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California Coastal Salmonid Population Monitoring in the Russian River Watershed: 2019

FRGP Grant #P1730412; Annual Report
Reporting Period: March 1, 2018 – October 15, 2019

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Contents

Executive Summary

On March 1, 2019 Sonoma Water (SW) and California Sea Grant (CSG) began implementation of a new contract that continues work begun in 2013 to monitor anadromous CCC Coho Salmon, CCC steelhead, and CC Chinook Salmon in the Russian River watershed. Work was 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). The CMP 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.To accomplish the goals of the CMP, we performed basin-wide spawner surveys in the Russian River for Coho and steelhead, basin-wide snorkel surveys for juvenile Coho, and operated life cycle monitoring (LCM) stations to measure status and trends in anadromous Coho and steelhead populations in the Russian River basin. With data generated from these field efforts we estimated basin-wide adult Coho and steelhead abundance, basin-wide spatial structure of juvenile Coho, freshwater survival of successive cohorts of Coho and steelhead in LCM creeks, and marine survival of successive cohorts of Coho and steelhead in the LCM creeks.

This annual report provides a summary of salmonid abundance at multiple life stages and at multiple spatial scales. We estimated Coho and steelhead adult abundance at lifecycle monitoring stations and basin-wide with spawner surveys in a GRTS ordered random sample of reaches. We esimated Coho and steelhead smolt abundance at multiple life cycle monitoring (LCM) stations. Sonoma Water also operated a downstream migrant and adult migrant LCM station at Mirabel dam site on the mainstem Russian River at rkm 39.67 aimed at assessing status and trends of Chinook Salmon. Juvenile Coho spatial structure in the Coho/steelhead sample stratum was estimated with snorkel surveys in a GRTS ordered random sample of reaches. Juvenile steelhead abundance was estimated using a modified basinwide visual estimation technique (BVET) at multiple LCM stations. The goal of these annual reports is to keep CDFW informed of the tasks accomplished in accordance with the primary activities and deliverables outlined in FRGP Grant #P1730412. Related monitoring data collected by CSG but funded by non-FRGP sources is reported in CSG (2004-2020).

Report Status

a) The funding agreement for this project was executed on May 30, 2018 and Amendment 1 was executed on November 6, 2018. The term of the grant is June 1, 2018 – November 15, 2021. The agreement between Sonoma Water and Regents of the University of California was executed on January 30, 2019.
b) Issues or concerns affecting schedule and/or budget: None
c) Activities for next annual reporting period:
    a. Adult monitoring
    b. Smolt monitoring
    c. Juvenile monitoring
d) Financial Reporting/Invoices:

$279,457.96 has been requested for reimbursement through October 15, 2019. During this same period, Sonoma Water has contributed $433,429.49 in cost share. $806,140.51 in cost share and $1,472,764.04 in grant funds remain.

Task Updates

Task 1. Monitoring Coordination and Planning

General monitoring coordination and planning tasks were performed throughout the reporting period and included contacting landowners, scheduling field crews and coordination of field activities associated with spawner surveys, DSMT, snorkel surveys, and electrofishing syrveys. After the completion of each season of field work, all data was rigorously error checked and final estimates of redd abundance, smolt abundance, and juvenile spatial structure were calculated for LCM streams and the Russian River basin. On July 24, 2019 a data package containing spawner survey data from the 2018/19 spawner season was submitted to CDFW for inclusion in the statewide CMP database. Three tri-annual progress reports based on adult, smolt, and juvenile monitoring were prepared and submitted to CDFW for review on July 1, November 1 (2019), and March 1 (2020) respectively.

Because of the rotating panel design, new reaches need to be surveyed for spawner surveys every year. Preparations for the 2019/20 spawner season began in July, 2019 and included a substantial landowner outreach effort. We attempted to gain access to roughly 15 new reaches by contacting over 100 landowners. The first step was a GIS exercise comparing the streams layer to the parcels layers for Mendocino and Sonoma counties. We identified all parcels that were adjacent to the 15-20 reaches next in the draw list that had not yet been accessed or contacted. We then used online resources to track down contact information for each landowner with property on each stream. All contact information obtained was vetted to determine validity. In many cases landowner contact information was outdated or unobtainable, so we attempted to contact neighbors of missing landowners to obtain updated information. In all over 300 contacts were made by phone, email, and personal communication to gain access to new reaches for the 2019/20 spawner season. All landowner contact records, contact information, response information and details about landowner preferences were stored in a relational database designed for that purpose. After access was obtained to a large enough portion of each new reach, crews were sent to determine habitat suitability and record relevant reach information. Parking spots, entry points, details of landowner access, and other details were recorded using Survey 123 (Esri) forms and stored in a relational database for use during the spawner season.

Task 2. Life Cycle Monitoring

Introduction

The CMP objective of life cycle monitoring is to detect trends in abundance of smolts and adults (Adams et al. 2011). For the preceeding grant (and all previous grants since we began CMP monitoring in 2013), the Coho and steelhead LCM was in Dry Creek. That preceeding grant ended February 28, 2019 partway through the spawning season. Since the final grant report for the previous grant was prepared prior to the end of spawning season, we reported spawner data through January 31, 2019 for the 2018/19 spawner season. In this first annual report, we summarize the full 2018/19 spawner season in the Dry Creek LCM and provide estimates calculated at the completion of field work (as these summaries and estimates were missing from the last final grant report). We also include results from Dry Creek DSMT.

For the current grant, we moved away from LCM in Dry Creek in favor of new LCM streams for reasons thoroughly discussed both in the final grant report for the previous grant (SW and CSG 2019), the 2018 Russian River CMP Technical Advisory Team meeting (June 6, 2018), and a request for amendment approved by CDFW in 2018. The new Russian River stream 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 1).

We operated downstream migrant traps (DSMT) on mainstem Dry Creek (rkm 3.30), 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 and steelhead smolts and at Sonoma Water's Mirabel dam site (rkm 39.67) on Russian River mainstem for Chinook smolts (Figure 1). A significant issue with relying solely on downstream migrant trapping at life cycle monitoring stations for steelhead is the fact that steelhead smolt migration occurs well before DSMTs can be safely installed and operated. Using DSMTs alone, steelhead smolt abundance will be underestimated by a significant amount in most cases. This is less of a problem for Coho smolts in the Russian River watershed where smolt migration typically occurs from March through June – a period when DSMTs can be successfully installed and operated, particularly in small tributary streams.

To avoid underestimating steelhead smolts produced in LCM streams, we conceptualized an approach for combining data from DSMTs with outputs from a pre-smolt steelhead abundance and survival model (SW and CSG 2014). This approach relies on steelhead smolt abundance estimates generated from pre-winter abundance estimates coupled with efficiency-adjusted detections of PIT-tagged steelhead at stationary PIT antenna arrays throughout the ensuing winter. We have since evaluated this approach for estimating steelhead smolt abundance and determined that while it is effective for smaller tributaries like Mill Creek where PIT antennas can be reliably operated through the winter, it can lead to bias in steelhead abundance estimates in larger tributaries like Dry Creek where PIT antenna efficiency can be compromised during winter (SW and CSG 2014). Indeed, this was one of the reasons we abandoned Dry Creek as an LCM system in favor of LCM on Mill, Green Valley, Dutch Bill and Willow Creeks. Because of promising initial results from utilizing these methods in Mill Creek, we began implementing them in the other LCM streams in summer/fall 2019. We will likely continue to implement this strategy in subsequent grants as it seems to have the greatest potential for obtaining accurate steelhead smolt estimates.

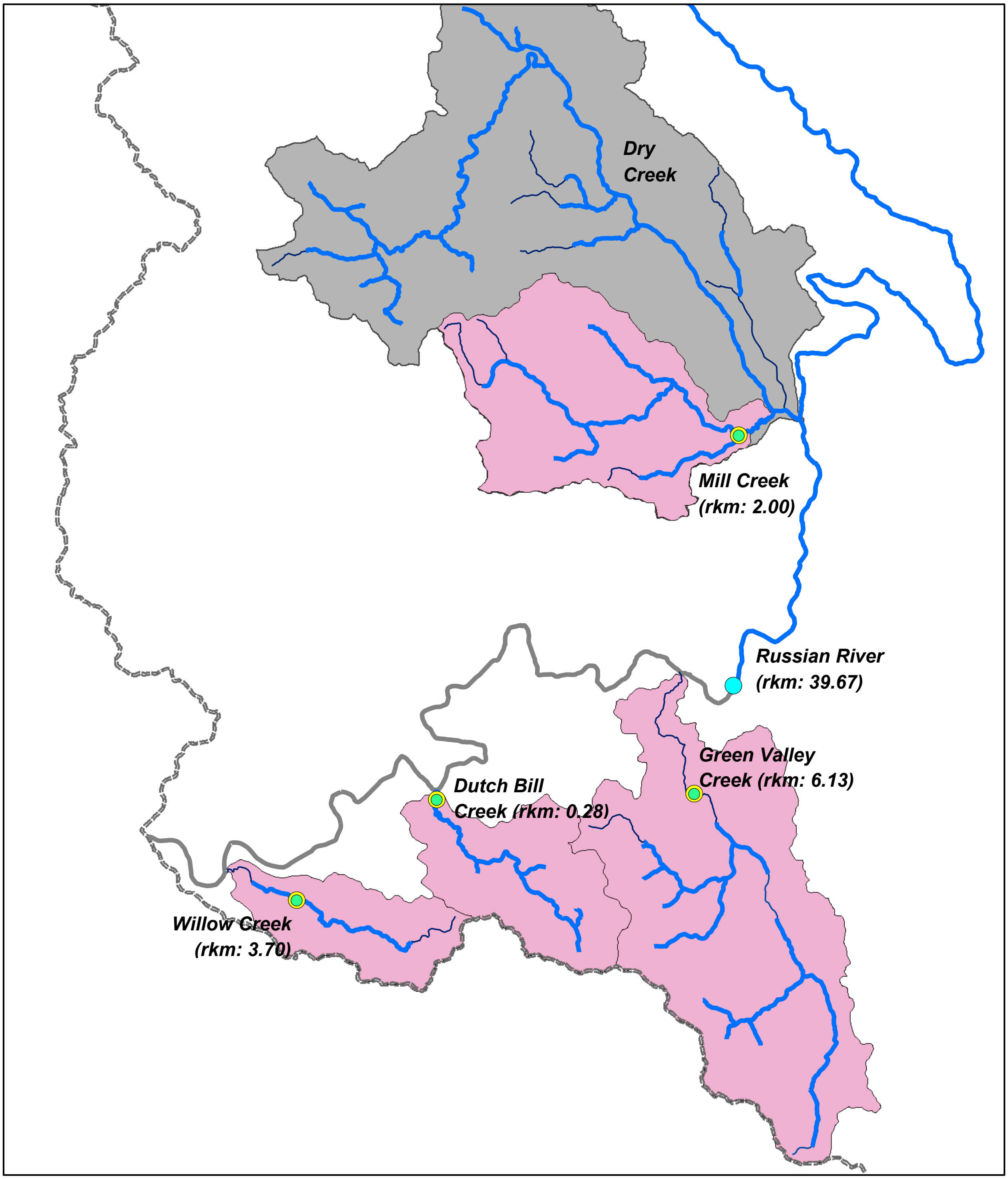


Figure 1. Current Coho salmon and steelhead LCM watersheds (pink polygon) and stations (green and yellow circles indicating fish trap combined with PIT antenna) and Chinook LCM station (blue circle). The Dry Creek watershed (gray polygon) was the former LCM system for Coho salmon and steelhead. Colored line segments represent reaches containing habitat for one or more species/life stage of anadromous salmonid.

