Implementation of California Coastal Salmonid Monitoring in the Russian River Watershed (2015-2019)

Final Report to the California Department of Fish and Wildlife, Fisheries Restoration Grants Program, Grantee Agreement: P1430411

Sonoma County Water Agency (Sonoma Water)
404 Aviation Boulevard
Santa Rosa, California 95403

California Sea Grant
600 American Way, Suite 1
Windsor, CA 95492

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Contributors:
Sonoma Water: Gregg Horton, Aaron Johnson, Andrea Pecharich, Justin Smith
California Sea Grant: Mariska Obedzinski, Andy McClary, Andrew Bartshire, Nick Bauer

Table of contents

List of tables

List of figures

List of appendices

Executive summary

Between June 2015 and February 2019, the Sonoma County Water Agency (Sonoma Water) and California Sea Grant continued implementation of the Coastal Monitoring Plan (CMP, Adams et al. 2011) in the Russian River Watershed. During this contract period, we further refined the Russian River sample frame and completed four seasons of data collection, adding to a long-term dataset which began in 2013 when CMP implementation first began in the Russian River watershed.

Although the sample frame for the Russian River was largely defined prior to this grant period via desktop exercises, it remained incomplete because field reconnaissance had not yet been conducted on a high proportion of reaches to confirm that they contain salmonid habitat. Multiple iterations of the sample frame (along with annual GRTS draws) occurred as we conducted reconnaissance and added and removed reaches. In 2016, we finalized the GRTS draw and continued to attribute each reach within the frame with species and life stage as field reconnaissance occurred. As of February 2019, we have completed juvenile and adult Coho Salmon and adult Chinook Salmon stratification, with stratification by juvenile and adult steelhead well underway. In addition, rotating panels were developed for both Coho and steelhead adult strata.

Life cycle monitoring was conducted in Dry Creek for Coho Salmon and steelhead and on the mainstem Russian River for Chinook Salmon. A combination of dual-frequency identification sonar (DIDSON), passive integrated transponder (PIT) detection systems and video was used to count returning adults, and spawner surveys were conducted in all suitable and accessible habitat within the Dry Creek watershed. We used downstream migrant traps on mainstem Dry Creek, Mill Creek (a tributary entering Dry Creek downstream of the Dry Creek trap) and at Sonoma Water's Mirabel dam site on the mainstem Russian River to count Coho, steelhead and Chinook smolts. We combined trap data with data from stationary PIT tag detection systems and/or used mark-recapture models to estimate smolt abundance. Because a significant portion of steelhead smolts migrate during the winter when traps cannot be operated, we used an alternative, pre-smolt abundance modeling approach to estimate steelhead smolt abundance that was based on summer electrofishing and winter PIT antenna operation in Dry Creek and Mill Creek.

Our life cycle monitoring data showed a steady increase in Coho Salmon and steelhead redd abundance in Dry Creek tributaries each year since we began CMP spawner surveys in 2013/14 until 2017/18 when redd abundance for both species decreased. In the case of Coho redds, some of this decrease was likely from an increase in the proportion of jack (age-2) returns (more jacks mean fewer redds). The number of redds from 2015/16 to 2017/18 observed in Pena Creek was consistently high, especially for steelhead, and the seasonal total of Coho redds was consistently highest in Mill Creek. The estimated Coho smolt abundance at the Mill Creek trap more than doubled since 2016; unfortunately, the trap catch on Dry Creek was too low to estimate Coho smolt abundance. Catches of steelhead smolts were also too low at both Dry Creek and Mill Creek to estimate abundance. Our alternative, model-based approach for estimating steelhead smolt abundance apparently worked well for Mill Creek, but the results for Dry Creek are inconsistent among years.

For basinwide monitoring, we used a random, spatially-balanced sampling approach (GRTS) to select reaches to survey for use in developing estimates of basinwide Coho and steelhead redd abundance. For the first two winters of the grant period, we conducted surveys for both species within the adult Coho stratum only (primarily lower basin). Beginning in 2017/18, we expanded our sampling to include the entire adult steelhead stratum. The winter of 2017/18 also represented the first year we employed a rotating panel design for Coho Salmon and steelhead surveys. We used this same GRTS-based sampling design each year to select reaches to snorkel survey in order to depict juvenile Coho Salmon spatial structure.

There was an increasing trend in basinwide Coho Salmon redd abundance that mirrored estimated Coho Salmon redd abundance in Dry Creek tributaries. In 2017/18, we conducted steelhead spawner surveys for the first time in the adult steelhead stratum. The estimate of 905 redds (±465 95% CI) shows low precision that could likely be improved by surveying more reaches, but an increased sampling rate would increase project cost. Juvenile Coho spatial structure sampling was highest in 2015 (37%) and lowest in 2017 (21%).

CMP implementation in the Russian River has been successful in several respects. In 2018, we generated the first basinwide estimate of steelhead redds (2017/18 season) and we have demonstrated the value of PIT tags and PIT antenna arrays for estimating smolt abundance. PIT tools have also allowed us to gain insights regarding Russian River salmonid life history diversity which is one of the four key population characteristics that comprise the viable salmonid population framework (McElhany et al. 2000). On Mill Creek, we developed and implemented a conceptually-sound approach that combines robust juvenile population estimates in the fall with year-round, stationary PIT antenna monitoring to help address the universal issue of estimating steelhead smolt abundance in northern California coastal systems at times when streamflow renders conventional downstream migrant trapping infeasible.

Unfortunately, however, we have also encountered impediments to successful life cycle monitoring in the Dry Creek watershed that will be impossible to overcome. Some of those challenges arise from the size of mainstem Dry Creek. These include completion of full spawner surveys for Coho Salmon and steelhead in mainstem Dry Creek and accurately estimating Coho Salmon and steelhead smolt production from a major portion of the Dry Creek watershed. Other challenges relate to the fact that we are using DIDSON to count the number of adult salmonids entering Dry Creek. While DIDSON is an excellent tool for counting adult, salmonid-sized fish entering Dry Creek, there is no way to accurately assign species without additional, reliable data and our attempts to implement and collect such data have been unsuccessful.

Because of these challenges, we consulted with representatives from the statewide CMP Science and Management Teams along with staff from California Department of Fish and Wildlife and NOAA Fisheries to discuss the possibility of changing our life cycle monitoring system from the Dry Creek watershed to a combination of Mill Creek (already being monitored as part of the Dry Creek life cycle monitoring system), Green Valley Creek, Dutch Bill Creek and Willow Creek. After agreeing to make this change, we have been preparing to implement much of what we learned in the Dry Creek system in these four lower basin tributaries during the next grant cycle which began March 1, 2019. Some of the benefits of selecting these tributaries include: existing monitoring infrastructure already maintained by Sonoma Water and California Sea Grant, a long history of employing all of the CMP monitoring methods in these tributaries, and the important habitat these four tributaries provide for Coho Salmon populations in the basin. Our monitoring objectives will remain consistent with the CMP by applying a mix of conventional and innovative approaches. We are confident that by bringing to bear the significant and collective fish monitoring experience of Sonoma Water and California Sea Grant we can meet CMP monitoring needs in Mill, Green Valley, Dutch Bill and Willow Creeks and provide high quality data to inform statewide CMP goals.

Introduction

Coho Salmon and steelhead numbers throughout California have declined, leading to the listing of both species under the California Endangered Species Act (CESA) and Federal Endangered Species Act (ESA). Coho Salmon in the Central California Coastal (CCC) Evolutionarily Significant Unit (ESU) are listed as endangered. Steelhead in the CCC ESU and Chinook Salmon in the California Coastal (CC) ESU are listed as threatened. The Russian River historically supported large populations of Coho Salmon and steelhead, and the National Marine Fisheries Service (NMFS) designated much of the watershed as critical habitat for Coho and Steelhead (NMFS 2008). Critical habitat for Chinook includes mainstem Russian River, Austin Creek, Mark West Creek, Dry Creek and Forsythe Creek. The Russian River is the largest watershed in the Coho Salmon CCC ESU comprising approximately one-third of the ESU and it is important to the survival and recovery of CCC steelhead and CC Chinook.

As stated in the California Coastal Salmonid Population Monitoring Plan (CMP, Adams et al. 2011), there is an immediate need for monitoring data in order to provide a measure of progress toward recovery, as well as to inform related management activities. The CMP goes further to state the importance of standardizing data collection methods so that data collected across drainages is comparable. To that end, the CMP describes the overall strategy, design, and methods for monitoring. The objectives of CMP monitoring are to estimate status and trends of Coho Salmon, steelhead, and Chinook Salmon by providing measures of the four Viable Salmonid Population (VSP) parameters (McElhany 2000): abundance, productivity, spatial structure, and diversity.

The Sonoma County Water Agency (Sonoma Water) has been collecting data from fish populations in the Russian River Basin since 1999 and California Sea Grant (CSG) has been collecting data from Coho Salmon and steelhead populations in the Basin since 2004. These programs represent a substantial monitoring infrastructure that we expanded upon to meet the objectives of the CMP. In 2013, Sonoma Water and CSG received the first Fisheries Restoration Grant Program (FRGP) grant to implement CMP monitoring in the Russian River watershed. Work completed during this first FRGP grant was summarized in the final grant report, submitted for California Department of Fish and Wildlife (CDFW) in 2015 (Sonoma Water and CSG 2015). A second FRGP grant was obtained in 2014 to continue CMP implementation seamlessly when the first grant ended in 2015. The current report summarizes monitoring that occurred during the term of this second FRGP grant (June 2015 to February 2019). At this time, further funding has been secured to continue Russian River CMP implementation through November 2021.

The major elements of CMP monitoring are life cycle monitoring and basinwide monitoring. Life cycle monitoring stations provide estimates of freshwater and ocean survival and include measures of adult and smolt abundance from counting stations as well as estimates of adult: redd ratios (Adams et al. 2011). Basinwide monitoring provides estimates of adult abundance and juvenile spatial structure with survey reaches selected in a random, spatially-balanced manner (Adams et al. 2011).

Project area

The Russian River is approximately 3,800 km^2 and includes over 200 tributaries that provide anadromous salmonid habitat. The watershed consists of a series of valleys surrounded by two mountainous coast ranges, the Mendocino Highlands to the west and the Maacamas Mountains to the east. The Santa Rosa Plain, Alexander Valley, Hopland (or Sanel) Valley, Ukiah Valley, Redwood Valley, Potter Valley and other small valleys comprise about 15 percent of the watershed. The remaining area is hilly to mountainous. Principle communities are Ukiah, Hopland, Potter Valley, Cloverdale, Healdsburg, Windsor, Forestville, Sebastopol, Santa Rosa, Rohnert Park, Cotati, and the Russian River resort area, stretching from Mirabel Park to the mouth of the Russian River, and contains the communities of Rio Nido, Guerneville, Monte Rio, Duncans Mills and Jenner.

Salmonid populations

Coho Salmon existed historically in the Russian River basin as two distinct populations; a large independent population in the lower basin, and a smaller population that occupied the tributaries in the northwest corner of the basin (Bjorkstedt et al. 2005). Now, both abundance and distribution of Coho have declined to the point that they are restricted primarily to tributaries in the lower third of the watershed and there is evidence of a loss of genetic diversity for Russian River Coho populations. In 2001 the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) was initiated to prevent extirpation of Coho in the basin. The primary goal of the Broodstock Program is to preserve genetic, ecological, and behavioral attributes of Russian River Coho Salmon by re-establishing self-sustaining runs in tributaries in the Russian River basin (NMFS 2008). At Don Clausen Fish Hatchery at Warm Springs dam, offspring of natural-origin Coho are reared to the adult stage and spawned. Progeny are released as juveniles into tributaries in their historic range with the expectation that a portion of them will return to reproduce naturally.

Historical estimates suggest that tens of thousands of steelhead inhabited the Russian River in the early to mid-20th century (NMFS 2008). Since then, populations have declined, but they remain widely distributed throughout the basin. Primary exceptions to this are barriers to anadromy caused by Coyote Valley Dam (CVD) and Warm Springs Dam (WSD) which have blocked large portions of historical steelhead habitat in the basin (Spence et al. 2012).

Relatively little is known about historical Chinook Salmon abundance and distribution in the Russian River, but spawning was likely confined to the mainstem and, opportunistically, in some of the larger tributaries (NMFS 2016; Chase et al. 2007). Current water supply operations provide consistent stream flow downstream of CVD in mainstem Russian River and WSD in mainstem Dry Creek. This steady flow coupled with low gradient and suitably-sized spawning substrate is attributed with creating consistent and suitable spawning habitat for Chinook (Cook 2008) and an annual adult return of approximately 1,100 to 6,700 individuals (Martini-Lamb and Manning 2014).

Project goals

The goals of this project were to (1) continue to refine the Russian River CMP sample frame and (2) continue implementation of the CMP in the Russian River watershed. We conducted monitoring to estimate adult abundance of adult Coho Salmon, steelhead and Chinook Salmon, spatial structure of juvenile Coho, and characterization of life history diversity of Coho, steelhead and Chinook. Operation of life cycle monitoring stations on Dry Creek, Mill Creek and mainstem Russian River were used to collect trend data on adults and smolts and to calculate spawner: redd ratios. A combination of passive integrated transponder (PIT) detection systems and collection of otoliths from adult carcasses and scale samples from smolts was used to characterize run-timing, age at smoltification and age of adult returns.

For all four years of the project, we conducted life cycle monitoring in Dry Creek and basinwide monitoring in reaches comprised of both Coho Salmon and steelhead habitat (the Coho-steelhead stratum). During the second two years of the project, we also conducted basinwide monitoring in habitat considered steelhead-only (the steelhead-only stratum, see Chapter I) thus expanding our efforts to a much larger portion of the Russian River basin. Life cycle monitoring for Chinook was conducted as well but construction of a new fish ladder at the Mirabel Dam interrupted our ability to provide data for all four years of the project period.

During the first year of the previous project, we convened the Russian River Coastal Monitoring Plan Technical Advisory Committee (RRCMPTAC) that includes members of the statewide CMP Science and Management Teams, CDFW and NMFS. A result of that effort was a plan describing the monitoring necessary to accomplish CMP goals in the Russian River watershed (Sonoma Water and CSG 2014). The RRCMPTAC met annually during the current project period so that team members could provide technical advice and guidance. Based on recommendations from the RRCMPTAC, we limited basinwide monitoring to the Coho-steelhead stratum during the first two years of the project in order to maximize the information gains given the available time and budget, and expanded to the steelhead-only stratum during the final two years of the project. Life cycle monitoring for Chinook Salmon was paid for by Sonoma Water.

Data collection, QA/QC and storage

All tabular data were recorded on Allegro MX and A2 (Juniper Systems) field computers by crews of trained field technicians. At the end of each sampling day, crews transferred data from the field computer into an Excel spreadsheet for initial QA/QC. The initial QA/QC was facilitated by a Visual Basic macro that prepared data by archiving raw data, formatting data, and creating a series of pivot tables designed to highlight common field data entry errors. Individual files that had been through the initial QA/QC were appended weekly to a single Excel spreadsheet where they went through a second round of QA/QC employing more pivot tables to highlight a wider variety of errors than the initial QA/QC. At the end of each season of data collection, a final QA/QC of the data was performed. This involved checking each column of data for inconsistencies, comparing raw and corrected files to files in the master file to make sure all data collected was accounted for, and reconciling any inconsistencies between tabular and spatial data. Weekly and final QA/QC was conducted by the project coordinator before upload to the statewide Aquatic Survey Program (ASP) database.

Spatial data were generally collected using Allegro field computers. MX Allegro's were modified with GPS antennas to allow for spatial data collection, whereas A2 Allegros were GPS capable out of the box. Field crews carried tablet computers to assist with navigation and to provide information about landowner access, parking and other logistical details. In the event that GPS capabilities on the Allegro were compromised (e.g., malfunctioning equipment, poor satellite reception) spatial data points were collected with tablet computers or a separate Garmin Explorer GPS device. Spatial data were entered directly into the tabular data on the Allegro, unless other devices were used. In such cases, spatial data coordinates were transferred into the tabular data upon returning to the office (prior to the initial QA/QC). Spatial data were imported to ArcMap for QA/QC. Gross spatial errors and missing points were identified during the second level QA/QC of tabular data. Spatial data were stored in a local spatial database prior to submission to the ASP database at the end of each field season.

Chapter I. Sample frame and rotating panels

Introduction

Much of the monitoring aimed at accomplishing the objectives of the CMP in the Russian River watershed is based on a sample frame which represents all reaches in the watershed that contain habitat for one or more species-life stage combinations of anadromous salmonids. In the Russian River, we considered multiple species-life stage combinations when defining the sample frame: adult and juvenile Coho Salmon, adult and juvenile steelhead and adult Chinook Salmon. We used the generalized random tessellation stratified (GRTS) spatially-balanced survey design outlined in Adams et al. (2011) to assign a draw order which was then used as a source for obtaining a statistically valid sample of reaches for basinwide adult (spawner) and juvenile (snorkel) surveys.

Methods and Results

In 2012, we began a series of meetings with professionals familiar with anadromous salmonid habitat in the Russian River to define the extent of spawning and juvenile rearing habitat for Coho Salmon, steelhead, and Chinook Salmon in the Russian River basin. Professional expertise and available GIS and related data (e.g., California Fish Passage Assessment Database, NMFS' Intrinsic Potential model) were used to define the extent of Coho, Chinook and steelhead spawning and juvenile rearing habitat in all streams of the Russian River Basin. We included portions of streams that contain habitat for one or more species that were downstream of known anadromy barriers. This exercise resulted in a universe of habitat space divided into 537 reaches approximately 1-3 km in length (2.4 km average) that served as the basis for the reach-based sampling starting in 2013. Collectively, the reaches that contain habitat for any of the species of interest are referred to as a "sample frame" (Adams et al. 2011). Reaches significantly shorter than 1 km were designated as "sub-reaches" and attached to the closest "parent-reach". When we sampled a parent-reach, we also sampled associated sub-reaches to maximize efficiency (Garwood and Ricker 2014). Reaches were then assigned a draw order using GRTS sampling in a manner that allows a spatially-balanced random sample of reaches following the process detailed in Garwood and Ricker (2011).

During the initial phase of sample frame development, for many reaches we had little to no first-hand knowledge of whether the reach contained salmonid habitat. Therefore, based on Adams et al. (2011) and input from the statewide CMP Science Team, we used desktop criteria (i.e., stream gradient and NMFS' IP model, Garwood and Ricker 2011) as well as best professional judgement from local fisheries biologists familiar with the watershed to make a first draft of the Russian River sample frame. The first draft of the sample frame included many reaches that were later determined not to contain salmonid habitat after field reconnaissance was conducted. This overly-inclusive draft sample frame was superior to one that failed to include reaches containing salmonid habitat because addition of reaches would alter the underlying GRTS reach numbering thus necessitating a new draw. Alternatively, removal of reaches from the sample frame has no such consequences. Because adding reaches is undesirable for this reason, guidance from the CMP Science Team suggested that we consider the sample frame to be in draft form for the first four years of CMP implementation and only consider adding reaches based on results of field reconnaissance during that period. During the project period, field reconnaissance did result in the reclassification of reaches previously excluded from the sample frame as containing salmonid habitat. These reclassifications necessitated renumbering of the GRTS reaches and assigning a new draw order. In winter 2017, the Russian River sample frame was finalized and the final GRTS draw order was generated. At this time we have surveyed or conducted field reconnaissance on the majority of the reaches in the lower basin (i.e., mainly Coho habitat) but there are still well over 100 reaches in the upper basin (mainly steelhead habitat) where we have not surveyed or conducted reconnaissance. As we continue to conduct field reconnaissance, we will continue to remove reaches that do not contain salmonid habitat. We will also make adjustments to reach boundaries where previously unknown/undocumented barriers to anadromy are found and suitable salmonid habitat is located upstream of these barriers. At the end of this contract period in February 2019, there were 469 reaches classified as containing salmonid habitat for at least one of the three anadromous salmonid species in the Russian River watershed (Figure I-1).

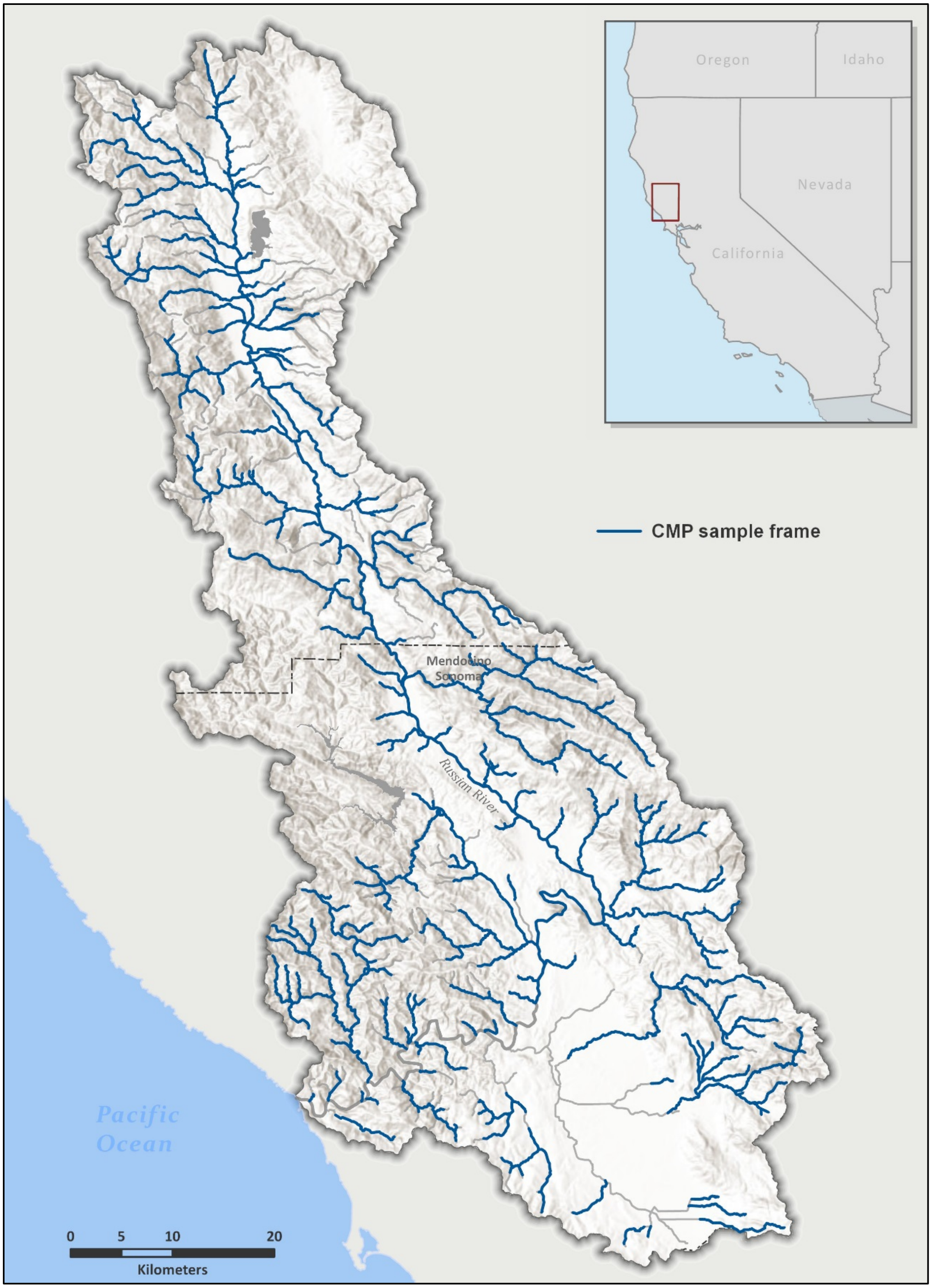


Figure I-1. Russian River watershed and CMP sample frame.

Species and life stage assignments

Although there is only one sample frame for the Russian River, we can make species and life stage assignments to each reach in the sample frame which is useful for making species- and life stage-specific inferences. To accomplish this we made an initial assessment as to whether the reach contained adult Coho, juvenile Coho, adult steelhead, juvenile steelhead, and/or adult Chinook habitat. To date, those assessments lead us to conclude that Coho habitat is primarily confined to the lower third of the basin (Figure I-2), steelhead habitat is widespread in streams throughout the watershed (Figure I-3) and Chinook habitat primarily occurs in the mainstem of the Russian River and in larger tributaries (Figure I-4). Species and life stage classifications were initially based on the desktop exercise used for early sample frame development, and then updated based on field reconnaissance and/or previous experience of local fish biologists from CDFW, Sonoma Water, NMFS, and CSG. We anticipate that continued reconnaissance will result in changes to species-life stage reach assignments until all reaches have been visited (Appendix A).

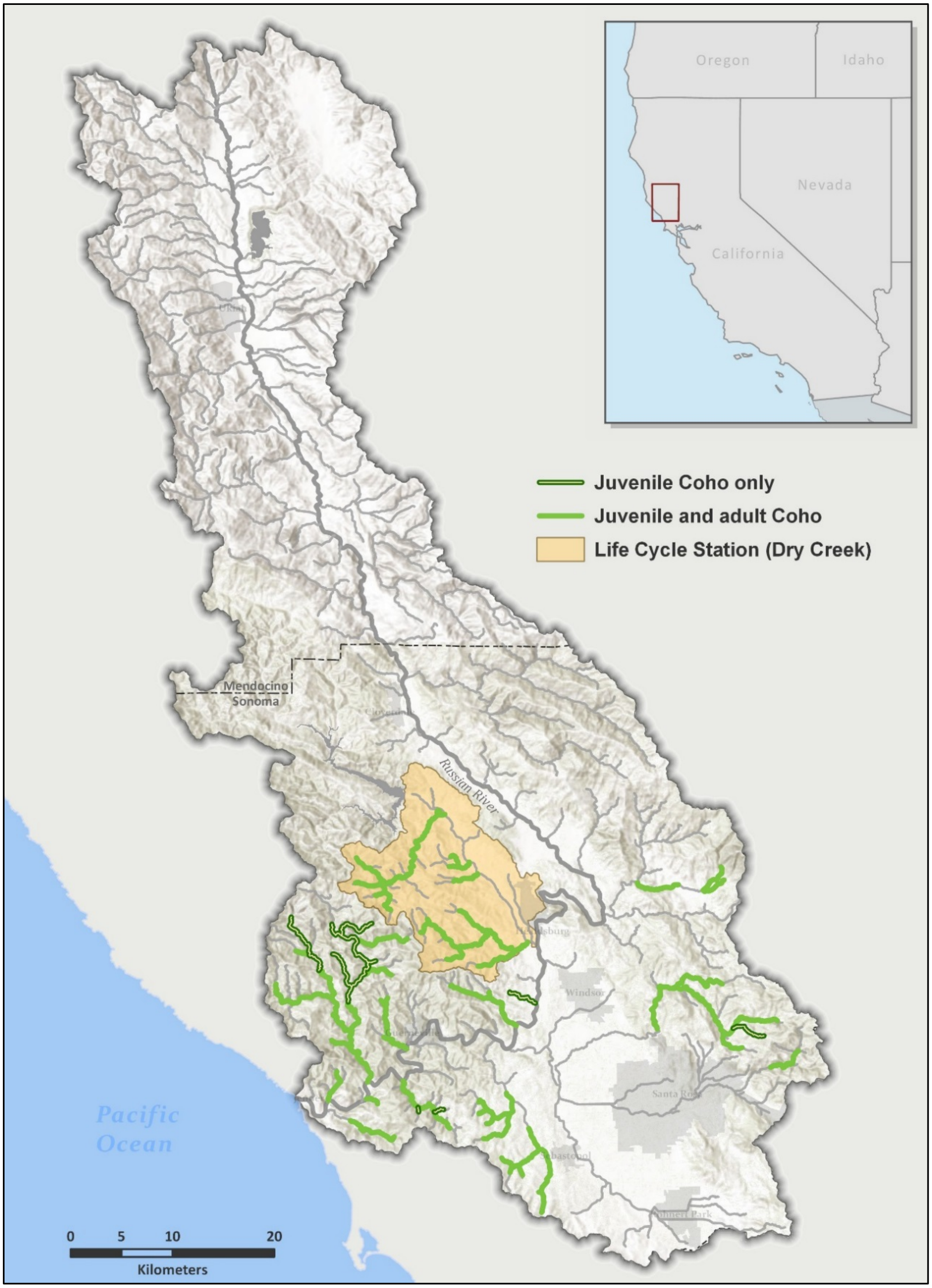


Figure I-2. Surveyable adult and juvenile Coho reaches within the Russian River watershed. Reaches where full spawner surveys for Coho cannot be conducted are not shaded (e.g., mainstem Dry Creek). Note that all reaches in the sample frame that provide Coho habitat also provide steelhead habitat.

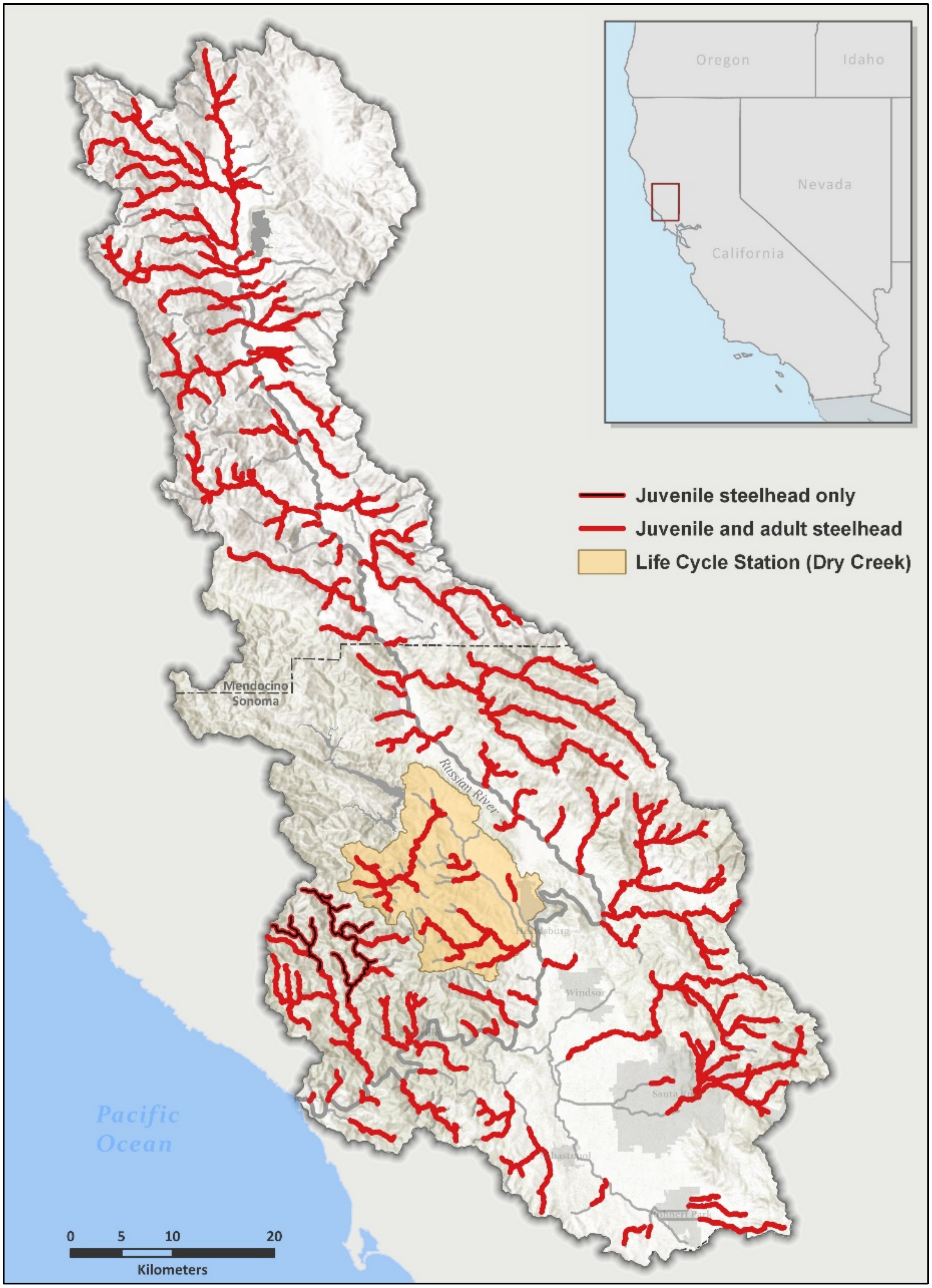


Figure I-3. Surveyable adult and juvenile steelhead reaches within the Russian River watershed. Reaches where full spawner surveys for steelhead cannot be conducted are not shaded (e.g., mainstem Dry Creek).

