Implementation of California Coastal Salmonid Population Monitoring in the Russian River Watershed

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Abstract

As stated in the California coastal salmonid population monitoring strategy design and methods (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 meet related management activities. The CMP goes further to state the importance of standardizing data collection methods, so data across drainages is comparable. To that end, the CMP describes the overall strategy, design, and methods. In 2013 we began implementing the strategies described in the CMP in the Russian River watershed. Funding for the first two years of monitoring was obtained through the Fisheries Restoration Grants Program (FRGP). This report describes monitoring from the onset of CMP implementation on June 1, 2013 to the completion of the term of the grant (October 31, 2015). Prior to the start of field monitoring, a sample frame was created using the methods of Garwood and Ricker 2011. During the first year of CMP implementation, we created a lifecycle monitoring station (LCS) in Dry Creek, a major tributary to the Russian River and home to state and federally listed coho salmon, steelhead and Chinook salmon. We monitored adult returns to Dry Creek with spawner surveys and via whitewater kayak surveys and with a fixed dual frequency identification sonar (DIDSON) combined with a digital video adult counting station installed near the mouth of Dry Creek (river km 0.36). Using a combination of the DIDSON/digital video adult counting station data, spawner surveys and returns to Warm Springs Hatchery (WSH, located at the upstream end of mainstem Dry Creek) we estimated adult returns of 170 coho, 6,936 steelhead and 1,311 Chinook to Dry creek during the 2013-14 spawner season. In 2014-15, we estimated adult returns of 60 coho, 2,578 steelhead, and 680 Chinook. The 2013-14 and 2014-15, the expanded counts of coho smolts were 11,155 and 12,538 and the estimated abundances of Chinook smolts were 232,173 (CV: 0.09) and 18,483 (CV: 0.11)[1] . No similar estimates for steelhead smolt abundance were possible in either year. The estimated proportion of area occupied (PAO) by juvenile coho in the 108 reaches in the coho-steelhead stratum was 0.16 in 2014. On the basis of sampling 32 ordered GRTS reaches of the 108 reaches in the coho-steelhead stratum (31% sampling intensity), we estimated 325 (95% CI: 200-449) and 740 (95% CI: 504-977) adult coho salmon and steelhead, respectively, spawned during the 2013-14 winter in the coho-steelhead stratum (these numbers do not include fish that returned to Warm Springs hatchery). Estimates also do not include fish that may have spawned in mainstem Dry Creek which is particularly problematic from the standpoint of developing a spawner: redd ratio for steelhead. Other issues with our spawner survey estimates in both the Dry Creek LCS and the coho-steelhead stratum are potentially inflated coho estimates, possibly due to the unknown species estimation we used. Methods of estimation of adult returns in the Dry Creek LCS using the DIDSON/digital video adult counting station need refinement as well, as they seem also to overestimate coho abundance in certain circumstances.

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[1] Estimate is through May 31, 2015

Introduction

Coho salmon and steelhead numbers throughout California have declined, leading to the listing of both species under state and federal endangered species acts. Coho in the Central California Coastal (CCC) Evolutionarily Significant Unit (ESU) have been listed as endangered and steelhead in the CCC ESU have been listed as threatened. The Russian River historically supported large populations of coho salmon and steelhead, and National Marine Fisheries Service (NMFS) has designated much of it critical habitat for both of these species (NMFS 2008). The Russian river is also the largest watershed in the CCC coho ESU draining roughly one third of the area. The Russian River basin is also important to the survival and recovery of CCC steelhead as it lies at the northern extent of the CCC steelhead range.

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

The Sonoma County Water Agency (Water Agency) has been collecting data from fish populations in the Russian River Basin since 1999 and the University of California Cooperative Extension/California Sea Grant (UC) has been collecting data from coho and steelhead populations in the Basin since 2004. These programs represent a substantial monitoring infrastructure to expand upon in order to meet the objectives of the CMP. In 2013 the Water Agency and UC received an FRGP grant to implement CMP monitoring in the Russian River watershed. This report summarizes the monitoring that occurred during the term of this first FRGP grant. At this time, further funding has been secured to continue to implement the CMP in the Russian River.

Methods

Project Area

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

The Russian River watershed is mainly agricultural, with an emphasis on orchard crops and vineyards. Major orchard crops are prunes, pears, and apples, with lesser crops of cherries and walnuts. Hops were once an important crop in the watershed, but the hop yards have been converted to orchards, vineyards, row crops, or other uses. There is much cattle and sheep-raising in the hilly areas surrounding the valleys. The watershed contains both dry and irrigated pasture, where hay and grains grow. Besides agriculture, there is a growing trend toward light industry and commercial development, with the major urban center being in the vicinity of Santa Rosa. Timber production, wine production, agricultural and animal products, gravel removal and processing, energy production, and miscellaneous light manufacturing operations are the primary industrial activities in the watershed. Recreation is also a major industry in the Russian River watershed. Besides recreational opportunities at Lakes Mendocino and Sonoma, the Russian River itself is extensively used for water sports such as canoeing, swimming, and fishing. Many summer homes and resorts are located along the Russian River near Healdsburg and between Mirabel Park and Duncans Mills.

There are many factors affecting listed salmonids in the Russian River basin. Generally, the most serious are changes to hydrology, habitat degradation, and habitat loss. Specific factors include operation of WSD and CVD, water diversion, channel maintenance, reservoirs, estuary breaching, artificial propagation and supplementation, mainstem Russian River channelization, agriculture, urban development and others (NMFS 2008).

Russian River Salmonid Populations

Coho salmon existed historically in the Russian River basin as two distinct populations; a large independent population in the lower basin, and a smaller population that occupied the tributaries in the northwest corner of the basin (Bjorkstedt et al. 2005). Now, both the abundance and distribution of coho have declined to the point that they are restricted primarily to tributaries in the lower third of the watershed and there is evidence of a loss of genetic diversity for Russian River coho populations. In 2001 the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP) was initiated to prevent extirpation of coho in the basin, preserve genetic, ecological, and behavioral attributes of Russian River coho by re-establishing self-sustaining runs of coho salmon in tributaries in the Russian River basin (NMFS 2008). At WSH, located at the Warm Springs Dam (WSD) facility, offspring of wild coho salmon are reared for release as juveniles in to tributaries in their historic range with the expectation that a portion of them will return to reproduce naturally.

NMFS (2008) describes the historic population structure for steelhead in the Russian River. Some estimates indicate tens of thousands of steelhead inhabited the Russian River in the early to mid-20th century. Since then, steelhead populations have declined, but they remain widely distributed throughout the basin. The primary exceptions to this are the barriers to anadromy caused by Coyote Valley Dam (CVD) and WSD which have blocked large portions of historical steelhead habitat in the basin (Spence et al. 2012).

Sampling Design

The goal of this project was to implement the California coastal salmonid population monitoring strategy design and methods (CMP Adams et al. 2011) in the Russian River watershed. The CMP uses the Viable Salmonid Population (VSP; McElhany et al. 2000) concept to assess the health and stability of salmonid populations. The four key population characteristics of the VSP conceptual framework are abundance, productivity, spatial structure, and diversity. We estimated abundance (of adult coho and steelhead), spatial structure (of juvenile coho), and diversity (of adult coho and steelhead). We also established a Lifecycle Monitoring Station (LCS) near the mouth of Dry Creek to collect trend data on adults and smolts and to calculate a spawner: redd ratio to use to convert redd abundance to adult abundance. Based on our contract, we focused on life cycle monitoring in Dry Creek during the first year of the project, and conducted both LCS monitoring and basinwide monitoring (adult abundance, spatial structure) during the second year of the project. Work to characterize population diversity consists of characterizing run-timing, age at smoltification and adult return age using a combination of PIT-tagging, otoliths and scale samples collected from adults and scale samples from smolts. Tissue samples have been sent to California Department of Fish and Wildlife (CDFW) for analysis.

During the first year of the project, we convened the Russian River Technical Advisory Committee (RRTAC) that includes members of the statewide CMP Technical and Management Teams, CDFW and NMFS. A result of that effort was a plan describing the monitoring we will implement in order to accomplish the goals of the CMP (Appendix A). The RRTAC met annually during the project period so that team members could provide technical advice and guidance. At the recommendation of the RRTAC, we limited basinwide monitoring to the reaches in the basin known to have both coho and steelhead habitat (the coho-steelhead stratum, described below), in order to maximize the information gains given the available time and budget.

Sample Frame

In 2012, we began a series of meetings with professionals familiar with anadromous salmonid habitat in the Russian River to define the spawning and juvenile rearing habitat space for coho salmon, steelhead, and Chinook salmon in the Russian River basin. Professional expertise and available GIS and related data (e.g., California Fish Passage Assessment Database, NMFS' Intrinsic Potential model) were used to define the extent of coho and steelhead spawning and rearing habitat in all streams of the Russian River Basin. We included portions of streams that contain habitat for one or more of the three species and were downstream of known barriers to upstream migration. This exercise resulted in a universe of habitat divided into 537 reaches approximately 1-3 km in length (2.4 km average) that served as the basis for the reach-based sampling conducted in 2013-2015. Reaches significantly shorter than 1 km were designated "sub-reaches" and attached to the closest "parent-reach". When we sampled a parent-reach, we also sampled associated sub-reaches to make the most of survey crew travel time (Garwood and Ricker 2014). The original sample frame had 108 reaches that contained steelhead and coho habitat (roughly confined to the southern third of the watershed), 348 reaches that contain steelhead habitat only, and 96 reaches that contained Chinook habitat (mostly confined to mainstem Russian River and mainstem Dry Creek). Reaches were drawn using Generalized Random Tessellation Stratified (GRTS) sampling in a manner that allows a spatially-balanced random sample of reaches following the process outlined by Garwood and Ricker (2011). We have continued to refine and update the sample frame throughout the course of the project period based on field reconnaissance and identification of previously unknown barriers to anadromy (**Figure 1**).

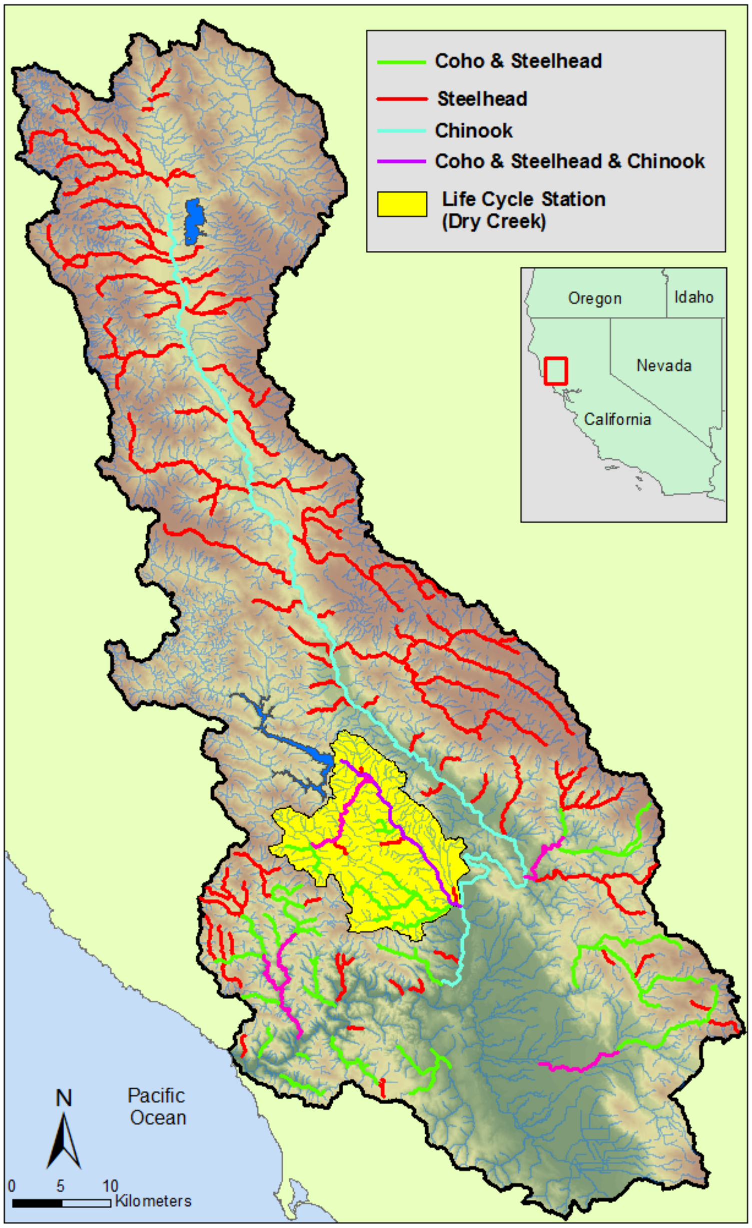


Figure 1. Sample frame for CMP implementation in the Russian River basin, version date: 1/22/2014.

Adams et al. (2011) describe methods for dividing sample reaches into rotating panels (i.e., 3-year, 12-year, and 30-year rotations) for simultaneous estimation of population status and trends. While this is our goal in the Russian, there is still some uncertainty especially in those reaches that contain only steelhead habitat. Depending on how these uncertainties are resolved, a certain level of refinement will be necessary. Therefore, the RRTAC including project staff agreed that we not attempt to implement the rotating panel during this initial two years of the project but should instead wait until additional refinements are incorporated into the sample frame.

A challenge to implementing the GRTS design, is the restricted distribution coho salmon habitat. In order to maintain the statistical integrity of the GRTS design, we employed the soft-stratification as outlined by Adams et al. (2011) and recommended by the RRTAC.

For the first year of the project period, we focused efforts on life cycle monitoring in Dry Creek. Dry creek was chosen as the life cycle station (LCS) because it is the only sub-watershed in the Russian that contains consistent habitat for coho, steelhead and Chinook. There has also been a significant salmonid monitoring infrastructure in Dry Creek since 2009.

For the second year of the project, we continued to operate the LCS on Dry Creek, but also expanded monitoring to include adult abundance monitoring and juvenile spatial structure monitoring in GRTS reaches. We expanded this monitoring into the coho-steelhead stratum based on recommendations from the RRTAC.