Methods

Spawner surveys

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

Redd species estimation

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

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

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

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

1. Observer redd species was assigned as the final redd species:
    a. for all observer certainty 1 redd species (i.e., species identification was possible and fish species certainty=1 for one or more fish associated with the redd);
    b. for any redd identified by the field crew as Chinook regardless of certainty level.
2. Estimated species from the Gallagher/Gough logistic regression equations was assigned as the final redd species for remaining redds where redd species certainty was >1 and redd measurements were made.

If field crews never observed a certainty 1 fish species associated with a redd and if measurements were never taken (making estimation with Gallagher/Gough logistic equations impossible), we used a method whereby fisheries biologists familiar with life-histories of salmonids in the watershed used their best professional judgement to estimate redd species. Decisions were based on the closest certainty 1 fish or redd species in time and space. The number of redds classified in this way never exceeded 2% in a season.

Redd abundance estimation

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

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

Smolt abundance

Downstream migrant traps (funnel and/or pipe) were operated on Mill, Green Valley, Dutch Bill, and Willow Creeks and rotary screw traps was operated on Dry Creek and Russian River during the spring when the majority of the Coho Salmon smolt outmigration occurs and when the flows are conducive to trap operation. Traps were tended daily with additional checks during peak outmigration and high flow and/or debris load. PIT tags were applied to individuals and data were collected in order to assess smolt abundance at LCM stations, population diversity, and to facilitate future estimation of marine survival and adult abundance.

Specific protocols for fish handling, work-up, and PIT-tagging for Mill, Green Valley, Dutch Bill, and Willow Creeks can be found in CSG (2019). At the mainstem Dry Creek trap site, we used a rotary screw trap with a 1.5 m diameter cone to capture juvenile salmonids moving downstream. Weir panels were installed adjacent to and extending upstream from the upstream end of the screw trap in a “V” configuration (i.e., trap at the downstream apex of the “V”) in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap (Figure 2). Fish captured in the trap were identified to species and enumerated. All fish ≥55 mm were scanned for PIT tags and Coho were scanned for CWTs. A subsample of each species was anesthetized using Alka Seltzer and measured for fork length (±1 mm) and mass (±0.1 g). A subsample of Chinook smolts was PIT-tagged or fin-clipped and released upstream of the trap to facilitate abundance estimates. All fish that were PIT-tagged were also measured and weighed prior to being tagged. Other species, including recaptured Chinook, were released downstream of the first riffle downstream of the trap. All anesthetized fish were allowed to recover fully in aerated buckets prior to release.

Figure 2. Downstream migrant trap at Dry Creek in Healdsburg (LCM station, rkm 3.30).

At the mainstem Russian River trap site, we operated two rotary screw traps adjacent to one another (one 1.5 m diameter cone and one 2.4 m diameter cone, (Figure 3) until later in the season when flows dropped and there was only enough thalweg width to operate a single trap. Fish captured in the trap were identified to species and enumerated. All fish ≥55 mm were scanned for a PIT tag and Coho were scanned for CWTs. A subsample of each species was anesthetized using Alka Seltzer and measured for fork length (±1 mm) and mass (±0.1 g). A subsample of Chinook smolts was PIT-tagged or fin-clipped and released upstream of the trap to facilitate abundance estimates. All fish that were PIT-tagged were also measured and weighed prior to being tagged. Other species, including recaptured Chinook, were released downstream of the first riffle downstream of the trap. All anesthetized fish were allowed to recover fully in aerated buckets prior to release.

Figure 3. Downstream migrant traps at Sonoma Water's Mirabel dam in Forestville (Chinook smolt LCM station, rkm 39.67).

Coho smolt abundance estimates at LCM stations on Mill, Green Valley, Dutch Bill, and Willow Creeks were based on a two-trap mark-recapture design (DARR: Bjorkstedt 2005; Bjorkstedt 2010). Details of the two-trap DARR approach can be found in CSG (2019).

Although a few Coho and steelhead smolts were captured in the Dry Creek and other LCM stations, we knew from previous experience that trap catches would be far too low to even attempt a mark-recapture estimate based on outmigrant trapping alone. Therefore, for steelhead smolt estimation we employed a pre-smolt abundance model that relied on backpack electrofishing in the late summer/early fall and year-round, stationary PIT antenna monitoring to estimate smolts and/or juvenile steelhead leaving the LCS. Detailed steps are described below (in sub-section "Steelhead pre-smolt abundance") and in SW and CSG (2019).

We attempted to employ one-trap mark-recapture design for Chinook Salmon smolts at the Chinook LCM station on Russian River mainstem. In the one-trap design, a sample of fish that were captured in the Mirabel trap each day were marked with a PIT tag, and subject to recapture in the trap by releasing them upstream of the trap.

Steelhead pre-smolt abundance

An end-of-summer abundance estimate of juvenile steelhead in life cycle monitoring streams was obtained using a combination of snorkeling and electrofishing surveys conducted between August 12 and October 16, 2019. Similar surveys were conducted in the Mill Creek system in the late summer of 2017 and 2018.

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). 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 snorkeled by a single diver who recorded the number of salmonids observed by species and age class, then pools were blocked off using nets at the upstream and downstream ends of the habitat unit to ensure closure, and multiple-pass electrofishing was conducted. All salmonids ≥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- vs. natural-origin. PIT tags were applied to untagged steelhead and Coho ≥60 mm and 2 g so that emigration from the tributary of tagging could be detected with a stationary PIT antenna array. Once fish were completely recovered from the anesthetic they were released into the pool from which they were captured.

An end-of-summer abundance estimate of juvenile steelhead life cycle monitoring streams found in pools was calculated in 2019 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 4).

Calibrated snorkel counts as described above can be used to estimate steelhead abundance in pool habitat, but cannot be used for habitat that cannot be snorkeled, including riffle habitat. An end-of-summer abundance estimate of juvenile steelhead life cycle monitoring streams found in riffle habitat units was calculated in 2019 using depletion electrofishing similar to the method used in pool habitat units. Riffle units were blocked off in a similar manner to pools. The same fish work-up and PIT-tagging criteria were also used for riffles. The average number of juvenile steelhead as estimated from electrofishing was calculated for each stream and then applied to the total number of riffles in the stream (counted during first-stage sampling) to estimate the abundance of juvenile steelhead found in riffle habitat. The pool and riffle estimates were then summed to generate the end-of-summer steelhead estimate.

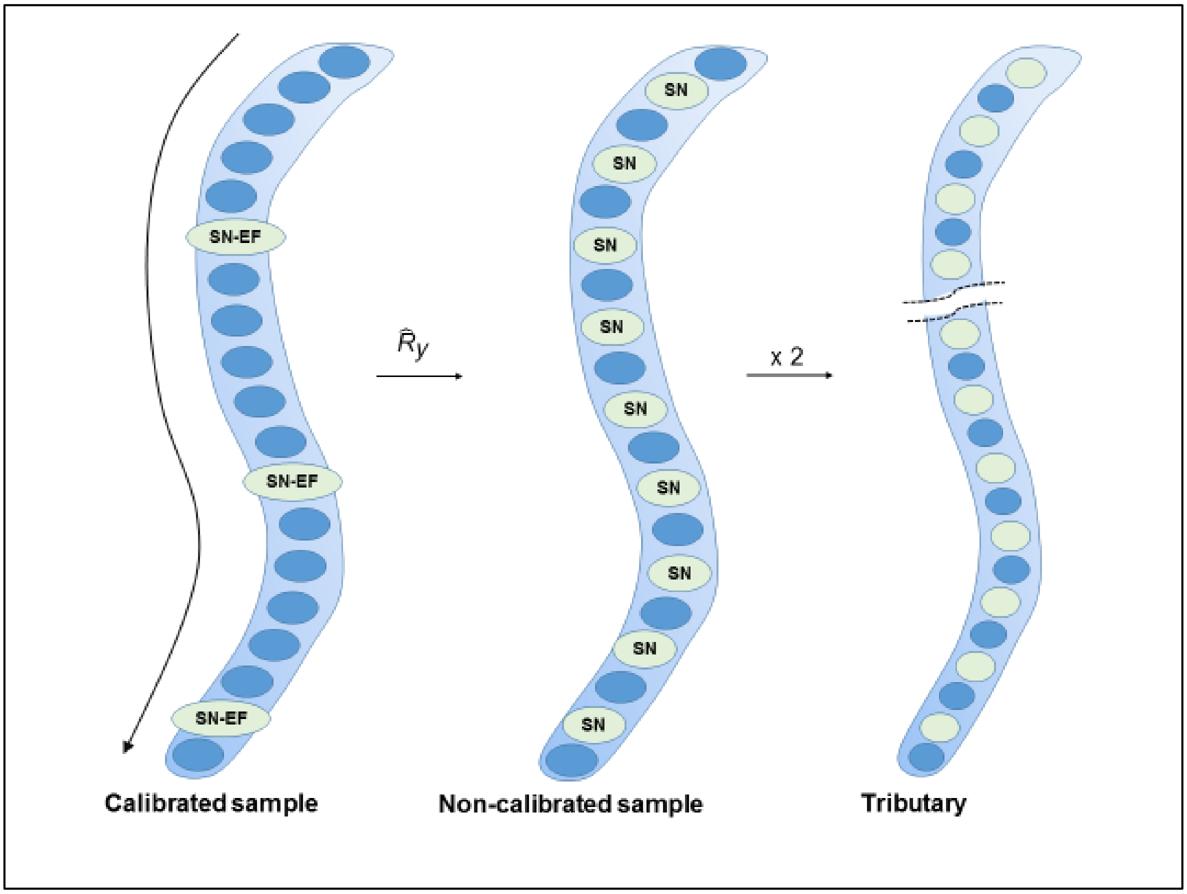


Figure 4. Sampling strategy for estimating juvenile steelhead population in LCM watersheds. A year- and stratum-specific calibration ratio ($\hat{R}_y$) calculated from pools selected to two-stage sampling was applied to all snorkeled pools and doubled to generate an estimate for each tributary.