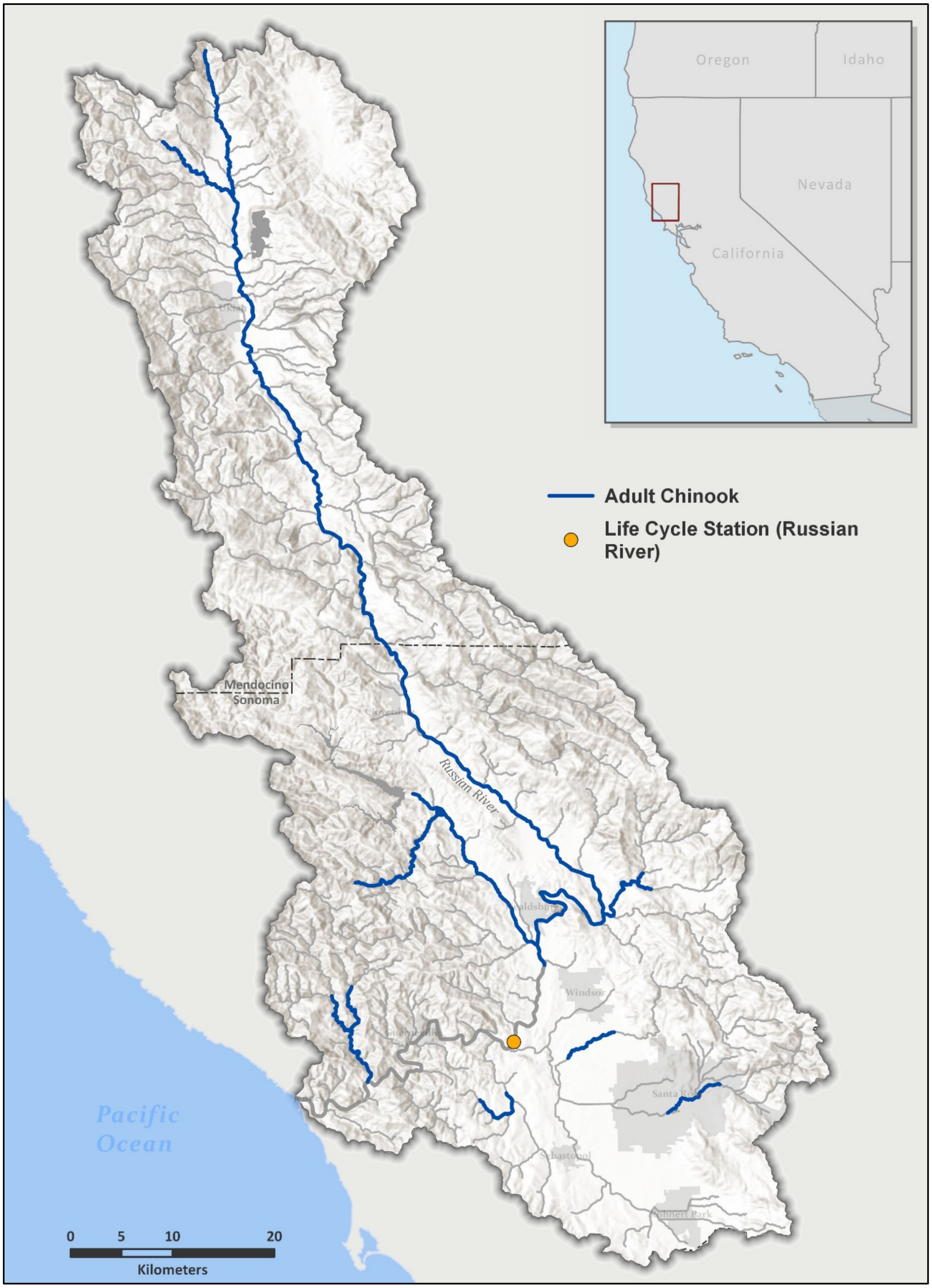


Figure I-4. Chinook spawning reaches within the Russian River watershed.

Basinwide Coho Salmon and steelhead adult sampling

We applied a soft-stratification approach as outlined in Adams et al. (2011) to determine the number of reaches for inclusion in species-specific, basinwide redd and adult abundance estimates. The basis of this approach was the species and life stage reach assignments described above. For each species-specific stratum, our starting point was the number of reaches within the Russian River sample frame that contained adult spawning habitat (103 Coho reaches and 426 steelhead reaches, Table I-1). There are two categories of sampling constraints that could limit our ability to survey all reaches in a given stratum: permanent and temporary. Permanent constraints include lack of physical access (such as no roads) that would make biweekly spawner surveys impossible and persistently high winter-time flows that would make surveys unsafe for survey crews. Temporary sampling constraints include lack of landowner permission to access the reach. Reaches with permanent sampling constraints were removed from soft-stratification (but not the sample frame) while reaches with temporary sampling constraints remained in the soft-stratification. Reaches removed from soft-stratification were excluded from reach expansion calculations while reaches remaining in the soft-stratification were included in reach expansion calculations. Of the 103 reaches in the adult Coho stratum and 426 reaches in the adult steelhead stratum (Table I-1), 23 and 31 could be consistently surveyed for Coho and steelhead, respectively, and were therefore included in basinwide redd estimates.

Juvenile Coho Salmon sampling

To determine the number of reaches for inclusion in basinwide juvenile Coho occupancy estimates, our starting point was the number of reaches within the Russian River sample frame that contained juvenile Coho rearing habitat (105 reaches, Table I-1). Similar to spawner surveys, we did not make inference to permanently constrained reaches where consistently poor underwater visibility in the summer makes surveying impossible. These reaches were generally lower in watersheds in areas of low gradient slough habitat (e.g., lower reaches of Green Valley and Willow Creeks). Reaches with permanent sampling constraints were removed from soft-stratification (but not the sample frame) while reaches with temporary sampling constraints remained in the soft-stratification. Reaches removed from soft-stratification were excluded from juvenile occupancy estimates while reaches remaining in the soft-stratification were included in juvenile occupancy estimates. Of the 105 reaches in the juvenile Coho stratum (Table I-1), 96 could be consistently snorkeled and were therefore included in juvenile Coho occupancy estimates.

Table I-1. Number of reaches by species-life stage stratum in the Russian River watershed as of February, 2019.

Species	Adult[1]		Juvenile	
	Habitat present	Consistently surveyable[2]	Habitat present	Consistently surveyable[2]
Coho Salmon	103	80	105	96
steelhead	426	395	426	417
Chinook Salmon	87	NA[3]	NA[3]	NA[3]

[1]All adult reaches are also classified as juvenile reaches (Adams et al. 2011).
[2]Data from the annual sample of reaches surveyed from the "Consistently surveyable" category are expanded to all consistently surveyable reaches but are not expanded to all reaches where habitat is present in the stratum.
[3]Basinwide spawner and juvenile surveys are not conducted for Chinook.

Rotating panels

Spawner survey reaches for each season were selected using a rotating panel design as outlined in Adams et al. (2011). This sampling design balances monitoring for status and trends by assigning a proportion of reaches to a panel that is sampled every year (improves trend detection) and dividing the remaining reaches into rotating panels which are sampled every 3, 6, 9 or 12 years (improves estimates used to evaluate status by increasing spatial balance). The reaches are first sorted by draw order from lowest to highest and then assigned to the rotating panels (Appendix A). We employed a soft-stratification approach as outlined in Adams et al. (2011) and created separate rotating panel designs for the Coho and steelhead adult strata to enable us to create statistically valid redd estimates for each species.

The number of Coho adult spawning reaches within the Russian River sample frame that can be sampled consistently is 80 (Table I-1). Due to temporary constraints (e.g., landowner access restrictions), we were able to sample 54 of the 80 reaches. Based on available resources as well as our objective of maximizing coverage of the stratum, we selected a sampling design with an annual panel consisting of 22 reaches and three panels of 10 reaches that will be sampled every three years (Table I-2). Reaches were assigned to panels by first sorting all of the reaches in the sample frame by draw order (lowest to highest). We then placed the first 22 accessible adult Coho reaches of the GRTS draw into the annual panel, the next ten into the first 3-year panel, the next ten into the second 3-year panel and so on until the rotating panels were filled. Two remaining reaches were placed in a reserve panel for use if any reaches within the panels become inaccessible in the future. If any of the reaches with temporary constraints (26/80) become accessible in the future, they will be added to the reserve panel.

Table I-2. Coho adult rotating panel design. Shaded panels represent panels sampled for a given year. See Appendix A for tributaries and reaches in each panel.

Sample frequency	Panel	Number reaches in panel	Year 1	Year 2	Year 3
Annual	1	22	22	22	22
3 year	2	10	10		
	3			10	
	4				10
Reaches sampled annually			32	32	32
Cumulative unique reaches			32	42	52

The number of adult steelhead spawning reaches that can be consistently sampled is 395 (Table I-1). During the project period, resources allowed for surveying a total of 30 reaches per year during the winters of 2017/18 and 2018/19. Given this constraint, we selected a rotating panel design for steelhead that includes an annual panel of 12 reaches, three panels of nine reaches that are sampled every three years and 12 panels of nine reaches that are sampled every 12 years (Table I-3). All remaining reaches are available as reserve reaches. Panel assignment for steelhead was more complex than for Coho because relatively little field reconnaissance or surveys had yet been conducted. Furthermore, at the onset of the project period, landowner access was uncertain for most reaches. There are over 4,500 parcels adjacent to reaches within the sample frame (Figure I-5), more than 95% of which are privately-owned, making it impractical to contact every landowner before assigning reaches to panels. Following consultation with members of the CMP Science Team and the RRCMPTAC, we elected to assign reaches to panels dynamically as field reconnaissance is conducted and landowner access is secured. For the first year, we requested access from landowners on the first 60 reaches in the GRTS draw with the hope of gaining access to at least 30 reaches. Once access was secured and reaches were confirmed to contain adult steelhead spawning habitat, reaches were assigned to panels based on the GRTS draw order. The first 12 reaches were assigned to panel 1, the next nine reaches were assigned to panel 2, and the next nine were assigned to panel 5 (Table I-3). Any reaches we obtained access to beyond the 30 required for the initial panels were used to populate panels for the following year. Each year we will use this method to populate new panels that will be surveyed in the current season until all of our panels have been filled (Table I-4). This method allows us to distribute the effort and resources required to obtain landowner access and conduct reconnaissance over multiple years while still retaining the statistical benefits of the GRTS design.

Table I-3. Steelhead rotating panel design. Shaded panels represent panels sampled for a given year. See Appendix A for tributaries and reaches in each panel.

Sample frequency	Panel	Number reaches in panel	Year 1	2	3	4	5	6	7	8	9	10	11	12
Annual	1	12	12	12	12	12	12	12	12	12	12	12	12	12
3 year	2	9	9			9			9			9		
	3			9			9			9			9	
	4				9			9			9			9
12 year	5	9	9											
	6			9										
	7				9									
	8					9								
	9						9							
	10							9						
	11								9					
	12									9				
	13										9			
	14											9		
	15												9	
	16													9
Reaches sampled annually			30	30	30	30	30	30	30	30	30	30	30	30
Cumulative unique reaches			30	48	66	75	84	93	102	111	120	129	138	147

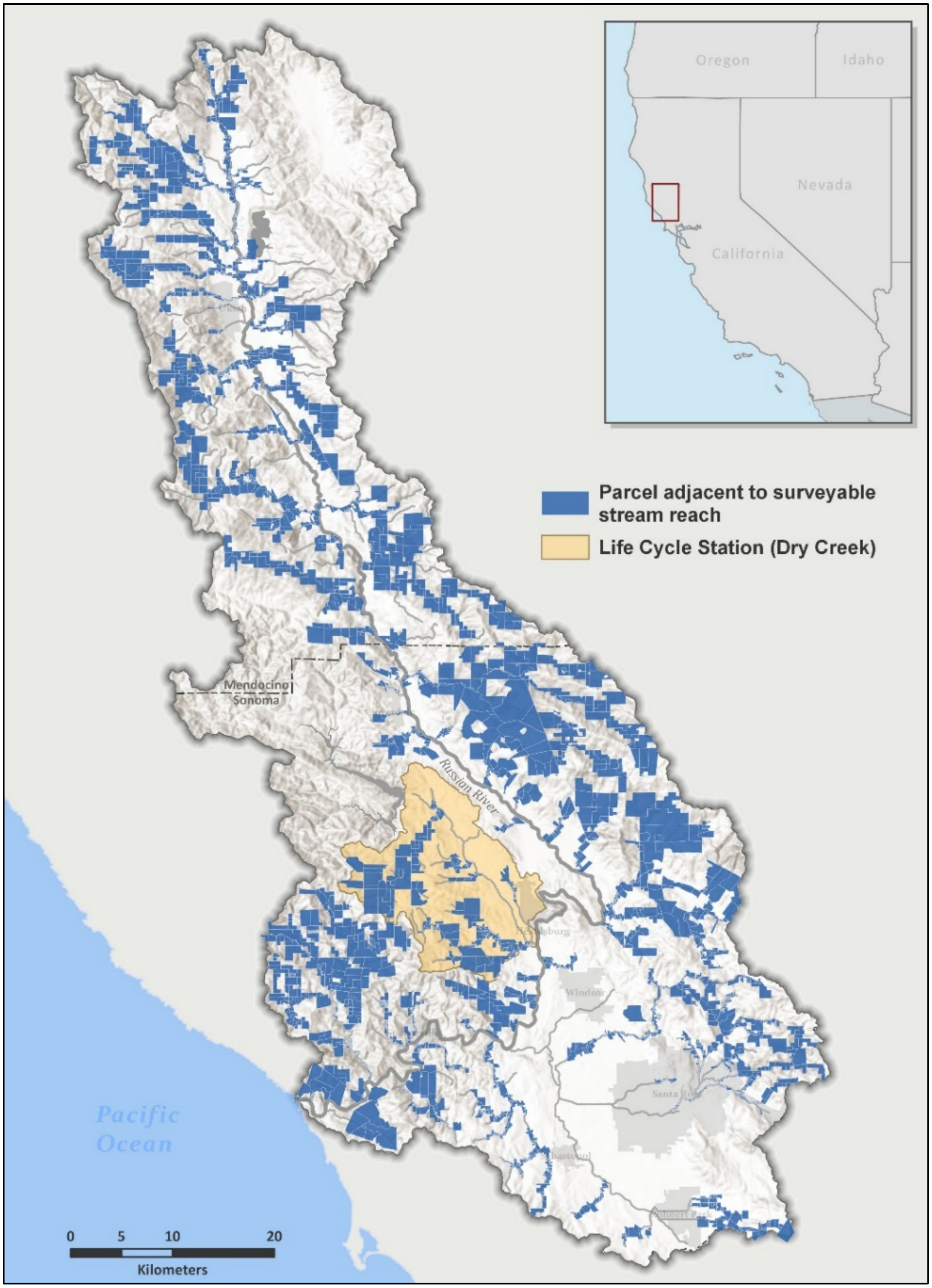


Figure I-5. Landowner parcels adjacent to reaches in the Russian River CMP sample frame.

Table I-4. Example of dynamic assignment of reaches to panels in adult steelhead stratum. Reaches unable to survey and reaches to fill the panel beyond the 2018/19 season are yet to be determined (TBD).

Panel[1]	Draw order	Number reaches in panel	Reaches unable to survey	Reaches needed to fill panel	Season assigned
1	1-24	12	12	24	2017/18
2	25-52	9	19	28	2017/18
5	53-75	9	14	23	2017/18
3	76-99	9	14	23	2018/19
6	100-120	9	11	20	2018/19
4	121-TBD	9	TBD	TBD	2019/20
7	TBD	9	TBD	TBD	2019/20
8	TBD	9	TBD	TBD	2020/21
9	TBD	9	TBD	TBD	2021/22
10	TBD	9	TBD	TBD	2022/23
11	TBD	9	TBD	TBD	2023/24
12	TBD	9	TBD	TBD	2024/25
13	TBD	9	TBD	TBD	2025/26
14	TBD	9	TBD	TBD	2026/27
15	TBD	9	TBD	TBD	2027/28
16	TBD	9	TBD	TBD	2028/29

[1]See Table I-3 and text for explanation of why panels are not populated consecutively.

Discussion

As described above, we have not yet finalized the Russian River sample frame. We will likely remove (but not add) reaches from the frame altogether over the next several years as the frame continues to be developed. We also may change our species and/or life stage soft-stratification as we visit these reaches in the future. As this happens, we will recalculate redd abundance and juvenile percent area occupied estimates as necessary, even for past years. Pre-existing knowledge of habitat in the lower basin where the vast majority of Coho habitat is located means that the adult and juvenile Coho strata are closer to being finalized. Because of this, changes in redd- or juvenile-related estimates is less likely for Coho than for steelhead.

Chapter II. Life cycle monitoring

Introduction

The CMP objective of life cycle monitoring is to detect trends in abundance of smolts and adults (Adams et al. 2011). We selected the Dry Creek watershed for life cycle monitoring of Coho Salmon and steelhead and the Russian River watershed upstream of Sonoma Water's Mirabel dam in Forestville (rkm 39.67) for life cycle monitoring of Chinook Salmon. Underwater video monitoring in fish ladders at Sonoma Water's Mirabel inflatable dam on mainstem Russian River during the fall are used to obtain a near-census of adult Chinook returning to the basin and downstream migrant traps at the base of the dam in the spring are used to estimate Chinook smolt abundance. The Coho and steelhead life cycle monitoring station (LCS) in Dry Creek is more complex. It is divided into (a) an adult LCS consisting of a dual-frequency identification sonar (DIDSON) operated during the adult salmonid migration season near the mouth of Dry Creek (rkm 0.36); (b) downstream migrant traps on mainstem Dry Creek (rkm 3.30) and Mill Creek (rkm 2.00); (c) PIT antennas near the mouth of Dry Creek (rkm 0.36) and Mill Creek (rkm 2.01) for steelhead smolts.

Methods

Adult abundance

Coho Salmon and steelhead

We used a DIDSON model 300m in short-range configuration to count adult salmonids moving into the Dry Creek LCS (rkm 0.36). The short-range configuration works best under 15m which was sufficient to see across the thalweg and most of the wetted area of Dry Creek at the installation site during all but the highest flows. The DIDSON camera was housed in a silt box to prevent silt from collecting on the camera's moving parts and to keep the lens clean. A spreader lens was installed to increase the recording area from the normal range (28 degrees by 14 degrees) up to 28 by 28 degrees, but this also cut resolution in half. We installed the system near the mouth of Dry Creek (rkm 0.36), downstream of all Dry Creek tributaries. The DIDSON was mounted just below the water surface on river right perpendicular to stream flow. The DIDSON was pointed across the stream and slightly downward (toward the substrate) so that it covered the largest portion of the stream's cross-section as possible. Data were recorded directly to external hard drives which were swapped out every few days. All data were reviewed by technicians at no more than eight times (8x) normal speed. During times of high turbidity or when fish were milling, DIDSON playback speed was adjusted to slower speeds that were most appropriate for prevailing conditions. In rare cases the frame rate was turned all the way down to 1x. Length of individual fish was estimated (± 2.5 cm) using the measuring tool available with the DIDSON software.

In past years, we operated a digital video camera in conjunction with the DIDSON as a way to prorate fish counts by species based on visual observation with the digital video camera (Sonoma Water and CSG 2015). The premise was that although it is not possible to identify species from DIDSON images alone, we would be able to identify a portion of them from digital video footage. At first this approach offered promise; however, following geomorphic changes at the site, the thalweg (and therefore the preferred adult pathway past the camera) moved too far away from the camera to allow species identification. Following mostly unsuccessful attempts to crowd fish closer to the camera, we determined the use of a video camera for prorating species was not consistent enough to be a viable approach at this site. We attempted other steps to "estimate" species from the DIDSON counts. First, we eliminated fish under 46 cm (approximately 18 in) from our raw count of fish swimming in an upstream direction past the DIDSON and considered the remaining fish to be possible adult salmonids. Next, we applied species ratios obtained from the mainstem Russian River digital video camera at Sonoma Water's Mirabel fish ladders (rkm 39.67) to assign species to the counts of fish seen on the DIDSON (Dry Creek enters the mainstem Russian approximately 24 rkm upstream of Mirabel dam). These proration ratios were calculated weekly and applied to counts seen on the Dry Creek DIDSON during the same week. This step was only possible during the time the Mirabel video system was operational (typically early-September to mid-December). Once the Mirabel video system was removed in a given year, we considered fish swimming past the DIDSON to be Chinook up to the median date at Mirabel (from historical annual video counts, Appendix B) when Chinook at Mirabel were no longer observed. After this date we considered fish >46 cm swimming past the DIDSON to be adult steelhead. These steps ignored species assignment of adult Coho and, because we used a 47 cm (18 in) size threshold, likely ignored a substantial number of adult salmonids that were jacks.

Chinook Salmon

The adult counting station for Chinook was located on the mainstem Russian River at Sonoma Water's inflatable dam in Forestville (river km 39.67). We used a continuous underwater video monitoring system to obtain annual counts of Chinook adults returning to the Russian River basin upstream of the Mirabel dam. This site is downstream of habitat that the vast majority of Chinook spawners use (Chase et al. 2007) and, in most years, the system is operated late enough into the season to encompass the majority of fish migrating past the dam (Appendix B).The monitoring system consists of an underwater video camera at the upstream end of each of two fish ladders located on either side of the inflatable dam. Each video system operated continuously throughout the majority of the adult Chinook migration period each season except for brief periods when the camera was inoperable (e.g., power outages). In case turbidity obscured fish from observation, we had a DIDSON on standby ready to record upstream fish movements. All data were reviewed by technicians. Installation of the video system occurred in early September prior to the onset of adult migration and removal occurred when Sonoma Water's inflatable dam was lowered for the season. During the 2015/16 adult Chinook migration season, a new fish ladder on the west side of the Russian River was under construction at the Mirabel Dam site so no adult Chinook monitoring was performed that season.

Redd abundance

Field data collection

Dry Creek tributaries

We used protocols outlined in Adams et al. (2011) and Gallagher et al. (2007) to survey all tributaries to Dry Creek in the Coho-steelhead stratum for salmonid redds, live adult fish, and carcasses (excluding mainstem Dry Creek and any reaches or portions of reaches where we were unable to secure landowner access). We attempted to sample reaches every 10-14 days, though storms and heavy rains (and subsequent turbidity) prevented crews from surveying at times. Our survey start dates during all seasons coincided with the first rains of the winter sufficient to connect tributaries to the mainstem. The minimum visibility threshold for surveys was 0.5 m though some surveys were completed below this threshold depending on the size of the stream and if crews thought they could effectively identify redds and fish. Reaches were surveyed by two observers walking the reach from a downstream to upstream direction. When a redd was encountered it was measured (±0.1 m), marked with flagging, and a GPS location was taken. If fish were actively guarding or digging a redd, redd measurements were estimated (±0.5 m) to avoid disturbing fish. Each redd was assigned a unique identification number. When live fish were encountered, species, length and condition were estimated. When carcasses were encountered, they were measured (±0.1 mm) and identified to species if possible. Carcasses were tagged with a metal hog tag on a piece of wire punched through the skin and around the spine just posterior of the dorsal fin. If possible, scale samples were collected and heads were removed for otolith collection. All carcasses, regardless of species, were scanned for PIT tags, coded wire tags (CWT), and examined for any fin clips or other markings that might indicate hatchery origin. GPS locations were taken for all live fish and carcass observations.

Dry Creek mainstem

Because of constant water releases from WSD, mainstem Dry Creek is highly channelized, incised, and deep; therefore data collection methods were adjusted. The entire 22 km length of the mainstem from the mouth to WSD was divided into two sections that were floated simultaneously by two teams of two observers in kayaks. We attempted to float both sections weekly or biweekly, though high flows and turbidity frequently prevented surveys. Generally, mainstem Dry Creek becomes too turbid to survey after the first heavy rains of the year (usually in late November or December) with surveyable conditions often not returning until late spring or summer. Surveys began when the first adult salmonids entering Dry Creek on the DIDSON were observed and continued until the first heavy rain. If visibility improved, surveys resumed opportunistically through the end of the steelhead spawning season in Dry Creek (generally mid-April). Redds and live fish were counted and species was estimated by crews in the field. Given the depth and velocity of Dry Creek it was impractical to measure redds. For each redd encountered, an individual GPS point was collected and the number of fish associated with each redd was recorded. GPS point locations were also recorded for observations of individual fish not associated with redds. Because of the velocity of Dry Creek, it was not practical to mark individual redds with flagging. Instead, GPS coordinates were used to distinguish new redds from old redds. GPS points were collected with a Trimble (Pro XH) GPS unit capable of recording points to an accuracy of less than 2 m. Prior to each survey, a background layer containing the coordinates for all old redds was loaded onto the GPS unit. Crews used this background map to determine if individual redds were marked on a previous survey. If a redd did not show up on the background map, crews assumed it was a new redd and recorded the location. Through the season, redd and fish data (both tabular and spatial) were uploaded to a Geodatabase using ArcGIS. At the end of the season, tabular data (including XY coordinates) was QA\QC'd and transferred to an Excel spreadsheet.

Redd species estimation

The species responsible for constructing a redd ("redd species") as well as the observer's confidence in that species assignment (redd "species certainty") was assigned to each redd observed in the field (by the field crew) based on the presence of live fish associated with the redd, or observed field characteristics of the redd that were indicative of a certain species. We defined "association" between a fish and a redd strictly on the basis of whether the individual was exhibiting digging and/or guarding behavior relative to the subject excavation or redd. Redd species certainty was assigned as follows:

1. Certain:
    - one or more live adult(s) associated with the redd that can be positively identified to species.
2. Somewhat certain:
    - one or more live adult(s) live adults associated with the redd but the crew could not identify to species;
    - no live adults associated with the redd, but based on redd characteristics redd species can be inferred.
3. Uncertain:
    - no live adults associated were with the redd and/or redd characteristics to indicate species were unclear.

Similarly, we assigned species certainty (1=certain; 2=somewhat certain; 3=uncertain) to observed live adult salmonids and carcasses.

Multiple methods were used to make a final redd species assignment at the end of the season. Upon classification of redd species in the field we sought to make a final redd species assignment at the end of the season. We evaluated the method of redd species classification recommended by Adams et al. (2011) and described in Gallagher and Gallagher (2005) and Gough (2010). This method uses logistic regression models to classify unknown redds based on redd measurements and time of spawning. This method was generally useful in distinguishing Coho redds from steelhead redds, but it incorrectly classified 100% of known Chinook redds as Coho redds leading to an inflated Coho redd abundance estimate. We also evaluated the non-parametric K-nearest neighbor algorithm (KNN) (Ricker et al. 2013). This method appeared to correctly classify Chinook redds more frequently than the Gallagher/Gough method, but it underestimated Coho redd abundance. This was likely due to the small number of certainty 1 Coho redds counted each season. Because both redd species classification methods are appeared biased for the Russian River, we decided to use a hybrid approach:

1. Observer redd species was assigned as the final redd species:
    a. for all observer certainty 1 redd species (i.e., species identification was possible and fish species certainty=1 for one or more fish associated with the redd);
    b. for any redd identified by the field crew as Chinook regardless of certainty level.
2. Estimated species from the Gallagher/Gough logistic regression equations was assigned as the final redd species for remaining redds where redd species certainty was >1 and redd measurements were made.
3. If field crews never observed a certainty 1 fish species associated with a redd and if measurements were never taken (making estimation with Gallagher/Gough logistic equations impossible), we used a method whereby fisheries biologists familiar with life-histories of salmonids in the watershed used their best professional judgement to estimate redd species. Decisions were based on the closest certainty 1 fish or redd species in time and space. The number of redds classified in this way never exceeded 2% in a season.

Redd abundance estimation

Once all redds were classified to species using the method described above, we estimated within-reach redd abundance following the methods of Ricker et al. (2014). These methods extend the Jolly-Seber capture-mark-capture model to allow for the estimation of a population total by making assumptions about the recruitment process, estimating survival of redds between sampling occasions via mark-recapture, then using these parameters to estimate counts for redds that are constructed and obscured between survey occasions. The estimation of total redd construction within a survey reach can be described as a flag-based open population mark-recapture experiment in which redds are either marked and/or recaptured on each survey occasion, and redds are individually identified and marked with unique redd IDs applied to flagging. The population of redds is considered open because new redds are recruited into the population when they are constructed then removed from the population when they become obscured from view. We estimated total abundance of redds in the Dry Creek tributaries using the simple random estimator described in Adams et al. (2011). Greater detail can be found in Ricker at al. (2014) and Adams et al. (2011).

We attempted to survey all reaches in Dry Creek tributaries containing habitat for Coho and steelhead. However, because the watershed is nearly all privately-owned, we were prevented by lack of landowner access from surveying some sections of reaches and some full reaches. There were six full reaches that contained habitat but we could not survey due to lack of landowner access. The number of redds in these reaches was not estimated; however, they were included in the calculation of the total redd abundance. There were two additional reaches where sections of the reach could not be surveyed because of landowner access. Those sections were addressed as follows. Redd density ($redds \cdot km^{-1}$) was calculated in the surveyed sections and the product of redd density and reach length (km) was used to estimate the number of redds in the unsurveyed sections. Estimates of total redds in these unsurveyed sections were calculated prior to calculation of total redd abundance. Within-reach variance could not be calculated for these unsurveyed reaches so they were not included in the calculation of total standard error of the total redd estimate.

Smolt abundance

Downstream migrant traps

In 2008, Sonoma Water established a downstream migrant trap (DSMT) site on mainstem Dry Creek (rkm 3.30) in order to detect trends in Coho Salmon smolt abundance resulting from large-scale habitat enhancement efforts along mainstem Dry Creek that were compelled by NMFS' Russian River Biological Opinion (RRBO, NMFS 2008). This site was selected at the time because (1) it is far enough upstream to be geomorphically stable meaning that data among years would is comparable in a relative sense and (2) landowner access is reliable (City of Healdsburg). Because the RRBO and Russian River CMP Monitoring Plan both have the objective of estimating trend detection, we recognized that this site could serve as a means of satisfying both programs. A complication, however, is the fact that Mill Creek, a significant salmonid-bearing tributary in the Dry Creek system, enters Dry Creek downstream of the mainstem Dry Creek trap site at rkm 1.10. Fortunately, CSG has a long-standing DSMT on Mill Creek that has been in operation each smolt season since 2005. Because of that, our premise was that we should be able to combine data from Dry Creek and Mill Creek DSMTs to account for this issue.

A significant issue with relying solely on downstream migrant trapping at life cycle monitoring stations for steelhead is the fact that steelhead smolt migration occurs well before DSMTs at most LCSs can be safely installed and operated. Using DSMTs alone, steelhead smolt abundance will be underestimated by a significant amount in most cases. This is less of a problem for Coho smolts in the Russian River watershed where smolt migration typically occurs from March through June – a period when DSMTs can be successfully installed and operated, particularly in small tributary streams.

To avoid underestimating steelhead smolts produced from the Dry Creek LCS, we conceptualized an approach for combining data from DSMTs with outputs from a pre-smolt steelhead abundance and survival model (Sonoma Water and CSG 2014). This approach relies on steelhead smolt abundance estimates generated from pre-winter abundance estimates coupled with efficiency-adjusted detections of PIT-tagged steelhead at stationary PIT antenna arrays throughout the ensuing winter.

For the Coho Salmon smolt portion of life cycle monitoring, we operated DSMTs on mainstem Dry Creek (rkm 3.30) and Mill Creek (rkm 2.00) (Figure II-1). For the Chinook smolt portion of life cycle monitoring, we conducted downstream migrant trapping just downstream of the Water Agency's Mirabel dam site on mainstem Russian River (rkm 39.67, Figure II-1). Traps were tended daily with additional checks during peak outmigration and during periods of high flows. During significant storms, traps were opened or removed for brief periods in order to prevent injury to fish, loss of equipment, and ensure safety of personnel. Additional details on downstream migrant trapping field and abundance estimation methods can be found in Sonoma Water data reports (2011 through 2018) and CSG data reports (2004 through 2017).

