FLOW AND SURVIVAL STUDIES TO SUPPORT ENDANGERED COHO RECOVERY IN FLOW-IMPAIRED TRIBUTARIES OF THE RUSSIAN RIVER BASIN

Annual Report for Wildlife Conservation Board Grant WC-1663CR

May 1, 2018 – April 30, 2019

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Introduction

In 2017, California Sea Grant (CSG) and University of California at Berkeley (UC Berkeley) were awarded three years of funding by the Wildlife Conservation Board (WCB) to conduct streamflow and coho salmon survival studies in Russian River tributaries. These studies are designed to aid in increasing streamflow in flow-impaired streams critical for the recovery of endangered coho salmon populations. With the assistance of this award, we are building upon previous research and an established monitoring infrastructure in the Russian River watershed. For Task 1, we are analyzing long-term datasets to determine which streamflow and related environmental metrics (dissolved oxygen, temperature, wetted volume) best predict summer survival of juvenile coho salmon. For Task 2, we are conducting sequential wet/dry mapping, snorkeling, and spawner surveys to document changes in wetted habitat conditions in relation to streamflow, fish distribution, flow augmentations and other streamflow improvement projects over the three years of the grant. In addition, we are using the wet/dry mapping data to develop a statistical model that predicts the level of stream drying in Russian River tributaries. The intention of these tasks is to aid resource managers and recovery partners in the prioritization, design, and evaluation of stream flow enhancement projects, allow optimization of the timing and quantity of water released from upstream storage ponds and wells, inform instream flow recommendations and water policy, and support planning for emergency actions in times of drought.

This report includes a summary of the second year of progress for WCB award WC-1663CR during the period of May 1, 2018 – April 30, 2019.

Task 1: Develop predictive models relating streamflow, environmental metrics and juvenile coho salmon survival in small coastal California streams

Background

From 2011 through 2017, California Sea Grant (CSG) collected juvenile coho salmon survival data in study reaches of Dutch Bill, Green Valley, Mill and Grape creeks for comparison with environmental metrics such as streamflow, wetted volume, dissolved oxygen and water temperature. These data have been used to determine that hydrologic connectivity is critical in supporting rearing juvenile coho salmon throughout the summer season, and that relationships between survival and environmental metrics vary among reaches and streams (Obedzinski et al. 2018). Field observations lead us to believe that hydrogeological factors (e.g., clay substrate v. alluvium, riparian cover, land use, etc.) play a strong role in influencing this variation. Through this grant funding, CSG has been working with the Carlson and Grantham labs at UC Berkeley to develop models to identify which environmental factors and streamflow metrics best predict coho salmon survival in small coastal California streams. Data used to build the models include a seven-year coho salmon survival and environmental data set collected by CSG through funds from Trout Unlimited (TU) and the National Fish and Wildlife Foundation, and hydrogeological and watershed-level data available in GIS. The goal of the modeling is to quantify general relationships across streams to aid in identifying flow thresholds for juvenile salmonid persistence throughout the summer season in coastal California streams.

During the first year of the project, CSG and UC Berkeley compiled a long term-survival, flow and habitat dataset, hired a postdoctoral scholar, and began analysis to determine which flow and other environmental metrics best predict summer survival of juvenile coho salmon rearing in small coastal California streams. CSG staff completed the compilation, formatting and transfer of seven years of PIT tag wanding, habitat and streamflow data from individual Excel spreadsheets and/or Access databases to a common SQL database where it could be linked for analysis. In November of 2017, CSG and UC Berkeley hired a postdoctoral scholar, Dr. Ross Vander Vorste, to assist with data analyses, modeling and dissemination of project results.

Year 2 Activities

Development of survival models

Ross Vander Vorste has continued to work on this portion of the project and, along with colleagues, has submitted a manuscript on the oversummer survival of juvenile coho salmon. The manuscript was submitted on May 1, 2019 and is currently under review in the journal Global Change Biology (impact factor 8.997).

As described in the draft manuscript, we estimated spatial and temporal variability of oversummer coho salmon survival using mark-recapture of nearly 20,000 tagged fish in intermittent stream pools during a seven-year period encompassing drought and non-drought conditions. We then determined the relative importance of physical habitat, streamflow, precipitation, landscape, and biological characteristics that may limit survival during drought (Figure 1). We found that survival was generally lower in drought years and that variability in survival was high across the study region (Figure 2), although several study sites maintained similar survival during drought and non-drought years. Habitats where survival is strongly reduced by drought are concerning because they may represent ecological traps, meaning that their ability to support oversummer survival is reduced during extreme drought. Whereas, our finding that many pool habitats maintained high survival even during extreme drought helps identify drought refugia that are important for juvenile coho salmon survival. Among the environmental variables associated with drought, we found duration of pool disconnection was most strongly correlated with reduced survival (Figure 1). Therefore, projected increases in drought severity could transform many refugial habitats into ecological traps, if duration of pool disconnection also increases.

During this reporting period, Ross presented this research at two conferences, including the Salmon Restoration Federation conference in Santa Rosa, CA in April and the Society for Freshwater Science conference in Salt Lake City, UT in May. Ross also presented this research at three invited talks at UC Merced, Henry’s Fork Foundation, and IRSTEA Lyon, France.

A second manuscript related to juvenile salmon movement during the 2011-2017 study period is in preparation. This work will address the possibility of juvenile fish to move into habitat refugia before pools become disconnected. Our initial findings showed that salmon movement was lower during drought years. We are exploring whether or not fish movement during times of pool connectivity is directed towards the drought refugia or the ecological traps identified in our survival analysis.

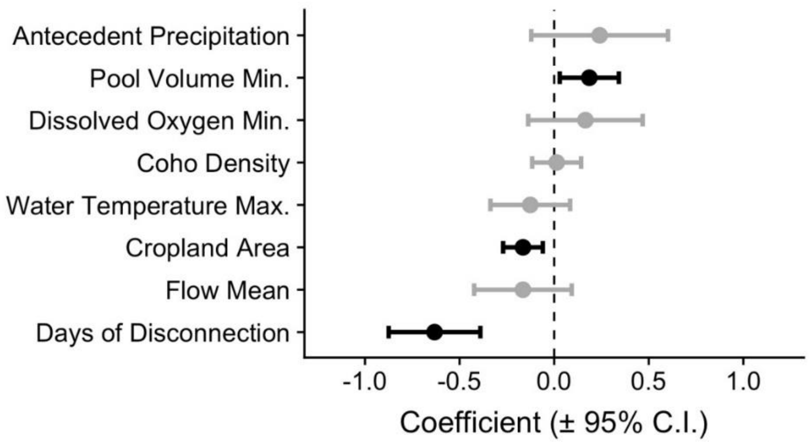

FIGURE 1. EFFECT SIZES (± 95% CONFIDENCE LIMITS) FOR 8 EXPLANATORY VARIABLES ON CUMULATIVE JUVENILE SALMON SURVIVAL DURING 2011–2017. EFFECTS SIZES ESTIMATES ARE THE MODEL COEFFICIENTS FROM GENERALIZED LINEAR MIXED EFFECTS MODELS. BLACK POINTS AND CONFIDENCE BARS ARE STATISTICALLY SIGNIFICANT, WHEREAS GREY COLORING INDICATES NON-SIGNIFICANT VARIABLES (P > 0.05).

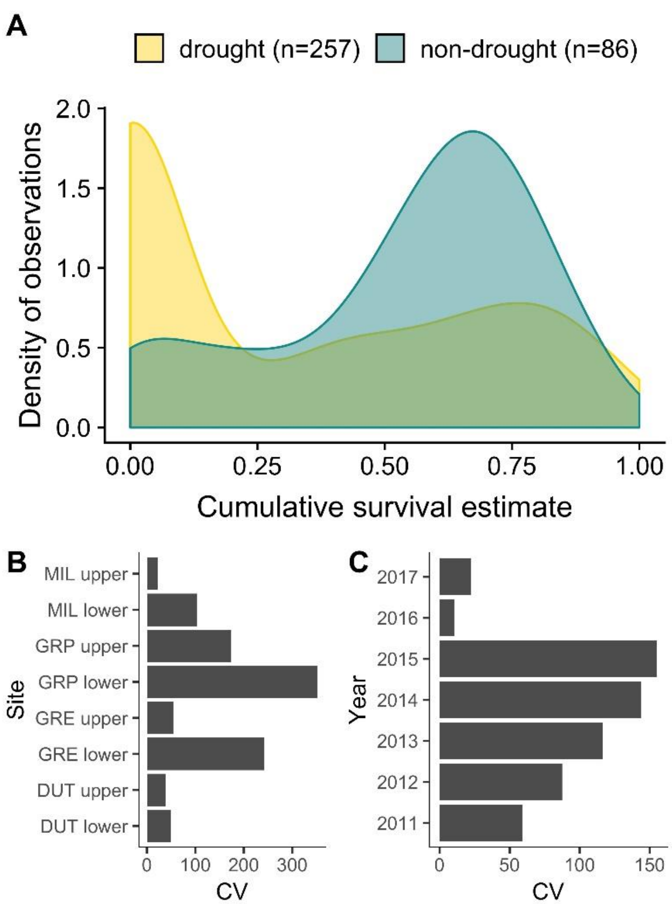

FIGURE 2. PROBABILITY DENSITY FUNCTION ILLUSTRATING DISTRIBUTION OF CUMULATIVE SALMON SURVIVAL ESTIMATES IN STREAM POOLS DURING DROUGHT (2012–2016, YELLOW) AND NON-DROUGHT (2011 & 2017, BLUE) YEARS (A). SPATIAL VARIABILITY IN CUMULATIVE SURVIVAL ESTIMATES AT 8 STUDY REACHES WITHIN THE RUSSIAN RIVER CATCHMENT (B). TEMPORAL VARIABILITY IN CUMULATIVE SURVIVAL ESTIMATES ACROSS STUDY REACHES (C). PRESUMED SURVIVAL ESTIMATES OF ZERO IN DRY STREAM REACHES THAT ARE REMOVED FROM SUBSEQUENT MODELS ARE ADDED FOR VISUAL ASSESSMENT.

Task 2: Document wetted habitat conditions in Dutch Bill, Green Valley and Mill creeks in relation to streamflow and fish distribution, and build a predictive model for surface water recession.

Background

In previous years, CSG developed a protocol to document the dynamic wetted habitat conditions of Russian River tributaries during the summer season, also referred to as wet/dry mapping. Wet/dry mapping surveys are performed by walking the stream channel and recording the transitions between wet and dry habitat on a GPS unit. Data from these surveys can be used to create maps and compare wetted habitat conditions at different points in time. In the Russian River, where surface flows frequently drop to levels hovering at or just above zero (levels that are within the measurement error of most current meters), wetted habitat maps provide an alternative approach to informing and evaluating patterns in stream drying and oversummer surface water conditions.

Prior to WCB funding for this effort, CSG conducted a single wet/dry mapping survey on each of the study streams during September of each year. While this has been useful in documenting wetted habitat conditions at the driest time of year (i.e., the worst conditions impacting annual juvenile survival), it has not allowed us to document drying patterns over the course of the summer, nor sufficiently inform and evaluate flow augmentation projects that are occurring in the study streams. Based on the demand by resource managers in recent years for these sequential surveys throughout the dry season, this grant provided funding to conduct wet/dry mapping at biweekly intervals between May and October, and to make those maps available to the public electronically on a weekly basis throughout the season. Ultimately, wetted habitat data from these repeated surveys, streamflow data, time lapse imagery of drying riffles, precipitation data and watershed-characterization data will be used to produce a model to predict when drying will occur in each stream under variable environmental conditions (see *Development of predictive model*).

Wet/dry mapping, snorkeling surveys to document the distribution of juvenile salmonids, and spawner surveys to document the distribution of redds collectively provide useful information to resource managers about the impact of low streamflow on fish. During the spring and summer seasons, CSG receives frequent requests from CDFW and NOAA Fisheries for current data displaying the numbers and distribution of fish in relation to current streamflow conditions. WCB grant funding is allowing us to bring together snorkeling and spawner survey data collected by the Coho Broodstock and Coastal Monitoring Programs with wetted habitat data collected through this project to produce maps displaying fish distribution in relation to drying stream conditions and provide that information to partners in-season. This information helps resource managers to prioritize and plan efforts to relocate fish from drying pools, as well as to identify flow-related survival bottlenecks, guide streamflow improvement project planning and determine whether projects are benefiting fish.

Year 2 Activities

Wetted Habitat

To document changes in wetted habitat conditions throughout the summer season, wet/dry mapping surveys were conducted on the primary, fish-bearing reaches of Dutch Bill, Green Valley and Mill creeks (Figure 3) at biweekly intervals between May and October. The former wet/dry mapping protocol developed by CSG for Russian River tributaries (CSG 2016) was refined slightly in each grant year (2017 and 2018) to better suit the objectives of this project. Every two weeks between May and October, a crew of two surveyors walked each creek from the mouth to the upstream limit of anadromous fish habitat and documented surface water conditions. A field computer and GPS unit were used to record each wet or dry stream section, or "line". Water temperature and dissolved oxygen (DO) concentrations were measured in the wetted sections of stream at 5-minute intervals, using a handheld YSI DO Pro20 logger, to determine suitability for juvenile salmonids and document trends over the study season. Upon return to the office, field crews uploaded data to the ArcGIS Online server where it was transferred to a cloud-based database. Raw data was then visually inspected and any extraneous line segments were manually corrected. The lines were run through a customized geospatial tool to fine-tune continuity of line segments and provide statistics for wetted habitat condition lengths and proportions.

Over the course of the summer, maps of wetted habitat conditions were generated for every biweekly survey (https://caseagrant.ucsd.edu/sites/default/files/2018_WH_Mapbook_10.pdf) and the project is summarized on CSG's website at https://caseagrant.ucsd.edu/project/coho-salmon-monitoring/wetted-habitat-assessments. A subset of maps are included here for Dutch Bill, Green Valley and Mill creeks: the first survey of the season (Figure 4, Figure 7, Figure 10), the survey where surface flow disconnection was first observed (Figure 5, Figure 8, Figure 11), and the last survey of the season (Figure 6, Figure 9, Figure 12).

In each stream, all habitat was wet during the first survey in May (Figure 4, Figure 7, Figure 10), but the timing and location where disconnection was first observed varied; in Dutch Bill and Mill Creeks disconnection first occurred in mid-June near the downstream ends of the survey reaches, whereas in Green Valley disconnection was first observed in early July in the middle of the survey reach (Figure 5, Figure 8, Figure 11). The location and degree of stream drying on the driest surveys of the season also varied by stream (Figure 6, Figure 9, Figure 12, Table 1), with more extensive drying at the downstream ends of the Dutch Bill and Mill reaches as compared to Green Valley Creek where short sections of dry or intermittent habitat were observed throughout the survey reach.

On average across all of the stream habitat surveyed, approximately 63% of the channel remained wet through the dry season, with 11% of total surveyed length becoming intermittent and 27% going completely dry. This was a substantial improvement in wetted fish habitat from previous drought years, 2012 through 2016 (Obedzinski et al. 2016a) but drier than summer 2017 when, across all streams, 72% of the channel remained wet through the dry season, 12% became intermittent and only 16% went completely dry. Most streams had a similar (<10%) proportion of late-summer wet habitat between 2017 and 2018, except for Mill and Felta creeks, which had 20% and 33% less wetted habitat, respectively.

Wetted habitat maps were shared in weekly emails to partners from multiple branches of CDFW, the Regional and State Water Quality Control Boards, NOAA Fisheries, Sonoma County Water Agency, Gold Ridge and

Sonoma Resource Conservation Districts, TU, Occidental Arts and Ecology Center's WATER Institute, US Army Corps of Engineers, UC Berkeley and the Camp Meeker Recreation and Parks District.

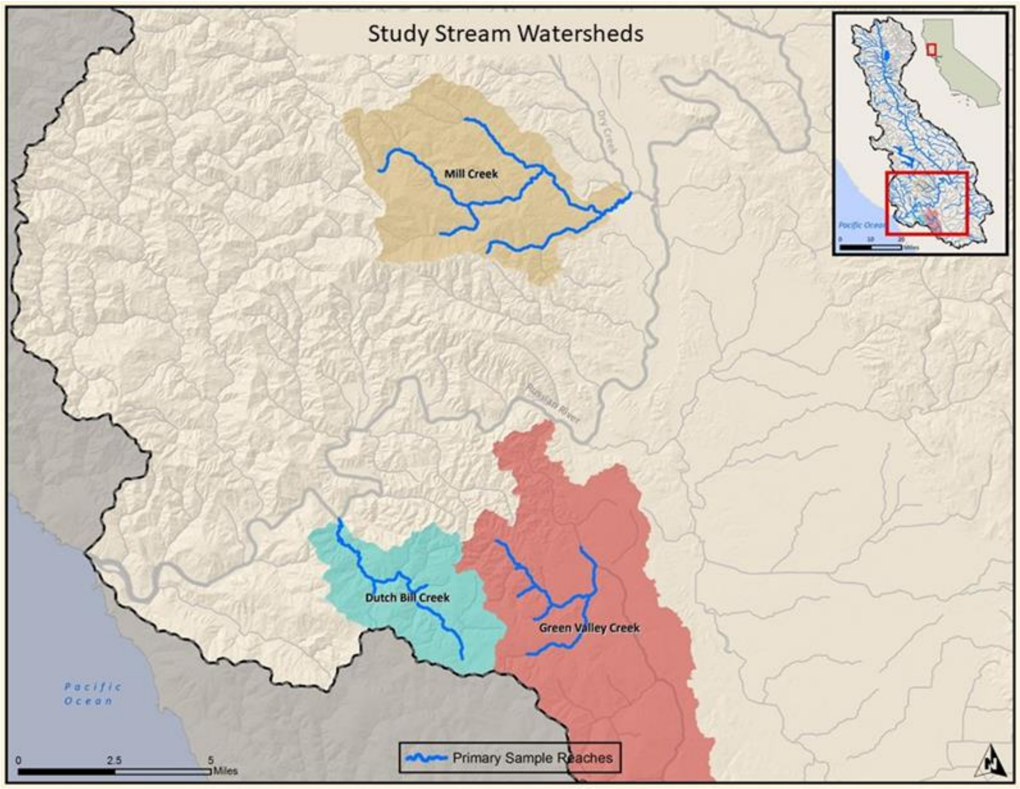

FIGURE 3. STUDY STREAMS IN THE LOWER RUSSIAN RIVER WATERSHED.

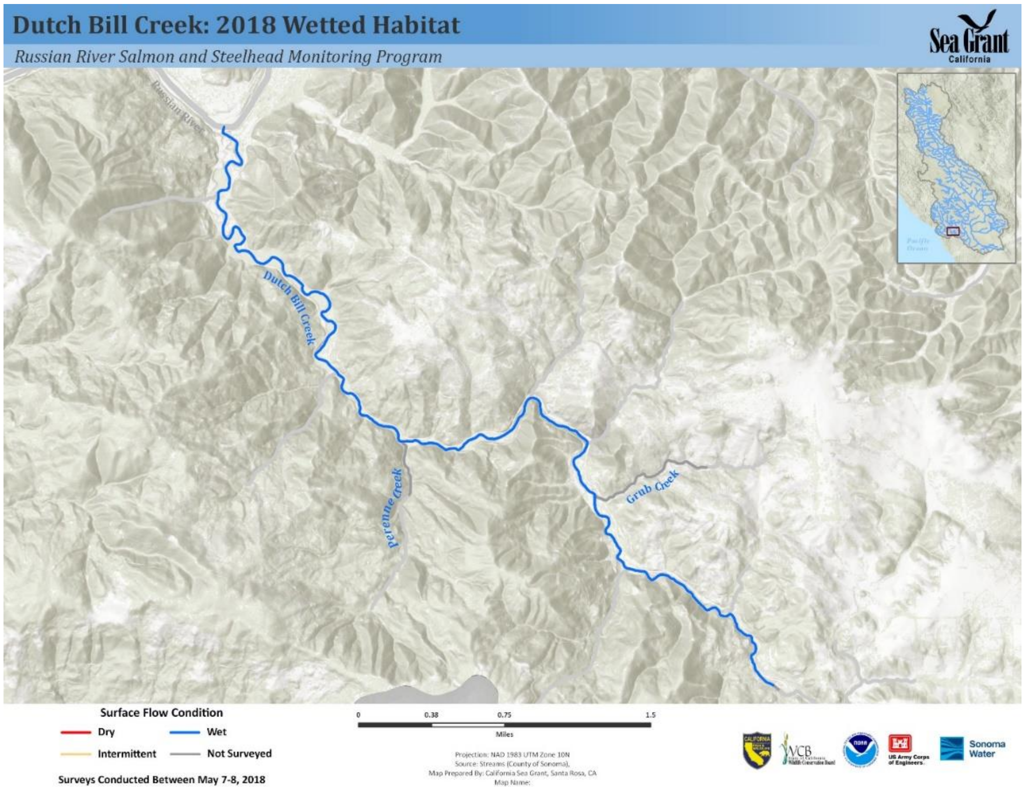

FIGURE 4. WETTED HABITAT CONDITIONS ON DUTCH BILL CREEK ON MAY 7-8, 2018; FIRST SURVEY OF THE SEASON.