Results

Redd abundance

Surveys began December 3, 2018 and were completed April 18, 2019. During that time we completed 144 surveys in Dry Creek tributary reaches. For the 2018/19 season, we observed Coho redds in 11 reaches and steelhead redds in 20 reaches. We observed the largest number of Coho redds in Mill Creek, and the largest number of steelhead redds in Pena Creek. Overall, Pena Creek had the highest number of observed salmonid redds (including the only Chinook redds observed in the Dry Creek basin, Figure 5). We also observed the largest number of

Coho individuals (live fish and carcasses) in Mill Creek and the largest number of steelhead individuals in Pena Creek (Figure 6). Estimates of Coho and steelhead redd abundance in the Dry Creek LCM (± 95% CI) were 58 (±19) and 489 (±120) respectively for the 2018/19 spawner season. Figure 7 compares the 2018/19 Coho and steelhead redd estimates to estimates from previous seasons.

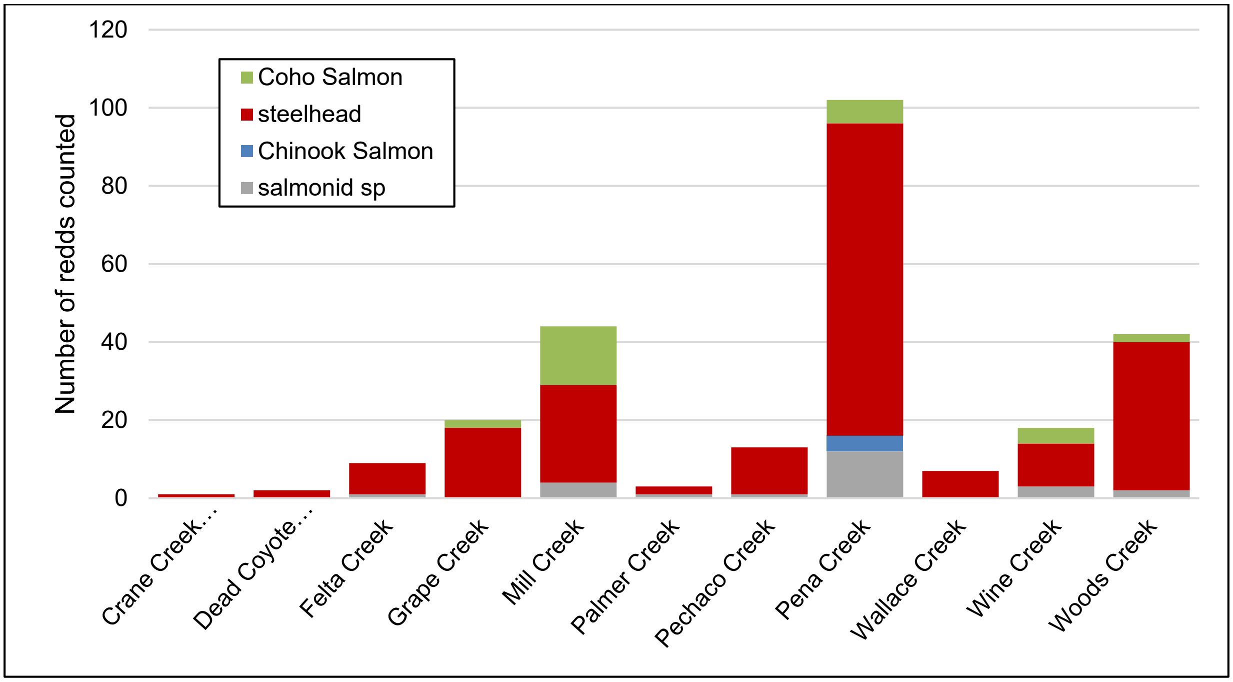


Figure 5. Number of new redds counted in Dry Creek tributaries for all three levels of redd species certainty. Only tributaries where redds were observed are included.

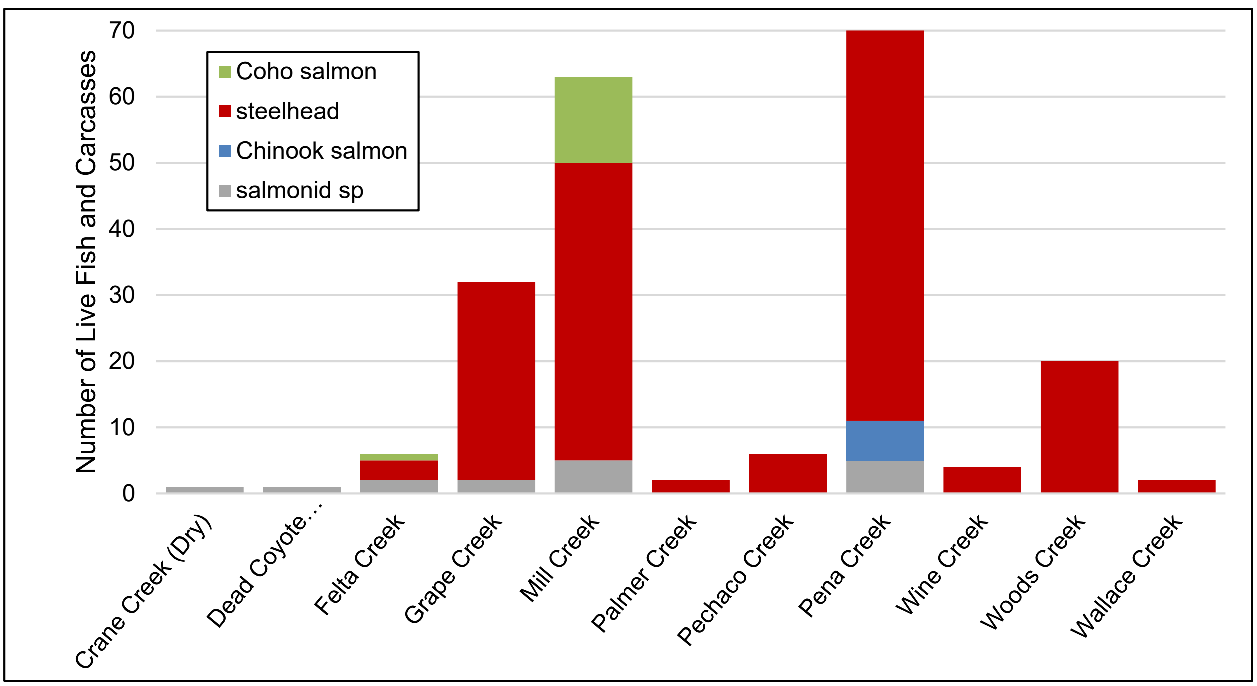


Figure 6. Number of live adult salmonids and carcasses counted by tributary for all three levels of fish species certainty. Only tributaries where live fish and carcasses were found are included. It is possible that some fish were counted more than once.

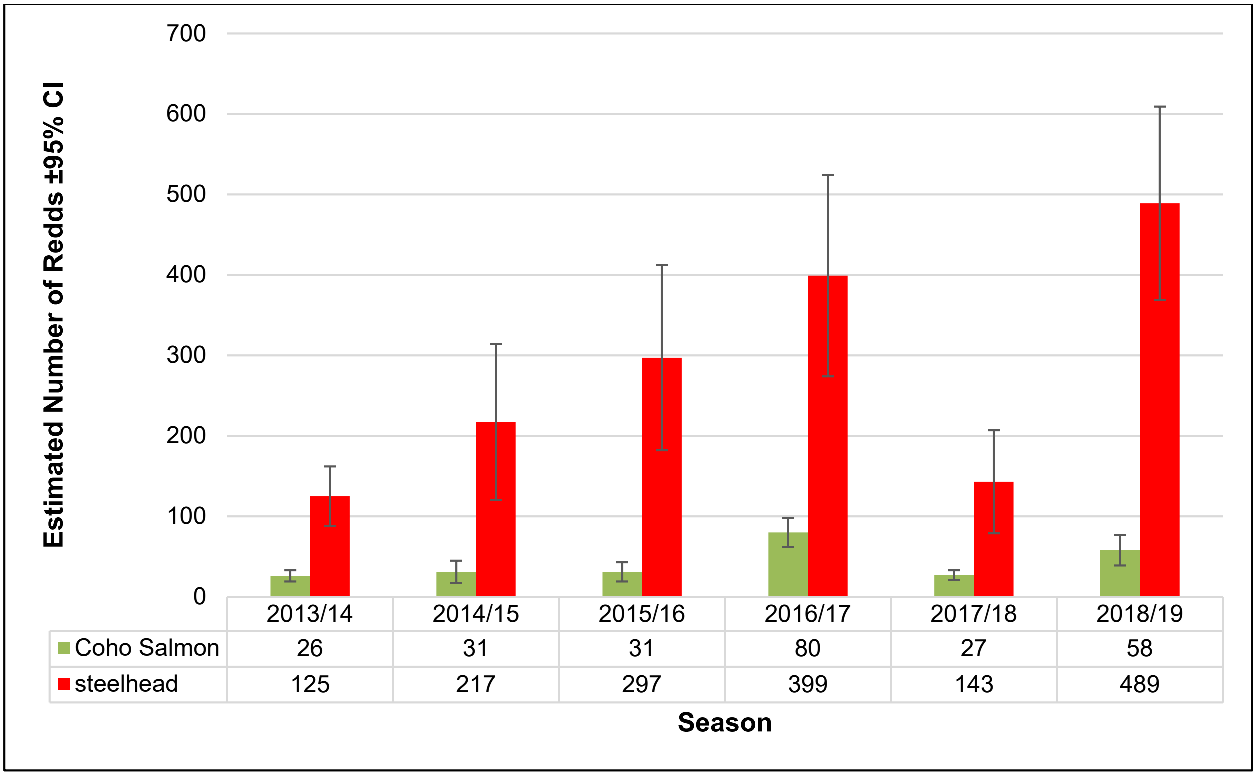


Figure 7. Estimated redd abundance for Coho and steelhead in Dry Creek tributaries by season. Estimates calculated prior to the current reporting period are shown in order to display trends.

Smolt abundance

Trap operation- At all DSMTs, trap operation was truncated relative to other years with install dates that were later than typical and interrupted due to high flows during what has historically been the peak migration season for Coho and Chinook smolts (mid- to late-May). Specific dates of trap operation for Mill, Green Valley, Dutch Bill, and Willow Creeks can be found in CSG (2019).

The largest number of Chinook smolts captured was in the mainstem Russian River trap (2,661) while the greatest number of Coho smolts captured was in the Green Valley Creek trap (4,887). The highest number of steelhead juveniles (parr and YOY) were caught in the Dry Creek trap (5,625) but only 65 steelhead smolts were captured at that site with numbers at the four new LCM stations ranging from 0 in Willow Creek to 12 in Green Valley Creek.