Data Collection, QA/QC and Storage

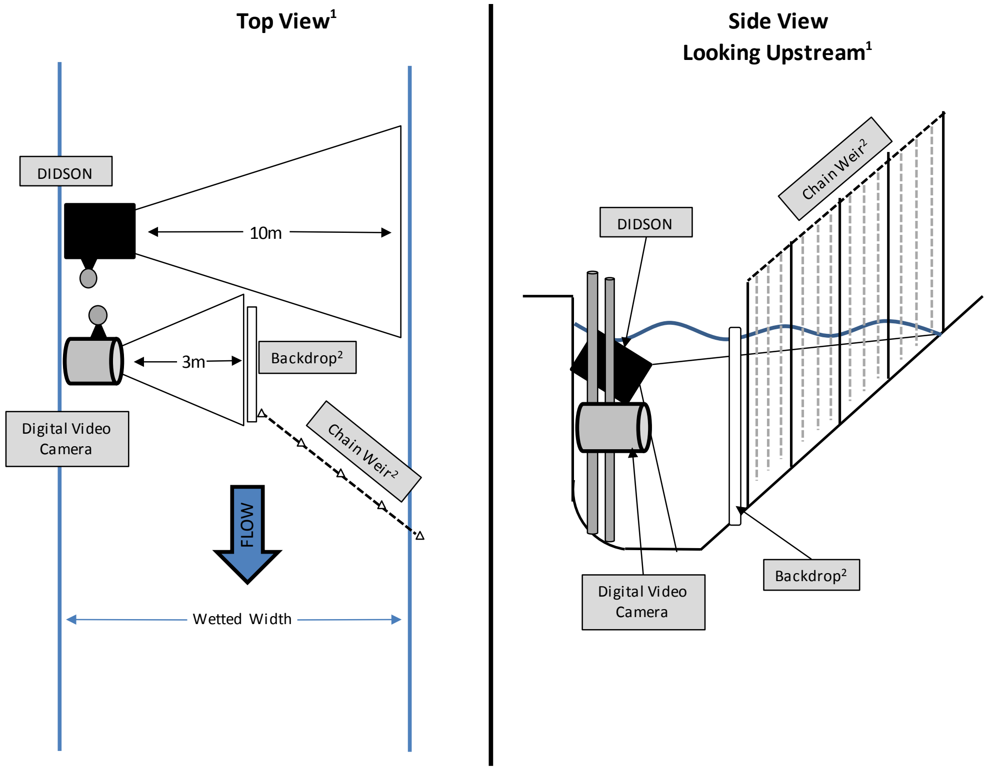
In the following sections we describe the details of field methodology for CMP surveys conducted from 2013 to 2015. All data were recorded on field computers by the field crew. At the end of the survey the crew loaded the data into Excel for initial QA/QC. Weekly and final QA/QC was conducted by the project coordinator before upload to the statewide ASP database.

Field Methods – Life Cycle Monitoring

Adult Abundance (DIDSON/Digital Video & Spawner Surveys)

DIDSON/digital video – We used a DIDSON system combined with continuous underwater video monitoring to count adult salmonids moving into the Dry Creek LCS. We installed the system near the mouth of Dry Creek (RKM 0.36), downstream of all Dry Creek tributaries. The DIDSON and digital video camera were mounted just below the water surface on river right perpendicular to stream flow. The DIDSON was pointed across the stream and slightly downward so that it covered the largest portion of the stream. During the 2014-2015 spawner season, a chain weir was installed starting from river left downstream of the DIDSON/digital video system and ending adjacent to the DIDSON just downstream (**Figure 2**). We installed the chain weir to guide fish closer to the camera and increase the percentage of fish that could be imaged on the digital video system and therefore identified to species. For the 2013-2014 spawning season, the DIDSON was installed November 9, 2013 and removed for the season April 7, 2014. The digital video camera was installed November 29, 2013 and removed (because of high flows and turbidity) February 2, 2014. For the 2014-2015 spawning season, the DIDSON was installed September1, 2014 and removed April 29, 2015. We installed the digital video camera on September 17, 2014. Due to heavy rainfall and high flows in Dry Creek, the digital video camera was removed on December 3, 2014 and the DIDSON was removed on December 10, 2014. On December 31, 2014 flows had come down enough to re-install the DIDSON, but turbidity remained too high for the digital video to be used to identify adults to species for the remainder of the season. On February 7, 2015 debris hit the pole that the DIDSON was mounted on causing it to turn toward the bank. Flows did not subside enough to reposition it until February 17, 2015. Other small gaps in DIDSON data occurred during both the 2013-2014 season and the 2014-2015 season due to power outages, power surges, and general equipment failures (**Figure 3**). DIDSON data were recorded directly to external hard drives which were swapped out every few days. Fish observed on the DIDSON were recorded and length was estimated from the

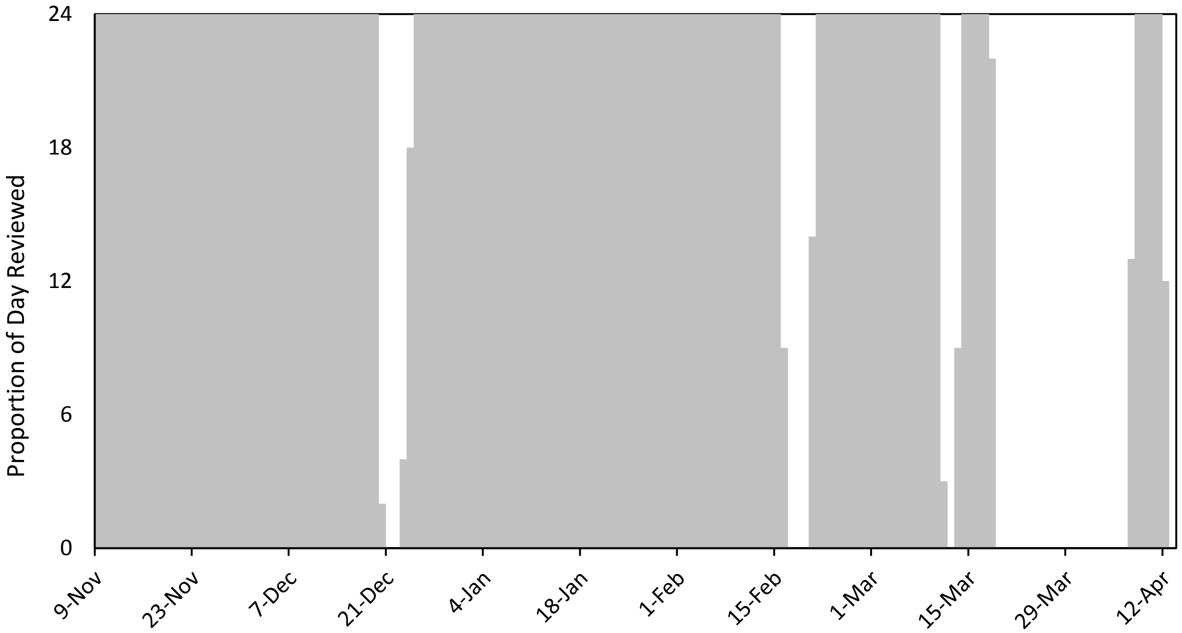
DIDSON. When a fish was observed passing close enough to the DIDSON to be observed on the digital video (~2-3m), the video data from roughly the same time was checked for the fish and its species recorded (if possible).



[1] Diagrams are not to scale

[2] Chain weir and digital video backdrop were used during the 2014-15 spawner season only

Figure 2. Diagram of DIDSON/digital video adult counting station installed near the mouth of Dry Creek (rkm 0.36), Russian River


(a) DIDSON Effort, 2013-14

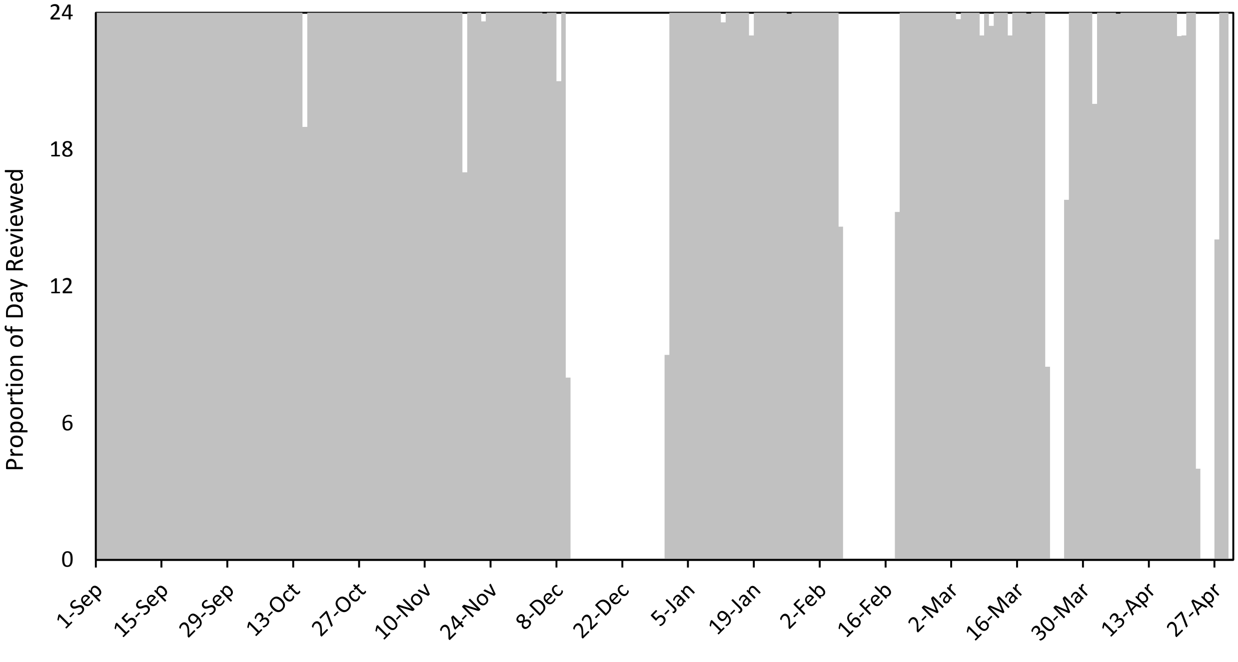

(b) DIDSON Effort, 2014-15

Figure 3. Summary of DIDSON operation on Dry Creek (rkm 0.36) during the (a) 2013-14 and (b) 2014-15 spawner seasons (shaded regions). Unshaded regions indicate gaps in DIDSON operation due to equipment malfunction, high flows or power outages.

Spawner surveys, small tributaries – During both the 2013-2014 and 2014-2015 spawning seasons, we used protocols outlined in Adams et al. (2011) and outlined in Gallagher et al. (2007) to survey the entire Dry Creek watershed for salmonid redds, live fish, and carcasses (excluding mainstem Dry Creek and any reaches or portions of reaches where we were unable to secure landowner access). With few exceptions, reaches were sampled every 10-14 days with the average time between surveys of 13.7 days during the 2013-2014 season and 14.3 days during the 2014-2015 season. Our survey start dates during both seasons coincided with the first rains of the winter sufficient to connect tributaries to the mainstem. During the 2013-2014 spawner season, tributaries connection occurred the first week of February and surveys commenced February 10 beginning with reaches that had sufficient visibility. During the 2014-2015 spawner season, tributary connection occurred during the first week of December and surveys commenced December 2 beginning with reaches that had sufficient visibility. (Minimum visibility threshold for surveys was 1.5 meters.) Reaches were surveyed by two observers walking upstream from the bottom of the reach to the top. When a redd was encountered it was measured, marked with flagging, and a GPS waypoint was taken. If there were fish actively guarding or digging a redd, measurements were estimated 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, if possible they were measured and identified to species. Carcasses were tagged with a 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. During the 2014-2015 season, GPS waypoints were taken for all live fish and carcass observations.

Spawner surveys, mainstem Dry Creek– Because of nearly constant releases from WSD, mainstem Dry Creek is highly channelized, incised, and deep. These conditions required us to adjust data collection methods relative to those described for smaller tributaries. The entire 22 km length of the mainstem from the mouth to WSD was divided into two sections that were floated by simultaneously by two teams of two observers in kayaks. The entire Dry Creek mainstem was floated weekly to biweekly 11 times during the 2013-2014 spawner season starting on October 23 and ending April 8. During the 2014-2015 spawner season, the mainstem was floated 3 times on November 11, November 19, and November 25. After the November 25 survey, heavy rains, high flows, and persistent high turbidity prevented subsequent surveys. Redds and live fish were counted and species estimated by crews in the field. However, because of the depth and velocity of Dry Creek, redds were not measured. During the 2013-2014 spawner season, GPS waypoints were taken on riffles containing redds and the total number of redds and fish associated with the waypoint was recorded. During the 2014-2015 season, each redd encountered was assigned an individual GPS waypoint and the number of fish on redds was recorded. GPS point locations were also recorded for observations of individual fish not associated with redds. During the 2013-2014 spawner season, GPS coordinates were recorded on Garmin (Etrex 20) GPS units. During the 2014-2015 GPS points were collected with Trimble (Pro XH) GPS units.

Smolt Abundance

We employed a combination of monitoring methods in order to accomplish tasks related to life cycle monitoring for smolts. Methods included continuously-operated stationary PIT antennas and downstream migrant traps combined with snorkeling and electrofishing for juveniles.

PIT antenna array – We installed and began continuous operation of a full-duplex flat plate PIT antenna array near the downstream end of Dry Creek at rkm 0.36 (**Figure 4**). The six antenna system was controlled with a series of antenna control nodes (one node per antenna) connected to a single master controller that logged time and date of tag detections. The configuration of antennas within the array allowed estimation of antenna efficiency for smolts as they migrated downstream. Except for brief periods of maintenance (up to a few hours), we have operated this system continuously since installation on October 29, 2013.

Figure 4. Paired, flat-plate PIT antenna array near the mouth of Dry Creek (rkm=0.36). Array consists of an upstream set of three antennas and a downstream set of three antennas. Individual antennas within a set are 20 feet long and anchored to the stream bed such that each set spans the wetted width of Dry Creek during all but high winter flows.

Downstream migrant traps – We operated downstream migrant traps (DSMT) on mainstem Dry Creek (rkm 3.30) and Mill Creek (rkm 2.00) (**Figure 5**). Mill Creek is the only significant salmonid-bearing tributary that enters mainstem Dry Creek downstream of the Dry Creek DSMT (rkm 1.1). To overcome the issue of underestimating coho and steelhead smolts if we were to only base our estimate on data from the Dry Creek DSMT (i.e., by not including Mill Creek smolts), we intended to combine estimates at the Dry Creek DSMT with estimates at the Mill Creek DSMT.