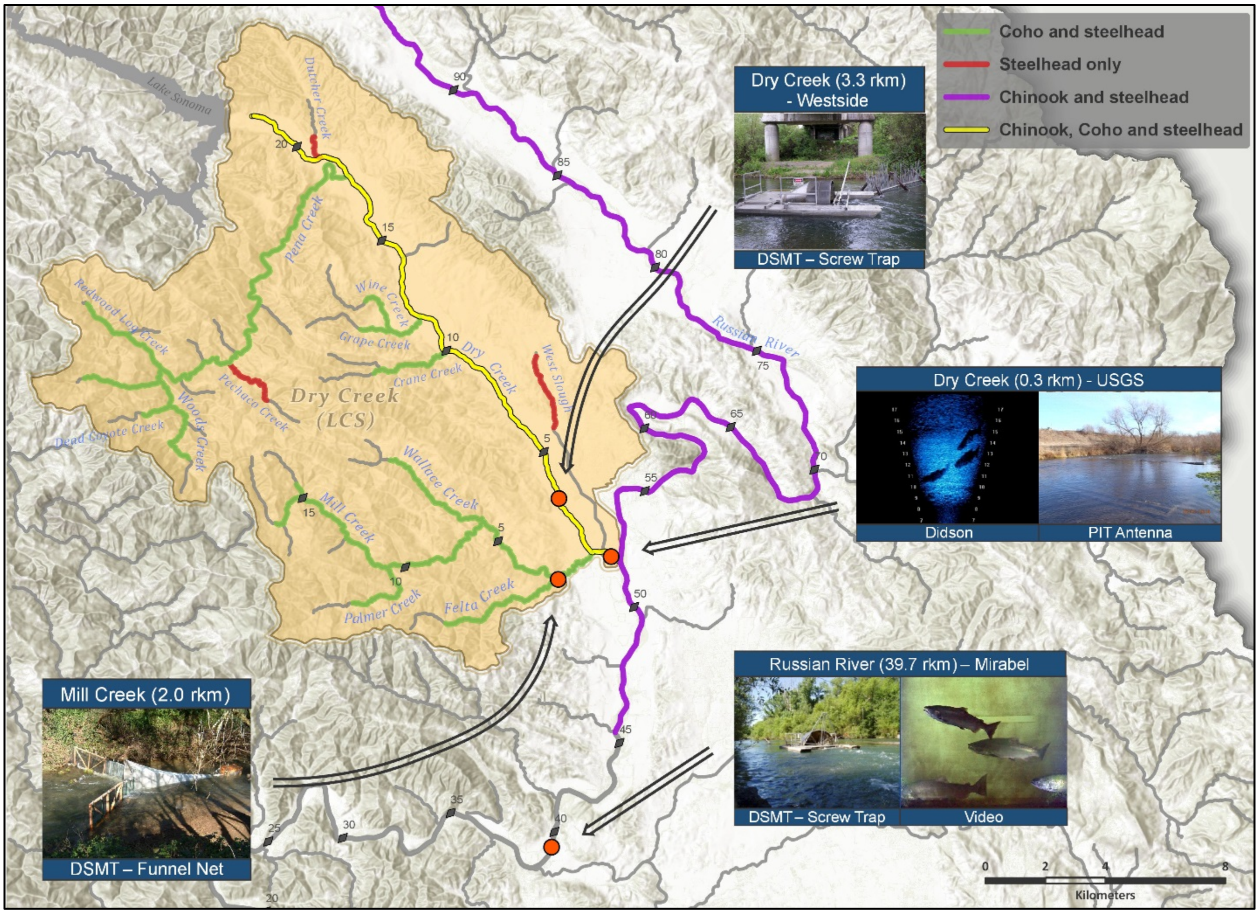


Figure II-1. Coho Salmon and steelhead life cycle monitoring stations (Dry Creek watershed) and Chinook Salmon life cycle station (Russian River).

At the mainstem Dry Creek trap site, we used a rotary screw trap with a 1.5 m diameter cone to capture juvenile salmonids moving downstream. Weir panels were installed adjacent to and extending upstream from the upstream end of the screw trap in a “V” configuration (i.e., trap at the downstream apex of the “V”) in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap. Fish captured in the trap were identified to species and enumerated. All fish ≥55 mm were scanned for PIT tags and Coho were scanned for CWTs. A subsample of each species was anesthetized using Alka Seltzer and measured for fork length (±1 mm) and mass (±0.1 g). A subsample of Chinook smolts was PIT-tagged or fin-clipped and released upstream of the trap to facilitate abundance estimates. All fish that were PIT-tagged were also measured and weighed prior to being tagged. Other species, including recaptured Chinook, were released downstream of the first riffle downstream of the trap. All anesthetized fish were allowed to recover fully in aerated buckets prior to release.

At the Mill Creek trap site, we used a funnel net to capture juvenile salmonids moving downstream. Fish captured in the trap were identified to species and enumerated and all salmonids ≥55 mm were scanned for a PIT tag and Coho were scanned for CWTs. A subsample of each species was anesthetized using a solution of tricaine methane-sulphonate (MS-222) and measured for fork length (±1 mm) and mass (±0.1 g). PIT tags were applied to every fourth hatchery-origin (CWT-only) Coho smolt (25%) and measured. All natural-origin fish (without PIT or CWT) were weighed and measured and a PIT tag was applied to every other fish (50%). Genetics samples were collected from a subsample of hatchery- and natural-origin Coho. All anesthetized fish were allowed to fully recover in aerated buckets prior to release.

At the mainstem Russian River trap site, we operated two rotary screw traps adjacent to one another (one 1.5 m diameter cone and one 2.4 m diameter cone, Figure II-2) until later in the season when flows dropped and there was only enough thalweg width to operate a single trap. An exception was in 2015 when active construction of a new fish ladder at Mirabel prevented us from operating a downstream migrant trap at this location. Fish captured in the trap were identified to species and enumerated. All fish ≥55 mm were scanned for a PIT tag and Coho were scanned for CWTs. A subsample of each species was anesthetized using Alka Seltzer and measured for fork length (±1 mm) and mass (±0.1 g). A subsample of Chinook smolts was PIT-tagged or fin-clipped and released upstream of the trap to facilitate abundance estimates. All fish that were PIT-tagged were also measured and weighed prior to being tagged. Other species, including recaptured Chinook, were released downstream of the first riffle downstream of the trap. All anesthetized fish were allowed to recover fully in aerated buckets prior to release.

Figure II-2. Downstream migrant traps at Sonoma Water's Mirabel dam in Forestville (Chinook smolt LCS, rkm 39.67).

Pre-smolt steelhead abundance model

Because of the difficulty in accurately estimating abundance of steelhead smolts using downstream migrant traps, we developed an approach using backpack electrofishing and year-round, stationary PIT antenna monitoring to estimate smolts and/or juvenile steelhead leaving the LCS. The steps in this approach were:

1. Estimate juvenile steelhead (pre-smolt) abundance in mainstem Dry Creek and Mill Creek with backpack electrofishing in early fall.
2. Apply PIT tags to juvenile steelhead (≥60 mm) captured during electrofishing surveys
3. Operate a year-round, stationary PIT antenna array as part of the Coho/steelhead smolt LCS on Dry Creek and Mill Creek.
4. Calculate a "survival index" as the proportion of PIT-tagged fish detected on the Dry Creek and Mill Creek PIT antenna arrays during the ensuing steelhead emigration period (November to June) and adjust that proportion to account for PIT antenna efficiency.
5. Apply the adjusted proportion from step 4 (the survival index) to the juvenile steelhead abundance estimates from the previous fall.

Pre-smolt steelhead abundance – Dry Creek mainstem

There are nine GRTS reaches in mainstem Dry Creek ranging in length from 1,666 m to 3,145 m. Given the long length of the reaches, a subsampling approach was used in which one contiguous stream section (sub-reach) was randomly selected from a reach-specific candidate list of sub-reaches for backpack electrofishing surveys within each of the nine GRTS reaches (Figure II-3). In order to identify those sub-reaches that (1) could be safely and effectively sampled with a backpack electrofishing unit and (2) we either had or could gain landowner access permission, a list of candidate sub-reaches were identified during a field survey prior to the commencement of sampling. Each reach contained 3 to 8 sub-reaches from which we randomly chose our sub-reach. This resulted in a spatially-balanced, random sample of sub-reaches.

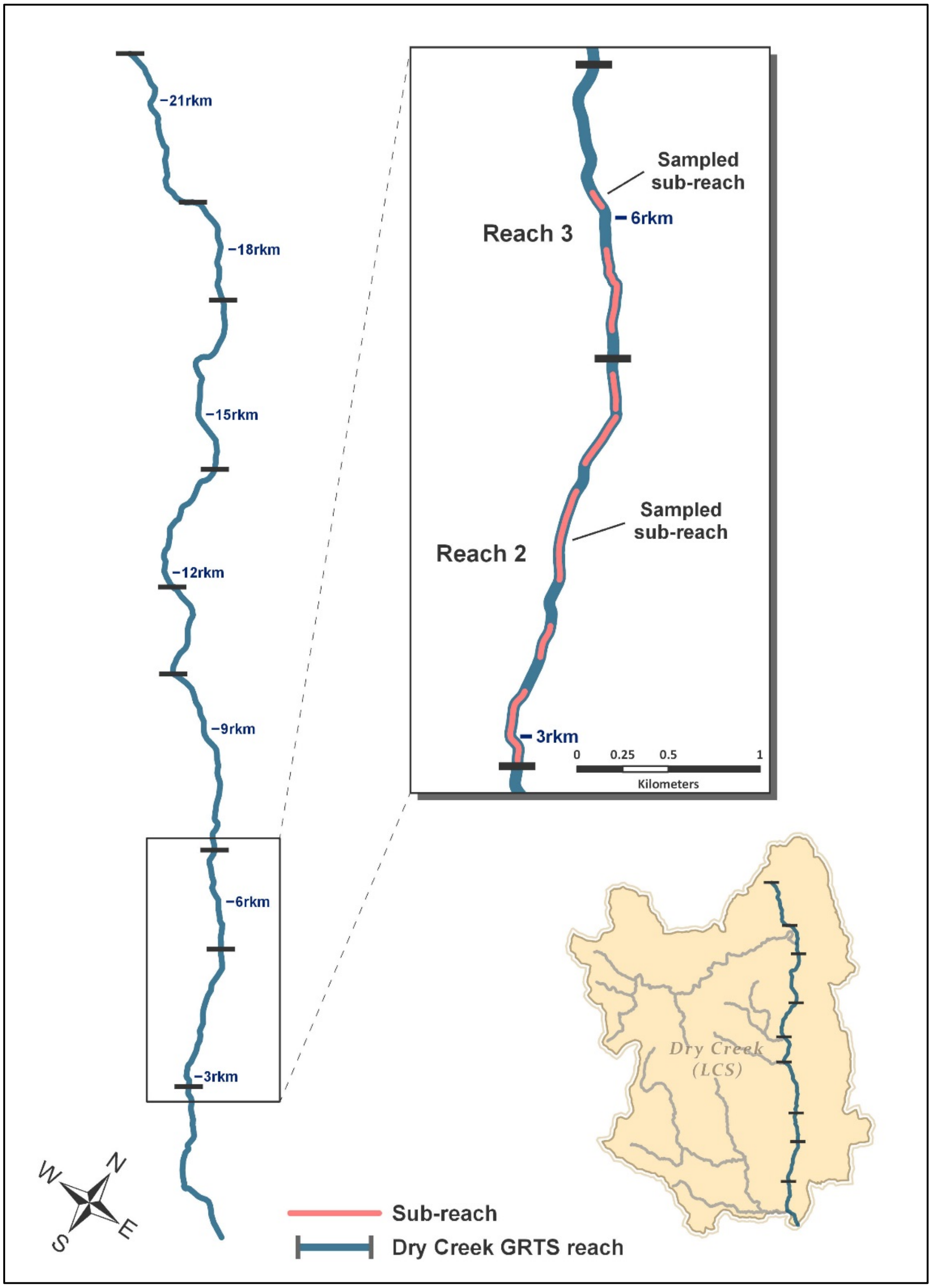


Figure II-3. Sub-reach stratification of mainstem Dry Creek used to estimate pre-smolt steelhead abundance in mainstem Dry Creek.

Juvenile population estimates were possible in eight (2018) or nine (2015-2017) sub-reaches per year. During late summer/early fall, backpack electrofishing surveys were conducted by making a single pass through the selected sub-reach on day one (the marking event) followed by a second pass two days later (the recapture event). PIT tags were applied to untagged steelhead ≥60 mm captured on day one and all individuals were released near their capture location and subject to recapture on day two. On day two, all steelhead ≥50 mm were scanned for a PIT tag for the mark recapture study, and PIT tags were applied to untagged steelhead ≥60 mm for the purpose of increasing the sample size of PIT-tagged fish for general life history monitoring. All salmonids captured during electrofishing were anesthetized and measured for fork length (±1 mm). Fish that had a PIT tag applied or observed were also weighed (±0.1 g). By applying PIT tags to juvenile steelhead, subsequent movement out of Dry Creek could be detected with a stationary PIT antenna array located near the mouth of Dry Creek. Once fish were completely recovered from the anesthetic they were released into the sub-reach from which they were captured.

The Petersen mark-recapture model in Program MARK (White and Burnham 1999) was used to estimate end-of-summer abundance ($\hat{n}_{sr}$) for each sampled sub-reach of the nine Dry Creek reaches. We assumed that recapture probability, mortality and the proportion of fish leaving the stream section (sub-reach) sampled between the marking and recapture events was the same for the marked group as it was for the unmarked group, such that the abundance estimates from the paired mark and recapture events would be unbiased (White et al. 1982). Reach-specific density estimates were calculated as the quotient of the abundance estimate for the sub-reach ($\hat{n}_{sr}$) and length of the sub-reach (l_{sr}). The product of the reach specific density estimate ($\hat{d}_r$) and the total reach length (l_r) was used to calculate reach-specific abundance ($\hat{n}_r$). The sum over all values $\hat{n}_r$ was used to calculate an abundance estimate of juvenile steelhead in mainstem Dry Creek each year ($\widehat{N}_y$).

Pre-smolt steelhead abundance – Dry Creek tributaries

An end-of-summer abundance estimate of juvenile steelhead in tributaries to Dry Creek was obtained using a combination of snorkeling and electrofishing surveys in the early fall in 2017 and 2018 (Figure II-4). Because of the results of an extended drought and our observation that long stream sections with significant numbers of juvenile salmonids in the summer had completely dried by fall (CSG 2016, CSG unpublished data), we elected to not conduct this sampling in 2015 and 2016.

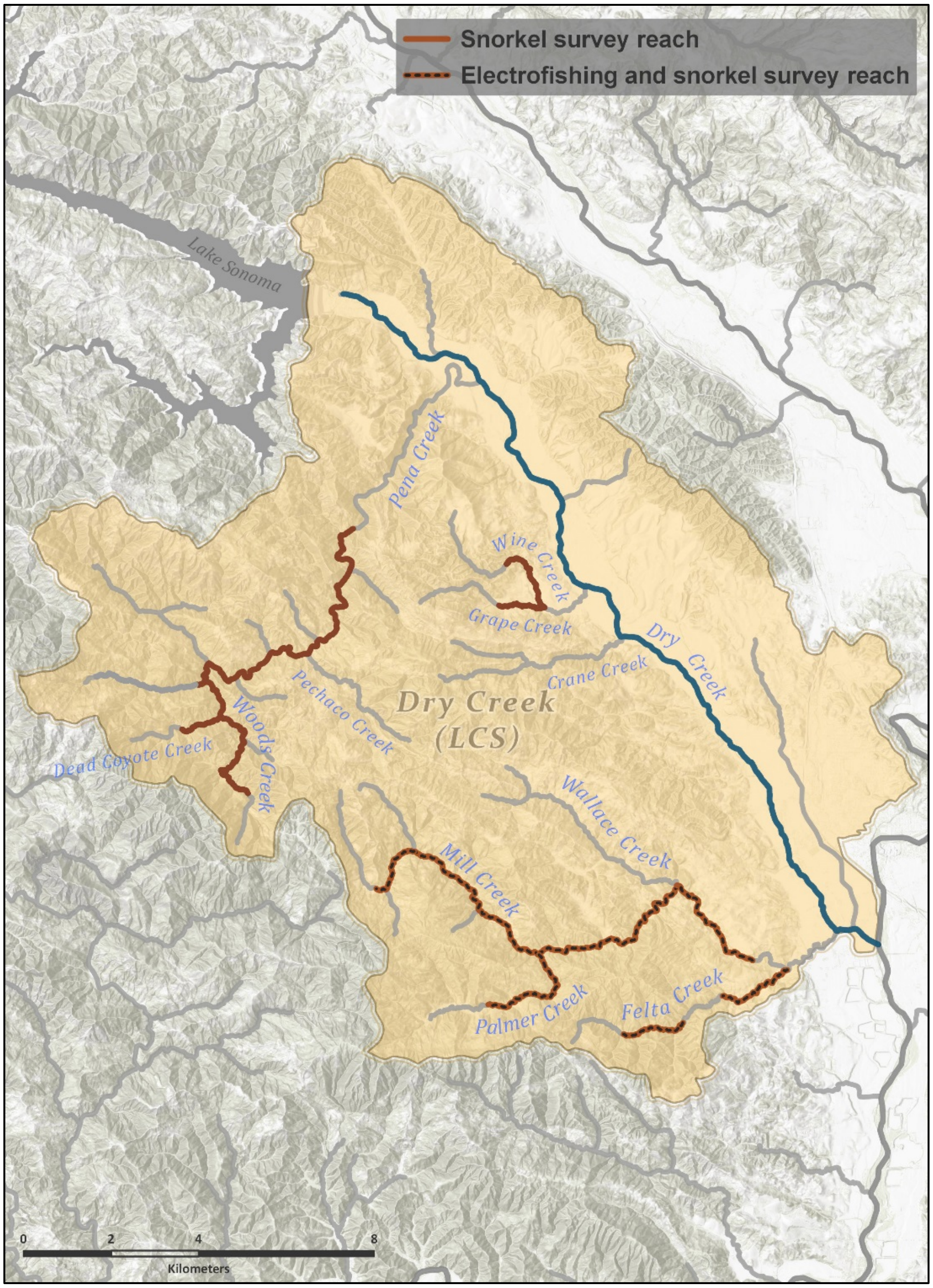


Figure II-4. Tributaries of mainstem Dry Creek sampled to estimate pre-smolt steelhead abundance.

Sampling techniques were similar to the two-stage sampling approach described in Hankin and Reeves (1988) and Dolloff et al. (1993). In the late summer/early fall a single pass snorkeling survey was conducted in every other pool (only pool habitat was sampled) for all wetted reaches. A single diver recorded the number of salmonids observed in each pool by species and age class. During the initial stage of sampling (snorkel surveys) each pool was measured (length and average width) and the number of large woody debris pieces was recorded. Large woody debris was defined as logs greater than 30 cm in diameter and 2 m in length occurring in or suspended less than 1 m above the wetted area (Flosi 2010). We employed an *n* pool protocol meaning that every n^{th} pool was sampled with *n* varying by year. Each year, every n^{th} pool that was snorkeled was selected for second stage sampling (backpack electrofishing surveys). Electrofishing surveys were completed within 0-3 days of the initial snorkel survey in each pool. During second stage sampling, pools were blocked off using nets at the upstream and downstream ends of the habitat unit to ensure closure, and multiple-pass electrofishing was conducted. All salmonids captured during electrofishing were anesthetized, weighed (±0.1 g) and measured (±1 mm), and scanned for PIT tags and coded wire tags in order to determine hatchery- vs. natural-origin. PIT tags were applied to untagged steelhead and Coho ≥60 mm and 2 g so that emigration from the tributary of tagging could be detected with a stationary PIT antenna array. Once fish were completely recovered from the anesthetic they were released into the pool from which they were captured.

An end-of-summer abundance estimate of juvenile steelhead in tributaries to Dry Creek was calculated in 2017 and 2018 using a method for calibrating snorkel counts similar to that described in Hankin and Reeves (1988) and Dolloff et al. (1993). Counts of juvenile salmonids in clear, small streams using snorkel surveys is an effective way to sample a large area in a short time with little impact to fish. However, the accuracy of observer counts varies and often underestimates the number of salmonids present. In order to achieve a more accurate estimate of the juvenile steelhead population, electrofishing surveys were paired with snorkel surveys to calculate a calibration ratio ($\widehat{R}_y$) of electrofishing (EF) abundance estimates to snorkel (SN) counts that could then be applied to stratum-specific snorkel counts in pools that were snorkeled within the same stratum (Figure II-5).

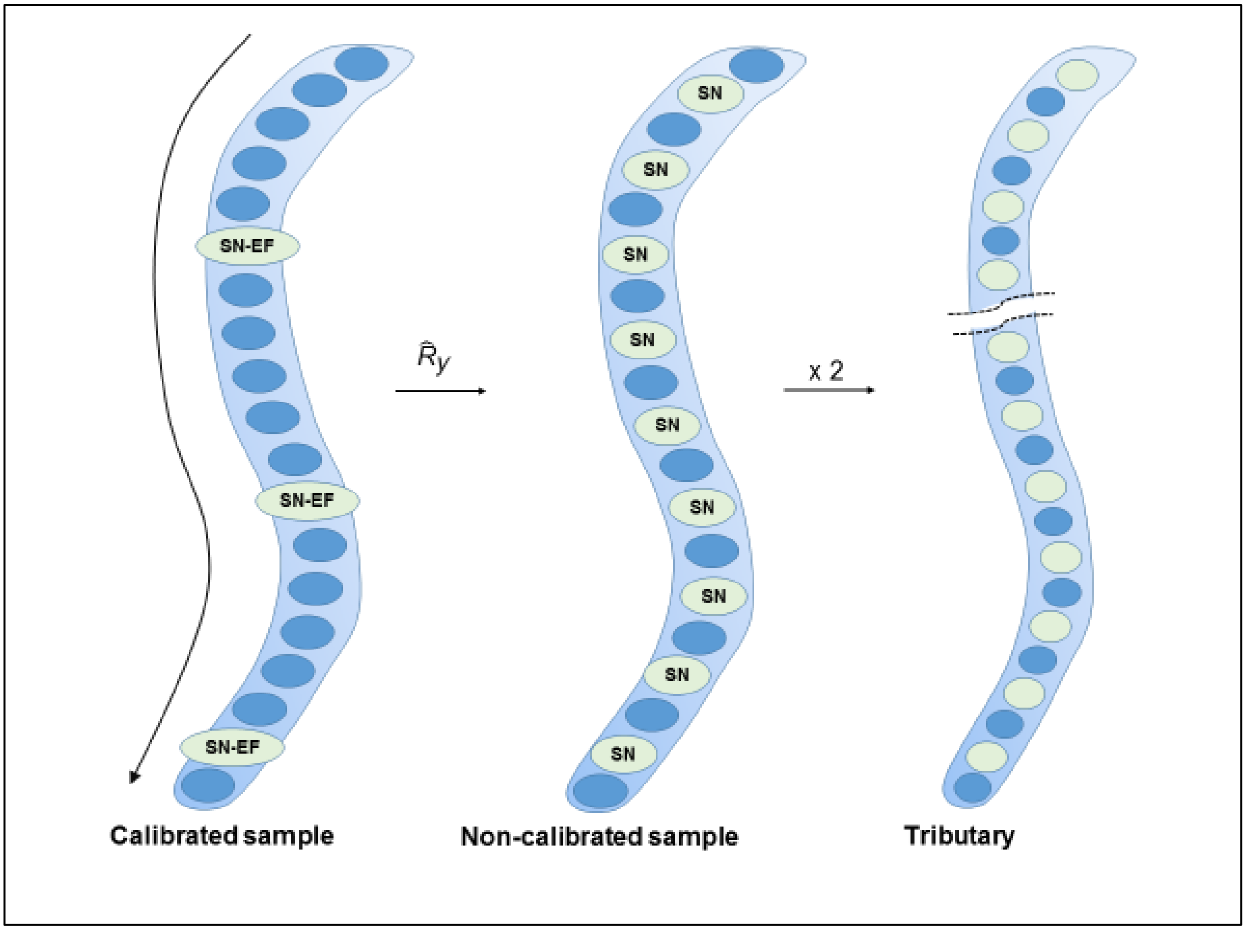


Figure II-5. Sampling strategy for estimating juvenile steelhead population in Dry Creek tributaries. A year-specific calibration ratio ($\hat{R}_y$) calculated from pools selected for two-stage sampling was applied to all snorkeled pools and doubled to generate an estimate for each tributary.

Survival index

Stationary PIT antenna arrays were operated year-round near the mouth of Dry Creek (rkm 0.36) and Mill Creek (rkm 2.00). Each array consisted of multiple antennas connected to a transceiver. Antennas were anchored flat on the streambed and configured in a manner such that fish moving downstream would first be subject to detection on the upstream antenna in the array before being subject to detection on the downstream antenna in the array. From this configuration of antennas, it was possible to estimate antenna efficiency as the proportion of PIT-tagged fish detected on the downstream antenna in a given array that were also detected on the upstream antenna in that same array. The raw number of fish detected on the lower array was divided by the antenna efficiency to expand the raw number to an estimated (“actual”) number of emigrants. The ratio of actual emigrants to the number of fish PIT-tagged the previous fall during electrofishing surveys was then calculated as the survival index. Finally, each survival index was multiplied by the estimated pre-smolt abundance estimate for Mill Creek and Dry Creek, respectively, and these estimates were combined to arrive at a single estimate of the number of steelhead emigrating from the Dry Creek system.

Abundance estimates

For downstream migrant traps, we based our abundance estimates on a two-trap (Coho Salmon smolts: Mill Creek) or one-trap (Chinook Salmon smolts: Russian River) mark-recapture design (DARR: Bjorkstedt 2005; Bjorkstedt 2010). Although a few steelhead smolts were captured in the Dry Creek and Mill Creek traps (range: 17 to 339), and a few Coho smolts were captured in the Dry Creek trap (105 to 339), the numbers were far too few to estimate abundance using DARR. In the two-trap design, a PIT antenna array located immediately upstream of the Mill Creek smolt trap acted as an upstream "trap" where fish were "marked" (marked fish = all PIT tag detections on the PIT antenna array), and the smolt trap served as a downstream trap where fish were subject to physical recapture. PIT-tagged fish detected at both the antenna array and captured in the trap were considered recaptures, and non-PIT-tagged fish and PIT-tagged fish only captured in the trap (but not the detected on the antenna) were considered unmarked fish. In the one-trap design, a sample of fish that were captured in the Mirabel trap each day were marked with a PIT tag, and subject to recapture in the trap by releasing them upstream of the trap.

Results

Adult abundance

Coho Salmon and steelhead

Except for brief periods of high turbidity or DIDSON malfunction, the Dry Creek DIDSON was operated from September through mid-April each year (Figure II-6 upper panel). The number of fish >46 cm observed ranged from 2,550 for the 2016/17 return year to 12,802 for the 201516 return year (Figure II-6 lower panel). While many of these fish counted were certainly adult salmonids, we have no way of distinguishing adult-sized salmonids from other large-bodied fish such as Sacramento Pikeminnow. Assuming that all fish >46 cm are adult salmonids we assigned probable species to our DIDSON counts for each completed season (Table II-1).

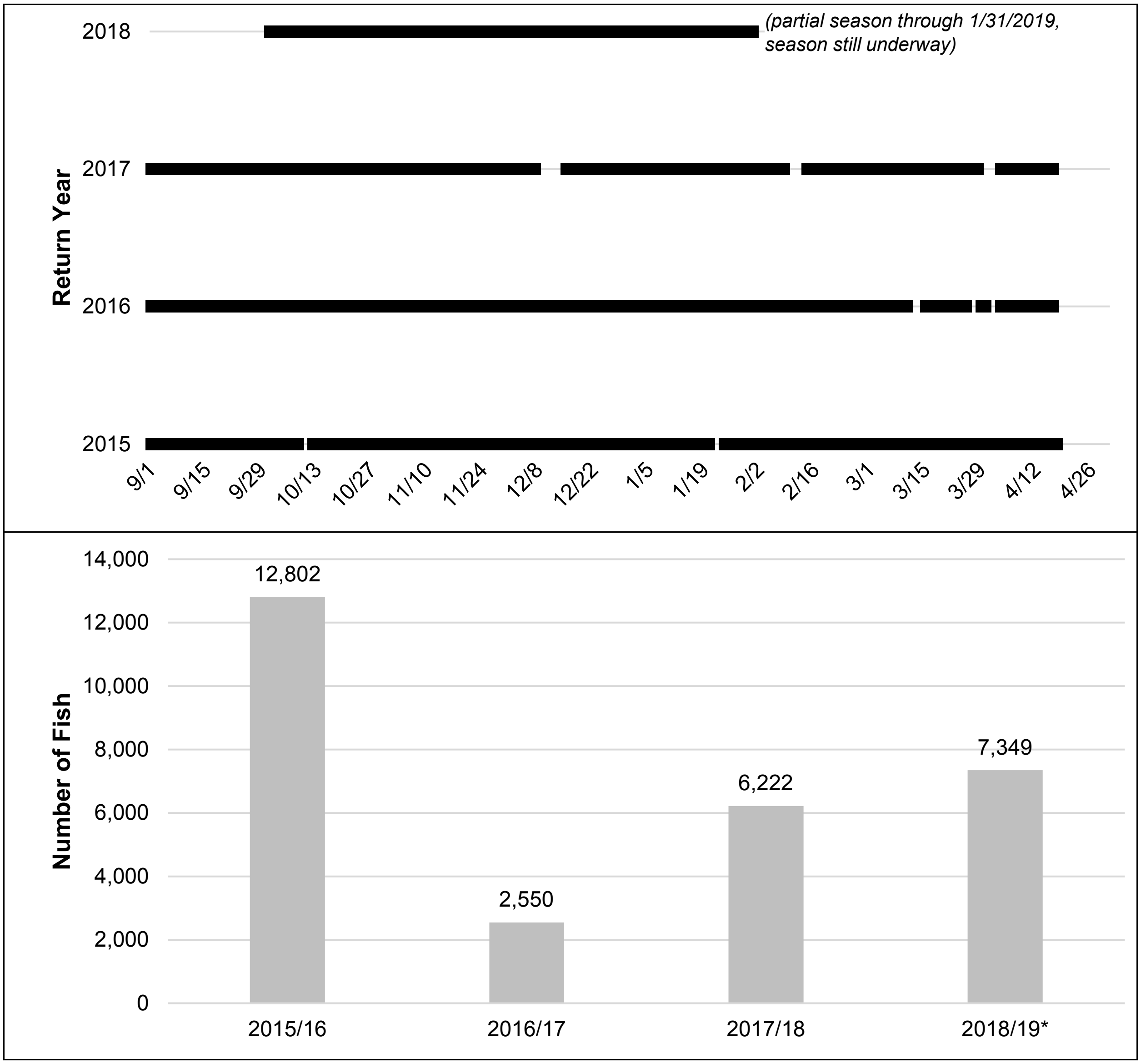


Figure II-6. Dates of operation of Dry Creek DIDSON (upper panel) and counts of fish >46 cm. Note that he 2018/19 season is still in progress therefore counts are partial through 1/31/2019.

Table II-1. Number of salmonid sp (fish >46 cm) and species assignments of Dry Creek DIDSON counts based on proration and historical run-timing from video observations at Sonoma Water's Mirabel dam in Forestville (Chinook adult LCS, rkm 39.67).

Return year	Salmonid sp	Coho Salmon	Steelhead	Chinook Salmon
2015/16	12,802	520	8,925	3,358
2016/17	2,550	78	663	1,809
2017/18	6,222	61	4,340	1,821
2018/19[1]	7,349			

[1]Partial count through 1/31/2019 – season still underway

Chinook Salmon

The Mirabel video system relies on flow through the fish ladders thus it can only operate when Sonoma Water's rubber dam is inflated. In 2016 the dam was deflated before the typical historical end date of the adult Chinook migration season (Figure II-7, Appendix B) but in 2017 and 2018 the period of operation encompassed the historical Chinook migration period (Figure II-7 upper panel). During the project period, counts ranged from approximately 1,100 fish to just over 2,000 (Figure II-7 lower panel). These counts are less than the historic average Chinook counts at Mirabel of approximately 3,200 fish (Appendix C).

