Implementation of California Coastal Salmonid Monitoring in the Russian River Watershed (2019-2022)

Final Report to the California Department of Fish and Wildlife, Fisheries Restoration Grants Program, Grantee Agreement: P1730412

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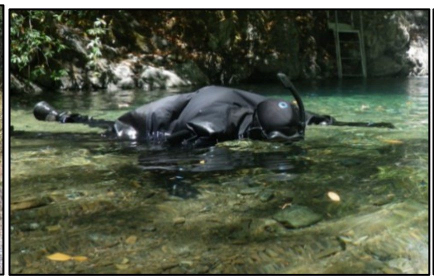


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Executive summary

On June 1, 2018, Sonoma Water was awarded a grant to continue work begun in 2013 to monitor anadromous Central California Coast (CCC) Coho Salmon, Central California Coast (CCC) steelhead, and California Coastal (CC) Chinook Salmon in the Russian River watershed. Sonoma Water sub-contracted with California Sea Grant (CSG) to assist in monitoring. The term of the original grant agreement was June 1, 2018 through November 15, 2021 but was later amended to include a no cost time extension to May 31, 2022. This extension was due to several unforeseeable events that were entirely beyond our control. These events include: (1) the shortened 2019/20 spawner season because of the COVID-19 pandemic; (2) scaled back BVET sampling in 2020 because of concern for the safety of personnel and fish if we were to work in the footprint of the Walbridge fire; (3) a delayed start to the 2020/21 spawner season because of the lack of rain. The requested time extension allowed us to compensate for some of the work we were unable to do in 2020. Actual data collection for the amended grant period occurred between February 1, 2019 and April 15, 2022.

Work is implemented in accordance with California Department of Fish and Wildlife (CDFW) Fish Bulletin 180, the California Coastal Salmonid Population Monitoring Plan (CMP, Adams et al. 2011) which uses the Viable Salmonid Population (VSP; McElhany et. al. 2000) concept to assess salmonid viability in terms of four key population characteristics: abundance, productivity, spatial structure, and diversity. 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 remains ongoing. 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 April 2022, we have nearly 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 (LCM) for Coho Salmon and steelhead was conducted in four sub-watersheds: Mill, Green Valley, Dutch Bill and Willow. LCM for Chinook Salmon was conducted on the mainstem Russian River. These sub-watersheds contain long-term LCM data sets collected by CSG dating back to 2012 in Willow, 2010 in Dutch Bill and 2005 in Mill and Green Valley. A combination of passive integrated transponder (PIT) detection systems and video was used to count returning adults, and spawner surveys were conducted for Coho and steelhead in all suitable and accessible habitat within the four LCM watersheds. We used downstream migrant traps in combination with PIT antennas on LCM streams to estimate Coho and steelhead smolt abundance. Chinook smolts were estimated using mark-recapture at Sonoma Water's Mirabel dam site on the mainstem Russian River. 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 is based on summer electrofishing and winter PIT antenna operation in the 4 LCM watersheds.

In the four LCM sub-watersheds, we continued to build on historical (2005-2018) LCM data sets collected by CSG. In 2021, estimates of Coho smolts were substantially lower in Mill, Green Valley and Dutch Bill as compared to 2019 and 2020 and steelhead smolt estimates showed a similar pattern with very low numbers in all four systems in 2021. We suspect that this was largely related to drought conditions. The Chinook Salmon smolt estimate was high in 2020 but had poor precision which was likely due to high seasonal variability in capture efficiency. Except for the 2021/22 spawner season, the estimated number of Coho redds was higher in Mill as compared to the other three LCM systems. The highest annual Coho redd estimate when summed across all four LCMs was in 2021/22. However, the 2021/22 spawner season marked the second lowest combined estimate of steelhead redds in LCM streams since CMP monitoring began in 2013. Adult Chinook counts were quite low in all three years reported.

For basinwide monitoring, Coho redd estimates were slightly above the historical (2013/14-present) average in 2020/21 and 2021/22 and somewhat below average in 2019/20. We conducted steelhead spawner surveys throughout the entire steelhead stratum in the first two seasons of the reporting period, but in the third season we conducted steelhead surveys in the combined Coho-steelhead stratum only (located in the lower basin). The 2020/21 basinwide steelhead redd estimates was 44% lower than the historical (2017/18-present) basinwide high in 2018/19. The low precision (range: 51%-71%) could likely be improved by surveying more reaches, but an increased sampling rate would increase project cost. In 2019 and 2021, juvenile Coho percent area occupied estimates were 37% lower than the historical (2013-present) average.

CMP implementation in the Russian River continues to be successful in several respects. We have demonstrated the value of PIT tags and PIT antenna arrays for estimating smolt abundance and demonstrated how to use these tools to overcome obstacles presented by wintertime environmental conditions that would otherwise preclude annual estimates of steelhead smolts and adult Coho and steelhead. For steelhead smolts, 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. PIT tools have also allowed us to gain insights regarding Russian River salmonid life history diversity (particularly steelhead) which is one of the four key population characteristics that comprise the viable salmonid population framework (McElhany et al. 2000).

Chapter I. 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.

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 a 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 (Sonoma Water and CSG 2019). Data collected for our third CDFW grant to implement CMP monitoring is reported here.

There were substantial hurdles that impeded our ability to sample as planned in 2020 and 2021: a shortened 2019/20 spawner season because of the COVID-19 pandemic, and scaled back juvenile sampling in 2020 because of concern for the safety of personnel and fish if we were to work in the footprint of the Walbridge fire. These events led to a request and approval for a no cost time extension to conduct and complete the 2021/22 spawner surveys. However, because of the amount of funding remaining from the original grant period, during the 2021/22 season steelhead spawner surveys were restricted to only those reaches containing adult habitat for both Coho Salmon and steelhead (the Coho-steelhead stratum in the lower basin). In the sections that follow, we describe the specific ways in which these impediments affected data interpretation and inference for the various types of sampling conducted.

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. To accomplish these goals, we conducted life cycle monitoring (LCM) and basinwide monitoring in reaches containing Coho Salmon and steelhead habitat from 2019-2022. Life cycle monitoring for Chinook was also conducted during this same time period. During the first full year of CMP implementation in 2014, 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. Life cycle monitoring for Chinook Salmon was paid for by Sonoma Water.

Data collection, QA/QC and storage

All tabular data were recorded on handheld 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. Following initial QA/QC, data were prepared for addition to our master database by archiving raw data, formatting data and creating a series of summary 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 master Excel spreadsheet where they were evaluated through a second round of QA/QC employing additional summary tables to highlight a wider variety of errors than the initial QA/QC. At the end of each season of data collection (i.e., spawner, downstream migrant trapping, snorkeling, electrofishing), a final QA/QC of the data was performed. Final QA/QC involved checking each column of data for inconsistencies, comparing raw and corrected files to files in the master database to ensure all data collected were 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 CDFW's statewide Aquatic Survey Program (ASP) database.

Spatial data were collected with GPS enabled field computers. Field crews also used electronic maps to assist with navigation and to provide information about landowner access, parking and other logistical details. In the event GPS capabilities on field computers were compromised (e.g., malfunctioning equipment, poor satellite reception) spatial data points were collected with a separate Garmin Explorer GPS device (if possible) then linked to the tabular data during post-processing. Spatial data were imported to ArcGIS Pro for QA/QC to identify gross spatial errors and missing points during second level data QA/QC. Spatial data were stored in a local spatial database prior to submission to the ASP database at the end of each field season.

Sample frame

Much of the monitoring aimed at accomplishing the CMP objectives 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. Additional details of sample frame development are covered in Sonoma Water and CSG (2019).

As of April 2022, we have surveyed or conducted field reconnaissance on most reaches in the lower basin (i.e., mainly Coho habitat) but there are still many 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 adjust reach boundaries where previously unknown/undocumented barriers to anadromy are found that block access to otherwise suitable salmonid habitat located upstream of these barriers. At the end of this contract period, there were 461 reaches classified as containing salmonid habitat for at least one of the three species-life stage combinations in the Russian River watershed (Figure I-1).

Although there is only one sample frame for the Russian River, we can make species and life stage assignments for 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 desktop exercise used for early sample frame development in 2013, and then updated based on field reconnaissance and/or previous experience of local fish biologists from CDFW, Sonoma Water, NMFS, and CSG. We soft-stratified the Russian River sample frame as follows: 106 Coho Salmon reaches; 414 steelhead reaches; and 94 Chinook Salmon reaches. Because of physical access and/or low visibility, some of these reaches are "permanently" unsurveyable for a given survey. This reduces the number of surveyable reaches to 81 for Coho and 94 for steelhead. We anticipate that continued reconnaissance will result in changes to species-life stage reach assignments until all reaches have been visited.

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. 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.

There are nearly 5,000 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. Details and examples of how rotating panels are dynamically populated can be found in Sonoma Water and CSG (2019).

Introduction

Because of our approach to sample frame development, 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.

Introduction

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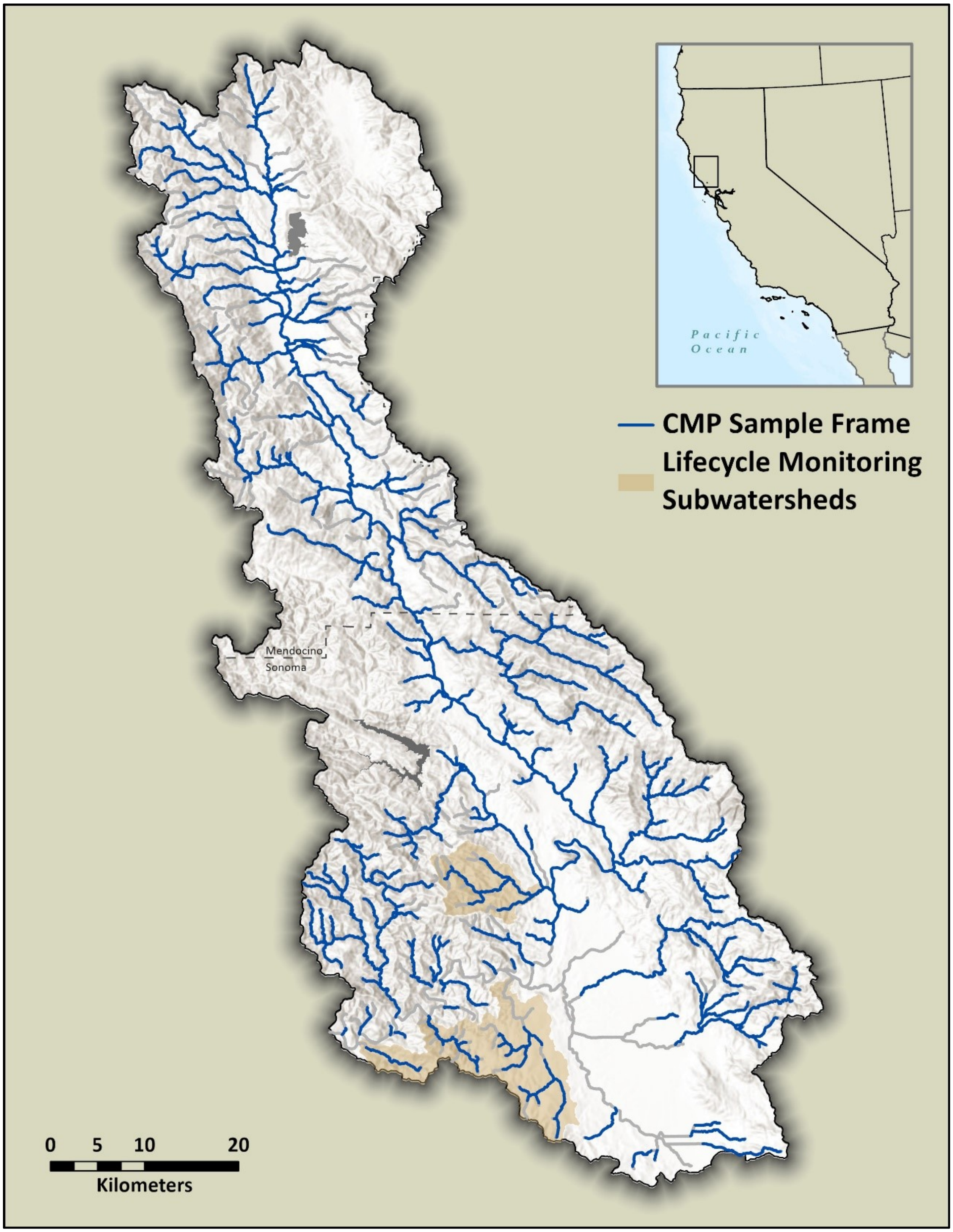


Figure I-1. Russian River watershed and CMP sample frame, April 2022.

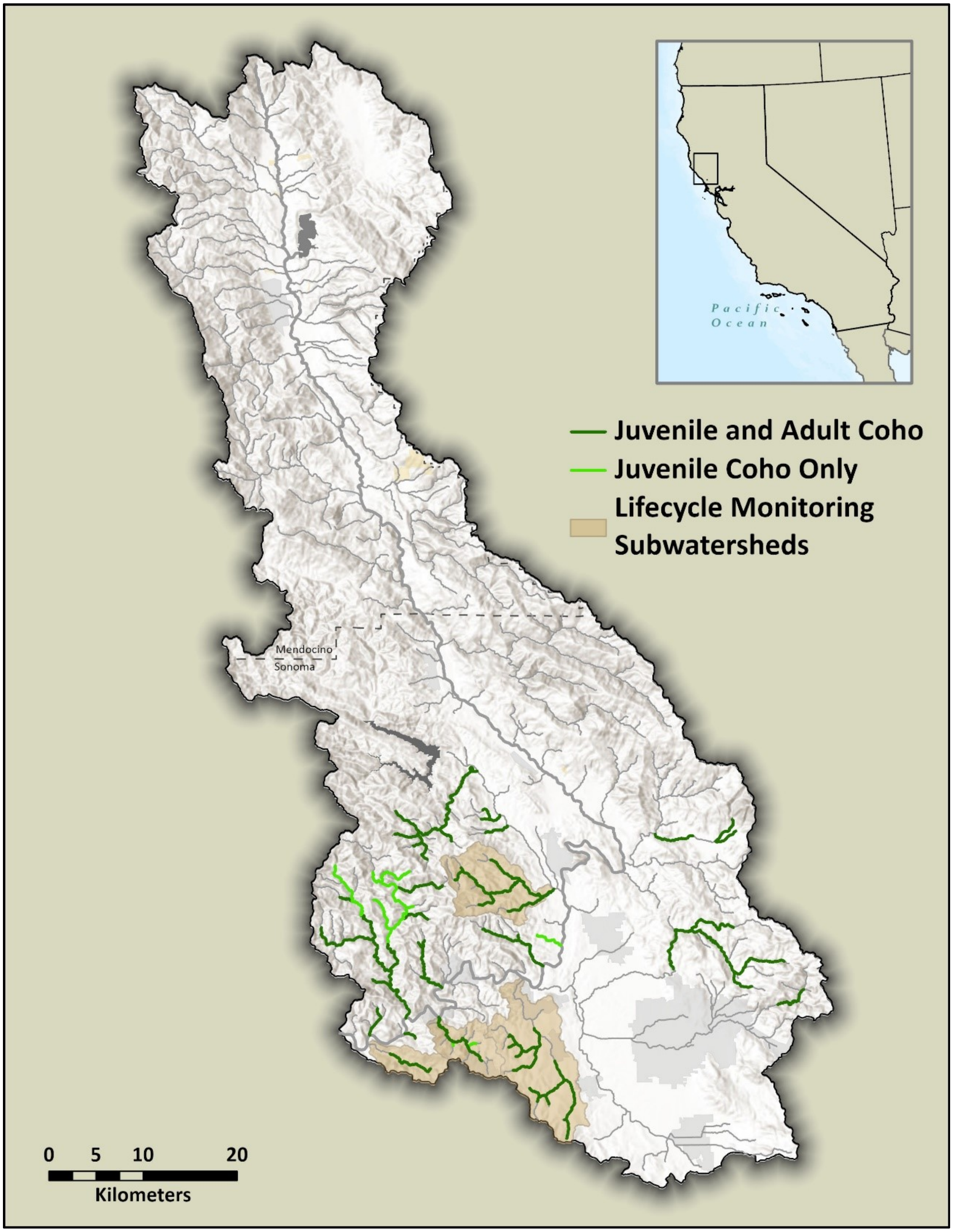


Figure I-2. Adult and juvenile Coho reaches within the Russian River watershed not including reaches that are unsurveyable due to permanent survey constraints, April 2022. Reaches where full spawner surveys for Coho cannot be conducted are not shaded (e.g., mainstem Dry Creek). Note that all reaches in the sample frame that provide Coho habitat also provide steelhead habitat.

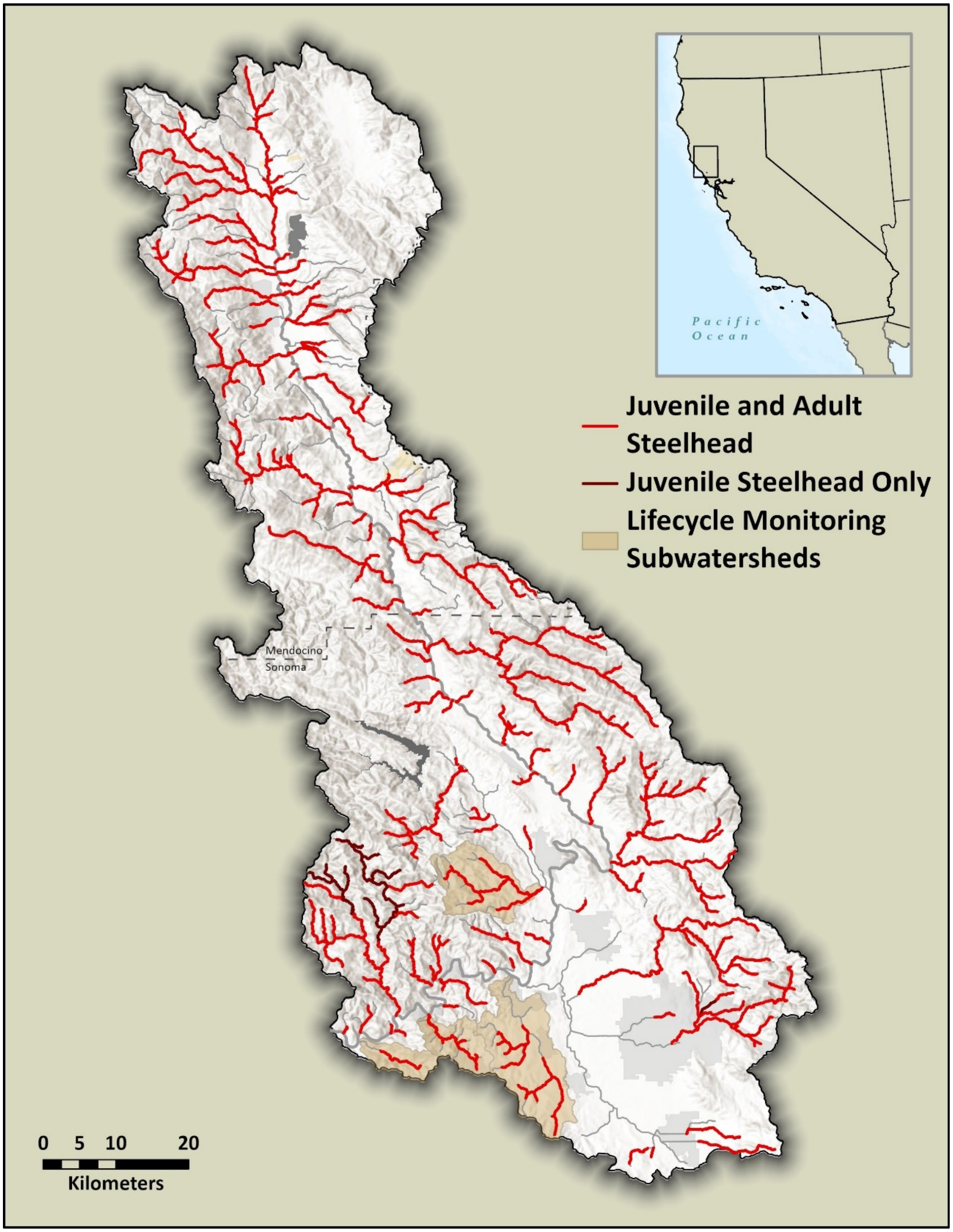


Figure I-3. Adult and juvenile steelhead reaches within the Russian River watershed not including reaches that are unsurveyable due to permanent survey constraints, April 2022. Reaches where full spawner surveys for steelhead cannot be conducted are not shaded (e.g., mainstem Dry Creek).

Figure I-4. Chinook spawning reaches within the Russian River watershed, April 2022.

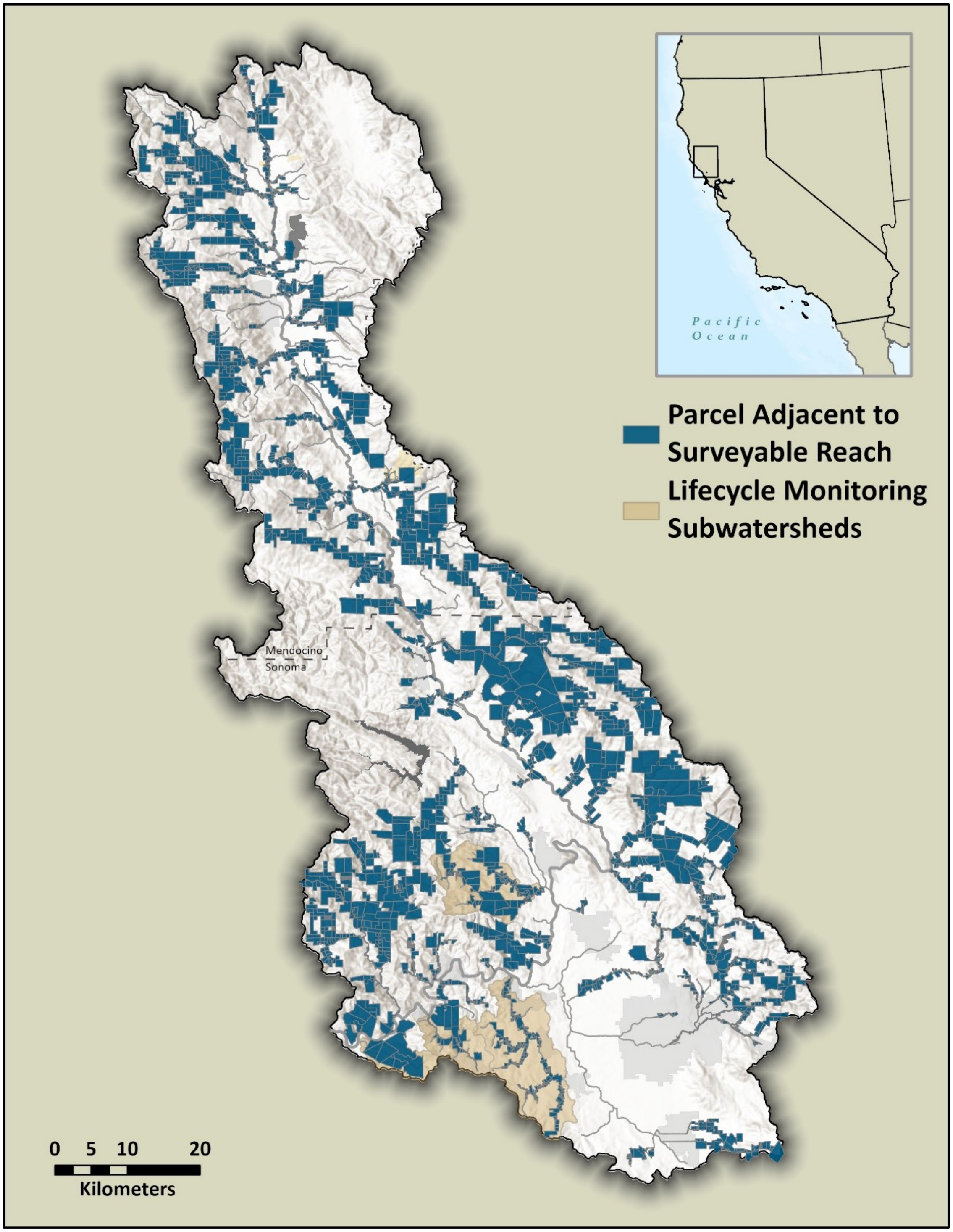


Figure I-5. Landowner parcels adjacent to reaches in the Russian River CMP sample frame.

