 to 66% in 2021 due to relaxed COVID-19 restrictions; however, it was still lower than in pre-pandemic years (average 71%). To maintain long-term datasets for relative abundance on many additional streams, we performed less-intensive single-pass surveys. These surveys allowed us to document whether successful spawning occurred during the winter of 2020/2021 and to compare distribution among years.

In order to sample before stream drying occurred, we started surveying earlier than in previous years and prioritized stream reaches that are known to experience flow impairment issues. Even with these preventive actions, extensive drying occurred early in the season and many streams were partially dry before snorkel crews could sample. An example of this drying is illustrated by wetted habitat conditions observed in Hulbert Creek in May, before snorkel surveys were scheduled to start for the summer (Figure 7). Of all the reaches surveyed, 67.5% had stream disconnections present during sampling, which was up from 64% during the summer of 2020, despite earlier sampling in 2021. One consequence of early snorkel samples is the under-reporting of juvenile steelhead young-of-the-year because the progeny of late-run adult steelhead in the spring were likely still occupying riffle and flat-water habitat during this early survey timing. In these reaches where large-scale drying occurred before snorkel samples could be performed, the absence of juvenile observations does not necessarily mean that no successful spawning took place. Another consequence of the drought was that the Broodstock Program did not release juveniles from the hatchery in the spring due to tributary water quality concerns. Releases of coho yoy did occur from the RSI into Yellowjacket Creek.

CSG conducted wetted habitat surveys in the late summer and early fall on the same reaches that were snorkeled during the summer months to document sections of stream as wet, intermittent, or dry, based on surface flow. We performed a spatial overlay of fish abundance and distribution data from early summer snorkel surveys over the wetted habitat maps to estimate impacts of stream drying on salmonids observed during snorkel surveys (Figure 8 - Figure 11). In all four intensively monitored Broodstock Program watersheds, a high proportion of the fish observed during snorkel surveys were exposed to dry or intermittent conditions in the fall, providing further evidence for a juvenile salmonid survival bottleneck that we have observed on an annual basis across many tributary streams. In Willow Creek, approximately 90% of the habitat where coho and steelhead young-of-the-year were rearing dried or experienced early intermittent conditions in the summer of 2021 (Figure 8).

Coho salmon PAO for the summer of 2021 was the second lowest since beginning CMP basinwide snorkel surveys in 2015 (Table 3). After removing Yellowjacket Creek due to pre-snorkel juvenile releases, natural-origin juvenile coho salmon were present in all four Broodstock Program intensive monitoring watersheds and in 17 of 43 juvenile coho salmon streams surveyed through the CMP Program in 2021. Ten or more coho salmon yoy were observed in 13 of the 43 coho salmon tributaries and in four reaches, we observed fewer than 10 coho yoy (Table 1, Figure 2). In previous years, we used 10 fish as a cutoff, above which we thought there was a higher probability that spawning occurred in the reach as opposed to juveniles immigrating from neighboring reaches; however, with the extreme early stream drying, this may be a poor assumption for 2021.

Although early summer occupancy estimates are an indicator of the extent of successful spawning, in years with widespread stream drying, they do not fully capture how much of the basin successfully supported rearing juveniles. In order to help answer this question, we estimated occupancy for two periods in 2021, namely: 1) an early season period (May to August) when snorkel surveys were conducted; and 2) a late-season period (August to September) which incorporated data on stream drying. We defined the first period as 'standard PAO' as this is the time period occupancy has been reported in previous seasons. For late-season occupancy (defined as 'end-of-season PAO'), the spatial overlay of early season snorkel pools with late-season wetted habitat conditions was used, and snorkel pools that fell in stretches of stream that were dry in the late season were treated as not occupied, while those that fell in habitat conditions that were either wet or intermittent were treated as occupied in the occupancy estimates. Preliminary analysis for 'end-of-season PAO' showed a drastic reduction in occupancy from 0.16 down to 0.09. This highlights the juvenile bottleneck present in the Russian River basin and the importance of looking at end-of-season conditions to get a thorough and accurate assessment of juvenile occupancy in the watershed. This 'end-of-season' occupancy metric also provides managers a better estimate of juvenile abundance leading into the fall season. We recommend continuation of collecting these data sets and calculating both occupancy estimates in the future, as well as attempting to calculate 'end-of-season PAO' for previous seasons where data are available.