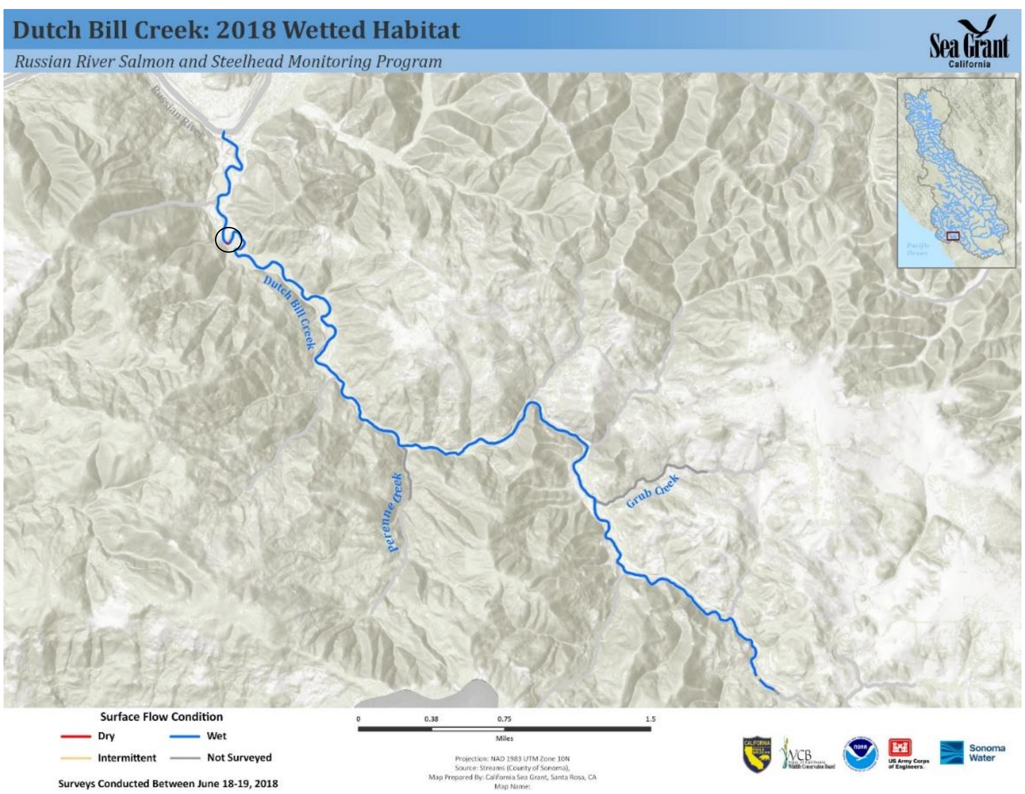

FIGURE 5. WETTED HABITAT CONDITIONS ON DUTCH BILL CREEK ON JUNE 18-19, 2018; FIRST SURVEY WHERE DISCONNECTION WAS OBSERVED.

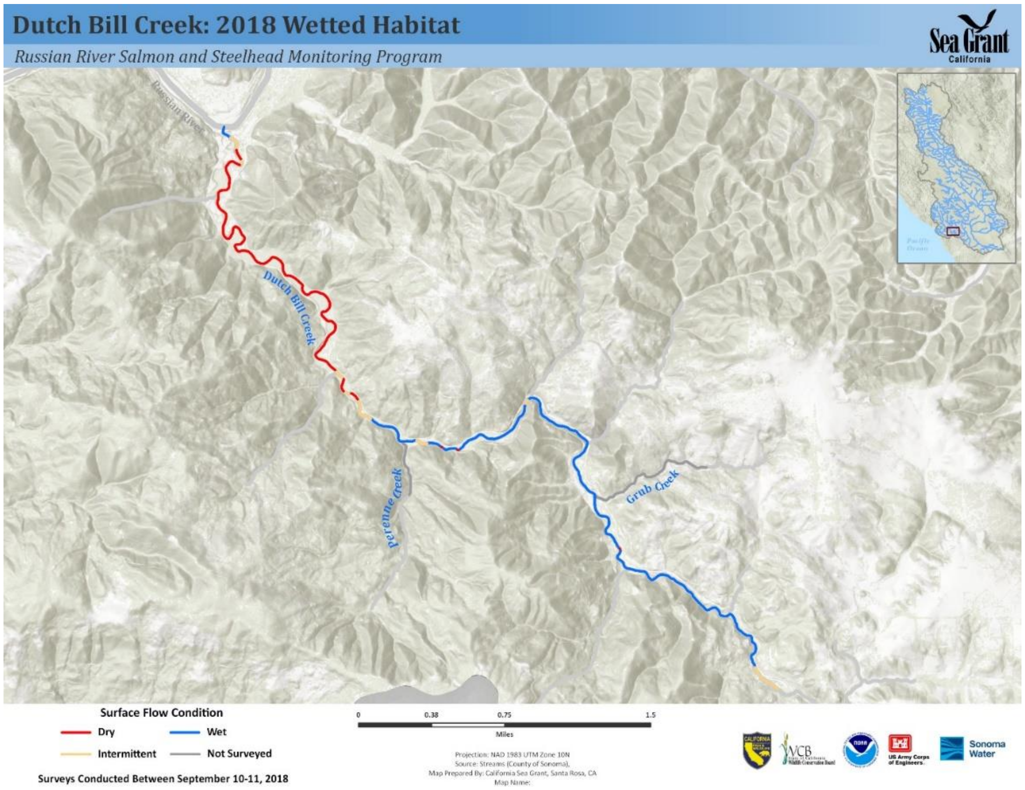

FIGURE 6. WETTED HABITAT CONDITIONS ON DUTCH BILL CREEK ON SEPTEMBER 10-11, 2018; DRIEST SURVEY, AS DEFINED BY THE LEAST AMOUNT OF WET HABITAT.

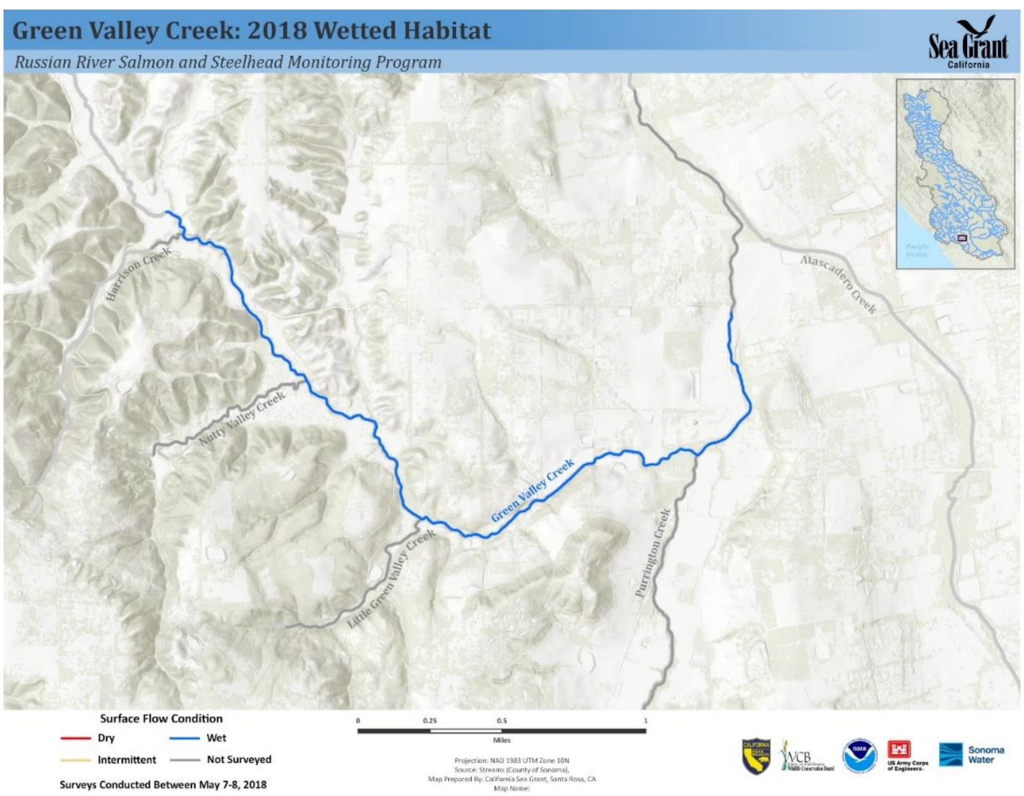

FIGURE 7. WETTED HABITAT CONDITIONS ON GREEN VALLEY CREEK ON MAY 7-8, 2018; FIRST SURVEY OF THE SEASON.

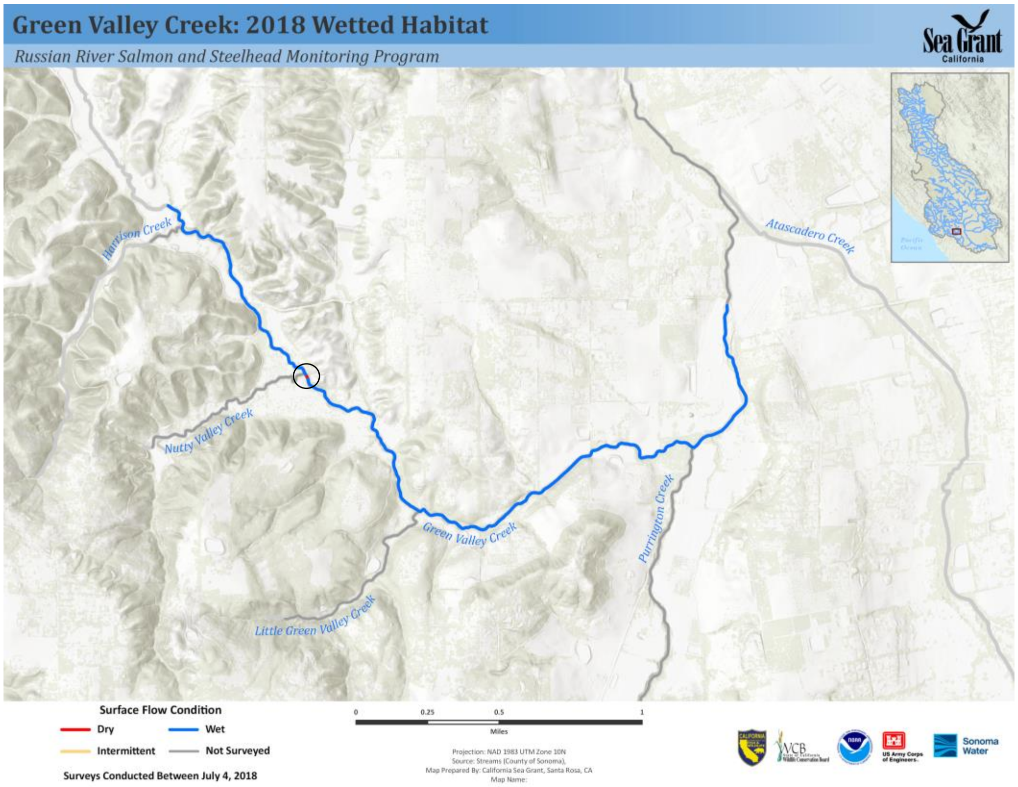

FIGURE 8. WETTED HABITAT CONDITIONS ON GREEN VALLEY CREEK ON JULY 4, 2018; FIRST SURVEY WHERE DISCONNECTION WAS OBSERVED.

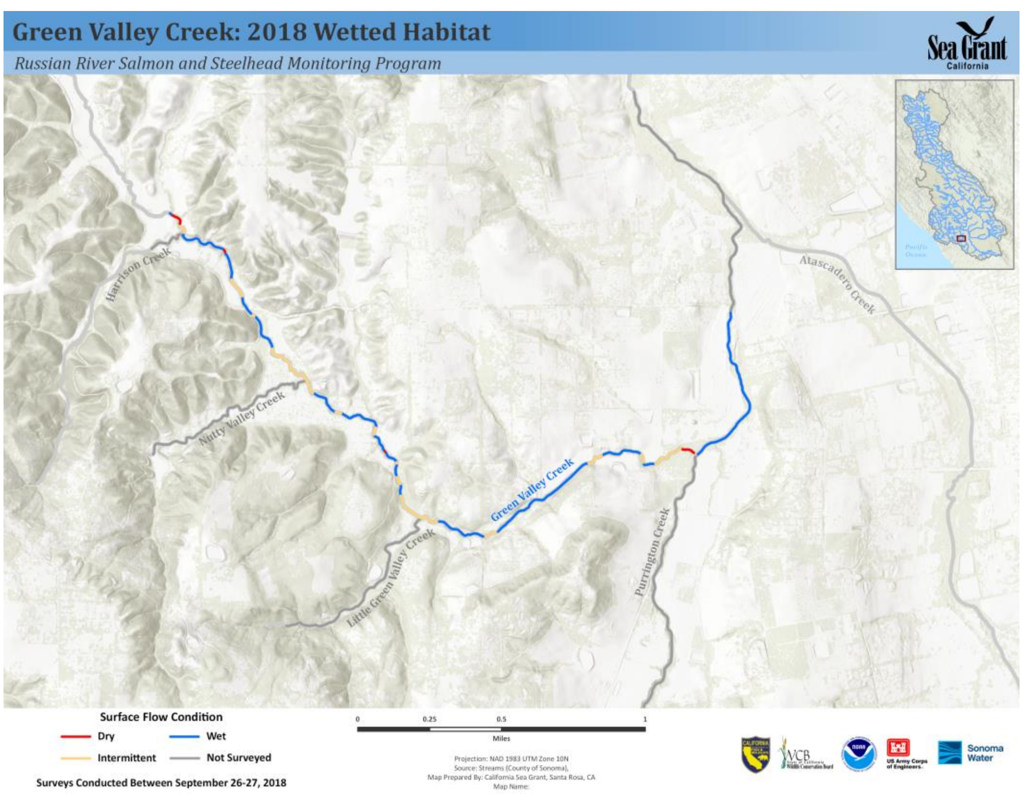

FIGURE 9. WETTED HABITAT CONDITIONS ON GREEN VALLEY CREEK ON SEPTEMBER 26-27, 2018; DRIEST SURVEY, AS DEFINED BY THE LEAST AMOUNT OF WET HABITAT.

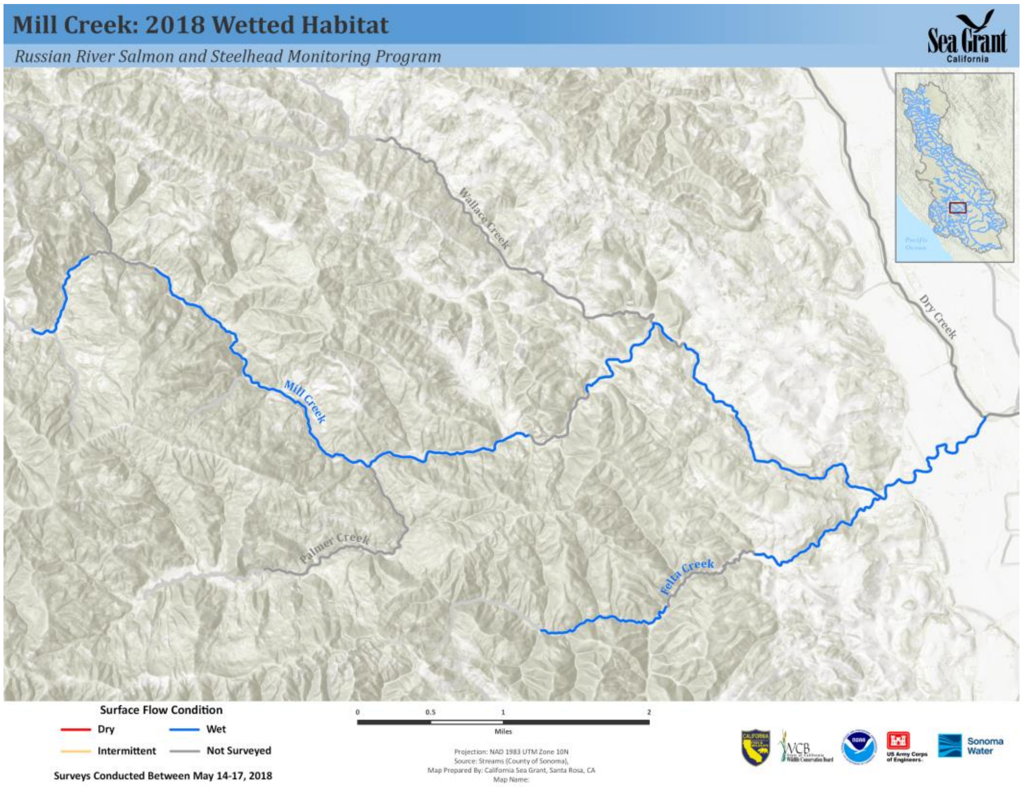

FIGURE 10. WETTED HABITAT CONDITIONS ON MILL CREEK ON MAY 14-17, 2018; FIRST SURVEY OF THE SEASON.

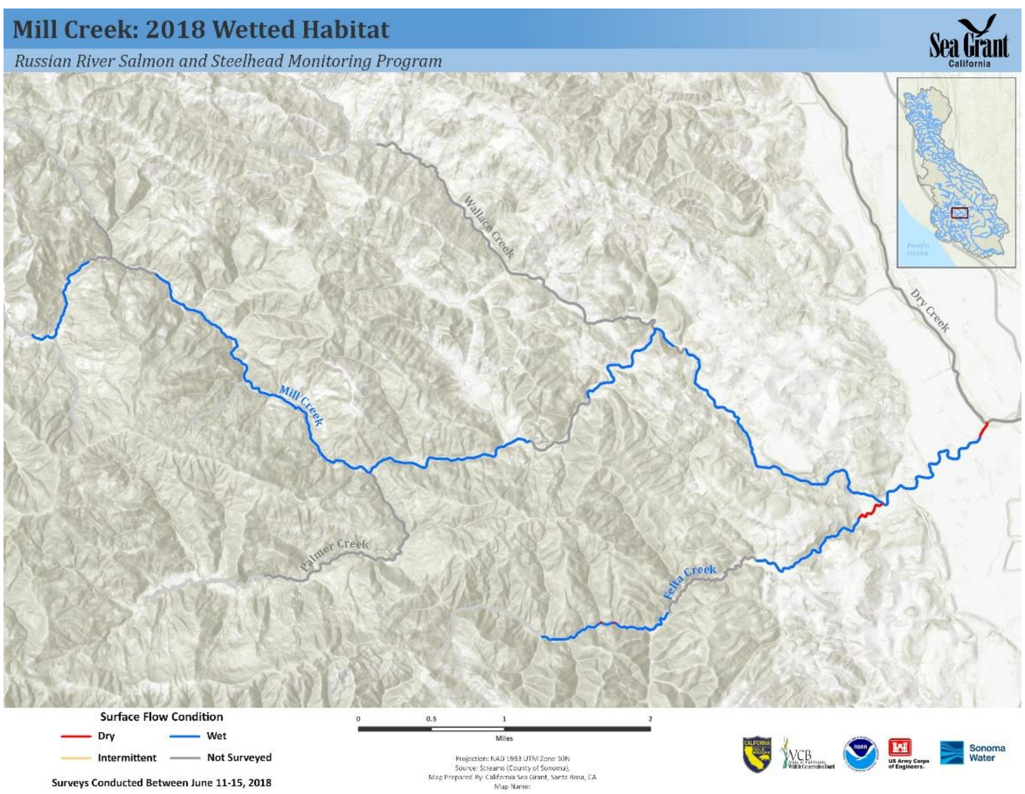

FIGURE 11. WETTED HABITAT CONDITIONS ON MILL CREEK ON JUNE 11-15, 2018; FIRST SURVEY WHERE DISCONNECTION WAS OBSERVED.