At the mainstem Dry Creek trap site we used a rotary screw trap with a 1.5 m diameter cone and on Mill Creek we used a funnel net to capture juvenile salmonids moving downstream. Weir panels and/or metal conduit were installed adjacent to and extending upstream from the upstream end of each trap in a "V" configuration (i.e., trap at the downstream apex of the "V") in order to divert downstream migrating salmonids into the trap that may have otherwise avoided the trap. Fish captured in the trap were identified to species and enumerated. A subsample of each species was anesthetized and measured for fork length each day. All fish were released downstream of the first riffle located downstream of the trap except for Chinook smolts on Dry Creek, some of which were marked and released upstream to estimate abundance (see 'Statistical Analysis Methods' section). Dates of operation for the Dry Creek trap were March 18 – August 14, 2014 and March 18 – July 30, 2015. Dates of operation for Mill Creek were March 12 – May 23, 2014 and March 11 – May 27, 2015.

Snorkeling and electrofishing for juveniles – In coastal California systems, obtaining accurate estimates of steelhead smolts is difficult. First, because steelhead smolts are excellent swimmers, they are adept at avoiding fixed DSMTs which leads to extremely low trap efficiency in tributaries to the Russian River including Dry Creek (Manning and Martini-Lamb 2011) and elsewhere (S. Ricker, D. Wright personal communication). Exacerbating the problem is the fact that steelhead smolt run-timing in coastal systems typically begins and peaks during mid to late winter when trap operation is unsafe to personnel and gear because of high flows associated with winter storms. To help overcome this problem, we piloted a monitoring approach that included overwinter survival estimates of juvenile steelhead that we PIT-tagged in Dry Creek tributaries (in a spatially-balanced manner) during electrofishing surveys conducted the prior year (or years depending on smolt age). Abundance of PIT-tagged smolts produced from Dry Creek tributaries could then be estimated from a combination of captures in the Dry Creek DSMT and on the PIT antenna array at the mouth of Dry Creek using a multistate mark-recapture model Horton et al. (2011). In order to account for the non-PIT-tagged portion of the population, we also conducted snorkel surveys immediately prior to the late summer/early fall electrofishing surveys mentioned above (an approach similar to Hankin and Reeves (1988). In combination, these surveys would lead to a prewinter abundance estimate for juvenile steelhead and facilitate a prewinter ratio of PIT-tagged to non-PIT-tagged juveniles for use in expanding the estimate of PIT-tagged smolts to an overall count (PIT-tagged + non-PIT-tagged) of steelhead smolts produced from Dry Creek tributaries.

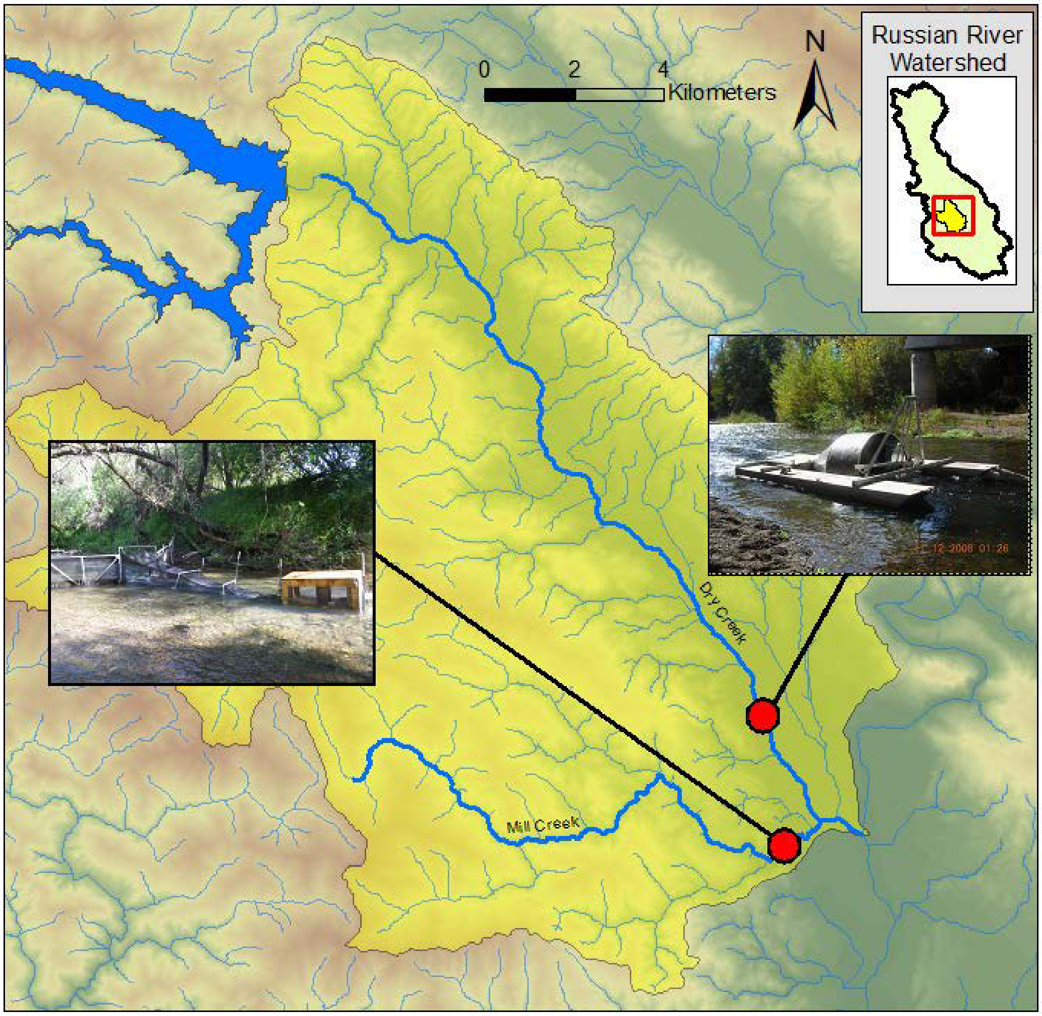


Figure 5. Downstream migrant trapping sites in the Dry Creek LCS on Dry Creek (rkm 3.30) and Mill Creek (rkm 2.00), Russian River Basin.

Field Methods – Coho-Steelhead Stratum Monitoring

Adult Abundance (Spawner Surveys)

During the 2014-2015 spawner season only, we employed the methods recommended by Adams et al. (2011) and outlined in Gallagher et al. (2007) to survey for redds, live fish, and carcasses in the coho-steelhead sample frame. Gallagher et al. (2010a) recommends a sampling rate of 15% or 41 reaches (whichever results in fewer reaches) to maximize statistical power. Based on recommendations from the RRTAC, we chose to sample as many reaches as possible given budget constraints. This resulted in a sample size of 32 reaches representing approximately 30% of the coho-steelhead sample frame. Because of lack of landowner access, we were forced to skip many of the lowest draw GRTS reaches (**Table 1**). Surveys began concurrently with LCS spawner surveys on December 2 and were completed April 15.

Table 1. List of surveyed and unsurveyed reaches in the coho-steelhead stratum to estimate total adult abundance during the 2014-15 spawner season, Russian River Basin, California (reaches ordered by GRTS draw order).

Draw Order	Tributary	Location Code	Surveyed	Reason for Exclusion/Inclusion
6	Black Rock Creek	103	N	Logistics
9	Santa Rosa Creek	190	N	Access
10	Felta Creek	262	N	Access
27	East Austin Creek	98	N	Logistics
35	Gray Creek	109	N	Logistics
37	Kidd Creek	90	Y	Low Draw Order
44	Mark West Creek	178	N	Access
45	Redwood Creek	304	Y	Low Draw Order
56	Mark West Creek	174	N	Access
62	Redwood Creek	302	Y	Low Draw Order
90	Willow Creek	76	Y	Low Draw Order
94	Austin Creek	83	N	Access
96	Green Valley Creek	153	Y	Low Draw Order
107	Yellowjacket Creek	307	N	Access
118	Porter Creek (MWC)	229	N	Access
121	Mark West Creek	179	Y	Low Draw Order
122	Porter Creek (MWC)	225	N	Access
123	Purrington Creek	165	Y	Low Draw Order
129	Santa Rosa Creek	184	N	Access
150	Pena Creek	278	Y	Low Draw Order
165	Woods Creek	282	Y	Low Draw Order
168	Santa Rosa Creek	187	N	Access
173	Gilliam Creek	105	N	Logistics
175	Maacama Creek	287	N	Access
189	Green Valley Creek	154	Y	Low Draw Order
190	Mark West Creek	176	Y	Low Draw Order
207	Santa Rosa Creek	186	N	Access
218	Mark West Creek	177	Y	Low Draw Order
227	Sheephouse Creek	78	Y	Low Draw Order
238	Porter Creek	237	Y	Low Draw Order
240	Maacama Creek	290	Y	Low Draw Order
252	Redwood Creek	303	Y	Low Draw Order
262	Wine Creek	273	Y	Low Draw Order
264	Santa Rosa Creek	189	Y	Low Draw Order
275	Maacama Creek	289	N	Access
278	Porter Creek (MWC)	227	N	Access
284	Gray Creek	108	N	Logistics

Draw Order	Tributary	Location Code	Surveyed	Reason for Exclusion/Inclusion
297	East Austin Creek	97	N	Logistics
301	Pena Creek	277	Y	Low Draw Order
312	Austin Creek	86	Y	Low Draw Order
318	Wallace Creek	264	N	Access
321	Mark West Creek	175	Y	Low Draw Order
324	Dutch Bill Creek	127	Y	Low Draw Order
325	Porter Creek	238	N	Access
327	Mill Creek	257	Y	Low Draw Order
330	Redwood Log Creek	280	N	Access
335	Pena Creek	276	Y	Low Draw Order
337	Austin Creek	85	Y	Low Draw Order
338	Felta Creek	263	Y	Low Draw Order
346	Mill Creek	259	Y	Low Draw Order
355	Porter Creek (MWC)	226	N	Access
363	Pechaco Creek	279	Y	Low Draw Order
366	East Austin Creek	92	Y	Low Draw Order
368	Pena Creek	275	N	Access
374	East Austin Creek	94	N	Logistics
378	Mission Creek	134	N	Access
379	Mill Creek	258	Y	Low Draw Order
386	Santa Rosa Creek	185	N	Access
392	Mill Creek	254	Y	Low Draw Order
396	East Austin Creek	95	N	Logistics
397	Felta Creek	261	Y	Low Draw Order
409	East Austin Creek	93	N	Logistics
412	Grape Creek	271	Y	Low Draw Order
413	Austin Creek	82	N	Logistics
428	Kellogg Creek	305	N	Access
437	Hulbert Creek	135	N	Logistics
438	Wallace Creek	265	Y	Low Draw Order
441	Ward Creek	114	N	Logistics
444	Porter Creek	235	Y	Low Draw Order
449	Austin Creek	87	Y	Low Draw Order
452	Thompson Creek	107	N	High Draw Order
453	Freezeout Creek	80	N	High Draw Order
464	Dutch Bill Creek	126	Y	Broodstock
470	East Austin Creek	96	N	High Draw Order
477	Devil Creek	110	N	High Draw Order
482	Kidd Creek	91	N	High Draw Order
487	Pena Creek	274	Y	LCS
504	Weeks Creek	232	N	High Draw Order

Draw Order	Tributary	Location Code	Surveyed	Reason for Exclusion/Inclusion
507	Willow Creek	77	Y	Broodstock
509	Hulbert Creek	136	N	High Draw Order
511	Palmer Creek	266	Y	LCS
514	Ward Creek	115	N	High Draw Order
517	Black Rock Creek	104	N	High Draw Order
518	Porter Creek	236	N	High Draw Order
521	Mill Creek	256	Y	LCS
544	Grape Creek	272	Y	LCS
545	Mark West Creek	180	N	High Draw Order
548	Devil Creek	111	N	High Draw Order
556	Austin Creek	81	N	High Draw Order
557	Hulbert Creek	134	N	High Draw Order

Juvenile Coho Spatial Structure

We used a modified version of the snorkel survey protocol of Garwood and Ricker (2013) to estimate occupancy for juvenile coho in the coho-steelhead stratum during the summer of 2014 only. We attempted to sample as many of the lowest GRTS drawn reaches in the coho-steelhead stratum as time and landowner access would allow. Surveys began May 28 and were completed August 22. 59 reaches were surveyed representing 55% of the coho-steelhead stratum. Teams of two observers sampled selected reaches on foot walking from the downstream end of the reach to the upstream end. Surveys included 2 passes, the first pass sampling every other pool in the reach (50%), the second pass sampling every 4th pool in the reach (25% of all pools and 50% of pools sampled on the first pass). Previous summer snorkel surveys in the Dry Creek LCS yielded widely varying counts from first to second pass. For that reason, we increased second pass surveys from 10% of reaches to 25%. Previous surveys also indicated that the contribution to the juvenile population from habitat units other than pools (flatwaters and riffles) was insignificant, thus we sampled only pools. A coin flip determined whether observers snorkeled odd- or even-numbered pools. Units were selected for sampling based on minimum pool metrics similar to Garwood and Ricker (2013). At each selected pool, one or two (depending on the size of the unit) observers snorkeled the unit and counted the number of salmonids present. Dive lights were used so that salmonids in complex habitat (woody debris, overhanging ledges, etc.) could be effectively counted. Salmonids were grouped into age class based on size. Habitat units selected for second pass were flagged by the first pass crew, and GPS locations were collected for all snorkeled pools. Non-salmonids were not counted but their presence was noted and approximate density estimated.

Statistical Analysis Methods

Spawner to Redd Ratio

Because of the difficulty in determining the true redd abundance in mainstem Dry Creek and the difficulty of determining the species of fish counted on the DIDSON during times when the digital video camera was not operating, we were not able to calculate a spawner to redd ratio in the Dry Creek LCS. When spawner to redd ratios were needed for calculating estimates of adult abundance from redd surveys we used spawner to redd ratios for coho and steelhead calculated in Gallagher et al. (2010b) as the grand mean of all basins and all years for (coho: 2.33 spawners/redd; steelhead: 1.22

spawners/redd). For Chinook, we used the spawner to redd ratio cited in Adams et al. (2011) (2.5 spawners/redd).