Snorkel surveys and early season wetted habitat assessments were used to inform CDFW of high priority areas in need of fish rescue efforts in near real-time. These data sources served as an on-the ground tool for coordinating responses to observed stream drying effects on the salmonid populations in the basin. During such efforts, CDFW collects fish from drying reaches and relocates them to either perennial stream reaches or to the hatchery facility, where they can later be released back into streams in the following spring or fall, once conditions have improved. A total of 1,187 coho smolts (52% of expanded smolts) and 2,084 coho yoy (53% of expanded yoy) were relocated from drying reaches during the summer of 2021.

During summer of 2021, there was a lot of post-fire activity within the Walbridge Fire footprint by agencies, private contractors, road crews, logging crews, and utilities. Due to the intensity of these operations, some sections of stream were skipped to ensure crew safety and some reaches within the footprint had lower stream visibility than in previous seasons. Wildfires can have negative impacts on anadromous streams, which often include an increase in landslides and fine sediment/ash inputs, a lack of riparian canopy leading to higher stream temperature (Beakes et al. 2014), and even burning in-stream wood structures. However, not all effects from fire are necessarily negative; for example, a post-fire increase in headwater streamflow was observed in upper Mill Creek (Mia van Docto, TU, personal communication). While studies show that post-fire increases in streamflow tend to decline in subsequent years as the forest regrows (Saxe et al. 2018), the effects may have contributed towards keeping juveniles alive throughout the fire and during the extreme drought conditions in summer 2021. In addition, burned forests often lead to increased natural wood recruitment which can create better, more complex habitat and create new ideal adult spawning and juvenile rearing habitat in following years (Flitcroft et al. 2016).

Another possible drought effect was low surface flow conditions in the spring which limited downstream migration of smolts, a likely cause for the highest observed parr counts (n = 1,147) over the last six years. We suspect that low flow constraints on fish passage trapped smolts that were attempting to emigrate and forced them to residualize. The second highest observed parr counts (n = 892) occurred in the drought of 2015, lending further evidence to this hypothesis.

Variation in growth among tributaries poses challenges to classifying juveniles as either yoy or parr, and this issue was particularly apparent during the summer of 2021. Life stage classification by field crews is determined based on best professional judgement according to fork length, but because growth opportunity varies among streams, general size cutoffs can lead to mis-classifications. For example, in one tributary stream, Redwood Creek (Atascadero) fish that were classified as yoy during snorkeling surveys based on their small size were temporarily captured and scanned for tags in order to determine their true age. The fish were found to be of hatchery origin, and we were able to determine that they were age-1 parr rather than yoy. Juvenile coho observed in Willow Creek were classified as yoy based on fork length but crews felt strongly based on visual characteristics that these fish were likely hold-overs from the previous year, as footnoted in Table 1. While we don't have the ability to capture a sample of fish from every stream reach to confirm age classes, it is important to be aware of the limitations of this approach for interpretation of results.