Chapter II. Life cycle monitoring

Introduction

The objective of CMP life cycle monitoring is to detect trends in abundance of smolts and adults (Adams et al. 2011). The systems we selected for life cycle monitoring of Coho and steelhead are: Mill Creek (including Felta and Palmer Creeks), Green Valley Creek (including Purrington Creek), Dutch Bill Creek and Willow Creek (Figure II-1). These tributaries were chosen for Coho and steelhead LCM because of the substantial monitoring infrastructure already in place and because of long-term datasets for smolt and adult Coho monitoring data collected by CSG to evaluate the Russian River Coho Salmon Captive Broodstock Program. Life cycle monitoring for Chinook was conducted on the mainstem Russian River at Mirabel dam. This site also had monitoring infrastructure in place and long-term datasets for smolt and adult Chinook monitoring data collected by Sonoma Water to fulfill obligations outlined in the Russian River Biological opinion.

We conducted census spawner surveys in Green Valley, Dutch Bill, and Willow creeks and near-census spawner surveys in Mill creek to estimate Coho and steelhead redd abundance and we operated PIT antenna arrays on all four Coho and steelhead LCM streams to estimate adult Coho abundance. We estimated Coho and Chinook smolt abundance (using downstream migrant trapping methods similar to those described in FB 180) on Mill Creek (rkm 2.00), Green Valley Creek (6.04 rkm), Dutch Bill Creek (rkm 0.28) and Willow Creek (rkm 3.69) for Coho smolts. At Sonoma Water's Mirabel dam site (rkm 39.67) on Russian River mainstem, we operated a downstream migrant trap (DSMT) for Chinook smolts (Figure II-1). From past experience, we know that in most years it is possible to generate robust estimates of Coho and Chinook smolt abundance from DSMT alone because Coho and Chinook smolt migration typically occurs from March through June which coincides with a period when DSMTs can be successfully installed and operated. In 2020, despite a truncated trapping season (due to COVID-19 restrictions), we were able to generate estimates of Coho smolts using a combination of DSMT and PIT antennas. Chinook estimates were generated with a mark-recapture estimate at a DSMT immediately downstream of the Mirabel dam.

A significant issue with relying on downstream migrant trapping for estimating steelhead smolt abundance is the fact that steelhead smolt migration occurs well before DSMTs can be safely installed and operated. Because of this, using DSMTs alone to estimate steelhead smolt abundance would result in a negatively biased population estimate. To avoid this, we instead relied on outputs from a pre-smolt steelhead abundance and survival model (SW and CSG 2020). This approach relies on steelhead smolt abundance estimates generated from pre-winter juvenile abundance estimates coupled with efficiency-adjusted detections of PIT-tagged steelhead at stationary PIT antenna arrays throughout the ensuing winter.

Methods

Adult abundance

Coho Salmon and steelhead

PIT antenna field methods

PIT tagging of hatchery origin Coho smolts has occurred at the Don Claussen Fish Hatchery at Warm Springs Dam in some capacity since 2007. PIT-tagged fish are released into several Russian River tributaries, including the four LCM tributaries. In addition, we applied PIT tags to approximately 50% of all natural-origin Coho Salmon smolts captured in downstream migrant traps on LCM streams. PIT-tagged fish are also subject to detection when they return as adults at stationary PIT tag detection systems near the mouths of the four LCM streams where paired antenna arrays are used to estimate antenna efficiency (Figure II-1). These antenna efficiency estimates will then be used to expand the number of PIT antenna detections. Because we know the tagged to un-tagged ratio in the source population (i.e., at the downstream migrant trap), we can use that ratio for a final expansion to arrive at an estimate for all adults returning to each LCM. Detailed field methods can be found in California Sea Grant (2004-2020). We plan to use similar methods to estimate adult steelhead abundance in LCM streams, but this requires a significant juvenile steelhead PIT tagging effort in the fall (because of the lack of a large pool of PIT-tagged hatchery fish). A significant tagging effort was accomplished in Mill Creek in 2017 and 2018 but this effort was not begun until 2019 in other LCM tributaries.

Adult abundance estimation

Estimates of the number of adult Coho salmon returning to LCM creeks were calculated by 1) counting the number of unique adult PIT tag detections on the lower antennas of each antenna array (minimum count); 2) dividing the minimum count for each stream by the proportion of PIT-tagged fish either released from the hatchery into each respective stream or tagged at the smolt trap (expanded count per stream); and 3) dividing the expanded count by the estimated efficiency of the lower antennas of each stream array (estimated count per stream). The efficiency of the lower antennas of each paired antenna array was estimated by dividing the number of detections on both upstream and downstream antennas by all detections on the upper antennas. Individual data recorded at the time of tagging was used to estimate the number of returns by release group (age and season of release). Detailed data analysis methods can be found in California Sea Grant (2004-2020).

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. The monitoring system consists of an underwater video camera at the upstream end of a fish ladder located on the west side of the inflatable dam. The video system operated continuously throughout the majority of the adult Chinook migration period each season except for periods when the camera was inoperable (e.g., power outages). 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.

Redd abundance

Field data collection

We used protocols outlined in Adams et al. (2011) and Gallagher et al. (2007) to survey all LCM streams for salmonid redds, live adult fish and carcasses (excluding some reaches and portions of reaches in Mill Creek 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 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 recorded. 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.

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 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 adjacent to a redd. Redd species certainty was assigned as follows:

Certainty 1. Certain:
- one or more live adult(s) associated with the redd that the crew can positively identify to species.

Certainty 2. Somewhat certain:
- one or more live adult(s) associated with the redd but the crew could not positively identify to species;
- no live adults associated with the redd, but based on redd characteristics redd species can be inferred.

Certainty -9999. Uncertain:
- no live adults associated with the redd and/or redd characteristics to indicate species were unclear.

Similarly, we assigned species certainty (1=certain; 2=somewhat certain; -9999=uncertain) to observed live adult salmonids and carcasses.

Upon classification of redd species in the field we sought to make a final redd species assignment at the end of the season. First, 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 area and date of first observation. This method was generally useful in distinguishing Coho redds from steelhead redds, but it incorrectly classified 100% of known Chinook redds as Coho redds. Consequently, this led to an inflated Coho redd abundance estimate. Because this and other redd species classification methods 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 2 or unknown 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 assigned redd species based on the closest certainty 1 fish in space and time. Since this situation only occurred when the crew could not get measurements on a redd (because fish were present), but also could not positively identify fish on a redd, this method was rarely used (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 are based on the Jolly-Seber capture-mark-capture model to allow for the estimation of redd abundance by making assumptions about the recruitment process and mark-recapture survival estimates of redds between sampling occasions. Estimated redd survival is then used to account for redds that are constructed and obscured between survey occasions (meaning they were never actually observed). The estimation of total redds constructed within a survey reach can be described as a flag-based open population mark-recapture experiment in which redds are (1) individually identified and marked with unique redd IDs upon first observation; (2) then recaptured on each survey occasion. 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 and therefore no longer visible. We estimated total abundance of redds in the four LCM tributaries using the simple random estimator described in Adams et al. (2011). Additional detail can be found in Ricker at al. (2014).

We attempted to survey all reaches in the four LCM tributaries containing habitat for Coho and steelhead. However, in Mill Creek and its tributaries (Felta, Wallace, and Palmer) there were three full reaches and sections of two other reaches that we could not survey due to lack of landowner access. Despite this they were included in the estimation of total redd abundance in Mill Creek as follows. For the two unsurveyed stream sections, redd density (redds·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. The estimated redd abundance for each unsurveyed stream section was then added to the estimate for the surveyed section in the reach to arrive at an adjusted redd abundance for each reach. 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 for the Mill Creek watershed.

Smolt abundance

Downstream migrant traps

Coho Smolt Abundance

Downstream migrant traps (funnel and/or pipe) were operated on Mill, Green Valley, Dutch Bill, and Willow Creeks during the spring when the majority of the Coho Salmon smolt outmigration occurs and when the flows were conducive to safe trap operation. Traps were tended daily with additional checks during peak outmigration and high flow and/or debris load.

An approach to estimate smolt abundance at each LCM station was employed. PIT tags were applied to a portion of individuals to assess population diversity and to facilitate future estimation of adult abundance and marine survival. Specific protocols for fish handling, work-up, and PIT-tagging for Mill, Green Valley, Dutch Bill, and Willow Creeks can be found in CSG (2020).

A two-trap mark-recapture design and analytical methodology was used to estimate the total number of Coho salmon smolts emigrating from each creek during the trapping season during the time traps were operated (Bjorkstedt 2005, 2010). An antenna array located immediately upstream of each smolt trap acted as an upstream “trap” where fish were “marked” (marked fish=all PIT-tag detections on antenna array). The smolt trap served as a downstream trap where fish were recaptured. 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 detected in the trap (but not the antenna) were considered unmarked fish.

Because traps were removed for over a month during the 2020 outmigration due to the COVID-19 pandemic, trap captures could not be used to calculate out-migration for that period. Instead, antenna detections were used to estimate abundance for that time period by multiplying the number of unique PIT tags detected during that time period by the ratio of untagged to tagged fish observed on each tributary during the period that traps were in operation. This number was then adjusted for the efficiency of each antenna array as calculated during the survival analysis period in order to estimate abundance over that time period. This abundance was then added to the estimated abundance for the period where traps were operating to obtain an estimate for the whole season (CSG 2020).

Life cycle monitoring

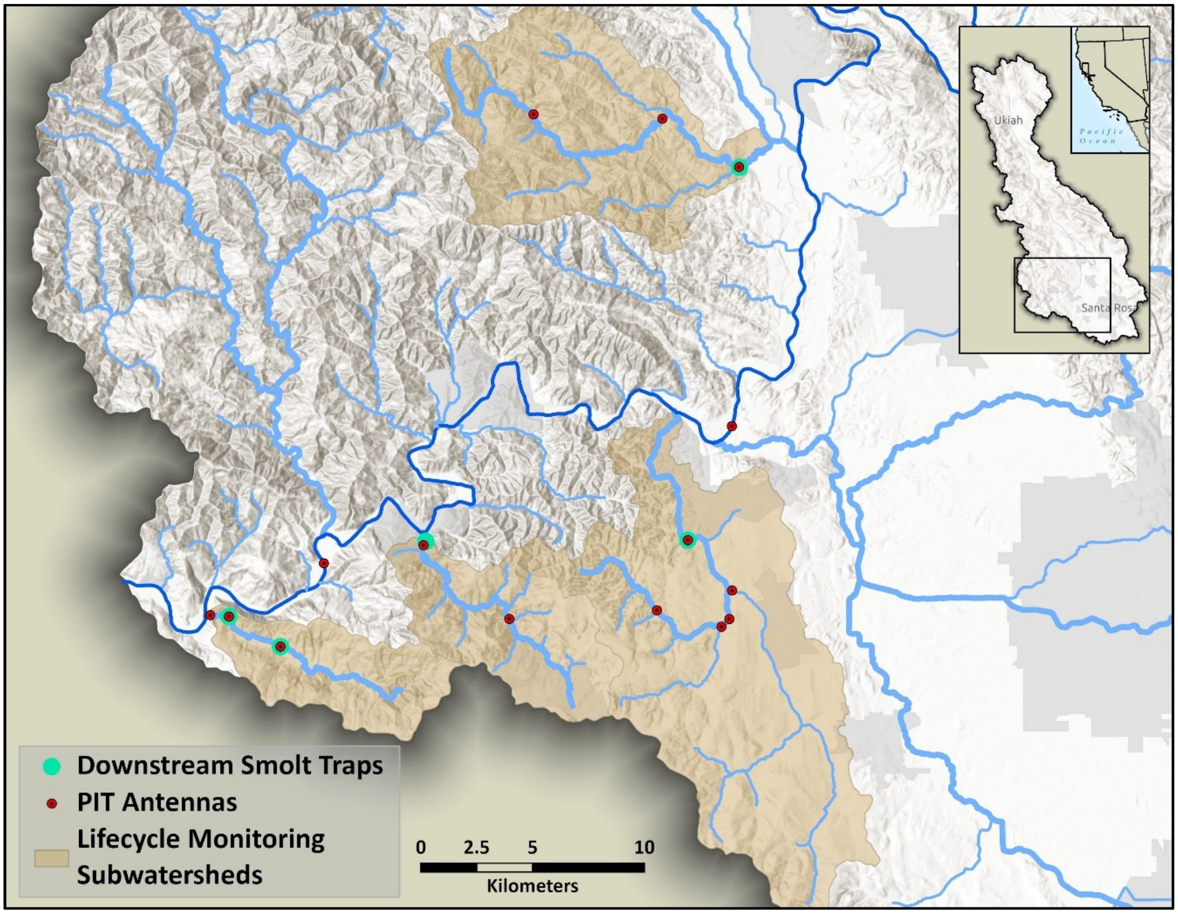


Figure II-1. Locations of fixed monitoring infrastructure for Coho Salmon and steelhead in the four LCM sub-watersheds and Chinook Salmon at the fixed LCM station at the Mirabel dam on the mainstem Russian River.

Chinook Smolt Abundance

At the mainstem Russian River trap site (rkm 39.67), we operated one rotary screw trap (1.5 m diameter cone) immediately downstream of the downstream opening of the fish ladder on the west side of the river (Figure II-2). All fish captured in the trap were identified to species and enumerated. All salmonids ≥55 mm were scanned for a PIT tag and all 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 fin-clipped and released upstream of the trap each day. A one-trap mark-recapture design and analytical methodology was used to estimate the total number of Chinook Salmon Chinook smolts emigrating past the trap during the time when traps were operated (Bjorkstedt 2005, 2010). 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 trap at Sonoma Water's Mirabel dam in Forestville (Chinook smolt LCM station, rkm 39.67).

Steelhead pre-smolt abundance

An end-of-summer abundance estimate of juvenile steelhead in LCM streams found in pools was calculated 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 relatively minor disturbance 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 ($\hat{R}_y$) 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-3).

Sampling occurred during August through October and varied each season as described below. Pre-smolt sampling began in the Mill Creek watershed in 2017 as part of a previous grant where the Dry Creek watershed was the LCM watershed for steelhead. In 2020 sampling efforts were impacted by multiple factors. With the need for extra precautions to maintain compliance with Sonoma Water and CSG's COVID-19 safety protocols, field efforts were reduced due to limitations in crew size. Additionally, the outbreak of the Walbridge fire on August 18, 2020, suspended field activities briefly due to safety concerns.

Life cycle monitoring

2018 and 2019

During pre-smolt sampling in 2018 and 2019, snorkel counts were calibrated with backpack electrofishing surveys. 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 for all wetted reaches. A single diver recorded the number of salmonids observed in each pool by species and age class. During first-stage 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 et al. 2010). After 2019, habitat metrics were no longer recorded during first-stage sampling.

To calculate a calibration ratio for steelhead juveniles observed while snorkeling, we employed an *n* pool protocol meaning that every n_{th} pool was sampled with *n* varying by stream. For each stream, every n_{th} pool that was snorkeled was selected for second-stage sampling (backpack electrofishing surveys). During second-stage sampling the selected pools were first snorkeled by a single diver who recorded the number of salmonids observed by species and age class. Next, 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 to obtain an abundance estimate. All salmonids ≥60 mm 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-origin vs. natural-origin. PIT tags were applied to untagged steelhead and Coho ≥60 mm and 2 g so that subsequent emigration from the tributary of tagging could be detected with a stationary PIT antenna array located near the mouth of each LCM stream. Once fish were completely recovered from the anesthetic, they were released into the pool from which they were captured.

In 2018 calibration ratios were calculated and applied based on four strata: large pools (>100 m^2) with few steelhead (≤10), large pools with many steelhead (>10), small pools (≤100 m^2) with few steelhead, and small pools with many steelhead. In 2019 calibration ratios were calculated and applied based on two strata: pools with few steelhead (≤ 10) and pools with many steelhead (>10). The stratum specific calibration ratio was then multiplied by the snorkel count in each pool to arrive at an adjusted snorkel count. Finally, adjusted snorkel counts were summed for each stream and then doubled to account for the pools that were not snorkeled during first-stage sampling to provide an overall abundance estimate for each stream (Figure II-3).

2020 and 2021

Because of the sampling constraints described above for 2020, and due to the extreme low flow conditions encountered in 2021 second-stage sampling was not conducted in either year. In 2020 single pass backpack electrofishing surveys were conducted to apply PIT tags to juvenile steelhead and Coho in some LCM streams, no electrofishing abundance estimate and therefore no calibration ratio from this sampling was calculated. In 2021 no electrofishing or PIT tagging occurred. Therefore, calibration ratios calculated during the 2019 season were applied to first-stage snorkel counts for the 2020, and 2021 seasons to calculate the pre-smolt abundance estimate.

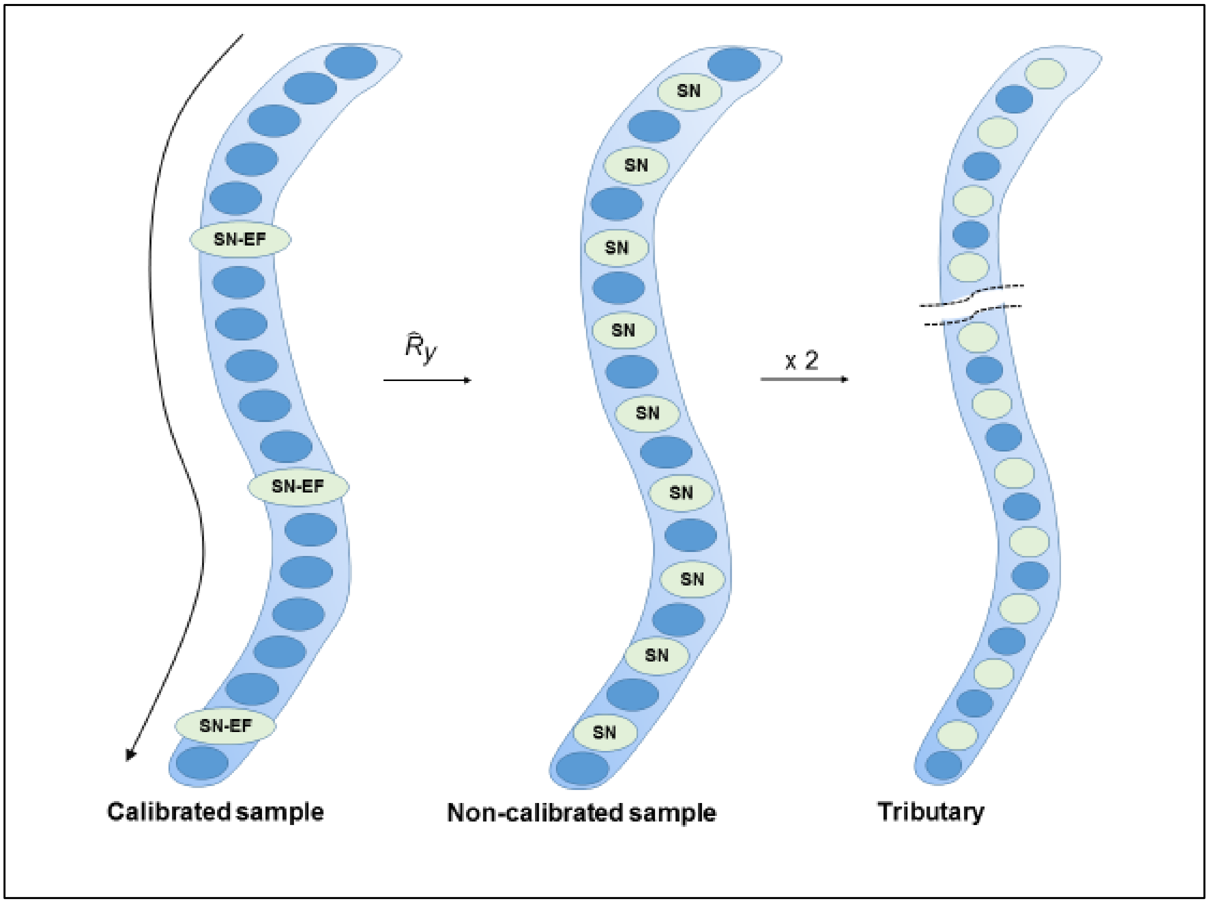


Figure II-3. Sampling strategy for estimating juvenile steelhead population in LCM tributaries. A year- and stratum-specific calibration ratio ($\hat{R}_y$) calculated from pools selected for two-stage sampling was applied to all snorkeled pools and doubled to generate an estimate for each tributary.

Steelhead smolt abundance

For steelhead smolt estimation we employed the pre-smolt abundance model described above and year-round, stationary PIT antenna monitoring to estimate smolts and/or juvenile steelhead leaving each LCS. Smolt estimates could only be generated in streams and seasons where conditions allowed juvenile abundance estimates and PIT-tagging the previous fall. Raw detections at the antenna arrays were expanded based on site specific antenna efficiency to calculate an expanded count of steelhead detections. The expanded detection count was divided by the number of juvenile steelhead PIT-tagged the previous fall to calculate a survival index. Finally, the survival index was multiplied by the pre-smolt abundance estimate from the previous fall (see Steelhead pre-smolt abundance) to calculate a steelhead smolt estimate in each LCM stream. In the absence of trapping and handling steelhead to determine which individuals are smolts, we relied on the timing of downstream movement out of their natal stream to classify these individuals as potential smolts. Individual steelhead were classified as smolts if they were detected at a given LCS during the period from November 1 through June 30 annually.

Results

Adult abundance

Coho Salmon

Estimates of Adult Coho abundance in LCMs were calculated for the 2018/19, 2019/20 and 2020/21 return seasons but have not yet been calculated for the 2021/22 return season (Figure II-4). Returns to LCMs in 2018/19 and 2019/20 were close to average but returns in 2020/21 were considerably lower and close to the lowest we have seen since CMP monitoring began in 2013. Despite low returns in 2020/21, there was a much higher proportion of three-year-old fish in Mill creek than in previous years.

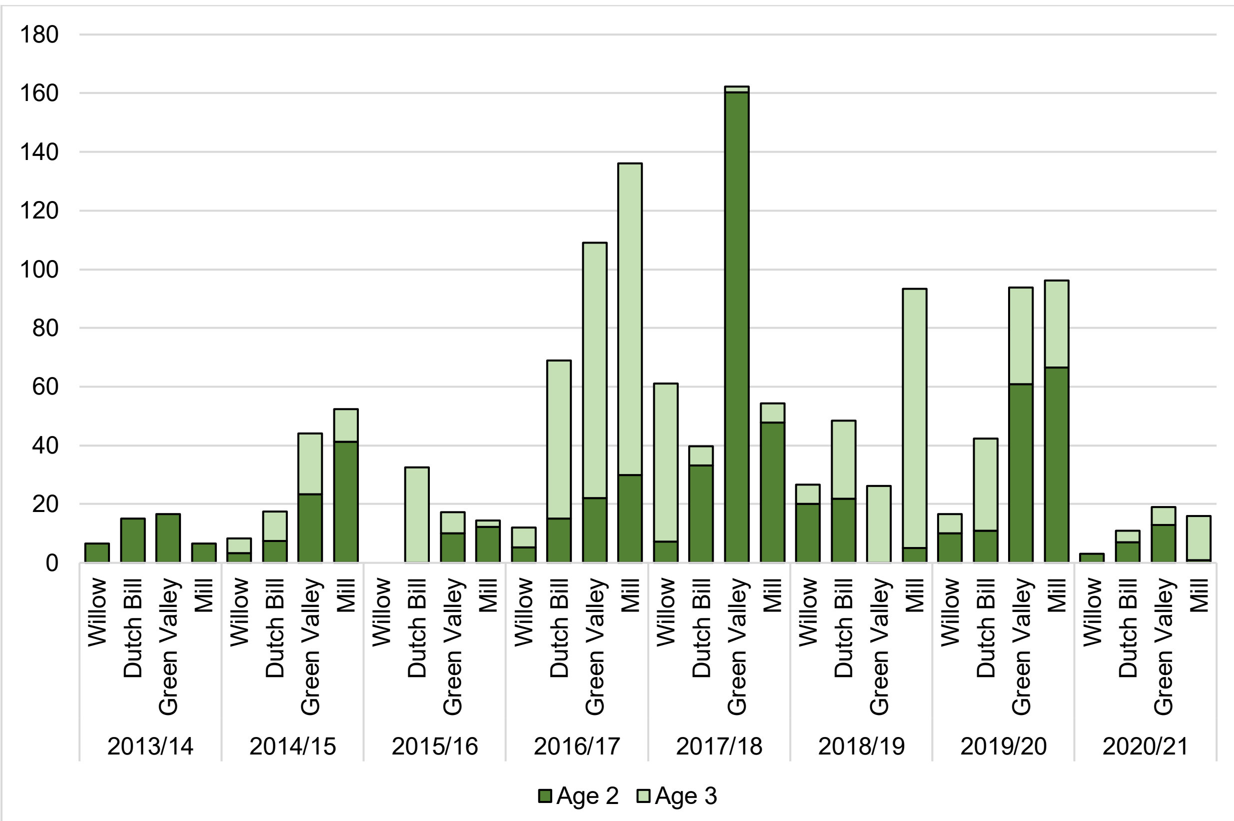


Figure II-4. Adult Coho abundance in LCM tributaries by return year and age class. Note that adult Coho abundance has not yet been calculated for the 2021/22 return year.