Redd Species Classification

We used two methods to classify unknown redds to species. The first was the method 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. We found this method to be somewhat useful in distinguishing coho redds from steelhead redds, but it incorrectly classified 100% of known Chinook redds as coho redds leading to and inflated coho abundance estimate. We also used the non-parametric K-nearest neighbor algorithm (knn) (Ricker et al. 2013). This method appeared to correctly classify Chinook redds more often than the Gallagher/Gough method, but seemed to underestimate coho abundance, though we did not have time for a formal assessment of the performance of this method in the Russian River watershed. We decided to use a modified version of the Gallagher and Gallagher (2005) and Gough (2010) logistic regression models. We classified any redds that had identifiable fish guarding or digging them as certainty 1 redds. For all certainty 1 redds, we did not use the regression equations to classify species instead relying on the classification made by the crew in the field. We also did not use the regression equations to classify any redds that field crews identified as Chinook at any level of certainty.

Adult Abundance – Life Cycle Monitoring

We came up with two main approaches to estimating adult returns to the Dry Creek LCS based on whether or not digital video data was available to prorate DIDSON counts to species.

Our preferred approach for estimating adult returns to Dry Creek incorporated both DIDSON and digital video data and therefore could only be used during the time that both were operating. With this method, salmonids counted on the DIDSON were apportioned to species based on the proportions of salmonids identified with digital video. Proportions of species obtained from the digital video could be pooled based on an appropriate time frame (by day, week, month, or over the whole season) based on the number of fish identified on the video to species. During the 2013-14 spawner season, the ratio of fish identified on the digital video to total fish counted on the DIDSON was low, so we pooled the species ratio from the digital video into a single ratio for the entire period that the digital video was operation. Because we were able to identify a larger proportion of salmonids on the digital video during the 2014-15 spawner season, we used daily species ratios from the digital video to prorate unknown fish counted on the DIDSON for each day. Any fish returning to Dry Creek before the video camera was operational (during both seasons) were assumed to be Chinook.

When the digital video was not operating our approach relied on the premise that adults returning to Dry Creek that survive to spawn have one of three fates: (1) they enter and are retained for spawning at WSH; (2) they spawn in Dry Creek tributaries; (3) they spawn in mainstem Dry Creek. We are able to count WSH fish and estimate tributary spawners; however, because we did not conduct spawner surveys in mainstem Dry Creek throughout the coho and steelhead spawning period, we were unable to directly estimate spawning in mainstem Dry Creek. Nevertheless, we could indirectly estimate that number by subtracting the “known location” spawners from the total DIDSON count to arrive at an estimate of the number of adults that spawned in mainstem Dry Creek. The next step was to assign species to the estimate of mainstem Dry Creek spawners. The approach varied by year depending on the information available. The basic concept, however, was to incorporate information about species composition from tributary spawner surveys, hatchery spawners and species-specific run-timing (see Appendix B for more detail).

Smolt Abundance – Life Cycle Monitoring

Coho salmon – We developed expanded counts of the number of coho smolts reaching the mouth of Dry Creek from detections at the PIT antenna near the mouth of Dry Creek (rkm=0.36) for the 2014 and 2015 smolt years (2013 and 2014 hatch years). The steps we used were:

1. Calculate the antenna detection efficiency of the PIT antenna array as the proportion of PIT-tagged coho smolts detected on the lower set of antennas in the array that were also detected on the upper set of antennas in the array during the smolt outmigration period (Zydlewski et al. 2006) (we assumed the period was March 1 – June 30 for both cohorts);
2. Count the number of PIT-tagged coho known to be upstream of the PIT antenna array prior to the smolt outmigration period[2];
3. Count the number of fish from step 2 that were detected on the upper set of Dry Creek antennas in the array during the smolt migration period and expand that count by the antenna efficiency from step 1.

The result from step 3 only provides an expanded count of the number of PIT-tagged coho smolts at the mouth of Dry Creek for a given cohort. In order to expand this count to include non-PIT-tagged coho smolts, we took additional steps:

4. Calculate the proportions of PIT-tagged fish originating from each stream in the system that were detected on the Dry Creek PIT antenna during the smolt migration period;
5. Calculate the ratio of PIT-tagged: non-PIT-tagged fish present in each stream prior to the smolt migration period[3];
6. Expand the proportions from step 4 by the stream-specific proportions from step 5.

In Dry Creek, the calculations in steps 1 – 6 above were based on hatchery-origin releases. In order to include natural-origin coho smolts, we took additional steps:

7. Calculate the ratio of hatchery-origin: natural-origin fish from sampling at DSMTs;
8. Apply this ratio to the expanded count from step 7.

Steelhead – Our intention was to pilot a project to develop an expanded count for steelhead smolts using steps similar to those outlined for coho except that we would have substituted steps where we relied on hatchery-origin fish with methods outlined in the 'Field Methods – Life Cycle Monitoring' section (i.e., snorkeling, electrofishing and PIT-tagging of juveniles in the year(s) prior to smoltification). Due to extremely low juvenile steelhead abundance in both project years, however, we were unable to generate the data necessary to derive expanded counts of steelhead smolts. Therefore, we report minimum DSMT counts as well as the proportion of steelhead smolts detected on the Dry Creek antenna array that were PIT-tagged during monitoring efforts in mainstem Dry Creek related to NMFS' Russian River Biological Opinion.

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[2] In our case this was simply the number of PIT-tagged fish released as part of the Russian River coho recovery effort. For systems where hatchery fish are not released, the number of fish PIT-tagged during pre-smolt sampling efforts would serve the same purpose.

[3] In our case this was known for hatchery-origin coho because we had an absolute count of PIT-tagged and non-PIT-tagged released by location. For systems where hatchery fish are not released, the abundance of non-PIT-tagged fish must be estimated by some other means (e.g., Hankin and Reeves (1988), 'Field Methods – Life Cycle Monitoring' section).

Chinook salmon – Each day during the smolt trapping season on Dry Creek, a random sample of up to 100 Chinook smolts ($\geq$60 mm) were fin-clipped or PIT-tagged and released approximately 100 m upstream of the trap for the purpose of estimating population abundance using program DARR (Bjorkstedt 2005). Fin-clipped or previously PIT-tagged fish that were recaptured in the trap were noted and released downstream. Because of monitoring data that provides evidence for negligible Chinook production downstream of the Dry Creek DSMT (Water Agency and UC/Sea Grant, unpublished data), we made no attempt to estimate Chinook smolt abundance on Mill Creek but instead report minimum counts of the few Chinook smolts captured at that site.

Adult Abundance – Coho-Steelhead Stratum

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 adjust 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 reds are either marked and/or recaptured on each survey occasion, and redds are individually identified and marked with individual 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, and “die” when they become obscured from view.

Redd survival from survey occasion $i-1$, to occasion i, S_i, can be estimated as the proportion of redds that were newly observed and flagged or previously flagged and recaptured on occasion $i-1$, M_{i-1}, that are still visible on occasion i, R_i:

$$\hat{S}_i = \frac{R_i}{M_{i-1}}$$

We chose to pool all survey occasions to construct a pooled survival that was applied to redd counts for estimation of total redd construction within a given reach and year. This pooled survival is defined as follows:

$$\hat{S}_p = \frac{\sum_{i=1}^{k-1} R_{i+1}}{\sum_{i=1}^{k-1} M_i}$$

where $\hat{S}_p$ is the pooled survival rate of flagged redds when i denotes the survey occation and k is the total number of survey occasions. The numerator is the sum of recaptured redds from the second survey occasion to the last survey occasion, and the denominator is the sum of marked redds and recaptured redds that were still visible from the first occasion to the second to last occasion. We estimated total redd abundance within a sample stream reach as:

$$\hat{\tau}_j = B_0 + \frac{\sum_{i=2}^{k} B_i - 1}{\sqrt{\hat{S}_p}}$$

where $\hat{\tau}_j$ is the estimate of the total number of redds within a sample reach j; B_i is the number of new redds on the ith survyey occasion; k is the total number of survey occasions; and B_0 is the number of redds observed on the first survey of the season. The numerator of the second term is the sum of all new redds observed from the second occasion to the last occasion, divided by survival of flagged redds pooled across all survey occasions for which at least one new redd of the target species was observed (Ricker et al. 2014).

We estimated total abundance of redds and spawner using the methods outlined in Adams et al. 2011. Total redd abundance was calculated with a Simple Random Sample estimator for total:

$$\hat{T} = N\left(\frac{\sum_{j=1}^{n}\hat{\tau}_j}{n}\right)$$

where N is the number of reaches in the coho-steelhead stratum, n is the number of reaches surveyed, and $\hat{\tau}_j$ is the total number of redds present of a certain species in sample reach *j*. The standard error of $\widehat{\mathrm{T}}$ was calculated using between reach variance derived from bootstrap resampling, and applying the finite population correction factor:

$$se(\hat{T}) = N\sqrt{\left(1-\frac{n}{N}\right)\hat{\theta}_b + \frac{1}{N_n}\left(\sum_{i=1}^{n}\hat{\theta}_w\right)}$$

Where $\hat{\theta}_b$ is the between-reach variance of bootstrapped replicates, and $\hat{\theta}_w$ is the within-reach variance of bootstrap replicates. The bootstrap resampling process is described in detail in Ricker et al. (2014). N is the total number of reaches in the coho-steelhead stratum and n is the total number of reaches sampled during the 2014-2015 spawner season. Carcasses were marked and recaptured following the procedure outlined in Gallagher et al. (2007), but the number of carcasses marked and recaptured was not sufficient to use a Jolly-Seber carcass capture-recapture estimator. We used the spawner: redd ratio described above (*Spawner to Redd Ratio*) to convert the total redd abundance in to a total spawner abundance following the protocols outlined in Adams et al. (2011).

Juvenile Coho Spatial Structure – Coho-Steelhead Stratum

Spatial structure monitoring for coho salmon was conducted by snorkeling randomly-selected, spatially-explicit (GRTS) reaches designated as containing habitat for juvenile coho. We employed 1-pass dive counts in every 2nd pool (50%) and 2-pass independent dive counts in every 10th pool (10%) in 59 of the 108 ordered GRTS reaches (54%) in order to estimate the probability of occupancy by coho salmon YOY (data from pools in ten sub-reaches were included in the 59 GRTS reaches). Because of our GRTS sampling design, this sample space represents our area from which to draw inferences for the entire juvenile coho habitat space in the Russian River watershed. Because of imperfect detection probability, we used the multi-scale occupancy estimation model of Nichols et al. (2008) to estimate the probability of occupancy at the pool scale given that the reach is occupied (θ) in addition to the probability of occupancy at the reach scale given that the area is occupied (ψ). The multi-scale occupancy model is based on detection probabilities estimated at the pool-level (*p*) from multiple sampling events in locations (pools) in the reach which, in turn, facilitate occupancy estimates at both the pool and reach level. In practice, θ can be interpreted as the proportion of pools within a reach that are occupied given coho YOY are present in the reach and ψ is an estimate of the proportion of reaches within the sample space that are occupied given coho YOY rea present in the sample space. Because these probabilities are conditional, their product is an estimate of the percent area occupied (PAO) which is the overall area in the sample space that is occupied by coho.

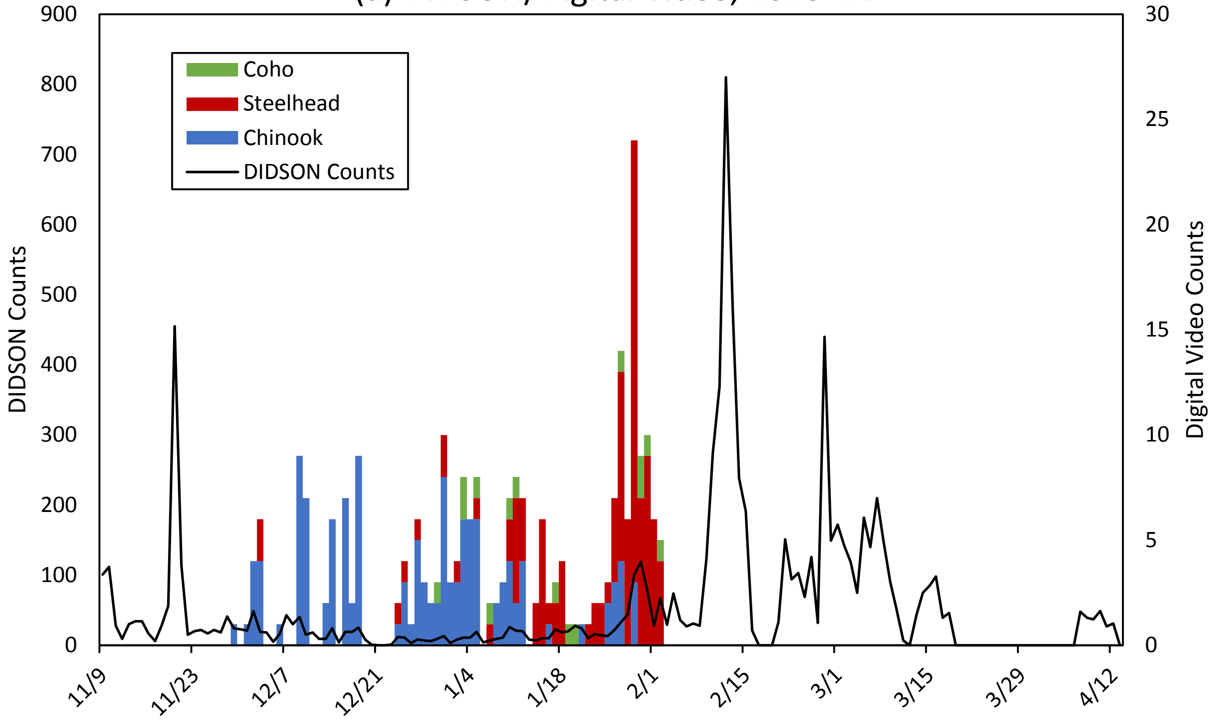
Results

Life Cycle Monitoring

Adult Abundance – 2013-14 Spawner Season

The DIDSON was installed at the mouth of Dry Creek on November 9, 2013 and removed for the season April 15, 2014. One large gap in DIDSON data occurred from March 18, 2014 to April 7, 2014 due to equipment failure. During the 2013-14 spawner season we recorded and reviewed over 2,900 hours of DIDSON footage over the course of the season **.** We counted 8,417 salmonids entering Dry Creek and of these 253 were visible and identifiable on the digital video: 131 Chinook, 107 steelhead, and 15 coho (**Figure 6**a).