The low streamflow and extensive drying that resulted from the 2021 drought had significant negative effects on rearing salmonids and overall ecosystem health. While this year's climatic conditions were extreme–2021 followed the severe drought of 2020 and was the second driest year in state record (California Department of Water Resources 2021)—the impacts to juvenile salmonids highlight streamflow impairment as a long-standing and persistent bottleneck to recovering these listed species. Climate models indicate that more frequent and intense drought conditions are likely to persist, so it is imperative that aggressive actions are taken to improve summer streamflow in all years. It is recommended that watershed-scale restoration approaches be implemented alongside site-specific flow enhancement projects and augmentations in order to restore hydrologic function and improve groundwater storage, as well as surface flow. The Streamflow Improvement Plans for Dutch Bill, Green Valley, Mill, and Grape creeks outline specific flow improvement actions for those systems (Russian River Coho Water Resources Partnership 2015; Russian River Coho Water Resources Partnership 2017; Russian River Coho Water Resources Partnership 2019; Trout Unlimited 2013). Looking to other regions tackling these issues, projects using native beaver mimicry have been shown to effectively increase groundwater storage and floodplain connectivity, and revert intermittent streams to historic perennial flow (Bouwes et al. 2016; Pollock et al. 2012). In addition, it is strongly recommended to protect summer flow refugia. Stream reaches that remained wet during the extreme drought conditions experienced in 2021 should be considered high priority for conservation, for flow protection efforts, and for rearing habitat enhancement projects. Stable, flexible funding sources and supportive permitting processes will be needed to facilitate the pace and scale of this work to match the urgency of climate change, if we are to have any chance of success in preserving our Russian River salmonid populations (Russian River Coho Water Resources Partnership 2022). Furthermore, our recent observations indicate that the impacts of the drought may be leading to changes in fish and available habitat distribution. For example, due to drought conditions over the winter of 2020/21, many fish were limited to spawning in the lowest reaches of accessible streams, like Austin and Dutch Bill Creeks, placing their offspring in areas that generally become intermittent or dry during the summer months. If such patterns persist, we may need to increase efforts to restore summer streamflow and juvenile rearing habitat in areas previously thought to serve primarily as migratory corridors to higher-quality upstream habitat. We recommend that resource managers carefully consider climate-driven changes such as these in determining restoration priorities.

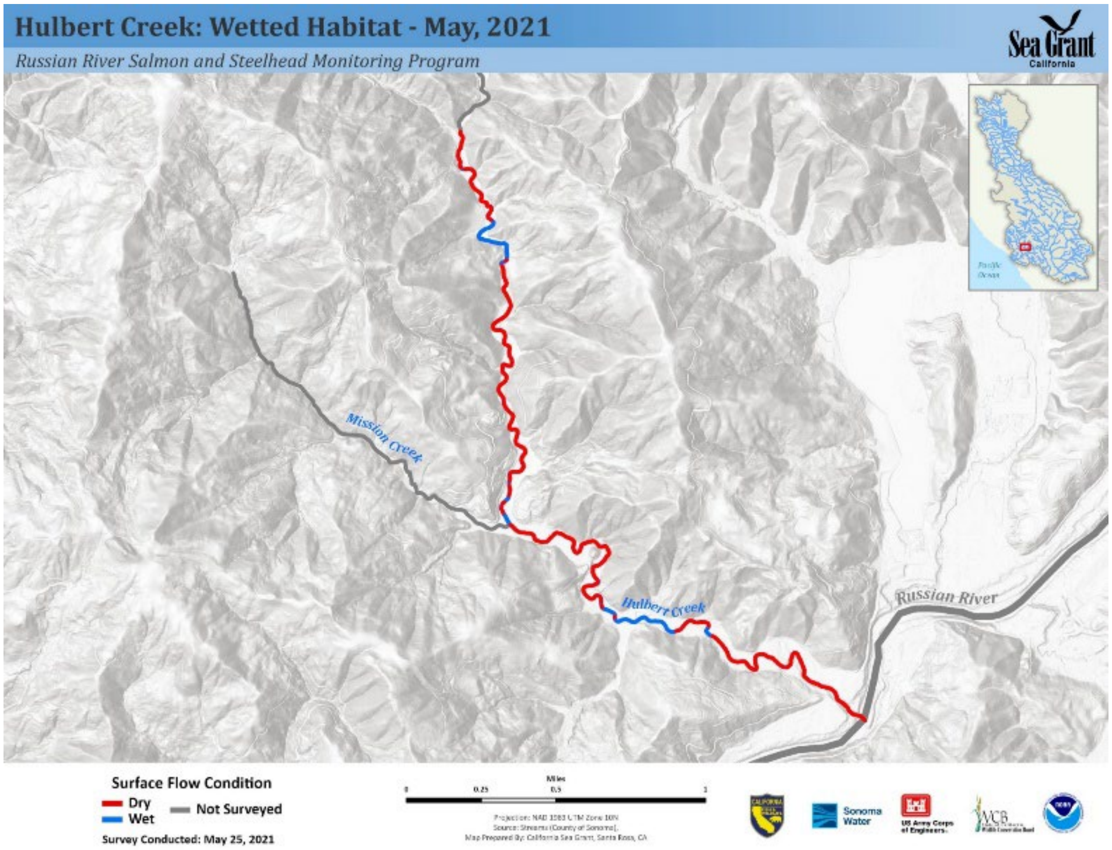

Figure 7. Wetted habitat conditions in Hulbert Creek on May 25, 2021. While this example depicts only one stream, it is representative of large-scale early drying that was evident across the Russian River basin in 2021.