Steelhead adult return detections

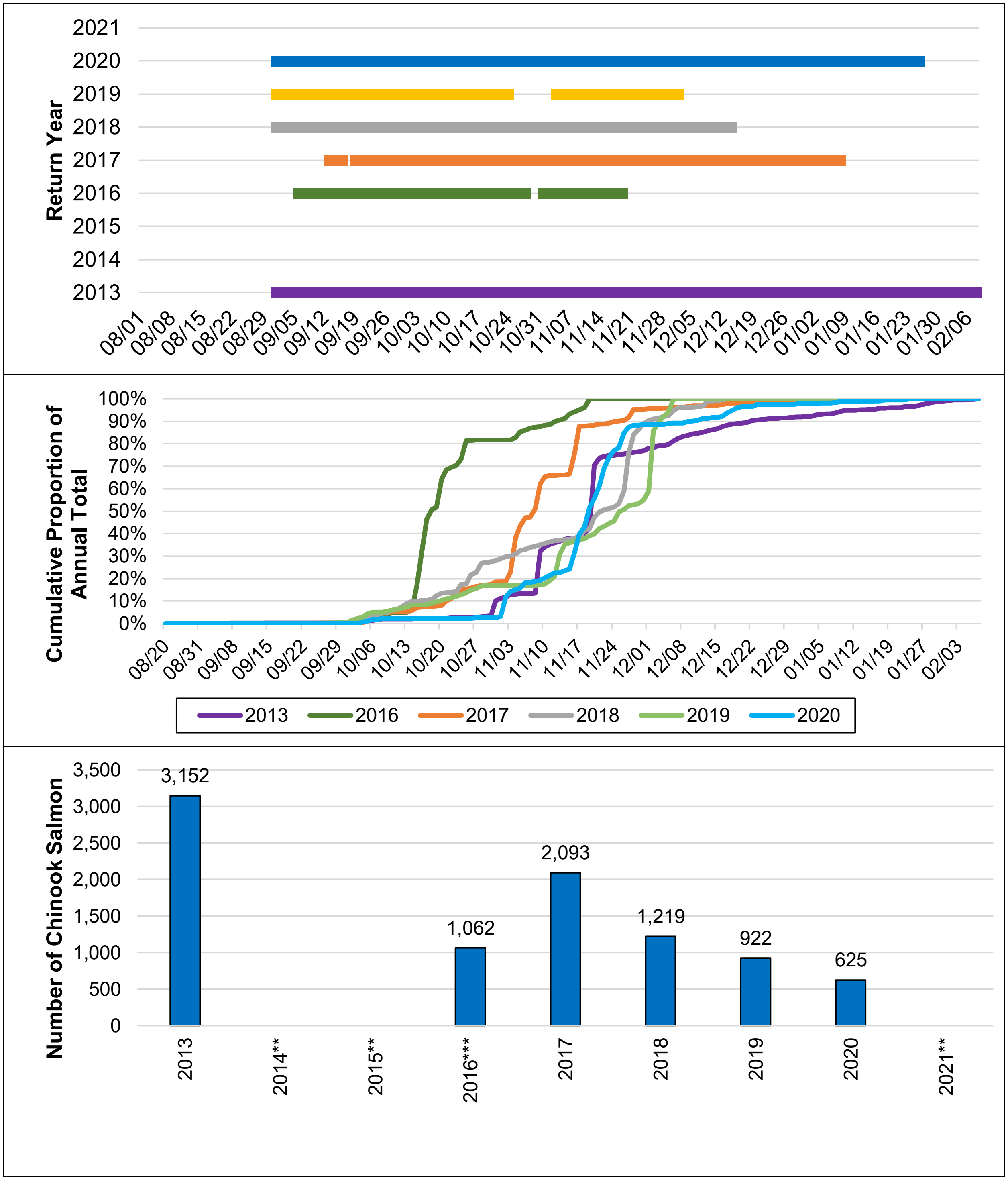
A significant tagging effort began in all LCMs in 2019, making the adult return season of 2021-2022 the first opportunity to estimate survival of steelhead to the adult stage. However, we were unable to calculate a reliable estimate due to the low number of adult steelhead that were detected. For steelhead tagged in late summer of 2019, we observed fish returning to Mill, Green Valley, and Willow Creeks (Table II-1). In the Mill Creek watershed, tagging efforts began in 2017 and we have observations of fish returning in March 2020, October 2021 and December 2021. There were no observations of fish returning from the 2018 tagging cohort.

Table II-1. Steelhead PIT tagged as pre-smolts that were detected as likely adults returning to the Russian River watershed listed by LCS stream or origin.

LCS	Tag date	Size at tagging (fork length)	Interval at large (days)	Return (detection) date
Mill Creek	10/2/2017	74 mm	554	3/26/2020
Mill Creek	10/4/2017	81 mm	1,013	10/24/2021
Mill Creek	9/26/2017	60 mm	1,379	12/30/2021
Mill Creek	10/7/2019	61 mm	812	3/19/2022
Green Valley Creek	9/12/2019	75 mm	626	1/6/2022
Willow Creek	9/24/2019	68 mm	893	3/5/2022
Willow Creek	9/25/2019	64 mm	828	12/31/2021

Chinook Salmon

The Mirabel video system relies on flow through fish ladders incorporated into the dam facility thus it can only operate when Sonoma Water's rubber dam is inflated. In most years, this period encompasses most of the adult Chinook migration period (Figure II-5, upper and middle panels). During the project period, counts ranged from approximately 625 fish to 922 fish (Figure II-5, lower panel). These counts are significantly less than the historic average Chinook counts at Mirabel of approximately 3,200 fish.



** Video cameras not operated in 2014 and 2015 because the site was under construction in order to construct new fish screens and ladder. A count was not obtained in 2021 because an early season storm precluded camera operation beyond October 23.

*** 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.

Figure II-5. Period of operation (upper panel), cumulative proportion of annual count (middle panel) and adult count passing Sonoma Water's Chinook Salmon LCS at Mirabel dam in Forestville (lower panel), 2013-2021.

Redd abundance

Coho and Steelhead LCM tributaries

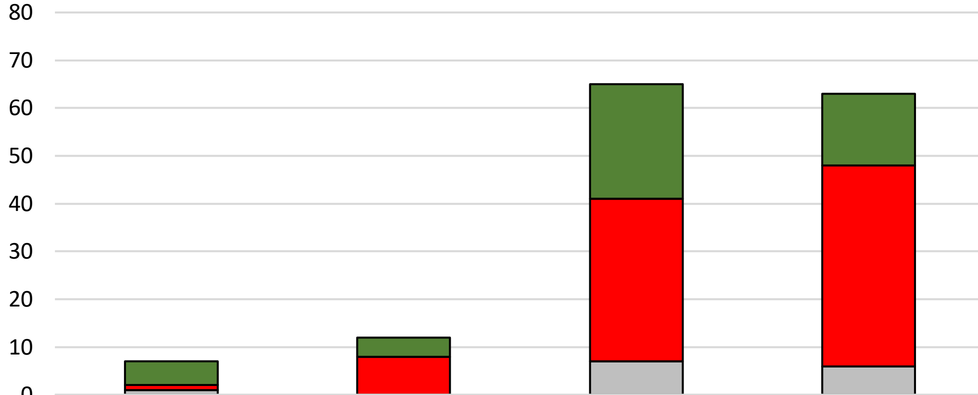
Spawner survey effort among years ranged from 102 surveys in 2018/19 to 191 in 2021/22 (Table II-2). Despite the shortened season in 2019/20 caused by COVID-19 pandemic restrictions, the 2018/19 spawner season had the fewest surveys completed in LCM tributaries. In each season we observed both Coho and steelhead redds in every tributary surveyed, except for Willow Creek during the 2020/21 spawner season when no redds of any species were recorded. During 2018/19, 2019/20 and 2020/21 there were more steelhead redds than Coho redds observed in most tributaries. This ratio was partially reversed in the 2021/22 spawner season when all LCM tributaries (except Mill Creek) had greater numbers of Coho redds than steelhead redds. There were also more Coho individuals (live fish and carcasses) seen in LCM tributaries during the 2021/22 spawner season, distinguishing it from the previous two seasons when more steelhead individuals were observed. An uncharacteristically high number of steelhead individuals were observed in Dutch Bill Creek during the 2020/21 spawner season, more than any other tributary in all three seasons (Figure II-6, Figure II-7). Mill Creek Coho redd estimates were the highest of any of the other LCM streams in 2019/20 and 2020/21, but in 2021/22 other LCM tributaries had higher estimates and were closer to estimates in Mill Creek. Estimates of steelhead redd abundance in LCM streams was generally low except for Mill Creek which generally had the highest estimates of steelhead redd abundance for the last three years. The other exception was Dutch Bill Creek in 2020/21 which had a surprisingly high estimate of steelhead redd abundance (Figure II-8).

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

Season	Season start	Season end	Number of surveys completed	Mean days between surveys (±95% CI)
2018/19	12/3/18	4/18/19	102	14.65 (±0.69)
2019/20	12/04/19	03/17/20	142	11.61 (±0.47)
2020/21	12/29/20	04/16/21	119	13.43 (±0.74)
2021/22	11/01/21	04/14/22	191	12.86 (±0.49)

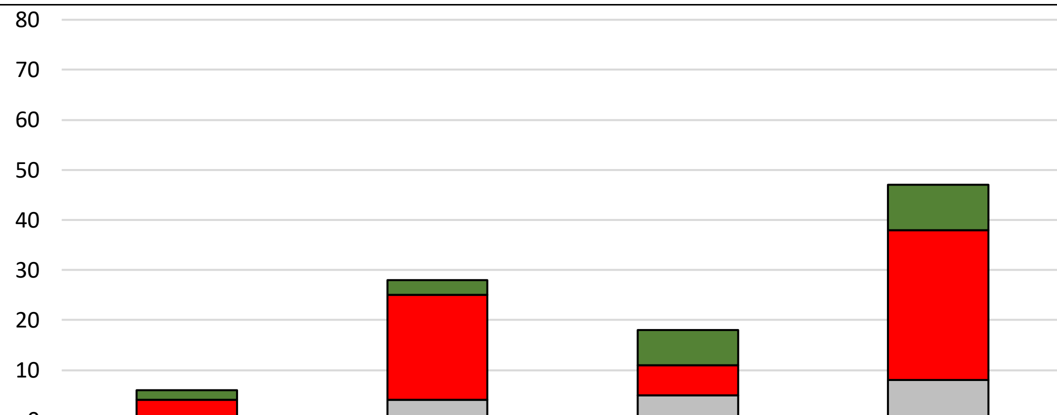
Life cycle monitoring

2018/19



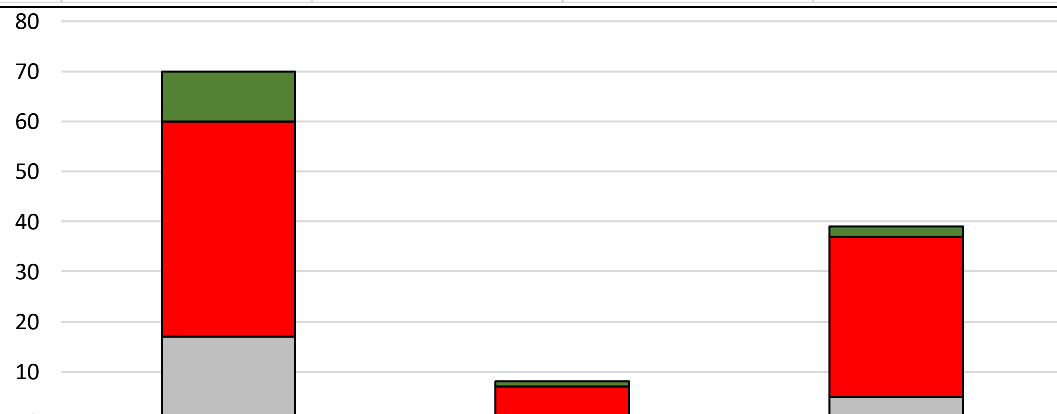
	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	5	4	24	15
STEELHEAD	1	8	34	42
SALMONID SP	1		7	6

2019/20



	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	2	3	7	9
STEELHEAD	4	21	6	30
SALMONID SP		4	5	8

2020/21



	Dutch Bill	Green Valley	Mill
COHO SALMON	10	1	2
STEELHEAD	43	7	32
SALMONID SP	17		5

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Life cycle monitoring

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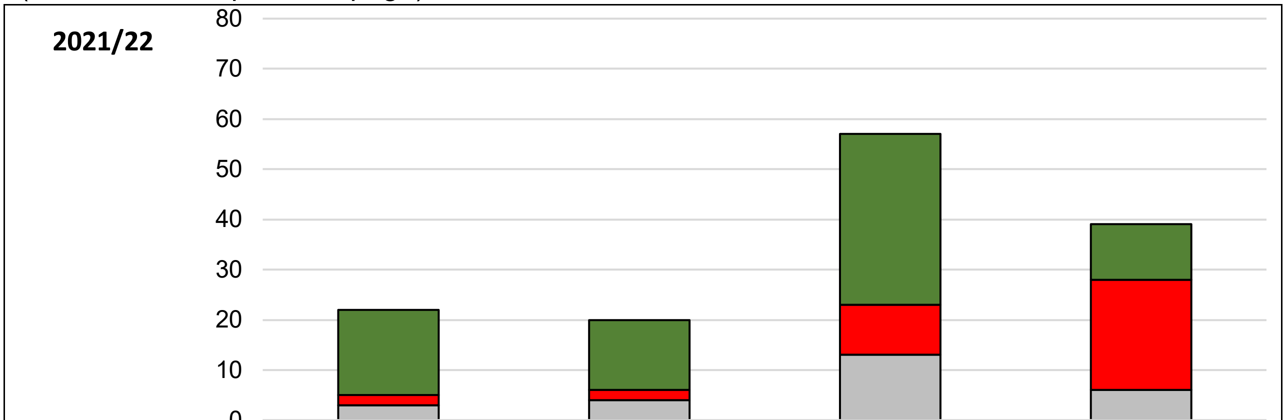
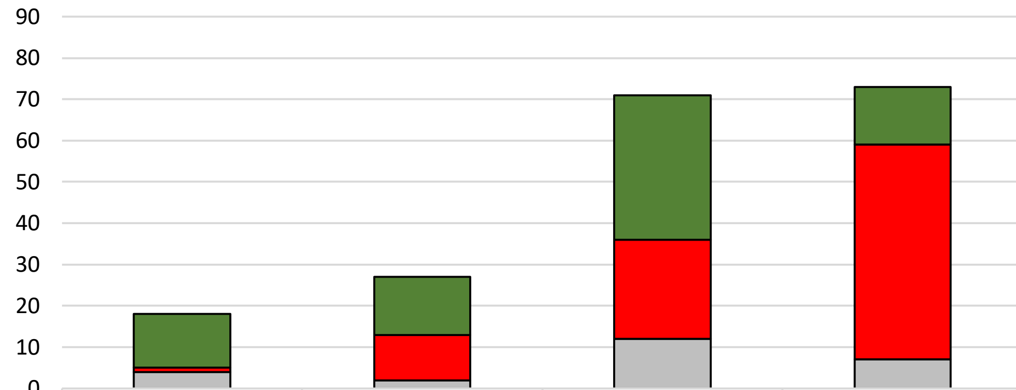


	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	17	14	34	11
STEELHEAD	2	2	10	22
SALMONID SP	3	4	13	6

Figure II-6. Number of new redds counted by season and tributary in life cycle monitoring watersheds for all three levels of redd species certainty. No redds were observed in the Willow Creek watershed during the 2020/21 spawner season. Vertical scale on plots has been standardized for comparison.

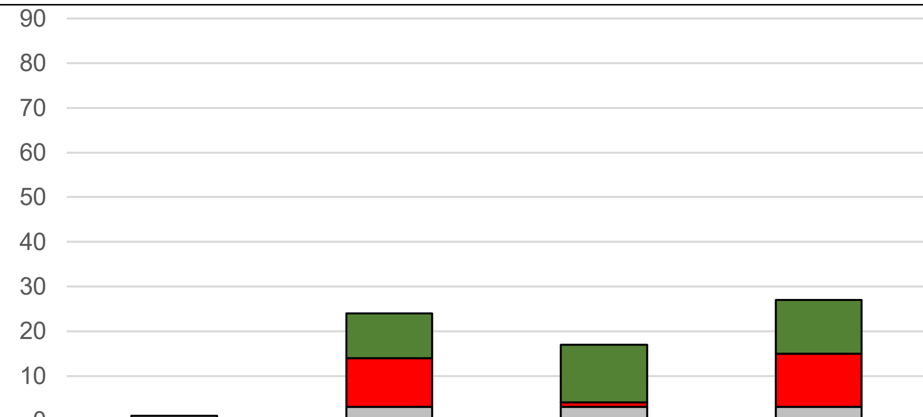
Life cycle monitoring

2018/19



	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	13	14	35	14
STEELHEAD	1	11	24	52
SALMONID SP	4	2	12	7

2019/20



	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON		10	13	12
STEELHEAD		11	1	12
SALMONID SP	1	3	3	3

2020/21

	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	1	3	1	1
STEELHEAD		71	2	5
SALMONID SP		5	2	5

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Life cycle monitoring

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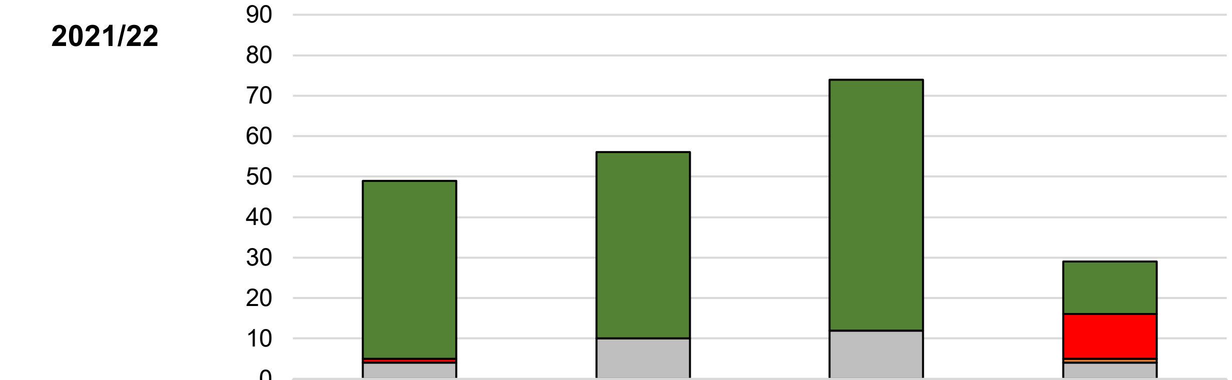


	Willow	Dutch Bill	Green Valley	Mill
COHO SALMON	44	46	62	13
STEELHEAD	1			11
Chum Salmon				1
SALMONID SP	4	10	12	4

Figure II-7. Number of live adult salmonids and carcasses counted by season and tributary for all three levels of fish species certainty. It is possible that some fish were counted more than once. Vertical scale on plots has been standardized for comparison.

Life cycle monitoring

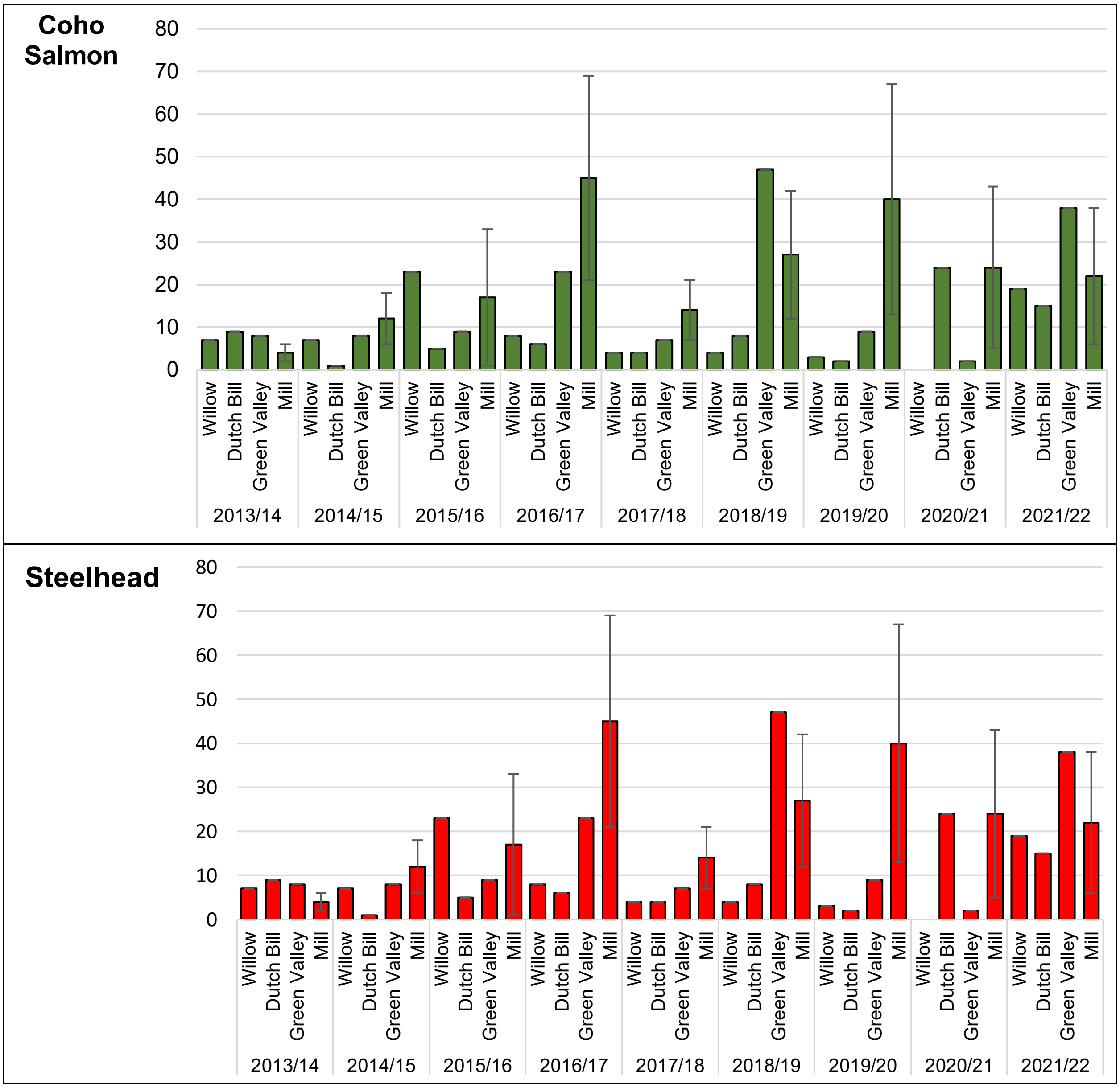


Figure II-8. Estimated redd abundance for Coho Salmon (upper panel) and steelhead (lower panel) in lifecycle monitoring sub-watersheds by season. Estimates calculated prior to the current grant reporting period are shown in order to display trends. 95% confidence levels were calculated only in Mill Creek because it was the only watershed where census surveys could not be completed due to lack of access.

Smolt abundance

Downstream migrant traps (Coho)

Downstream migrant trapping effort for Coho in the four LCM streams is summarized in Table II-3 below. Estimates of Coho smolt abundance were highly varied, ranging from 692 in Mill Creek in 2021 to 13,949 in Green Valley Creek in 2019. Green Valley Creek consistently had the highest estimates of Coho smolt abundance for the last three years. This is expected as Green Valley Creek also consistently had the highest number of hatchery Coho smolts released, except for 2019 when smolt releases were relatively even for 3 of the four LCM tributaries (Willow Creek excluded, Figure II-9). Overall, Coho smolt estimates in LCM tributaries were lowest in 2021 (Figure II-10).

Table II-3. Summary of DSMT effort in LCM tributaries from 2019 to 2021.