(a) DIDSON/Digital Video, 2013-14



(b) DIDSON/Digital Video 2014-15

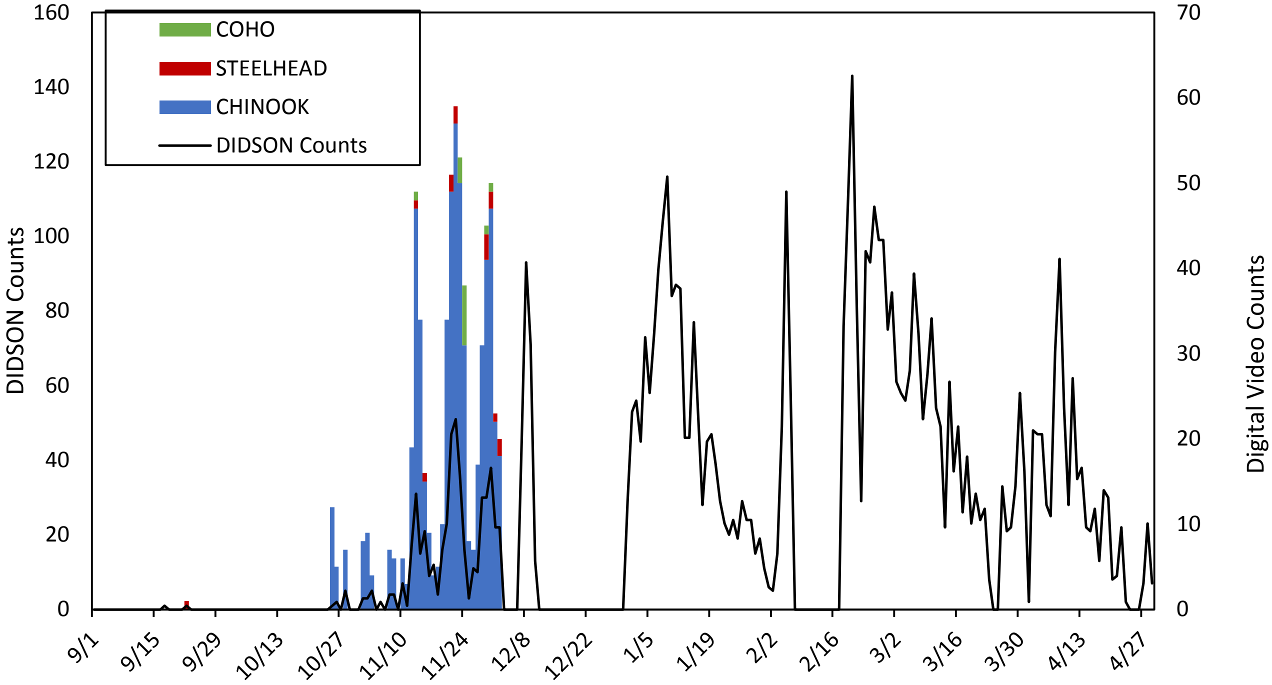
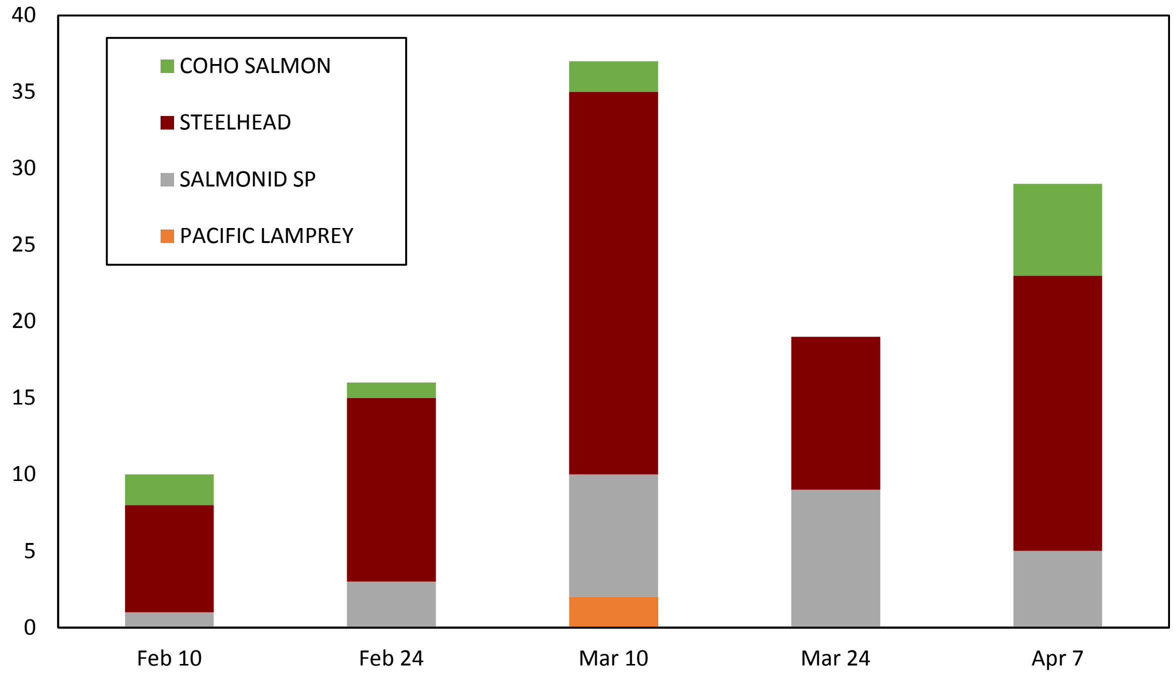


Figure 6. Summary of DIDSON/digital video data at the adult counting station on Dry Creek (rkm 0.36) for the 2013-14 spawner season (a) and the 2014-15 spawner season (b).

We conducted 94 surveys in 12 tributaries in the Dry Creek LCS (not including mainstem Dry Creek) during the 2013-14 spawner season. We observed 109 new salmonid redds; 11 coho, 72 steelhead, and 26 unidentified salmonid redds as well as 2 pacific lamprey redds (**Figure 7**a). We counted 44 live fish; 20 coho, 22 steelhead, and 2 unidentified salmonids (**Figure 8**a). We also counted 14 carcasses: 4 coho, 6 steelhead, 1 Chinook, and 3 unidentified salmonid (**Figure 9**a). Of these 14, 8 were marked with individual tags but none were recaptured. We conducted weekly to biweekly spawner surveys via kayak over the entire length of mainstem Dry Creek from October 23, 2013 to April 8, 2014. Over the course of these surveys, we counted a total of 1556 salmonid redds; 1328 Chinook redds, and 228 steelhead redds. Crews also counted 889 live salmonids; 821 live Chinook, and 68 live steelhead. Species designations for both redds and live fish were made solely on the basis of the date redds and fish were observed. All redds and fish observed during and after the February 20, 2014 spawner survey were designated steelhead. Prior to that date, all redds and fish were designated Chinook. Carcasses were not counted.

We estimated adult returns of 170 coho, 6936 steelhead and 1311 Chinook to the Dry creek LCS during the 2013-14 spawner season. These estimates were based on DIDSON/digital video data from the Dry Creek adult counting station and returns to WSH (**Table 2**).

(a) LCS Redds, 2013-14



(b) LCS Redds, 2014-15

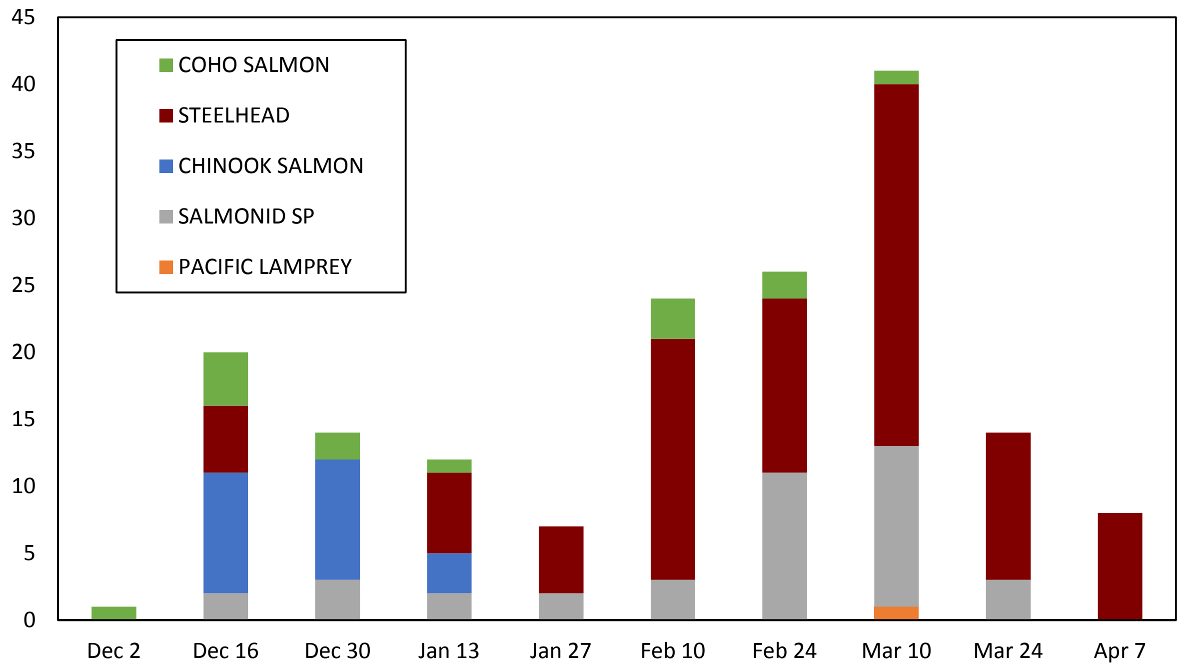
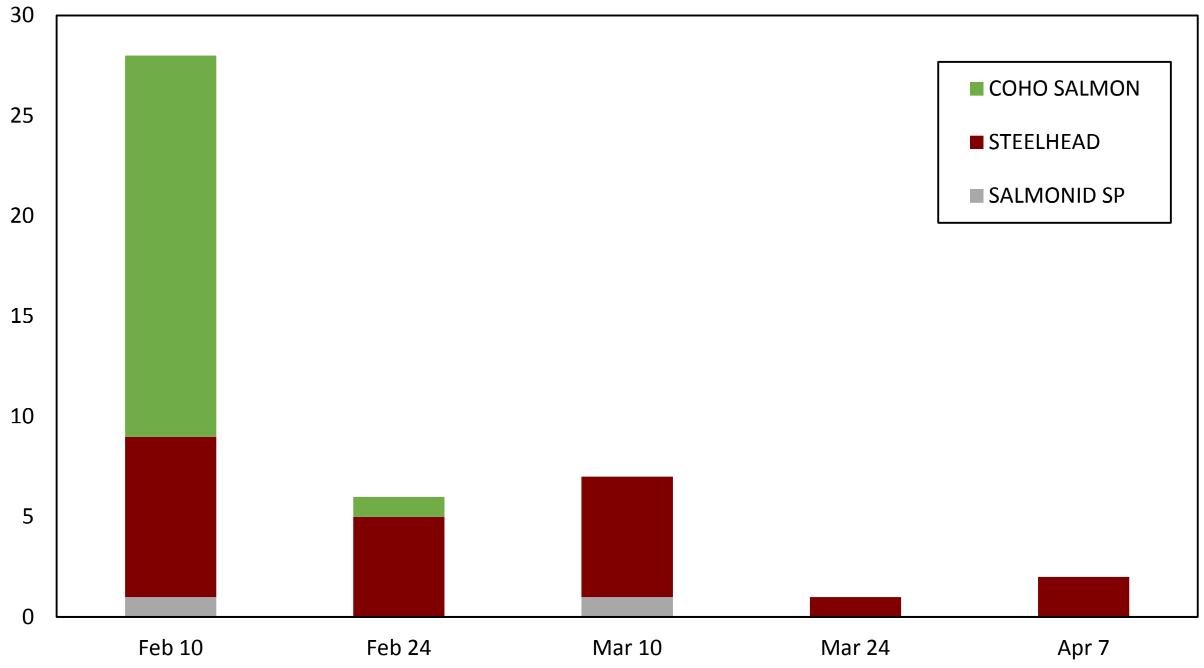


Figure 7. Total new redds counted in the Dry Creek watershed (excluding mainstem Dry Creek) during the 2013-14 spawner season (a) and 2014-15 spawner season (b).