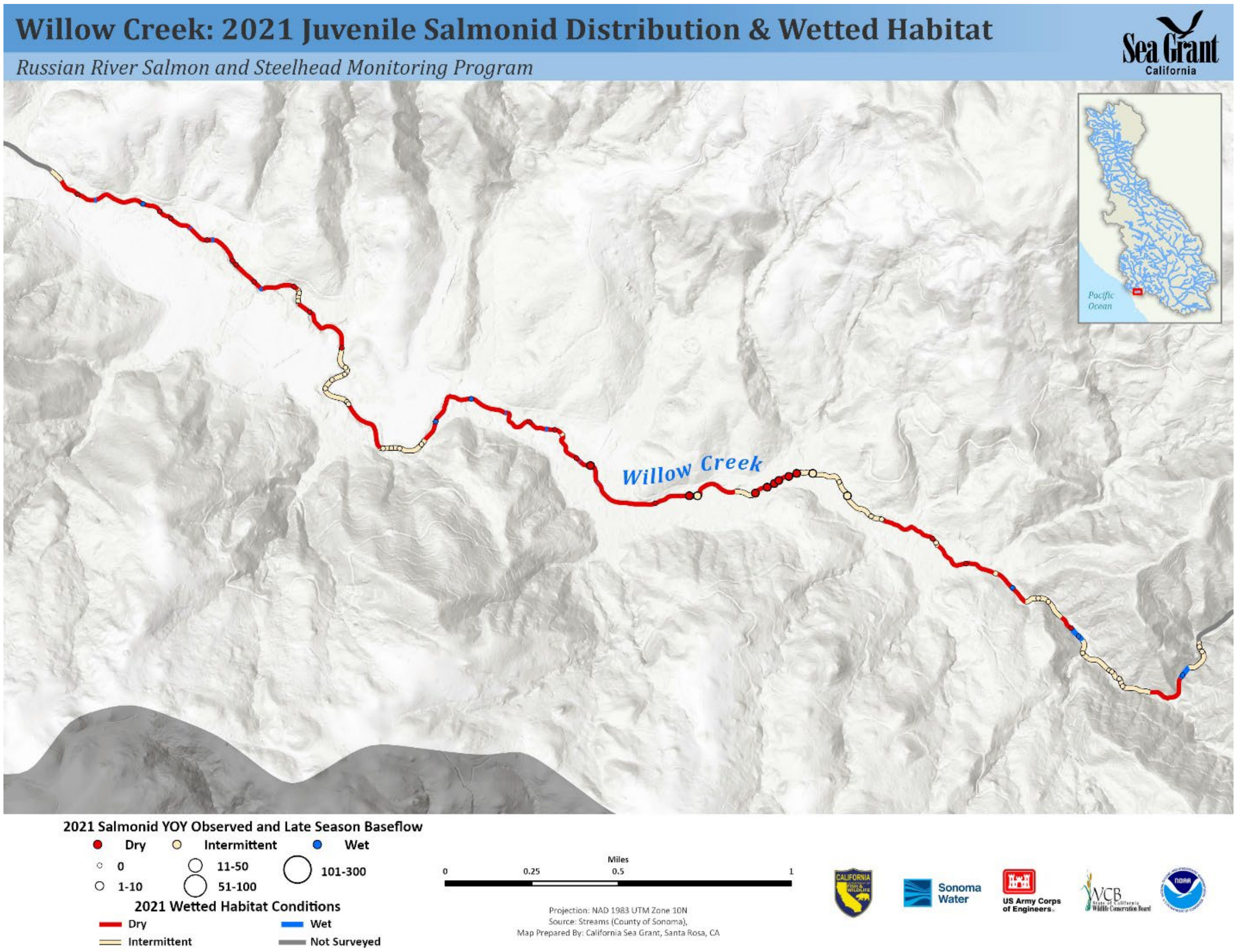

Figure 8. Willow Creek juvenile salmonid density and distribution from summer 2021 overlaid with fall 2021 wetted habitat conditions.