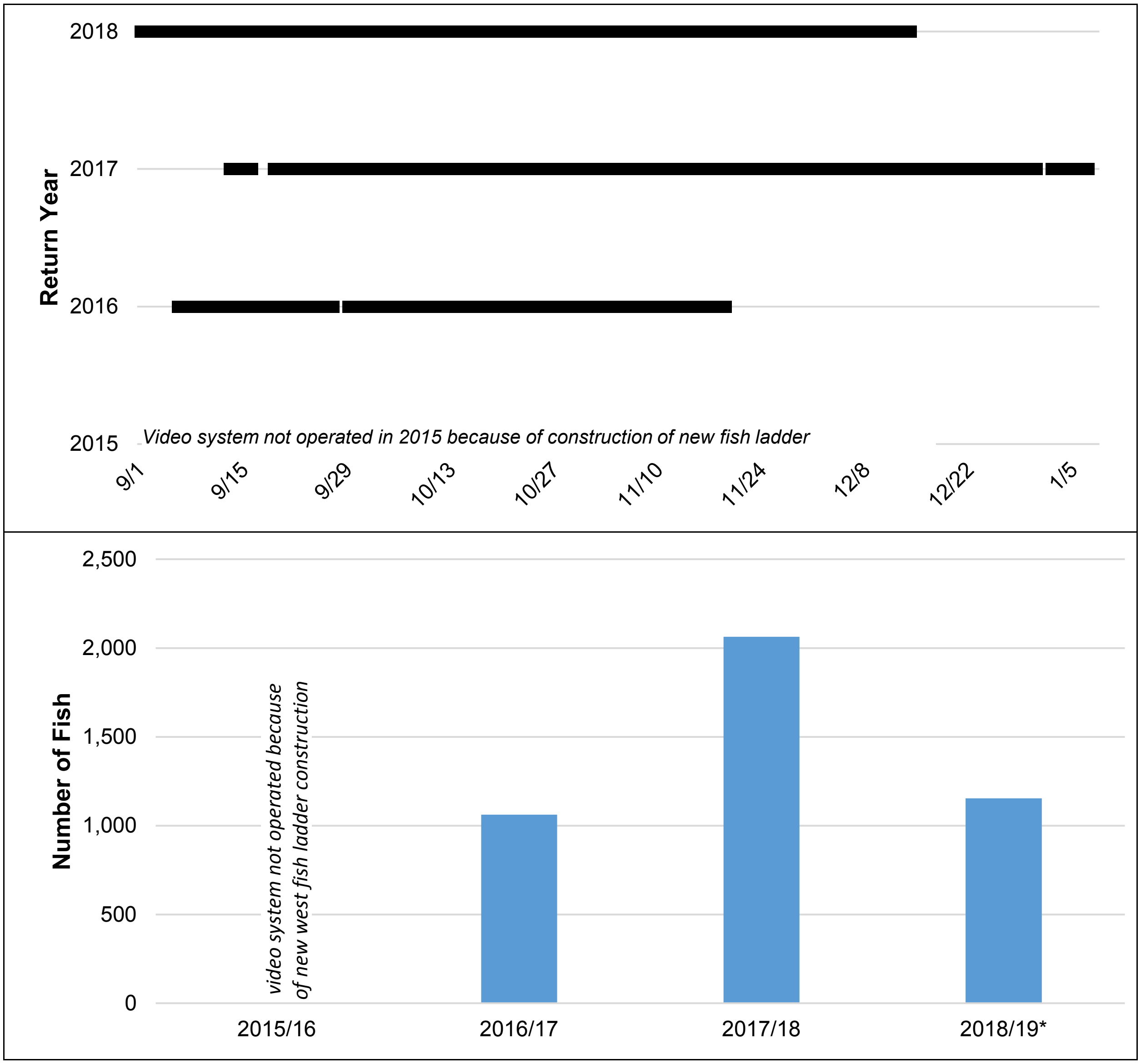


Figure II-7. Dates of operation of Russian River Chinook Salmon adult LCS (Mirabel dam video system) (upper panel) and counts of adult Chinook Salmon (lower panel). Note that salmonid sp for 2018/19 return year have not yet been prorated to species; therefore the number of Chinook will likely change.

Redd abundance

Dry Creek tributaries

The start date for spawner surveys in the Dry Creek watershed was November or December, depending on when rain reconnected tributaries to mainstem Dry Creek (thus allowing fish access), and continued through mid-April (Table II-2, Appendix D). The number of surveys and the reaches surveyed varied by year and depended on survey conditions. For the 2015/16, 2016/17 and 2017/18 seasons, we observed Coho and/or steelhead redds in 17, 15 and 15 reaches, respectively. Season totals were strongly influenced by counts in Pena Creek especially for the 2015/16 and 2016/17 seasons (Figure II-8, Figure II-9, Appendix E, Appendix F). Estimates of Coho and steelhead redd abundance increased steadily from the 2013/14 season through the 2016/17 season but dropped off in 2017/18 (Figure II-10).

Table II-2. Summary of the life cycle monitoring spawner survey effort in Dry Creek tributaries.

Species	Season	Season start	Season end	Number of surveys completed	Reaches used for estimate	% LCM[1] Reaches	Mean days between surveys (±95% CI)
Coho Salmon	2015/16	12/7/15	4/15/16	171	16	72%	13.16 (±0.98)
	2016/17	11/1/16	4/19/17	208	16	72%	12.00 (±0.96)
	2017/18	11/29/17	4/20/18	212	17	77%	12.63 (±0.73)
	2018/19[1]	12/3/18	1/29/19	90	17	77%	NA
steel-head	2015/16	12/7/15	4/15/16	171	17	71%	13.35 (±0.98)
	2016/17	11/1/16	4/19/17	208	17	71%	12.23 (±1.02)
	2017/18	11/29/17	4/20/18	212	18	75%	12.74 (±0.73)
	2018/19[1]	12/3/18	1/29/19	90	18	75%	NA

[1]Life Cycle Monitoring
[2]Partial count through 1/31/2019 – season still underway

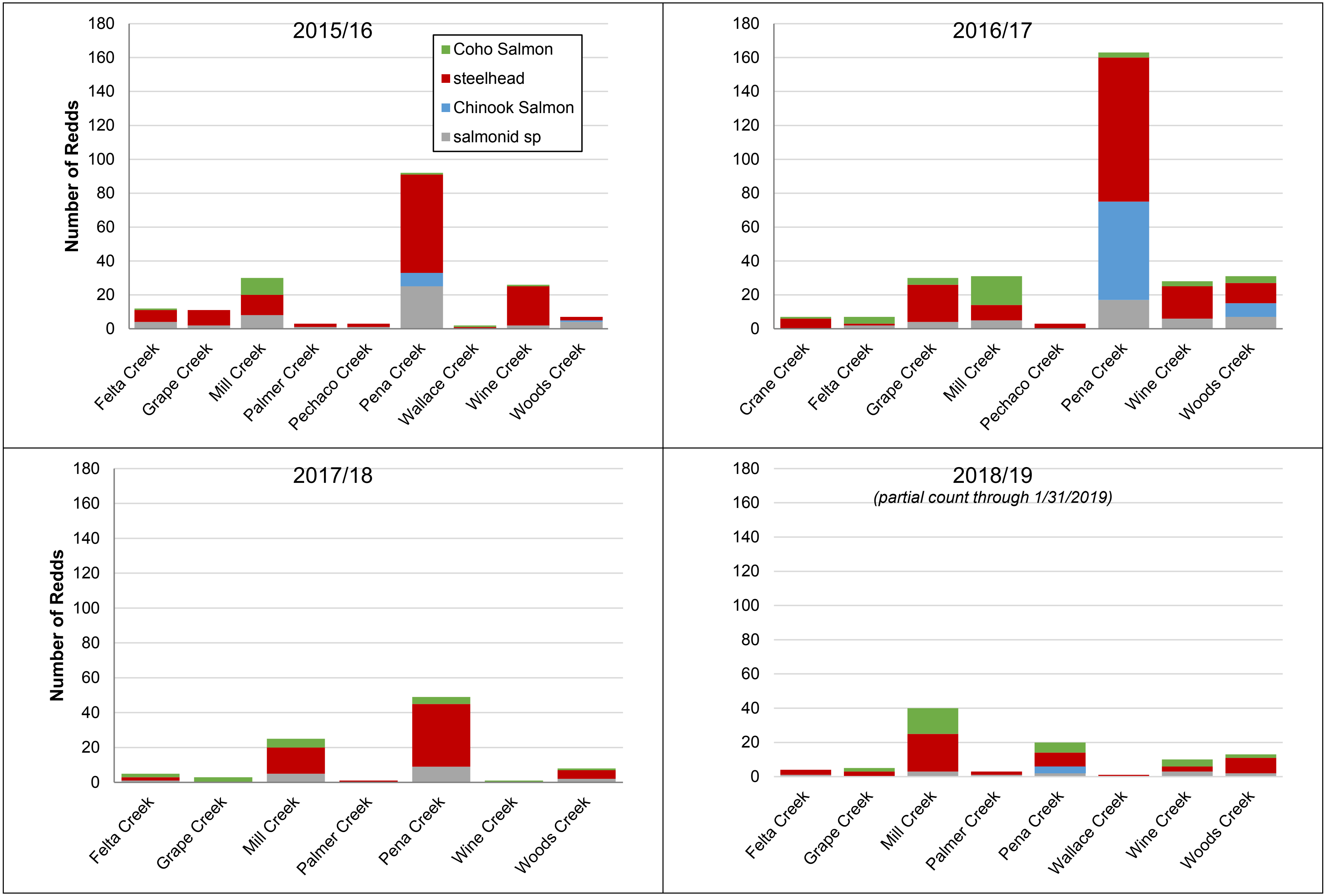


Figure II-8. Number of new redds counted by season and tributary in Dry Creek tributaries for all three levels of redd species certainty. Only tributaries where redds were observed are included.

Figure II-9. Number of live adult salmonids and carcasses counted by season and tributary for all three levels of fish species certainty. Only tributaries where live fish and carcasses were found are included. It is possible that some fish were counted more than once. Note differences in vertical scale among plots.

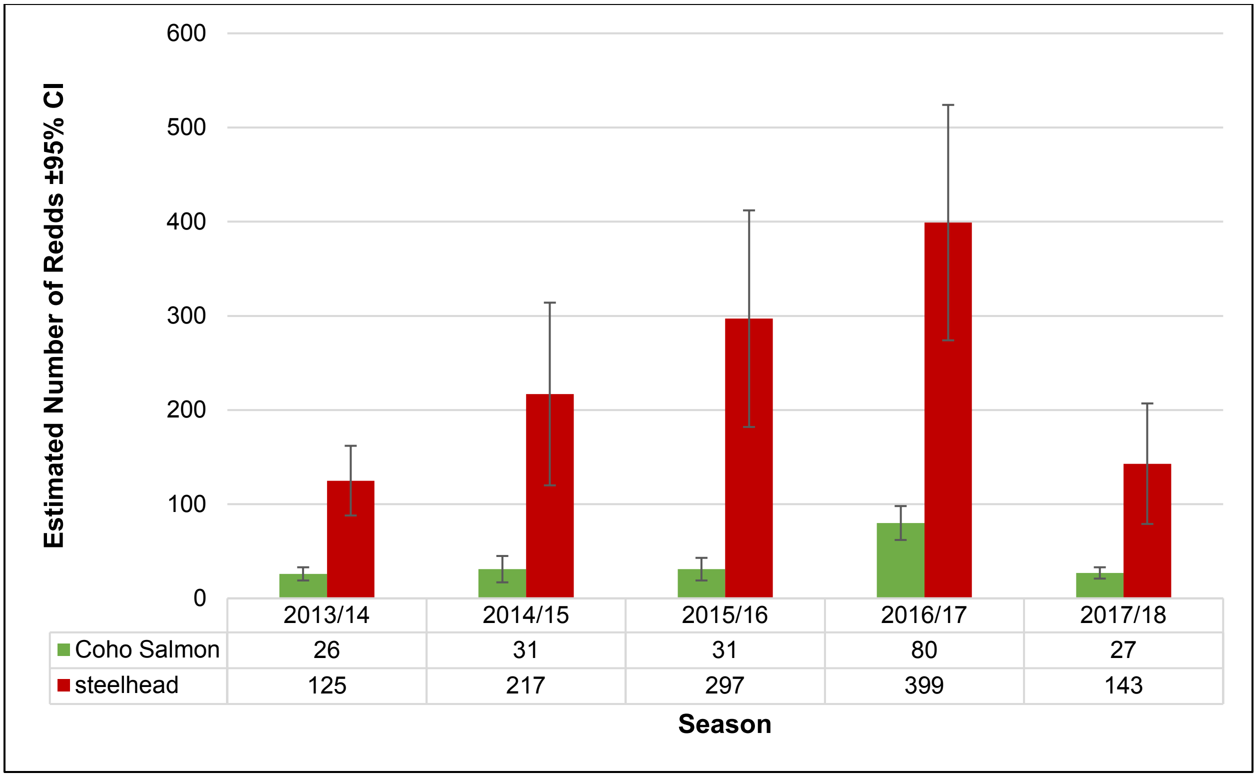
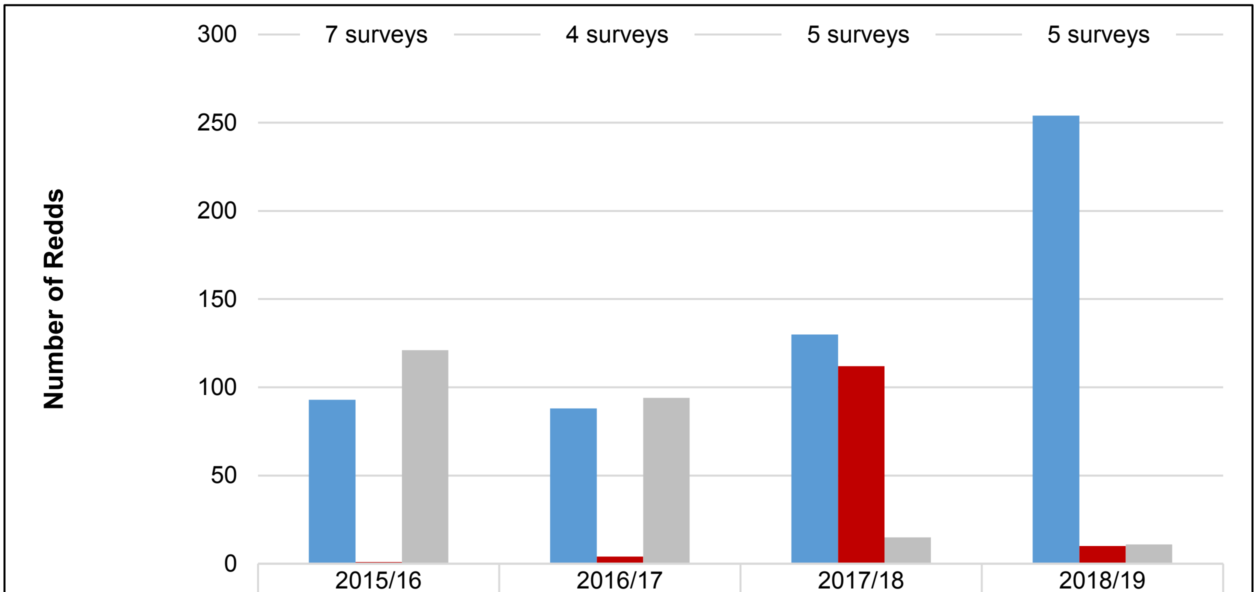


Figure II-10. Estimated redd abundance for Coho Salmon and steelhead in Dry Creek tributaries by season. Estimates calculated prior to the current grant reporting period are shown in order to display trends.

Dry Creek mainstem

Between 2015 and 2019 we completed 21 spawner surveys of the full 22 km length of mainstem Dry Creek. During the 2016/17 spawner season, heavy rains and runoff in late December produced high flows and turbidity that persisted throughout the spawner season thereby curtailing our ability to continue surveys beyond December 21. Conversely, during the 2017/18 spawner season early rains impacted our ability to conduct early surveys but that was followed by an extended period of dry conditions allowing us to conduct surveys later into the season. A high of 250 new Chinook redds were observed during the 2018/19 (Figure II-11). With the exception of 2017/18, because of high turbid water we were unable to conduct spawner surveys that were coincidental with steelhead spawning.



	2015/16	2016/17	2017/18	2018/19
Chinook Salmon	93	88	130	254
steelhead	1	4	112	10
salmonid sp.	121	94	15	11

Figure II-11. Number of new redds counted by season during mainstem Dry Creek spawner surveys.

Smolt abundance

Downstream migrant traps

The number of Coho and steelhead smolts captured in the mainstem Dry Creek trap was generally low and this was particularly true for Coho in 2018 when only 105 were caught in the Dry Creek trap (Figure II-12). In the Mill Creek trap, however, the catch was over ten-fold higher. Steelhead smolt capture was very low in both traps in all four years.

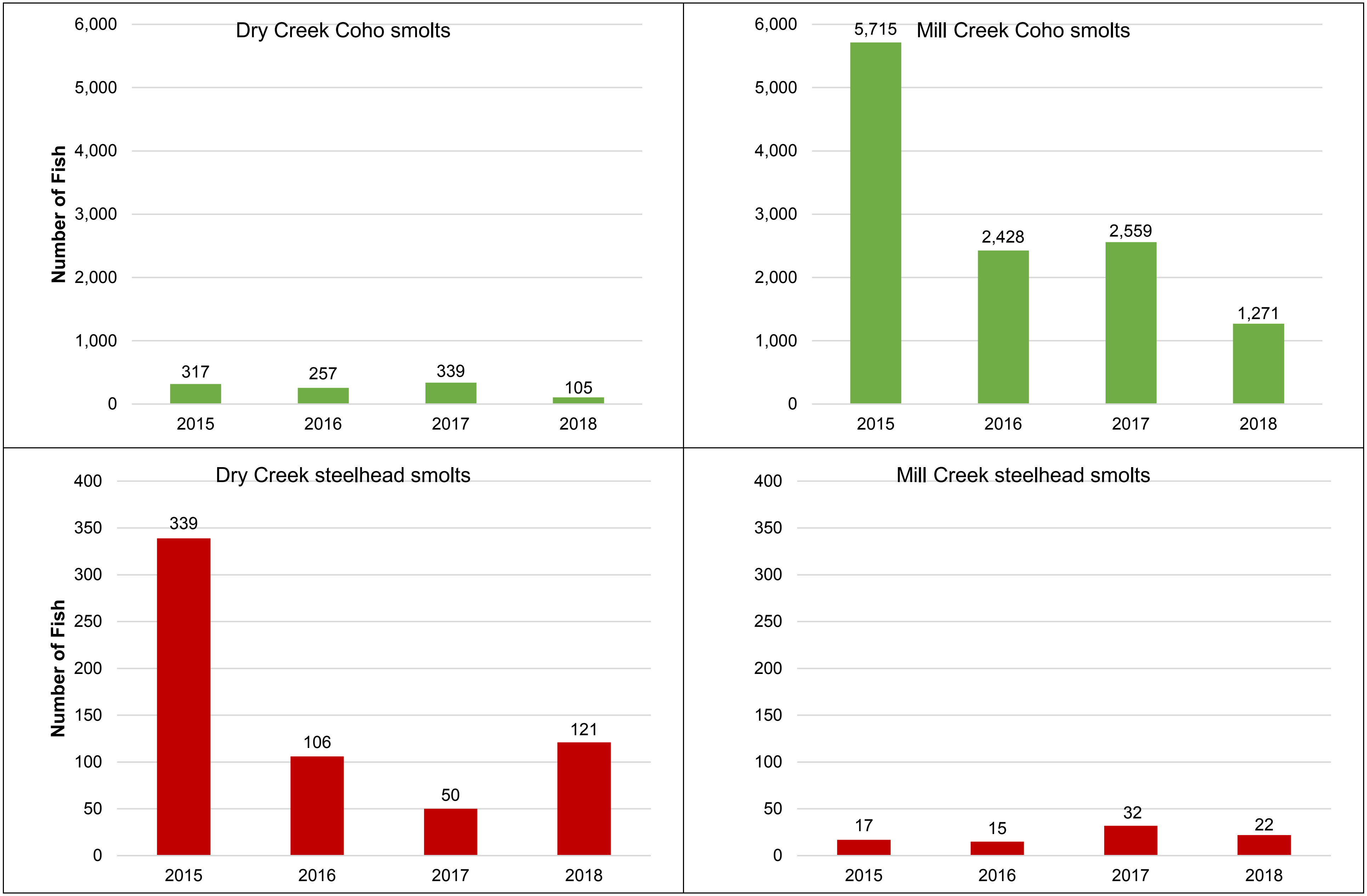


Figure II-12. Number of Coho smolts (upper panels) and steelhead smolts (lower panels) captured in the Dry Creek and Mill Creek downstream migrant traps, 2015-2018.

The number of Chinook smolts captured in the mainstem Russian River trap was 650 in 2017 and 2,663 in 2018. The Mirabel trap was not fished in 2015 or 2016 because of ongoing construction of a new fish ladder on the west side of Sonoma Water's inflatable dam. In addition, ongoing fish ladder construction in spring 2017 resulted in late trap installation which presumably led to low trap catches.

Pre-smolt steelhead abundance model

Pre-smolt steelhead abundance – Dry Creek mainstem

Electrofishing surveys in mainstem Dry Creek were conducted between August 13 and October 15 each year. The length of each sampled sub-reach ranged from 55 m to 535 m, with a mean sub-reach length of 240 m and an average depth of 0.48 m. The composition and quality of the sampled sub-reaches varied within and between years. Due to this variability there were instances when portions of a sub-reach were not sampled because they were too deep (over 1 m) or flows were too fast to safely and effectively operate a backpack electrofisher.

The pre-smolt steelhead population estimate for mainstem Dry Creek ranged from a high of over 50,000 in 2017 to a low of approximately 30,000 in 2018 (Figure II-13). The four-year average on mainstem Dry Creek of approximately 39,000 fish was over four-fold higher than the two-year average of 8,600 in the tributaries. The reach-specific mainstem Dry Creek density estimates tended to be the lowest in reach 5 (rkm 9.99-11.62) (Figure II-14). In 2018, we were not able to calculate a population estimate for reach 5 due to the poor sampling efficacy in a sub-reach that was deep with slow moving water. Therefore, the Dry Creek population estimate for reach 5 in 2018 was approximated from the average population estimates of the previous three years of sampling in that reach and included in the total 2018 Dry Creek estimate.

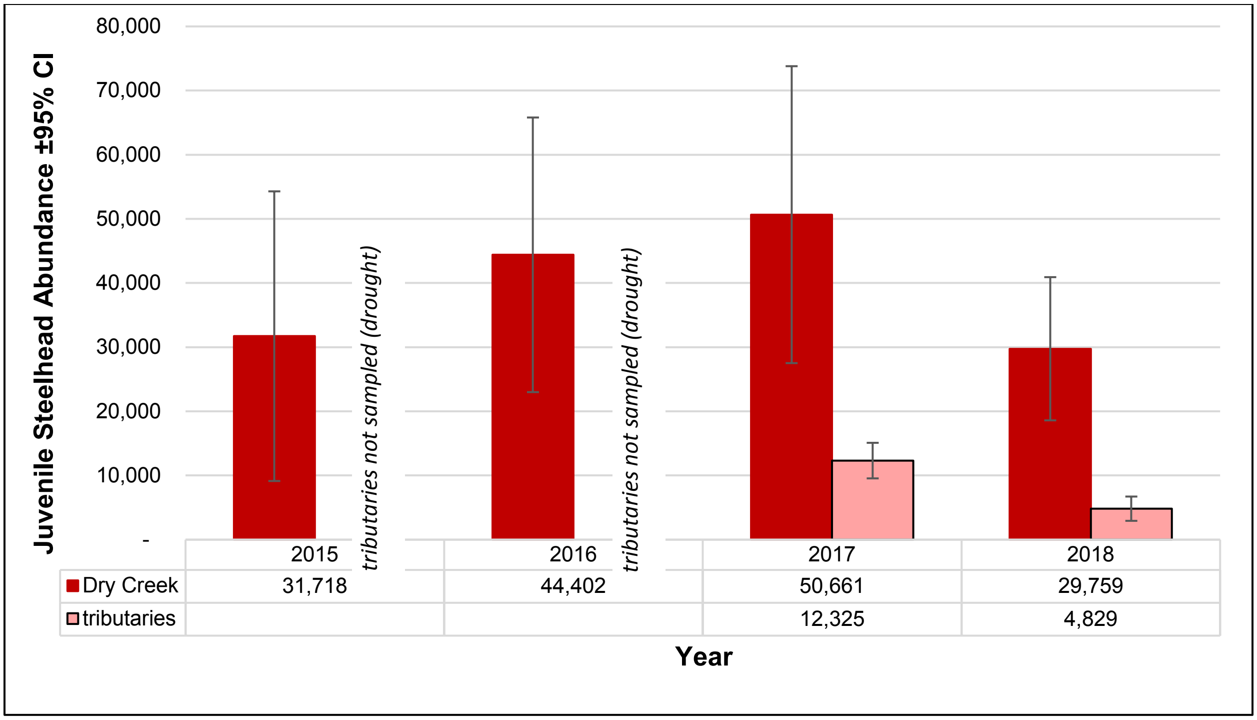


Figure II-13. Pre-smolt steelhead population estimates for mainstem Dry Creek from 2015 to 2018 and tributaries to Dry Creek from 2017 to 2018. Sampling was not conducted in the tributaries during 2015 and 2016 due to drought conditions.

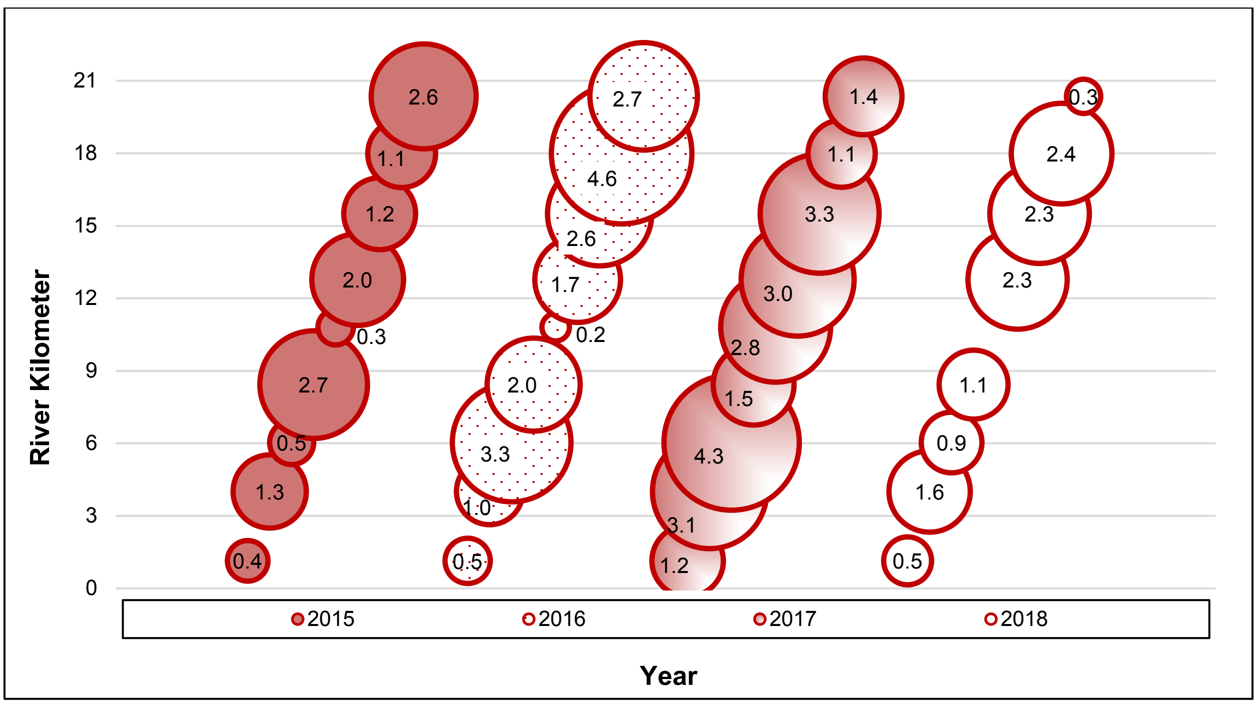


Figure II-14. Reach specific estimates of pre-smolt steelhead density (fish·m^{-1}) from 2015 to 2018. Bubble size represents the relative density and the calculated value is presented inside each bubble. The y-axis represents reach location within Dry Creek where 0 km is the confluence with the Russian River and 22 km is Warm Springs dam.

Pre-smolt steelhead abundance – Dry Creek tributaries

We hypothesized that our ability to observe juvenile fish while snorkeling may have been influenced by pool size, pool complexity, number of fish and observer experience. If present, such variability could translate to variability in the calibration ratio and higher uncertainty in our two-stage abundance estimate. Therefore, in order to apply the most appropriate calibration ratio ($\widehat{R}_p = \hat{n}_{ef} \cdot n_{sn}^{-1}$;where $\hat{n}_{ef}$ is the number of juvenile steelhead estimated based on depletion electrofishing and n_{sn} is the number of juvenile steelhead observed during snorkel surveys), we used ANOVA with pool metrics (pool area, number of fish observed, reach, large wood) as categorical factors to help explain variability in $\widehat{R}_p$ among pools. In 2017, the number of fish observed (snorkel count) had a marginal influence on $\widehat{R}_p$ ($p=0.069$) and in 2018 both the number of fish observed and pool size had a strong influence on $\widehat{R}_p$ ($p = 0.002$ and $p = 0.023$, respectively). Based on these results there were two values of $\widehat{R}_y$ applied to snorkel counts in 2017 and four values of $\widehat{R}_y$ applied to snorkel counts in 2018 (Table II-3).

Table II-3. Calibration ratios ($\widehat{R}_y$) used to generate estimates for the population of juvenile steelhead in tributaries to Dry Creek during the late summer/early fall in 2017 and 2018.

Year	Snorkel count	Pool size	$\widehat{R}_y$	$\widehat{se}$	95% LCI	95% UCI
2017	≤ 10	na	3.19	0.46	2.24	4.14
	>10	na	1.86	0.14	1.55	2.17
2018	≤ 10	≤ 100m^2	2.30	0.34	1.60	3.01
		>100m^2	4.60	0.69	2.82	6.38
	>10	≤ 100m^2	1.10	0.37	-0.49	2.69
		>100m^2	1.71	0.15	1.38	2.05

The year- and stratum-specific correction factor ($\widehat{R}_y$) for snorkel counts was applied to the number of steelhead juveniles observed during snorkel surveys in the late summer/early fall to calculate an annual population estimate for seven small tributary streams of Dry Creek that collectively represent the majority of juvenile steelhead habitat space in tributaries of Dry Creek. Pools were grouped by one or two categorical variables depending on the year (Table II-3) and the corresponding correction factor was applied to snorkel counts. To generate a population estimate, the sum of corrected snorkel counts (i.e. after applying $\widehat{R}_y$) for each tributary stream in each year was doubled to account for the fact that we only snorkeled every other pool.

A total of 404 pools were snorkeled in 2017, representing 50% of accessible pool habitat in the selected tributary streams. Second stage electrofishing surveys were conducted in 10% of the pools in Mill Creek, Felta Creek and Palmer Creek (39 pools) with all sampling completed between September 25 and October 5, 2017. A total of 309 pools were snorkeled in 2018, representing 50% of the accessible pool habitat in the selected tributary streams. Second stage electrofishing surveys were conducted in 17% of the pools in Mill Creek, Felta Creek and Palmer Creek (74 pools). Due to lack of surface flow and marginal water quality conditions, the lowest portion of Felta Creek and the upper portion of Mill Creek was excluded from the second stage sampling in 2018. Initial stage sampling was completed between September 24 and October 16, 2018 and second stage sampling was completed between October 1 and October

15, 2018. Pre-smolt steelhead population estimates for the seven Dry Creek tributaries ranged from over 6,300 in Mill Creek in 2017 to fewer than 10 in Wine Creek in 2018 (Figure II-15). The total estimated abundance of pre-smolt steelhead from the sampled tributary streams was 12,325 (±2,772 95% CI) in 2017 and 4,829 (±1,892 95% CI) in 2018 (Figure II-13).