(a) LCS Live Fish, 2013-14



(b) LCS Live Fish, 2014-15

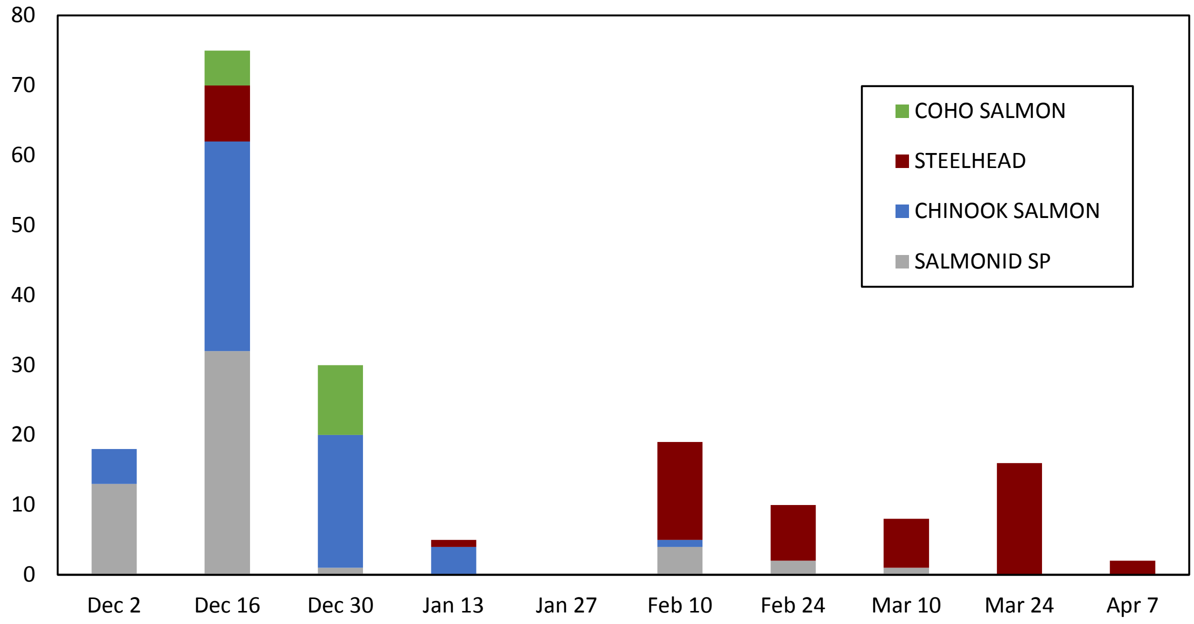
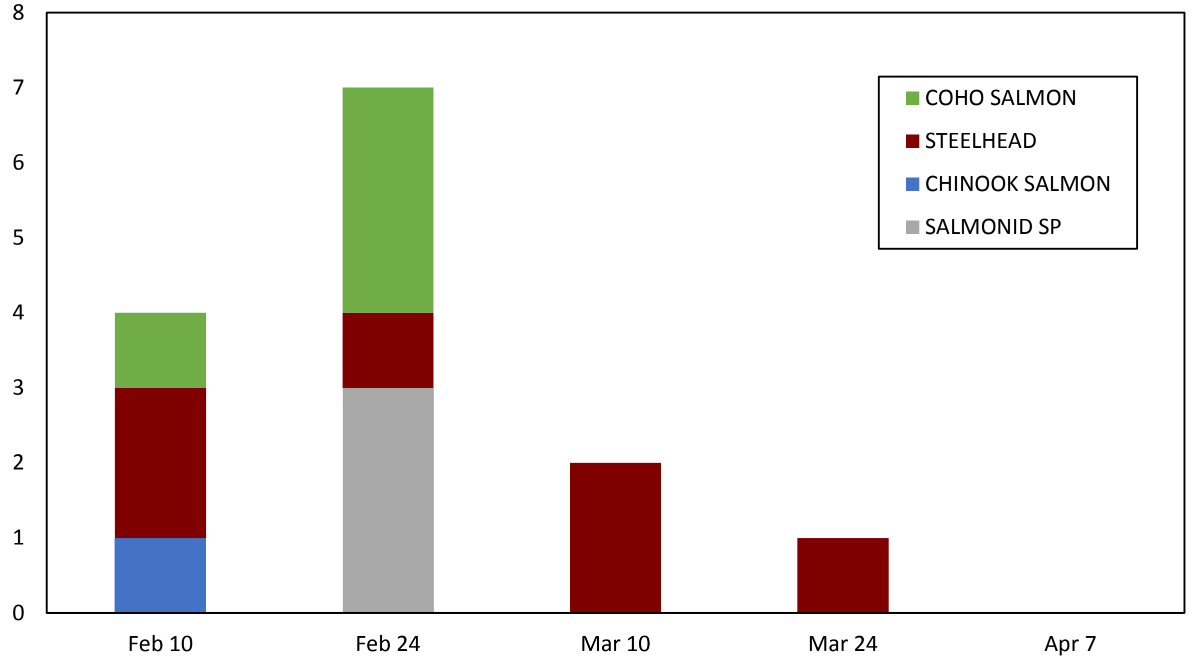


Figure 8. Total live adult salmonids counted in the Dry Creek watershed (excluding mainstem Dry Creek) during the 2013-14 spawner season (a) and 2014-15 spawner season (b).


(a) LCS Carcasses, 2013-14

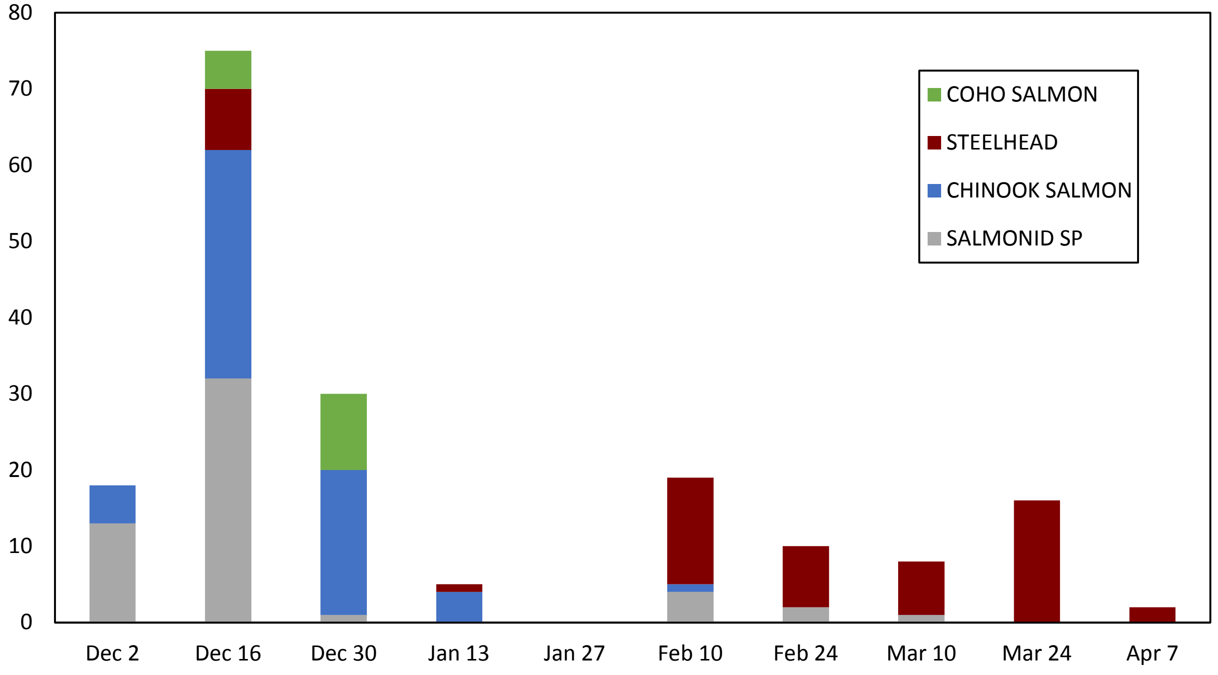

(b) LCS Carcasses, 2014-15

Figure 9. Total adult salmonid carcasses counted in the Dry Creek watershed (excluding mainstem Dry Creek) during the 2013-14 spawner season (a) and 2014-15 spawner season (b).

Table 2. Summary of DIDSON/digital video adult counting station estimates for total adult salmonid returns to the Dry Creek LCS during the 2013-14 spawner season.

Period	Digital video	Method	Metric	Chinook salmon	Coho salmon	Steelhead	Unknown	Total
Nov 9 - Feb 2	On	1	DIDSON				2531	
			Video count	131	15	107		253
			Video proportion	0.518	0.059	0.423		
			subTotal[1]	*1311*	*150*	*1070*	-	
Feb 3 - Apr 27[2]	Off	2b	DIDSON	-	-	-	5886	
			Hatchery count	0	6	1743		1749
			Hatchery proportion	0	0.003	0.997		
			subTotal[3]	*0*	*20*	*5866*		
			TOTAL	*1311*	*170*	*6936*		

[1] Proration of DIDSON count based on proportions of species identified on digital video pooled over the entire time the camera was operating.

[2] Includes one large gap in DIDSON data (see **Figure 3**a).

[3] DIDSON counted fish after digital video removal assigned to species based on proportion of species returning to WSH.

Smolt Abundance

The trap counts for Dry Creek and Mill Creek in both years included wild steelhead smolts and a mix of hatchery-origin and untagged (no CWT or PIT) coho. The untagged coho were most likely naturally-produced. Dry Creek trap catches included several-thousand Chinook while the Mill Creek DSMT only captured a few individuals in 2014 (**Table 3**).

The 2013-14 and 2014-15, the expanded counts of coho smolts were 11,155 and 12,538 and the estimated abundances of Chinook smolts were 232,173 (CV: 0.09) and 18,483 (CV: 0.11)[4] . No similar estimates for steelhead smolt abundance were possible in either year.

Table 3. DSMT trap capture of salmonid smolts by stream in the LCS, 2014 and 2015

Trap Site	Species	2014	2015
DRY CREEK	COHO SALMON (total)	923	313
	CWT and PIT absent	*54*	*49*
	Hatchery-origin	*858*	*264*
	no CWT or PIT scan	*11*	*0*
	STEELHEAD	350	313
	CHINOOK SALMON	21521	4517
MILL CREEK	COHO SALMON (total)	1,398	5,332
	CWT and PIT absent	*171*	*192*
	Hatchery-origin	*1,178*	*5,140*
	no CWT or PIT scan	*49*	*0*
	STEELHEAD	8	17
	CHINOOK SALMON	18	0

The 2013-14 and 2014-15, the expanded counts of coho smolts were 11,155 and 12,538 and the estimated abundances of Chinook smolts were 232,173 (CV: 0.09) and 18,483 (CV: 0.11)[5] . No similar estimates for steelhead smolt abundance were possible in either year.

Adult Abundance – 2014-15 Spawner Season

The DIDSON was installed at the mouth of Dry Creek on September 1, 2014 and removed for the season April 27, 2015. Two large gaps in DIDSON data occurred during the season. The first was from December 10, 2014 to December 31, 2014 when the DIDSON was removed in anticipation of high flows. The second was from February 6, 2015 to February 18, 2015 when a piece of debris hit the DIDSON and pointed it toward the bank. At the time, flows were high enough that we could not enter the creek to reposition the DIDSON. We recorded and watched over 3100 hours of DIDSON footage over the course of the season (**b**)**.** We counted 5688 salmonids entering Dry Creek and of these 650 were visible and identifiable on the digital video: 622 Chinook, 15 steelhead, and 13 coho (**Figure 6b**).

We conducted 153 surveys in the 9 tributaries in our LCS on Dry Creek (not including mainstem Dry Creek) during the 2014-15 spawner season. We observed 166 new salmonid redds; 14 coho, 93

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[4] Estimate is through May 31, 2015

[5] Estimate is through May 31, 2015

steelhead, 21 Chinook, and 38 unidentified salmonid redds as well as 1 pacific lamprey redd (**Figure 7**b). We counted 183 live fish; 15 coho, 56 steelhead, 59 Chinook, and 53 unidentified salmonids (**Figure 8**b). We also counted 63 carcasses; 5 coho, 7 steelhead, 43 Chinook, and 8 unidentified salmonid (**Figure 9**b). Of these 63, 32 were marked with individual tags and 9 were recaptured. We conducted spawner surveys via kayak over the entire length of mainstem Dry Creek on November 11, 19, and 25 2014. After the November 25 survey heavy rains, high flows, and high turbidity prevented further surveys. Over the course of the three surveys, crews counted a total of 129 salmonid redds; 110 unidentified salmonid redds, 18 Chinook redds, and 1 steelhead redd. Crews also counted 115 live salmonids; 86 unidentified salmonids, and 29 Chinook. Carcasses were not counted.

We estimated adult returns of 60 coho, 2578 steelhead, and 680 Chinook to the Dry Creek LCS during the 2014-15 spawner season based on DIDSON counts, digital video counts, redd surveys, and hatchery returns (**Table 4**). We calculated a second estimate of 72 adult coho based on redd counts in the tributaries and hatchery returns for comparison.

Table 4. Summary of DIDSON/digital video adult counting station estimates for total adult salmonid returns to the Dry Creek LCS during the 2014-15 spawner season.

Period	Digital video	Method	Metric	Chinook salmon	Coho salmon	Steelhead	Unknown	Total
Sep 1 - Dec 2	On	1	*DIDSON count*				*503*	
			Video count	215	2	4		221
			subTotal[1]	*483*	*15*	*5*		
Dec 3- Apr 29[2]	Off	2a, 2b	*DIDSON count*				*5207*	
			Spawner estimate[3]	54	43	145		242
			Hatchery count	13	2	2180		2195
			subTotal	67	45	2325		2437
			DIDSON remaining in mainstem				2770	
			subTotal	*197*[4]	*0*	*2573*[5]		
			TOTAL	*680*	*60*	*2578*		

[1] Proration of DIDSON count based on daily proration of unknowns (daily proration values not shown)

[2] Includes two large gaps in DIDSON data (see **Figure 3**b)

[3] Number of fish estimated in tributaries based on spawner surveys

[4] All fish on DIDSON from Dec 3 - Dec 10 when video was out are assumed to be Chinook

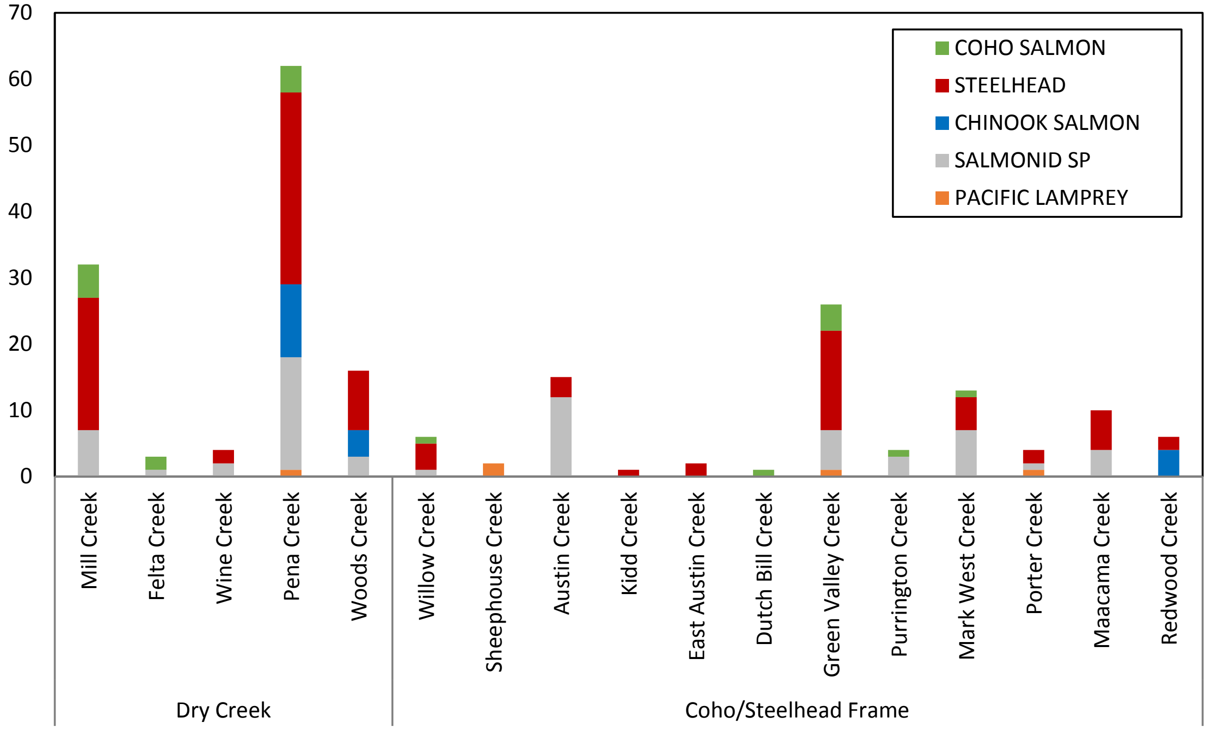
[5] All fish on DIDSON from Dec 30 - April 30 are assumed to be steelhead