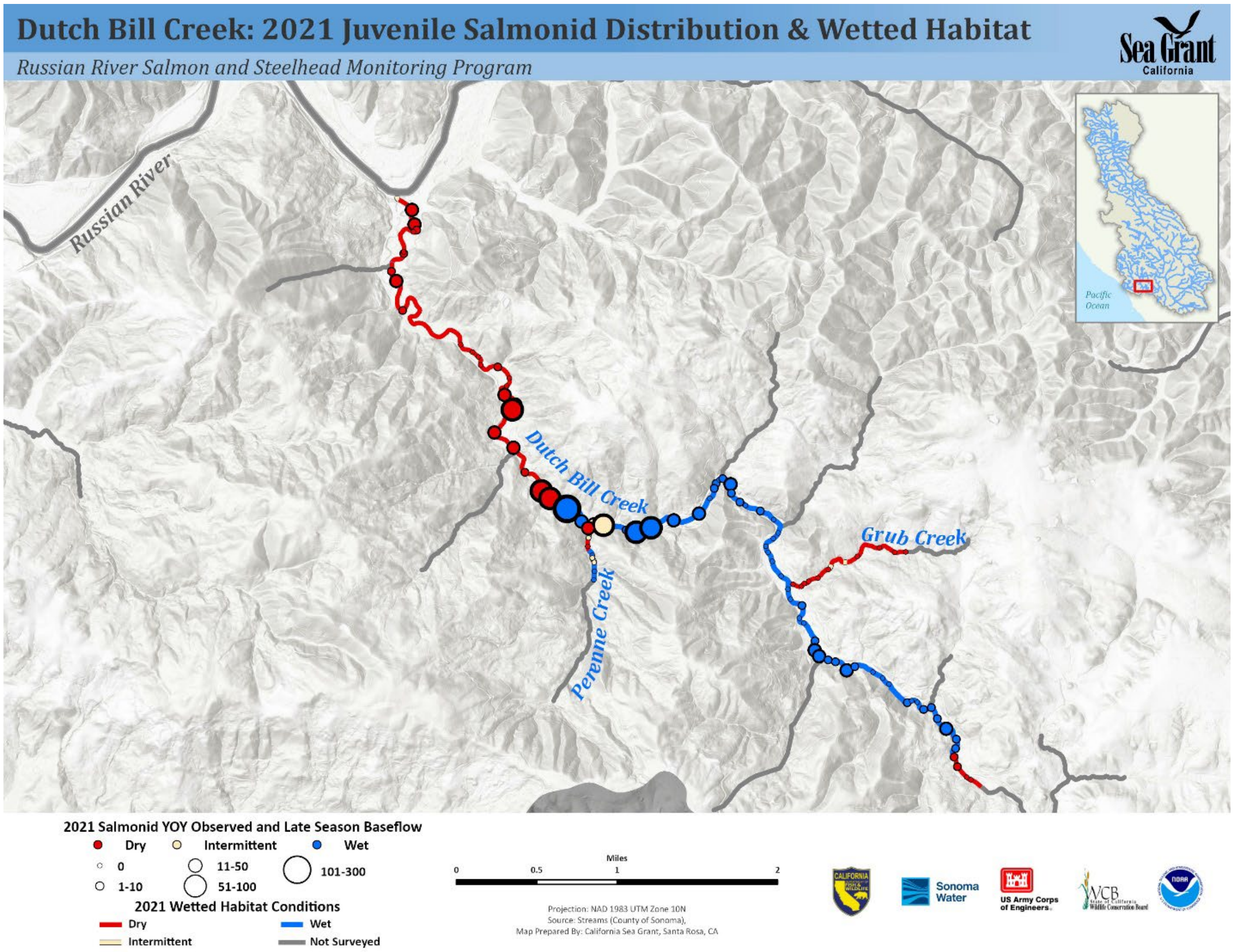

Figure 9. Dutch Bill Creek juvenile salmonid density and distribution from summer 2021 overlaid with fall 2021 wetted habitat conditions. Note that the smallest circle indicates no coho observations in the associated pool.