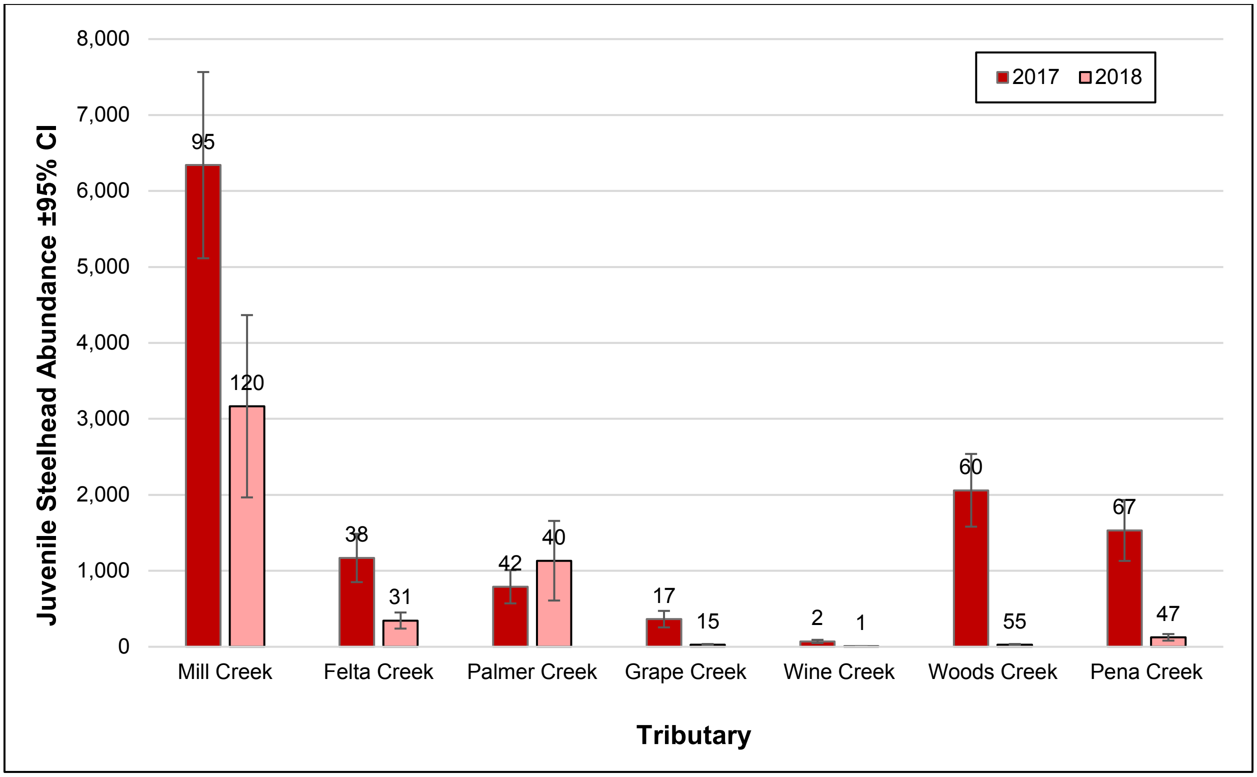


Figure II-15. End-of-summer population estimates for juvenile steelhead in selected Dry Creek tributaries for 2017 and 2018. Values at the top of each bar indicate the number of pools snorkeled.

Survival index

During the fall through spring steelhead emigration period in 2017/18, the raw proportion (i.e., not adjusted for antenna efficiency) of fish emigrating from Mill Creek was 23% (321 out of 1,390 individuals that were PIT-tagged in fall 2017) but the raw proportion emigrating from Dry Creek was much lower (4-8%) (Table II-4). Dry Creek antenna efficiency varied among years and was lower in Dry Creek than in Mill Creek in winter 2017/18.

Table II-4. Year and stream of PIT-tagging and number of fish detected at the mouth of Dry Creek and Mill Creek during the ensuing steelhead emigration period of November 1 through June 30.

Year PIT-tagged	Stream	Number PIT-tagged	Raw detections at mouth	Raw proportion emigrating	Antenna efficiency	Survival index
2015	Dry Creek	1,671	61	0.04	0.56	0.07
2016	Dry Creek	1,470	52	0.04	0.56	0.06
2017	Dry Creek	1,668	141	0.08	0.29	0.30
	Mill Creek	1,390	321	0.23	0.88	0.26

Abundance estimates

We were able to estimate Coho smolt abundance each year from 2015 to 2018 at the Mill Creek trap only. Abundance ranged from 6,655 in 2016 to 18,207 in 2015 (Figure II-16). Catches were too low at the Dry Creek smolt trap to allow estimates. Due to fish ladder construction, we could only estimate Chinook smolt abundance at Mirabel in 2018 (46,519; ±15,838 95% CI).

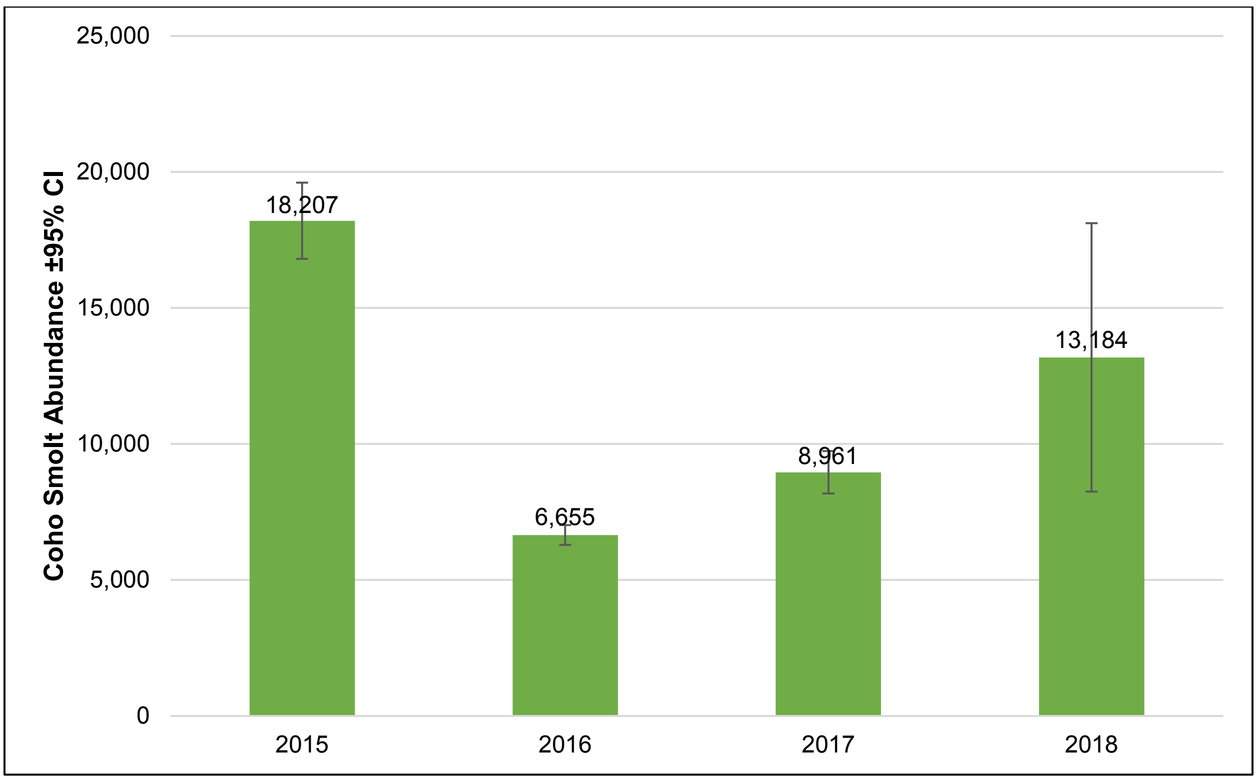


Figure II-16. Estimated Coho smolt abundance from the 2-trap DARR estimator at the Mill Creek downstream migrant trap, 2015-2018.

It was not possible to estimate steelhead smolt abundance using downstream migrant traps; therefore, we applied the survival index described above to estimate the number of steelhead emigrating from the Dry Creek LCS (Table II-5). In 2015 and 2016 the estimated number of emigrants from Dry Creek was very low (2,068 and 2,800, respectively) but markedly higher in 2017 (14,989).

Table II-5. Estimated number of steelhead pre-smolt emigrants from mainstem Dry Creek and Mill Creek.

Year PIT-tagged	Stream	Survival index	Fall pre-smolt abundance	Number of emigrants
2015	Dry Creek	0.07	31,718	2,068
2016	Dry Creek	0.06	44,402	2,800
2017	Dry Creek	0.30	50,661	14,989
	Mill Creek	0.26	8,299	2,178

Discussion

Adult abundance

The Dry Creek DIDSON worked well for detecting adult, salmonid-sized fish entering Dry Creek but was inadequate both for differentiating between species of salmonids and for differentiating adult salmonids from other adult, salmonid-sized fish (i.e., 18 inches or >46 cm). While we were able to devise methods for assigning species to salmonid counts on the DIDSON, our methodology likely led to inaccuracies in species counts that varied by year and are impossible to quantify or correct.

During the 2015/16 spawner season, we recorded 12,802 “salmonids” (i.e., length >46 cm) passing the DIDSON as they entered Dry Creek (Figure II-6). This count is nearly double the next largest count in the reporting period. After applying proration (see Methods), this led to an estimate of 8,925 steelhead returning to Dry Creek (Table II-1) which seems unlikely given the number of steelhead returning to Warm Springs Hatchery (4,329) and the amount of available habitat in the Dry Creek watershed. Species misidentification was a likely contributor to this high estimate. For example, a 61 cm Sacramento Pikeminnow that was PIT-tagged on August 22, 2018 was detected on the Dry Creek PIT tag antenna array 76 times on 30 of the 117 days between September 11, 2018 and January 6, 2019. These detections coincided with the time period that we were operating the DIDSON to count adult salmonids so it is likely that this single individual was incorrectly recorded as an adult salmonid multiple times. Salmonid behavior could have been another contributing factor. The site where the DIDSON is mounted is not static. It changes as sand, gavel, and silt are removed and deposited by high winter flows in Dry Creek and the Russian River. When the DIDSON was first installed, the site had favorable conditions for DIDSON monitoring (i.e., narrow channel near the bank with fairly consistent, thalweg near the DIDSON camera). Over time, conditions at the site have widened and split (in some years) and the consistent, unidirectional flow now includes eddies. These changed conditions seem to have increased milling behavior at the site which likely resulted in multiple counts of the same fish. Unfortunately, as with errors in species identification, it is impossible to know what portion of fish were counted multiple times as a result of this behavior.

Another impediment to accurately assigning species to DIDSON counts is overlap in run-timing among the three species we monitored. During the early- to mid-portion of the adult Chinook migration season, we are fairly confident in our assumption that nearly 100% of adult-sized fish entering Dry Creek that were actually salmonids (which is uncertain) were adult Chinook. However, later in the Chinook migration season, overlap in run-timing increases which translates into an increased probability of a fish on the DIDSON being either a Coho or steelhead (Figure II-17). Prior to the historically-based end of Chinook migration in mid-December (based on data from the mainstem Russian Mirabel video system), we handled this by applying species ratios observed on the Mirabel video to Dry Creek DIDSON counts. After mid-December, we assumed that all large-bodied fish entering Dry Creek on the DIDSON were steelhead. However, there are at least three potential problems with this approach. First, it assumes that species ratios entering Dry Creek are the same as species ratios in the mainstem Russian River at Mirabel. Second, it assumes that the end of the Chinook migration period (mid-December) does not vary among years. Third, it does not allow for attributing fish counts to Coho thereby completely ignoring the fact that Coho are certainly entering Dry Creek after mid-December (Figure II-17).

Redd abundance

We were able to assign species to redds in Dry Creek tributaries with a slight modification to the approach outlined in Adams et al. (2011) that included the non-parametric KNN (Ricker et al. 2013) for the few redds we were unable to obtain measurements for in a given season. However, due to the swift, deep conditions prevalent in mainstem Dry Creek, we were not able to obtain physical measurements of redds and instead relied solely on species designations made by crews in the field. This method did not work well when visibility deteriorated later in the adult Chinook migration season and positive species identifications were less likely. Consequently, our Chinook redd counts are more accurate during the first one-half to two-thirds of the season but relatively inaccurate during the final portion of the season. For this reason, our species-specific redd abundance estimates in mainstem Dry Creek are probably biased low for all three species.

Smolt abundance

We were able to obtain consistently accurate and precise estimates of Coho Salmon smolt abundance on Mill Creek for all four years of Russian River CMP implementation; however, low catches of Coho smolts on mainstem Dry Creek have precluded any Coho smolt estimate for Dry Creek leaving us with a minimum count (trap catch) only. Because of low steelhead smolt trap catch on Dry and Mill creeks and the mismatch between trap operation and smolt timing (Figure II-17), we were unable to rely on trap catches alone for steelhead smolt abundance estimates; therefore, we turned to the pre-smolt steelhead abundance model. Based on that model, pre-smolt steelhead estimates were much higher for mainstem Dry Creek compared to its tributaries (Figure II-13). In part this was due to the fact that controlled releases into Dry Creek from Lake Sonoma provide consistent water flow (approximately 110 $ft^3 \cdot s^{-1}$, Figure II-17) that is likely beneficial to rearing steelhead. This is especially true in comparison to smaller, unregulated tributaries where surface flows even in the summer can vary widely within and among years thus having a large impact on available wetted habitat for rearing steelhead (CSG 2016).

It is precisely because of managed flows in Dry Creek, however, that we were unable to sample juvenile rearing habitat in mainstem Dry Creek in a manner that accurately represented the available habitat. Although we attempted to randomly select sub-reaches to sample in the nine Dry Creek reaches, we were constrained to stream sections that were shallow enough to safely and effectively sample with backpack electrofishing gear (Figure II-18). This led to a failure to sample deeper, swifter habitat types where juvenile densities may have differed from our shallower stream sections. For this reason, we have greater confidence in the steelhead pre-smolt population estimates in tributaries to Dry Creek than we do in mainstem Dry Creek. In tributaries, we were able to sample a larger portion of the habitat and we were able to do so in a more representative manner. The error associated with the pre-smolt steelhead estimate in the tributaries averaged about 30% of the estimate for all streams combined compared to 50% for mainstem Dry Creek. Given our two-stage sampling approach in the tributary streams, we were able to sample 50% of available pool habitat compared to only 6-22% of total stream length in Dry Creek.

In addition to issues with our mainstem Dry Creek pre-smolt abundance estimates, we have concerns regarding some of the data leading to our survival index estimates for mainstem Dry Creek (Table II-5). Most of this concern stems from issues related to the suitability of mainstem Dry Creek for steelhead life cycle monitoring. Because of its large size and the timing of steelhead smolt migration, it is difficult to monitor using more conventional downstream migrant trapping (as is recommended in Adams et al. 2011) and perhaps only marginally less difficult to monitor with a stationary PIT antenna array. We attribute the lower antenna efficiency on Dry Creek as compared to Mill Creek to the fact that Dry Creek has a much larger drainage area and is subject to backwatering from mainstem Russian River during high winter flows – both of which can effect antenna efficiency especially if steelhead are emigrating during high flow periods (Figure II-17). We also had relatively fewer raw detections on Dry Creek which is inconsistent with our expectation that, based on a larger average size at tagging (106 mm in Dry Creek vs. 79 mm in Mill Creek), there should be a higher probability of tagged fish emigrating as smolts from Dry Creek during the ensuing winter as compared to Mill Creek. We assert that a major contributing factor is that much greater water depths at the Dry Creek PIT antenna site persisted for longer duration which would translate into fish getting past the Dry Creek antenna array without ever being within the antenna detection field. At the US Geological Survey gage station at the mouth of Dry Creek where the Dry Creek antenna array is located, the median water depth from 2015-2018 during the steelhead smolt emigration period (January-May) was 2.6 m deeper than the water depth of 0.6 m at the Dry Creek base flow of approximately 110 $ft^3 \cdot s^{-1}$. In 2015, 43 of the 91 days (47%) between January 1 and March 1 when the majority of steelhead emigration from Dry Creek occurred, it was >3.6 m deep at the antenna site as compared to the 0.6 m base flow water depth. This likely contributed to the questionably low estimate of emigrants from Dry Creek in 2016 and 2017 (2,068 and 2,800, respectively) and a somewhat less questionable estimate in 2017 (14,989).

Although the above-described challenges prohibited us from obtaining unbiased steelhead smolt abundance estimates in Dry Creek, the approach was highly successful in the Dry Creek tributaries in 2017 and 2018. Early fall snorkel surveys in the Dry Creek tributaries were an efficient method of acquiring a base count of juvenile steelhead in all tributary habitat. Mill Creek was selected as the stream for estimation of the survival index because of the existing PIT tag antenna array operated by the Broodstock Program. Unlike in Dry Creek, we were able to successfully electrofish pools in Mill Creek and apply 988-1,390 PIT tags to juvenile steelhead each year in a spatially representative manner based on juvenile distributions observed during snorkel surveys. Over 20% of the Mill Creek steelhead tagged in fall of 2017 were detected leaving Mill Creek the following spring, which allowed us to estimate a survival index and smolt abundance estimate with greater confidence than that in Dry Creek. As we continue this approach in Mill Creek during the next few years, we will be able to further evaluate this approach for steelhead monitoring and determine whether or not we are tagging at a high enough rate to estimate adult returns. We will also be able to gain a better understanding of steelhead life history patterns such as migration timing and age structure.

One final issue with our estimates of steelhead emigration (whether unbiased or not) comes from questions of whether steelhead emigrants are actually smolts when they leave their stream of origin. Given their size at tagging and the growth rates we have observed in Dry Creek and elsewhere, we expect that many if not all of the emigrants we detected could attain an adequate "smolt size" (>150 mm) by the time they entered the estuary. Because of our network of PIT antenna arrays downstream of Dry Creek, we have some opportunity to evaluate these questions by looking at detections of steelhead emigrants from both Dry Creek and Mill Creek on downstream PIT antenna arrays. An interesting finding from the 2017 tagging cohort is that although a similar number of emigrants from each group were detected on the estuary antenna array at Duncans Mills (11 from Dry Creek and 12 from Mill Creek), 32 fish were detected on Porter Creek, Mark West Creek, and Green Valley Creek antenna arrays (combined) after leaving Mill yet only one of the Dry Creek emigrants was detected on any of those same arrays (Mark West Creek). In the case of Mark West and Green Valley creeks, the distance fish had to move upstream in order to be detected was 4 to 6 km indicating that emigrants from Mill Creek may have been less prepared to smolt than emigrants from Dry Creek.

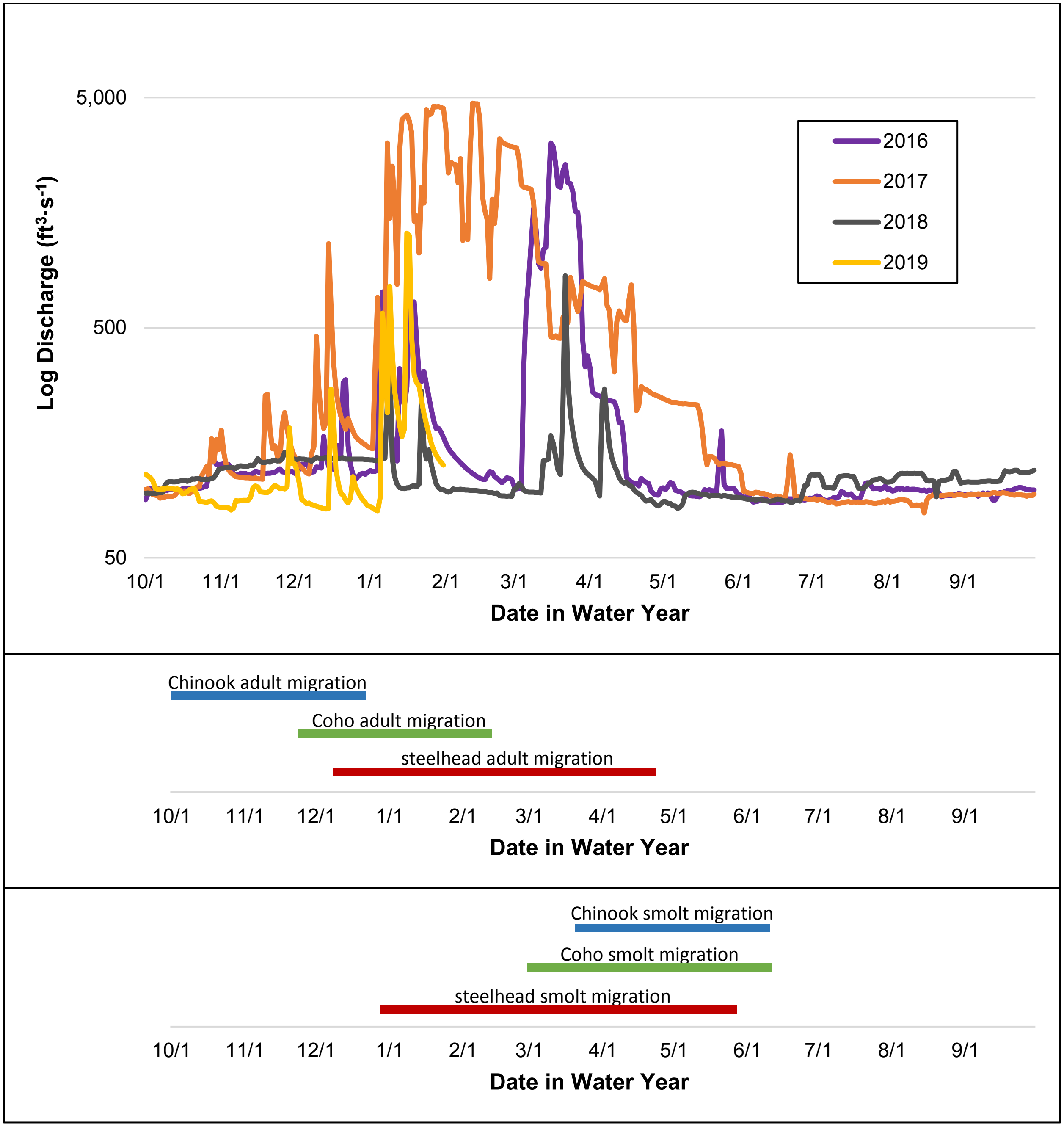


Figure II-17. Dry Creek hydrograph by water year, and typical migration season for Coho, steelhead and Chinook based on PIT antenna detections and downstream migrant trap catches in Dry and Mill creeks, video data at the Chinook LCS and CMP spawner surveys in Dry Creek tributaries.

Figure II-18. Typical conditions in mainstem Dry Creek during juvenile sampling in September.

Chapter III. Basinwide monitoring

Introduction

Basinwide sampling using a GRTS framework is designed to work in concert with life cycle monitoring to provide information on population status and trends at the watershed scale. These data can be combined with CMP data from other coastal systems to measure progress toward population recovery at the ESU scale (Adams et al. 2011). In this chapter, we provide results of basinwide adult abundance sampling (from spawner surveys) and juvenile spatial structure sampling (from snorkel surveys) aimed at accomplishing basinwide CMP objectives.

Methods

Redd abundance (basinwide)

Field methods for basinwide spawner surveys were almost identical to those described above for spawner surveys in the Dry Creek LCS. The difference was that while a near-census of reaches was conducted for all tributaries of Dry Creek, a subsample of reaches for basinwide surveys were chosen based on the GRTS ordering and placed into rotating panels (see Chapter I). During the 2015/16, and 2016/17 spawner seasons, we employed the methods recommended by Adams et al. (2011) and outlined in Gallagher et al. (2007) to survey for redds, live fish, and carcasses in the adult Coho-steelhead sample stratum. During the 2017/18 and 2018/19 spawner seasons, we used the same methods to survey for redds, live fish, and carcasses in both the Coho-steelhead sample stratum and the steelhead-only sample stratum (reaches in Figure I-2 that do not overlap with Coho) with separate estimates calculated in each stratum for each species. Reaches where landowner access could not be secured for at least 75% of the reach length were skipped and the next reach in the GRTS draw was substituted.

We estimated basinwide redd abundance in the Coho-steelhead sample stratum (80 reaches, Figure I-2) in 2015/16 through 2017/18 and in the steelhead sample stratum (395 reaches, Figure I-3) in 2017/18 using estimation methods identical to the methods described for deriving total redd estimates from spawner surveys in the Dry Creek LCS (Ricker et al. 2014; Adams et al. 2011). Like the Dry Creek LCS surveys, this approach employed both a within-reach and among-each expansion each season. At the time of this report, the 2018/19 spawner season was incomplete thus we only report counts to date for that season.

Juvenile Coho Salmon spatial structure

A total of 96 reaches within the Russian River sample frame were categorized as juvenile Coho reaches (Figure I-2). Each summer between 2015 and 2018, we surveyed all of the reaches where we had landowner access. In 2015, we sampled 59 reaches, representing 60% of the juvenile Coho stratum, and in 2016 to 2018 we sampled between 72 and 77 reaches representing approximately 75% of the juvenile Coho stratum.

Sampling to estimate juvenile Coho occupancy was based on modifications of protocols in Garwood and Ricker (2014). In each survey reach, two independent snorkeling passes were completed. On the first pass, fish were counted in every other pool within the reach, with the first pool sampled (pool 1 or pool 2) 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 3 m^2. For use in occupancy models, a second pass was completed the following day in which every other pool that was snorkeled during the first pass was snorkeled a second time (every fourth pool). A GPS point was collected at the downstream end of each pool snorkeled on the pass 1 survey.

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. In larger pools requiring two snorkelers, two lanes were agreed upon and each snorkeler moved upstream through their designated lane at a similar rate. Final counts for the pool were the sum of both lane counts. All observed salmonids were identified to species (salmonids only) 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, QA/QC'd, and transferred to a SQL database. Spatial data were downloaded, QA/QC'd, and stored in an ArcGIS geodatabase for map production.

A multiscale occupancy model was used to estimate the probability of juvenile Coho occupancy at the reach scale (ψ) and conditional occupancy at the pool scale (θ), given presence in the reach (Nichols et al. 2008; Garwood and Larson 2014). Detection probability (p) at the pool scale was accounted for using the data from repeat dives. The proportion of area occupied (PAO) for the sample frame was then estimated as the product of the reach and pool scale occupancy parameters ($\psi * \theta$). All models were run in Program MARK (White and Burnham 1999). Snorkel surveys were carried out prior to release of hatchery juveniles to ensure that occupancy estimates reflected natural-origin fish. In 2016, three reaches were snorkeled after fish had been released in upstream tributaries so observations may have included a small number of hatchery-origin YOY in addition to natural-origin YOY.

Results

Redd abundance (basinwide)

The start date for basinwide spawner surveys was in November or December, concurrent with the start of spawner surveys in the Dry Creek LCS, depending on when rain reconnected tributaries (thus allowing fish access), and continued through mid-April (Table III-1). The reaches surveyed and the number of surveys conducted in each reach varied by year and depended on survey conditions. For the 2015/16, 2016/17 and 2017/18 seasons, we observed Coho and/or steelhead redds in 16, 15 and 25 tributaries, respectively (Figure III-1, Figure III-2, Figure III-3, Figure III-4) with the increase in 2017/18 arising because we expanded our efforts into the adult steelhead only stratum. Coho adults were most frequently observed in Green Valley Creek (Figure III-5). Estimates of total Coho redd abundance increased steadily from the 2013/14 season through the 2016/2017 season but declined in 2017/18 (Figure III-6). Basinwide steelhead redd abundance (905; ±465 95% CI) was only estimated for the 2017/18 season (the 2018/19 season is not yet complete).

Table III-1. Summary of basinwide spawner survey effort.

Species	Season	Season start	Season end	Number of surveys completed	Reaches used for estimate	% Sample stratum	Mean days between surveys (±95% CI)
Coho Salmon	2015/16	12/7/15	4/15/16	276	31	39%	14.65 (±1.02)
	2016/17	11/1/16	4/19/17	445	33	42%	11.99 (±0.65)
	2017/18	11/29/17	4/20/18	493	32	41%	14.56 (±0.98)
	2018/19[1]	12/3/18	1/29/19	218	32	41%	NA
steel-head	2017/18	11/29/17	4/20/18	493	29	7%	14.92 (±2.06)
	2018/19[1]	12/3/18	1/29/19	218	30	8%	NA

[1]Partial count through 1/31/2019 – season still underway

Figure III-1. Distribution and count of Coho redds by season and reach in the adult Coho stratum outside and within the Dry Creek LCS.

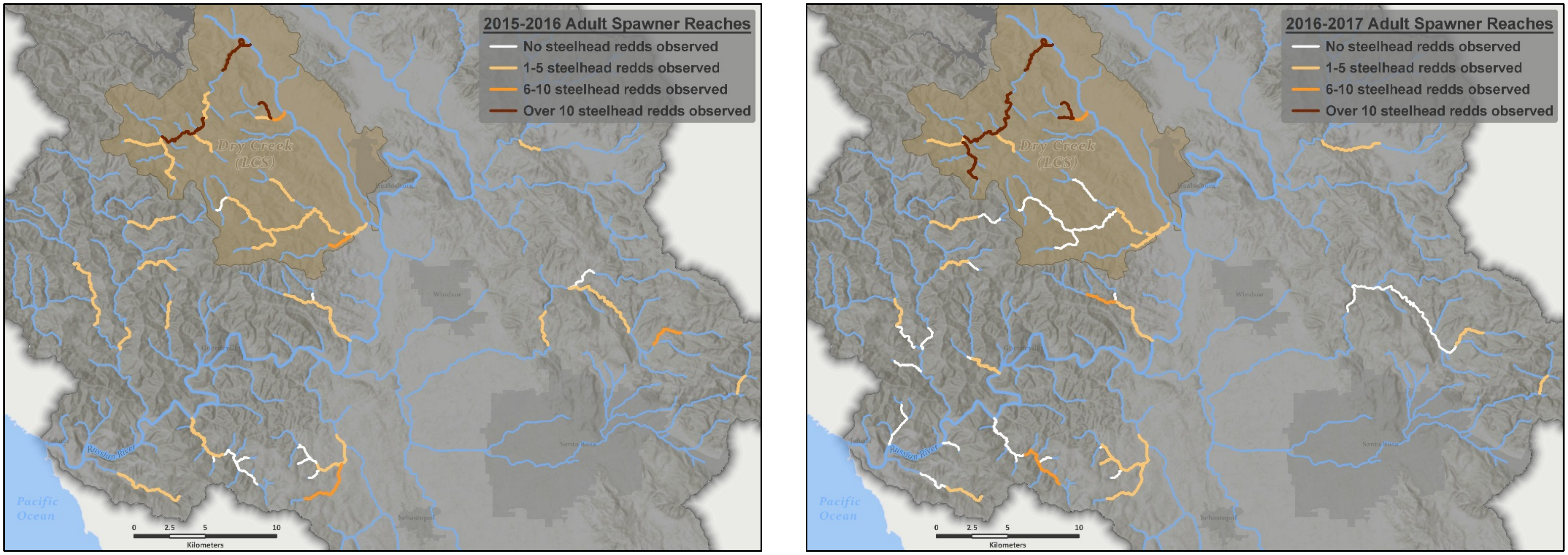


Figure III-2. Distribution and count of steelhead redds by season and reach in the adult Coho stratum outside of the Dry Creek LCS and the adult steelhead stratum within the Dry Creek LCS, 2015/16 and 2016/17 seasons.