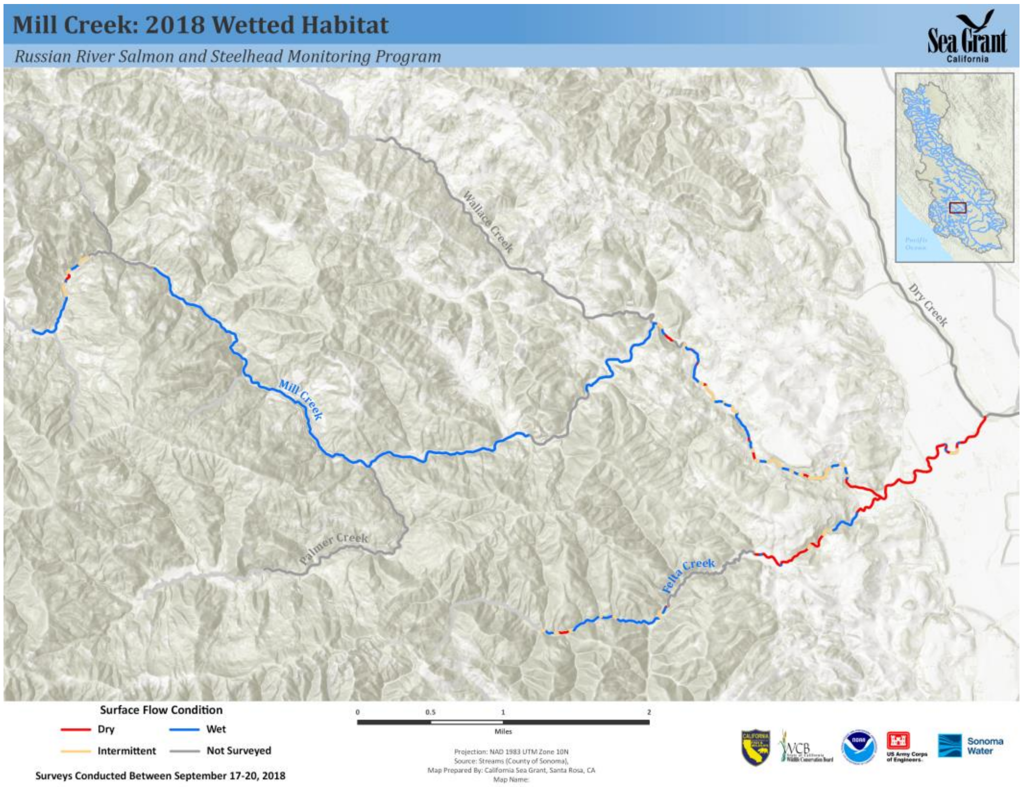

FIGURE 12. WETTED HABITAT CONDITIONS MILL CREEK ON SEPTEMBER 17-20, 2018; DRIEST SURVEY, AS DEFINED BY THE LEAST AMOUNT OF WET HABITAT.

TABLE 1. LENGTH AND PERCENTAGE OF DRY, INTERMITENT AND WET HABITAT OBSERVED DURING THE DRIEST, LATE-SUMMER WET/DRY SAMPLE, 2018.

		Driest Survey Wetted Habitat Condition (length in m, % of stream sampled)		
Tributary	**2018 Survey Date**[1]	**Dry**	**Intermittent**	**Wet**
Dutch Bill Creek	9/10-11	3,395 (35%)	994 (10%)	5,270 (55%)
Green Valley Creek	9/26-27	162 (3%)	1,535 (28%)	3,706 (69%)
Purrington Creek	8/28	0 (0%)	136 (3%)	4,309 (97%)
Mill Creek	9/17-20	2,950 (21%)	1,915 (13%)	9,533 (66%)
Felta Creek	9/17-20	1,510 (42%)	600 (16%)	1,522 (42%)
Wallace Creek	8/30	2,215 (89%)	218 (9%)	44 (2%)
Palmer Creek	8/29	0 (0%)	0 (0%)	2,895 (100%)

[1] *Purrington, Wallace and Palmer creeks were only surveyed once during summer 2018.*

WATER QUALITY

In addition to the spot measurements of DO collected during wet/dry mapping surveys in the summer of 2018 (https://caseagrant.ucsd.edu/sites/default/files/2018_WH_Mapbook_10.pdf), continuous water quality data were collected in two pools in each of the study streams between late-May and October. The pools were selected to represent conditions in both a marginally flow-impaired lower stream reach and a relatively unimpaired upper stream reach, though it should be noted that DO concentrations often vary by site when streamflow is at or near surface flow disconnection. Onset U26 DO loggers were deployed in pools in each of the six stream reaches (noted by river kilometer in Table 2) to measure DO and water temperature concentrations at 15-minute intervals over the dry season. These data were downloaded from the loggers into Microsoft Excel using HOBOware software and imported into a SQL database.

Continuous DO and temperature data from the single study pool in each of two reaches of Dutch Bill, Green Valley and Mill creeks were plotted for the summer period, along with the Regional Water Quality Control Board's minimum daily DO objective for the North Coast of 6.0 mg/L (NCRWQCB 2015) and the observed salmonid mortality threshold of 3.0 mg/L (McMahon 1983) (Figure 13 - Figure 18). DO remained above the mortality threshold for 97-100% of the study period in all logger pools, but dropped below that threshold 3% of the time in Lower Green Valley and Lower Mill reaches (Table 2). It met or exceeded the regional objective for the majority of the study season in all sample pools, though less than 80% of the time in both Green Valley Creek reaches (Table 2). The Lower Green Valley reach experienced the most DO impairment throughout the season, with 48% of all 15-minute samples below the regional objective (Table 2, Figure 15).

The optimum summer water temperature range for juvenile coho is 10° to 15°C (McMahon 1983). At water temperatures greater than 20° C, significant decreases in swimming speed and increases in mortality due to disease have been noted to occur (McMahon 1983). Water temperatures during the study period commonly exceeded the optimal range for salmon but were below the 20° C tolerance range in all reaches for the entire summer, with the exception of the Lower Mill reach, where temperatures exceeded 20° C for 8% of the 15-minute samples and reached a peak of 22.2° C in late-June (Figure 17). Water temperatures in the study pools were, generally, well below the 25.5° C mortality threshold (McMahon 1983) in all reaches. Temperatures were warmest in late June and early June, but remained fairly consistent throughout the summer season.

TABLE 2. LOCATION OF WATER QUALITY LOGGERS AND PERCENT OF SAMPLE PERIOD WATER TEMPERATURE AND DO MET SUITABILITY CRITERIA.

Stream	Study Reach	River Kilometer [1]	% Time Temperature Within Tolerance Range [2]	% Time DO Met Regional Objective [3]	% Time DO Above Mortality Threshold [4]
Dutch Bill	Lower	3.87	100%	80%	100%
Dutch Bill	Upper	6.51	100%	98%	100%
Green Valley	Lower	12.16	100%	52%	97%
Green Valley	Upper	13.40	100%	76%	99%
Mill	Lower	6.10	92%	88%	97%
Mill	Upper	12.39	100%	99%	100%

[1] *Approximate distance upstream of mouth along stream channel.*

[2] *Within the salmon tolerance range of ≤ 20 ° C.*

[3] *Meets the regional objective of ≥ 6 mg/L daily minimum DO concentration.*

[4] *Above lab-observed salmonid mortality threshold of 3 mg/L.*

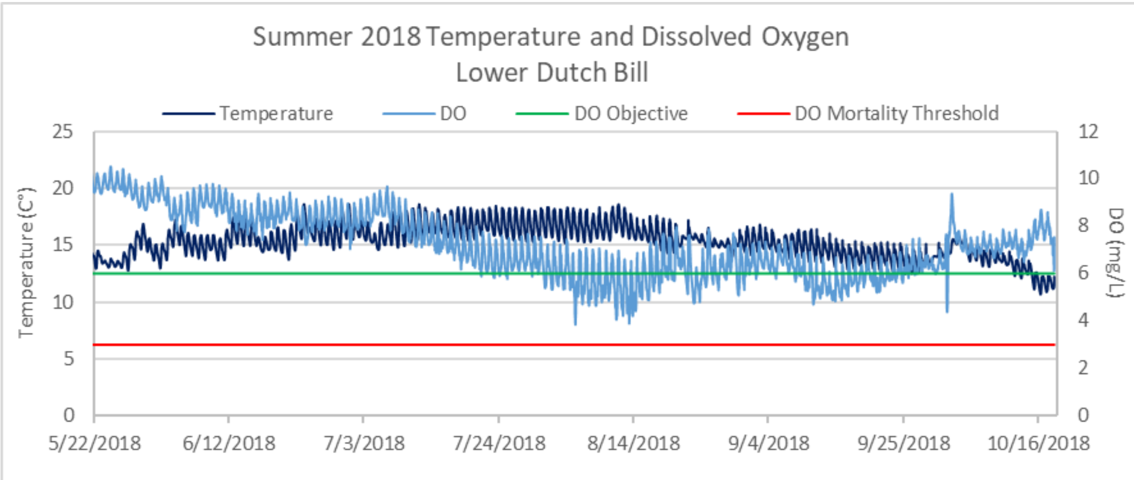

FIGURE 13. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE LOWER DUTCH BILL STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

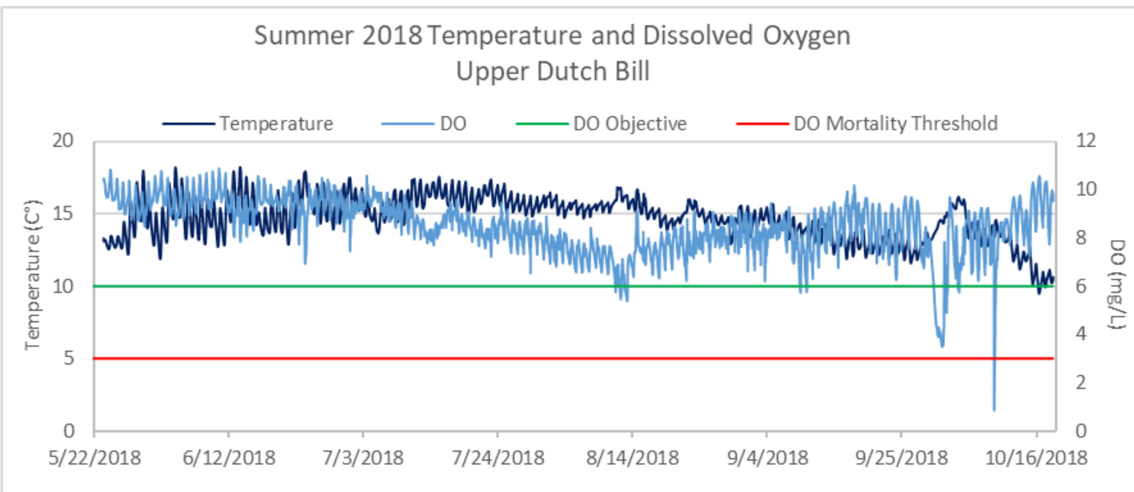

FIGURE 14. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE UPPER DUTCH BILL STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

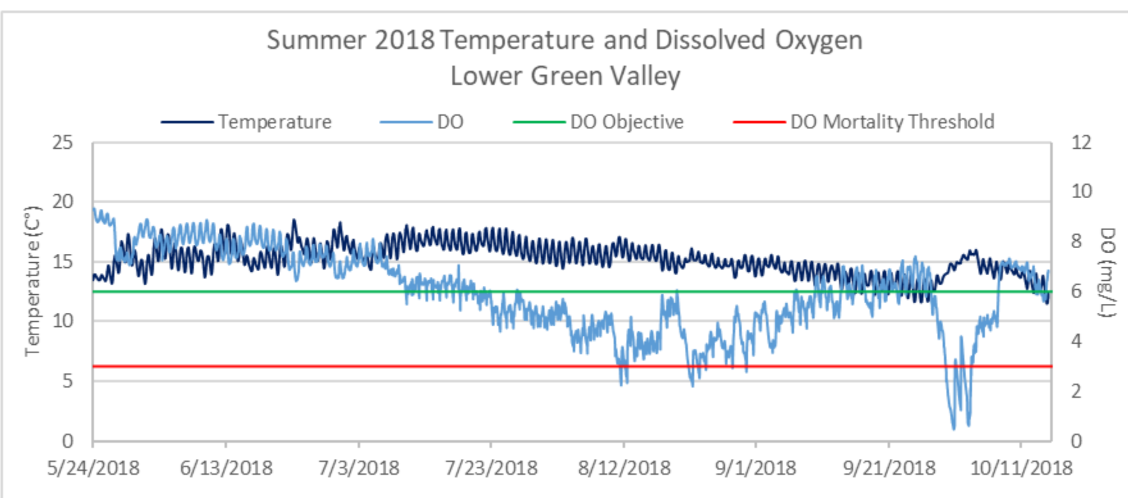

FIGURE 15. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE LOWER GREEN VALLEY STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

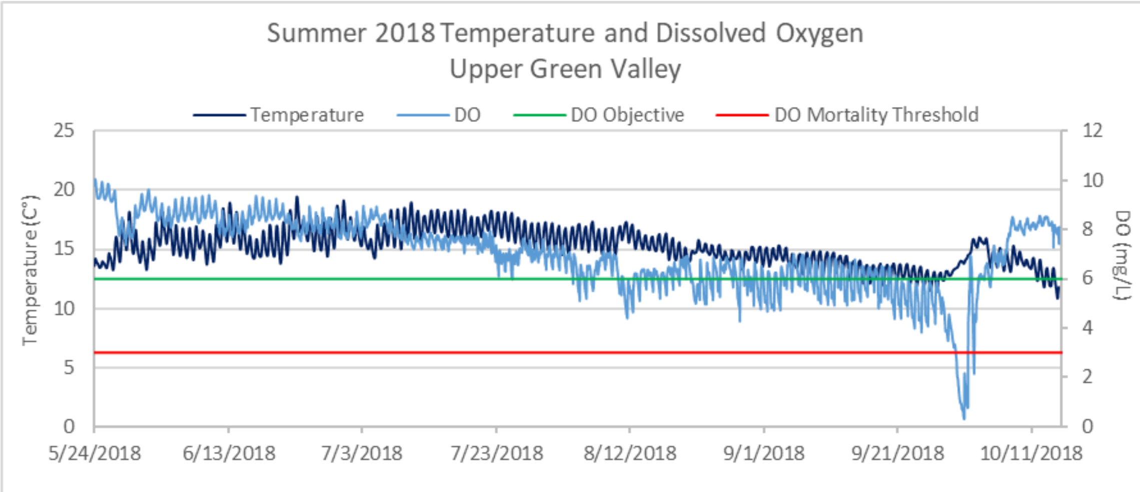

FIGURE 16. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE UPPER GREEN VALLEY STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

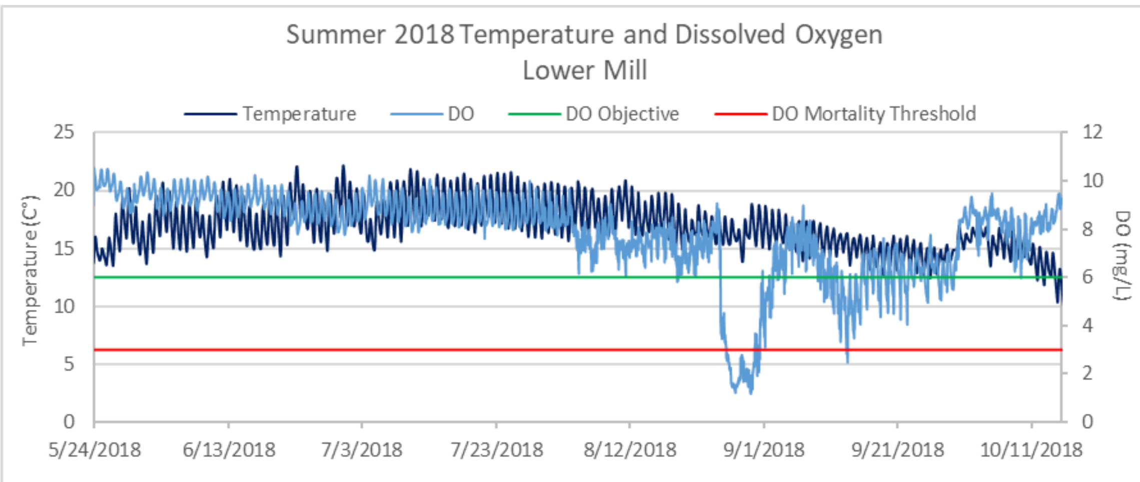

FIGURE 17. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE LOWER MILL STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

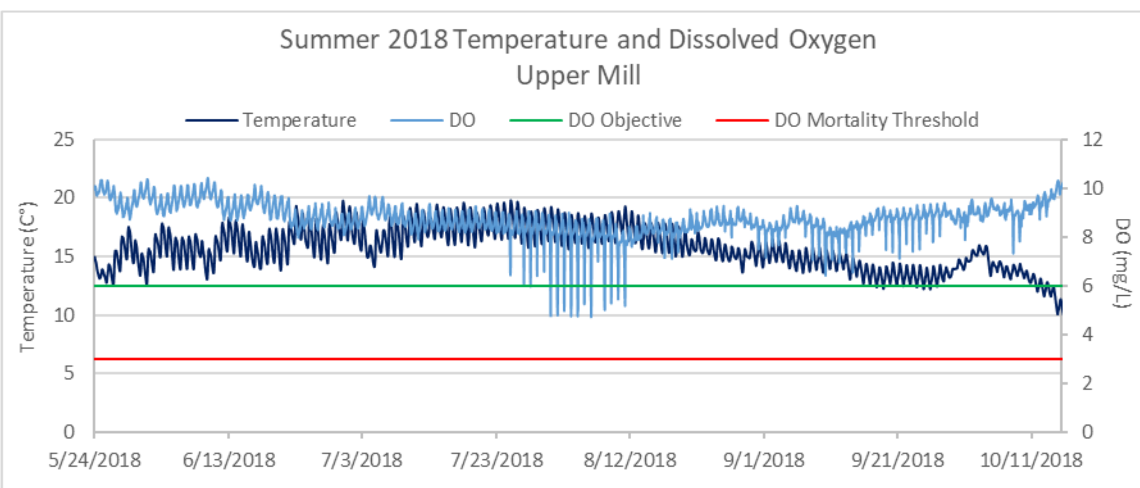

FIGURE 18. WATER TEMPERATURE AND DISSOLVED OXYGEN IN THE UPPER MILL STUDY POOL, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), SUMMER 2018.

STREAMFLOW AND CONNECTIVITY

Pressure transducers were operated throughout the summer season in Dutch Bill, Green Valley and Mill creeks by TU staff through the Coho Partnership effort. In-Situ Level Troll 500 vented pressure transducers recorded stream stage (water level) within a stable pool in each of the six priority stream reaches at 15-minute intervals throughout the 2018 dry season (May - October). Staff plates were also installed at each site to correct for pressure transducer drift and other factors that could cause phase shifts (i.e., changes in the relationship between stage and streamflow) over the course of the project.

Telemetered gages were installed on Green Valley and Mill creeks in May 2018 (Figure 19) and real-time stage data are available online at https://www.hydrovu.com/. Currently, the Mill Creek gage is experiencing technical difficulties and, after unsuccessful attempts to resolve them, TU hydrologists are exploring options to replace the gage with a State Water Quality Control Board instrument.

TU hydrologists visited each pressure transducer site at approximately monthly intervals, beginning in May, to download stage data, record staff plate depths and measure streamflow following protocols adapted from the CDFW Standard Operating Procedures for Discharge Measurements in Wadeable Streams (CDFW 2013). Discharge data was also collected at these sites at biweekly intervals by CSG staff, in conjunction with the wet/dry mapping, using the Sontek Flowtracker Handheld-ADV that was purchased through this grant to improve the level of accuracy of extremely low velocity measurements. TU hydrologists used both discharge data sets to develop rating curves based on correlations of discharge and stage at each gaging site, which were then used to generate estimates of streamflow over the summer season.

In each of the study reaches, streamflow receded over the summer season until the first rains on September 30 (Figure 20 - Figure 26; note different scales on y-axis between creeks). Streamflow was below 1.0 ft^3/s in all reaches for most of the May through October study period, and below 0.5 ft^3/s for the majority of the summer season. In September, which was the driest month of 2018 (and most years), average streamflow was under 0.35 ft^3/s in all reaches, ranging from just 0.03 ft^3/s in Lower Green Valley Creek to 0.32 ft^3/s in Upper Dutch Bill Creek. Differences in streamflow within and between streams likely reflect variability in drainage area, as well as in localized surface water conditions, which are affected by numerous variables including site-specific geology, groundwater characteristics, inputs and withdrawals.

Game cameras purchased by Anthropocene Institute were installed in early summer, along with intermittency loggers, at representative riffle crests within each study reach where the first drying of the season was expected to occur. Time lapse images and intermittency logger data were carefully reviewed to determine the date of surface flow disconnection in every reach in which stream disconnection was observed. This information was evaluated, along with data from previous years, in order to identify the streamflow at which pools become disconnected in order to support the development of connectivity thresholds for the Coho Partnership. Connectivity thresholds are defined as the amount of streamflow needed to maintain pool connection. The Partnership uses connectivity thresholds as a basis for determining the minimum amount of streamflow that needs to be returned to designated priority stream reaches in order to reduce the number of days of stream disconnection and, thereby, increase the probability of juvenile coho salmon survival.

The 2018 connectivity data generated from the wetted habitat surveys, riffle cameras and intermittency loggers was compared to observations from previous years, and used to update the Coho Partnership's working table of connectivity thresholds for each priority reach (Table 3).