Year	Tributary	StartDate	EndDate
2019	Willow	4/11/2019	6/24/2019
2019	Dutch Bill	4/7/2019	7/3/2019
2019	Green Valley	4/12/2019	6/28/2019
2019	Mill	3/19/2019	6/24/2019
2020	Willow	4/23/2020	6/3/2020
2020	Dutch Bill	4/13/2020	6/6/2020
2020	Green Valley	4/25/2020	6/3/2020
2020	Mill	4/24/2020	6/3/2020
2021	Willow	3/11/2021	6/1/2021
2021	Dutch Bill	3/10/2021	5/3/2021
2021	Green Valley	3/13/2021	6/3/2021
2021	Mill Creek	3/9/2021	5/20/2021

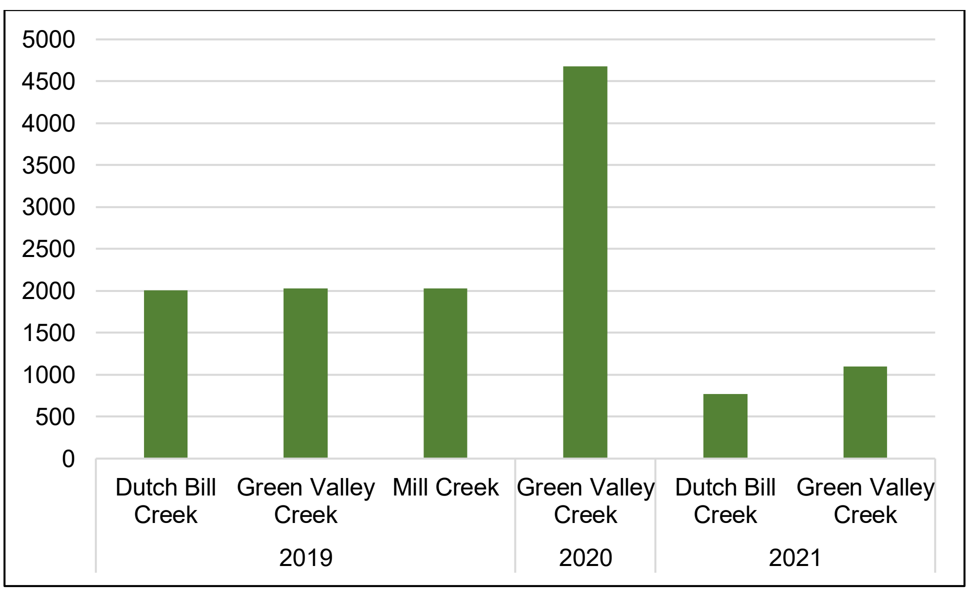


Figure II-9. Hatchery smolt releases into LCM tributaries from 2019-2021.

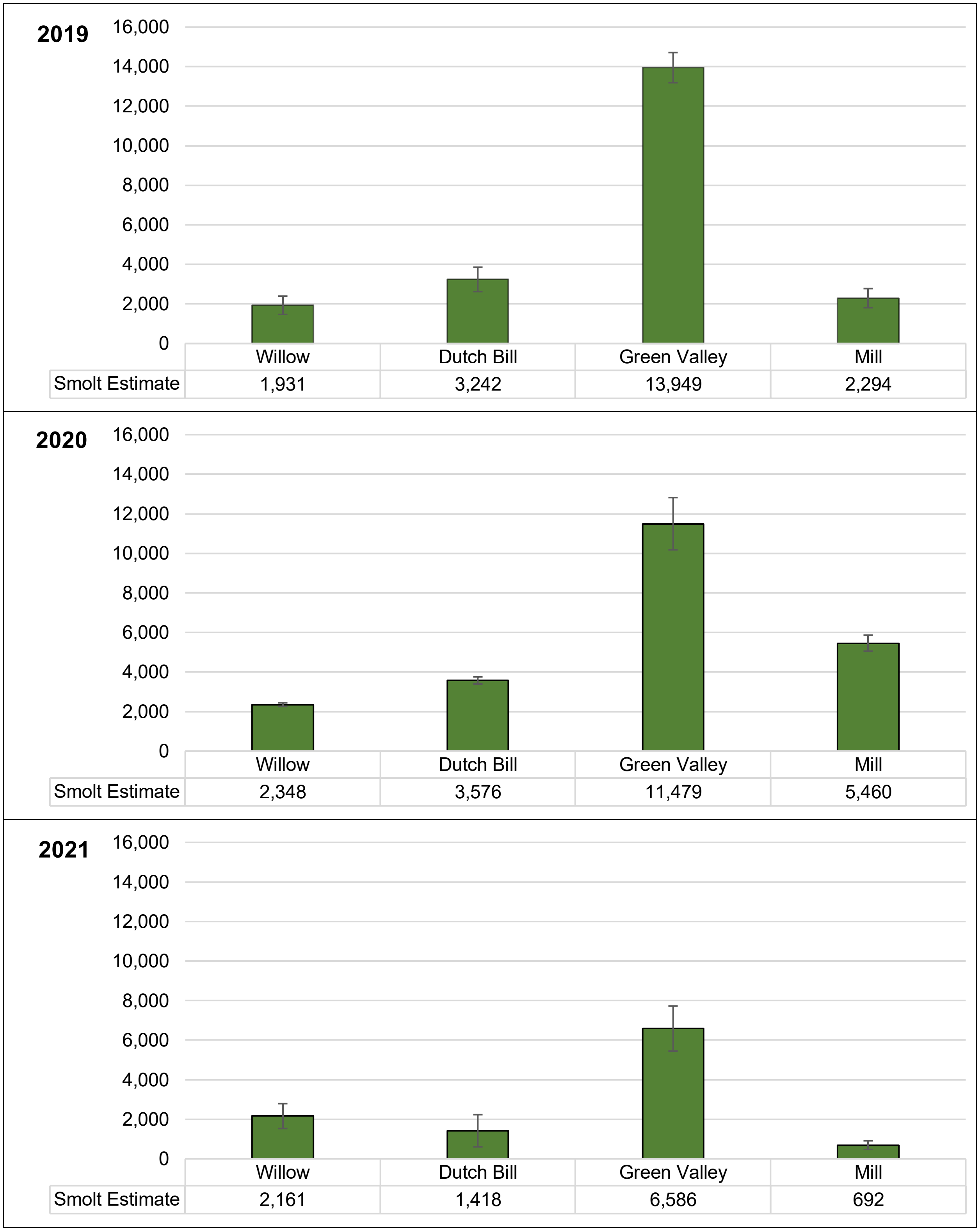


Figure II-10. Coho Salmon smolt abundance estimates (±95% confidence intervals) for Mill, Green Valley, Dutch Bill, and Willow Creeks in 2019, 2020, and 2021. Vertical scale on plots has been standardized for comparison.

Downstream migrant traps (Chinook)

Because of river flows and dam operation, beginning and end dates of trap operation has varied widely over the years (Figure II-11, upper panel). This has likely contributed to substantial bias (i.e., in years when a significant portion of the smolt run is missed) and high within-season variability in trap efficiency which would contribute to low precision of abundance estimates (Figure II-11, lower panel).

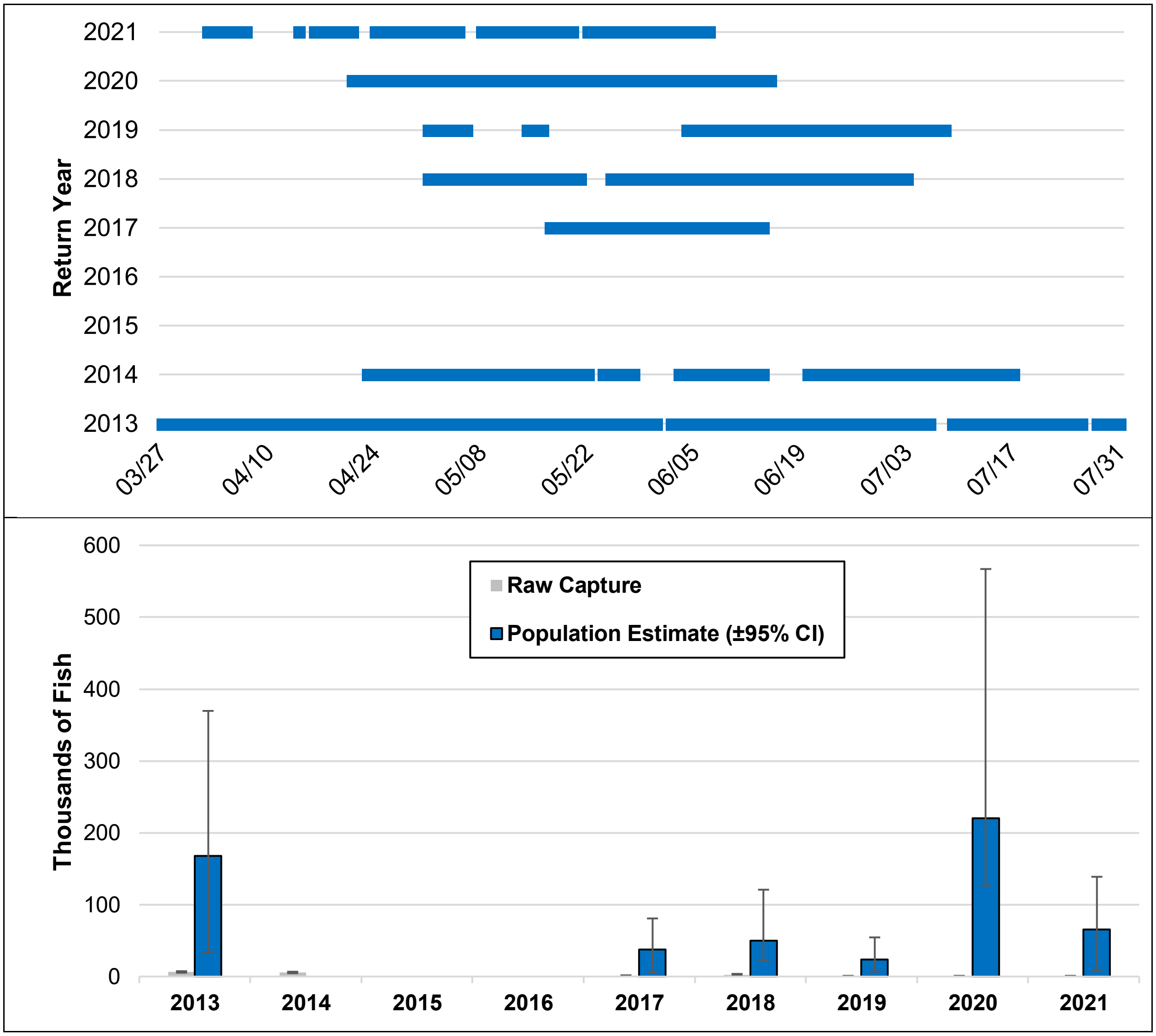


Figure II-11. Population estimates for Chinook Salmon smolts at Mirabel LCM on the mainstem Russian River (rkm 39.67), 2013-2021. Note that due to fish ladder construction, the trap was not operated in 2015 and 2016 and because of operational difficulties a population estimate was not possible in 2014.

Pre-smolt steelhead abundance

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 ($\hat{R}_p$=$\hat{n}_{ef}$ $\cdot n_{sn}^{-1}$; where $\hat{n}_{ef}$ is the number of juvenile steelhead estimated based on depletion electrofishing and $\hat{n}_{sn}$ is the number of juvenile steelhead observed during snorkel surveys), we evaluated a number of variables that we believed could contribute to variation in $\hat{R}_p$. We found little correlation between pool metrics (pool area, ratio of pool length and pool width, pieces of large woody debris) and $\hat{R}_p$. Only in 2018 was pool size found to influence $\hat{R}_p$ (p = 0.023) and the number of fish observed had the strongest influence on $\hat{R}_p$ (p = 0.002). In 2019 we saw a negative correlation between the number of fish observed during snorkeling (snorkel count) in each unit and $\hat{R}_p$ (r = -0.368). We used ANOVA to examine the number of fish observed, observer, and tributary as categorical factors to help explain variability in $\hat{R}_p$ among pools. We found that each of these variables had some influence on the mean $\hat{R}_p$, with snorkel count (groups: steelhead ≤10 and steelhead >10) having the strongest effect (F (1,181) = 20.921, p = 0.00001).

The year- and stratum-specific calibration ratio $\hat{R}_y$ 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 LCM watersheds (Table II-4). Pools were grouped based on strata and the corresponding calibration ratio was applied to snorkel counts from the first-stage sampling effort. To generate a population estimate, the sum of corrected snorkel counts (i.e., after applying $\hat{R}_y$) for each tributary stream was doubled to account for the fact that during first-stage sampling only every other pool was snorkeled.

Table II-4. Stratum-specific calibration ratio ($\hat{R}_y$) applied to first-stage sampling snorkel counts used to derive pre-smolt juvenile steelhead population estimates where n is the number of pools used to calculate $\hat{R}_y$.

Years applied	Stratum	n	$\hat{R}_y$	± 95% CI
2018	≤ 10 sthd, pool area ≤ 100m^2	28	2.30	0.71
2018	≤ 10 sthd, pool area >100m^2	6	4.60	1.78
2018	> 10 sthd, pool area ≤ 100m^2	3	1.10	1.59
2018	> 10 sthd, pool area >100m^2	11	1.71	0.34
2019, 2020, 2021	≤ 10 sthd	109	3.73	0.50
2019, 2020, 2021	> 10 sthd	74	1.93	0.60

First-stage sampling (single pass snorkel surveys) was completed in the four LCS each year with one exception. In 2020 due to direct impacts of the Walbridge fire in the Mill Creek watershed no snorkel surveys were conducted for safety reasons. Abundance of juvenile steelhead during the late summer was greatest in 2019 in all LCS, ranging from 11,596 ± 2,910 95%CI in Mill Creek to 4,220 ± 904 95%CI in Willow Creek (Figure II-12). After 2019 steelhead abundance declined dramatically each year to a low of 1,755 ± 341 in Mill Creek and 60 ± 8 in Willow Creek during 2021 (Figure II-12). Because it is the basis for the 2019 season, the 2018 Mill Creek watershed pre-smolt steelhead estimate is reported here.

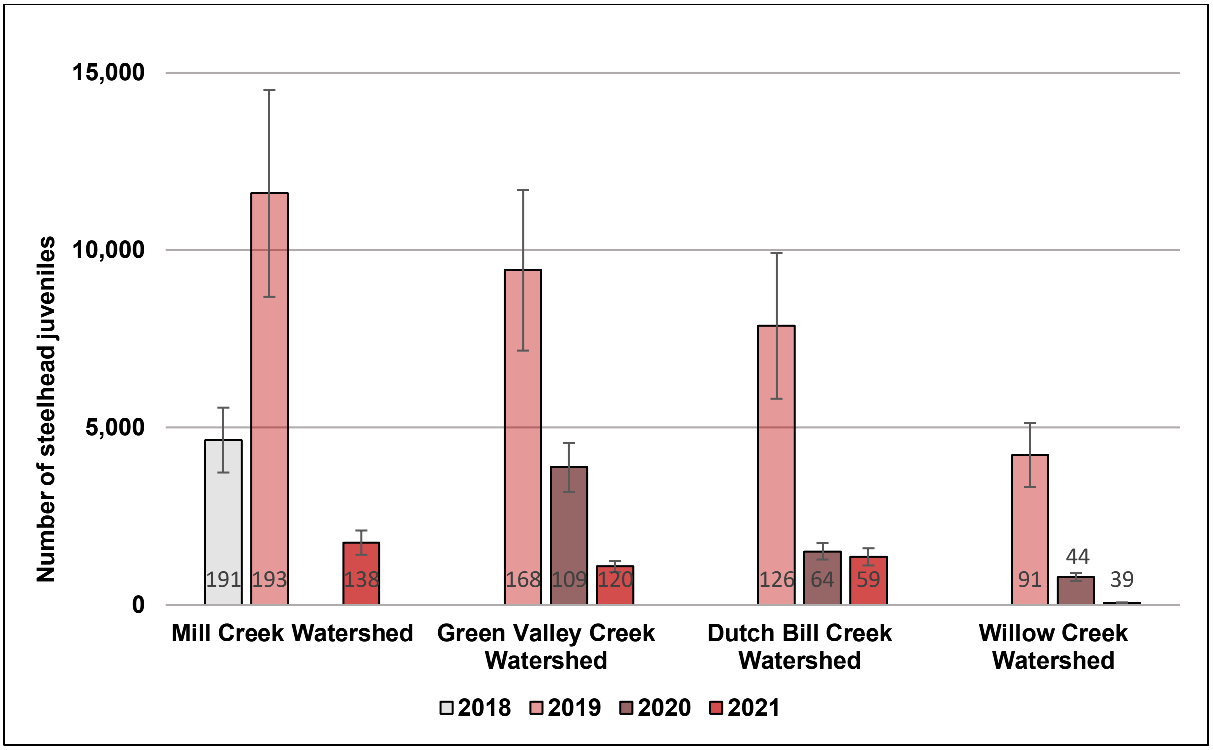


Figure II-12. Pre-smolt estimates for steelhead found in pool habitats at the end of summer from four Russian River LCM watersheds. Error bars represent ± 95% CI and the number at the base of each column represents the number of pools sampled to generate the population estimate.

Steelhead smolt abundance

Based on PIT antenna detections near the mouth of all four LCS, the timing of steelhead emigration varied by watershed and season. During the 2019-2020 season over half of all steelhead detected leaving the Mill Creek and Dutch Bill Creek LCS emigrated between November 15, 2019 and December 15, 2019 (65% and 55% respectively), whereas in Green Valley Creek over 72% of all steelhead detected emigrated between March 15, 2020 and April 15, 2020 (Figure II-13). Almost all of the steelhead emigrating from the Willow Creek LCS were detected after March 15, 2020 (94%) with the last detection on July 25, 2020 (Figure II-13). The following season (2020-2021) steelhead emigrants were detected at the mouth of the Mill, Green Valley[1], and Dutch Bill Creek LCS from January 7 through May 4, 2021 (Figure II-14).

[1] Note that because of extremely low flows in 2020, second-stage sampling in the Green Valley Creek watershed could only be conducted in Purrington Creek meaning that the 2020 fall juvenile abundance estimate only applies to Purrington Creek.

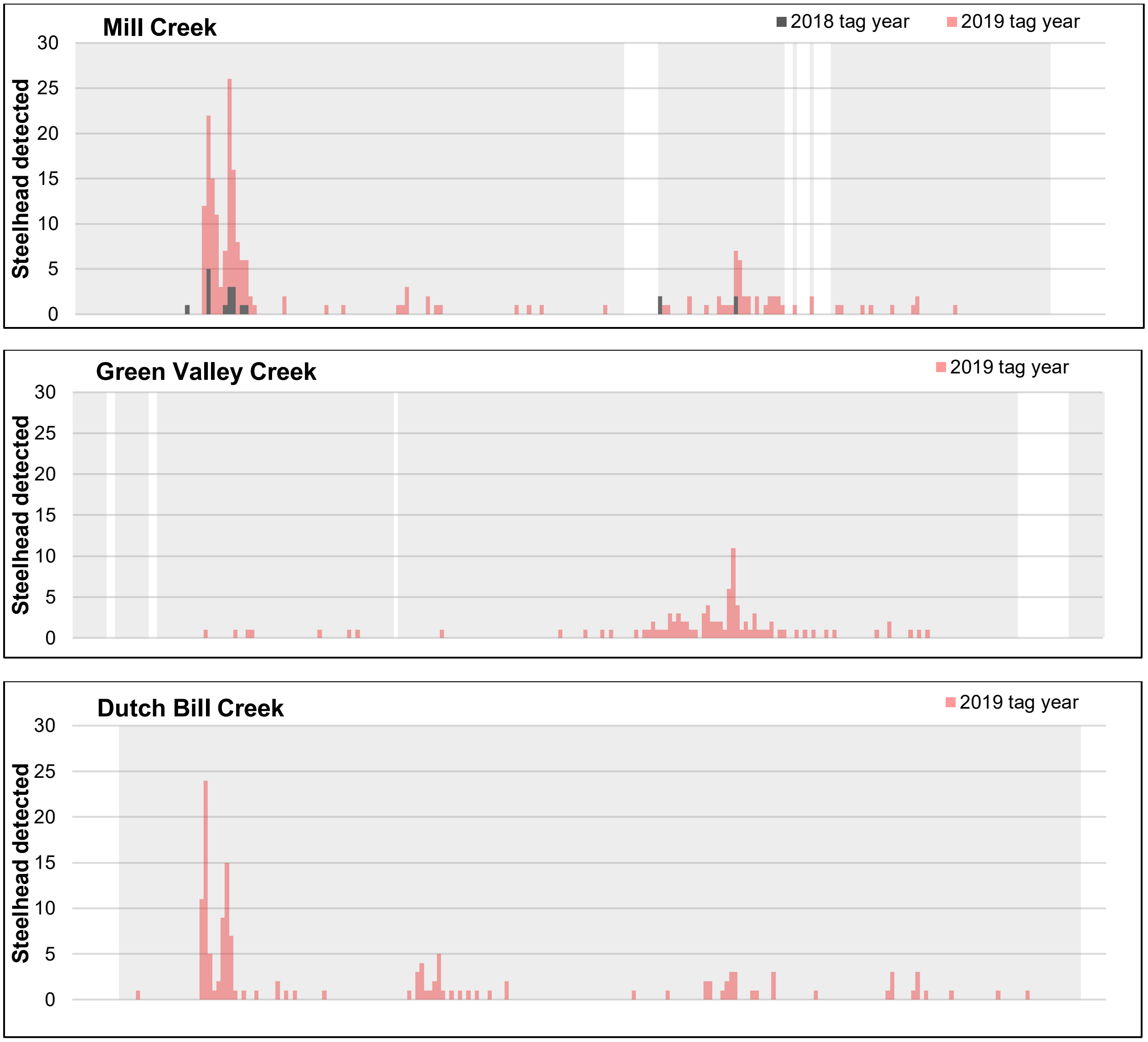


Figure II-13. Number of individual steelhead tagged during late summer sampling that were detected at LCS antenna arrays between November 2019 and June 2020 based on maximum detection date. Shaded grey area indicates the period of antenna operation.

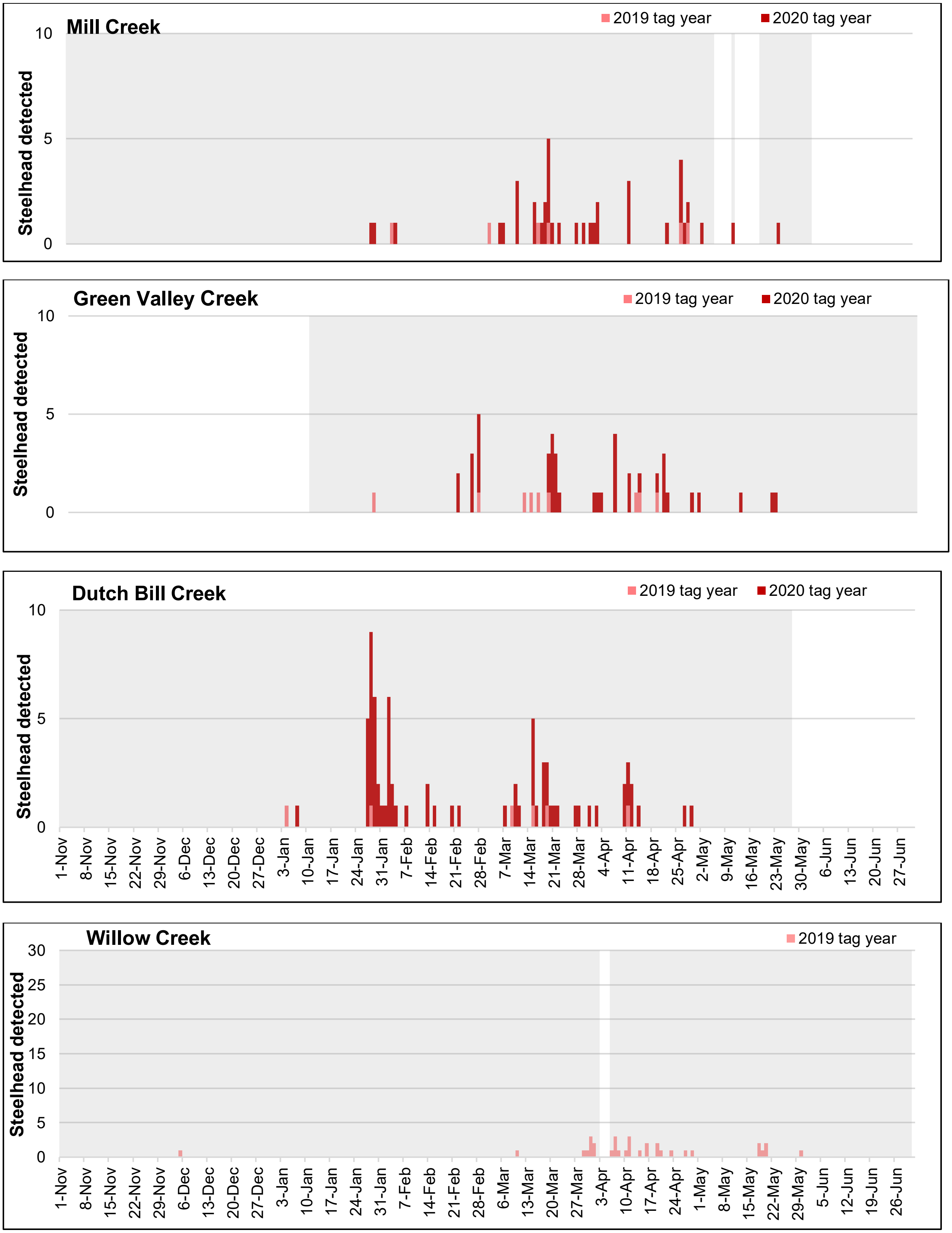


Figure II-14. Number of individual steelhead tagged during late summer sampling that were detected at LCS antenna arrays between November 2020 and June 2021 based on maximum

detection date. Shaded grey area indicates the period of antenna operation. In 2020 only Purrington Creek in the Green Valley Creek watershed was sampled during second stage sampling.