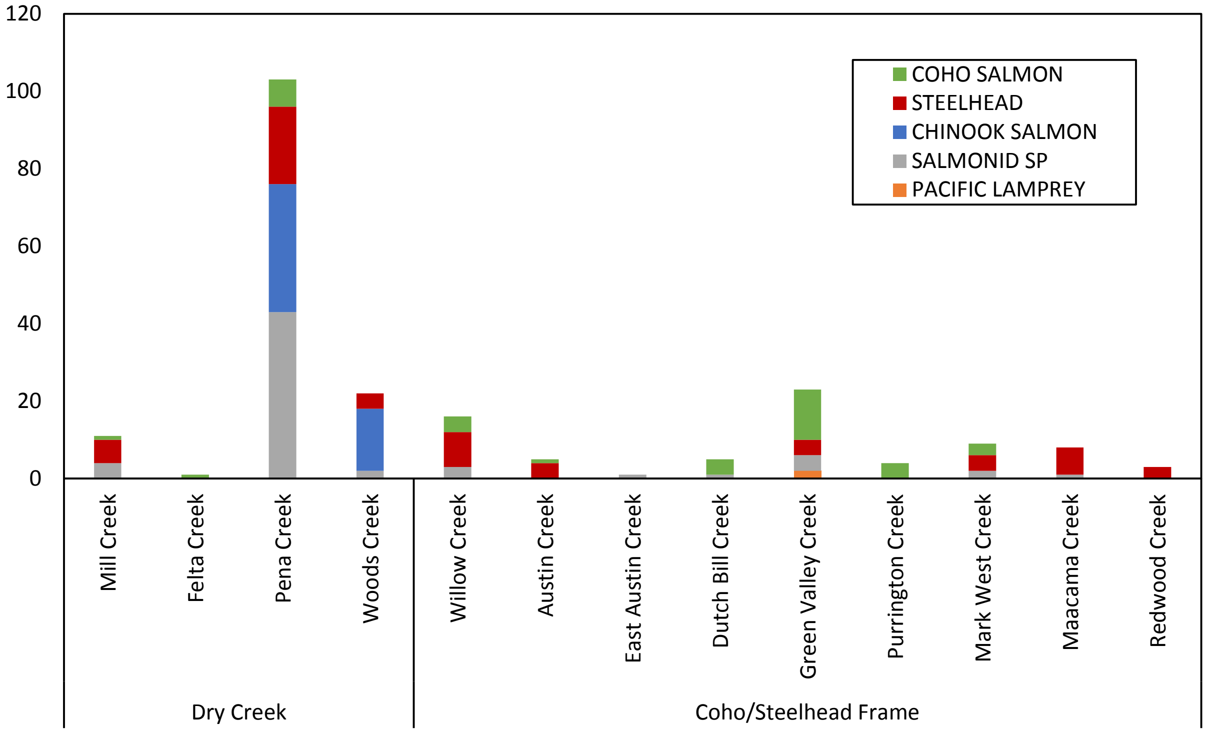
Coho-Steelhead Stratum Monitoring

Adult Abundance

For the purpose of estimating adult abundance in the coho-steelhead stratum, we conducted 276 surveys in the first 32 reaches in the GRTS draw that met all of the following conditions; (1) they were in the coho-steelhead stratum, (2) they were physically accessible in the winter, (3) we had permission to access them from landowners with properties adjacent to the creek, and (4) they had sufficient coho and steelhead habitat to continue to be included in the coho-steelhead stratum. A summary of GRTS reaches sampled and skipped can be found in **Table 1**. This monitoring occurred only during the 2014-15 spawner season. We observed 207 new salmonid redds; 19 coho, 100 steelhead, 19 Chinook, and 64 unidentified salmonid redds as well as 5 pacific lamprey redds **Figure 10**a). A map of all redds observed in the coho-steelhead stratum during the 2014-15 spawner season can be found in **Figure 11**. We counted 209 live salmonids; 38 coho, 61 steelhead, 49 Chinook, and 61 unidentified salmonids as well as 2 Pacific Lamprey **(Figure 10b**). We also counted 66 salmonid carcasses; 16 coho, 4 steelhead, 40 Chinook, and 6 unidentified salmonid as well as 1 Pacific Lamprey (**Figure 10**c). Of these 66, 35 were marked with individual tags and 12 were recaptured.

The total adult abundance estimate for coho salmon in the coho-steelhead stratum for the 2014-15 spawner season (95% confidence intervals in parentheses) was 325 (200-449). The total abundance estimate for steelhead in the coho-steelhead stratum for the 2014-15 spawner season was 740 (504-977).


(a) GRTS Redds, 2014-15


(b) GRTS Live Fish, 2014-15

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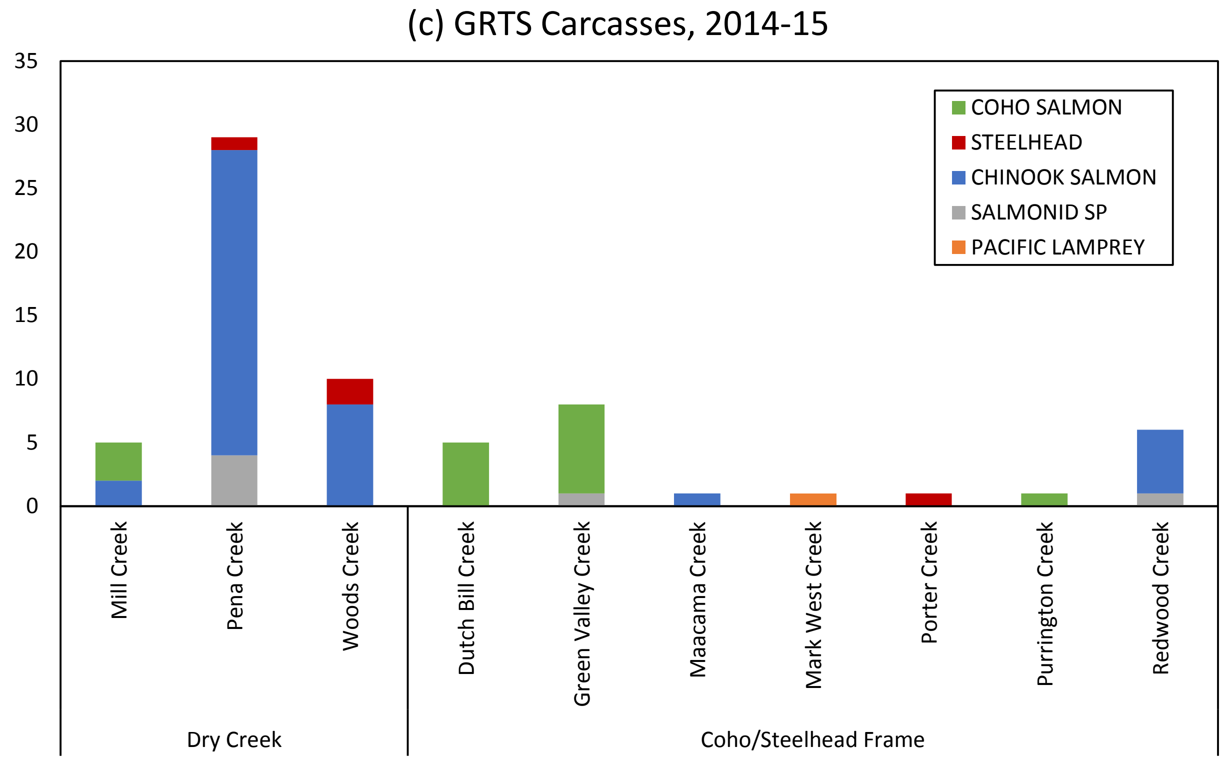

Figure 10. Summary of GRTS ordered spawner surveys in the coho-steelhead stratum during the 2014-15 spawner season; (a) number of new redds counted, (b) number of live salmonids counted, (c) number of salmonid carcasses counted.

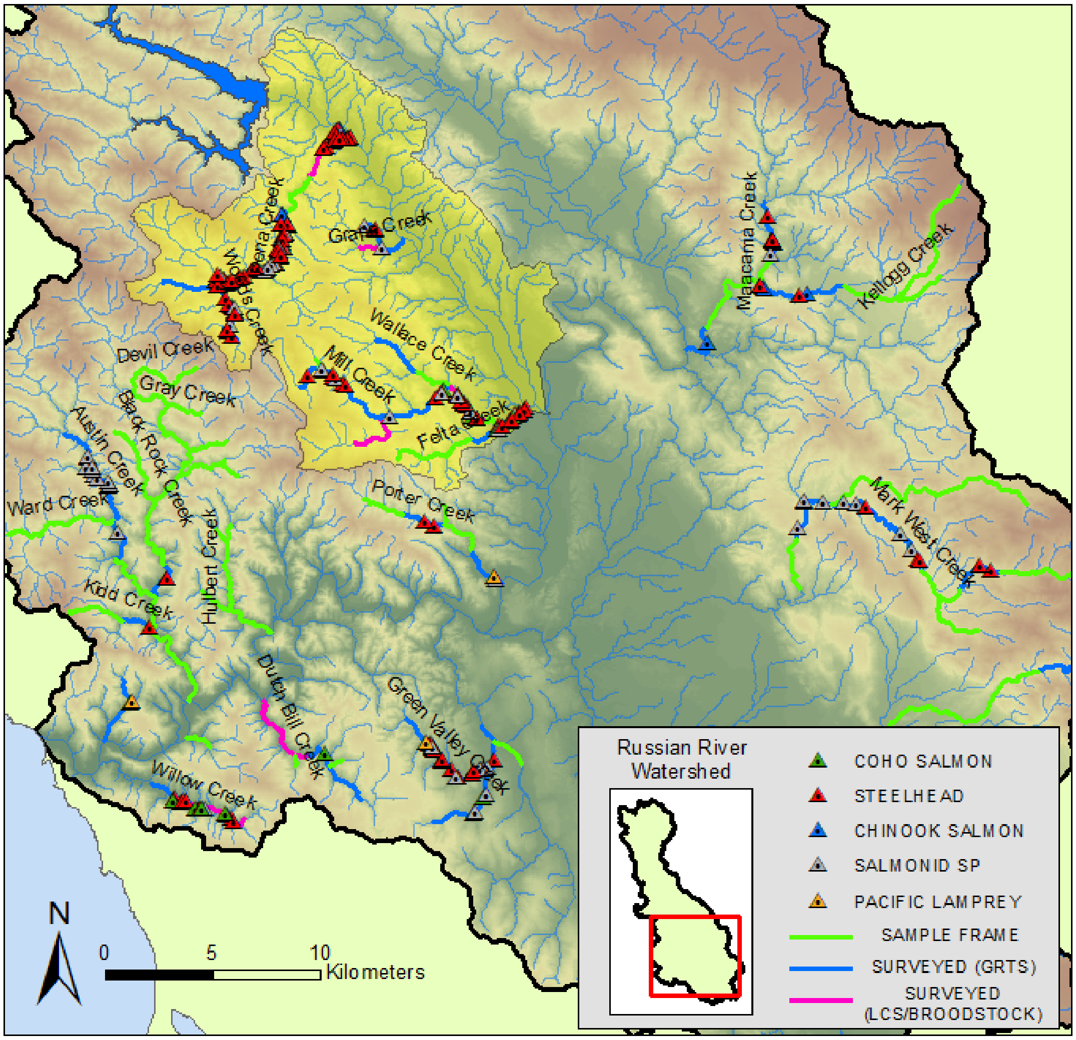

Figure 11. Summary of spawner surveys in the coho-steelhead stratum during the 2014-15 spawner season. Redds are marked based on species called by the crew in the field. Green lines are reaches in the coho-steelhead stratum that were not surveyed, blue lines are reaches that were surveyed as part of the GRTS sample for adult abundance estimation, and pink lines are reaches surveyed as part of broodstock program monitoring or CMP lifecycle monitoring.

Juvenile Coho Spatial Structure

Of the reaches used in estimating occupancy of coho salmon YOY, we conducted single-pass sampling only in 941 pools and 2-pass sampling in an additional 231 pools (**Table 5**). We used data from the pools surveyed by 2-pass snorkeling to estimate occupancy using the multi-scale model. The estimate of p (the probability of detection given species presence) was 0.66 (SE=0.07). The estimate of θ (probability of occupancy at the pool scale given the species occupied the reach, $\theta|\psi$) was 0.34 (SE=0.06) and the estimate of ψ (probability of occupancy at the reach scale given the species occupied the coho-steelhead stratum) was 0.47 (SE=0.11). We derived proportion of area occupied (PAO) as the product of θ and ψ to arrive at an overall occupancy for the entire coho-steelhead stratum in 2014 of 0.16.