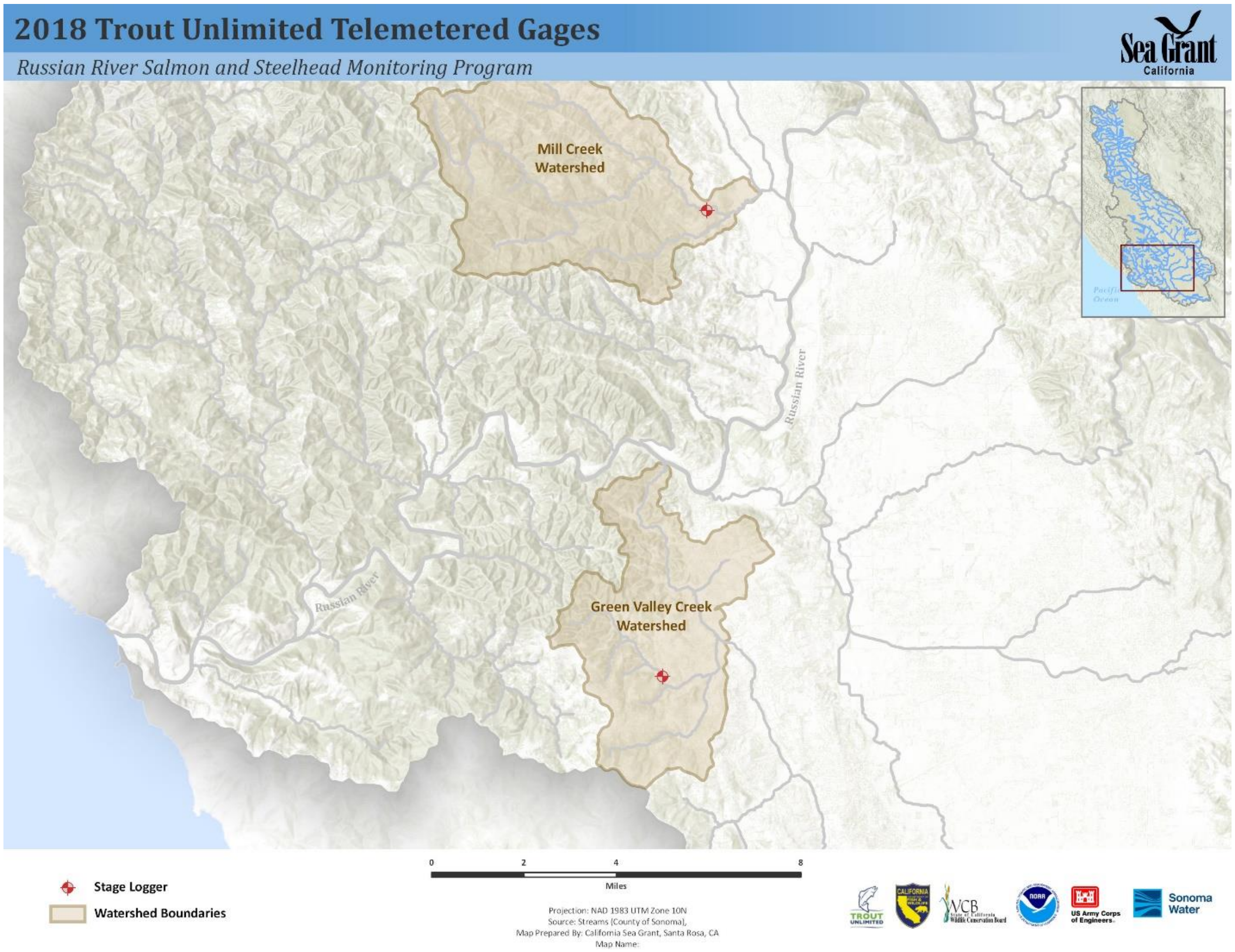

FIGURE 19. ONLINE PRESSURE TRANSDUCER GAGES ON GREEN VALLEY AND MILL CREEKS, INSTALLED BY TROUT UNLIMITED IN 2018.

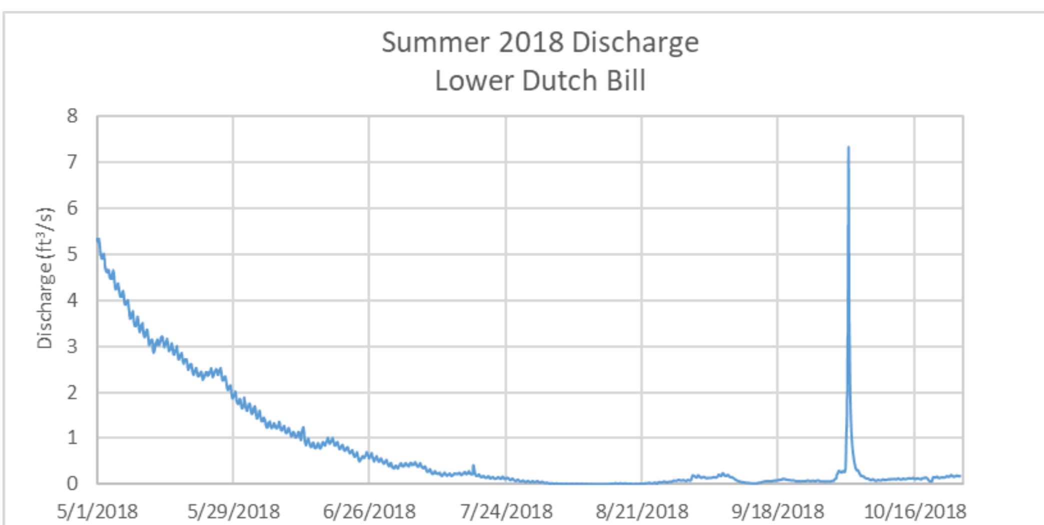

FIGURE 20. STREAMFLOW IN THE LOWER DUTCH BILL STUDY REACH AT RIVER KILOMETER 3.87, MAY TO OCTOBER 2018.

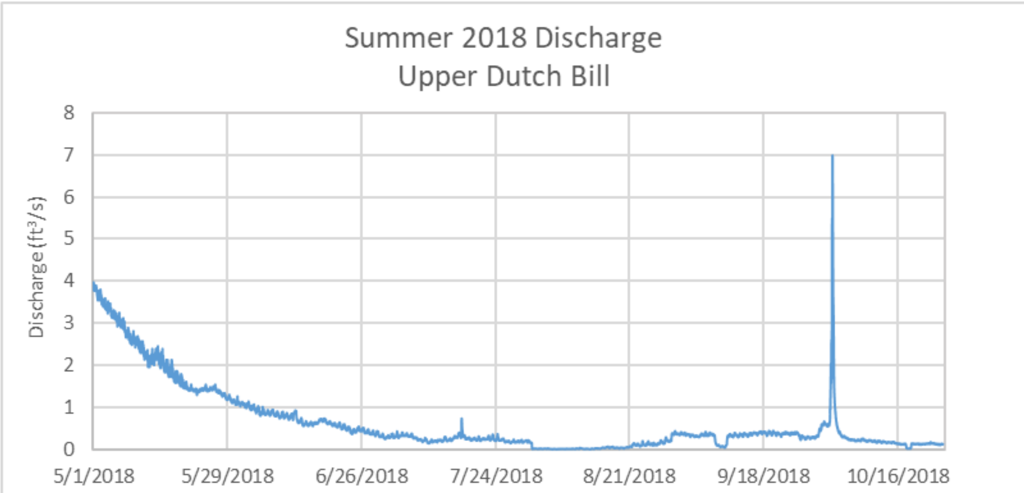

FIGURE 21. STREAMFLOW IN THE UPPER DUTCH BILL STUDY REACH AT RIVER KILOMETER 6.51, MAY TO OCTOBER 2018.

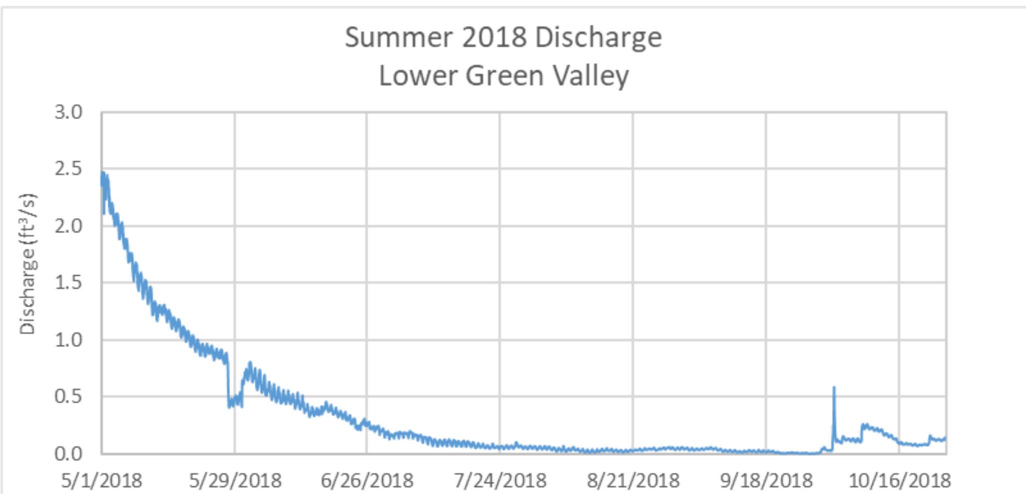

FIGURE 22. STREAMFLOW IN THE LOWER GREEN VALLEY STUDY REACH AT RIVER KILOMETER 12.16, MAY TO OCTOBER 2018.

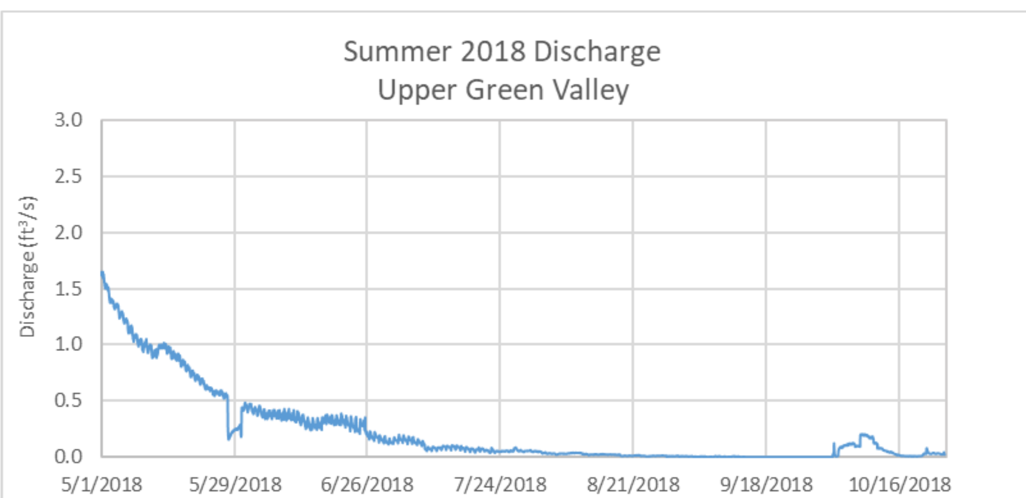

FIGURE 23. STREAMFLOW IN THE UPPER GREEN VALLEY STUDY REACH AT RIVER KILOMETER 13.40, MAY TO OCTOBER 2018.

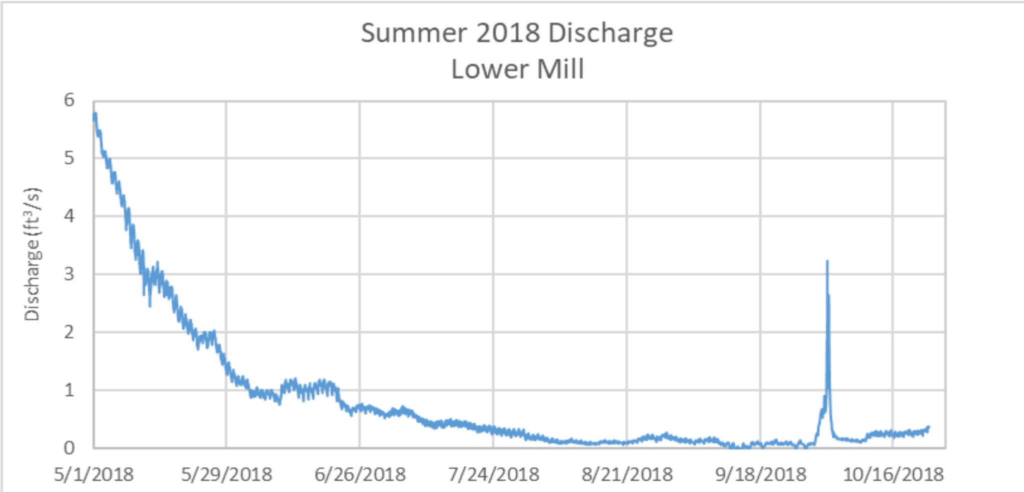

FIGURE 24. STREAMFLOW IN THE LOWER MILL STUDY REACH AT RIVER KILOMETER 6.10, MAY TO OCTOBER 2018.

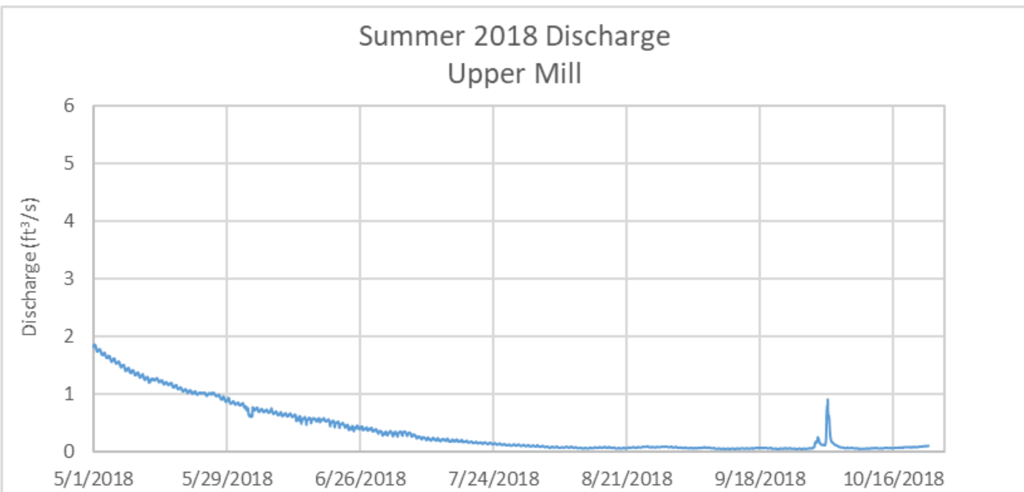

FIGURE 25. STREAMFLOW IN THE UPPER MILL STUDY REACH AT RIVER KILOMETER 12.39, MAY TO OCTOBER 2018.

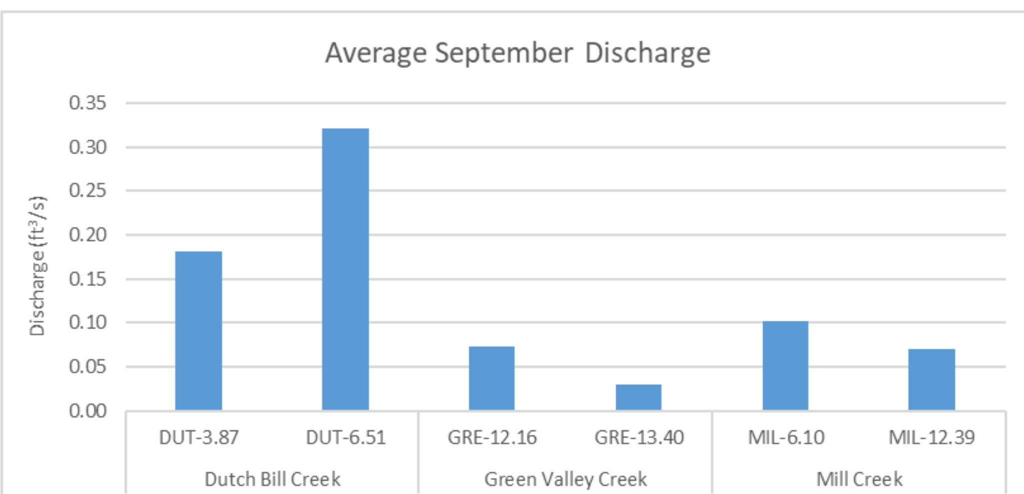

FIGURE 26. AVERAGE DISCHARGE IN DUTCH BILL, GREEN VALLEY AND MILL CREEKS BY STUDY REACH, SEPTEMBER, 2018. REACH CODE IS COMPRISED OF THE FIRST THREE CHARACTERS OF THE STREAM NAME AND THE DISTANCE UPSTREAM OF THE MOUTH IN RIVER KILOMETERS.

TABLE 3. CONNECTIVITY THRESHOLDS FOR PRIORITY, FISH-BEARING REACHES OF DUTCH BILL, GREEN VALLEY AND MILL CREEKS.

Tributary	Associated Stream Reach[1]	Connectivity Threshold (ft^3/s)[2]
Dutch Bill Creek	3.14 - 5.97	0.50
Dutch Bill Creek	5.97 - 10.59	0.20
Green Valley Creek	9.36 - 10.32	0.10
Green Valley Creek	10.32 -12.49	0.20
Green Valley Creek	12.49 - 16.09	0.10
Mill Creek	2.99 - 6.10	0.20
Mill Creek	6.10 - 9.97	0.15
Mill Creek	9.97 - 15.54	0.20

[1] *Distance upstream from mouth in river kilometers.*

[2] *Streamflow required to maintain habitat connection through entire reach. Estimated to the nearest 0.05 ft^3/s. Based on average daily streamflow on last known day of connection for years between 2010-2018.*

REDD DISTRIBUTION

In the winter of 2017-18, spawner surveys were conducted by the Coho Broodstock and Coastal Monitoring Programs in all accessible reaches within the Dutch Bill, Green Valley and Mill creek watersheds that are defined as juvenile coho salmon habitat by the Russian River Coastal Monitoring Program effort (Adams et. al. 2011; SCWA and UC 2015; Obedzinski et. al. 2016b). Each reach was surveyed at an interval of 10-14 days throughout the spawning season. On each survey, CSG and Sonoma Water biologists hiked reaches from downstream to upstream looking for adult salmon individuals (live or carcass) and redds. Redds were identified to species based on the presence of identifiable adult fish or from observed redd morphology. All salmonids were identified to species (coho salmon, Chinook salmon or steelhead) or as an unknown salmonid if identification was not possible. Geospatial coordinates were recorded for all redd and fish observations. Allegro field computers were used for data entry and, upon returning from the field, data files were downloaded, error checked in Microsoft Excel and transferred into a SQL database. Redd distribution in the study streams was later compared with 2018 wetted habitat spatial data (see *Fish distribution in relation to wetted habitat conditions*).

A total of 73 salmonid redds were observed in Dutch Bill, Green Valley and Mill creeks during spawner surveys throughout the winter of 2017-2018. Redds were totaled by species for each stream; coho salmon, steelhead or unknown salmonid (Table 4). Using the spatial data collected during the spawner surveys, we mapped the distribution of observed redds by species (Figure 27 - Figure 29). Additional results from these surveys can be found in the spawner season monitoring report at: https://caseagrant.ucsd.edu/sites/default/files/2017-2018_WinterReport_CA%20SeaGrant.pdf.

TABLE 4. TOTAL COHO SALMON, STEELHEAD AND UNKNOWN SALMONID REDDS OBSERVED IN THE DUTCH BILL, GREEN VALLEY AND MILL CREEK WATERSHEDS DURING WINTER 2017-2018.