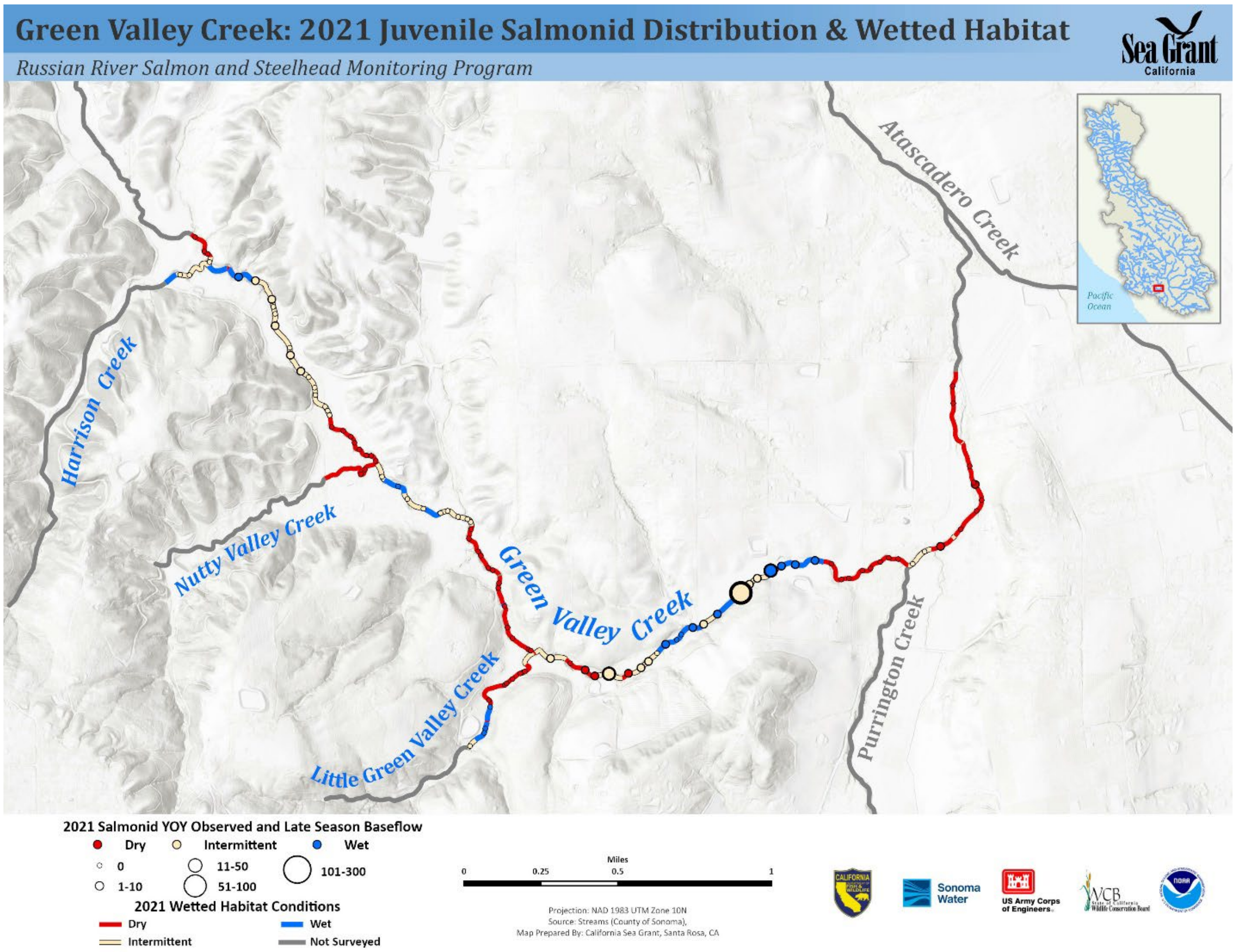

Figure 10. Green Valley Creek juvenile salmonid density and distribution from summer 2021 overlaid with fall 2021 wetted habitat conditions. Note that the smallest circle indicates no coho observations in the associated pool.