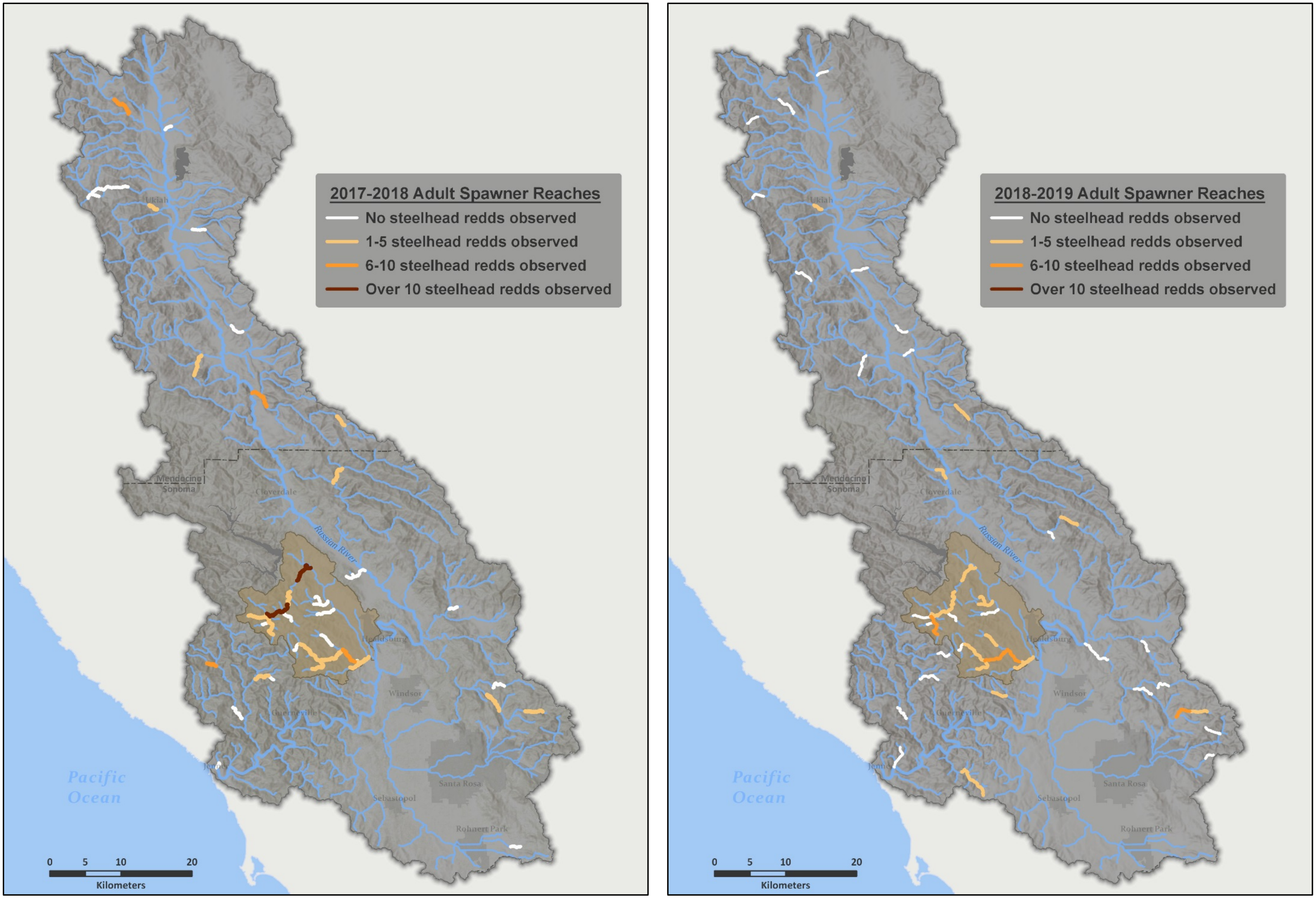


Figure III-3. Distribution and count of steelhead redds by season and reach in the adult steelhead stratum outside and within the Dry Creek LCS, 2017/18 and 2018/19 seasons.

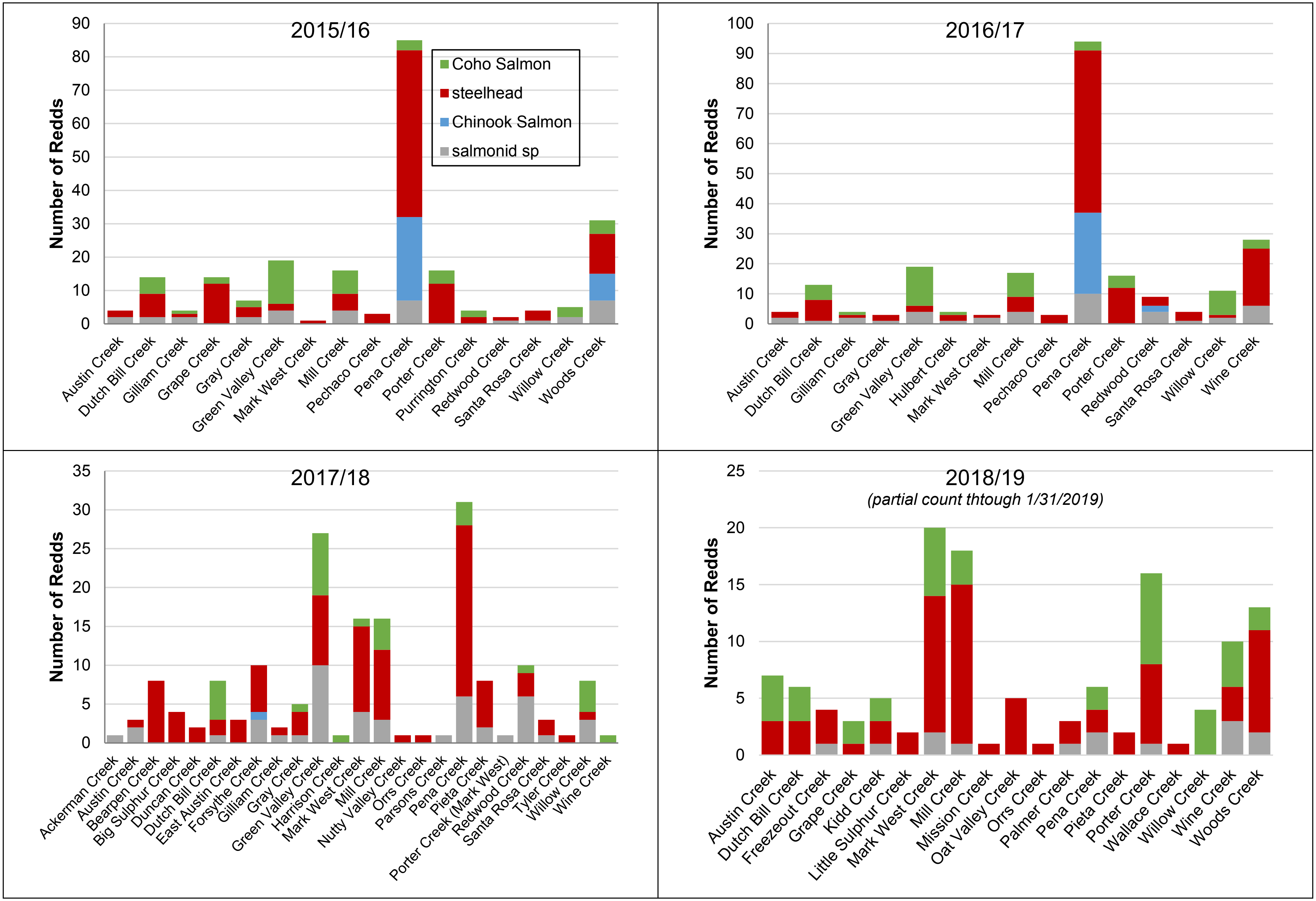


Figure III-4. Number of new redds counted in basinwide spawner surveys by season and tributary for all three levels of redd species certainty. Only tributaries where redds were found are included. Note that not all habitat within each creek may have been surveyed in a given year (i.e., only reaches included in the rotating panel for a given season were surveyed). Note differences in vertical scale among plots.

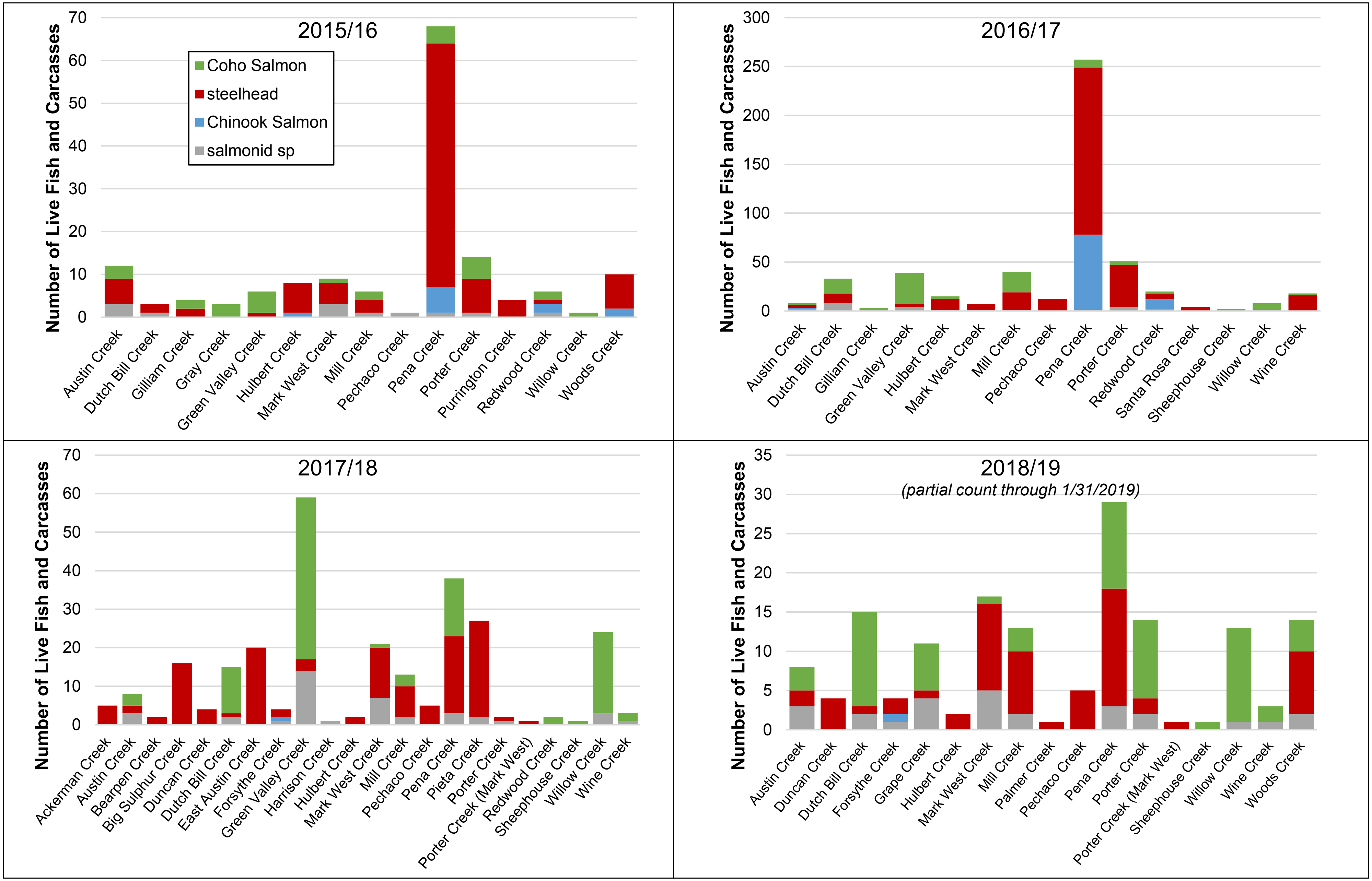


Figure III-5. Number of live adult salmonids and carcasses counted in basinwide spawner surveys by season and tributary for all three levels of fish species certainty. Only tributaries where live fish and carcasses were found are included. It is possible that some fish could have been counted more than once. Note that not all habitat within each creek may have been surveyed in a given year (i.e., only reaches included in the rotating panel for a given season were surveyed). Note differences in vertical scale among plots.

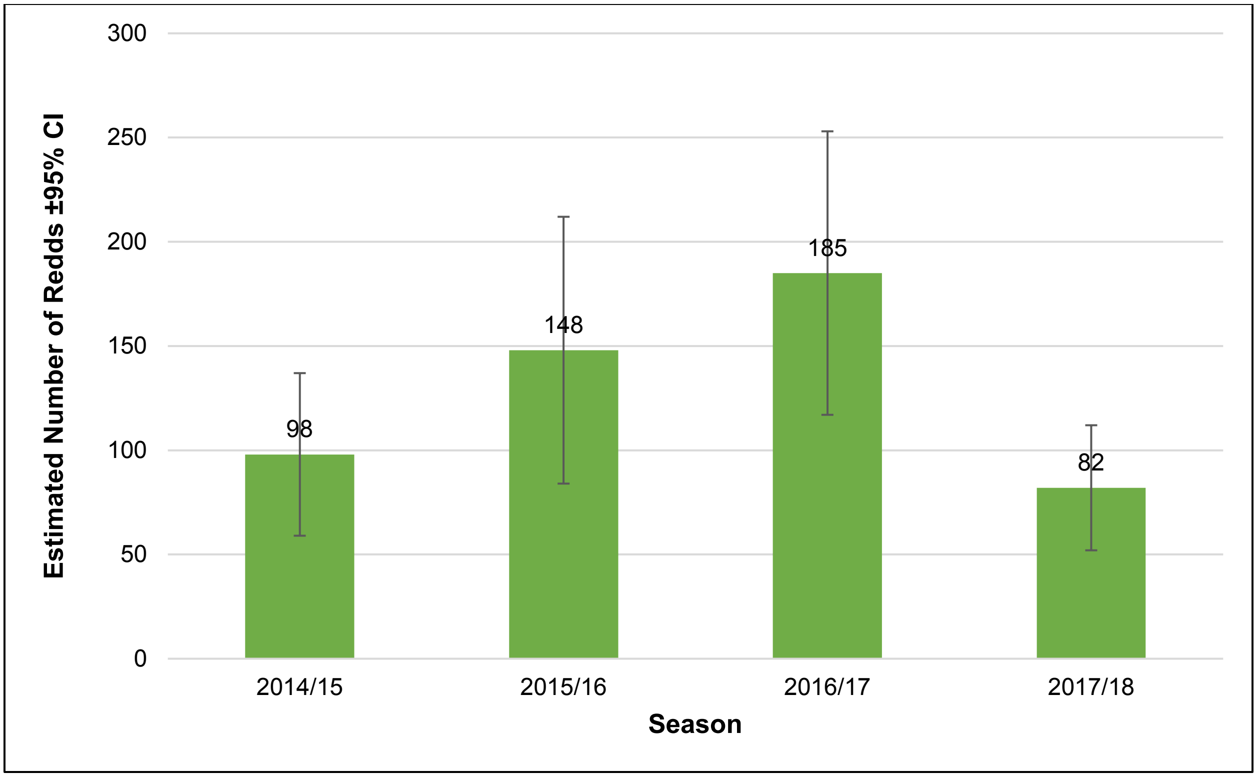


Figure III-6. Basinwide estimates of redd abundance for Coho Salmon.

Juvenile Coho Salmon spatial structure

Juvenile Coho were distributed throughout 20 to 24 of the 28 to 36 reaches surveyed (Figure III-7, Appendix G) with highest counts consistently in Green Valley Creek. Based on results of the multiscale occupancy model, we estimate that the probability of Coho YOY occupying a given reach (ψ) within the basinwide Russian River Coho juvenile stratum ranged from 0.50 to 0.70 between 2015 and 2018 (Table III-2). The conditional probability of Coho YOY occupying a pool within a reach, given that the reach was occupied (θ), ranged from 0.42 to 0.54. The proportion of the Coho stratum occupied (PAO) ranged from 0.21 to 0.37.

Table III-2. Coho YOY occupancy estimates and proportion of area occupied from 2015 through 2018.

Year	Reaches sampled	Ψ^1 (95% CI)	θ^2 (95% CI)	PAO[3]
2015	58	0.68 (0.54-0.79)	0.54 (0.49-0.59)	0.37
2016	72	0.70 (0.58-0.80)	0.47 (0.43-0.51)	0.33
2017	73	0.50 (0.38-0.61)	0.42 (0.39-0.46)	0.21
2018	70	0.58 (0.46-0.69)	0.43 (0.39-0.46)	0.25

[1] Probability of a reach being occupied
[2] Probability of pool occupancy given the reach is occupied
[3] Proportion of area occupied

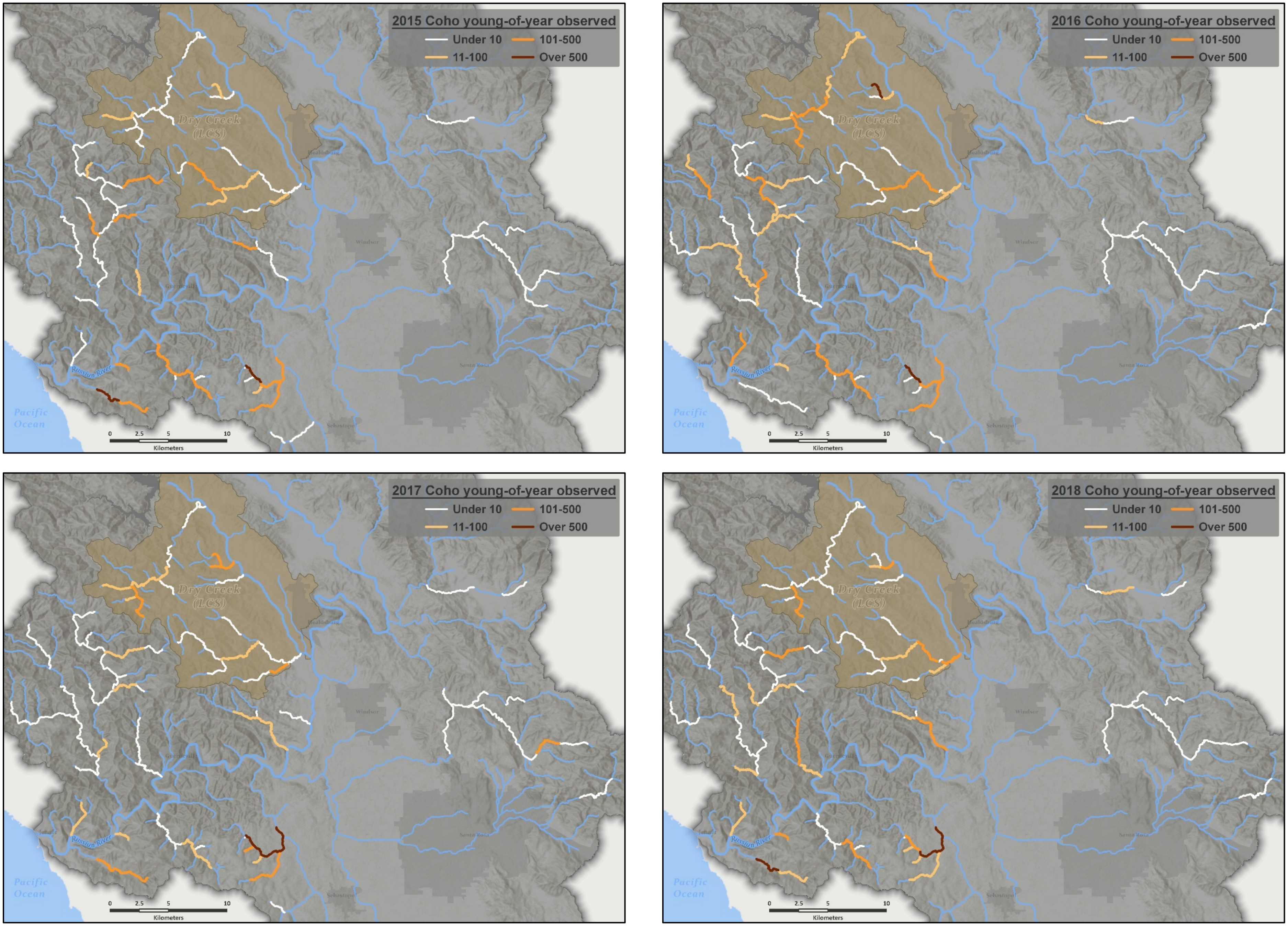


Figure III-7. Distribution and count of juvenile Coho by season and reach in the juvenile Coho stratum.

Discussion

In the Russian River watershed, we have used CMP protocols to estimate basinwide Coho Salmon redd abundance since 2014/15 and 2017/18 marked the first known basinwide steelhead redd abundance estimate in the Russian. These estimates were largely facilitated by finalization of the sample draw for the Russian River CMP sample frame which gives us a solid foundation to base our Coho and steelhead rotating panels.

Because of the sheer number of reaches in the basin containing steelhead habitat, and because of the labor-intensive nature of conducting spawner surveys, we were able to sample only a very small percentage of the available steelhead habitat (7 to 8%, Table III-1). In order to adequately capture the variability in salmonid abundance and productivity, Gallagher (2010) recommends a sampling effort of 15% of the reaches in the sample frame or 41 reaches (whichever is fewer). While we approached the 41 reach benchmark, we were only about halfway to the desired 15% target. To put that into perspective, we used 29 or 30 reaches to make inference for 395 reaches. This is in no way to disparage the statistically-sound GRTS framework, rather it is meant as a reality check for those guiding the future direction of statewide CMP monitoring as to the labor- and cost-intensive nature of this sampling methodology.

A possible way of increasing the percentage of available steelhead habitat sampled without increasing the amount of effort, is to make use of less labor-intensive snorkel survey methods for juvenile steelhead in the summer using the GRTS-based ordering to draw sample reaches and use those snorkel survey results as an index to adult abundance. While Adams et al. (2011) do not prioritize spatial structure monitoring for steelhead, they do state that “the CMP will revisit prioritization of steelhead spatial structure surveys, incorporating them as soon as possible after project implementation begins.”. While we are committed to rigorously following the sampling strategies of the CMP as outlined in Adams et al. (2011) and certainly recognize the value of spawner surveys, our view is that GRTS-ordered snorkel surveys for steelhead in the Russian River could be a useful way to augment spawner surveys. The presence and relative abundance of juveniles is a more direct measure of reproductive success than the presence and/or relative abundance of redds. Snorkel surveys cause the least impact on ESA/CESA-listed species and are cost-efficient, requiring significantly less effort than spawner surveys. Snorkel surveys require two visits per reach per season vs. 10-20 visits per reach per season required for spawner surveys in order to obtain an accurate redd estimate. Summer-time snorkel surveys are also not subject to unsurveyable winter-time conditions that can make spawner surveys impossible for extended periods. Snorkel surveys would also make it possible to rapidly ground-truth previously-unknown habitat space (as is the case in the Russian River watershed) which could be particularly useful and efficient for CMP programs in the early stages of development.

One purpose for estimating adult returns to the LCS is to develop season-specific estimates of spawner: redd ratios that can be applied to basinwide redd estimates in order to estimate basinwide adult abundance (Adams et al. 2011). In Dry Creek, we were unable to accurately generate species-specific estimates of returning adults each year so we were unable to apply LCS spawner: redd ratios to basinwide redd estimates. In Mill Creek and three other Broodstock Program monitoring tributaries, CSG had the ability to estimate spawner: redd ratios for Coho and found that there is tremendous variability among tributaries and years (3.1 to 23.1, CSG 2017; CSG 2018). This is likely explained by high variability in age-structure (more jacks mean higher spawner: redd ratio) (CSG 2017; CSG 2018). Given this variability among years and streams, we question the validity of using spawner: redd ratios for converting redd estimates to adult abundance. Instead, we recommend just using redd estimates as a more suitable metric for accurately evaluating status and trends. If conversion of redds to adults is necessary, we recommend using an average spawner: redd ratio based on multiple LCSs to account for the potentially high variability.

CMP monitoring in the Russian River watershed has benefitted ongoing recovery programs and habitat enhancement efforts. While the Coho Broodstock Program conducts intensive monitoring on four tributaries to help evaluate specific hatchery release strategies, CMP basinwide monitoring compliments this effort by collecting data on non-release streams and examining basinwide trends in Coho population metrics. CMP snorkel and spawner surveys in combination with wet-dry mapping led by CSG have allowed us to identify tributary reaches that are heavily used by salmon and steelhead for spawning that become disconnected or dry the following summer. These late summer stream flows are a critically-important factor shaping juvenile Coho population in particular (e.g., Pena Creek, Figure III-4 which has high concentrations of fish and is prone to extensive drying each summer). These data have guided broodstock collection and fish rescue operations conducted by CDFW in Pena Creek and elsewhere. Our data have also showed the immediate benefits to Coho and steelhead spawners and their offspring by remediation of barriers to upstream migration in Mill Creek. These findings and their implications for population recovery are examples of one of the expected outcomes of CMP monitoring listed in Adams et al. (2011).

Conclusions and recommendations

Through our CMP monitoring efforts, we have been able to generate consistent basinwide estimates of the number of Coho Salmon redds in the Russian River watershed each year and we are beginning to generate basinwide estimates of the number of steelhead redds as well. Aspects of our life cycle monitoring that have shown promise are the Coho and steelhead smolt abundance estimates from Mill Creek and adult and smolt Chinook Salmon abundance estimates at the Russian River LCS. We have also been successful in estimating adult returns, smolt outmigration and spawner: redd ratios in Mill Creek, a sub-watershed of Dry Creek that is currently part of the LCS for Dry Creek life cycle monitoring.

PIT tags and antennas are foundational to many of the life cycle-related estimates generated from fish monitoring in the Russian River. Without the capabilities afforded by PIT tools, it would be difficult (Coho Salmon) or impossible (steelhead) to consistently and accurately estimate smolt abundance even from tributaries smaller than Dry Creek (e.g., Mill Creek). Detections of tagged fish on PIT antenna arrays have also been instrumental in documenting adult Coho returns, and the associated expanded adult counts have become an important consideration in evaluating Coho Salmon recovery strategies. In the Russian River, approximately 150,000 hatchery-origin, juvenile Coho are typically released into the watershed each year, and a known fraction of these fish are PIT-tagged prior to release from the hatchery. This facilitates expanded adult Coho counts and estimates of juvenile overwinter survival. We do not have the same advantage when it comes to juvenile steelhead; however, by employing a systematic steelhead tagging program that is part of a broader pre-smolt abundance model, we have demonstrated that multiple CMP-related objectives can be addressed through a carefully-planned and executed PIT-tagging program: sub-basin scale estimates of juvenile steelhead (Chapter II); overwinter freshwater survival of Coho to the smolt stage (CSG 2018); insights regarding Russian River salmonid life history diversity (Chapter II). We are also working toward estimation of overwinter freshwater survival of steelhead to the smolt stage and have begun to understand the magnitude of migration mortality as smolts make their way downstream through the Russian River.

Because of high winter flows when the majority of steelhead adult and smolt migration in north coast California systems occurs, life cycle monitoring for steelhead is particularly challenging. Our selection of Dry Creek for life cycle monitoring was based primarily on the fact that it contains consistent populations of Coho, steelhead and Chinook thus presenting the opportunity to develop spawner: redd ratios for all three species in a single location. Dry Creek is also important because it provides a consistent supply of cold water suitable for juvenile rearing as well as a geomorphic context that lends itself to an abundance of suitable spawning habitat. This is in contrast to many tributaries in the Russian where suitable juvenile rearing habitat shrinks or disappears by late summer (CSG 2016). Because of controlled water releases from Lake Sonoma, however, mainstem Dry Creek is difficult to sample juvenile populations by snorkeling or electrofishing and impossible to develop consistent and accurate smolt estimates using downstream migrant traps. As has been covered elsewhere in this report, the fact that there is an overlap in run-timing of our three target CMP species, DIDSON-based adult counts are inadequate.

Dry Creek is the only major steelhead-bearing stream in the Russian River watershed with controlled flows. Summertime flows in mainstem Dry Creek are sustained by water releases from Lake Sonoma (approximately 110 $ft^3 \cdot s^{-1}$) all summer long (Figure II-17) and winter flows are managed for flood control. From a geomorphic and hydrologic perspective, Dry Creek is better characterized as a small river as opposed to other unregulated tributaries in the basin that provide Coho and steelhead habitat. Despite this difference, however, Dry Creek is an important steelhead producer within the Russian River watershed especially during late summer or drought years when surface flows often become disconnected in smaller tributaries (CSG 2016).

At the outset of CMP implementation in the Russian River, our expectation was that some of the same tools (i.e., PIT tags/antennas, combined DIDSON-digital video) helpful in solving some of the monitoring challenges faced elsewhere in the basin could be applied to overcome similar challenges for life cycle monitoring in Dry Creek. Although we experienced some success early on, it became clear that (1) there are deficiencies in the life cycle monitoring data we have collected from Dry Creek that preclude us from making consistent and accurate estimates of key life cycle monitoring metrics, and (2) we will be unable to fully address those deficiencies if we continue to attempt life cycle monitoring in Dry Creek.

In a watershed the size of the Russian River, it is clear that a single LCS will not accurately represent all streams in the basin. An alternative approach is to operate multiple LCSs throughout the watershed. The Coho Broodstock Program is currently conducting the equivalent of life cycle monitoring for Coho Salmon (but not steelhead) on Mill, Green Valley, Dutch Bill and Willow creeks (funded by US Army Corps of Engineers and Sonoma Water). Because these streams are located in the lower one-third of the basin, they are not spatially representative of all streams throughout the watershed. However, because there is significant monitoring infrastructure in place they provide a cost-effective opportunity to employ a multi-LCS approach. For the scope of work in the next grant (March 2019-November 2021), we will reallocate resources for conducting life cycle monitoring on Dry Creek towards augmenting pre-existing Coho life cycle monitoring in the above-mentioned tributaries to include steelhead.

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Appendices

Appendices

Appendix A. Draw order of GRTS reaches stratified by species-life stage and associated rotating panels. Note: nis=not in either life stage strata for species; us=unsurveyable reach due to “permanent” constraints (see text); na=not yet assigned to a panel.