Tributary	Coho Salmon	Steelhead	Unknown Salmonid
Dutch Bill Creek	5	2	1
Green Valley Creek	8	10	10
Purrington Creek	2	4	3
Mill Creek	5	12	5
Felta Creek	2	2	1
Wallace Creek	0	0	0
Palmer Creek	0	1	0

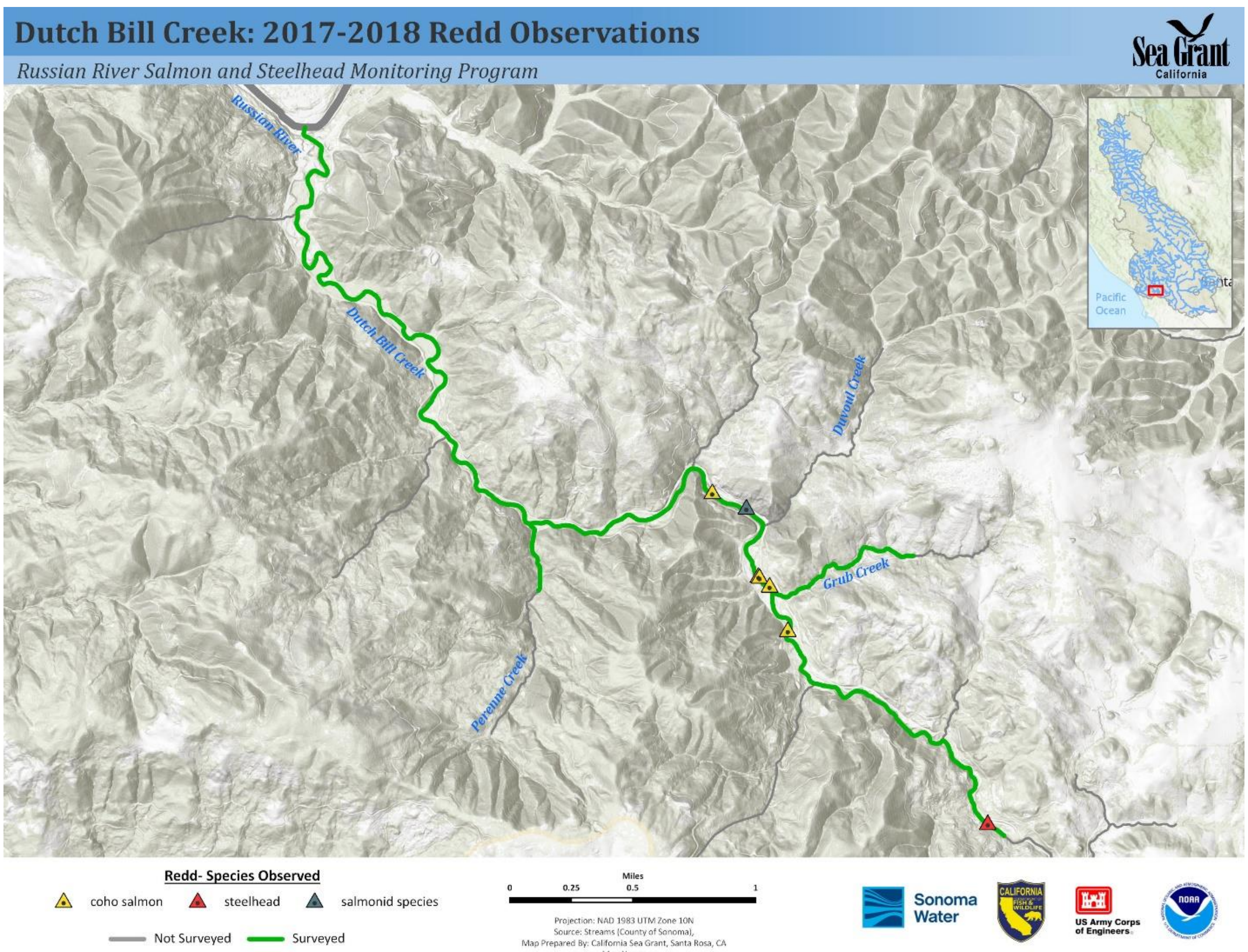

FIGURE 27. SALMONID REDDS OBSERVED IN THE DUTCH BILL CREEK WATERSHED DURING THE 2017-2018 SPAWNER SEASON.

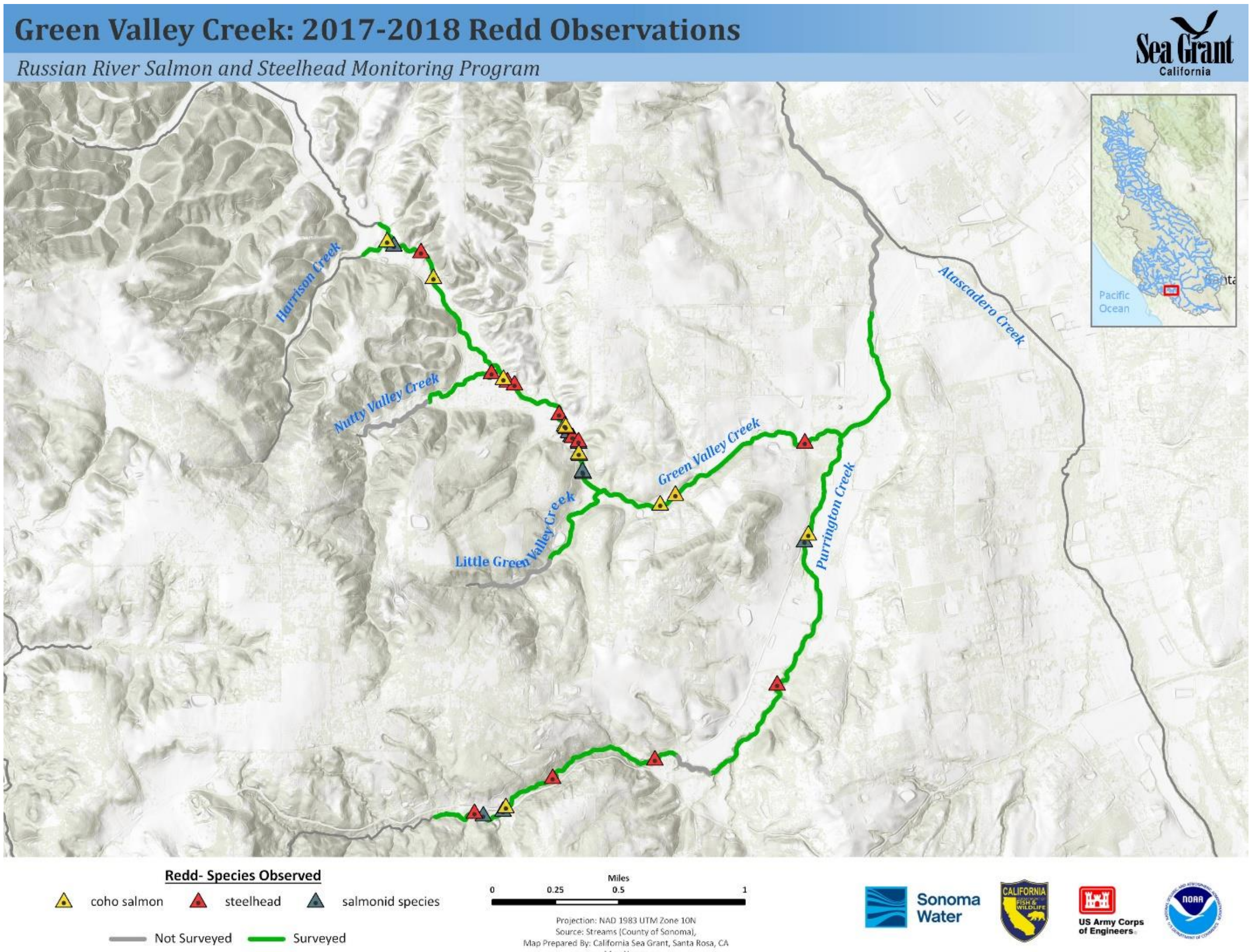

FIGURE 28. SALMONID REDDS OBSERVED IN THE GREEN VALLEY CREEK WATERSHED DURING THE 2017-2018 SPAWNER SEASON.

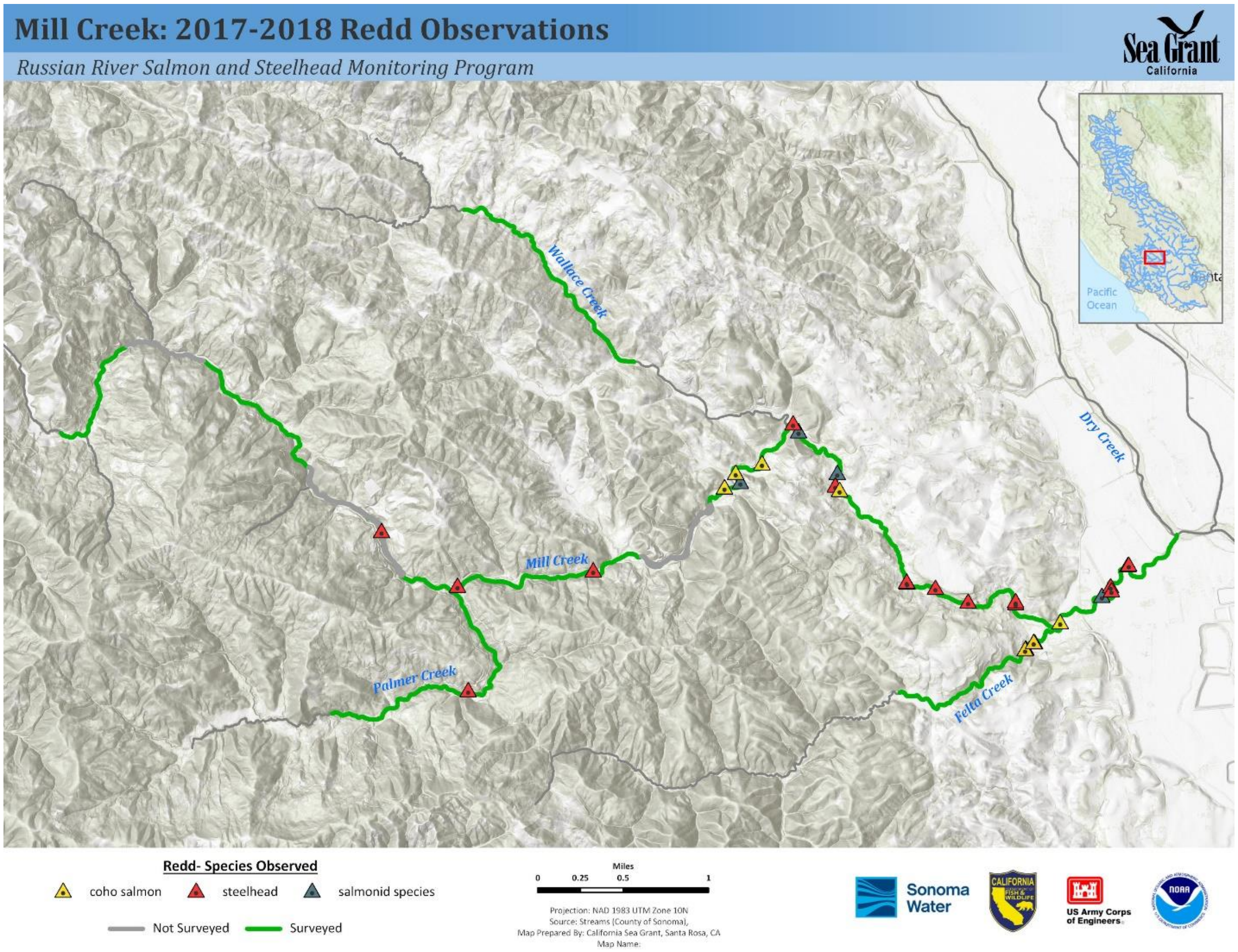

FIGURE 29. SALMONID REDDS OBSERVED IN THE MILL CREEK WATERSHED DURING THE 2017-2018 SPAWNER SEASON.

JUVENILE DISTRIBUTION

In June and early July of 2018, snorkeling surveys were conducted by the Coho Broodstock and Coastal Monitoring Programs to document the relative abundance and spatial distribution of juvenile coho salmon and steelhead in all accessible reaches within the Dutch Bill, Green Valley and Mill creek watersheds that are defined as juvenile coho salmon habitat by the Russian River Coastal Monitoring Program effort (Adams et. al. 2011; SCWA and UC 2015; Obedzinski et. al. 2016b). CSG and Sonoma County Water Agency biologists snorkeled every other pool in each stream reach and counted the number of coho salmon and steelhead yoy present. GPS points were collected at each survey pool so that juvenile densities could be spatially displayed. Data was entered into field computers and, upon return to the office, downloaded, error-checked and uploaded into a SQL database. Juvenile salmonid distribution in the study streams was later compared with 2018 wetted habitat spatial data (see *Fish distribution in relation to wetted habitat conditions*).

A total of 1,610 coho and 4,162 steelhead yoy were observed during snorkel surveys in all three study streams. Because only 50% of pools were sampled, this count was doubled, or “expanded” for a rough estimate of 11, 542 salmonid yoy. Juvenile coho salmon were present in all stream reaches except Wallace Creek and steelhead were present in all surveyed reaches (Table 5, Figure 30 - Figure 32).

TABLE 5. OBSERVED AND EXPANDED COUNTS OF COHO SALMON AND STEELHEAD YOUNG-OF-THE-YEAR IN THE DUTCH BILL, GREEN VALLEY AND MILL SYSTEMS IN THE SUMMER OF 2018.

Tributary	Number of Pools Snorkeled [1]	Coho Salmon Yoy	Expanded [2] Coho Salmon Yoy	Steelhead Yoy	Expanded [2] Steelhead Yoy
Dutch Bill Creek	100	190	380	310	620
Green Valley Creek	83	883	1,766	752	1,504
Purrington Creek	76	63	126	867	1,734
Mill Creek	168	383	766	1,597	3,194
Felta Creek	58	81	162	123	246
Wallace Creek	28	0	0	181	362
Palmer Creek	45	10	20	332	662

[1] *Every second pool was snorkeled. Number varies based on presence of wet pools in accessible stream reaches at time of survey.*

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

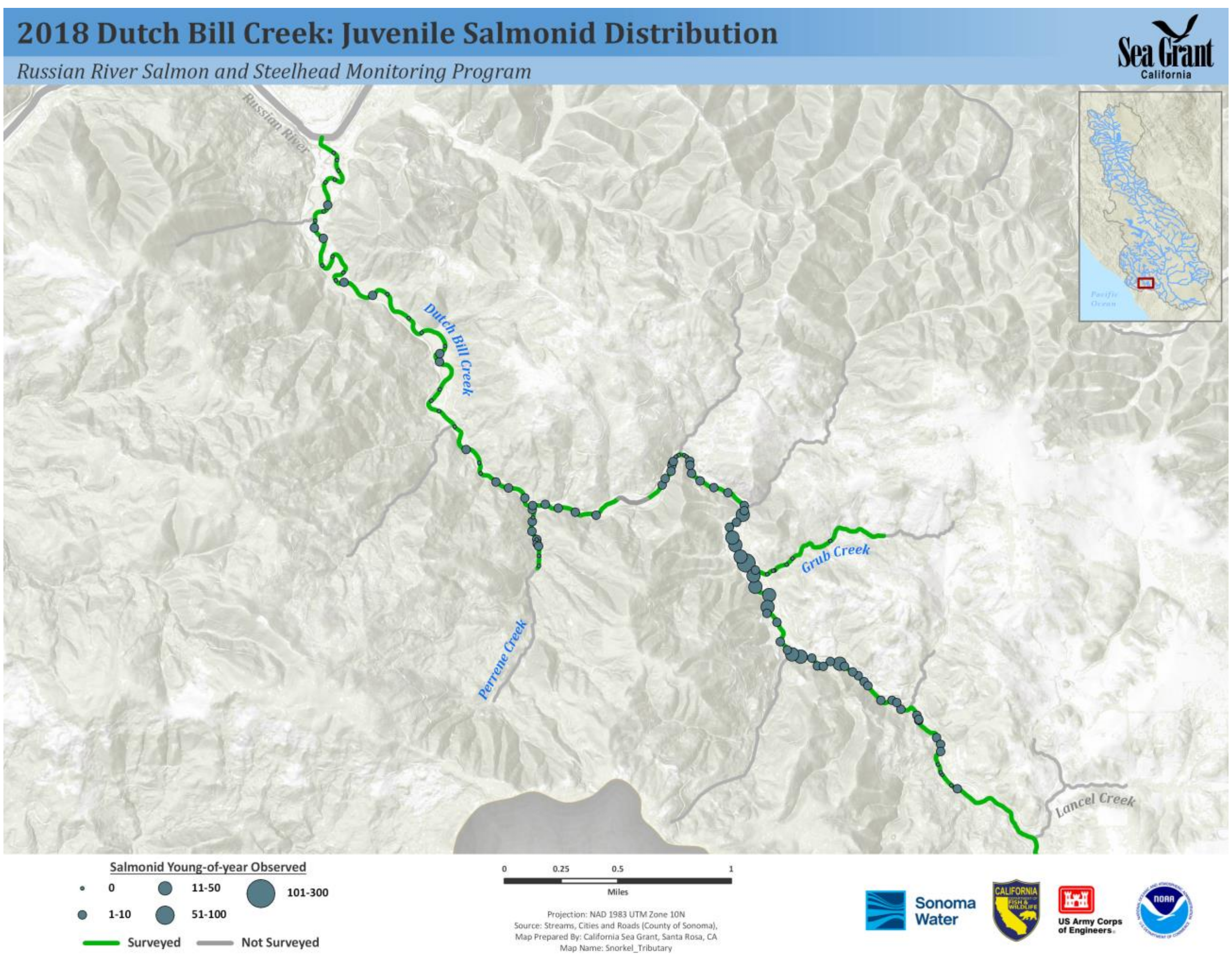

FIGURE 30. DENSITY AND DISTRIBUTION OF COHO SALMON AND STEELHEAD YOY OBSERVED IN DUTCH BILL CREEK, 2018.

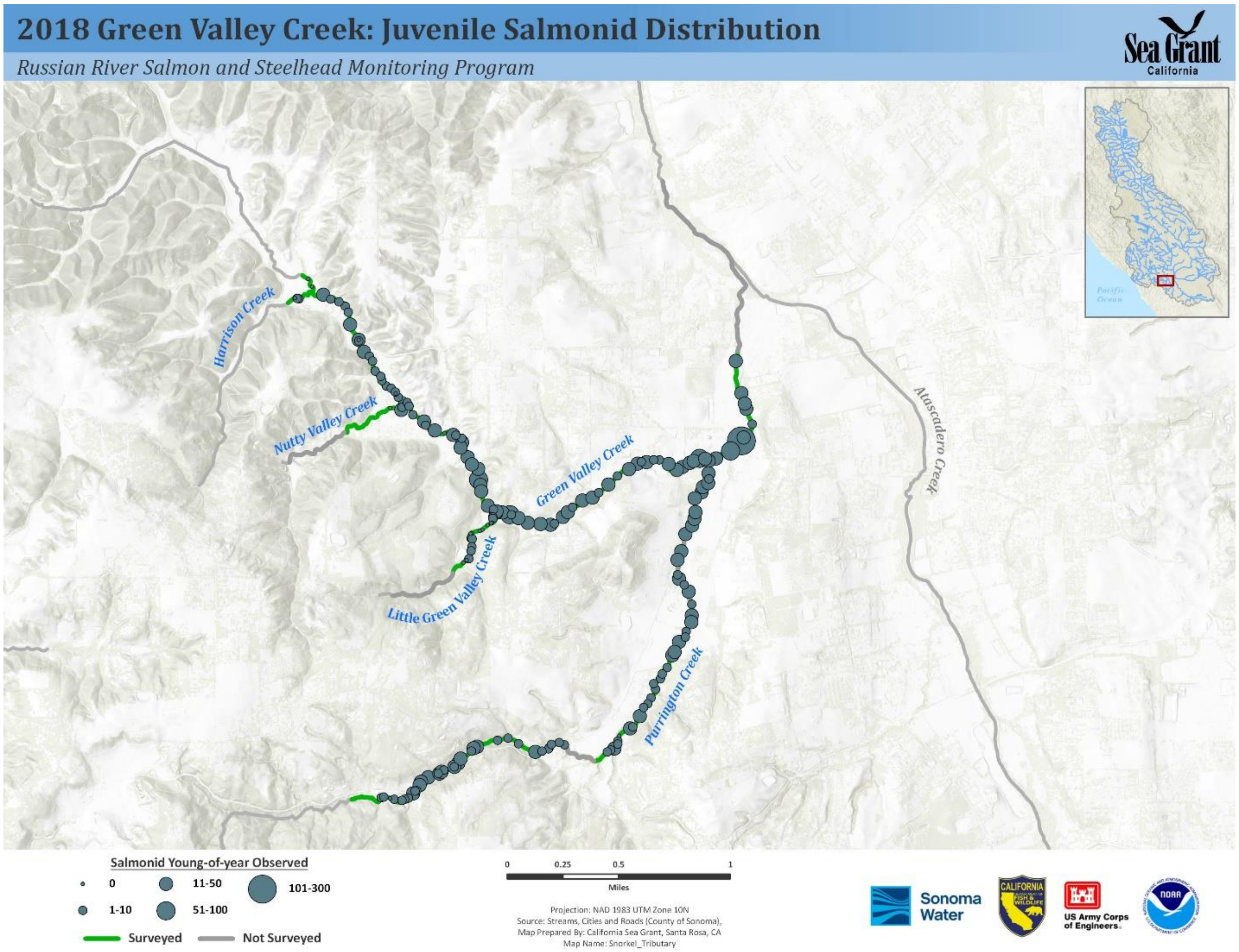

FIGURE 31. DENSITY AND DISTRIBUTION OF COHO SALMON AND STEELHEAD YOY OBSERVED IN GREEN VALLEY CREEK, 2018.