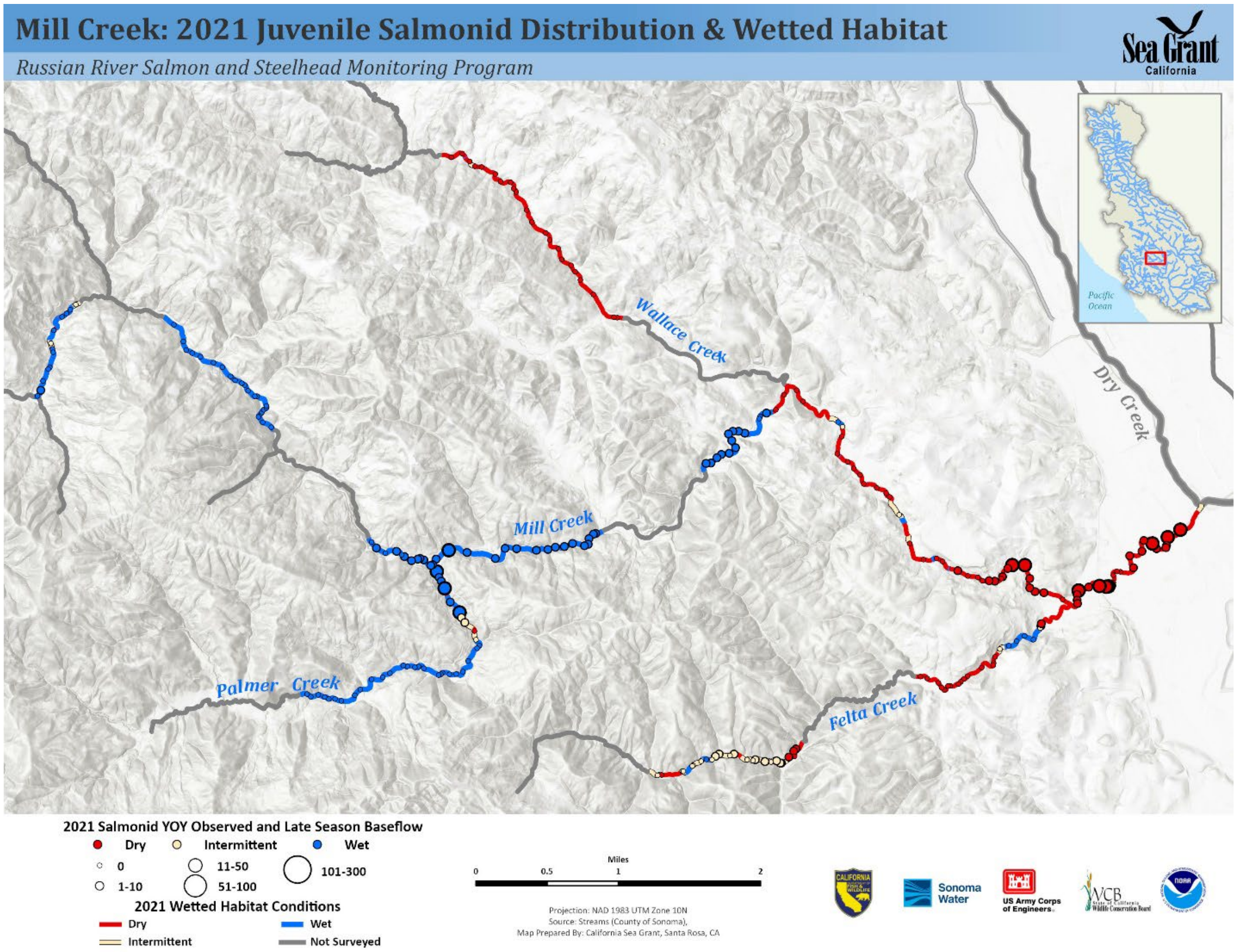

Figure 11. Mill Creek juvenile salmonid density and distribution from summer 2021 overlaid with fall 2021 wetted habitat conditions. Note that the smallest circle indicates no coho observations in the associated pool.

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