During the fall through spring steelhead emigration period, the raw proportion (i.e., not adjusted for antenna efficiency) of fish that were tagged in the summer and then emigrated from each LCS ranged from 22% at Mill Creek during the 2018-2019 season to 6% at Willow Creek during the 2019-2020 season (Table II-5). PIT antenna efficiency was similar in all LCSs (range 0.79 – 0.96, Table II-5). The estimated number of steelhead emigrating from all LCSs ranged from 2,319 in Mill Creek (2019-2020) to 145 in Purrington Creek, in the Green Valley watershed (2020-2021) (Figure II-15). Due to low water conditions no second-stage sampling was conducted during the late summer of 2021 (CSG unpublished data), therefore, we are unable to provide a steelhead smolt estimate for the 2021-2022 emigration season.

Table II-5. Number of steelhead PIT-tagged by LCS and number of fish detected at the mouth of respective streams during the ensuing steelhead emigration period of November 1 through June 30.

Season	LCS sub-watershed	Number PIT-tagged	Raw detections at mouth	Raw proportion emigrating	Antenna efficiency	Survival index
2018-2019	Mill Creek	987	220	0.22	0.92	0.24
2019-2020	Mill Creek	1,031	185	0.18	0.90	0.20
	Green Valley Creek	1,003	94	0.09	0.86	0.11
	Dutch Bill Creek	973	140	0.14	0.85	0.17
	Willow Creek	523	33	0.06	0.79	0.08
2020-2021	Mill Creek	366	37	0.10	0.96	0.10
	Purrington Creek[1] (GVC)	699	39	0.06	0.86	0.06
	Dutch Bill Creek	442	69	0.16	0.94	0.17
	Willow Creek	0	-	-	-	-

[1] Purrington Creek was the only stream in the Green Valley Creek sub-watershed sampled during second-stage sampling in 2020.

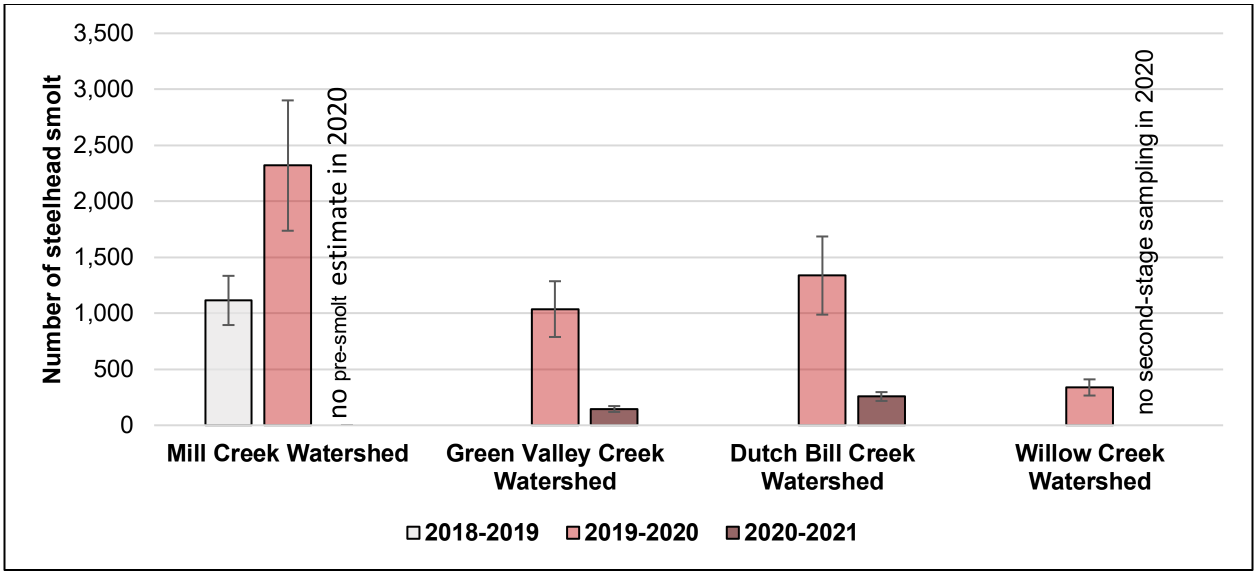


Figure II-15. Smolt estimates for steelhead from four Russian River watersheds. Error bars represent ± 95% CI. Smolt estimates are based on pre-smolt estimates and subsequent detection of PIT tagged fish, therefore none are available for Mill Creek or Willow Creek watersheds for the 2020-2021 season. Estimate in 2020-2021 season for Green Valley Creek watershed is from Purrington Creek only.

Steelhead life history variation

For each LCS we detected individuals emigrating from their natal stream over one year after they were initially sampled (Figure II-13,Figure II-14). For juveniles tagged in the summer of 2020 we detected 9 steelhead from the Mill Creek watershed, 7 from the Dutch Bill Creek watershed, and 19 from the Green Valley Creek watershed emigrating from their natal streams between October 25, 2021 and March 31, 2022. While these individuals are of unknown hatch year, based on their size at tagging (average fork length 77.2 mm) they are likely 2+ steelhead at time of emigration. This life history strategy has been document in previous sampling seasons (SW and CSG 2019, SW and CSG 2021).

Discussion

Adult abundance

The winters of 2018/19 and 2019/20 were characterized by moderate rainfall with creeks opening in December prior to the usual peak of Coho spawning. Most fish were detected entering the watershed between late November and early December. Likely due to these favorable flow conditions, we recorded two of the highest return of Coho adults since starting CMP monitoring in 2013. The majority of the fish were two-year-olds (Figure II-4). This is in contrast to 2020/21 when flow conditions were not ideal and adult Coho returns were much lower. In 2020/21 the first storms large enough to open creeks for spawning access did not occur until January and there was likely a reduction in spawning in these creeks as a result. The cohort of smolts and juveniles in 2018 was also small which may have led to a smaller return of spawners. In both seasons CSG was able to detect evidence of Coho returning to streams other than their natal stream, and this pattern seemed to increase during seasons with less favorable flow conditions for spawning. In 2019/20 they found evidence that fidelity in pre-smolts and smolts was highest in Dutch Bill and Dry Creek and lower in Green Valley and Mill Creeks. This could be related to habitat quality in those creeks, or possibly differences in imprinting time. There is also evidence that when flow conditions were worse many fish returned to Dry Creek where flows are artificially maintained at high levels even in low flow years (CSG 2020, CSG 2021). We recommend continued support of the work by CSG to evaluate adult Coho returns in detail as it compliments and puts into perspective work done for the CMP.

Redd abundance

Redd and individual counts in LCM streams were low in 2019/20 and 2020/21 (with the exception of Dutch Bill Creek in 2020/21), but in 2021/22 we saw the highest counts of Coho redds since beginning surveys in 2013/14. The large numbers of steelhead counted in Dutch Bill Creek in 2020/21 were likely due to hatchery fish releases in the lower mainstem of the Russian river at the Monte Rio boat launch (directly adjacent to the mouth of Dutch Bill Creek). The effect of these hatchery releases is discussed in more detail in chapter III in the discussion of basinwide spawner surveys. With the exception of Mill Creek, all LCM creeks saw record numbers of Coho during the 2021/22 season. Likely, this was in part due to favorable flow conditions for Coho spawning in 2021/22. We had a large atmospheric river event hit Sonoma County bringing a new 24-hour record of rainfall of over 7 inches. All tributaries were connected and spawner surveys began earlier than they have since 2016/17. A review of the hydrograph from 2021/22 shows an early connection then a follow up of less intense storms later on (Figure II-16). These subsequent smaller storms occurred during the usual peak of Coho spawning and created flow and turbidity conditions ideal for Coho spawning and upstream movement. They were also not so large as to create turbidity lasting several days/weeks as larger storms often do. This perfect combination of enough turbidity to provide cover for migrating fish and encourage upstream migration, but not so much turbidity that it severely limits the ability to survey creeks is a rare occurrence. Much more frequently in the past we have seen a pattern of later and later initial flows large enough to connect tributaries for the first time in a season. Often times these flows occur after the usual peak in spawning activity. When flows do come, they often blow out creeks for long periods limiting our ability to count and record redds if they are there. It is difficult to tease apart whether the improved Coho redd estimates are the result of increased spawning or improved ability to record redds, but it seems fairly clear that favorable flow conditions contributed to these increased counts.

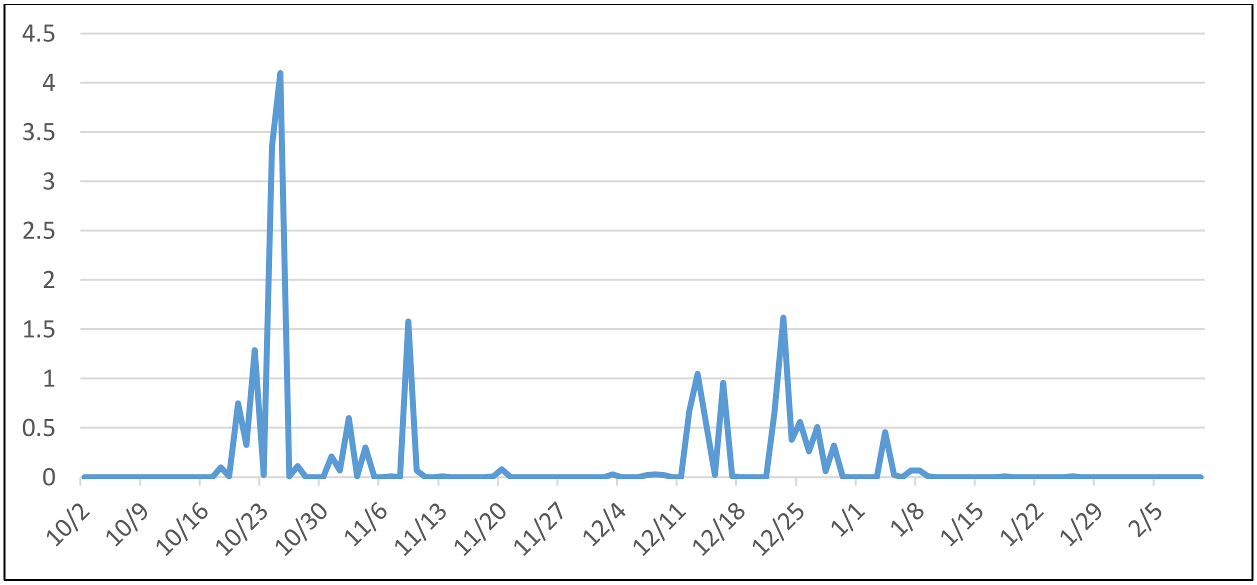


Figure II-16. Precipitation (inches) at the Santa Rosa rain monitoring station during the 2021/22 spawner season.

Smolt abundance

Coho

Coho smolt abundance estimation was affected by flows and the pandemic. High winter flows in February 2019 likely affected antenna detection efficiency in all LCM streams to an unknown extent. The start of DSMT was delayed by high flows and then a large storm in late May interrupted trapping. These flow related issues reveal the necessity of including flow as a covariate when calculating smolt numbers to help explain the effects of flow on antenna detection efficiency. If we could establish a robust flow/efficiency relationship we might be better equipped to estimate overwinter survival. Despite a late start to the season in 2020 due to COVID-19 restrictions, we were able to calculate a robust Coho smolt estimate. This was accomplished with the use of PIT tags and antennas. While we strive to follow the protocols laid out in FB 180 whenever possible, we are aware that there is little to no guidance in FB 180 regarding the use of PIT antennas and tags for juvenile abundance estimation. We recommend in future iterations of FB 180 a thorough consideration of the potential benefits of using PIT equipment to obtain and augment juvenile salmonid estimates. The 2021 season saw the lowest numbers of Coho smolt abundance estimates recorded in LCM tributaries, with the exception of Willow Creek. Likely severe drought conditions affected survival, but it is possible that estimation of smolt abundance and survival relying on smolts arriving at a DSMT site may not be accurate. We had anecdotal evidence that many would-be smolts may have been trapped upstream of trapping sites by shallow riffles in habitat that was not ideal, but not necessarily deadly.

Steelhead

Two-stage sampling of juvenile steelhead in the late summer has proven to be an effective method for generating steelhead smolt abundance estimates in the LCS. Additionally, the ability to use a stratum specific calibration ratio ($\hat{R}_y$) to calibrate first-stage snorkel counts when conditions are not suitable for electrofishing has provided means to calculate pre-smolt abundance estimates without exposing fish to unnecessary stress. Pre-smolt estimates peaked at a total of 33,111 for all LCS combined in 2019 to a low of 4,246 in 2021, which represents an 87% difference. Poor stream conditions observed in the summers of 2020 and 2021 (low dissolved oxygen, high water temperatures, and low water levels) are possible contributing factors to the observed decline. As expected, steelhead smolt abundance was considerably lower in the 2020-2021 season compared to the 2019-2020 season, due both to lower pre-smolt abundance and lower survival rates. While we will be unable to calculate survival to smolt stage for the 2021-2022 cohort (no fish were PIT tagged) we can assume based on the significant amount of stream drying observed and poor water quality in the remaining wetted sections that survival to this stage would be extremely low.

Detections of tagged steelhead has provided additional information on various life history strategies. While we cannot know the exact age at emigration, based on size at tagging and date of emigration we do observe steelhead emigrating from their natal streams as likely age-1+ and age-2+. While most emigrants are observed in the season immediately following the late summer sampling (assumed to be age-1+), we have observed between 3% to 10% of emigrants leaving their natal streams as age-2+. We have also observed variation in the assumed age at return for adult steelhead between 2.5 and 5 years after emigrating.

Chinook

Abundance estimates of Chinook smolts at the Mirabel dam LCS are affected by periods of trap inoperation which, in some years can last several days. If that occurs when a significant number of smolts are emigrating, our population estimate could be biased low by a substantial amount. In the future, we plan to explore ways to overcome the issue by exploring the use of previous years' data and/or data from adjacent mark-recapture strata to account for these gaps.

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 identical to those described above for spawner surveys in the four LCM sub-watersheds. While near-census of reaches was conducted for LCMs, a subsample of reaches for basinwide surveys were chosen based on the GRTS ordering and placed into rotating panels (see Chapter I). Within the Russian River sample frame and excluding sub-reaches, a total of 81 reaches were categorized as adult Coho reaches (Figure I-2) and 383 reaches were categorized as adult steelhead reaches (Figure I-3) that could be reliably sampled given what we considered permanent constraints due to lack of physical access in winter. During the 2019/20, and 2020/21 spawner seasons, we employed 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 and the steelhead-only sample stratum with separate estimates calculated in each stratum for each species. During the 2021/22 spawner season we used the same methods, but estimates were calculated only for Coho in the Coho-steelhead sample stratum. In all seasons 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.

Redd estimation methods were identical to the methods described for deriving total redd estimates from spawner surveys in the four LCMs (Ricker et al. 2014; Adams et al. 2011). This approach employed both a within-reach and among-each expansion each season. In 2021/22, we estimated Coho redd abundance only in the Coho-steelhead sample stratum. At the time of this report, the 2021/22 spawner season data collection is complete, and estimates have been calculated, but certain end-of-season data validation and correction steps have not occurred, so estimates should be considered preliminary.

Juvenile Coho Salmon spatial structure

A total of 81 reaches (excluding sub-reaches) within the Russian River sample frame were categorized as juvenile Coho reaches (Figure I-2) that could be reliably sampled given what we considered permanent constraints due to poor visibility. Each summer from 2019 to 2021, we surveyed all reaches where we had landowner access. 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. The problem of 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 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.

Results

Redd abundance

The start date for basinwide spawner surveys was in November or December and depending on when rain reconnected tributaries (thus allowing fish access) and continued through mid-April. The reaches surveyed and the number of surveys conducted in each reach varied by year and depended on survey conditions. During the 2019/20 spawner season, COVID-19 restrictions required the abandonment of spawner surveys one moth prior to the usual season end date. During the 2020/21 spawner season, the first storms large enough to connect tributaries did not occur until the end of December, resulting in a truncated beginning of the spawning season (Table III-1). Observations of steelhead redds were distributed fairly even throughout the watershed, whereas Coho redd observations generally occurred in a smaller number of reaches. In most cases, these were reaches where stocking of hatchery juveniles occurs with the exception of Pena Creek in 2018/19 and 2019/20 and Austin Creek in 2020/21 (though juveniles have been stocked in East Austin, a major tributary of Austin) (Figure III-1, **Error! Reference source not found.**, Figure III-3, Figure III-4). Similar to findings from LCM monitoring streams, steelhead redds were far more frequently observed compared to Coho redds in 2018/19, 2019/20 and 2020/21, but in 2021/22 we saw greater numbers of Coho redds than steelhead in almost all streams that had both (Figure III-3). A surprising finding from live fish and carcass counts from both 2019/20 and 2021/22 was the large proportion of total Chinook individuals counted in the Pena Creek watershed when compared the proportion of redds that were identified as Chinook in that watershed Figure III-3, Figure III-4). Despite 2021/22 exhibiting the highest counts of Coho redds since surveys started in 2013, the overall estimate for the basin was similar to 2020/21, which was slightly better than average. Coho redd estimates in 2019/20 were below average. Steelhead estimates declined in 2019/20 and 2020/21 from a peak in 2018/19. In 2021/22 we did not survey in the steelhead-only sample frame, so basinwide steelhead redd estimates could not be calculated (Figure III-5).

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

Species	Season	Season start	Season end	Reaches used for estimate	% Sample stratum	Mean days between surveys (±95% CI)
Coho Salmon	2018/19	12/3/2018	4/18/2019	32	40%	14.92 (±0.68)
	2019/20	12/4/2019	3/17/2020	32	40%	11.54 (±0.25)
	2020/21	12/29/2020	4/16/2021	32	40%	13.97 (±0.47)
	2021/22	11/1/2021	4/14/2022	35	43%	13.58 (±0.38)
steel-head	2018/19	12/3/2018	4/18/2019	30	8%	14.85 (±0.57)
	2019/20	12/4/2019	3/17/2020	30	8%	11.61 (±0.24)
	2020/21	12/29/2020	4/16/2021	32	8%	14.15 (±0.43)

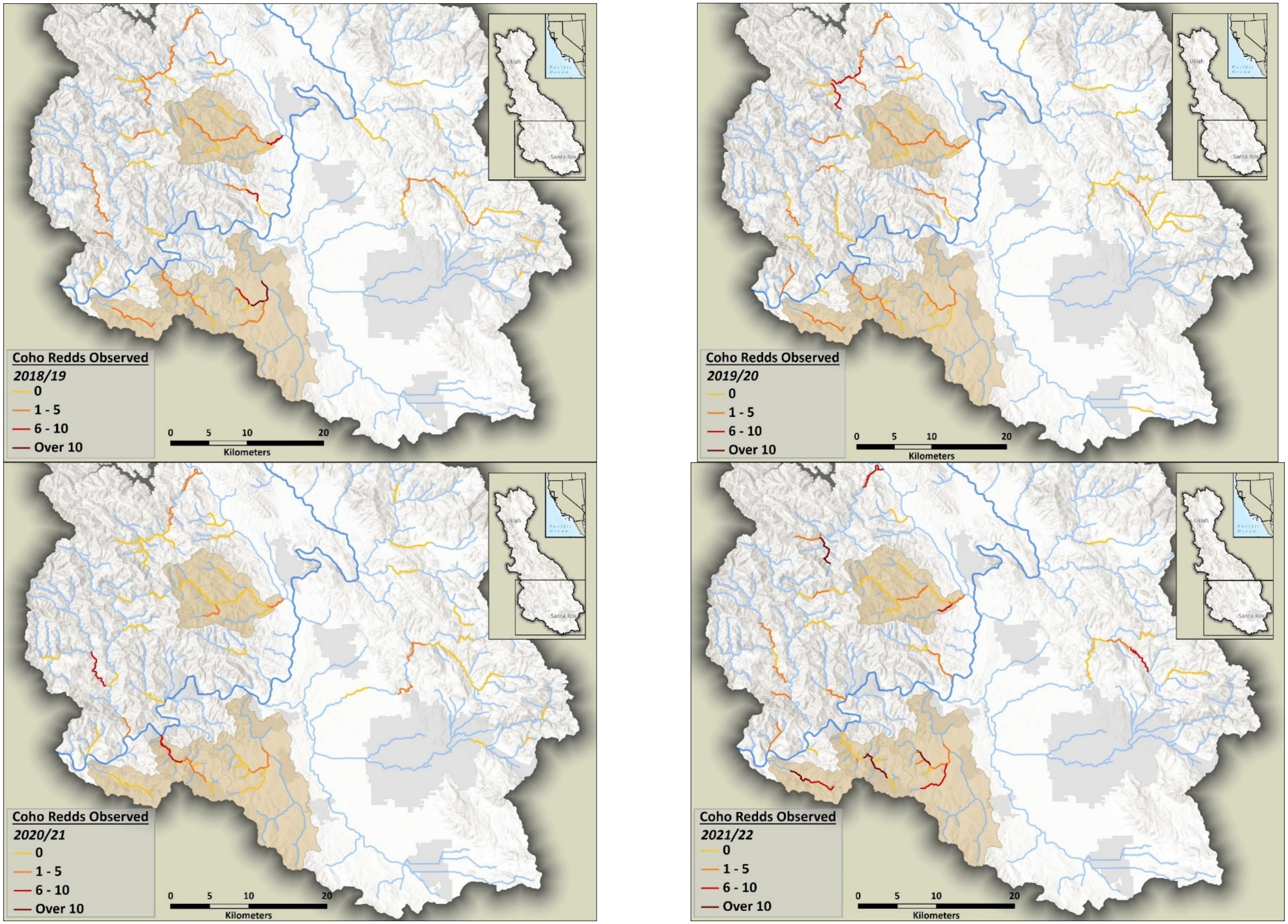


Figure III-1. Distribution and binned counts of Coho redds by season and reach in the adult Coho stratum, including LCM watersheds 2018/19 to 2021/22.