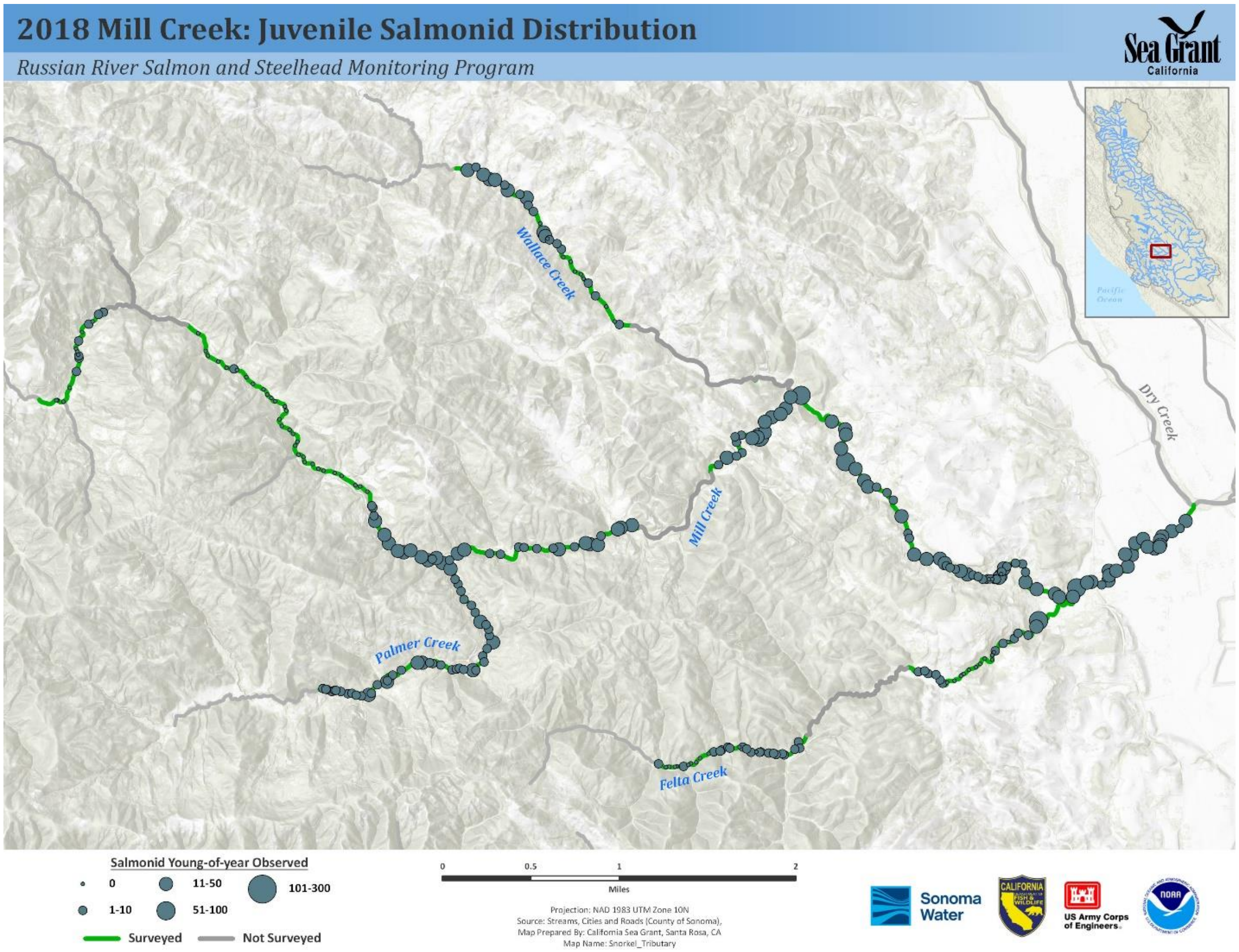

FIGURE 32. DENSITY AND DISTRIBUTION OF COHO SALMON AND STEELHEAD YOY OBSERVED IN MILL CREEK, 2018.

Fish distribution in relation to wetted habitat conditions

In order to relate redd and juvenile salmonid distribution data to wetted habitat data, spatial joins were conducted in GIS such that each redd observed during spawner surveys and each pool snorkeled was assigned a wetted habitat condition (wet, intermittent or dry) according to the wet/dry mapping survey of interest. We were interested in determining: 1) what proportion of returning adults spawned in locations where their offspring would have access to sufficient wetted habitat throughout the summer (presuming that they remained in the vicinity of the redd); and 2) what proportion of rearing juvenile salmon and steelhead were potentially impacted by drying stream conditions given their location during snorkeling surveys. While it is possible that fish observed in early summer snorkeling surveys may have had the opportunity to move to other locations within the streams, it appears unlikely based on CSG's previous PIT tag monitoring over multiple summer seasons and common observations of fish strandings in previous years.

To evaluate the greatest impact of low-flow conditions on rearing salmonids during the 2018 season, redd observations from winter 2017-2018 spawner surveys and salmonid yoy distribution data from summer 2018 snorkeling surveys were overlaid with wetted habitat maps from the *driest* survey of the 2018 season (Figure 33 - Figure 38). This data was then summarized to determine the proportion of all redds and juvenile fish that were observed in areas that went completely dry, became intermittent or remained wet (Table 6). Over all streams, 61% of redds and 69% of juveniles were observed in locations where habitat remained wet throughout the summer season, and the remainder were observed in locations that became dry or intermittent (Table 6). The number of coho salmon and steelhead yoy distributed in each late-summer habitat condition (wet, dry or intermittent) in 2018 was similar to 2017, but there was a 13% decrease in redds observed in areas that remained wet, a 150% increase in those that were observed in areas that became intermittent, and a 24% decrease in redds observed in areas that later dried. By far, the greatest proportion of redds and fish observed in locations that became dry in the summer of 2018, as in the summer of 2017, was in the Mill Creek watershed (Table 6).

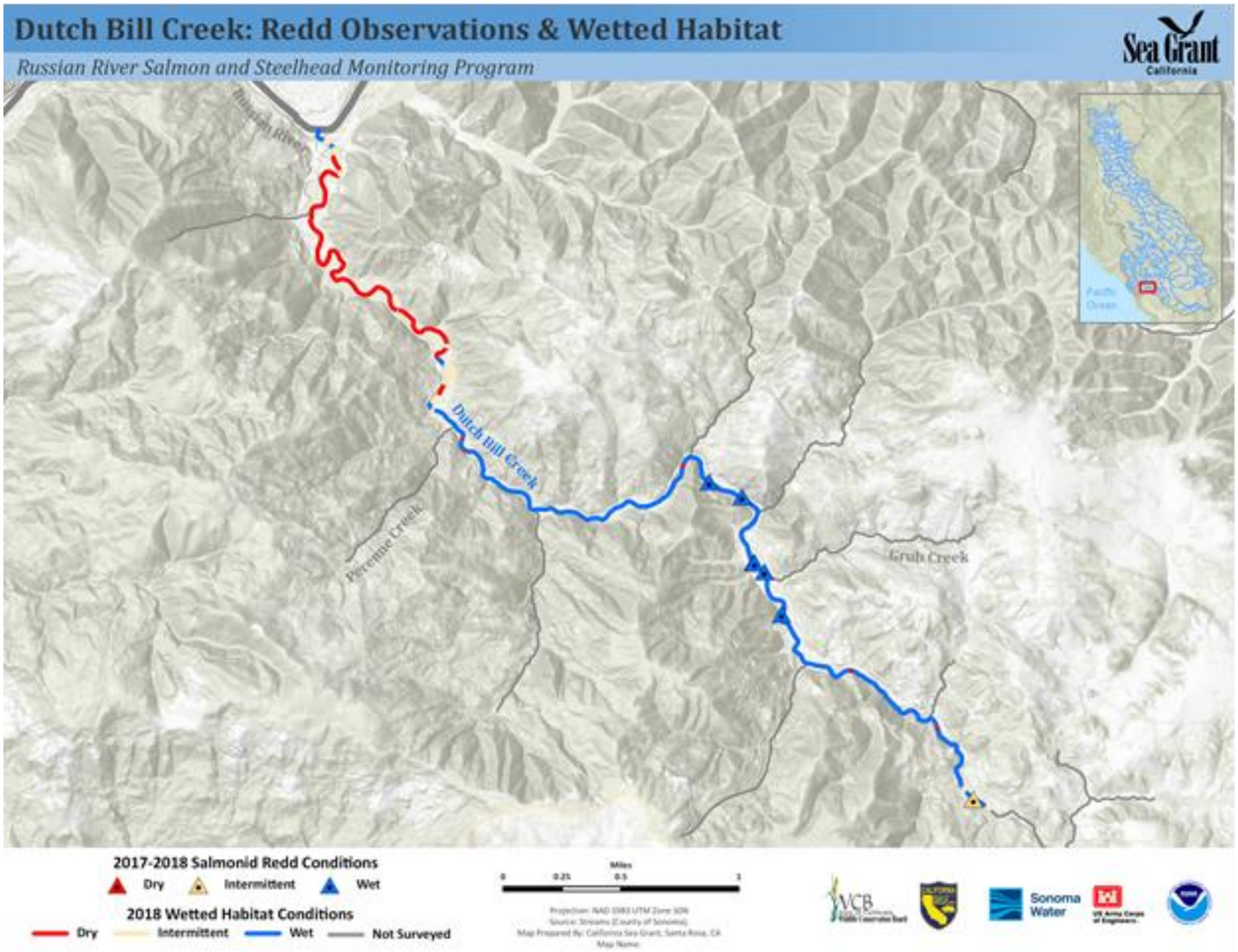

FIGURE 33. WINTER 2017-2018 DUTCH BILL CREEK REDD LOCATIONS IN RELATION TO LATE-SUMMER 2018 WETTED HABITAT CONDITIONS.

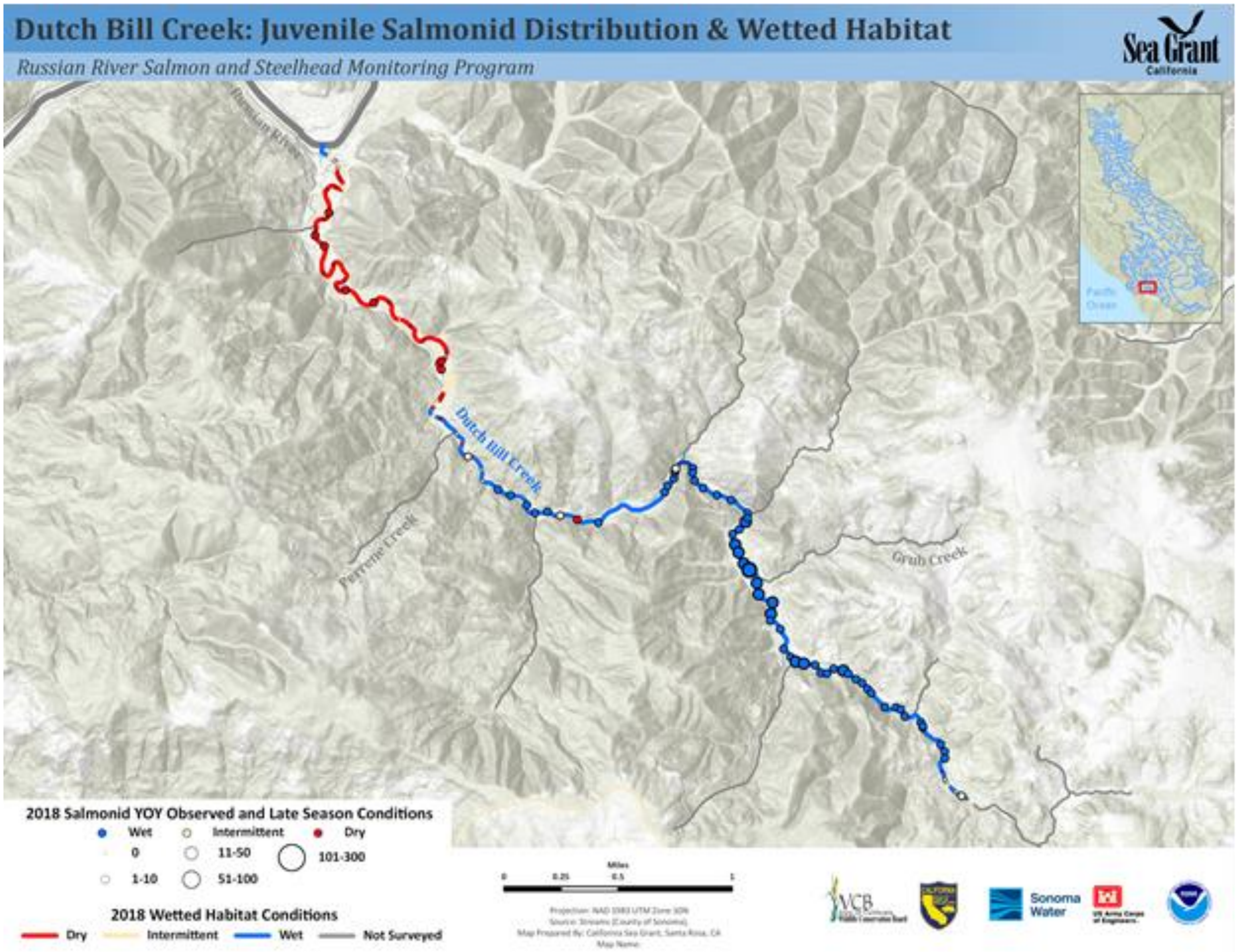

FIGURE 34. EARLY-SUMMER SALMONID YOUNG-OF-YEAR DISTRIBUTION IN DUTCH BILL CREEK IN RELATION TO LATE-SUMMER WETTED HABITAT CONDITIONS, 2018.

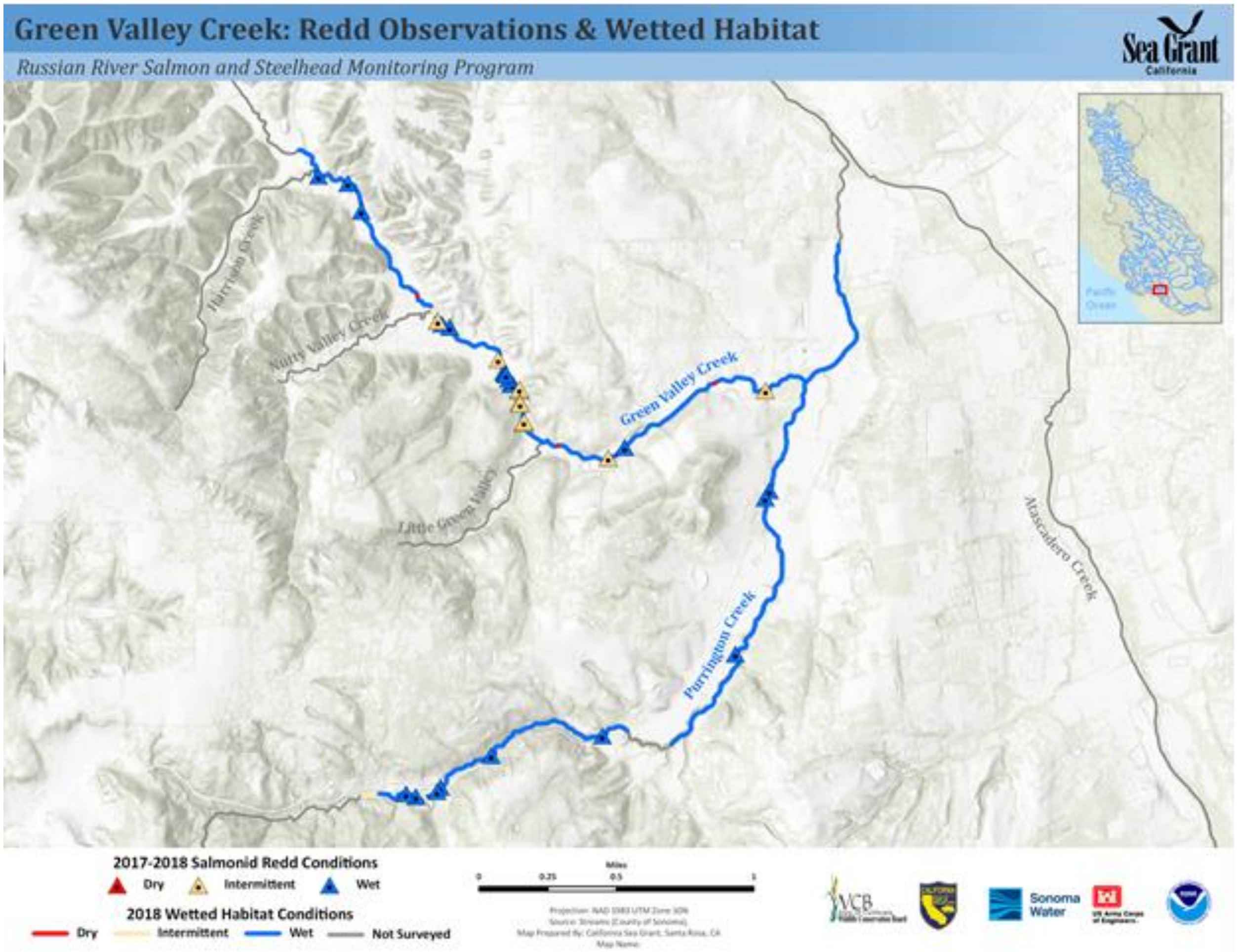

FIGURE 35. WINTER 2017-2018 GREEN VALLEY CREEK REDD LOCATIONS IN RELATION TO LATE-SUMMER 2018 WETTED HABITAT CONDITIONS.

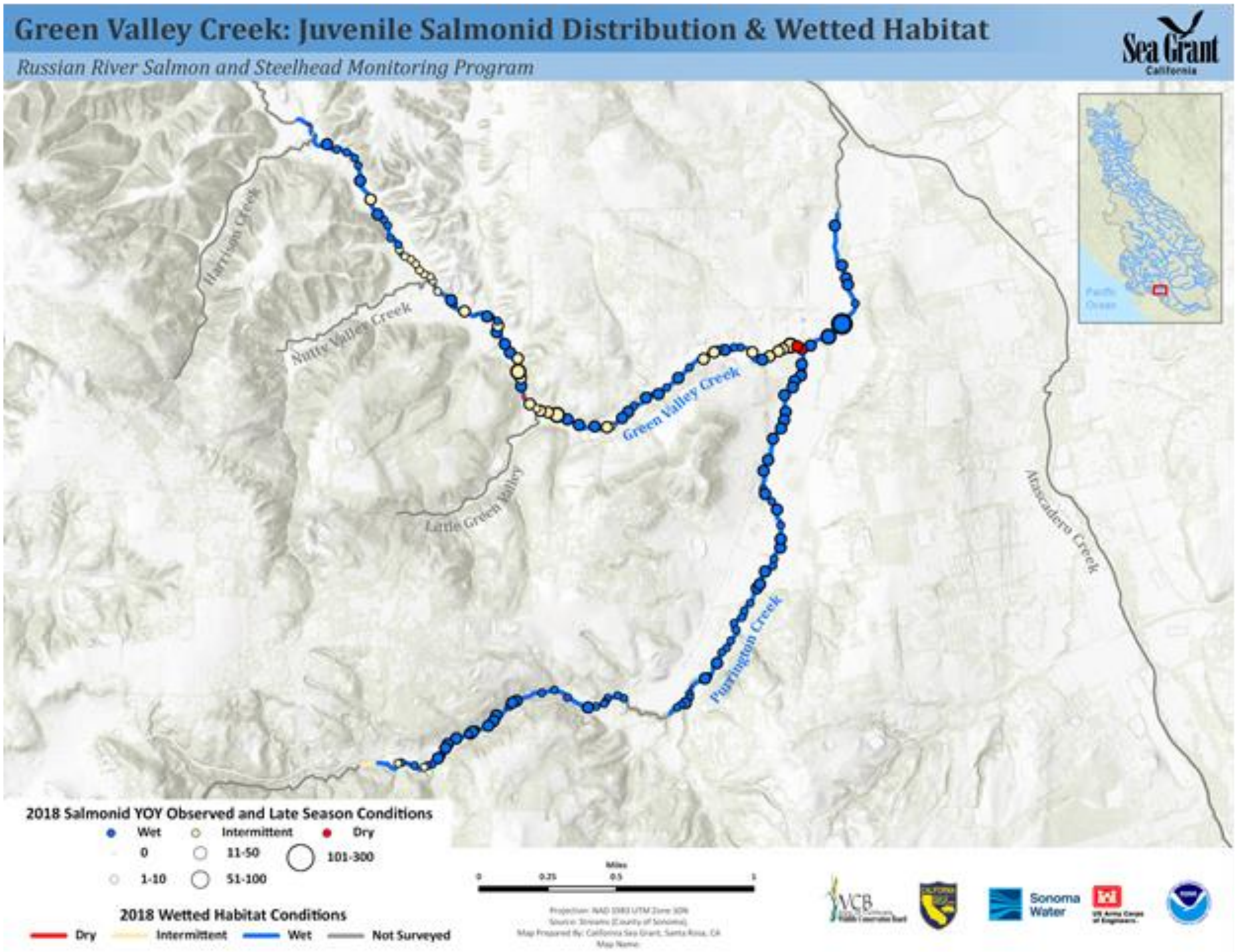

FIGURE 36. EARLY-SUMMER SALMONID YOUNG-OF-YEAR DISTRIBUTION IN GREEN VALLEY CREEK IN RELATION TO LATE-SUMMER WETTED HABITAT CONDITIONS, 2018.