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
1	508	ALE 2	Alder Creek	no	no	yes	yes	nis	1
2	227	MPO 3	Porter Creek (Mark West)	yes	yes	yes	yes	1	1
3	242	219 1	109404219	no	no	yes	yes	nis	us
4	279	PEC 1	Pechaco Creek	no	no	yes	yes	nis	1
5	553	SHC 2	Salt Hollow Creek	no	no	yes	yes	nis	lost access
6	206	BAD 2	Badger Creek	no	no	yes	yes	nis	1
7	141	FIF 2	Fife Creek	no	no	yes	yes	nis	us
8	432	DUN 1	Duncan Creek	no	no	yes	yes	nis	1
9	493	ORR 2	Orrs Creek (upper basin)	no	no	yes	yes	nis	1
10	371	LIT 9	Little Sulphur Creek	no	no	yes	yes	nis	us
11	103	BLA 1	Black Rock Creek	no	yes	no	yes	nis	us
12	455	487 1	109397487	no	no	yes	yes	nis	us
13	517	HEN 4	Hensley Creek	no	no	yes	yes	nis	us
14	316	COO 1	Coon Creek	no	no	yes	yes	nis	us
17	523	YOR 4	York Creek	no	no	yes	yes	nis	us
18	180	MAR 15	Mark West Creek	yes	yes	yes	yes	1	1
19	84	AUS 4	Austin Creek	yes	yes	yes	yes	1	1
20	105	GIL 1	Gilliam Creek	yes	yes	yes	yes	1	1
21	530	FOR 4	Forsythe Creek	no	no	yes	yes	nis	1
22	301	993 1	109408993	no	no	yes	yes	nis	us
23	146	765 3	109393765	no	no	yes	yes	nis	us
24	458	PAR 3	Parsons Creek	no	no	yes	yes	nis	1
25	483	MUP 2	Mill Creek (upper basin)	no	no	yes	yes	nis	2
26	321	BEA 1	Bear Creek	no	no	yes	yes	nis	us
27	115	WAR 2	Ward Creek	yes	yes	yes	yes	nis	us
28	473	SBR 1	South Branch Robinson Creek	no	no	yes	yes	nis	us
29	173	MAR 8	Mark West Creek	no	no	yes	yes	nis	us
31	343	PFC 1	Porterfield Creek	no	no	yes	yes	nis	us
33	532	FOR 6	Forsythe Creek	no	no	yes	yes	nis	us
34	185	SAN 5	Santa Rosa Creek	no	no	yes	yes	nis	us
35	73	JEN 1	Jenner Gulch	no	no	yes	yes	nis	2
36	256	MIL 2	Mill Creek (Dry)	yes	yes	yes	yes	1	2
37	542	BAK 1	Bakers Creek	no	no	yes	yes	nis	us
38	229	MPO 5	Porter Creek (Mark West)	no	no	yes	yes	nis	us
39	81	AUS 1	Austin Creek	yes	yes	yes	yes	nis	us
40	434	409 1	109420409	no	no	yes	yes	nis	us
41	503	ACK 4	Ackerman Creek	no	no	yes	yes	nis	2
42	366	LIT 4	Little Sulphur Creek	no	no	yes	yes	nis	us
43	353	BIG 5	Big Sulphur Creek	no	no	yes	yes	nis	2
44	448	MDO 3	McDowell Creek	no	no	yes	yes	nis	us
45	171	MAR 6	Mark West Creek	no	no	yes	yes	nis	2
46	292	FRA 2	Franz Creek	no	no	yes	yes	nis	2
48	417	TYL 3	Tyler Creek	no	no	yes	yes	nis	2
49	550	WKR 1	Walker Creek	no	no	yes	yes	nis	us
50	186	SAN 6	Santa Rosa Creek	no	no	yes	yes	nis	us
52	265	WAL 2	Wallace Creek	yes	yes	yes	yes	1	2

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
53	479	HOW 1	Howell Creek	no	no	yes	yes	nis	us
54	330	PET 1	Peterson Creek	no	no	yes	yes	nis	5
55	99	EAU 8	East Austin Creek	no	yes	no	yes	nis	us
56	460	MOR 2	Morrison Creek	no	no	yes	yes	nis	us
57	515	HEN 2	Hensley Creek	no	no	yes	yes	nis	us
58	308	MPA 1	Mill Park Creek	no	no	yes	yes	nis	5
59	365	LIT 3	Little Sulphur Creek	no	no	yes	yes	nis	us
60	402	PIE 1	Pieta Creek	no	no	yes	yes	nis	5
61	218	MCR 3	Crane Creek (Hinebaugh)	no	no	yes	yes	nis	5
63	250	DRY 7	Dry Creek	no	no	no	no	nis	us
65	504	ACK 5	Ackerman Creek	no	no	yes	yes	nis	5
66	177	MAR 12	Mark West Creek	yes	yes	yes	yes	1	5
68	278	PEN 5	Pena Creek	yes	yes	yes	yes	1	5
69	554	ZAN 1	Zana Creek	no	no	yes	yes	nis	5
71	142	RDF 1	Redwood Creek (Fife)	no	no	yes	yes	nis	us
72	425	FLZ 3	Feliz Creek	no	no	yes	yes	nis	us
74	370	LIT 8	Little Sulphur Creek	no	no	yes	yes	nis	us
75	122	BPC 1	Bearpen Creek	no	no	yes	yes	nis	5
78	319	MCD 1	McDonnell Creek	no	no	yes	yes	nis	us
79	251	DRY 8	Dry Creek	no	no	no	no	nis	us
80	391	EDW 1	Edwards Creek	no	no	yes	yes	nis	us
81	496	ORR 5	Orrs Creek (upper basin)	no	no	yes	yes	nis	us
82	179	MAR 14	Mark West Creek	yes	yes	yes	yes	1	3
83	120	POL 2	Pole Mountain Creek	no	no	yes	yes	nis	us
84	109.1	GRA 3	Gray Creek	yes	yes	yes	yes	1	3
85	543	BAK 2	Bakers Creek	no	no	yes	yes	nis	us
86	294	FRA 4	Franz Creek	no	no	yes	yes	nis	3
87	237	POR 3	Porter Creek	yes	yes	yes	yes	1	3
88	431	FLZ 9	Feliz Creek	no	no	yes	yes	nis	us
89	485	MCC 2	McClure Creek	no	no	yes	yes	nis	us
90	369	LIT 7	Little Sulphur Creek	no	no	yes	yes	nis	3
91	117	WAR 4	Ward Creek	no	no	yes	yes	nis	us
92	475	IND 1	Indian Creek	no	no	yes	yes	nis	3
93	176	MAR 11	Mark West Creek	yes	yes	yes	yes	1	3
94	326	SAU 3	Sausal Creek	no	no	yes	yes	nis	us
95	346	OAT 1	Oat Valley Creek	no	no	yes	yes	nis	3
96	416	TYL 2	Tyler Creek	no	no	yes	yes	nis	us
97	537	JAC 3	Jack Smith Creek	no	no	yes	yes	nis	3
98	195	DUC 1	Ducker Creek	no	no	yes	yes	nis	us
99	78	SHE 1	Sheephouse Creek	yes	yes	yes	yes	1	6
100	262	FEL 2	Felta Creek	yes	yes	yes	yes	reserve	us
101	494	ORR 3	Orrs Creek (upper basin)	no	no	yes	yes	nis	us
102	305	KEL 1	Kellogg Creek	yes	yes	yes	yes	us	us
103	127	DUT 2	Dutch Bill Creek	yes	yes	yes	yes	1	6
104	436	BRO 1	Brother Creek	no	no	yes	yes	nis	us
106	356	BIG 8	Big Sulphur Creek	no	no	yes	yes	nis	us
107	364	LIT 2	Little Sulphur Creek	no	no	yes	yes	nis	us
108	405	PIE 4	Pieta Creek	no	no	yes	yes	nis	6
109	156	ATA 2	Atascadero Creek	yes	yes	yes	yes	us	us

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
110	285	BAR 1	Barnes Creek	no	no	yes	yes	nis	6
111	342	493 1	109394493	no	no	yes	yes	nis	us
112	418	TYL 4	Tyler Creek	no	no	yes	yes	nis	us
113	560	FIS 1	Fisher Creek	no	no	yes	yes	nis	6
114	209	SAL 1	Salt Creek	no	no	yes	yes	nis	6
115	128	DUT 3	Dutch Bill Creek	no	no	yes	yes	nis	6
116	446	MDO 1	McDowell Creek	no	no	yes	yes	nis	6
118	377	LOV 1	Lovers Gulch Creek	no	no	yes	yes	nis	6
119	111	DEV 2	Devil Creek	no	yes	no	yes	us	us
120	459	MOR 1	Morrison Creek	no	no	yes	yes	nis	1
121	65	MAI 47	Russian River	no	no	yes	yes	nis	na
122	303	RED 2	Redwood Creek	yes	yes	yes	yes	1	na
124	395	CUM 2	Cummiskey Creek	no	no	yes	yes	nis	na
125	220	COP 1	Copeland Creek	no	no	yes	yes	nis	na
126	244	DRY 1	Dry Creek	no	no	no	no	us	us
127	246	DRY 3	Dry Creek	no	no	no	no	us	us
129	509	283 1	109411283	no	no	yes	yes	nis	na
130	231	HUM 1	Humbug Creek	no	no	yes	yes	nis	na
131	94	EAU 3	East Austin Creek	no	yes	no	yes	us	us
132	280	RWL 1	Redwood Log Creek	no	no	yes	yes	nis	na
133	68	MAI 50	Russian River	no	no	yes	yes	nis	na
135	82	AUS 2	Austin Creek	yes	yes	yes	yes	us	na
137	499	313 1	109417313	no	no	yes	yes	nis	na
138	328	GEO 1	George Young Creek	no	no	yes	yes	nis	na
139	89	AUS 9	Austin Creek	no	yes	no	yes	us	us
140	454	MCN 3	McNab Creek	no	no	yes	yes	nis	na
141	211	BLU 1	Blucher Creek	no	no	yes	yes	nis	na
142	329	GIR 1	Gird Creek	no	no	yes	yes	nis	na
143	274	PEN 1	Pena Creek	yes	yes	yes	yes	1	na
144	350	BIG 2	Big Sulphur Creek	no	no	yes	yes	nis	na
145	545	MFO 2	Mill Creek (Forsythe)	no	no	yes	yes	nis	na
146	234	VAN 1	Van Buren Creek	yes	yes	yes	yes	us	na
147	121	BJC 1	Blue Jay Creek	no	no	yes	yes	nis	na
148	98	EAU 7	East Austin Creek	no	yes	no	yes	us	us
149	535	JAC 1	Jack Smith Creek	no	no	yes	yes	nis	na
150	297	BID 1	Bidwell Creek	no	no	yes	yes	nis	na
151	149	395 1	109403395	no	no	yes	yes	nis	na
152	443	437 1	109397437	no	no	yes	yes	nis	na
153	498	SUL 2	Sulphur Creek (upper basin)	no	no	yes	yes	nis	na
154	358	BIG 10	Big Sulphur Creek	no	no	yes	yes	nis	na
155	112	SLC 1	Sulphur Creek (lower basin)	no	no	no	yes	nis	us
156	471	597 1	109397597	no	no	yes	yes	nis	na
157	175	MAR 10	Mark West Creek	yes	yes	yes	yes	1	na
158	325	SAU 2	Sausal Creek	no	no	yes	yes	nis	na
159	345	CLO 1	Cloverdale Creek	no	no	yes	yes	nis	na
160	380	FRS 1	Frasier Creek	no	no	yes	yes	nis	na
161	539	ELD 2	Eldridge Creek	no	no	yes	yes	nis	na
162	199	MBR 1	Middle Brush Creek	no	no	yes	yes	nis	na
163	76	WIL 3	Willow Creek	yes	yes	yes	yes	1	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
164	263	FEL 3	Felta Creek	yes	yes	yes	yes	reserve	na
165	489	DLN 2	Doolin Creek	no	no	yes	yes	nis	na
166	314	BRI 4	Briggs Creek	no	no	yes	yes	nis	na
167	161	JON 2	Jonive Creek	yes	yes	yes	yes	us	na
168	429	FLZ 7	Feliz Creek	no	no	yes	yes	nis	na
169	513	HWD 1	Howard Creek	no	no	yes	yes	nis	na
170	355	BIG 7	Big Sulphur Creek	no	no	yes	yes	nis	na
171	352	BIG 4	Big Sulphur Creek	no	no	yes	yes	nis	na
172	410	COL 3	Coleman Creek	no	no	yes	yes	nis	na
173	160	JON 1	Jonive Creek	yes	yes	yes	yes	us	na
175	273	WIN 1	Wine Creek	yes	yes	yes	yes	1	na
176	396	CUM 3	Cummiskey Creek	no	no	yes	yes	nis	na
177	558	ROC 1	Rocky Creek	no	no	yes	yes	nis	na
178	190	SAN 10	Santa Rosa Creek	no	no	yes	yes	nis	na
179	134	HUL 1	Hulbert Creek	yes	yes	yes	yes	1	na
181	488	DLN 1	Doolin Creek	no	no	yes	yes	nis	na
182	361	BIG 13	Big Sulphur Creek	no	no	yes	yes	nis	na
183	104	BLA 2	Black Rock Creek	no	yes	no	yes	us	us
184	462	MOR 4	Morrison Creek	no	no	yes	yes	nis	na
185	516	HEN 3	Hensley Creek	no	no	yes	yes	nis	na
187	336	377 1	109399377	no	no	yes	yes	nis	na
188	411	VAS 1	Vasser Creek	no	no	yes	yes	nis	na
189	217	MCR 2	Crane Creek (Hinebaugh)	no	no	yes	yes	nis	na
190	245	DRY 2	Dry Creek	no	no	no	no	us	us
191	248	DRY 5	Dry Creek	no	no	no	no	us	us
192	422	357 1	109405357	no	no	yes	yes	nis	na
193	506	ACK 7	Ackerman Creek	no	no	yes	yes	nis	na
194	201	739 1	109413739	no	no	yes	yes	nis	na
195	85	AUS 5	Austin Creek	yes	yes	yes	yes	1	na
196	97	EAU 6	East Austin Creek	no	yes	no	yes	us	us
197	552	SHC 1	Salt Hollow Creek	no	no	yes	yes	nis	na
198	383	SQU 3	Squaw Creek	no	no	yes	yes	nis	na
199	148	HOB 1	Hobson Creek	no	no	yes	yes	nis	na
201	480	HOW 2	Howell Creek	no	no	yes	yes	nis	na
202	323	ING 1	Ingalls Creek	no	no	yes	yes	nis	na
203	125	193 1	109398193	no	no	yes	yes	nis	na
204	472	621 1	109397621	no	no	yes	yes	nis	na
205	215	GOS 1	Gossage Creek	no	no	yes	yes	nis	na
207	344	SBP 1	South Branch Portfield Creek	no	no	yes	yes	nis	na
208	347	OAT 2	Oat Valley Creek	no	no	yes	yes	nis	na
209	549	629 1	109407629	no	no	yes	yes	nis	na
210	192	BRU 1	Brush Creek	no	no	yes	yes	nis	na
211	83	AUS 3	Austin Creek	yes	yes	yes	yes	us	na
212	257	MIL 3	Mill Creek (Dry)	yes	yes	yes	yes	1	na
213	529	FOR 3	Forsythe Creek	no	no	yes	yes	nis	na
214	295	FRA 5	Franz Creek	no	no	yes	yes	nis	na
215	77	WIL 4	Willow Creek	yes	yes	yes	yes	2	na
216	438	YOU 1	Young Creek	no	no	yes	yes	nis	na
217	521	YOR 2	York Creek	no	no	yes	yes	nis	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
218	388	515 1	109415515	no	no	yes	yes	nis	na
219	113	TOB 1	Toben Creek	no	no	no	yes	nis	us
220	450	147 1	109405147	no	no	yes	yes	nis	na
223	341	ICA 2	Icaria Creek	no	no	yes	yes	nis	na
224	415	TYL 1	Tyler Creek	no	no	yes	yes	nis	na
225	547	MFO 4	Mill Creek (Forsythe)	no	no	yes	yes	nis	na
226	205	BAD 1	Badger Creek	no	no	yes	yes	nis	na
227	154	GRE 2	Green Valley Creek	yes	yes	yes	yes	2	na
228	258	MIL 4	Mill Creek (Dry)	yes	yes	yes	yes	2	na
230	332	MLL 1	Miller Creek	no	no	yes	yes	nis	na
231	100	EAU 9	East Austin Creek	no	no	no	yes	nis	us
233	519	EFR 1	East Fork Russian River	no	no	yes	yes	nis	na
234	302	RED 1	Redwood Creek	yes	yes	yes	yes	2	na
235	351	BIG 3	Big Sulphur Creek	no	no	yes	yes	nis	na
236	408	COL 1	Coleman Creek	no	no	yes	yes	nis	na
237	191	PAU 1	Paulin Creek	no	no	yes	yes	nis	na
238	224	HOR 1	Horse Hill Creek	no	no	yes	yes	nis	na
239	249	DRY 6	Dry Creek	no	no	no	no	us	us
240	400	031 1	109405031	no	no	yes	yes	nis	na
241	561	COR 1	Corral Creek	no	no	yes	yes	nis	na
242	189	SAN 9	Santa Rosa Creek	yes	yes	yes	yes	2	na
243	140	FIF 1	Fife Creek	no	no	yes	yes	nis	na
244	445	DOO 1	Dooley Creek	no	no	yes	yes	nis	na
245	482	MUP 1	Mill Creek (upper basin)	no	no	yes	yes	nis	na
246	389	COB 1	Cobb Creek	no	no	yes	yes	nis	na
247	114	WAR 1	Ward Creek	yes	yes	yes	yes	us	na
248	464	531 1	109412531	no	no	yes	yes	nis	na
249	522	YOR 3	York Creek	no	no	yes	yes	nis	na
250	315	LBC 1	Little Briggs Creek	no	no	yes	yes	nis	na
251	334	353 1	109399353	no	no	yes	yes	nis	na
253	222	COP 3	Copeland Creek	no	no	yes	yes	nis	na
255	276	PEN 3	Pena Creek	yes	yes	yes	yes	2	na
256	393	EDW 3	Edwards Creek	no	no	yes	yes	nis	na
257	230	MMW 1	Mill Creek (Mark West)	no	no	yes	yes	nis	na
258	67	MAI 49	Russian River	no	no	yes	yes	nis	na
259	203	499 1	109406499	no	no	yes	yes	nis	na
260	497	SUL 1	Sulphur Creek (upper basin)	no	no	yes	yes	nis	na
261	378	577 1	109405577	no	no	yes	yes	nis	na
262	158	ATA 4	Atascadero Creek	yes	yes	yes	yes	us	na
263	311	BRI 1	Briggs Creek	no	no	yes	yes	nis	na
264	92	EAU 1	East Austin Creek	yes	yes	yes	yes	2	na
265	107	THO 1	Thompson Creek	no	yes	no	yes	us	us
266	145	765 2	109393765	no	no	yes	yes	nis	na
268	118	BOC 1	Big Oat Creek	no	no	yes	yes	nis	na
269	474	SBR 2	South Branch Robinson Creek	no	no	yes	yes	nis	na
271	390	ASH 1	Ash Creek	no	no	yes	yes	nis	na
272	536	JAC 2	Jack Smith Creek	no	no	yes	yes	nis	na
273	196	DUC 2	Ducker Creek	no	no	yes	yes	nis	na
274	534	SEW 1	Seward Creek	no	no	yes	yes	nis	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon Adult	Coho Salmon Juvenile	Steelhead Adult	Steelhead Juvenile	Coho panel	Steelhead panel
275	304	RED 3	Redwood Creek	no	no	yes	yes	nis	na
276	502	ACK 3	Ackerman Creek	no	no	yes	yes	nis	na
277	376	NBL 3	North Branch Little Sulphur Creek	no	no	yes	yes	nis	na
278	170	MAR 5	Mark West Creek	no	no	yes	yes	nis	na
279	153	GRE 1	Green Valley Creek	yes	yes	yes	yes	2	na
280	476	845 1	109391845	no	no	yes	yes	nis	na
281	110	DEV 1	Devil Creek	no	yes	no	yes	us	us
283	374	NBL 1	North Branch Little Sulphur Creek	no	no	yes	yes	nis	na
284	403	PIE 2	Pieta Creek	no	no	yes	yes	nis	na
285	269	WES 1	West Slough	no	no	yes	yes	nis	na
286	507	ALE 1	Alder Creek	no	no	yes	yes	nis	na
287	178	MAR 13	Mark West Creek	yes	yes	yes	yes	2	na
288	555	417 1	109413417	no	no	yes	yes	nis	na
289	382	SQU 2	Squaw Creek	no	no	yes	yes	nis	na
290	492	ORR 1	Orrs Creek (upper basin)	no	no	yes	yes	nis	na
291	453	MCN 2	McNab Creek	no	no	yes	yes	nis	na
292	159	ATA 5	Atascadero Creek	yes	yes	yes	yes	us	na
293	392	EDW 2	Edwards Creek	no	no	yes	yes	nis	na
294	119	POL 1	Pole Mountain Creek	no	no	yes	yes	nis	na
295	108	GRA 1	Gray Creek	yes	yes	yes	yes	2	na
296	236	POR 2	Porter Creek	yes	yes	yes	yes	3	na
297	430	FLZ 8	Feliz Creek	no	no	yes	yes	nis	na
298	357	BIG 9	Big Sulphur Creek	no	no	yes	yes	nis	na
299	101	EAU 10	East Austin Creek	no	no	no	yes	nis	us
301	349	BIG 1	Big Sulphur Creek	no	no	yes	yes	nis	na
302	541	849 1	109410849	no	no	yes	yes	nis	na
303	193	BRU 2	Brush Creek	no	no	yes	yes	nis	na
304	495	ORR 4	Orrs Creek (upper basin)	no	no	yes	yes	nis	na
305	500	ACK 1	Ackerman Creek	no	no	yes	yes	nis	na
306	404	PIE 3	Pieta Creek	no	no	yes	yes	nis	na
307	157	ATA 3	Atascadero Creek	yes	yes	yes	yes	us	na
308	419	HOI 1	Hoil Creek	no	no	yes	yes	nis	na
309	133	SMI 1	Smith Creek	no	no	yes	yes	nis	na
311	87	AUS 7	Austin Creek	no	yes	no	yes	us	us
312	289	MAA 3	Maacama Creek	no	no	yes	yes	nis	na
313	333	GLL 1	Gill Creek	no	no	yes	yes	nis	na
315	247	DRY 4	Dry Creek	no	no	no	no	us	us
316	511	247 1	109411247	no	no	yes	yes	nis	na
317	259	MIL 5	Mill Creek (Dry)	yes	yes	yes	yes	3	na
318	528	FOR 2	Forsythe Creek	no	no	yes	yes	nis	na
319	452	MCN 1	McNab Creek	no	no	yes	yes	nis	na
320	491	GIB 2	Gibson Creek	no	no	yes	yes	nis	na
321	468	ROB 3	Robinson Creek	no	no	yes	yes	nis	na
322	214	WAS 1	Washoe Creek	no	no	yes	yes	nis	na
324	184	SAN 4	Santa Rosa Creek	no	no	yes	yes	nis	na
325	116	WAR 3	Ward Creek	yes	yes	yes	yes	us	na
326	298	BID 2	Bidwell Creek	no	no	yes	yes	nis	na
327	235	POR 1	Porter Creek	yes	yes	yes	yes	3	na
328	384	SQU 4	Squaw Creek	no	no	yes	yes	nis	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
329	102	EAU 11	East Austin Creek	no	no	no	yes	nis	us
331	344.1	537 1	109394537	no	no	yes	yes	nis	na
332	548	MFO 5	Mill Creek (Forsythe)	no	no	yes	yes	nis	na
333	238	POR 4	Porter Creek	yes	yes	yes	yes	us	na
334	478	753 1	109397753	no	no	yes	yes	nis	na
335	439	MID 1	Middle Fork Feliz Creek	no	no	yes	yes	nis	na
336	514	HEN 1	Hensley Creek	no	no	yes	yes	nis	na
337	412	VAS 2	Vasser Creek	no	no	yes	yes	nis	na
338	401	MDD 1	McDonald Creek	no	no	yes	yes	nis	na
339	188	SAN 8	Santa Rosa Creek	yes	yes	yes	yes	us	na
340	144	765 1	109393765	no	no	yes	yes	nis	na
341	359	BIG 11	Big Sulphur Creek	no	no	yes	yes	nis	na
342	86	AUS 6	Austin Creek	yes	yes	yes	yes	3	na
343	288	MAA 2	Maacama Creek	no	no	yes	yes	nis	na
344	335	109 1	109390109	no	no	yes	yes	nis	na
346	505	ACK 6	Ackerman Creek	no	no	yes	yes	nis	na
347	96	EAU 5	East Austin Creek	no	yes	no	yes	us	us
348	527	FOR 1	Forsythe Creek	no	no	yes	yes	nis	na
349	457	PAR 2	Parsons Creek	no	no	yes	yes	nis	na
350	123	BPC 2	Bearpen Creek	no	no	yes	yes	nis	na
351	469	ROB 4	Robinson Creek	no	no	yes	yes	nis	na
353	348	OAT 3	Oat Valley Creek	no	no	yes	yes	nis	na
354	197	DRU 1	Drucker Creek	no	no	yes	yes	nis	na
355	90	KID 1	Kidd Creek	yes	yes	yes	yes	3	na
356	228	MPO 4	Porter Creek (Mark West)	no	no	yes	yes	nis	na
357	80	FRE 1	Freezeout Creek	yes	yes	yes	yes	3	na
358	66	MAI 48	Russian River	no	no	yes	yes	nis	na
359	367	LIT 5	Little Sulphur Creek	no	no	yes	yes	nis	na
360	240	GRI 1	Griffin Creek	no	yes	yes	yes	nis	na
361	293	FRA 3	Franz Creek	no	no	yes	yes	nis	na
362	533	FOR 7	Forsythe Creek	no	no	yes	yes	nis	na
363	266	PAL 1	Palmer Creek	yes	yes	yes	yes	3	na
364	465	891 1	109397891	no	no	yes	yes	nis	na
365	338	CRO 1	Crocker Creek	no	no	yes	yes	nis	na
367	271	GRP 1	Grape Creek	yes	yes	yes	yes	3	na
368	397	CUM 4	Cummiskey Creek	no	no	yes	yes	nis	na
369	208	351 1	109406351	no	no	yes	yes	nis	na
370	139	LIV 1	Livereau Creek	no	no	yes	yes	nis	na
371	360	BIG 12	Big Sulphur Creek	no	no	yes	yes	nis	na
372	525	001 1	109417001	no	no	yes	yes	nis	na
373	312	BRI 2	Briggs Creek	no	no	yes	yes	nis	na
374	221	COP 2	Copeland Creek	no	no	yes	yes	nis	na
377	282	WOO 1	Woods Creek	yes	yes	yes	yes	3	na
378	143	SWE 1	Sweetwater Creek	no	no	yes	yes	nis	na
379	433	JOH 1	Johnson Creek	no	no	yes	yes	nis	na
380	124	RSC 1	Red Slide Creek	no	no	yes	yes	nis	na
382	470	ROB 5	Robinson Creek	no	no	yes	yes	nis	na
383	232	WEE 1	Weeks Creek	yes	yes	yes	yes	us	na
384	544	MFO 1	Mill Creek (Forsythe)	no	no	yes	yes	nis	na

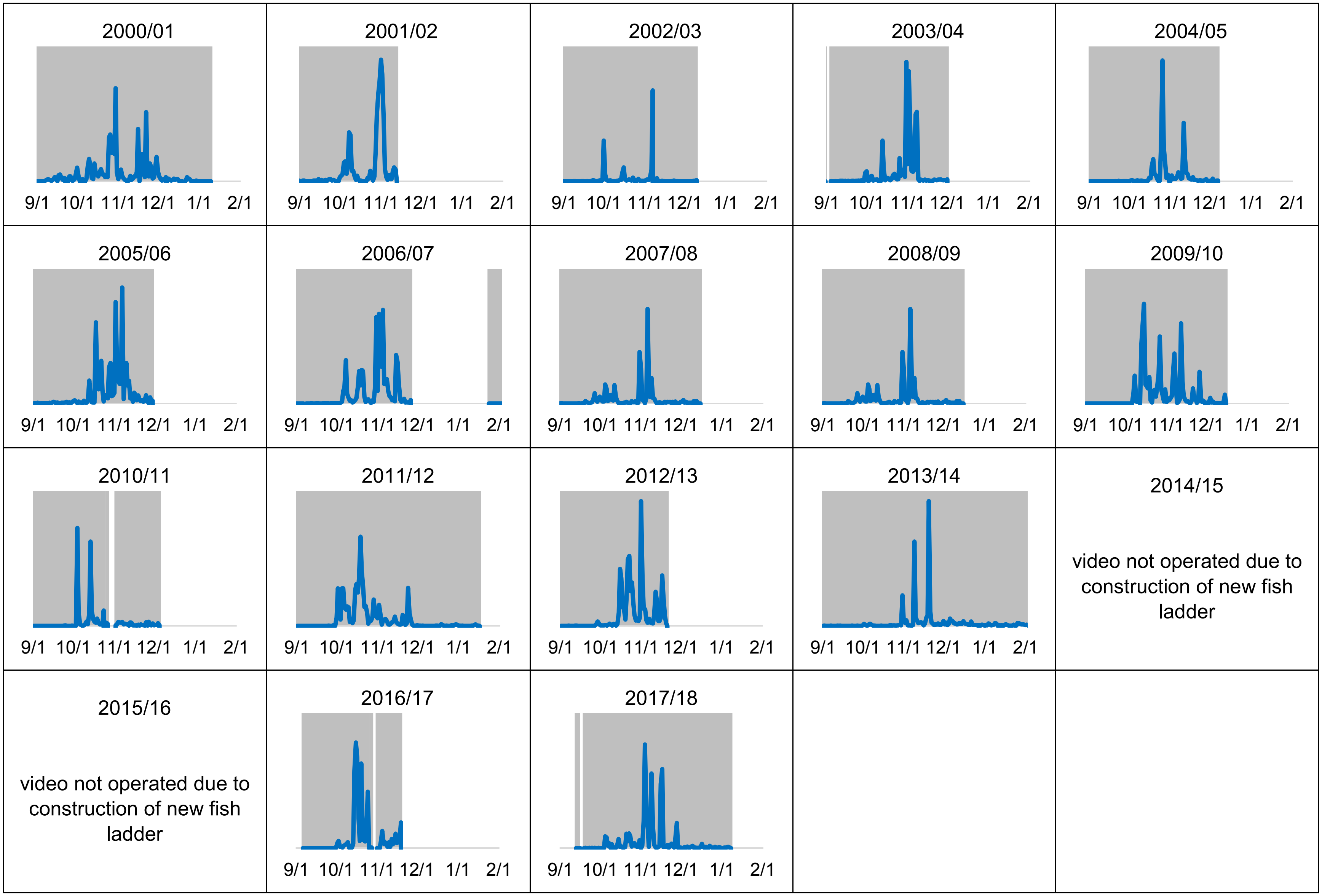
Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
385	226	MPO 2	Porter Creek (Mark West)	yes	yes	yes	yes	us	na
386	487	NFM 1	North Fork Mill Creek	no	no	yes	yes	nis	na
387	174	MAR 9	Mark West Creek	yes	yes	yes	yes	3	na
388	79	ORS 1	Orrs Creek (lower basin)	no	no	yes	yes	nis	na
389	261	FEL 1	Felta Creek	yes	yes	yes	yes	4	na
390	126	DUT 1	Dutch Bill Creek	yes	yes	yes	yes	4	na
391	427	FLZ 5	Feliz Creek	no	no	yes	yes	nis	na
392	363	LIT 1	Little Sulphur Creek	no	no	yes	yes	nis	na
393	286	MRT 1	Martin Creek	no	no	yes	yes	nis	na
394	339	BRR 1	Barrelli Creek	no	no	yes	yes	nis	na
395	72	MAI 54	Russian River	no	no	yes	yes	nis	na
396	202	797 1	109413797	no	no	yes	yes	nis	na
398	368	LIT 6	Little Sulphur Creek	no	no	yes	yes	nis	na
399	518	151 1	109417151	no	no	yes	yes	nis	na
400	219	119 1	109395119	no	no	yes	yes	nis	na
401	420	367 1	109405367	no	no	yes	yes	nis	na
402	243	219 2	109404219	no	no	yes	yes	nis	na
403	135	HUL 2	Hulbert Creek	yes	yes	yes	yes	4	na
404	327	SAU 4	Sausal Creek	no	no	yes	yes	nis	na
405	88	AUS 8	Austin Creek	no	yes	no	yes	us	us
407	252	DRY 9	Dry Creek	no	no	no	no	us	us
408	546	MFO 3	Mill Creek (Forsythe)	no	no	yes	yes	nis	na
409	69	MAI 51	Russian River	no	no	yes	yes	nis	na
410	486	923 1	109416923	no	no	yes	yes	nis	na
411	467	ROB 2	Robinson Creek	no	no	yes	yes	nis	na
412	225	MPO 1	Porter Creek (Mark West)	yes	yes	yes	yes	4	na
413	354	BIG 6	Big Sulphur Creek	no	no	yes	yes	nis	na
415	307	YEL 1	Yellowjacket Creek	yes	yes	yes	yes	us	na
416	163	RCA 1	Redwood Creek (Atascadero)	yes	yes	yes	yes	us	na
417	375	NBL 2	North Branch Little Sulphur Creek	no	no	yes	yes	nis	na
418	362	507 1	109390507	no	no	yes	yes	nis	na
419	291	FRA 1	Franz Creek	no	no	yes	yes	nis	na
420	272	GRP 2	Grape Creek	yes	yes	yes	yes	4	na
421	70	MAI 52	Russian River	no	no	yes	yes	nis	na
422	484	MCC 1	McClure Creek	no	no	yes	yes	nis	na
423	461	MOR 3	Morrison Creek	no	no	yes	yes	nis	na
424	520	YOR 1	York Creek	no	no	yes	yes	nis	na
425	409	COL 2	Coleman Creek	no	no	yes	yes	nis	na
426	216	MCR 1	Crane Creek (Hinebaugh)	no	no	yes	yes	nis	na
427	421	363 1	109405363	no	no	yes	yes	nis	na
428	200	MBR 2	Middle Brush Creek	no	no	yes	yes	nis	na
429	93	EAU 2	East Austin Creek	yes	yes	yes	yes	us	na
431	136	HUL 3	Hulbert Creek	yes	yes	yes	yes	4	na
432	322	BEA 2	Bear Creek	no	no	yes	yes	nis	na
434	531	FOR 5	Forsythe Creek	no	no	yes	yes	nis	na
435	109	GRA 2	Gray Creek	yes	yes	yes	yes	4	na
436	538	ELD 1	Eldridge Creek	no	no	yes	yes	nis	na
437	428	FLZ 6	Feliz Creek	no	no	yes	yes	nis	na
438	447	MDO 2	McDowell Creek	no	no	yes	yes	nis	na