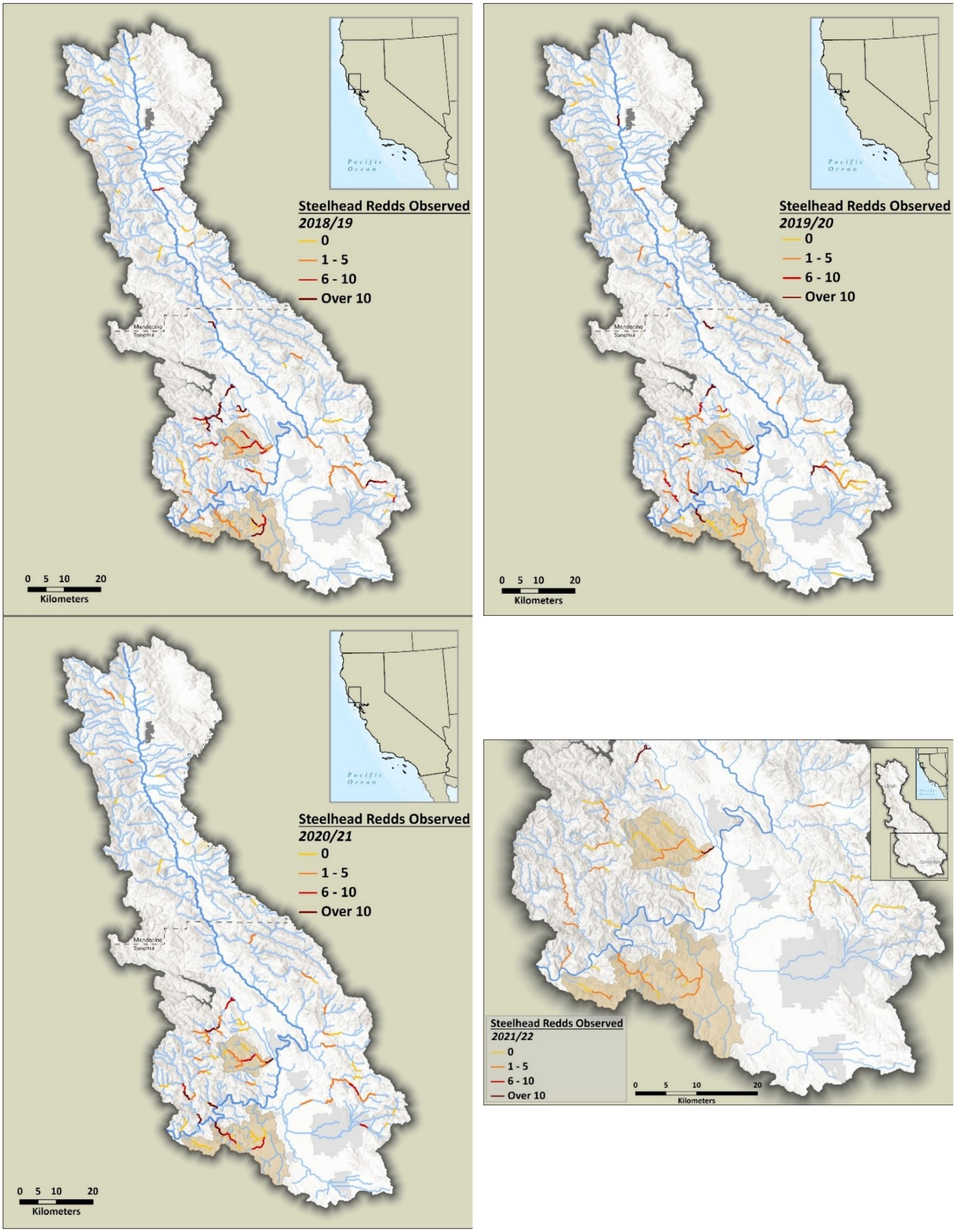
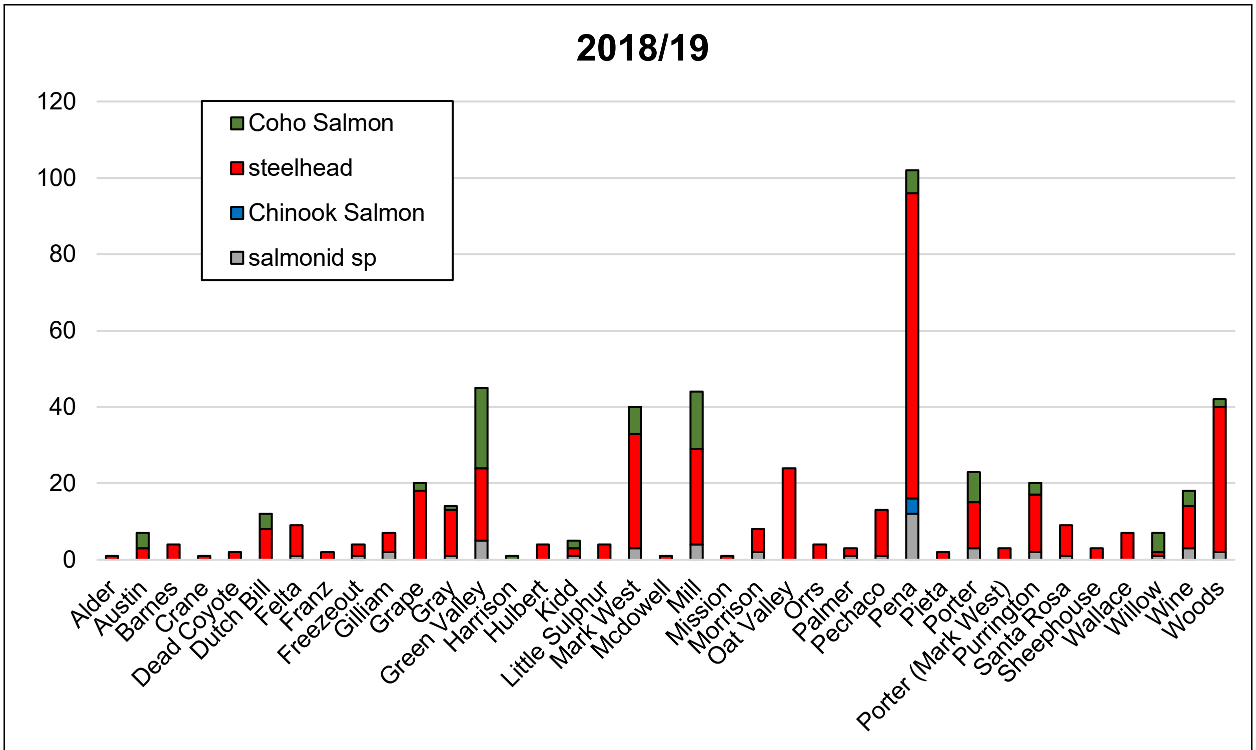
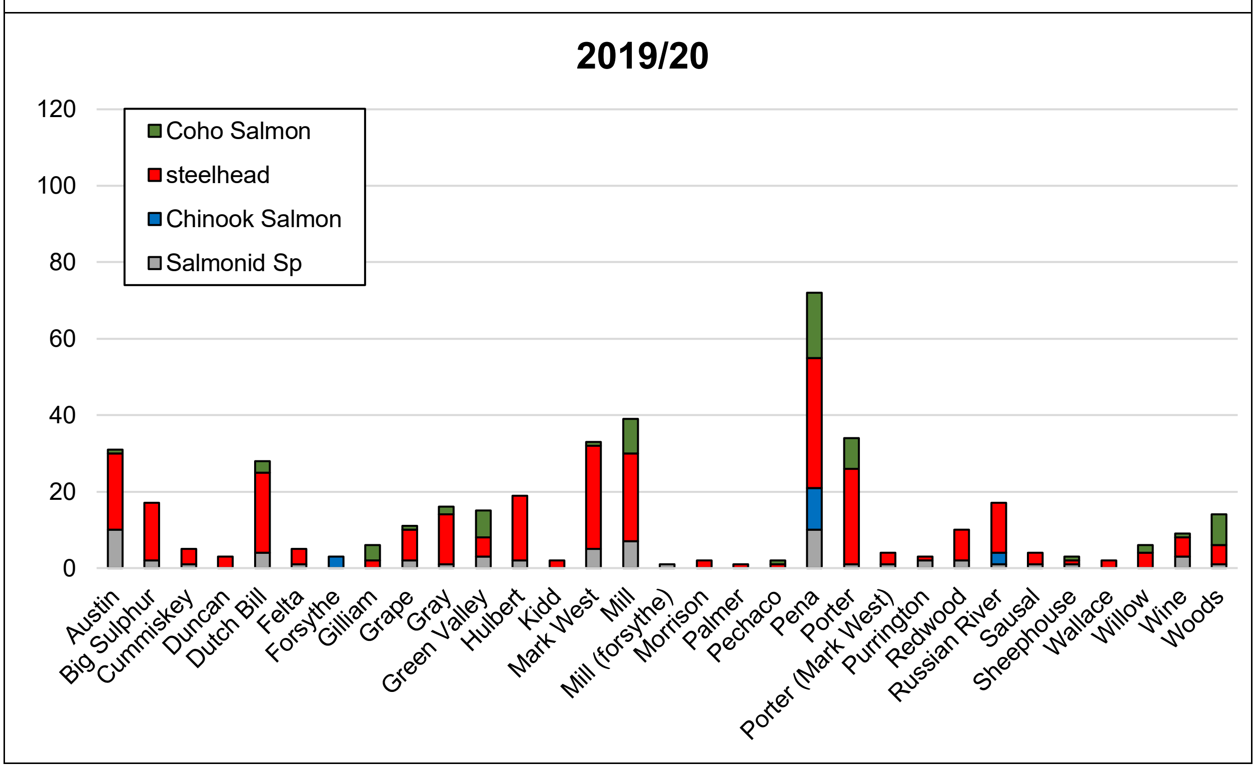


Figure III-2. Distribution and binned counts of steelhead redds by season and reach in the adult steelhead stratum (2018/19 to 2020/21) and the adult Coho stratum (2021/22) including LCM watersheds.





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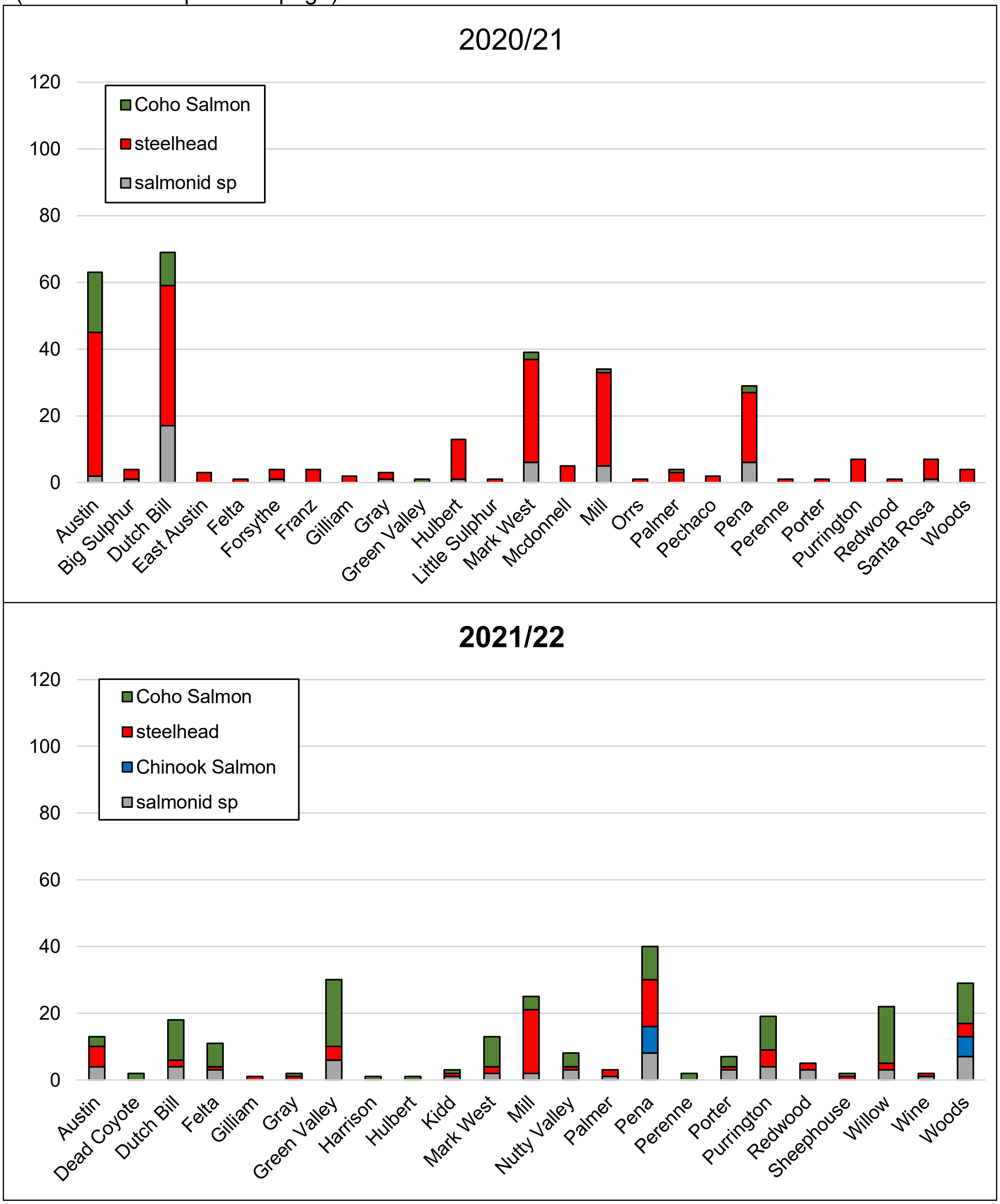
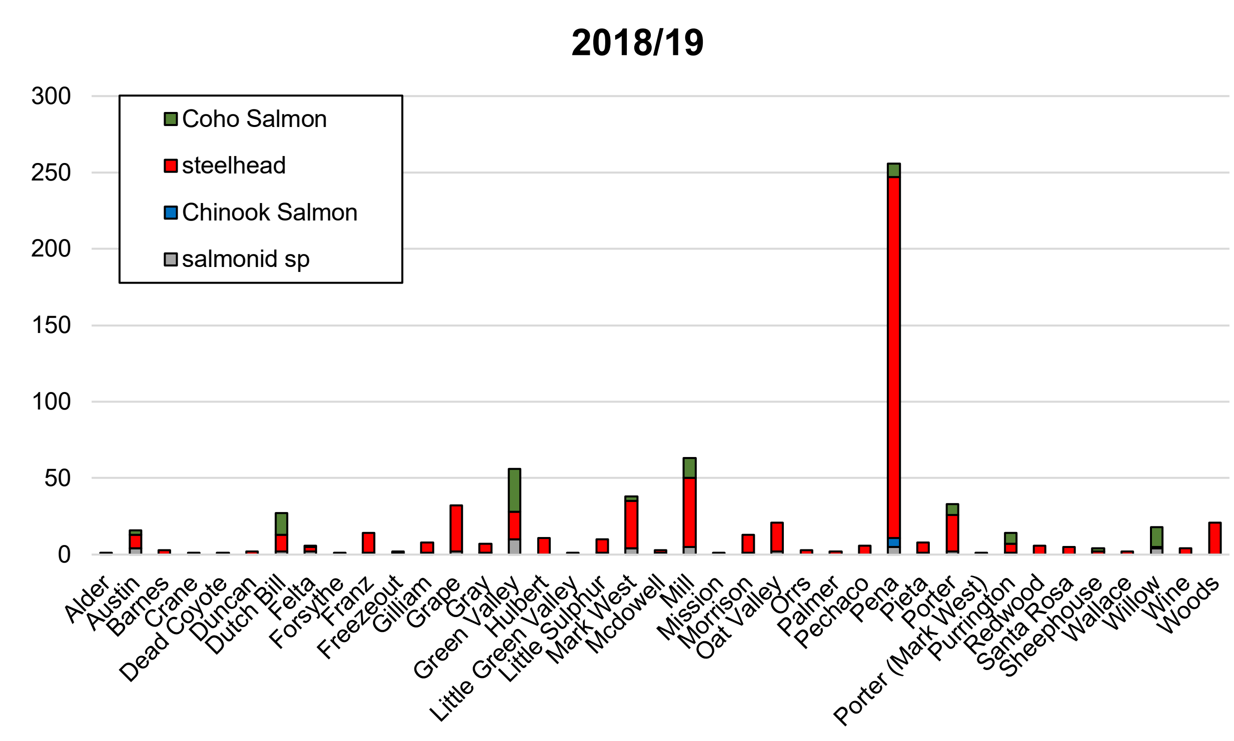
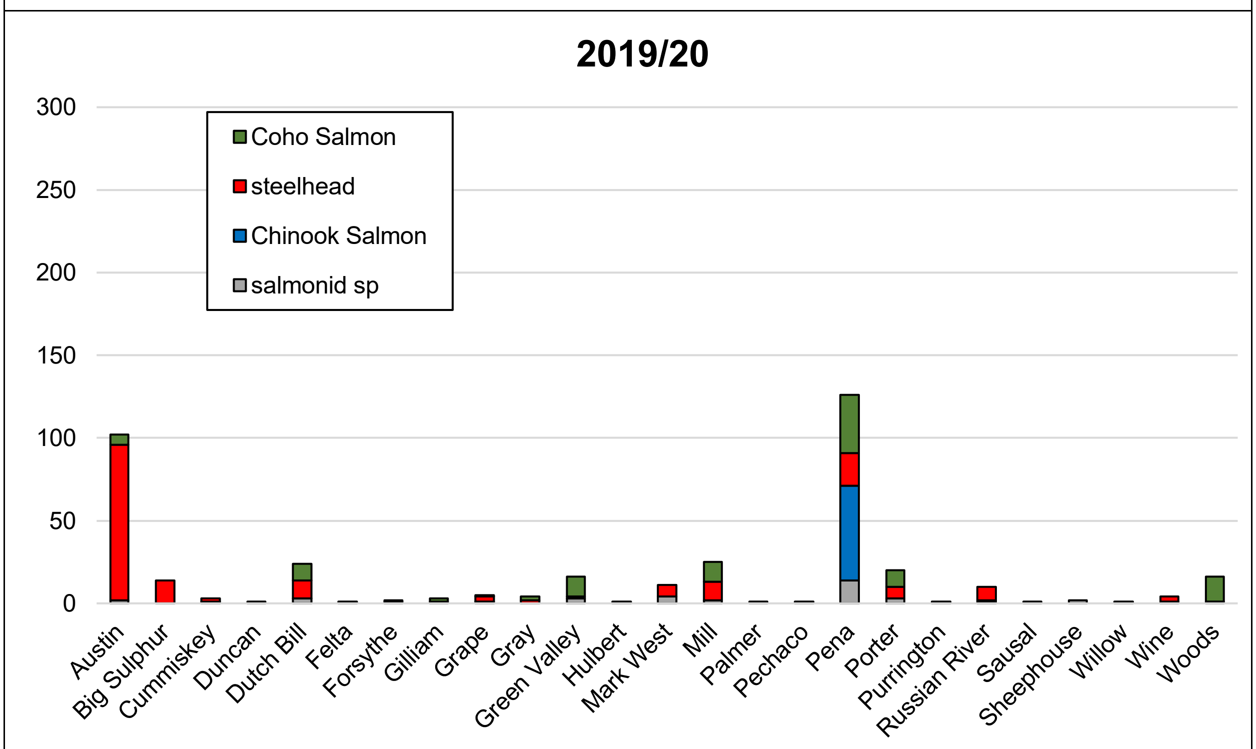


Figure III-3. Number of new redds counted in basinwide spawner surveys by season and tributary for all three levels of redd species certainty. Only tributaries where redds were found are included. Note that not all habitat within each creek may have been surveyed in a given year (i.e., only reaches included in the rotating panel for a given season were surveyed).





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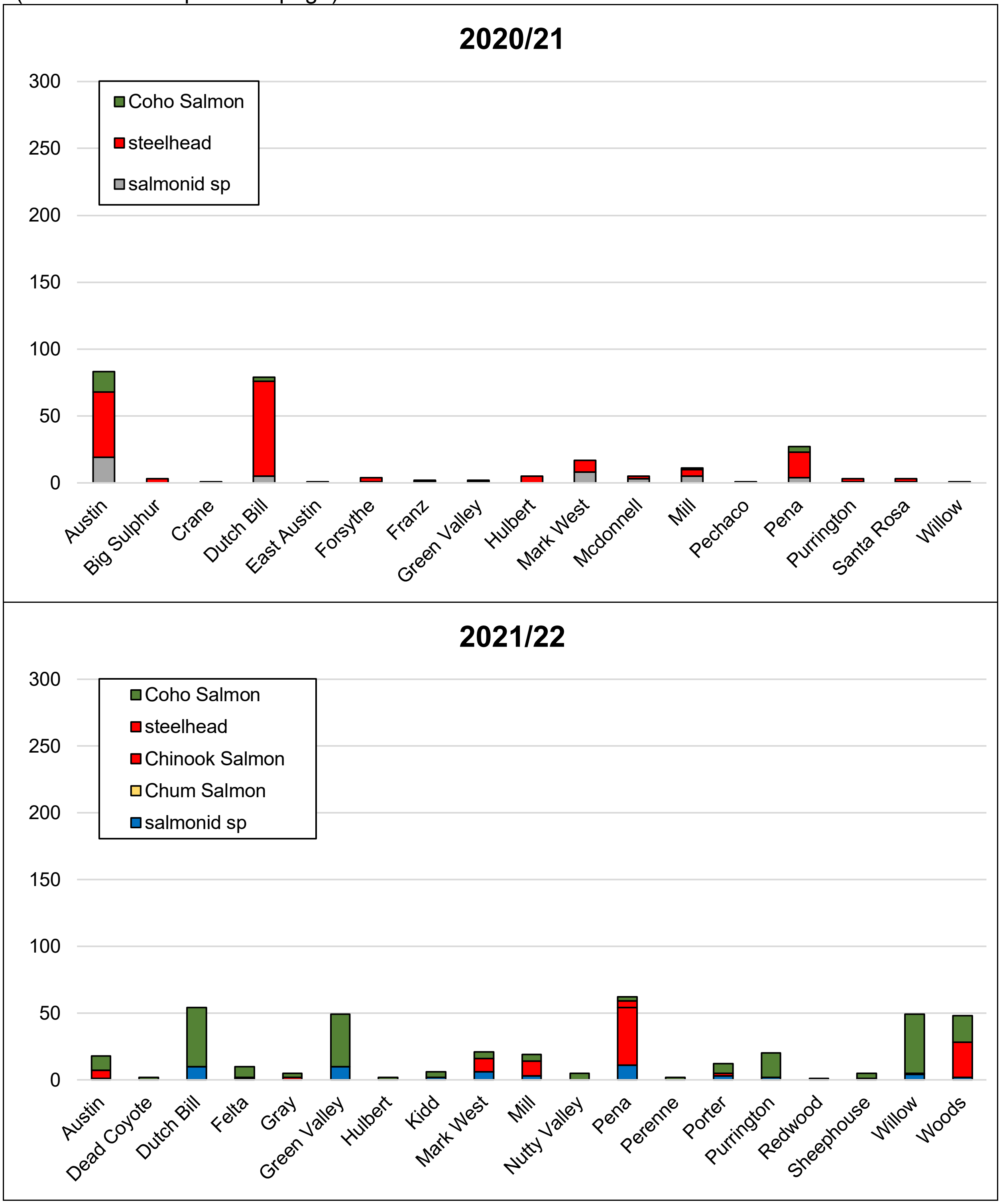

Figure III-4. Number of live adult salmonids and carcasses counted in basinwide spawner surveys by season and tributary for all three levels of fish species certainty. Only tributaries where live fish and carcasses were found are included. It is possible that some fish could have been counted more than 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).

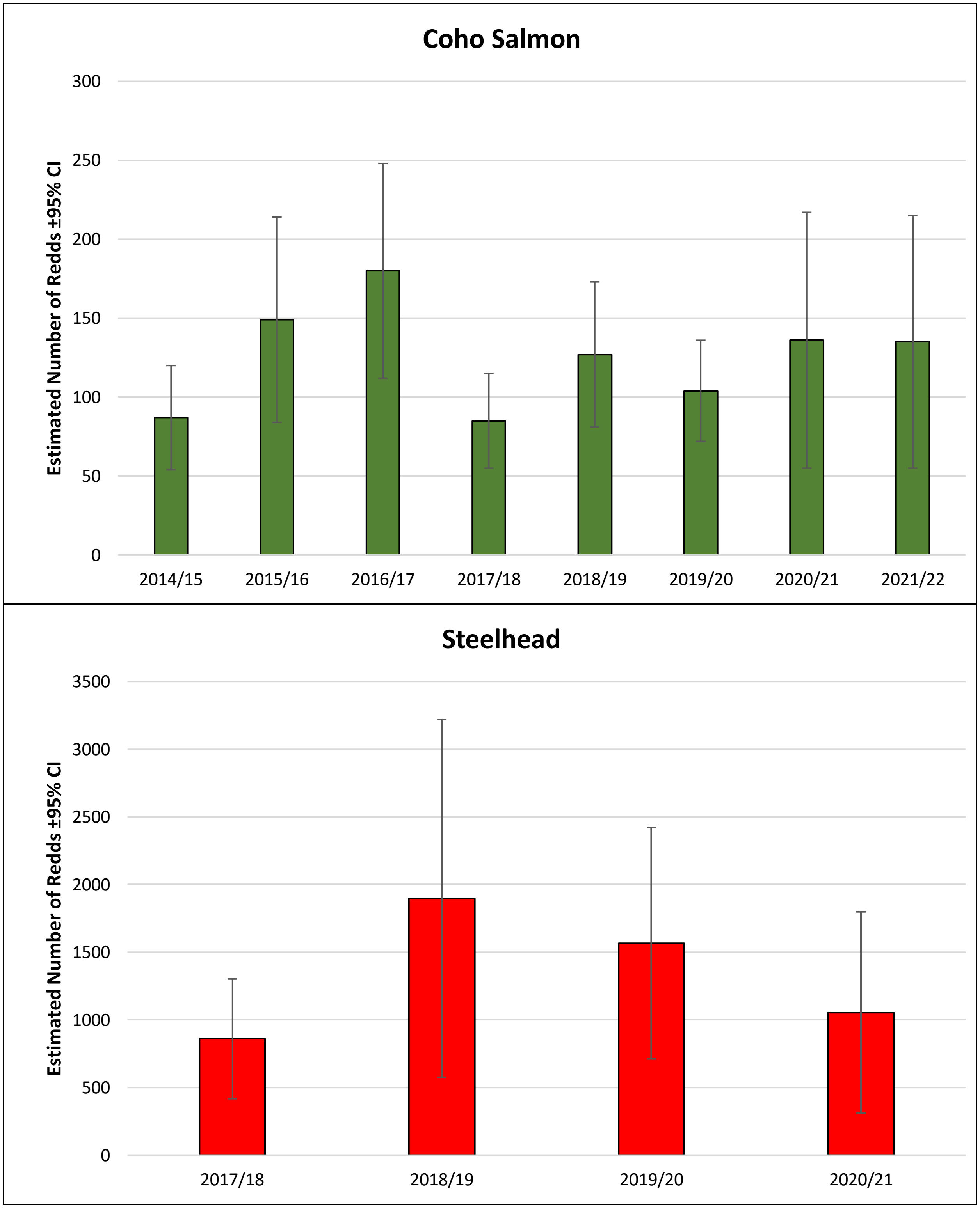

Figure III-5. Basinwide estimates of redd abundance for Coho Salmon (upper panel) and steelhead (lower panel). Note: basinwide redd estimates for steelhead in 2021/22 are not included because surveys were completed only in the Coho-steelhead sample stratum during that season. Also note difference in vertical scale on figures.