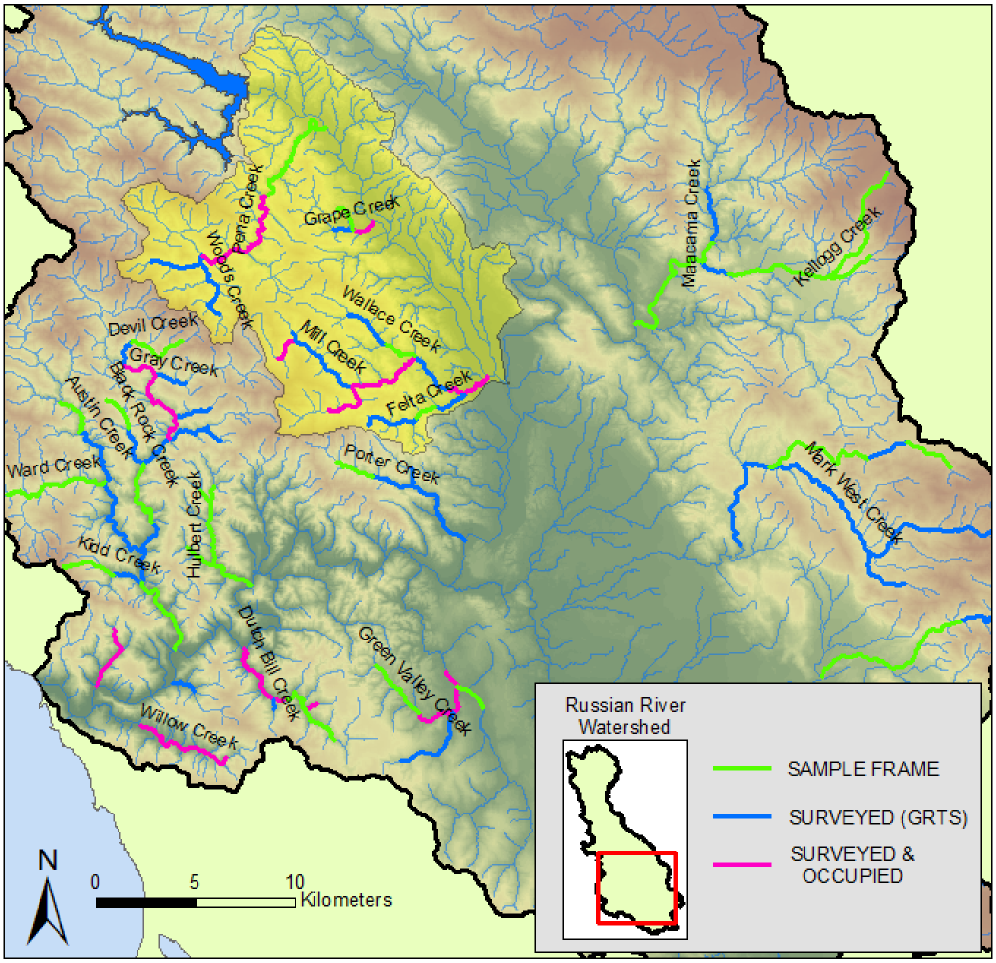

Figure 12. Summary of coho occupancy in the coho-steelhead stratum 2014, Russian River Basin, California.

Table 5. Summary statistics of coho salmon occupancy and relative abundance based on snorkel surveys occurring in 68 ordered GRTS reaches during the summer of 2014, Russian River Basin, California (data for sub-reaches are shown here).

			Number of units			Number of fish	
Tributary	Location code	Reach length (m)	1 pass	2 pass	Occupied[6]	Total	Mean / pool
Willow Creek	76	2651	28	7	5	6	0.2
Willow Creek	77	3200	34	9	7	13	0.3
Sheephouse Creek	78	3548	49	13	1	2	0
Freezeout Creek	80	1361	22	5	1	2	0.1
Austin Creek	83	2392	5	1	1	3	0.5
Austin Creek	84	2517	10	2	1	1	0.1
Austin Creek	85	2271	4	1	0	0	0
Austin Creek	86	3809	15	4	0	0	0
Kidd Creek	90	1673	11	2	0	0	0
East Austin Creek	92	2011	8	1	0	0	0
East Austin Creek	95	2023	10	2	2	8	0.7
East Austin Creek	96	1991	10	2	10	228	19
East Austin Creek	97	2480	11	3	9	67	4.8
East Austin Creek	98	2081	14	3	15	283	16.6
Black Rock Creek	103	2285	13	3	0	0	0
Gilliam Creek	105	2470	16	4	0	0	0
Schoolhouse Creek	106	999	6	1	0	0	0
Thompson Creek	107	1910	9	2	0	0	0
Gray Creek	108	1803	11	3	0	0	0
Gray Creek	109	2076	19	5	0	0	0
Devil Creek	110	1490	9	2	0	0	0
Dutch Bill Creek	126	4728	30	8	13	332	8.7
Dutch Bill Creek	127	4209	32	7	7	160	4.1
Perenne Creek	129	541	6	1	0	0	0
Grub Creek	130	720	8	1	0	0	0
Green Valley Creek	153	4628	34	9	3	3	0.1
Green Valley Creek	154	3545	31	8	19	295	7.6
Purrington Creek	165	4500	42	11	0	0	0
Harrison Creek	165.3	230	1	1	0	0	0
Mark West Creek	172	3421	14	3	0	0	0
Mark West Creek	174	2846	14	3	0	0	0
Mark West Creek	175	3407	14	3	0	0	0
Mark West Creek	176	3151	16	4	0	0	0
Mark West Creek	177	3572	18	4	0	0	0
Mark West Creek	178	2855	18	5	0	0	0
Mark West Creek	179	2669	21	6	0	0	0

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[6] Based on pass 1 count only

			Number of units			Number of fish	
Tributary	Location code	Reach length (m)	1 pass	2 pass	Occupied[6]	Total	Mean / pool
Mark West Creek	180	3662	22	5	0	0	0
Santa Rosa Creek	188	2899	22	6	0	0	0
Santa Rosa Creek	189	1477	8	1	0	0	0
Porter Creek (MWC)	228	2293	4	2	0	0	0
Weeks Creek	232	3243	3	1	0	0	0
Porter Creek	235	2461	13	2	0	0	0
Porter Creek	236	2289	8	2	0	0	0
Porter Creek	237	2170	19	5	0	0	0
Press Creek	239	915	2	1	0	0	0
Mill Creek	254	2400	13	3	2	12	0.8
Mill Creek	255	570	9	2	0	0	0
Mill Creek	256	2725	8	3	0	0	0
Mill Creek	257	4231	30	7	19	470	12.7
Mill Creek	258	4079	14	4	2	40	2.2
Mill Creek	259	1474	11	3	2	6	0.4
Felta Creek	261	1830	8	2	0	0	0
Felta Creek	263	3113	19	5	0	0	0
Wallace Creek	265	2730	3	1	0	0	0
Palmer Creek	266	2750	17	4	4	11	0.5
Angel Creek	267	500	4	2	0	0	0
Crane Creek	270	2977	3	1	0	0	0
Grape Creek	271	1396	12	2	2	2	0.1
Grape Creek	272	1096	2	1	0	0	0
Pena Creek	276	2634	12	4	12	181	11.3
Pena Creek	277	4766	20	5	1	2	0.1
Pena Creek	278	3150	8	1	0	0	0
Pechaco Creek	279	2352	7	1	0	0	0
Woods Creek	282	3799	11	2	0	0	0
Dead Coyote Creek	283	1032	6	1	0	0	0
Maacama Creek	290	3112	9	2	0	0	0
Redwood Creek	302	1662	1	1	0	0	0
TOTAL			941	231	138	2127	

Discussion

Life Cycle Monitoring

Adult Abundance

During the 2013-14 spawner season, only 3 redds in the Dry Creek LCS were certainty 1, meaning they were observed with fish actively digging or guarding them. This prevented any formal test of the accuracy of Gallagher predictions of redd species during that season. It is likely however, based on the possible over prediction of coho redds during the 2014-15 spawner season, that Gallagher equations are responsible for an overestimation of coho redds for the 2013-14 season. It is also possible that our estimation of coho is high because of the small proportion of fish that were identifiable on the digital video. On January 19 and 20, (2014) 20 and 28 salmonids were counted on the DIDSON respectively. Yet each day, only one salmonid (a coho in each case) was identifiable on the digital video. Using our methods of species classification, this led to all 48 salmonids being classified as coho (a likely overestimate). During the 2014-15 spawner season, and in subsequent seasons, we set up a chain weir to guide a larger proportion of salmonids closer to the digital video camera so that they will be identifiable. This seems to have led to a more accurate estimation of species during the 2014-15 spawner season. We will continue to evaluate methods for increasing the proportion of salmonids identifiable on digital video.

The physical characteristics of mainstem Dry Creek prevented us from estimating the abundance of adult salmonids in Dry Creek using methods called for by Adams et al. (2011). Mainstem Dry Creek is highly channelized, incised, and has year-round flows from the WSD. These flows and physical characteristics create depths and flows that prohibit the taking of redd measurements (which prevents species estimation with Gallagher and Gallagher (2005) regression equations). During both the 2013-14 and 2014-15 spawner season, we attempted to count redds in mainstem Dry Creek with kayak surveys. In 2013-14, we used methods that did not prevent double counting of redds. We also were prevented from surveying during any time of the season other than the time when we expect (based on DIDSON/digital video data) the majority of mainstem spawning was Chinook. In 2014-15, we revised our methods so that the difference between old and new redds was formally recorded. Unfortunately, we were prevented by high turbidities from counting mainstem redds during the time of the season when we would expect to see steelhead spawning. In the future, a formal comparison of different methods of assigning redd species in the Russian River basin needs to be completed taking into account that fact that certain methods are not feasible in Dry Creek.

Coho-Steelhead Stratum Monitoring

Adult Abundance

During the 2014-15 spawner season we surveyed 42 reaches (including LCS reaches and reaches surveyed as part of broodstock monitoring), yet only 32 were high enough in the draw order to be included in the adult estimate for the coho-steelhead stratum. This represents a significant effort and a large amount of data that could be used to inform the estimates required for CMP monitoring. At the very minimum, known redds, known live fish, and known carcasses counted in reaches not used for the estimate of total adult abundance, could be used to inform the knn predictor, which would likely lead to better performance. A formal comparison of the redd prediction methods of Gallagher et al. (2007) and the knn redd prediction methods (utilizing this “extra data”) should be undertaken in the near future.

Going forward, we will try to develop ways to leverage this data without adding bias to the spatially explicit random sample provided by GRTS sampling.

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Appendicies

Appendix A. Sample frame development resources and metadata

GIS data

Base Layers

- National Hydrography Dataset (NHD) High resolution NHD flowline adapted to CA streams. DFG Northern Region Data Management and GIS Group, Contact: Tom Christy, tom.christy@wildlife.ca.gov.
- California Fish Passage Assessment Database (PAD), (Calfish). Available at: http://www.calfish.org
- Coastal Landscape Analysis and Modeling Dataset (CLAMS IP model) (Burnett et al. 2003) adapted for California by Agrawal et al. (2005).
- LiDAR Digital Elevation Model, Sonoma County, University of Maryland and Sonoma County Agricultural and Open Space District, 2013. Available at: http://sonomavegmap.org/data-downloads/
- 6-inch/pixel resolution aerial imagery, Sonoma County, University of Maryland and Sonoma County Agricultural and Open Space District. 2013. Available at: http://sonomavegmap.org/data-downloads/
- 2015-16 Sonoma County Parcel Data, County of Sonoma GIS, Santa Rosa, CA.

Salmonid Distribution Layers, Available at: http://www.calfish.org

- Coastal California Chinook Salmon Distribution (Calfish)
- Coho salmon Distribution (Calfish)
- Winter Steelhead Distribution (Calfish)

Stream habitat survey and barrier reports

Stream Habitat Assessments, Coastal Watershed Planning and Assessment Program, CDFW. http://coastalwatersheds.ca.gov/Home.aspx

Taylor et al. 2003

Historical data

Spence B. et al. Oct. 2015. Historical occurrence of coho salmon in streams of the Central California Coast coho salmon evolutionarily significant unit. NOAA technical memorandum, NMFS.

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Appendix B. Detailed Approach for Proration of DIDSON Counts

We came up with alternative methods to estimate adult returns to the Dry Creek LCS based on whether or not digital video data was available to prorate DIDSON counts to species:

1) Our primary method for estimating adult returns to dry creek incorporated both DIDSON and digital video data and therefore could only be used during the time that both were in the creek recording data. With this method, salmonids counted on the DIDSON were apportioned to species based on the proportions of salmonids identified with digital video. Proportions of species obtained from the digital video could be pooled based on an appropriate time frame (by day, week, month, or over the whole season) based on the number of fish identified on the video to species. During the 2013-14 spawner season, the ratio of fish identified on the digital video to total fish counted on the DIDSON was low, so we pooled the species ratio from the digital video into a single ratio for the entire period that the digital video was operation. During the 2014-15 spawner season, because we were able to identify a larger proportion of salmonids on the digital video, we used daily species ratios from the digital video to prorate unknown fish counted on the DIDSON for each day. Any fish returning to Dry Creek before the video camera was operational (during both seasons) were assumed to be Chinook.
2) The second incorporated data other than digital video to assign species to DIDSON counts, so it was used during those times (during both the 2013-14 season and the 2014-15 season) when the digital video data could not be obtained because of high flows and/or turbidity. This method involved estimating the number of fish leaving mainstem Dry Creek to spawn and subtracting those “known” fish from the total number of fish seen on the DIDSON to arrive at a number of fish remaining in mainstem Dry Creek to spawn. These “known” fish assumed to be leaving mainstem Dry Creek to spawn, were estimated using two methods (A and B described below). The remaining “Dry Creek mainstem spawners” were then assigned to species based on some known proportion. During the 2013-14 spawner season, we chose to assign these “mainstem spawners” to species based on the proportion of salmonids that arrived at the hatchery during the time the DIDSON was running without the digital video. During the 2014-15 spawner season, we chose to assign these “mainstem spawners” based on the date they entered Dry Creek (i.e. the date they were counted on the DIDSON). We estimated the end of Chinook spawning to be December 30, so we called all the “mainstem spawners” that entered Dry Creek before that date Chinook and all salmonids arriving after that date were called steelhead.
    a) We estimated the number of “known” fish that left mainstem Dry Creek to spawn using spawner surveys in the tributaries during the time the DIDSON was running without the digital video. The total coho, steelhead and Chinook adults entering the Dry Creek tributaries were estimated using the total new redds seen in the tributaries and multiplying them by species specific spawner to redd ratios from Gallagher 2010 and Crawford et al. (2007).

We assumed that any fish leaving mainstem Dry Creek that were not accounted for in the tributaries of dry creek, were ending up at WSH. Warm Springs Hatchery personnel keep count of adult returns for the spawner season. During the 2013-14 spawner season, we used these hatchery returns not only to estimate the number of fish leaving mainstem Dry Creek, but also to assign the “mainstem spawner” salmonids to species based on the proportion of each species returning to the hatchery.

Appendix C. Implementation of the California Coastal Salmonid Monitoring Plan in the Russian River (available upon request)