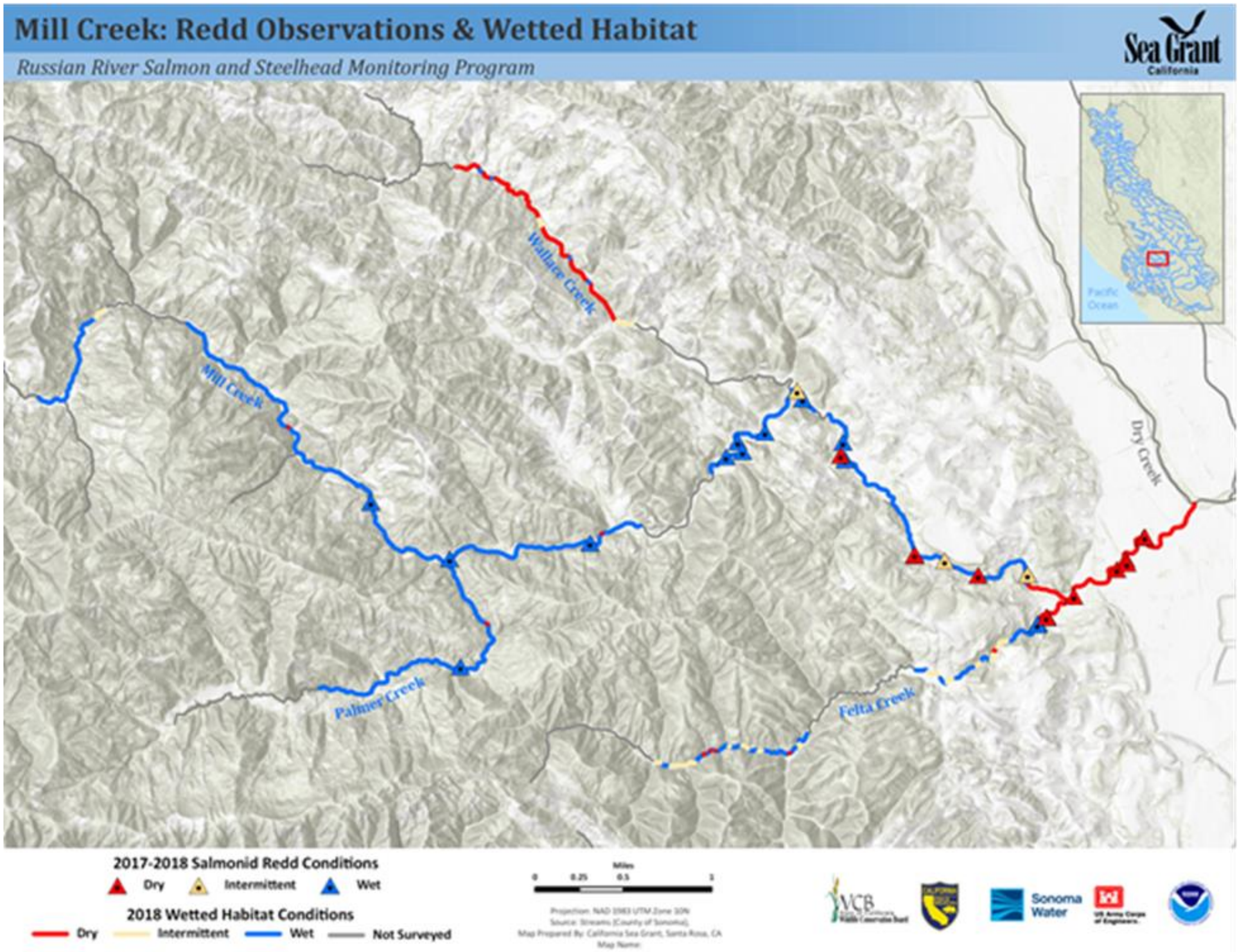

FIGURE 37. WINTER 2016-2017 MILL CREEK REDD LOCATIONS IN RELATION TO LATE-SUMMER 2018 WETTED HABITAT CONDITIONS.

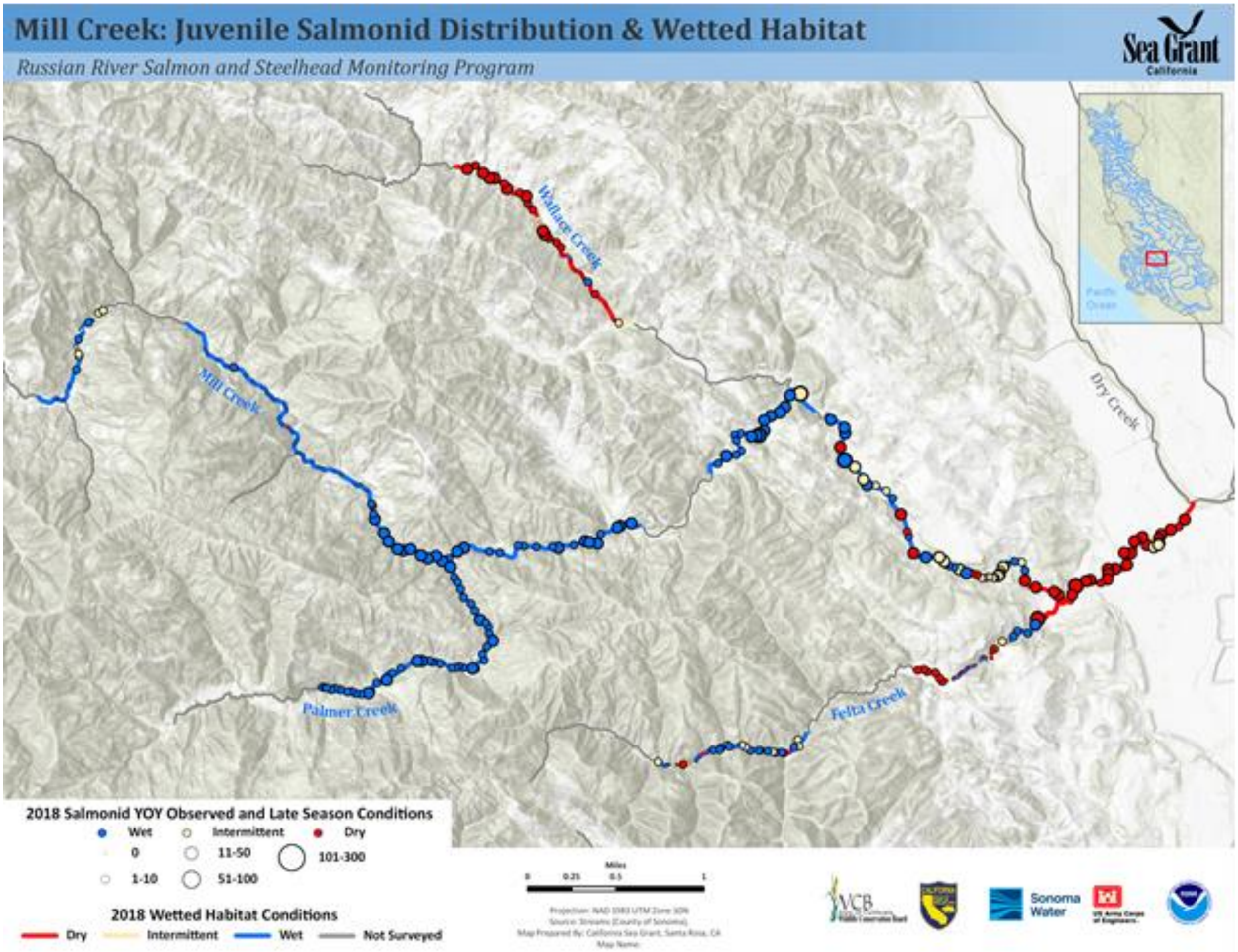

FIGURE 38. EARLY-SUMMER SALMONID YOUNG-OF-YEAR DISTRIBUTION IN MILL CREEK IN RELATION TO LATE-SUMMER WETTED HABITAT CONDITIONS, 2018.

TABLE 6. NUMBER AND PERCENTAGE OF SALMONID REDDS OBSERVED IN WINTER 2017-2018 AND JUVENILE SALMONIDS OBSERVED IN 2018 IN RELATION TO LATE SUMMER WETTED HABITAT CONDITIONS IN 2018. NA = NOT SURVEYED.

Tributary	Salmonid Redds			Juvenile Salmonids [1]		
	Dry	Intermittent	Wet	Dry	Intermittent	Wet
Dutch Bill Creek	0 (0%)	1 (13%)	7 (88%)	12 (2%)	25 (5%)	463 (93%)
Green Valley Creek	0 (0%)	12 (44%)	15 (56%)	38 (2%)	668 (41%)	929 (57%)
Purrington Creek	0 (0%)	0 (0%)	9 (100%)	0 (0%)	10 (1%)	920 (99%)
Mill Creek	10 (42%)	4 (17%)	10 (42%)	687 (23%)	428 (14%)	1,873 (63%)
Felta Creek	2 (40%)	0 (0%)	3 (60%)	115 (39%)	43 (15%)	138 (47%)
Wallace Creek	NA	NA	NA	176 (97%)	1 (1%)	4 (2%)
Palmer Creek	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	606 (100%)
All streams	**12 (16%)**	**17 (23%)**	**45 (61%)**	**1,028 (14%)**	**1,175 (17%)**	**4,933 (69%)**

[1] *Coho salmon and steelhead young-of-the-year (yoy).*

Development of predictive model

UC Berkeley PhD student, Hana Moidu, has made significant progress on developing a model to predict stream drying in Russian River tributaries. Her work has used GIS, field assessments of wet-dry mapping, and statistical models to predict the spatial and temporal distribution of wetted habitats in tributaries of the Russian River. Using random forest models, she has identified key physical drivers of wetted habitat and her models are able to predict of the degree and distribution of intermittency. Our findings show that important predictor variables include distance along the tributary from the mouth, late-season precipitation, and canopy cover, indicating that both hydrologic and geomorphic forces interact variably to influence streamflow permanence. The models were tested for sensitivity and specificity within the Russian River watershed and had error rates between 3.87% - 8.46% (Figure 39). A manuscript related to these results is in preparation. During this reporting period, Hana presented this work at the Salmon Restoration Federation conference in April 2019 and at the Society for Freshwater Science conference in May 2019.

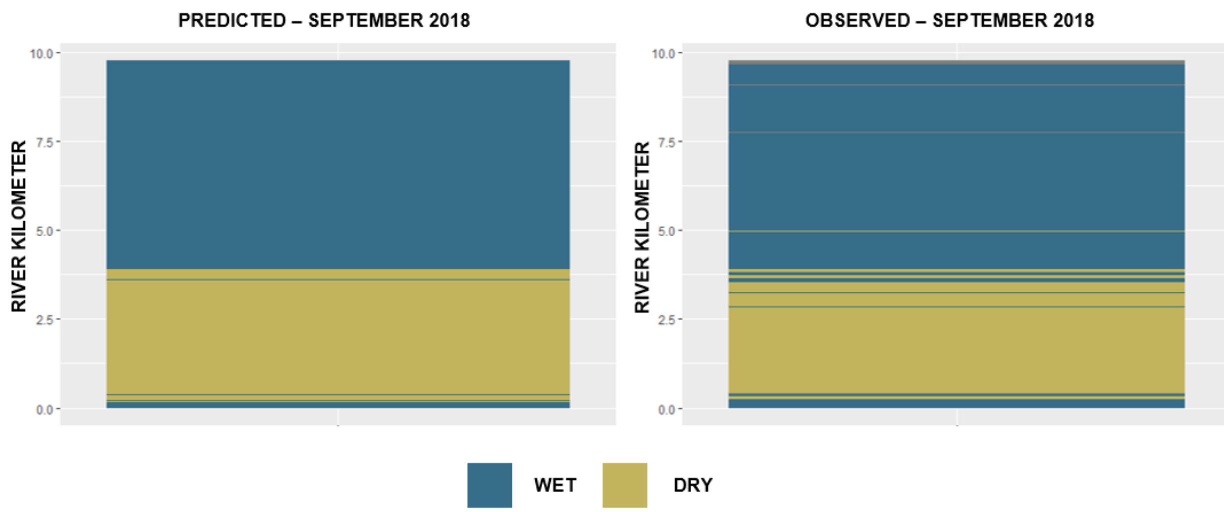

FIGURE 39. PREDICTED AND OBSERVED LENGTH OF WET AND DRY HABITAT IN DUTCH BILL CREEK, SEPTEMBER 2018; 3.87% MSE.

Flow release evaluation

CSG researchers were able to use data from the 2018 biweekly wet/dry mapping effort to support the initiation of three small-scale instream flow releases and to document the effects of those releases. There were two flow releases into Green Valley Creek and one into Dutch Bill Creek; the former from off-channel storage ponds and the later from a municipal source. While stream habitat units typically exhibit a general downward trend in DO concentrations over the summer season, the date at which DO falls below fish impairment levels in priority stream reaches varies annually, depending on weather and environmental conditions. Frequent wetted habitat surveys allowed us to identify the onset of DO impairment and inform resource managers on timing of flow releases to support the most effective use of the limited augmentation water available.

In Green Valley Creek, DO concentrations and stream connectivity steadily declined over the sample period and spot measurements of DO were beginning to drop below the regionally-established objective by the August 15-16 survey (Figure 40). Although the stream-scale average DO concentration was above the impairment threshold, rapid declines in water quality have been observed after pool disconnection in past years and the relief that comes with fall precipitation was still weeks away. On August 20 and 29, agency partners were able to implement two small-scale flow releases in Green Valley Creek to keep water quality and wetted habitat from further decreasing.

At the lower release point, below Bones Road, partner agencies facilitated a release of 0.1 ft^3/s beginning on August 20. In anticipation of this release, CSG deployed five continuous DO loggers above and below the release point to identify impacts to water quality. However, minimal water was observed entering the creek during the August 29 wet/dry survey. Below the release point, the stream conditions continued to worsen and dry (Figure 42). Observations indicated what was later learned from the landowners to be true; that the release had been unexpectedly halted due to infrastructure complications just days after initiation. The furthest upstream Green Valley Creek flow release, initiated on August 29, had an estimated release amount of 0.2 ft^3/s and also experienced infrastructure issues that prevented water from entering the creek and maintaining stream connectivity. A short, previously-dry section of creek was documented as wet on August 30, but by the September 12 survey conditions were worsening. The flow gage and dissolved oxygen logger located 830 meters below the release point did not record any quantifiable impact to streamflow or water quality (Figure 43).

On Dutch Bill Creek, partner agencies coordinated the Camp Meeker Recreation and Parks District release, which began on August 27 and ended on November 30. An average of 0.09 ft^3/s was released over the course of this period, though the amount varied by day. On the August 28 wet/dry survey, small sections of the creek between the release point and Perenne Creek had rewet (Figure 44 - Figure 45). By September 24-25, this reach had reconnected with the exception of one short intermittent segment, and a previously-dry flow cross section three kilometers downstream of the release point was measurably wet (Figure 46). This release improved stream connectivity and maintained pool volume for approximately three kilometers below the release point. DO conditions were stable and either near or above the 6 mg/L threshold before the release, but September increases in DO corresponded to augmentation amounts in the logger pool 0.5 kilometers below the release point (Figure 47).

WCB-funded wetted habitat surveys and water quality loggers allowed CSG researchers to inform beneficial timing, as well as document success and limitations of, these small-scale instream flow releases. The wet/dry maps, flow and DO data collected through these efforts have led the partner agencies coordinating these efforts to pursue infrastructure improvements for the two Green Valley Creek flow releases in 2019.

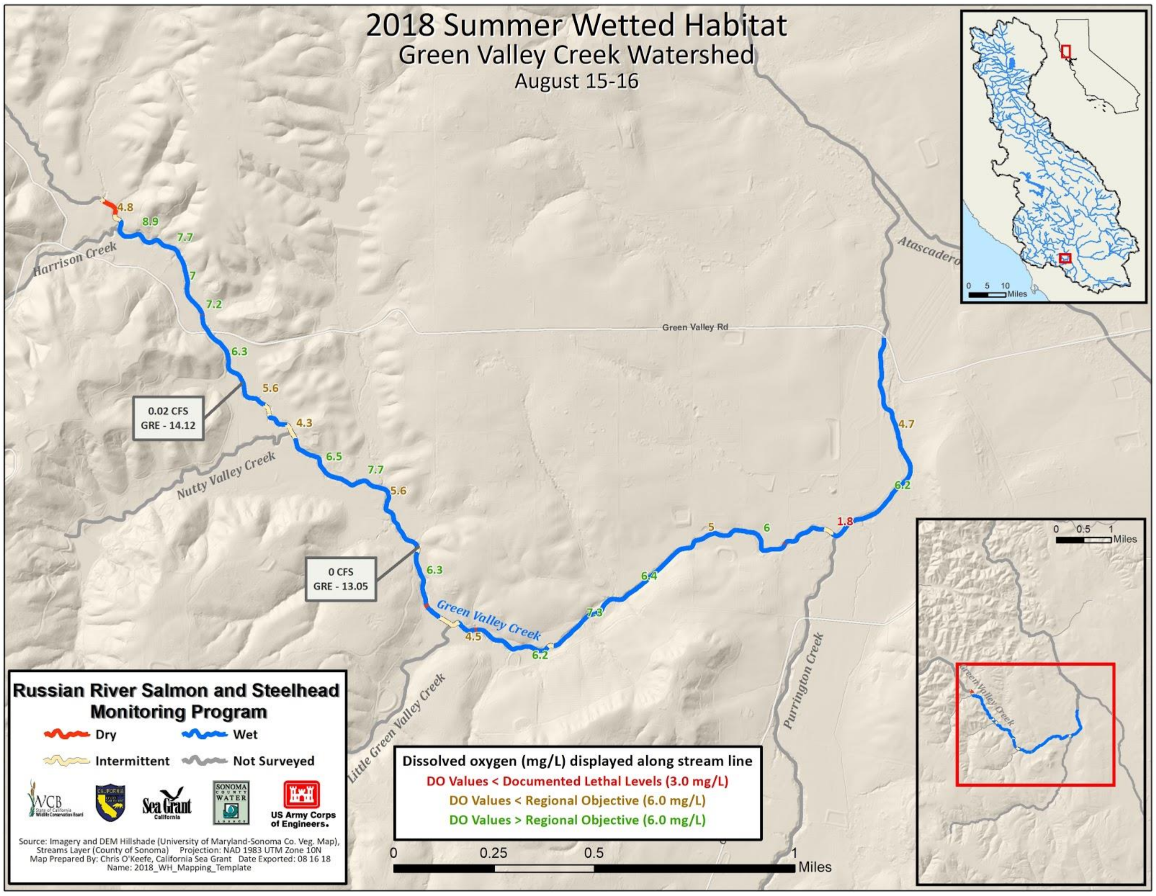

FIGURE 40. GREEN VALLEY CREEK WETTED HABITAT CONDITIONS AND DO CONCENTRATIONS, AUGUST 15-16 2018.