Juvenile Coho Salmon spatial structure

In 2019, Coho salmon YOY were observed in 36 of the 75 juvenile Coho salmon reaches surveyed and in 23 of the 45 juvenile Coho salmon streams snorkeled (48% and 51%, respectively, Figure III-6). In 2020, Coho yoy were observed in 50 of the 74 juvenile Coho salmon reaches surveyed and in 31 of the 43 juvenile Coho salmon streams snorkeled (68% and 72%, respectively). In 2021, Coho YOY were observed in 32 of the 74 juvenile Coho salmon reaches surveyed and in 18 of the 44 juvenile Coho salmon streams snorkeled (44% and 41%, respectively,). Because natural-origin and hatchery-origin juveniles cannot be distinguished by snorkel surveys, and because some reached contained hatchery released fish at the time of sampling, not all sampled reaches and streams could be included in estimates of PAO. For example, in 2019 and 2021 reaches from Mark West and Yellowjacket Creeks (respectively) were excluded from PAO estimation because of the influence of hatchery releases. 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 0.44 to 0.52 between 2019 and 2021. The conditional probability of Coho YOY occupying a pool within a reach, given that the reach was occupied (θ), ranged from 0.31 to 0.59 (Table III-2). The proportion of the Coho stratum occupied (PAO) ranged from 0.15 to 0.37. The highest PAO of the three reporting seasons was 2020, and the two other reporting seasons (2019 and 2021) were the two lowest PAO estimates recorded (Figure III-7).

Table III-2. Coho YOY occupancy estimates and proportion of area occupied from 2019 through 2021.

Year	StartDate	End Date	Reaches sampled	Ψ[1] (95% CI)	θ[2] (95% CI)	PAO[3]
2019	5/28/19	8/7/19	70	0.44 (0.33-0.56)	0.33 (0.29-0.38)	0.15
2020	5/11/20	8/6/20	51	0.63 (0.49-0.75)	0.59 (0.54-0.63)	0.37
2021	5/11/21	8/24/21	63	0.52 (0.38-0.64)	0.31 (0.26-0.36)	0.16

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

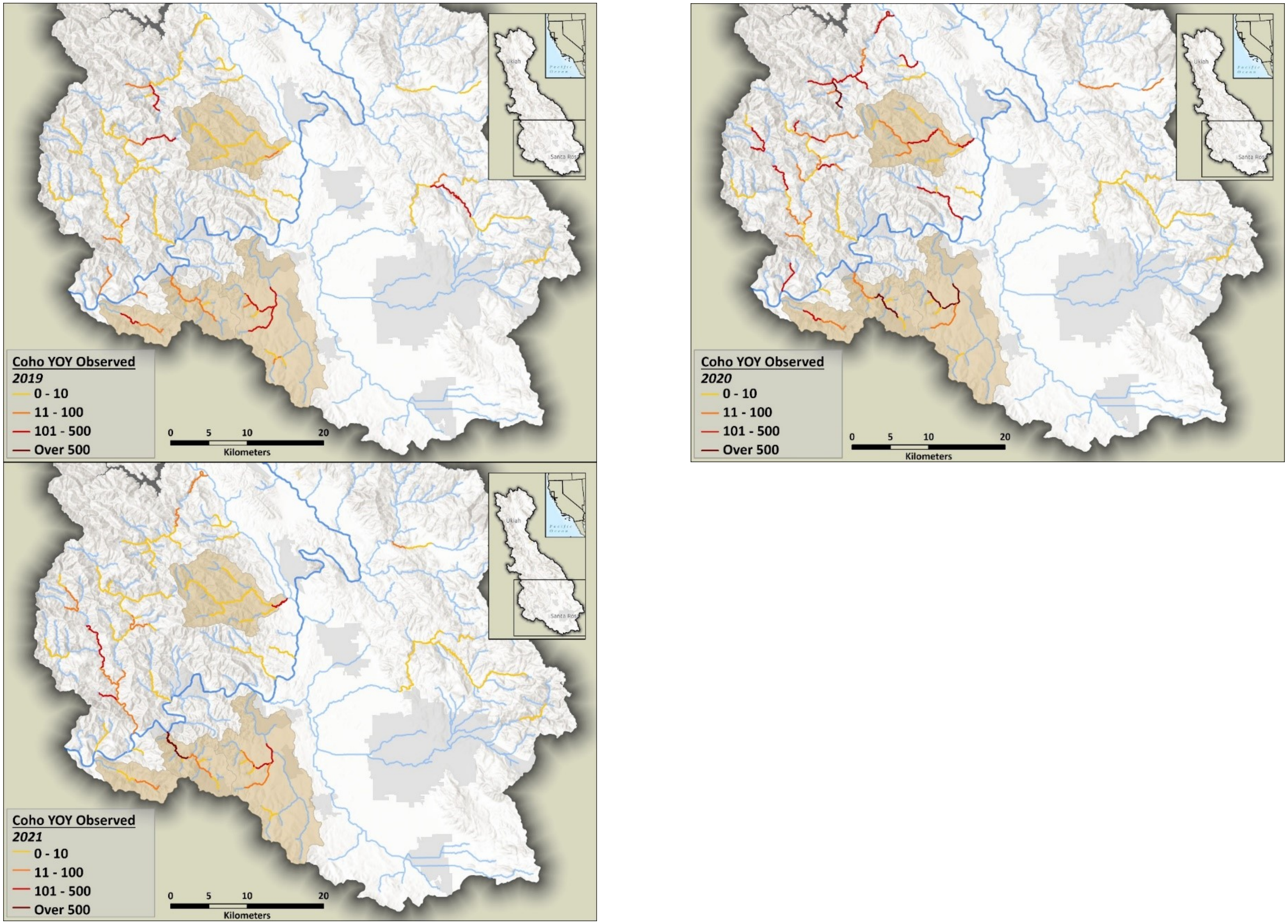

Figure III-6 Distribution and binned counts of juvenile Coho by season and reach in the juvenile Coho stratum.

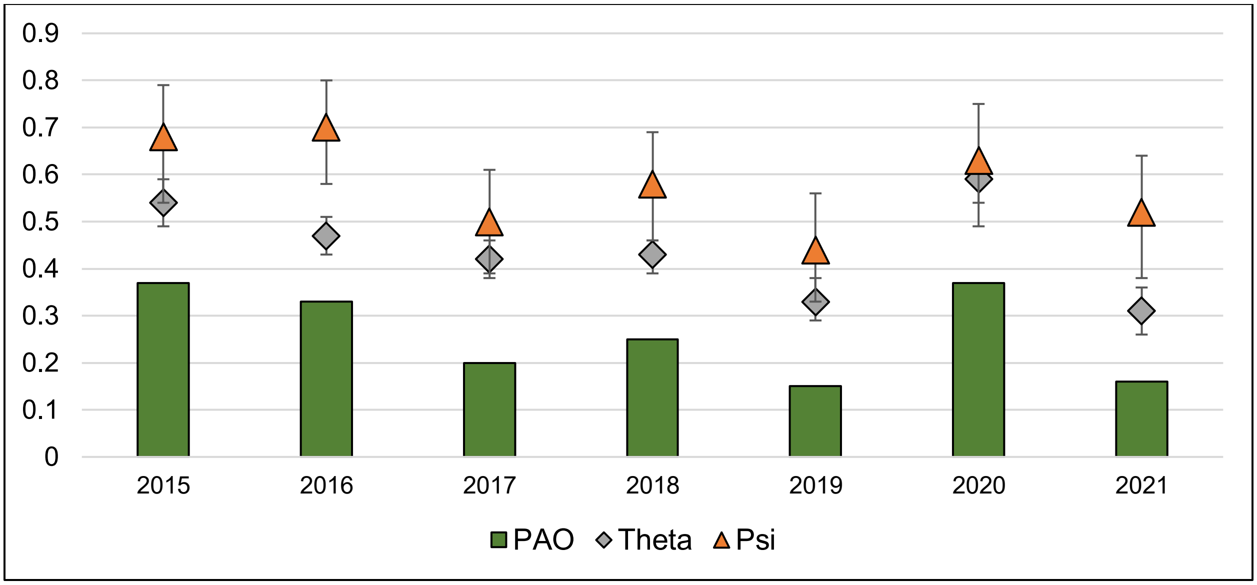

Figure III-7. Multi-scale occupancy (pool scale: Theta, reach scale: Psi) with 95% confidence intervals and Percent Area Occupied (PAO) for juvenile Coho in the Coho-steelhead sample stratum.

Discussion

Redd abundance

During the reporting period spawner survey estimates were likely affected by many factors including historic drought conditions and hatchery releases of spawned adult steelhead. Sampling during the 2019/20 season was also curt short because of the COVID-19 pandemic. was also likely affected by the During the 2019/20 spawner season surveys began December 4th with storms large enough to connect creeks and retore fish passage. Unfortunately, rainfall was not sustained, and the last significant rainfall of the spawner survey season occurred on Jan 26, 2020, after which, many creeks began to disconnect and dry out. On March 15 and 16 2020, roughly ¾ inch of rain fell in Santa Rosa causing a slight increase in spawning activity in Mill Creek. This was followed almost immediately by the suspension of spawner surveys for the season on March 17 because of restrictions imposed to limit the spread of COVID-19. Under normal conditions, spawner surveys would continue until April 15 and in past seasons, roughly 40% of steelhead redds observed were observed during the period between March 17 and April 15 (Figure III-8). The suspension of surveys in 2019/20 likely caused steelhead redd estimates to be biased low.

Basinwide monitoring

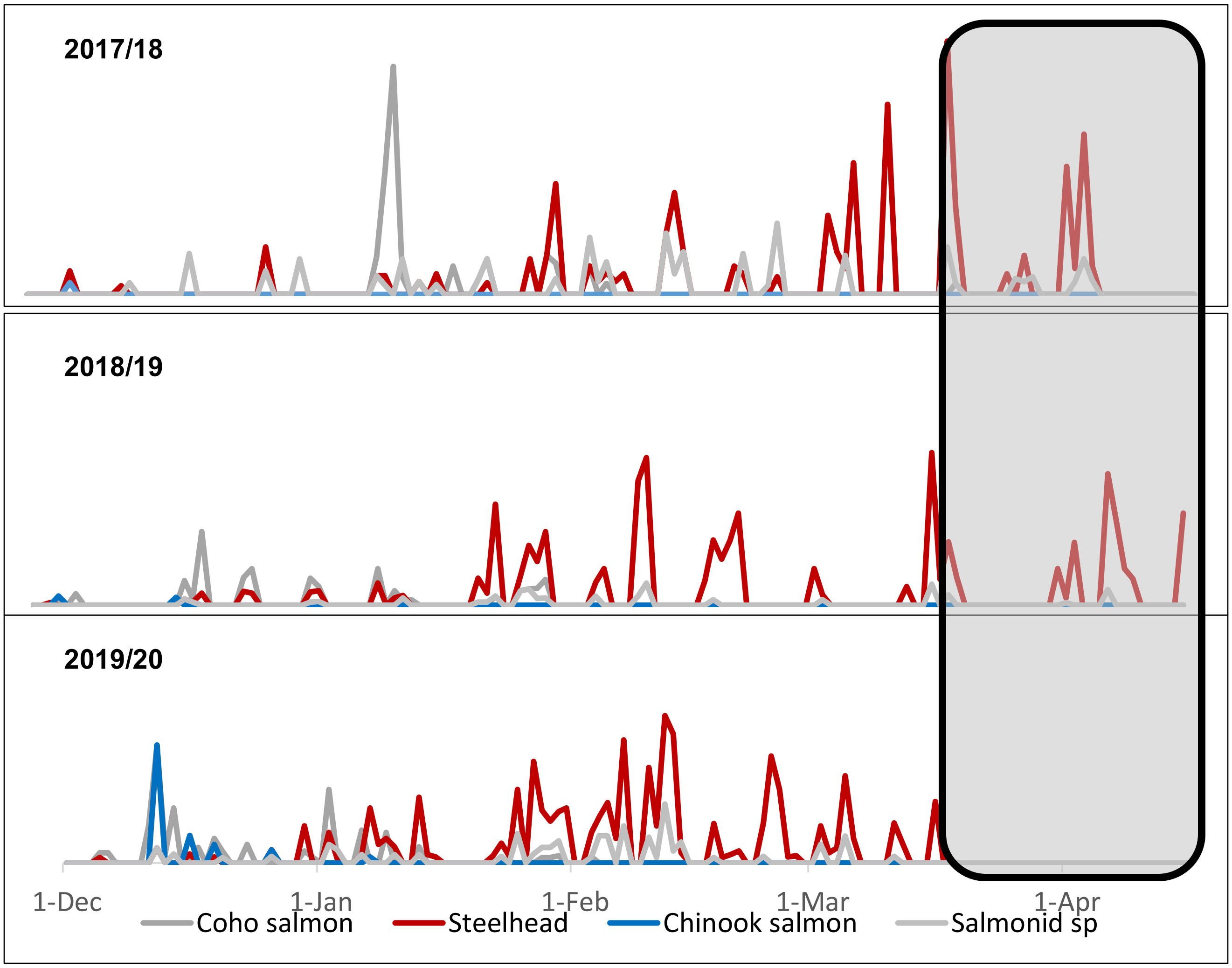

Figure III-8. Timing of spawning activity during the 2017/18, 2018/19, and 2019/20 spawner seasons. During the 2019/20 spawner season, spawner surveys were suspended on March 17 because of restrictions imposed to limit the spread of COVID-19. The gray box highlights the period between March 17 and April 15 which was lost in 2019/20, but when roughly 40% of the total steelhead redds were observed in the two prior seasons.

During the 2020/21 spawner season the first significant storm did not occur until Jan 26-27 when roughly 2 inches of rain fell in Santa Rosa and the maximum rainfall reached 0.3 in/hour. Many creeks connected after the usual peak in Coho spawning activity (roughly December 15-January 15) and one creek (Fife Creek) did not connect at all. Dry conditions led to a small number of redds becoming partially or completely dewatered prior to the end of spawner surveys. Hatchery releases of spawned and unspawned steelhead likely affected redd estimates. Many steelhead arriving at the Warm Springs and Coyote Valley hatcheries that could not be spawned (and some that were spawned) were released at the Monte Rio boat launch. This release site is directly adjacent to the mouth of Dutch Bill Creek and roughly 5 km upstream of the mouth of Austin Creek. There is some evidence that these released fish led to increased redd counts in both creeks. An unknown number of steelhead releases were tagged with Floy tags, and crews recorded a large proportion of these Floy-tagged fish in Dutch Bill Creek, compared to the total individuals recorded. A smaller proportion of Floy-tagged fish were counted in Austin Creek, but this may have been due to the difficulty of spotting Floy tags on fish in a generally larger creek like Austin compared to a smaller creek like Dutch Bill (Figure III-9**Error! Reference source not found.**). Austin Creek was included in the sample draw (and therefore included in calculation of basin-wide redd estimates) for both Coho and steelhead, whereas Dutch Bill Creek was only included in the sample draw for Coho. As an exercise to gauge the effect these hatchery released fish may have had on total redd estimates, we calculated estimates for basin-wide Coho redds without Austin and Dutch Bill Creeks and calculated basin-wide steelhead redds without Austin Creek and compared these estimates to the actual redd estimates with those creeks included. The basin-wide Coho redd estimate would have decreased by 65% and the basin-wide steelhead redd estimate would have decreased by 46% without these reaches included.

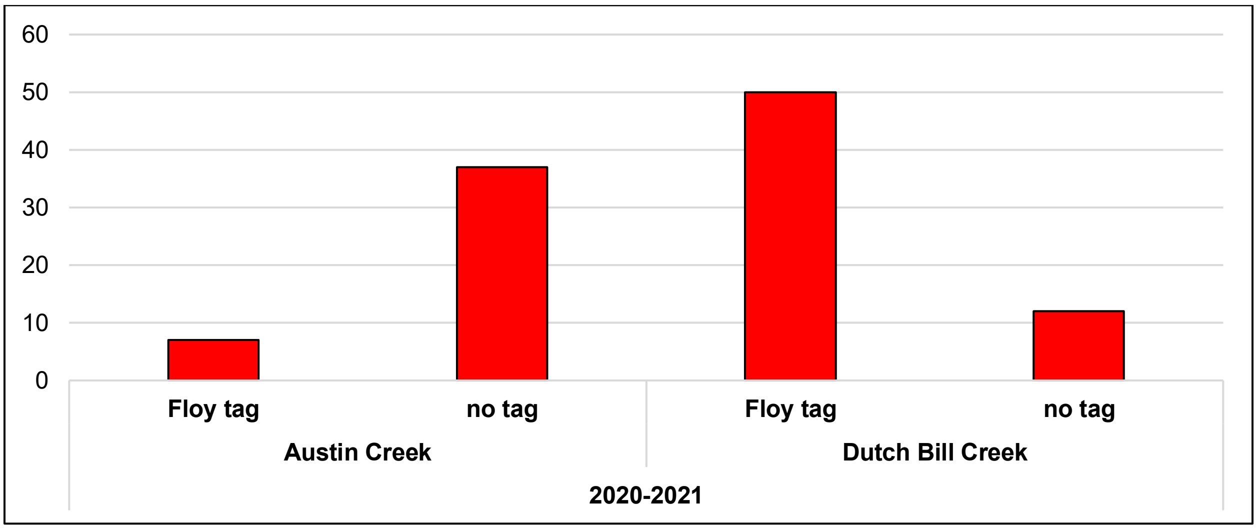

Figure III-9. Floy-tagged individuals counted in Austin and Dutch Bill creeks during the 2020/21 spawner season for all levels of certainty.

In 2021/22 a large atmospheric river event hit Sonoma County bringing a new 24-hour record of rainfall of over 7 inches. All tributaries were connected and spawner surveys began earlier than they have since 2016/17. Subsequent smaller storms during the usual peak of Coho spawning (December 15-January 15, **Figure III-10**) created flow and turbidity conditions ideal for Coho spawning and upstream movement (see Chapter II Discussion above for more detail). These conditions were likely at least partially responsible for the largest number of Coho salmon redds counted in a season since surveys began in 2013. Despite these high redd counts, the basinwide redd estimate for Coho was only slightly above average and nearly identical to the estimate from last season when far fewer Coho redds were counted. This result was surprising, but partially explained by the random sample of reaches for estimate calculation and the distribution of Coho redds. A vast majority of the Coho redds counted were in LCM streams, and several of the most productive of these were not included in the random GRTS sample for basinwide redd estimation. Reaches that were highly productive, but not included in the estimate were not included in these 10 reaches: Green Valley (reach 1, 2), Purrington (reach 1), Mill (reach 1), Felta (reach 1), Willow (reach 4), and Dutch Bill (reach 1). Of the 120 Coho redds counted with certainty 1 or 2, 53 were counted in these 10 reaches (roughly 44%). Unfortunately, the random sample and the likely inflation of the 2020/21 Coho estimate due to lower Russian River hatchery released fish (described above), likely combined to produce the counterintuitive combination of 2 very similar basinwide redd estimates in seasons with very dissimilar redd counts.

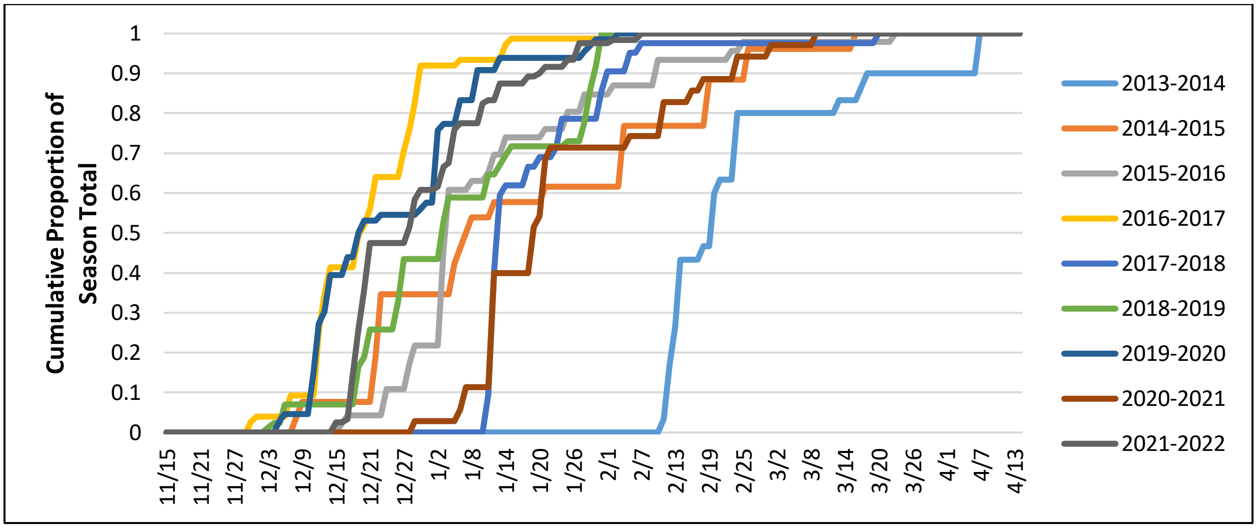

Figure III-10. Coho spawning activity each spawner season from 2013-2021 by date. Peaks in spawning activity each year generally occurred between December 15 and January 15 with the exception of 2013/14 which did not bring rain until February.

In Pena Creek, generally a productive Coho stream, we did not see large numbers of certainty 1 Coho redds in 2021/22, and many of the certainty 2 Coho redds were estimated as steelhead using our species estimation methods. It is possible that redd species estimation methods also led to a lower Coho estimate and higher steelhead estimate in 2021/22. Two confusion matrices were constructed comparing 2021/22 redd species estimates for predicted redds (redds called certainty 2 or unknown). One matrix compared species estimations made by the crew in the field to estimations made by the modified Gallagher methods used throughout the reporting period (Table III-3). The other matrix compared species estimations made by the crew in the field to estimations made by KNN methods (Ricker 2014). It is possible the modified Gallagher estimation method led to a low-biased Coho estimate since it called 27 redds steelhead that were called Coho by the crew in the field. Conversely, The KNN method of redd species estimation may have led to an inflated Coho estimate based on the fact that it assigned 23 redds as Coho that the field crews classified as steelhead. To explore these discrepancies in other seasons, differences in species estimation techniques were compared for the last seven seasons (2021/22 was not included). These graphs show that numbers of redds estimated by each method vary greatly compared to one another, and patterns in differences between the methods are difficult to discern. It appears that differences in Coho estimation methods seem more pronounced than steelhead especially in the last three seasons (Figure III-11). Modified Gallagher methods are highly influenced by the number of days since the first survey which varied considerably in the last few seasons. Severe drought conditions have led to some very late starts to the season, so this could be influencing redd species estimation generally and Coho redd estimation specifically. Sonoma Water and CSG have begun preliminary studies of methods to improve KNN redd estimation to incorporate stream distance (instead of just XY position). We feel that this could potentially lead to more effective methods of redd species estimation.

Basinwide monitoring

Table III-3. Confusion matrices comparing estimated species for predicted redds (certainty 2 or unknown) for different estimation methods. The upper table compares field crew estimation (far left column) to modified Gallagher methods (top row) which were used throughout the reporting period. The lower table compares field crew estimation (far left column) to KNN estimation (top row).