Coho Salmon smolts- The largest estimate of Coho smolts leaving any of the 4 life cycle monitoring streams was 13,949 (± 762) from Green Valley Creek (Figure 8). As in previous years, catches of Coho smolts were too low (110) at the Dry Creek smolt trap to allow an estimate.

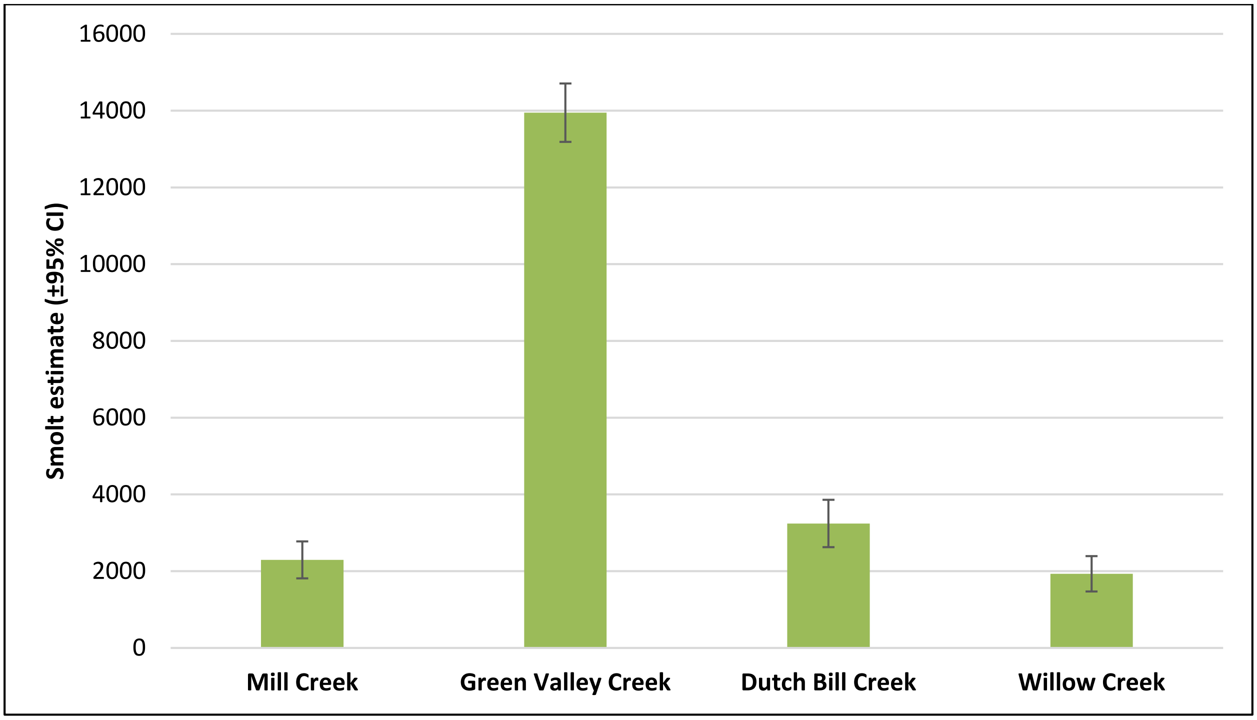


Figure 8. Coho Salmon smolt abundance estimates (±95% confidence intervals) for Mill, Green Valley, Dutch Bill, and Willow Creeks.

Steelhead smolts- During fall through spring steelhead emigration period in 2018/19, the raw proportion (i.e., not adjusted for antenna efficiency) of fish emigrating from Mill Creek was 22% (220 out of 987 individuals that were PIT-tagged in fall 2018) but the raw proportion emigrating from Dry Creek was much lower (3%) (Table 1). PIT antenna efficiency was similar in Dry Creek and Mill Creek; however the period of operation of the Dry Creek antenna array was significantly truncated due to a complete compromise of array integrity in late February. Consequently, the survival index significantly under-represents the true number actually emigrating from Dry Creek which, in turn, leads to a significant under-representation of the true number of steelhead actually emigrating from Dry Creek as smolts in the winter/spring of 2018/19.

Table 1. Number of steelhead PIT-tagged by stream in fall of 2018 and number of fish detected at the mouth of respective streams during the ensuing steelhead emigration period of November 1 through June 30.

Stream	Number PIT-tagged	Raw detections at mouth	Raw proportion emigrating	Antenna efficiency	Survival index
Dry Creek	1,145	50[1]	0.03	0.96[2]	0.05
Mill Creek	987	220	0.22	0.92	0.24

[1] The antenna at the mouth of Dry Creek was not operational after February 20, 2019. Using the proportion of steelhead emigrants detected at the Mill Creek antenna during the period of November 1, 2018 to February 20, 2019 (46%) the raw detections at Dry Creek was expanded from 23 to 50.

[2] Antenna efficiency at Dry Creek was calculated for the period of November 1, 2018 to February 20, 2019 and is likely an over estimate since the antenna was removed when river depth increased, the same conditions that would reduce antenna efficiency.

The estimated number of steelhead emigrating from Mill Creek in 2018/19 was 1,170 (Table 2). Although conceptually sound, our notion of applying the survival index for Dry Creek in a similar manner described above to estimate the number of steelhead emigrating from Dry Creek is not recommended because of the significant bias in the Dry Creek survival index arising from the truncated operation period in 2018/19.

Table 2. Estimated number of steelhead pre-smolt emigrants from mainstem Dry Creek and Mill Creek from fall surveys conducted in 2018.

Stream	Survival index	Fall pre-smolt abundance	Number of emigrants
Dry Creek	0.06	29,759	N/A
Mill Creek	0.24	4,829	1,170

<u>Chinook Salmon smolts</u>- Because of high flows, a Chinook smolt estimate at the mainstem Russian River trap site could not be calculated because of a 17 day gap in trap operation (May 17 to June 3) which coincided with the historic peak of Chinook smolt outmigration at that site.

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 ($\hat{R}_p$=$\hat{n}_{ef}$·$n^{-1}{}_{sn}$;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 did not find any correlation between pool metrics (pool area, ratio of pool length and pool width, pieces of large woody debris) and $\hat{R}_p$ (Table 3). We did see a negative correlation between the number of fish observed during snorkeling (snorkel count) in a given 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 the 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).

Table 3. Pool metrics used to describe the variability in habitat among tributaries sampled in second-stage sampling at the end-of-summer 2019.

LCM watershed	stream	Sample size	mean pool area (m^2)	± 95% CI	mean length/width ratio	± 95% CI	mean LWD count	± 95% CI
Mill Creek	Mill Creek	34	135	63.69	5.34	1.235	0.65	0.308
	Felta Creek	16	25	8.02	4.46	1.454	0.25	0.308
	Palmer Creek	13	62.4	23.1	4.19	1.411	1.47	1.15
Green Valley Creek	Green Valley Creek	34	50.3	13.16	5.22	0.986	1.65	0.648
	Purrington Creek	27	31	10.99	3.98	0.813	0.46	0.428
Dutch Bill Creek	Dutch Bill Creek	33	116	40.25	5.35	0.934	0.76	0.478
Willow Creek	Willow Creek	26	64.2	24.57	4.76	1.155	1.96	0.804
All streams		184	75.4	15.24	4.87	0.41	1.03	0.223
Correlation coefficient (with $\hat{R}_p$)			r = 0.0046		r = -0.0584		r = -0.1431	

The year- and stratum-specific correction factor $(\hat{R}_y)$ for snorkel counts (Table 4) 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. Pools were grouped based on the number of steelhead observed (≤ 10 and >10) and the corresponding correction factor 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 we only snorkeled every other pool.

Table 4. Stratum- specific calibration ratio ($\hat{R}_y$) applied to first-stage sampling snorkel counts used to derive juvenile steelhead population estimates for end-of-summer 2019. One calibrated pool with an $\hat{R}_p$ equal to 25 was removed from analysis after being identified as an outlier.

Stratum	Number of pools	$\hat{R}_y$	95% LCI	95% UCI
≤ 10 steelhead	109	3.73	3.23	4.22
> 10 steelhead	74	1.93	1.33	2.53

A total of 2,078 pools were snorkeled during first-stage sampling in 2019, representing 50% of accessible pool habitat in the LCM watersheds. Second-stage electrofishing surveys were conducted in every fourth pool in the Green Valley, Dutch Bill and Willow Creek watersheds, and in every tenth pool in the Mill Creek watershed. The percentage of pools sampled during second-stage varied by watershed due to the fact that only pools with good water quality, and under 1.2 meter depth could be sampled using depletion electrofishing (Table 5). First-stage sampling was completed between August 12 and October 16, and second-stage sampling was completed between August 15 and October 15. Due to lack of surface flow and marginal water quality conditions, the lowest portion of Dutch Bill Creek and Willow Creek and the upper portion of Dutch Bill Creek was excluded from second-stage sampling in 2019. Due to the time constraints of the sampling season, smaller sub-reaches in the Dutch Bill Creek watershed (Grub and Perenne Creeks) and the Green Valley Creek watershed (Harrison, Little Green Valley and Nutty Valley Creeks) were also excluded from second-stage sampling. End-of-summer steelhead population estimates for pool habitat in the LCM watersheds ranged from over 7,500 in Mill and Dutch Bill Creeks to fewer than 50 in Perenne and Harrison Creeks (Table 5). The Mill Creek watershed had the largest juvenile steelhead estimate, and the 2019 Mill Creek watershed estimate was greater than in previous years (Figure 9).

A total of 47 riffles were sampled during second-stage sampling, this represents only 3.2% of all the riffles counted in the LCM watersheds. Of the sampled riffles over half (55.3%) had no fish. The end-of-summer steelhead population estimates for riffle habitat in the LCM watersheds ranged from over 900 in Dutch Bill Creek to zero in Felta Creek (Table 5). The total estimated abundance of pre-smolt steelhead from the LCM watersheds was 33,110 (±18,566 95% CI) for pool habitat and 3,014 (±2,707 95% CI, Table 5) for riffle habitat.

Table 5. Juvenile steelhead population estimates and sampling effort in LCM watersheds during end-of-summer 2019.