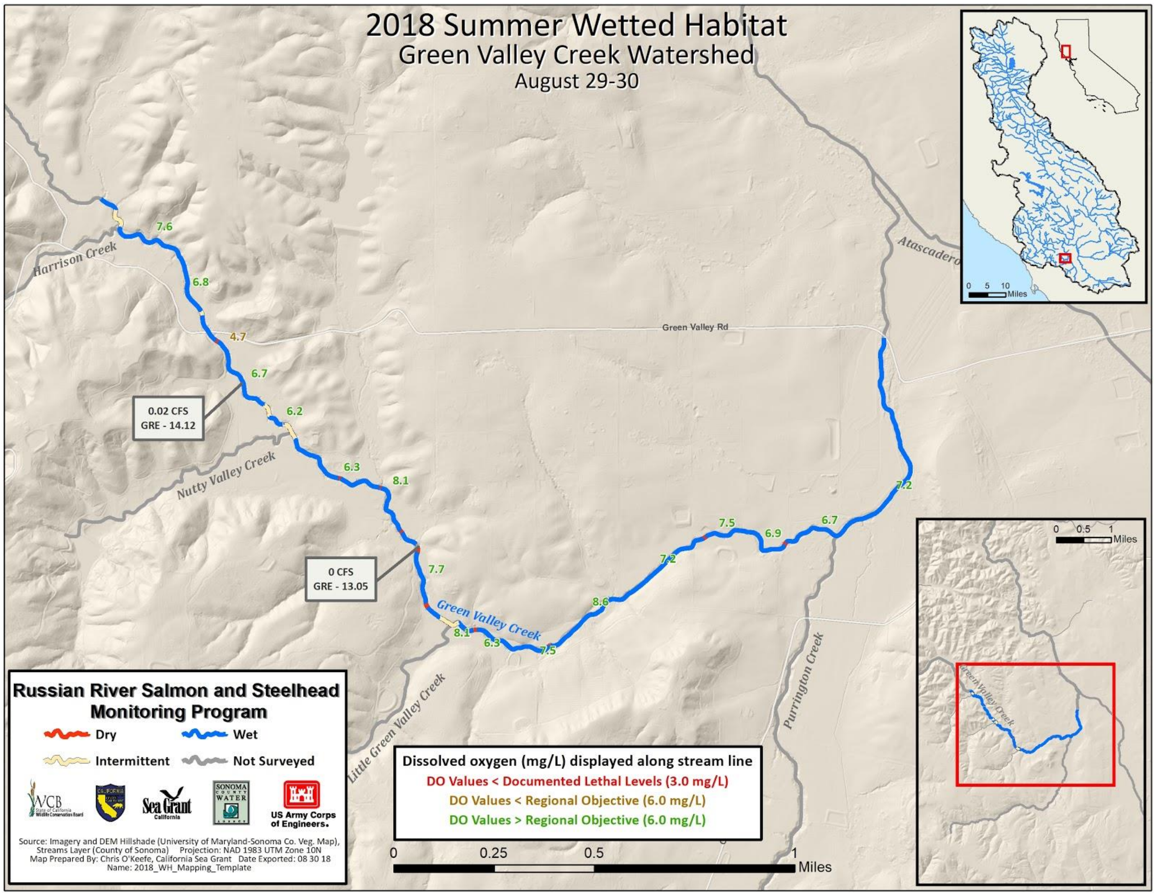

FIGURE 41. GREEN VALLEY CREEK WETTED HABITAT CONDITIONS AND DO CONCENTRATIONS ON AUGUST 29-30, 2018.

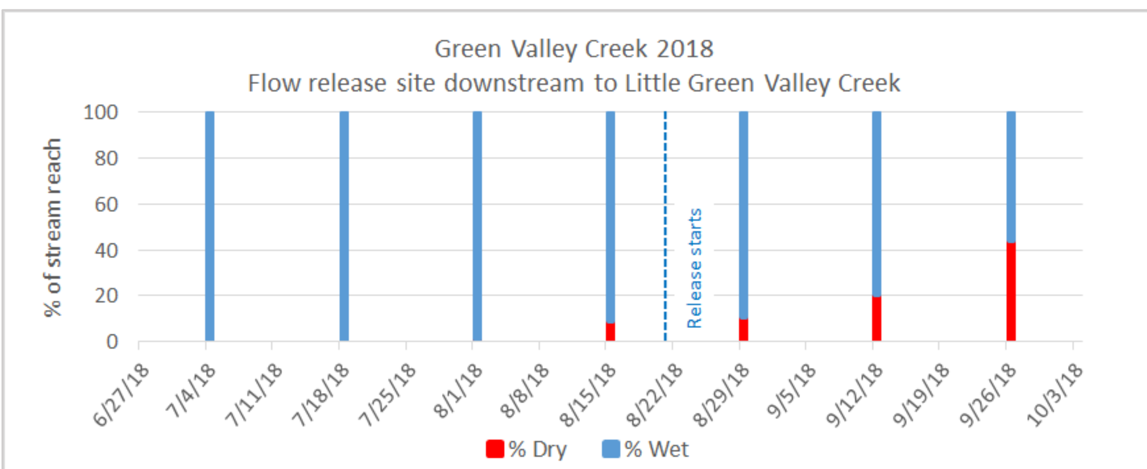

FIGURE 42. WETTED HABITAT CONDITIONS BELOW THE LOWER GREEN VALLEY FLOW RELEASE SITE.

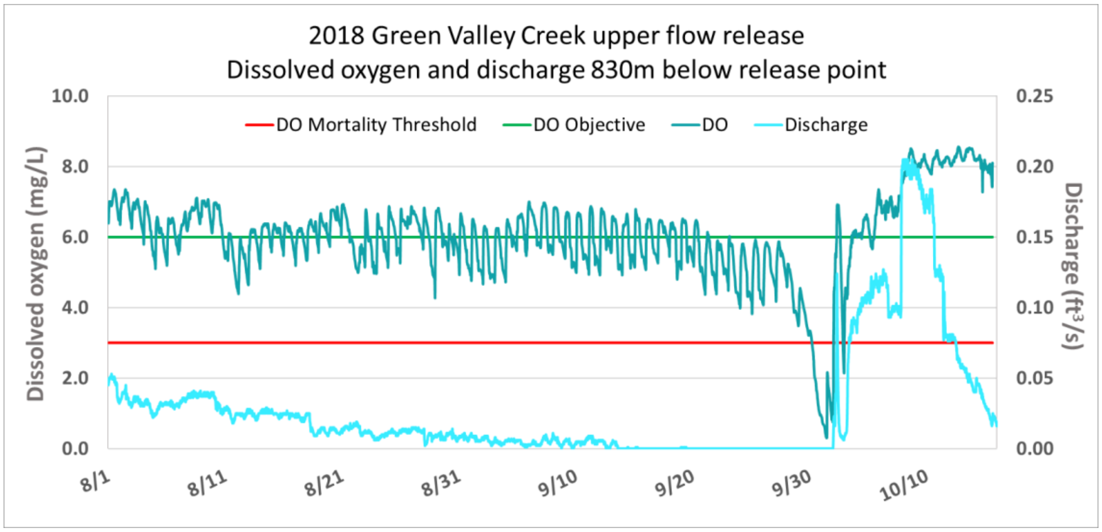

FIGURE 43. STREAMFLOW AND DISSOLVED OXYGEN DATA FROM LOGGERS 830 METERS DOWNSTREAM OF THE FURTHERST UPSTREAM GREEN VALLEY CREEK FLOW RELEASE, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), AUGUST-OCTOBER 2018.

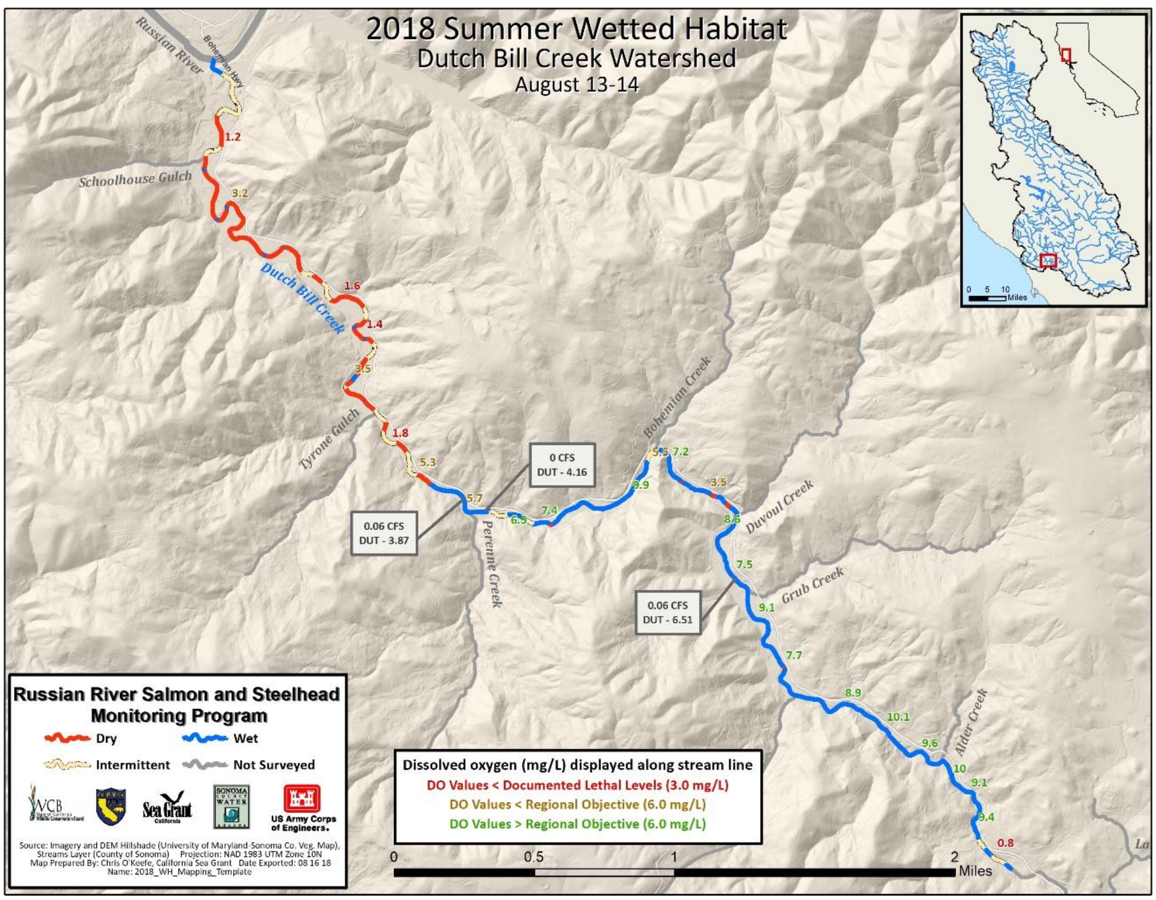

FIGURE 44. DUTCH BILL CREEK WETTED HABITAT CONDITIONS AND DO MEASUREMENTS ON AUGUST 13-14, 2018.

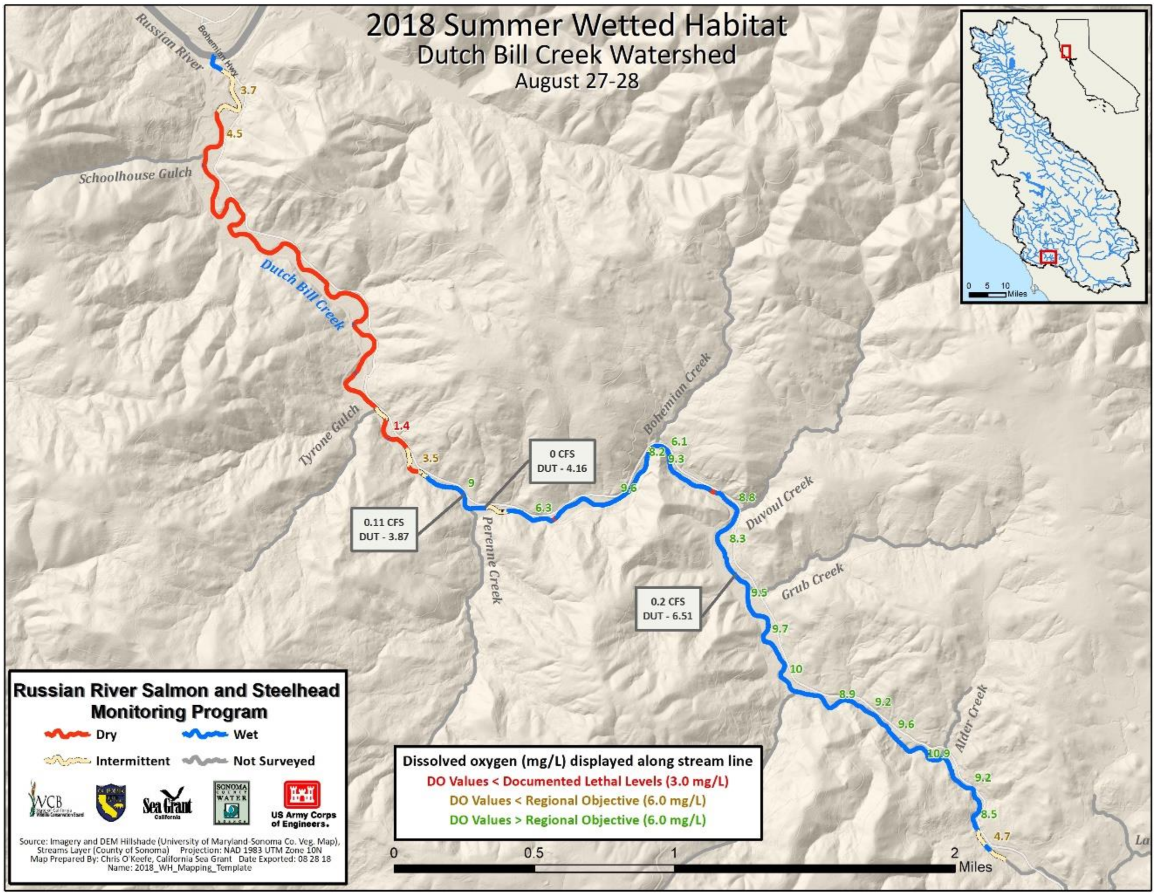

FIGURE 45. DUTCH BILL CREEK WETTED HABITAT CONDITIONS AND DO MEASUREMENTS ON AUGUST 27-28, 2018.

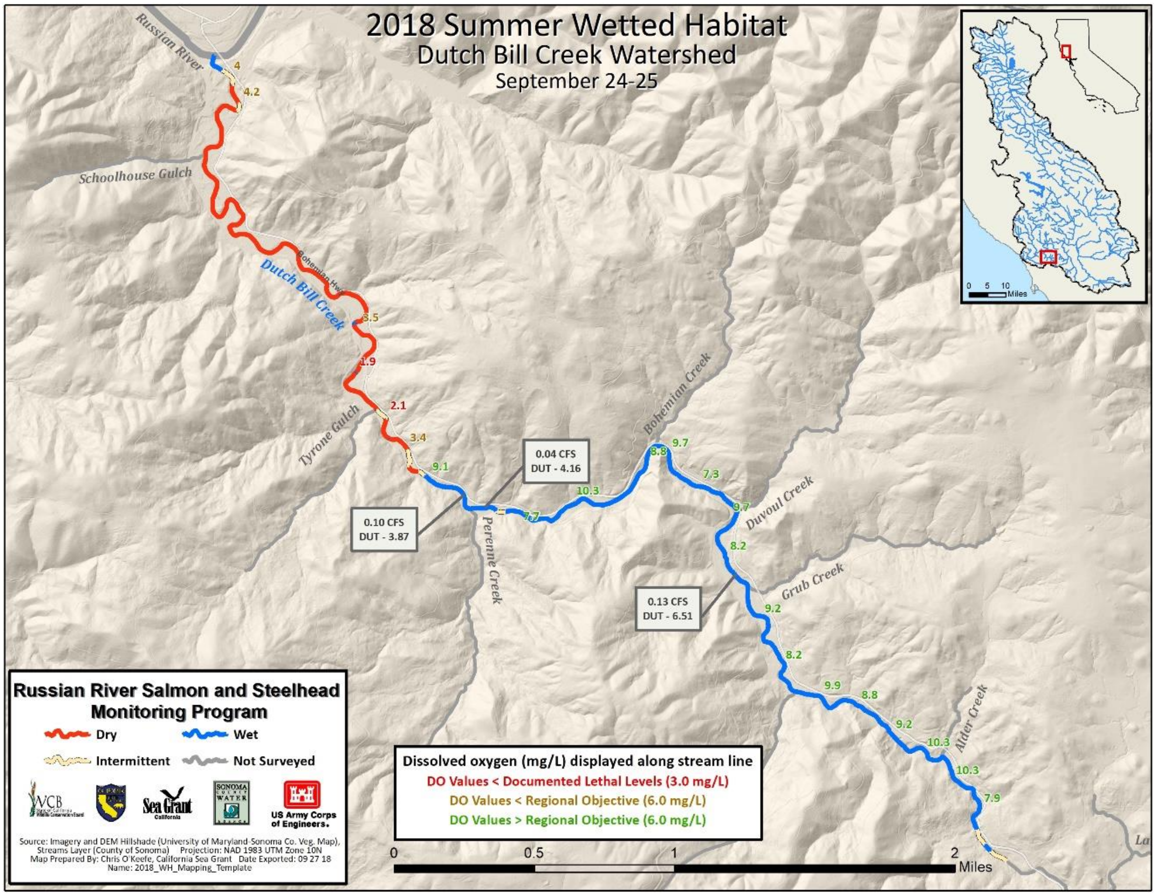

FIGURE 46. DUTCH BILL CREEK WETTED HABITAT CONDITIONS AND DO MEASUREMENTS ON SEPTEMBER 24-25, 2018.

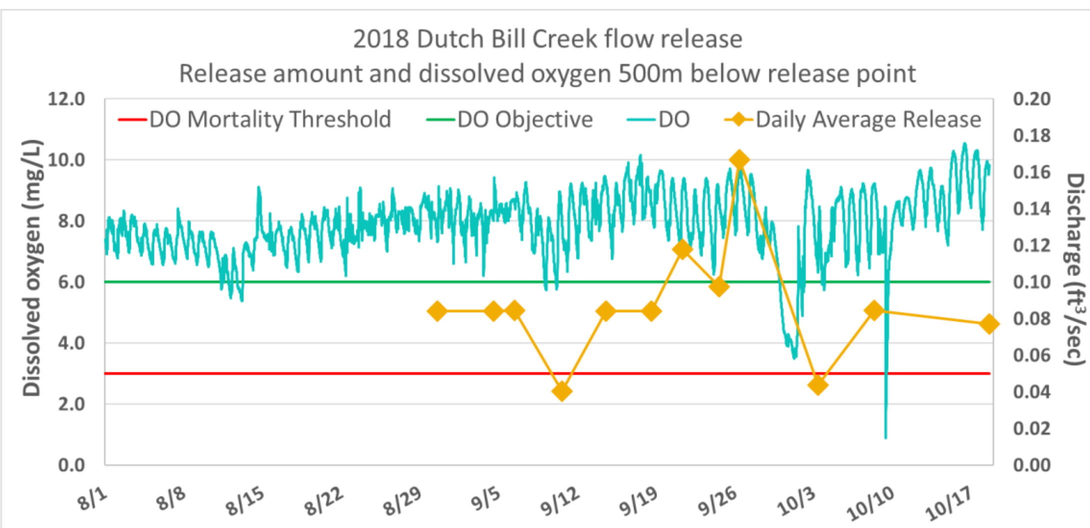

FIGURE 47. DAILY AVERAGE VOLUME OF WATER RELEASED INTO DUTCH BILL CREEK AND DISSOLVED OXYGEN CONCENTRATION FROM A LOGGER 500 METERS DOWNSTREAM OF THE DUTCH BILL CREEK FLOW RELEASE, PLOTTED WITH REGIONAL DO OBJECTIVE (6.0 MG/L) AND SALMONID MORTALITY THRESHOLD (3.0 MG/L), AUGUST-OCTOBER 2018.

TECHNICAL MEETING AND 2019 MONITORING PLAN

On March 21, 2019, CSG held a meeting to share updates on WCB-funded grant activities conducted over the summer of 2018. This meeting also served as a forum for all partners conducting flow-related research on Russian River tributaries to share information about their efforts over the past year, as well as their plans for the 2019 field season. It created a valuable, previously non-existent, opportunity to promote communication regarding the various complimentary efforts occurring within the watershed and to coordinate related low-flow activities among cooperating partners for the 2019 summer season. Thirty-three individuals from nine partner agencies and organizations attended.

CSG staff presented outcomes from the 2018 wet/dry mapping effort and flow monitoring, results from an ongoing study of dissolved oxygen, as well as outcomes from the Porter Creek flow augmentation study. CSG GIS Specialist, Andrew Bartshire, also presented information about the new map portal that was developed to disseminate project information in 2019. Ted Grantham, of UC Berkeley, shared the results of the two WCB-funded modeling efforts. Two branches of CDFW presented outcomes from their 2018 work related to cannabis and the Mark West Creek Habitat and Instream Flow Study. State Water Quality Control Board staff shared an update on their modeling efforts and analysis of water use datasets in Russian River tributaries. O'Conner Environmental, Inc. presented an in-depth overview of the results of their Mark West Creek Flow Availability Analysis and Mill Creek Watershed Streamflow Study. TU shared preliminary findings from the Lower Mill Creek Groundwater Study and the Coho Partnership's Green Valley Creek groundwater monitoring effort. Finally, staff from NOAA, the Gold Ridge RCD and TU discussed the status of the 2019 flow releases on Dutch Bill and Green Valley creeks. CSG staff also facilitated discussion and coordination of 2019 low-flow season activities and priorities, and development of a general summer monitoring plan.

CSG's plan for monitoring in 2019 is to continue to conduct wet/dry mapping of the same stream reaches at the same intervals as 2018. Wetted habitat maps and associated water quality and streamflow data will be disseminated among all coordinating partners on an ongoing basis via a publically-accessible ArcGIS Online web-based map portal (https://russianrivercoho.maps.arcgis.com/apps/MapSeries/index.html?appid=9296ce42714a4647a655a4e8567a8d0b). This virtually real-time data will help to guide in-season management decisions (e.g., fish rescues and flow releases).

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