Estimated Species	Coho Salmon	Steelhead	Chinook Salmon
Coho Salmon	46	27	
Steelhead	7	63	
Chinook Salmon			6
Salmonid sp	9	44	2

Estimated Species	Coho Salmon	Steelhead	Chinook Salmon
Coho Salmon	58	10	5
Steelhead	23	42	5
Chinook Salmon			6
Salmonid sp	31	16	8

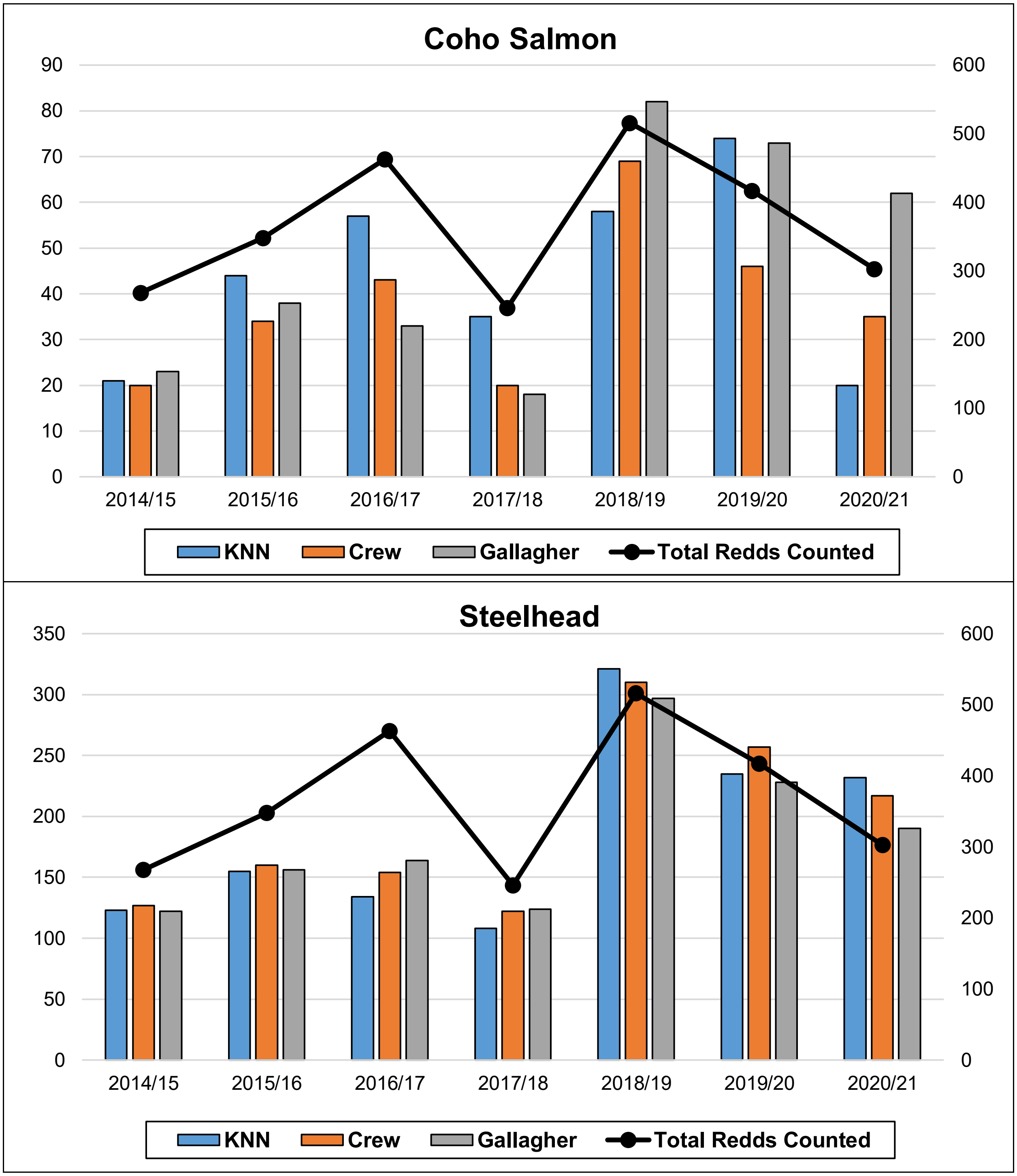

Figure III-11. Comparison of species estimation methods (Modified Gallagher and KNN) for estimated redds (certainty 2 and unknown) with species calls by crews in the field from 2014 to 2021. Upper panel shows totals estimated as Coho by different methods and lower panel shows totals estimated as steelhead by different methods.

Drought conditions persisted throughout the reporting period and undoubtedly affected salmonid populations at multiple life stages. Because spawning activity generally occurs during periods of high flow In the past, redd drying prior to fry emergence is not considered as prone to low water issues as compared to summer juvenile habitat. During this reporting period, however, it was clear that more effective ways of capturing the effects of dry conditions on adult spawning success are needed. Prior to 2020/21 there was no formal way for crews to record dry or partially dry redds. Partway through the 2020/21 spawner season, we devised a simplified method for formally recording this data and incorporated it into the structure of our data collection forms and databases. We developed three categories for redds: “dry”, “partially dry”, and “wet”. “Dry” referred to redds that were completely dewatered from the highest point on the tail spill to the lowest point of the pot. “Wet” referred to redds that were completely under water. “Partially Dry” referred to any redd that was in between these two extremes. Because this third category was a catch-all for everything between wet and dry, it was used for redds where only the very top of the tail spill was sticking out of the water and for redds where there was only the smallest bit of moisture at the bottom of the pot. The likelihood of subsurface flows suitable for egg incubation would be very different for redds in these two situations, indicating that our metric may need improvement. With climate change, the issue of drying redds will likely be an important one to capture in a meaningful way going forward. We will revisit this metric prior to the beginning of next year’s spawner season and attempt to develop something that will be more effective at estimating subsurface flows and egg survival.

Spatial structure

Severe drought (and subsequent fires) affected our ability to conduct surveys. In 2020 sampling had to be reduced due (in part) to potential and actual fire danger. Despite the reduced effort, the relatively high PAO estimate and relatively tight confidence intervals around estimates of occupancy in 2020 gives us confidence that even with reduced effort we can effectively capture trends in juvenile Coho distribution. In 2020 and 2021, snorkel surveys were started considerably earlier than the 2019 season so that reaches could be surveyed prior to large portions of streams going dry. This illustrates a potential problem with relying solely on Coho occupancy estimates to evaluate over summer habitat use. It should be recognized that occupancy estimates, while an important tool for evaluating habitat use at a snapshot in time, should be coupled with sampling that captures changes that occur over the course of the summer. CSG has implemented wetted habitat monitoring surveys in the late summer to capture some of the effects of drying streams on Coho juvenile populations. In 2021, for example, they estimated that 67.5% of the streams sampled during summer snorkel surveys had stream disconnections present during sampling. This number was up from 64% during the summer of 2020. CSG has also spatially overlayed fish abundance and distribution data with wetted habitat data to estimate impacts of stream drying on salmonids observed during snorkel surveys. Finally, they calculated a second, end of season PAO to show how habitat use changed throughout the summer (CSG 2022). We feel that wetted habitat data collected in this way is particularly important and should be prioritized in the future as it complements and puts into perspective data collected for CMP. As climate change persists, the problems of drying streams and reduced habitat will require innovative solutions.

Persistent drought conditions in the Russian River basin during each summer of the reporting period likely affected Coho juvenile distribution and survival. Two of the three PAO estimates for the reporting period were the lowest on record since 2015 when these surveys began. It is likely that these low PAO estimates have much more to do with over-summer conditions in streams than with spawning success. PAO estimates did not track with basinwide Coho redd estimates revealing a counterintuitive disconnection between redd construction and juvenile Coho spatial structure (Figure III-12). It is not possible to completely rule out redd success as a source of this disconnection. As discussed above, there is some evidence that it is becoming more common for redds to be dewatered prior to hatch and emergence, but because the numbers of fully dry redds is fairly low, it is much more likely that summer conditions are driving PAO estimates. Consideration of and potential augmentation of summertime flows is recommended to improve PAO for Coho in the future.

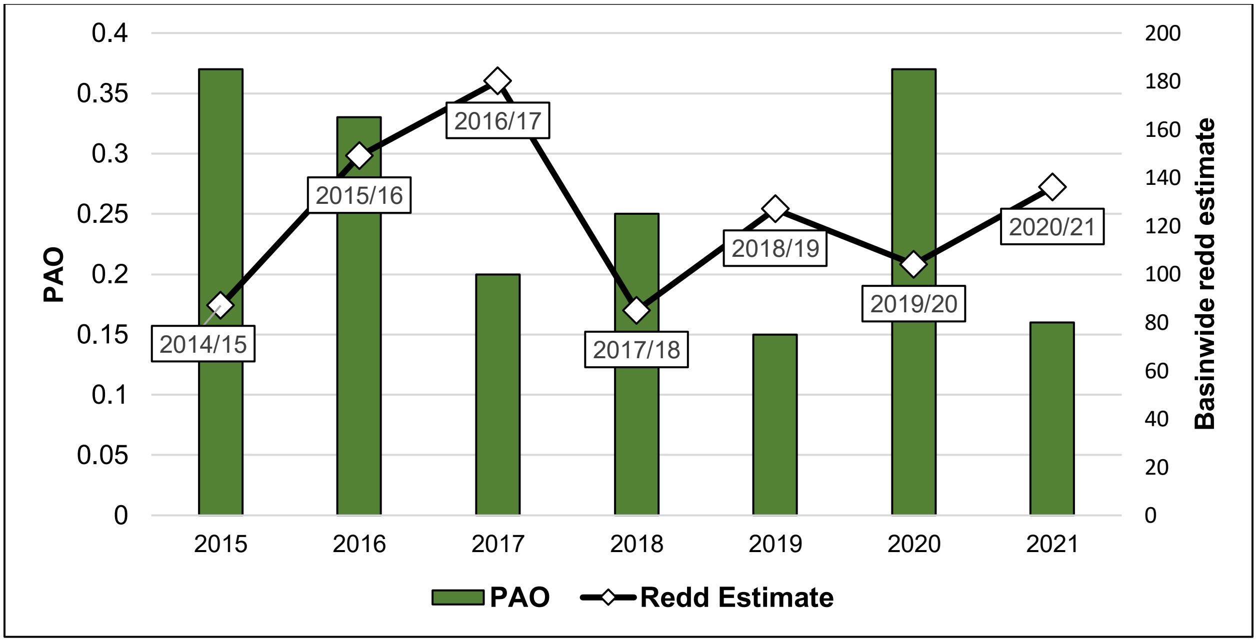

Figure III-12. Estimates of Coho juvenile PAO with adult redd estimates from the previous winter overlayed. Note the difference in vertical scale.

While we do not report estimates for steelhead occupancy, summer snorkel surveys can be a potential method for evaluating steelhead use of habitat (in the Coho-steelhead stratum only). However, this side benefit is reduced when surveys are started earlier because steelhead may not be large enough to be identifiable by snorkelers in early May when surveys must be started to get ahead of drying streams. These effects on steelhead assessment with snorkeling should be taken into account if snorkeling is ever used in place of spawner surveys to evaluate steelhead spatial structure.

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 populations in particular (e.g., Pena Creek 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).

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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" survey constraints (see text); reserve=a reach that could be used in the event a reach with a lower draw order cannot be used in a given season; 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 (Ackerman)	no	no	yes	yes	nis	1
2	227	MPO 3	Porter Creek (MWC)	yes	yes	yes	yes	1	1
3	242	EAS 1	Eastside Creek	no	no	no	yes	nis	nis
4	279	PEC 1	Pechaco Creek	yes	yes	yes	yes	na	1
5	553	SHC 2	Salt Hollow Creek	no	no	yes	yes	nis	reserve
6	206	BAD 2	Badger Creek	no	no	yes	yes	nis	1
7	141	FIF 2	Fife Creek	no	no	yes	yes	nis	1
8	432	DUN 1	Duncan Creek	no	no	yes	yes	nis	1
9	493	ORR 2	Orrs Creek	no	no	yes	yes	nis	1
10	371	LIT 9	Little Sulphur Creek	no	no	yes	yes	nis	2
11	103	BLA 1	Black Rock Creek	yes	yes	yes	yes	us	us
13	517	HEN 4	Hensley Creek	no	no	yes	yes	nis	na
17	523	YOR 4	York Creek	no	no	yes	yes	nis	reserve
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	LFC 1	Little Francis Creek	no	no	yes	yes	nis	2
23	146	POC 3	Pocket Canyon Creek	no	no	yes	yes	nis	na
24	458	PAR 3	Parsons Creek	no	no	yes	yes	nis	1
25	483	MUP 2	Mill Creek (Upper RR)	no	no	yes	yes	nis	2
27	115	WAR 2	Ward Creek	yes	yes	yes	yes	na	8
28	473	SBR 1	South Branch Robinson Creek	no	no	yes	yes	nis	8
29	173	MAR 8	Mark West Creek	no	no	yes	yes	nis	8
31	343	PFC 1	Porterfield Creek	no	no	yes	yes	nis	na
33	532	FOR 6	Forsythe Creek	no	no	yes	yes	nis	reserve
34	185	SAN 5	Santa Rosa Creek	no	no	yes	yes	nis	8
35	73	JEN 1	Jenner Gulch	no	no	yes	yes	nis	2
36	256	MIL 2	Mill Creek	yes	yes	yes	yes	1	2
37	542	BAK 1	Bakers Creek	no	no	yes	yes	nis	8
38	229	MPO 5	Porter Creek (MWC)	no	no	yes	yes	nis	na
39	81	AUS 1	Austin Creek	yes	yes	yes	yes	na	8
40	434	EAG 1	Eagle Rock Creek	no	no	yes	yes	nis	na
41	503	ACK 4	Ackerman Creek	no	no	yes	yes	nis	2
42	366	LIT 4	Little Sulphur Creek	no	no	yes	yes	nis	reserve
43	353	BIG 5	Big Sulphur Creek	no	no	yes	yes	nis	2
44	448	MDO 3	McDowell Creek	no	no	yes	yes	nis	reserve
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	reserve
50	186	SAN 6	Santa Rosa Creek	no	no	yes	yes	nis	na
52	265	WAL 2	Wallace Creek	yes	yes	yes	yes	1	2
53	479	HOW 1	Howell Creek	no	no	no	yes	nis	nis
54	330	PET 1	Peterson Creek	no	no	yes	yes	nis	5
55	99	EAU 8	East Austin 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		
56	460	MOR 2	Morrison Creek	no	no	yes	yes	nis	na
57	515	HEN 2	Hensley Creek	no	no	yes	yes	nis	reserve
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	na
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	yes	yes	yes	yes	us	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	na
72	425	FLZ 3	Feliz Creek	no	no	yes	yes	nis	na
74	370	LIT 8	Little Sulphur Creek	no	no	yes	yes	nis	8
75	122	BPC 1	Bearpen Creek	yes	yes	yes	yes	na	5
78	319	MCD 1	McDonnell Creek	no	no	yes	yes	nis	8
79	251	DRY 8	Dry Creek	yes	yes	yes	yes	us	us
80	391	EDW 1	Edwards Creek	no	no	yes	yes	nis	reserve
81	496	ORR 5	Orrs Creek	no	no	yes	yes	nis	reserve
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	na
84	109.1	GRA 3	Gray Creek	yes	yes	yes	yes	1	3
85	543	BAK 2	Bakers Creek	no	no	yes	yes	nis	na
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	reserve
89	485	MCC 2	McClure Creek	no	no	yes	yes	nis	na
90	369	LIT 7	Little Sulphur Creek	no	no	yes	yes	nis	3
91	117	WAR 4	Ward Creek	no	no	yes	yes	nis	na
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	na
95	346	OAT 1	Oat Valley Creek	no	no	yes	yes	nis	3
96	416	TYL 2	Tyler Creek	no	no	yes	yes	nis	na
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	reserve
101	494	ORR 3	Orrs Creek	no	no	yes	yes	nis	na
102	305	KEL 1	Kellogg Creek	yes	yes	yes	yes	na	reserve
103	127	DUT 2	Dutch Bill Creek	yes	yes	yes	yes	1	6
104	436	BRO 1	Brother Creek	no	no	yes	yes	nis	na
106	356	BIG 8	Big Sulphur Creek	no	no	yes	yes	nis	na
107	364	LIT 2	Little Sulphur Creek	no	no	yes	yes	nis	na
108	405	PIE 4	Pieta Creek	no	no	yes	yes	nis	6
109	156	ATA 2	Atascadero Creek	yes	yes	yes	yes	na	na
110	285	BAR 1	Barnes Creek	no	no	yes	yes	nis	6
111	342	NEW 1	Newman Creek	no	no	yes	yes	nis	na
112	418	TYL 4	Tyler Creek	no	no	yes	yes	nis	na
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

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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	yes	yes	yes	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	4
122	303	RED 2	Redwood Creek	yes	yes	yes	yes	1	4
124	395	CUM 2	Cummiskey Creek	no	no	yes	yes	nis	4
125	220	COP 1	Copeland Creek	no	no	yes	yes	nis	4
126	244	DRY 1	Dry Creek	yes	yes	yes	yes	us	us
127	246	DRY 3	Dry Creek	yes	yes	yes	yes	us	us
129	509	OSC 1	Orr Springs Creek	no	no	yes	yes	nis	reserve
130	231	HUM 1	Humbug Creek	no	no	yes	yes	nis	4
131	94	EAU 3	East Austin Creek	yes	yes	yes	yes	us	us
132	280	RWL 1	Redwood Log Creek	yes	yes	yes	yes	na	na
133	68	MAI 50	Russian River	no	no	yes	yes	nis	na
135	82	AUS 2	Austin Creek	yes	yes	yes	yes	na	4
137	499	NON 1	NoName Creek	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	yes	yes	yes	yes	us	us
140	454	MCN 3	McNab Creek	no	no	yes	yes	nis	na
141	211	BLU 1	Blucher Creek	no	no	no	yes	nis	nis
142	329	GIR 1	Gird Creek	no	no	yes	yes	nis	na
143	274	PEN 1	Pena Creek	yes	yes	yes	yes	1	4
144	350	BIG 2	Big Sulphur Creek	no	no	yes	yes	nis	4
145	545	MFO 2	Mill Creek (Forsythe)	no	no	yes	yes	nis	4
146	234	VAN 1	Van Buren Creek	no	no	yes	yes	nis	7
147	121	BJC 1	Blue Jay Creek	no	no	yes	yes	nis	reserve
148	98	EAU 7	East Austin Creek	yes	yes	yes	yes	us	us
149	535	JAC 1	Jack Smith Creek	no	no	yes	yes	nis	reserve
150	297	BID 1	Bidwell Creek	no	no	yes	yes	nis	7
151	149	MJA 1	Mount Jackson Creek	no	no	yes	yes	nis	7
152	443	PAG 1	Page Creek	no	no	yes	yes	nis	reserve
153	498	SUL 2	Sulphur Creek (Upper RR)	no	no	yes	yes	nis	reserve
154	358	BIG 10	Big Sulphur Creek	no	no	yes	yes	nis	7
155	112	SLC 1	Sulphur Creek	no	no	yes	yes	nis	us
156	471	GOL 1	Gold Creek	no	no	yes	yes	nis	na
157	175	MAR 10	Mark West Creek	yes	yes	yes	yes	1	7
158	325	SAU 2	Sausal Creek	no	no	yes	yes	nis	7
159	345	CLO 1	Cloverdale Creek	no	no	yes	yes	nis	na
160	380	FRS 1	Frasier Creek	no	no	yes	yes	nis	7
161	539	ELD 2	Eldridge Creek	no	no	yes	yes	nis	7
163	76	WIL 3	Willow Creek	yes	yes	yes	yes	1	7
164	263	FEL 3	Felta Creek	yes	yes	yes	yes	reserve	reserve
165	489	DLN 2	Doolin Creek	no	no	yes	yes	nis	na
166	314	BRI 4	Briggs Creek	no	no	yes	yes	nis	reserve
167	161	JON 2	Jonive Creek	yes	yes	yes	yes	na	na
168	429	FLZ 7	Feliz Creek	no	no	yes	yes	nis	reserve
169	513	HWD 1	Howard Creek	no	no	yes	yes	nis	reserve
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	na	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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
182	361	BIG 13	Big Sulphur Creek	no	no	yes	yes	nis	na
183	104	BLA 2	Black Rock Creek	yes	yes	yes	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	FOX 1	Fox Ridge Creek	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	yes	yes	yes	yes	us	us
191	248	DRY 5	Dry Creek	yes	yes	yes	yes	us	us
192	422	LAF 1	La Franchi Creek	no	no	yes	yes	nis	na
193	506	ACK 7	Ackerman Creek	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	yes	yes	yes	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	KIN 1	King Ridge Creek	no	no	yes	yes	nis	us
204	472	CLE 1	Cleland Creek	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	SUN 1	Sundance Creek	no	no	yes	yes	nis	na
210	192	RIN 1	Rincon Creek	no	no	yes	yes	nis	na
211	83	AUS 3	Austin Creek	yes	yes	yes	yes	na	na
212	257	MIL 3	Mill Creek	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
218	388	BCC 1	Bear Canyon Creek	no	no	yes	yes	nis	na
219	113	TOB 1	Toben Creek	no	no	yes	yes	nis	us
220	450	NOK 1	Nokomis Creek	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	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	yes	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

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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	yes	yes	yes	yes	us	us
240	400	SOL 1	Solace Creek	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 RR)	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	na	na
248	464	PYR 1	Pyramid Creek	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	PRC 1	Pocket Ranch Creek	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 (MWC)	no	no	yes	yes	nis	na
258	67	MAI 49	Russian River	no	no	yes	yes	nis	na
259	203	OAK 1	Oakmont Creek	no	no	yes	yes	nis	na
260	497	SUL 1	Sulphur Creek (Upper RR)	no	no	yes	yes	nis	na
261	378	RAT 1	Rattlesnake Creek	no	no	yes	yes	nis	na
262	158	ATA 4	Atascadero Creek	yes	yes	yes	yes	na	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	yes	yes	yes	yes	us	us
266	145	POC 2	Pocket Canyon Creek	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
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	CAS 1	Casabonne Creek	no	no	yes	yes	nis	na
281	110	DEV 1	Devil Creek	yes	yes	yes	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 (Ackerman)	no	no	yes	yes	nis	na
287	178	MAR 13	Mark West Creek	yes	yes	yes	yes	2	na
288	555	SCH 1	School Creek	no	no	yes	yes	nis	na
289	382	SQU 2	Squaw Creek	no	no	yes	yes	nis	na
290	492	ORR 1	Orrs Creek	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	na	na

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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	yes	yes	nis	us
301	349	BIG 1	Big Sulphur Creek	no	no	yes	yes	nis	na
302	541	MAC 1	MacMurray Creek	no	no	yes	yes	nis	na
303	193	RIN 2	Rincon Creek	no	no	yes	yes	nis	na
304	495	ORR 4	Orrs Creek	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	na	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	yes	yes	yes	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	yes	yes	yes	yes	us	us
316	511	DAY 1	Day Creek	no	no	yes	yes	nis	na
317	259	MIL 5	Mill Creek	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	na	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
329	102	EAU 11	East Austin Creek	no	no	yes	yes	nis	us
331	344.1	RMC 1	Red Mountain Creek	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	na	na
334	478	FER 1	Fern Canyon Creek	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	na	na
340	144	POC 1	Pocket Canyon Creek	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	PRC 1	Pocket Ranch Creek	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	yes	yes	yes	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

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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 (MWC)	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	ERC 1	El Roble Creek	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	MLT 1	Millington Creek	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	GGC 1	Gold Gulch Creek	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	us
382	470	ROB 5	Robinson Creek	no	no	yes	yes	nis	na
383	232	WEE 1	Weeks Creek	yes	yes	yes	yes	na	na
384	544	MFO 1	Mill Creek (Forsythe)	no	no	yes	yes	nis	na
385	226	MPO 2	Porter Creek (MWC)	yes	yes	yes	yes	na	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 RR)	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	OAK 1	Oakmont Creek	no	no	yes	yes	nis	na
398	368	LIT 6	Little Sulphur Creek	no	no	yes	yes	nis	na
399	518	CLG 1	College Creek	no	no	yes	yes	nis	na
401	420	MOU 1	Mountain House Creek	no	no	yes	yes	nis	na
402	243	EAS 2	Eastside Creek	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	yes	yes	yes	yes	us	us
407	252	DRY 9	Dry Creek	yes	yes	yes	yes	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	VIC 1	Vichy 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		
411	467	ROB 2	Robinson Creek	no	no	yes	yes	nis	na
412	225	MPO 1	Porter Creek (MWC)	yes	yes	yes	yes	4	na
413	354	BIG 6	Big Sulphur Creek	no	no	yes	yes	nis	na
414	75	WIL 2	Willow Creek	no	yes	no	yes	nis	nis
415	307	YEL 1	Yellowjacket Creek	yes	yes	yes	yes	na	na
416	163	RCA 1	Redwood Creek (Atascadero)	yes	yes	yes	yes	na	na
417	375	NBL 2	North Branch Little Sulphur Creek	no	no	yes	yes	nis	na
418	362	GEY 1	Geysers Creek	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	DSC 1	Duncan Springs Creek	no	no	yes	yes	nis	na
429	93	EAU 2	East Austin Creek	yes	yes	yes	yes	na	na
431	136	HUL 3	Hulbert Creek	yes	yes	yes	yes	4	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
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	na	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	RIN 3	Rincon Creek	no	no	yes	yes	nis	na
455	296	FRA 6	Franz Creek	no	no	yes	yes	nis	na
456	481	ROS 1	Rosemary Hill Creek	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	na	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	PRA 1	Pratt Creek	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

Appendices

Draw order	Frame number	Reach name	Tributary	Coho Salmon		Steelhead		Coho panel	Steelhead panel
				Adult	Juvenile	Adult	Juvenile		
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	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	yes	yes	yes	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