LCM watershed	Stream	First-stage (n)	Second-stage (n)	Juvenile steelhead estimate: pool	± 95% CI	Juvenile steelhead estimate: riffle	± 95% CI (n)
	Mill Creek	332	35	7,616	2,052	538[1]	424
	Felta Creek	137	16	1,688	316	0	0
	Palmer Creek	125	13	2,291	542	224	127
Mill Creek watershed		594	64	11,595	2,910	757[2]	498(15)
	Green Valley Creek	367	35	5,432	1,357	316	414
	Purrington Creek	239	28	3,783	878	634	214
	Harrison Creek	6	0	45	6	N/A	N/A
	Little Green Valley Creek	19	0	119	16	N/A	N/A
	Nutty Valley Creek	12	0	52	7	N/A	N/A
Green Valley Creek watershed		643	63	9,431	2,263	956	797(15)
	Dutch Bill Creek	450	34	7,715	2,033	902	968
	Grub Creek	31	0	112	15	N/A	N/A
	Perenne Creek	13	0	37	5	N/A	N/A
Dutch Bill Creek watershed		494	34	7,864	2,053	1,193	1,281(7)
	Willow Creek	347	25	4,220	904	108	131
Willow Creek watershed		347	25	4,220	904	108	131(10)
All streams		**2,078**	**184**	**33,110**	**8,130**	**3,014[3]**	**2,707**

[1] Tributary estimates for steelhead juveniles in riffle habitat were calculated using the tributary-specific steelhead average expanded by the number of riffles in that tributary.
[2] In an effort to account for tributaries not selected for second-stage sampling, watershed estimates for steelhead juveniles in riffle habitat were calculated using the watershed-specific steelhead average expanded by the total number of riffles in the watershed.
[3] Total steelhead estimate for riffle habitat is the sum of the watershed-specific estimates.

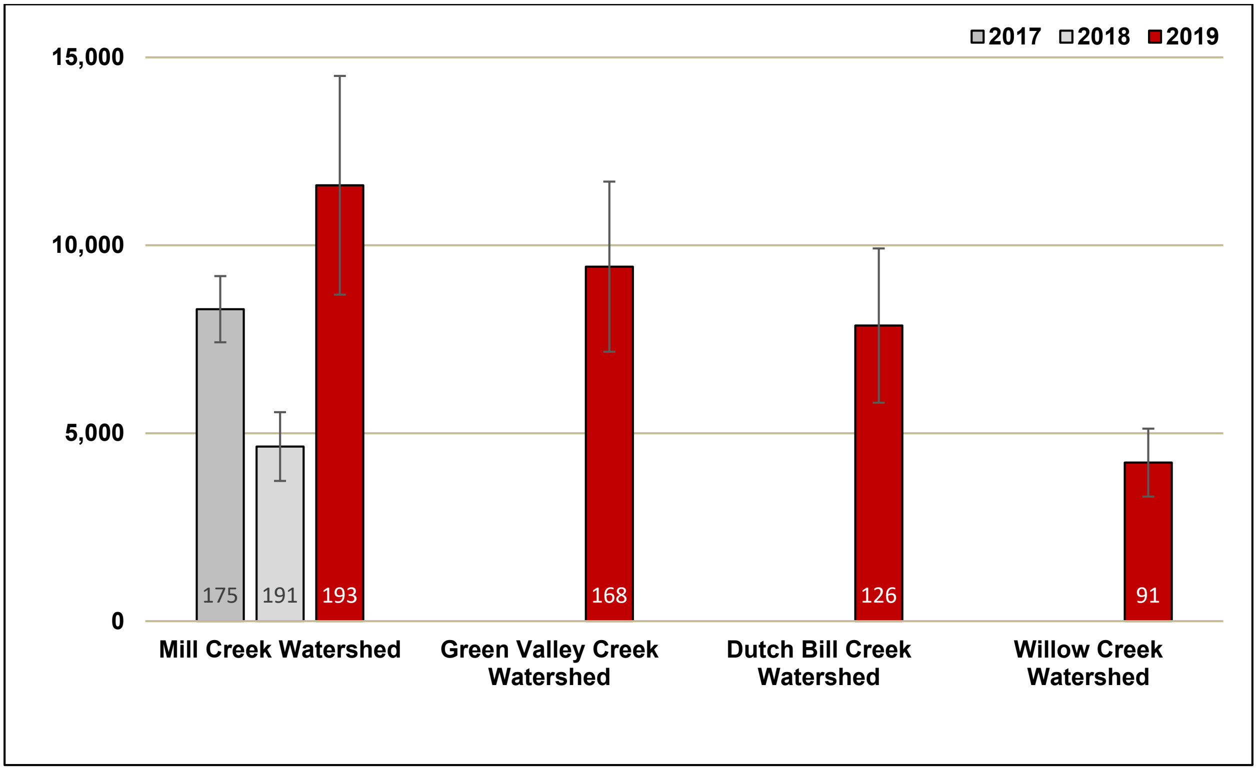


Figure 9. End-of-summer estimates for juvenile steelhead (found in pool habitat) from four Russian River watersheds. Green Valley Creek, Dutch Bill Creek and Willow Creek watersheds were added as LCM stations in 2019. The number at the base of each column represents the number of pools sampled to generate the population estimate.

Discussion

Redd abundance

Because of the depth and consistent high flows in the Dry Creek mainstem, we were unable to utilize the spawner survey methods outlined in Adams et al. (2011) and were therefore unable to include mainstem Dry Creek spawning in our overall estimate of redds in the Dry Creek basin. We have had the opportunity most seasons to do a few spawner surveys via kayak in mainstem Dry Creek and these surveys indicate significant spawning (mostly Chinook and steelhead) occurs in most years in the mainstem. For this reason (and others), we have moved LCM monitoring out of the Dry Creek basin and are focusing subsequent LCM efforts on other Russian River tributaries (Mill, Dutchbill, Green Valley, and Willow Creeks) where spawner survey methods recommended by Adams et al. (2011) can be consistently applied to all available Coho and steelhead habitat.

Sampling conditions-Smolt Estimate

High winter flows exceed flood stage in the Russian River at Guerneville in February 2019. These conditions resulted in failure of the Dry Creek PIT antenna array in late February and likely adversely impacted antenna detection efficiency to an unknown degree on the four new LCM streams (Mill, Green Valley, Dutch Bill and Willow Creeks). The start of the downstream migrant trapping season was delayed by higher than normal flows in early spring and an unusual late spring storm that interrupted trapping in May.

Conclusions and recommendations – Smolt Estimate

Consequences of the difficult sampling conditions in winter/spring 2019 included an inability to estimate Chinook Salmon smolt abundance at the Russian River LCM station and Coho smolt abundance estimates in the new LCM streams were biased-low by an unknown amount. These same conditions also resulted in an inability to accurately apply the pre-smolt steelhead abundance and survival model to estimate the number of steelhead smolts leaving Dry Creek although we were able to apply the model to estimate steelhead smolts leaving Mill Creek.

In the future, we plan to take steps to include stream flow or stage as a covariate to help explain antenna detection efficiency. By developing relationships between flow and detection efficiency, we could more accurately estimate overwinter survival of juveniles to the smolt stage while reducing bias in smolt abundance estimates. Another possibility would be to apply these relationships as a way to estimate smolt abundance even during periods when downstream migrant traps could not be operated because of high flows.

Pre-smolt steelhead abundance

2019 was our first opportunity to generate an end-of-summer estimate for the number of juvenile steelhead in the new LCM watersheds. We were able to conduct second-stage sampling in 184 pools with the average percent of pools for each watershed ranging from 5.4% for the Mill Creek watershed to 3.4% for the Dutch Bill Creek watershed, with each stream selected for second-stage sampling having more than 12 pools sampled. However, even with the addition of more streams to our LCM protocol, we did not find that differences in habitat contributed to differences in the calibration ratio ($\hat{R}_y$) used to calculate the end-of-summer steelhead estimate. We did find a significant difference in the $\hat{R}_y$ when comparing results between snorkelers ($F(3,162)=6.5095$, $p=0.00035$). Most of the snorkeling during second-stage sampling was completed by two observers (observer A = 41.3%, observer B = 35.9%) with observer B having consistently higher $\hat{R}_p$ (4.16 ± 0.66 95%CI compared to 2.56 ± 0.62 95%CI). The influence of number of fish observed (≤ 10 steelhead; >10 steelhead) on $\hat{R}_p$ remained consistent among snorkelers. During first-stage sampling more observers (10) were needed to sample over 2,000 pools, so we were not able to calculate a specific $\hat{R}_y$ for each snorkeler. It is unclear how to utilize a snorkeler specific $\widehat{R}_y$ when we do not have the same observers conducting surveys in the first- and second-stage sampling efforts, so we used only number of fish observed during snorkeling to stratify the samples and to compute the $\widehat{R}_y$ used to generate the population estimate. In future sampling we hope to develop a metric allowing observers to rank the level of difficulty encountered when sampling a pool (i.e. easy, moderate, difficult). This metric could be used as a grouping variable when exploring factors influencing variation in $\hat{R}_p$, and could be applied to pools sampled by any observer.

Riffle habitat was sampled in order to account for juvenile steelhead not residing in pools, however the majority (55.3%) of riffles sampled had no salmonids present. In some streams many riffles were small and shallow, and would not provide adequate habitat even for very small steelhead young-of-the-year (YOY). In some cases the inter-pool habitat did not meet the criteria for riffle habitat (modified from Flosi et al. 2010) and was instead classified as flatwater or glide habitat. In future years we plan to develop a method for sampling the non-pool habitat that would include these additional habitat types in order to generate an estimate for steelhead not residing in pools.

Calculation of the end-of-summer steelhead estimates in an important part of our life cycle monitoring but it is only the first step in estimating the number of steelhead smolts produced each year in our LCM watersheds. During first-stage sampling we calculated a size-based (≥60 mm), reach-specific target for the number of steelhead juveniles that would be PIT-tagged during second-stage sampling. Using this target number, juvenile steelhead were PIT-tagged in relative proportion to their abundance throughout the specific LCM watershed. Detections of PIT-tagged steelhead at stationary antenna arrays located at the mouth of each LCM will be used in conjunction with the tributary-specific, juvenile steelhead survival model to estimate the number of smolts produced from each LCM watershed.

Tasks 3 and 4. 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). Here we provide results of basinwide adult redd abundance sampling (from spawner surveys) and juvenile spatial structure sampling (from snorkel surveys) aimed at accomplishing basinwide CMP objectives.

Methods

Redd abundance

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

We estimated basinwide redd abundance in the Coho-steelhead sample stratum (81 reaches) and in the steelhead sample stratum (386 reaches) for the 2018/19 spawner season using estimation methods identical to the methods described for deriving total redd estimates from spawner surveys in the Dry Creek LCS (Ricker et al. 2014; Adams et al. 2011). Like the Dry Creek LCS surveys, this approach employed both a within-reach and among-each expansion each season.

Juvenile coho occupancy

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, juvenile Coho Salmon and steelhead 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 0.3 m in an area at least as long as the maximum wetted width and a surface area of greater than 3 m^2. 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). These data were then used in an occupancy model to estimate occupancy at the reach scale and occupancy at the pool scale for Coho Salmon only. A GPS point was collected at the downstream end of each pool snorkeled on the pass 1 survey.