Appendices

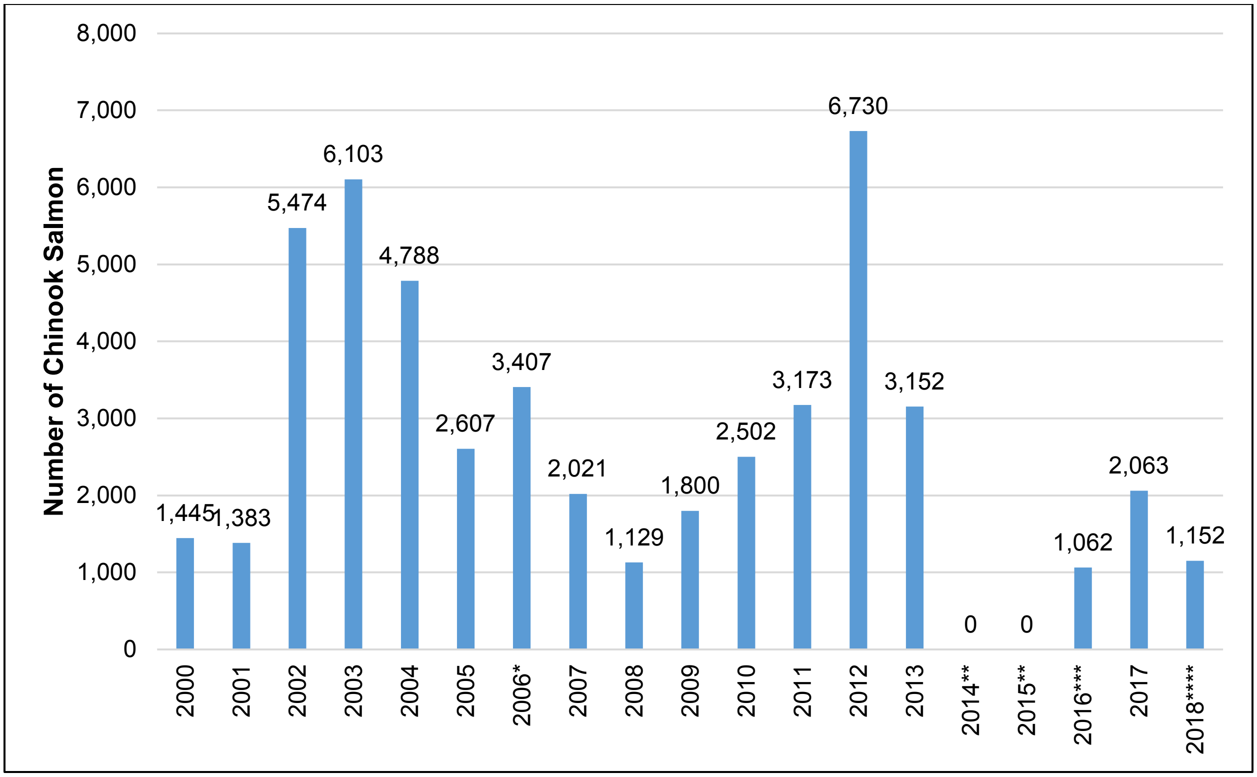
Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
439	406	PIE 5	Pieta Creek	no	no	yes	yes	nis	na
440	187	SAN 7	Santa Rosa Creek	no	no	yes	yes	nis	na
441	165	PUR 1	Purrington Creek	yes	yes	yes	yes	4	na
442	313	BRI 3	Briggs Creek	no	no	yes	yes	nis	na
443	162	SEX 1	Sexton Creek	yes	yes	yes	yes	us	na
444	381	SQU 1	Squaw Creek	no	no	yes	yes	nis	na
445	183	SAN 3	Santa Rosa Creek	no	no	yes	yes	nis	na
446	287	MAA 1	Maacama Creek	no	no	yes	yes	nis	na
447	71	MAI 53	Russian River	no	no	yes	yes	nis	na
448	423	FLZ 1	Feliz Creek	no	no	yes	yes	nis	na
450	463	MOR 5	Morrison Creek	no	no	yes	yes	nis	na
452	270	CRA 1	Crane Creek (Dry)	yes	yes	yes	yes	4	na
453	398	CUM 5	Cummiskey Creek	no	no	yes	yes	nis	na
454	194	BRU 3	Brush Creek	no	no	yes	yes	nis	na
455	296	FRA 6	Franz Creek	no	no	yes	yes	nis	na
456	481	663 1	109397663	no	no	yes	yes	nis	na
457	320	MCD 2	McDonnell Creek	no	no	yes	yes	nis	na
458	172	MAR 7	Mark West Creek	no	no	yes	yes	nis	na
459	324	SAU 1	Sausal Creek	no	no	yes	yes	nis	na
460	264	WAL 1	Wallace Creek	yes	yes	yes	yes	us	na
461	426	FLZ 4	Feliz Creek	no	no	yes	yes	nis	na
462	275	PEN 2	Pena Creek	yes	yes	yes	yes	4	na
463	449	213 1	109405213	no	no	yes	yes	nis	na
464	340	ICA 1	Icaria Creek	no	no	yes	yes	nis	na
465	407	PIE 6	Pieta Creek	no	no	yes	yes	nis	na
466	198	DRU 2	Drucker Creek	no	no	yes	yes	nis	na
467	466	ROB 1	Robinson Creek	no	no	yes	yes	nis	na
469	501	ACK 2	Ackerman Creek	no	no	yes	yes	nis	na
470	290	MAA 4	Maacama Creek	no	no	yes	yes	nis	na
471	223	COP 4	Copeland Creek	no	no	yes	yes	nis	na
472	254	MIL 1	Mill Creek (Dry)	yes	yes	yes	yes	reserve	na
473	424	FLZ 2	Feliz Creek	no	no	yes	yes	nis	na
474	95	EAU 4	East Austin Creek	no	yes	no	yes	us	us
475	456	PAR 1	Parsons Creek	no	no	yes	yes	nis	na
477	394	CUM 1	Cummiskey Creek	no	no	yes	yes	nis	na
478	277	PEN 4	Pena Creek	yes	yes	yes	yes	reserve	na
479	399	CUM 6	Cummiskey Creek	no	no	yes	yes	nis	na

Appendices



Appendix B. Adult Chinook Salmon run-timing (shown as a proportion of the season total) and dates of video system operation at Sonoma Water's Mirabel dam in Forestville (Chinook adult LCS, rkm 39.67). Grey-shaded regions indicate periods when the video system was operating.

Appendices



Appendix C. Adult Chinook Salmon returns past Sonoma Water's Mirabel dam in Forestville (Chinook adult LCS, rkm 39.67), 2000-2018.

Season notes:

* In 2006 the video cameras were reinstalled and operated from 4/1-6/27/2007 but no Chinook were observed.

** Video cameras not operated in 2014 and 2015 because the site was under construction in order to construct the new fish screens and ladder.

*** Typically 1 camera is operated in both fish ladders but in 2016 a video camera was only operated in the east ladder for the final 10 days of the season.

**** Salmonid sp counts have not yet been prorated for 2018.

Appendices

Appendix D. Reaches where spawner surveys were conducted by season, 2015/16 to 2018/19.

Frame number	Tributary	Reach name	2015/16	2016/17	2017/18	2018/19
73	Jenner Gulch	JEN 1	no	no	yes	no
76	Willow Creek	WIL 3	yes	yes	yes	yes
77	Willow Creek	WIL 4	yes	yes	yes	yes
78	Sheephouse Creek	SHE 1	no	yes	yes	yes
80	Freezeout Creek	FRE 1	no	yes	no	yes
84	Austin Creek	AUS 4	no	yes	yes	yes
85	Austin Creek	AUS 5	yes	yes	yes	yes
86	Austin Creek	AUS 6	yes	no	no	yes
90	Kidd Creek	KID 1	no	yes	yes	yes
92	East Austin Creek	EAU 1	yes	yes	yes	no
95	Oat Valley Creek	OAT 1	no	no	no	yes
105	Gilliam Creek	GIL 1	yes	yes	yes	yes
106	Schoolhouse Creek	GIL 1	yes	yes	yes	yes
108	Gray Creek	GRA 1	yes	yes	yes	yes
109	Gray Creek	GRA 2	yes	yes	yes	yes
109.1	Gray Creek	GRA 3	no	yes	yes	yes
122	Bearpen Creek	BPC 1	no	no	yes	no
126	Dutch Bill Creek	DUT 1	yes	yes	yes	yes
127	Dutch Bill Creek	DUT 2	yes	yes	yes	yes
128	Dutch Bill Creek	DUT 3	no	no	no	yes
129	Perenne Creek	DUT 1	yes	yes	yes	yes
130	Grub Creek	DUT 2	yes	yes	yes	yes
134	Hulbert Creek	HUL 1	no	yes	yes	yes
136	Hulbert Creek	HUL 3	yes	no	no	no
137	Mission Creek	HUL 1	no	yes	yes	yes
153	Green Valley Creek	GRE 1	yes	yes	yes	yes
154	Green Valley Creek	GRE 2	yes	yes	yes	yes
165	Purrington Creek	PUR 1	yes	yes	yes	yes
165.1	Little Green Valley Creek	GRE 1	yes	yes	yes	yes
165.2	Nutty Valley Creek	GRE 2	yes	yes	yes	yes
165.3	Harrison Creek	GRE 2	yes	yes	yes	yes
171	Mark West Creek	MAR 6	no	no	no	no
174	Mark West Creek	MAR 9	yes	no	no	yes
175	Mark West Creek	MAR 10	no	yes	yes	yes
176	Mark West Creek	MAR 11	yes	yes	yes	yes
177	Mark West Creek	MAR 12	yes	yes	yes	yes
178	Mark West Creek	MAR 13	no	yes	yes	yes
179	Mark West Creek	MAR 14	yes	yes	yes	yes
180	Mark West Creek	MAR 15	no	no	yes	yes
189	Santa Rosa Creek	SAN 9	yes	yes	yes	yes
206	Badger Creek	BAD 2	no	no	no	yes
209	Salt Creek	SAL 1	no	no	no	yes
218	Crane Creek (Hinebaugh)	MCR 3	no	no	yes	no
225	Porter Creek (Mark West)	MPO 1	yes	no	no	no
227	Porter Creek (Mark West)	MPO 3	no	no	yes	yes
235	Porter Creek	POR 1	yes	yes	yes	yes

Appendices

Frame number	Tributary	Reach name	2015/16	2016/17	2017/18	2018/19
236	Porter Creek	POR 2	yes	yes	yes	yes
237	Porter Creek	POR 3	yes	yes	yes	yes
239	Press Creek	POR 3	yes	yes	yes	yes
254	Mill Creek	MIL 1	yes	yes	yes	yes
256	Mill Creek	MIL 2	yes	yes	yes	yes
257	Mill Creek	MIL 3	yes	yes	yes	yes
258	Mill Creek	MIL 4	yes	yes	yes	yes
259	Mill Creek	MIL 5	yes	yes	yes	yes
261	Felta Creek	FEL 1	yes	yes	yes	yes
265	Wallace Creek	WAL 2	yes	yes	yes	yes
266	Palmer Creek	PAL 1	yes	yes	yes	yes
270	Crane Creek (Dry)	CRA 1	no	no	yes	yes
271	Grape Creek	GRP 1	yes	yes	yes	yes
272	Grape Creek	GRP 2	yes	yes	yes	yes
273	Wine Creek	WIN 1	yes	yes	yes	yes
274	Pena Creek	PEN 1	yes	yes	yes	yes
276	Pena Creek	PEN 3	yes	yes	yes	yes
277	Pena Creek	PEN 4	yes	yes	yes	yes
278	Pena Creek	PEN 5	yes	yes	yes	yes
279	Pechaco Creek	PEC 1	yes	yes	yes	yes
282	Woods Creek	WOO 1	yes	yes	yes	yes
283	Dead Coyote Creek	WOO 1	no	no	yes	yes
285	Barnes Creek	BAR 1	no	no	no	yes
294	Franz Creek	FRA 4	no	no	no	yes
302	Redwood Creek	RED 1	yes	yes	yes	yes
303	Redwood Creek	RED 2	no	yes	yes	yes
308	Mill Park Creek	MPA 1	no	no	yes	no
330	Peterson Creek	PET 1	no	no	yes	no
331	Sofia Creek	PET 1	no	no	yes	no
353	Big Sulphur Creek	BIG 5	no	no	yes	no
369	Little Sulphur Creek	LIT 7	no	no	no	yes
377	Lovers Gulch Creek	LOV 1	no	no	no	yes
402	Pieta Creek	PIE 1	no	no	yes	no
405	Pieta Creek	PIE 4	no	no	no	yes
417	Tyler Creek	TYL 3	no	no	yes	no
432	Duncan Creek	DUN 1	no	no	yes	yes
446	McDowell Creek	MDO 1	no	no	no	yes
458	Parsons Creek	PAR 3	no	no	yes	yes
459	Morrison Creek	MOR 1	no	no	no	yes
475	Indian Creek	IND 1	no	no	no	yes
483	Mill Creek (upper basin)	MUP 2	no	no	yes	no
493	Orrs Creek	ORR 2	no	no	yes	yes
503	Ackerman Creek	ACK 4	no	no	yes	no
504	Ackerman Creek	ACK 5	no	no	yes	no
508	Alder Creek (Ackerman)	ALE 2	no	no	yes	yes
530	Forsythe Creek	FOR 4	no	no	yes	yes
553	Salt Hollow Creek	SHC 2	no	no	yes	no

Appendices

Frame number	Tributary	Reach name	2015/16	2016/17	2017/18	2018/19
554	Zana Creek	ZAN 1	no	no	yes	no
560	Fisher Creek	FIS 1	no	no	no	yes
Total number of reaches sampled			**48**	**54**	**76**	**77**

Appendices

Appendix E. New Coho Salmon redds observed during spawner surveys from 2015-2019. Species designations are made by field crews and represent multiple levels of certainty. Note that blank cells indicate the reach was not sampled for that season. The only reaches that appear in this table are reaches where at least one Coho Salmon redd was observed during the reporting period. For a full list of reaches sampled by year, see Appendix D.

Frame number	Tributary	Reach name	Reach ID	2015/16	2016/17	2017/18	2018/19
76	Willow Creek	WIL 3	RR-WIL-003.49:006.15	4	3	2	4
77	Willow Creek	WIL 4	RR-WIL-006.15:009.16	7	5	2	1
84	Austin Creek	AUS 4	RR-AUS-007.34:009.86		0	0	1
85	Austin Creek	AUS 5	RR-AUS-009.86:012.13	0	0	0	1
86	Austin Creek	AUS 6	RR-AUS-012.13:015.94	3			2
90	Kidd Creek	KID 1	RR-KID-000.00:001.67		0	0	2
105	Gilliam Creek	GIL 1	RR-GIL-000.00:002.32	2	1	0	0
108	Gray Creek	GRA 1	RR-GRA-000.00:001.80	1	0	1	0
109	Gray Creek	GRA 2	RR-GRA-001.80:003.88	0	2	2	1
126	Dutch Bill Creek	DUT 1	RR-DUT-000.00:004.81	2	0	0	1
127	Dutch Bill Creek	DUT 2	RR-DUT-004.81:009.04	1	5	5	3
134	Hulbert Creek	HUL 1	RR-HUL-000.00:002.83		1	0	0
136	Hulbert Creek	HUL 3	RR-HUL-005.16:007.20	1			
153	Green Valley Creek	GRE 1	RR-GRE-007.80:012.49	0	8	3	13
154	Green Valley Creek	GRE 2	RR-GRE-012.49:016.09	4	8	6	9
165	Purrington Creek	PUR 1	RR-PUR-000.00:004.50	1	2	2	3
175	Mark West Creek	MAR 10	RR-MAR-027.19:030.60		0	0	2
176	Mark West Creek	MAR 11	RR-MAR-030.60:033.75	1	0	0	4
177	Mark West Creek	MAR 12	RR-MAR-033.75:037.32	1	0	1	0
178	Mark West Creek	MAR 13	RR-MAR-037.32:040.18		0	0	1
235	Porter Creek	POR 1	RR-POR-000.00:002.43	1	0	0	0
236	Porter Creek	POR 2	RR-POR-002.43:004.65	1	3	1	6
237	Porter Creek	POR 3	RR-POR-004.65:006.83	0	1	0	2
254	Mill Creek	MIL 1	RR-MIL-000.00:002.46	1	9	1	8
256	Mill Creek	MIL 2	RR-MIL-003.03:005.75	9	1	1	2
257	Mill Creek	MIL 3	RR-MIL-005.75:009.98	0	6	3	1
258	Mill Creek	MIL 4	RR-MIL-009.98:014.06	0	1	0	4
261	Felta Creek	FEL 1	RR-FEL-000.00:001.83	1	4	2	0
265	Wallace Creek	WAL 2	RR-WAL-001.83:004.43	1	0	0	0
270	Crane Creek	CRA 1	RR-CRA-000.00:002.98			0	0
271	Grape Creek	GRP 1	RR-GRP-000.00:001.39	0	2	1	2
272	Grape Creek	GRP 2	RR-GRP-001.39:002.49	0	2	2	0
273	Wine Creek	WIN 1	RR-WIN-000.00:001.65	1	3	1	4
274	Pena Creek	PEN 1	RR-PEN-000.00:004.05	0	0	2	2
276	Pena Creek	PEN 3	RR-PEN-006.49:009.12	0	3	1	1
277	Pena Creek	PEN 4	RR-PEN-009.12:013.89	1	0	1	3
282	Woods Creek	WOO 1	RR-WOO-000.00:003.80	0	4	1	2
302	Redwood Creek	RED 1	RR-RED-000.00:001.66	2	0	1	0

Appendices

Appendix F. New steelhead redds observed during spawner surveys from 2015-2019. Species designations are made by field crews and represent multiple levels of certainty. Note that blank cells indicate the reach was not sampled for that season. The only reaches that appear in this table are reaches where at least one steelhead redd was observed during the reporting period. For a full list of reaches sampled by year, see Appendix D.

Frame number	Tributary	Reach name	Reach ID	2015/16	2016/17	2017/18	2018/19
76	Willow Creek	WIL 3	RR-WIL-003.49:006.15	1	0	0	0
77	Willow Creek	WIL 4	RR-WIL-006.15:009.16	3	1	1	1
78	Sheephouse Creek	SHE 1	RR-SHE-000.00:003.55		0	0	3
80	Freezeout Creek	FRE 1	RR-FRE-000.00:001.38		0		3
85	Austin Creek	AUS 5	RR-AUS-009.86:012.13	5	2	1	3
86	Austin Creek	AUS 6	RR-AUS-012.13:015.94	3			0
90	Kidd Creek	KID 1	RR-KID-000.00:001.67		0	0	2
92	East Austin Creek	EAU 1	RR-EAU-000.00:002.00	1	0	3	
105	Gilliam Creek	GIL 1	RR-GIL-000.00:002.32	3	1	1	4
108	Gray Creek	GRA 1	RR-GRA-000.00:001.80	2	2	3	1
109	Gray Creek	GRA 2	RR-GRA-001.80:003.88	1	1	3	5
109.1	Gray Creek	GRA 3	RR-GRA-003.88:005.95		0	0	4
122	Bearpen Creek	BPC 1	RR-BPC-000.00:001.63			8	
126	Dutch Bill Creek	DUT 1	RR-DUT-000.00:004.81	5	0	0	0
127	Dutch Bill Creek	DUT 2	RR-DUT-004.81:009.04	0	7	2	5
128	Dutch Bill Creek	DUT 3	RR-DUT-009.04:010.59				2
134	Hulbert Creek	HUL 1	RR-HUL-000.00:002.83		2	0	1
136	Hulbert Creek	HUL 3	RR-HUL-005.16:007.20	3			
153	Green Valley Creek	GRE 1	RR-GRE-007.80:012.49	5	1	2	8
154	Green Valley Creek	GRE 2	RR-GRE-012.49:016.09	0	2	8	9
165	Purrington Creek	PUR 1	RR-PUR-000.00:004.50	6	2	4	3
174	Mark West Creek	MAR 9	RR-MAR-024.34:027.19	2			1
176	Mark West Creek	MAR 11	RR-MAR-030.60:033.75	2	0	1	0
177	Mark West Creek	MAR 12	RR-MAR-033.75:037.32	3	0	1	2
178	Mark West Creek	MAR 13	RR-MAR-037.32:040.18		0	1	1
179	Mark West Creek	MAR 14	RR-MAR-040.18:042.85	7	1	3	6
180	Mark West Creek	MAR 15	RR-MAR-042.85:046.51			5	3
189	Santa Rosa Creek	SAN 9	RR-SAN-028.22:029.70	1	3	2	2
235	Porter Creek	POR 1	RR-POR-000.00:002.43	3	2	0	0
236	Porter Creek	POR 2	RR-POR-002.43:004.65	4	4	0	2
237	Porter Creek	POR 3	RR-POR-004.65:006.83	3	6	0	5
254	Mill Creek	MIL 1	RR-MIL-000.00:002.46	5	4	6	4
256	Mill Creek	MIL 2	RR-MIL-003.03:005.75	2	5	6	7
257	Mill Creek	MIL 3	RR-MIL-005.75:009.98	1	0	2	7
258	Mill Creek	MIL 4	RR-MIL-009.98:014.06	4	0	1	4
261	Felta Creek	FEL 1	RR-FEL-000.00:001.83	7	1	2	6
265	Wallace Creek	WAL 2	RR-WAL-001.83:004.43	1	0	0	1
266	Palmer Creek	PAL 1	RR-PAL-000.00:002.75	2	0	1	2
270	Crane Creek	CRA 1	RR-CRA-000.00:002.98			0	0
271	Grape Creek	GRP 1	RR-GRP-000.00:001.39	8	10	0	1
272	Grape Creek	GRP 2	RR-GRP-001.39:002.49	1	12	0	2
273	Wine Creek	WIN 1	RR-WIN-000.00:001.65	23	19	0	3
274	Pena Creek	PEN 1	RR-PEN-000.00:004.05	39	30	15	17
276	Pena Creek	PEN 3	RR-PEN-006.49:009.12	2	20	4	6
277	Pena Creek	PEN 4	RR-PEN-009.12:013.89	12	31	14	12

Appendices

Frame number	Tributary	Reach name	Reach ID	2015/16	2016/17	2017/18	2018/19
278	Pena Creek	PEN 5	RR-PEN-013.89:017.04	5	4	3	1
279	Pechaco Creek	PEC 1	RR-PEC-000.00:002.35	2	3	0	1
282	Woods Creek	WOO 1	RR-WOO-000.00:003.80	2	12	5	15
285	Barnes Creek	BAR 1	RR-BAR-000.00:001.94				3
294	Franz Creek	FRA 4	RR-FRA-008.96:010.95				2
302	Redwood Creek	RED 1	RR-RED-000.00:001.66	3	1	2	0
303	Redwood Creek	RED 2	RR-RED-001.66:004.58		2	1	0
346	Oat Valley Creek	OAT 1	RR-OAT-000.00:002.12				5
353	Big Sulphur Creek	BIG 5	RR-BIG-009.64:012.69			4	
369	Little Sulphur Creek	LIT 7	RR-LIT-016.58:019.48				2
402	Pieta Creek	PIE 1	RR-PIE-000.00:003.69			6	
405	Pieta Creek	PIE 4	RR-PIE-008.30:011.30				2
417	Tyler Creek	TYL 3	RR-TYL-005.81:007.57			1	
432	Duncan Creek	DUN 1	RR-DUN-000.00:003.29			2	0
493	Orrs Creek	ORR 2	RR-ORR-002.48:004.15			1	1
508	Alder Creek (Ackerman)	ALE 2	RR-ALE-001.54:003.60			0	1
530	Forsythe Creek	FOR 4	RR-FOR-007.58:011.24			6	0

Appendices

Appendix G. Reaches snorkeled to estimate percent area occupied and for depicting spatial distribution of juvenile Coho Salmon in the juvenile Coho stratum, 2015-2018. Note that blank cells indicate the reach was not sampled that year.

Frame number	Tributary	Reach name	Reach ID	2015	2016	2017	2018
75	Willow Creek	WIL 2	RR-WIL-001.79:003.49		0		
76	Willow Creek	WIL 3	RR-WIL-003.49:006.15	1065	11	558	1274
77	Willow Creek	WIL 4	RR-WIL-006.15:009.16	585	3	199	113
78	Sheephouse Creek	SHE 1	RR-SHE-000.00:003.55	1	277	22	75
80	Freezeout Creek	FRE 1	RR-FRE-000.00:001.38	371	105	35	389
83	Austin Creek	AUS 3	RR-AUS-004.94:007.34		84	0	0
84	Austin Creek	AUS 4	RR-AUS-007.34:009.86		30	0	0
85	Austin Creek	AUS 5	RR-AUS-009.86:012.13	7	13	0	0
86	Austin Creek	AUS 6	RR-AUS-012.13:015.94	7	9	0	28
88	Austin Creek	AUS 8	RR-AUS-018.53:021.24		201	7	13
89	Austin Creek	AUS 9	RR-AUS-021.24:024.87		49	1	0
90	Kidd Creek	KID 1	RR-KID-000.00:001.67	0	15	6	25
92	East Austin Creek	EAU 1	RR-EAU-000.00:002.00	0	197	38	2
93	East Austin Creek	EAU 2	RR-EAU-002.00:004.30	4			
94	East Austin Creek	EAU 3	RR-EAU-004.30:006.00	9			
95	East Austin Creek	EAU 4	RR-EAU-006.00:008.03	0	73	11	0
96	East Austin Creek	EAU 5	RR-EAU-008.03:010.02	0	118	0	0
97	East Austin Creek	EAU 6	RR-EAU-010.02:012.50	3	230	0	0
98	East Austin Creek	EAU 7	RR-EAU-012.50:014.58	1	287	0	0
99	East Austin Creek	EAU 8	RR-EAU-014.58:016.67	0	2	0	0
100	East Austin Creek	EAU 9	RR-EAU-016.67:018.45	0	0	0	0
103	Black Rock Creek	BLA 1	RR-BLA-000.00:002.29	210	0	2	61
105	Gilliam Creek	GIL 1	RR-GIL-000.00:002.32	278	115	62	41
107	Thompson Creek	THO 1	RR-THO-000.00:001.91	0	4	0	0
108	Gray Creek	GRA 1	RR-GRA-000.00:001.80	9	66	27	263
109	Gray Creek	GRA 2	RR-GRA-001.80:003.88	311	58	35	316
109.1	Gray Creek	GRA 3	RR-GRA-003.88:005.95	190	15	0	0
110	Devil Creek	DEV 1	RR-DEV-000.00:001.49	89	5	0	0
112	Sulphur Creek	SLC 1	RR-SLC-000.00:002.04		0	0	
114	Ward Creek	WAR 1	RR-WAR-000.00:003.45		58	14	
115	Ward Creek	WAR 2	RR-WAR-003.45:005.86		0	0	0
116	Ward Creek	WAR 3	RR-WAR-005.86:008.10		0	0	0
126	Dutch Bill Creek	DUT 1	RR-DUT-000.00:004.81	357	343	1	68
127	Dutch Bill Creek	DUT 2	RR-DUT-004.81:009.04	650	330	83	254
134	Hulbert Creek	HUL 1	RR-HUL-000.00:002.83		0	9	56
135	Hulbert Creek	HUL 2	RR-HUL-002.83:005.16		0	0	170
136	Hulbert Creek	HUL 3	RR-HUL-005.16:007.20		0	1	211
153	Green Valley Creek	GRE 1	RR-GRE-007.80:012.49	666	687	1933	872
154	Green Valley Creek	GRE 2	RR-GRE-012.49:016.09	1262	827	1161	477
163	Redwood Creek (Atascadero)	RCA 1	RR-RCA-000.00:001.63		0	0	
165	Purrington Creek	PUR 1	RR-PUR-000.00:004.50	238	268	255	91
174	Mark West Creek	MAR 9	RR-MAR-024.34:027.19	13	1	0	0
175	Mark West Creek	MAR 10	RR-MAR-027.19:030.60	16	0	0	0
176	Mark West Creek	MAR 11	RR-MAR-030.60:033.75	9	8	2	0
177	Mark West Creek	MAR 12	RR-MAR-033.75:037.32	0	1	0	0
178	Mark West Creek	MAR 13	RR-MAR-037.32:040.18	9	0	0	5
179	Mark West Creek	MAR 14	RR-MAR-040.18:042.85	0	0	370	0

Appendices

Frame number	Tributary	Reach name	Reach ID	2015	2016	2017	2018
180	Mark West Creek	MAR 15	RR-MAR-042.85:046.51			5	0
188	Santa Rosa Creek	SAN 8	RR-SAN-025.32:028.22		0	0	0
189	Santa Rosa Creek	SAN 9	RR-SAN-028.22:029.70		0	0	0
224	Horse Hill Creek	HOR 1	RR-HOR-000.00:001.71		0	0	
225	Porter Creek (Mark West)	MPO 1	RR-MPO-000.00:002.65	0	0	0	2
227	Porter Creek (Mark West)	MPO 3	RR-MPO-004.65:006.94	0	0	0	0
232	Weeks Creek	WEE 1	RR-WEE-000.00:003.24	0			
235	Porter Creek (Russian)	POR 1	RR-POR-000.00:002.43	4	275	42	495
236	Porter Creek (Russian)	POR 2	RR-POR-002.43:004.65	7	41	32	165
237	Porter Creek (Russian)	POR 3	RR-POR-004.65:006.83	772	119	68	33
240	Griffin Creek	GRI 1	RR-GRI-000.00:003.41			1	
241	Frost Creek	FRO 1	RR-FRO-000.00:002.37		0		
254	Mill Creek	MIL 1	RR-MIL-000.00:002.46	7	242	22	343
256	Mill Creek	MIL 2	RR-MIL-003.03:005.75	13	399	6	228
257	Mill Creek	MIL 3	RR-MIL-005.75:009.98	153	231	53	19
258	Mill Creek	MIL 4	RR-MIL-009.98:014.06	311	7	18	1
259	Mill Creek	MIL 5	RR-MIL-014.06:015.54	4	0	0	0
261	Felta Creek	FEL 1	RR-FEL-000.00:001.83	50	28	236	100
262	Felta Creek	FEL 2	RR-FEL-001.83:003.00			0	
263	Felta Creek	FEL 3	RR-FEL-003.00:006.10	0	0	0	0
265	Wallace Creek	WAL 2	RR-WAL-001.83:004.43	0	0	0	0
266	Palmer Creek	PAL 1	RR-PAL-000.00:002.75	18	0	12	19
270	Crane Creek	CRA 1	RR-CRA-000.00:002.98			0	0
271	Grape Creek	GRP 1	RR-GRP-000.00:001.39	7	162	440	396
272	Grape Creek	GRP 2	RR-GRP-001.39:002.49	0	0	295	50
273	Wine Creek	WIN 1	RR-WIN-000.00:001.65	102	737	133	20
274	Pena Creek	PEN 1	RR-PEN-000.00:004.05		78	0	0
275	Pena Creek	PEN 2	RR-PEN-004.05:006.49				0
276	Pena Creek	PEN 3	RR-PEN-006.49:009.12	3	91	0	6
277	Pena Creek	PEN 4	RR-PEN-009.12:013.89	2	302	21	9
278	Pena Creek	PEN 5	RR-PEN-013.89:017.04	13	73	58	11
279	Pechaco Creek	PEC 1	RR-PEC-000.00:002.35	0	1	0	0
282	Woods Creek	WOO 1	RR-WOO-000.00:003.80	0	568	447	430
302	Redwood Creek (Maacama)	RED 1	RR-RED-000.00:001.66	0	11	0	8
303	Redwood Creek (Maacama)	RED 2	RR-RED-001.66:004.58	0	11	0	31
307	Yellowjacket Creek	YEL 1	RR-YEL-000.00:002.53			0	0
			Total number of reaches sampled	59	74	77	72