During each survey, snorkeler(s) moved from the downstream end of each pool (pool tail crest) to the upstream end, surveying as much of the pool as water depth allowed. Dive lights were used to inspect shaded and covered areas. In order to minimize disturbance of fish and sediment, snorkelers avoided sudden or loud movements. Double counting was minimized by only counting fish once they were downstream of the observer. In larger pools requiring two snorkelers, two lanes were agreed upon and each snorkeler moved upstream through their designated lane at a similar rate. Final counts for the pool were the sum of both lane counts. All observed salmonids were identified to species and age class (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 ($\hat{\psi}$) and conditional occupancy at the pool scale ($\hat{\theta}$), 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 parameter estimates ($\hat{\psi} * \hat{\theta}$). 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 only. Three reaches on Gray Creek that were considered Coho habitat were not included in the occupancy estimate because YOY were released from an RSI into those reaches and it was impossible to determine origin while snorkeling. Two reaches on Mark West Creek were also excluded from the occupancy estimate because they were stocked prior to snorkel surveys being completed.

Results

Redd abundance

The start date for basinwide spawner surveys was December 3, 2018, concurrent with the start of spawner surveys in the Dry Creek LCS, and with the date rain reconnected tributaries (thus allowing fish access). Surveys were completed April 18, 2019. Over the course of the season we completed 319 surveys in 51 reaches in the coho-steelhead and steelhead sample strata. In the coho-steelhead sample stratum, we used 32 reaches (roughly 41% of the stratum) to calculate total redd abundance for the stratum. The average time between surveys (± 95% CI) in the coho-steelhead stratum was 22.15 (±1.65) with a maximum time between surveys of 77 days. In the steelhead sample stratum, we used 32 reaches (roughly 8% of the stratum) to calculate total redd abundance for the stratum. The average time between surveys (± 95% CI) in the steelhead stratum was 22.15 (±2.39) with a maximum time between surveys of 80 days. We observed the largest number of Coho redds in Green Valley Creek (Figure 12), and the largest number of steelhead redds in Pena Creek (Figure 13). Overall, Pena Creek had the highest number of observed salmonid redds of any reach sampled in the basin (Figure 10). We also observed the largest number of Coho individuals (live fish and carcasses) in Green Valley Creek and the largest number of steelhead individuals in Pena Creek (Figure 11). The estimate of Coho redd abundance in the Russian River basin (± 95% CI) was 127 (±46) for the 2018/19 spawner season. The estimate of steelhead redd abundance in the Russian River basin (± 95% CI) was 2031 (±1301) for the 2018/19 spawner season. The Coho estimate is a moderate increase from the previous season’s drop in abundance, whereas the steelhead estimate is more than double that of the previous season (Figure 14, Figure 15).

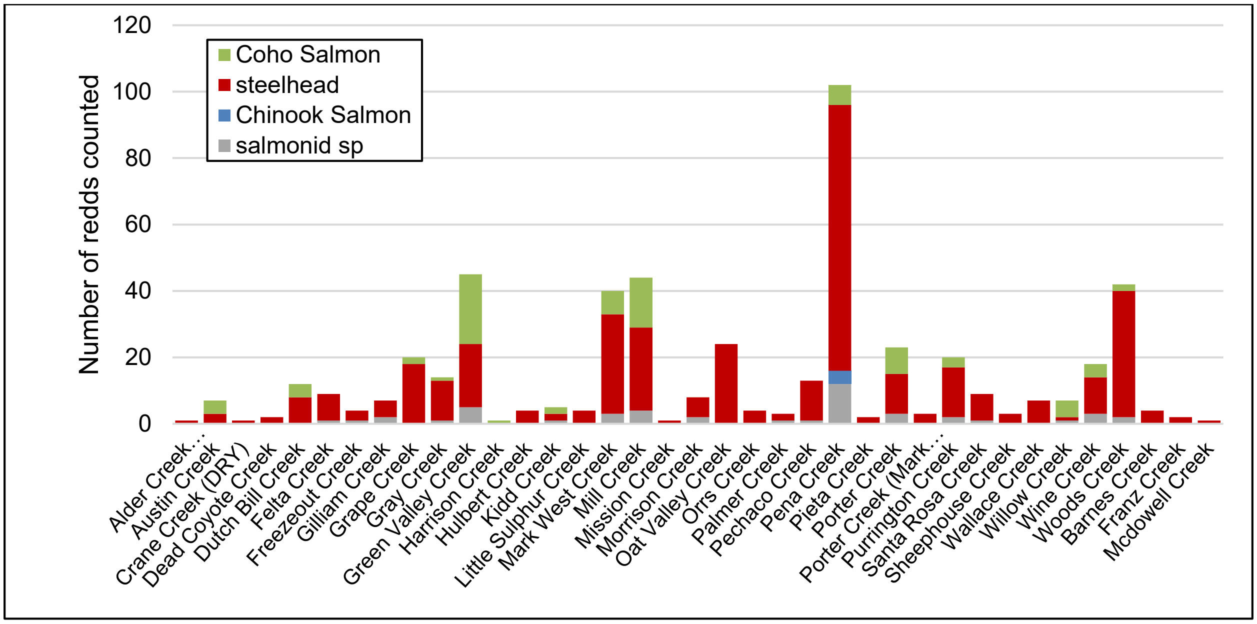


Figure 10. Number of new redds counted in basinwide spawner surveys by tributary for all three levels of redd species certainty. Only tributaries where redds were found are included. Note that not all habitat within each creek may have been surveyed in a given year (i.e., only reaches included in the rotating panel for a given season were surveyed).

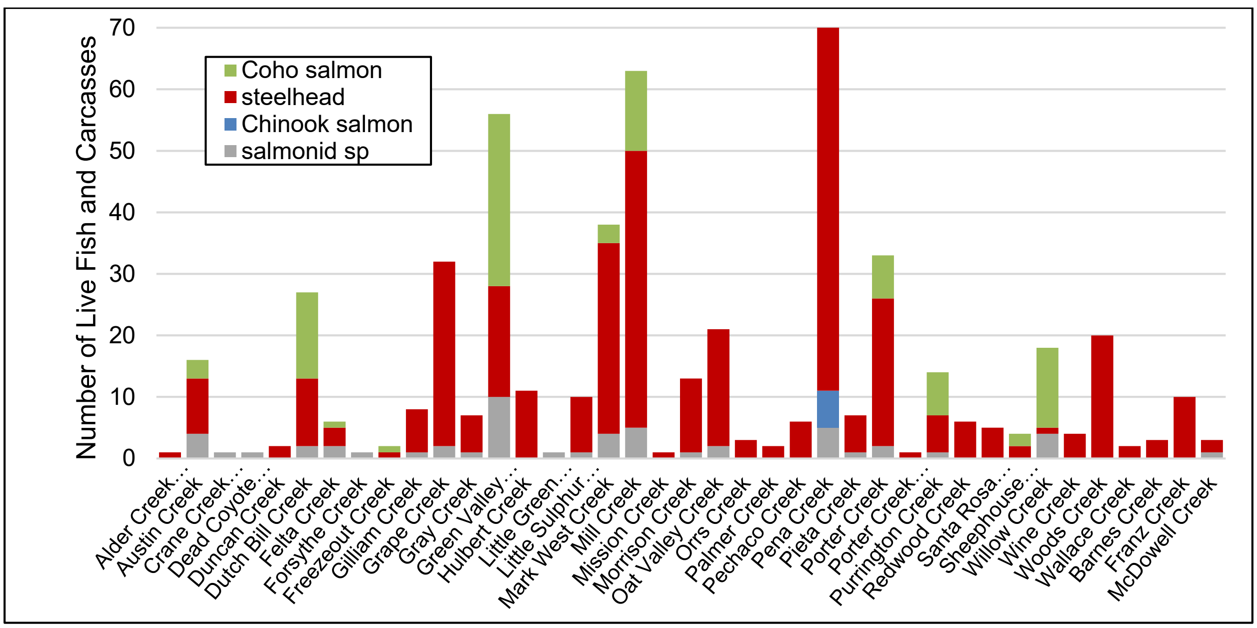


Figure 11. Number of live adult salmonids and carcasses counted in basinwide spawner surveys by tributary for all three levels of fish species certainty. Only tributaries where live fish and carcasses were found are included. It is possible that some fish could have been counted more than once. Note 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).

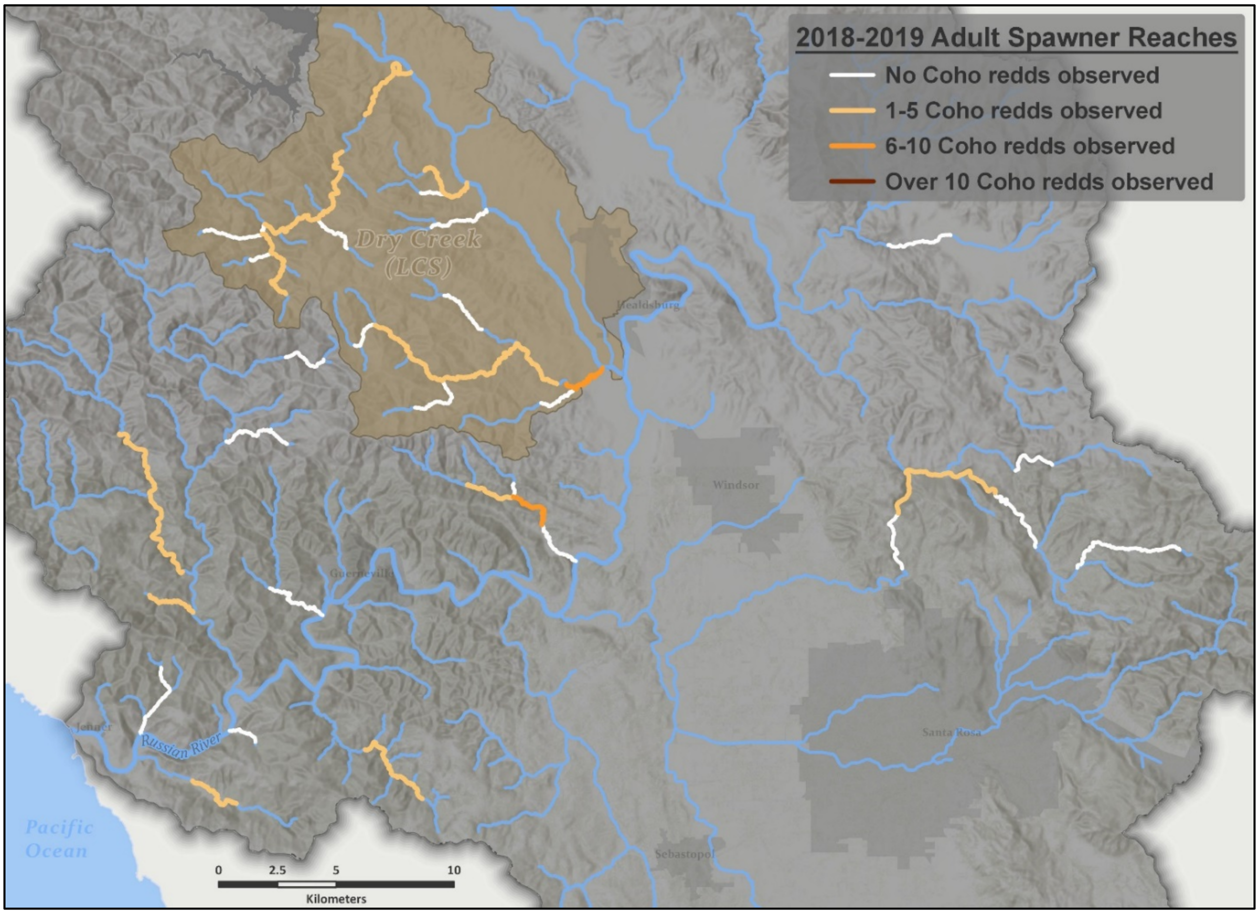


Figure 12. Spatial distribution of coho redds in the coho/steelhead sample stratum.

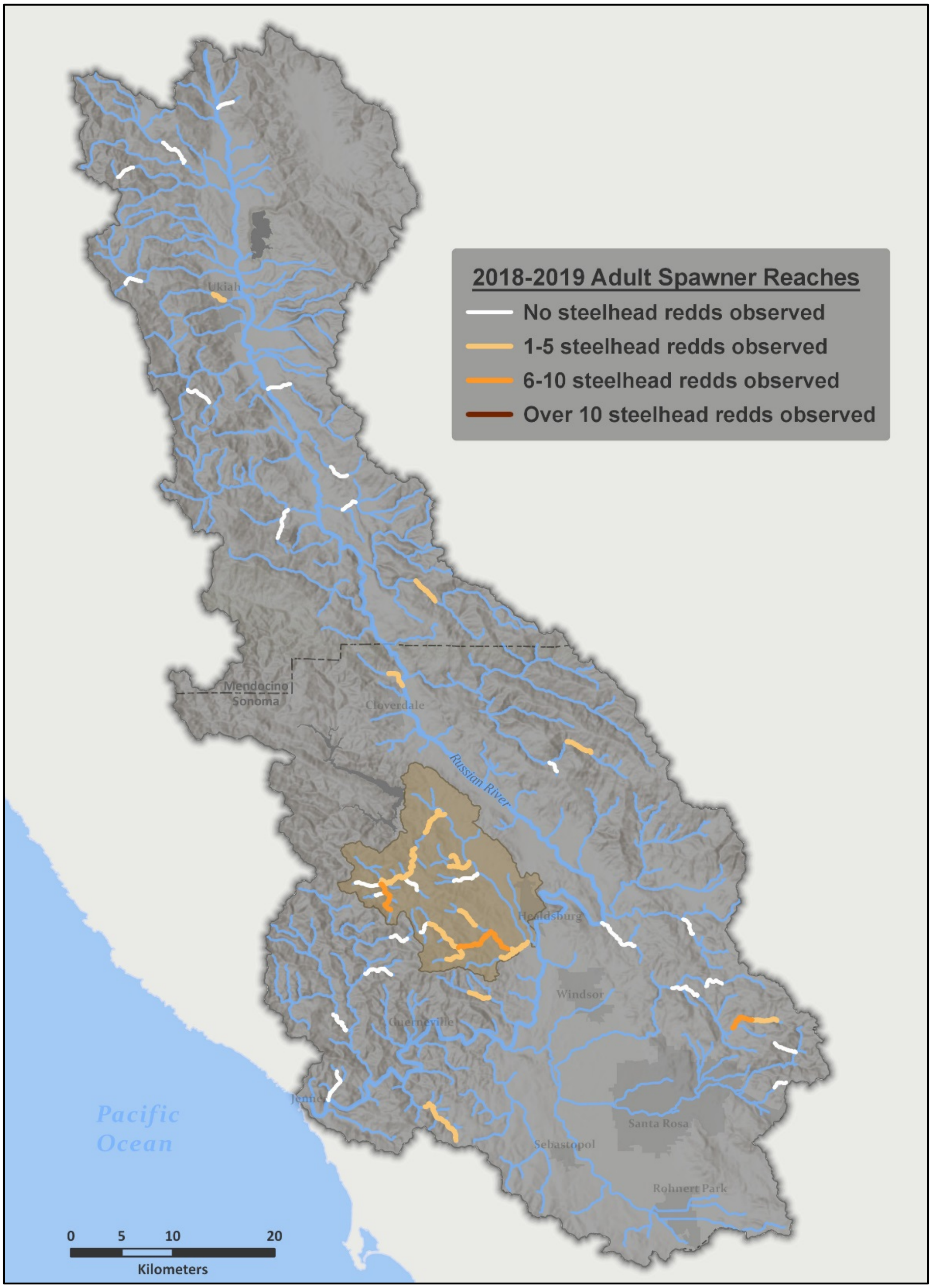
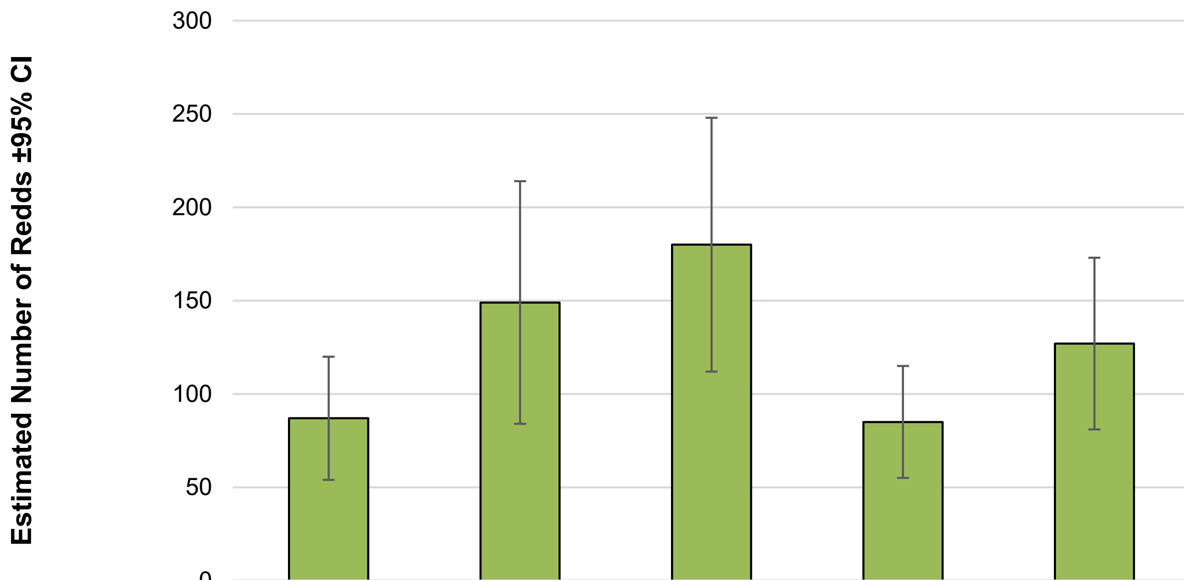
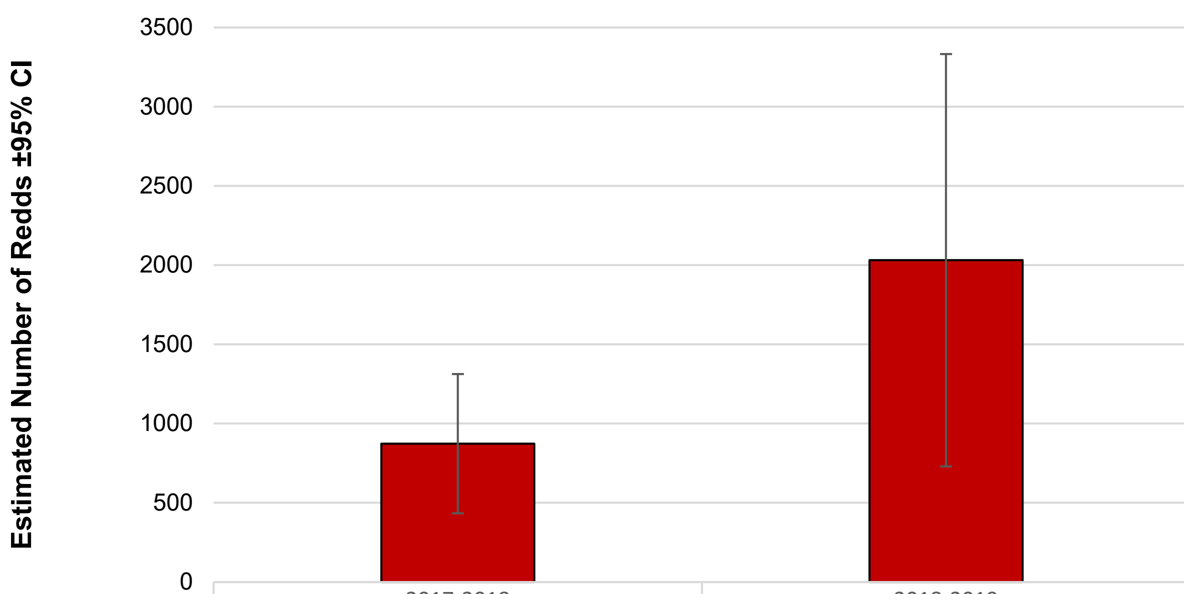


Figure 13. Spatial distribution of steelhead redds in the steelhead-only sample stratum.



	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
TotalReddEstimate	87	149	180	85	127

Figure 14. Basinwide estimates of redd abundance for Coho by season. Estimates calculated prior to the current reporting period are shown in order to display trends. Estimates were recalculated in May, 2020 to reflect changes in the number of reaches in the coho/steelhead stratum.



	2017-2018	2018-2019
TotalReddEstimate	873	2031

Figure 15. Basinwide estimates of redd abundance for steelhead by season. Estimates calculated prior to the current reporting period are shown in order to display trends. Estimates were recalculated in May, 2020 to reflect changes in the number of reaches in the steelhead-only stratum.

Juvenile coho occupancy

Juvenile Coho Salmon were observed in 23 tributaries and 46% of the 72 reaches snorkeled (excluding Gray Creek and the two reaches on Mark West Creel for reasons listed above) with the highest counts consistently in Green Valley Creek (Figure 16). Based on results of the multiscale occupancy model, we estimate that the probability of Coho Salmon YOY occupying a given reach within the basinwide Russian River Coho stratum in 2019 was 0.46 (0.34 - 0.58, 95% CI), and the conditional probability of Coho YOY occupying a pool within a reach, given that the reach was occupied was 0.34 (0.30-0.39, 95% CI). The proportion of the Coho stratum occupied (PAO) was 0.16.

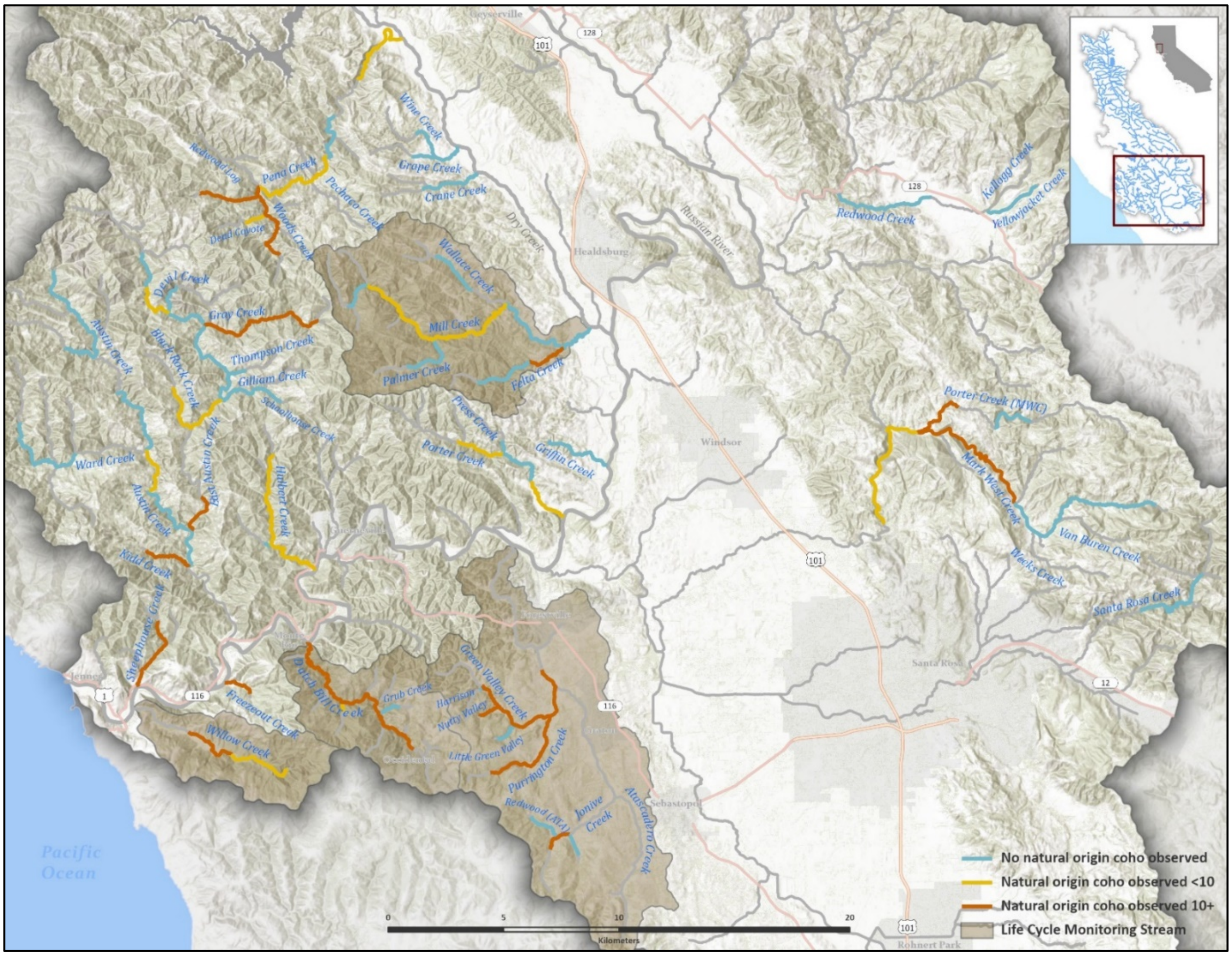


Figure 16. Natural-origin juvenile Coho Salmon distribution from snorkel surveys in the Russian River basin, 2019.

Discussion

Redd abundance

During the 2018/19 spawning season multiple large storms occurred including one on February 27, 2019 where the Russian River crested at roughly 27 ft., flooding communities adjacent to the river. The resulting frequent and persistent turbidity prevented consistent biweekly surveys in most tributaries where spawner surveys were attempted and led to intervals between surveys much higher than the 14 day target recommended in Gallagher et al. (2007). The total number of surveys per reach is also considerably lower than in previous seasons. Effort was inconsistent between reaches surveyed because smaller reaches where turbidity cleared more quickly may have been oversampled compared to larger, muddier reaches. Several tributaries that normally take a long time to clear (Forsythe Creek, McDowell Creek, and Pieta Creek) were only visited a few times through the season because of persistent, unsuitable visibility. We attempted to correct for this by extending surveys slightly beyond the usual April 15 deadline to visit some of the most neglected reaches one more time before quitting for the season. All these factors likely led to an underestimation of both Coho and steelhead redds.

Juvenile coho occupancy

Coho PAO was the lowest it has been since we began conducting basinwide snorkel surveys to estimate spatial structure in 2015 (Table 6, Figure 17). Coho redd abundance in 2018/19 was nearly identical to the five year average of 128 (estimated redd range: 82 in 2017/18 to 185 in 2016/17). Therefore, we suspect that in a relative sense the low PAO in 2019 was driven more by heavy rains and high flows from several large storms during the winter of 2018-2019 as opposed to redd numbers. Many of the storm events occurred late in the season, well after the peak of Coho spawning meaning that high flows could have resulted in significant redd scour leading to fewer Coho hatching and a correspondingly low PAO. As we continue to build our data sets, we intend to overlay redd count estimates with juvenile occupancy and smolt abundance estimates in LCM streams to evaluate stock-recruit relationships.

Table 6. Summary of results from basinwide snorkel surveys for Coho Salmon in the Russian River Basin (2015-2019).

Year	PAO	Reach scale occupancy ($\widehat{\psi}$) (95% CI)	Pool scale occupancy ($\widehat{\theta}$) (95% CI)	Number of reaches sampled
2015	0.37	0.68 (0.54-0.79)	0.54 (0.49-0.59)	58
2016	0.33	0.7 (0.58-0.8)	0.47 (0.43-0.51)	72
2017	0.2	0.5 (0.38-0.61)	0.42 (0.39-0.46)	73
2018	0.25	0.58 (0.46-0.69)	0.43 (0.39-0.46)	69
2019	0.16	0.46 (0.34-0.58)	0.34 (0.3-0.39)	72

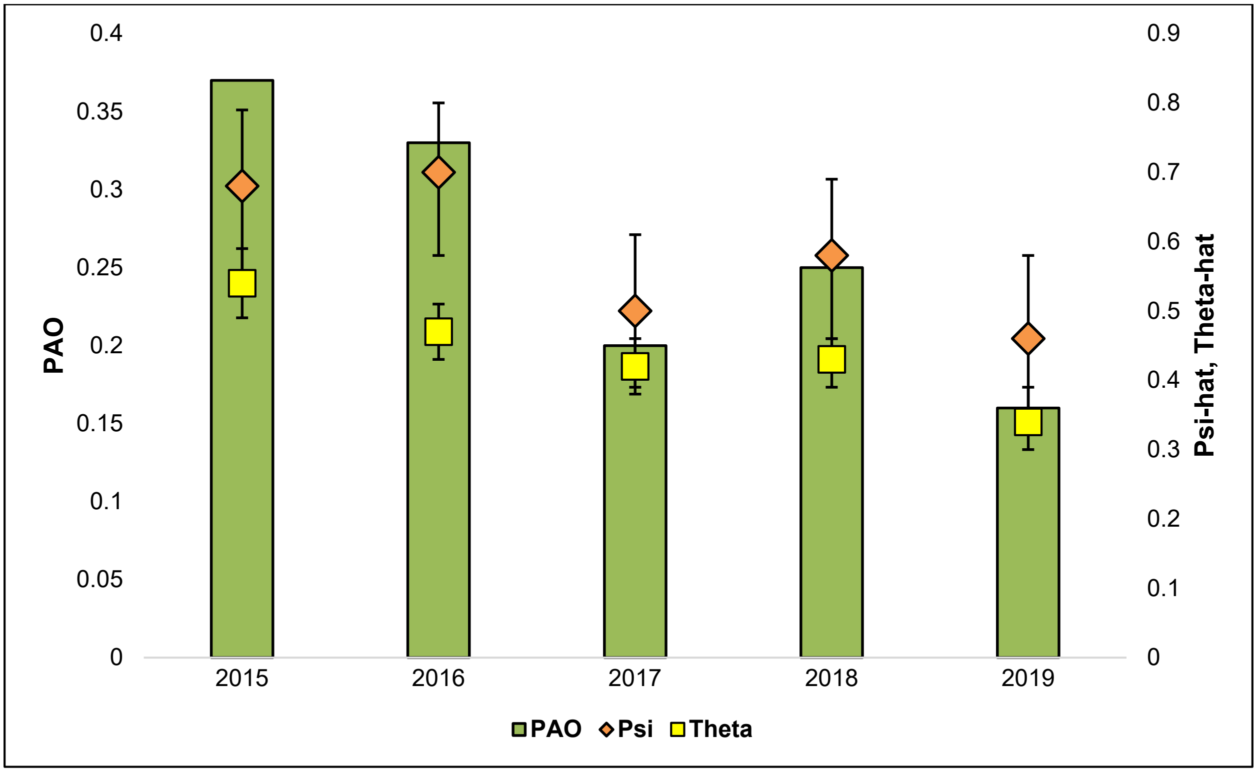


Figure 17. Estimated proportion of area occupied (PAO), occupancy at the reach scale ($\widehat{\psi}$), and occupancy at the pool scale ($\hat{\theta}$) for Coho Salmon in the Russian River Basin (2015-2019).

We noted lower juvenile Coho Salmon detection probability (*p*) in 2019 (0.65) as compared to other years (average 0.84). We suspect that this may have been the result of factors that were somewhat unique to 2019. First, in pools where the number of fish present was extremely low (ex. 1-2 individuals, which was often the case in 2019 sampling), differences between pass 1 and pass 2 counts of only one or two fish would have a relatively greater effect on $\hat{p}$ than in pools where the number of fish present was higher. A second factor that may have compounded this issue was the relatively high summer flows in 2019 (relative to previous seasons) which would have meant a greater degree of between-pool connectivity and a higher possibility of fish moving out of a given pool between pass 1 and pass 2 especially if they were disturbed by the pass 1 snorkel event. While we do not think these issues necessarily affected point estimates of occupancy, it is possible that they could affect estimate accuracy. In the future we intend to evaluate these issues further and seek ways to account for them if appropriate, for example, the inclusion of pool count as a covariate in the occupancy model.

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