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Long-term Monitoring of Coho Salmon and Steelhead During Freshwater Life Stages in Coastal Marin County

2017Annual Report (Revised September 2020)

Natural Resource Report NPS/SFAN/NRR—2020/2175

ON THIS PAGE
Field staff transfer fish captured while performing electrofishing surveys to recovery buckets using nets for passing in Redwood Creek, Marin County, CA.
Photo courtesy of Martha Ture

ON THE COVER
A male hatchery reared coho salmon moves upstream to spawn in Redwood Creek, Marin County CA.
Photo courtesy of National Park Service

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Natural Resource Report NPS/SFAN/NRR—2020/2175

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Executive Summary

The San Francisco Bay Area Network (SFAN) of the National Park Service (NPS) Inventory and Monitoring Program monitors populations of coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) in watersheds at Point Reyes National Seashore, Golden Gate National Recreation Area, and Muir Woods National Monument. The watersheds, including Olema Creek, Redwood Creek, and Pine Gulch Creek, represent the majority of streams supporting salmonids in Marin County, California, and support the southernmost stable populations of coho salmon on the Pacific Coast. The NPS SFAN Inventory and Monitoring Program and California Department of Fish and Wildlife have supported monitoring of multiple coho salmon life stages in coastal Marin County watersheds since 1998. Monitoring includes:

- adult escapement surveys, which document the number of adult salmonids that successfully "escape" ocean fisheries and return to their natal streams to spawn, as well as the number of redds (gravel nests where salmonids lay their eggs) created; and
- outmigrant smolt trapping, where the number of smolts (at least year-old juvenile salmonids that have undergone changes to cope with a marine environment) are captured, measured and counted as they make their way towards the ocean; and
- basinwide juvenile coho surveys and summer index reach monitoring which seek to quantify the number of juvenile salmonids present in the watersheds during the summer months.

Multiple life-stage monitoring allows for a more accurate representation of the coho population, especially given the complex life history of the coho salmon. Coho salmon have a three-year life-cycle in which they spend the first year of life in their natal stream followed by nearly two years in the ocean before returning to their natal stream to spawn. Since generations of related fish reproduce every third year, the coho population is divided into three distinct year classes, or cohorts. Cohorts are labeled 1, 2, and 3. Cohort 1 was the first to be monitored by NPS in 1997-1998 as one generation returned to spawn in the winter and the next generation hatched and emerged in spring and were surveyed as juveniles during the summer. These fish were surveyed again when they left the creeks as smolts in 1999 and for a third time as spawning adults in the winter of 2000-2001. Succeeding generations of cohort 1 hatched in 2001, 2004, 2007, 2010, 2013, and 2016. Cohort 2 are those fish that hatched in 1999, 2002, 2005, 2008, 2011, 2014, and 2017 and cohort 3 fish hatched in 2000, 2003, 2006, 2009, 2012 and 2015. This report presents a summary of monitoring results for the 2016-2017 spawner season, 2017 smolt trapping season, and 2017 summer juvenile surveys. The adults and juveniles monitored belong to different generations of cohort 2, while the year-old outmigrating smolts belong to cohort 1.

Adult coho escapement surveys on Olema Creek for 2016-2017 showed a decrease in cohort 2 adults returning to spawn (15 redds in 2016-2017 compared to 32 redds in 2013-2014), while Redwood Creek showed an increase in returning adults (16 redds in 2016-2017 compared to 5 redds in 2013-2014). Pine Gulch Creek had no adult coho observed for the seventh year in a row.

A basinwide visualization technique was used to calculate the abundance of juvenile coho residing in Olema and Redwood Creeks during the summer of 2017. On Olema Creek, a basinwide coho population estimate of 400, 95% CI [181:619] was calculated. The juvenile coho population estimate for Redwood Creek was 1,106, 95% CI [785:1,427]. The Olema Creek population estimate was lower than the last time this cohort was observed as juveniles. In contrast, Redwood Creek juvenile coho population estimate was higher than the previous time this cohort was observed. No juvenile coho were observed on Pine Gulch Creek.

The Olema Creek coho smolt production estimate of 5,677, 95% CI [4,538:6,816] was slightly lower than expected given the range of the summer 2016 juvenile estimate of 17,337, 95% CI [12,527:22,147]. Factors contributing to this lower estimate may include but are not limited to: a decreased rate of overwinter survival due to a wet winter, and over estimation of juveniles during summer 2016 basinwide surveys. On Redwood Creek, the 2017 smolt estimate was 853, 95% CI [606:1,108]. This is a decrease from 2014 (2,342, 95% CI [1,119:2,342]). The Redwood Creek coho smolt production estimate was likely lower due to the similar factors as those faced by the Olema Creek population. Based on the absence of juvenile coho during the summer of 2016, no smolt trap was placed in Pine Gulch Creek during the spring of 2017.

List of Acronyms

CCCESU:	Central California Coast Evolutionarily Significant Unit
CDFW:	California Department of Fish and Wildlife
CI:	Confidence Interval
CMP:	California Department of Fish and Wildlife Coastal Monitoring Plan
YoY:	Juvenile salmonid Young-of-Year, less than one year in age
GOGA:	Golden Gate National Recreation Area
GSS:	General Systematic Survey
I&M:	Inventory and Monitoring Program
MMWD:	Marin Municipal Water District
MUWO:	Muir Woods National Monument
NMFS:	National Marine Fisheries Service
NPS:	National Park Service
PIT:	Passive Integrated Transponder
PORE:	Point Reyes National Seashore
SFAN:	San Francisco Bay Area Network
SD:	Standard Deviation
1+:	Juvenile salmonid of one year in age or older
SPAWN:	Salmon Protection and Watershed Network
Year-Year:	All year-year references refer to the spawning year
WY:	Water Year (October-September)

1 Introduction

The San Francisco Bay Area Network (SFAN) of the National Park Service (NPS) Inventory and Monitoring Program has identified salmonids as one of the network's vital signs, or indicators of ecosystem health. Monitoring a balanced and integrated set of vital signs meets the scientific monitoring needs of current park management, but will also help detect unanticipated environmental conditions in the future. Salmonids represent a particularly high priority vital sign for SFAN because coho salmon (Oncorhynchus kisutch) and steelhead (O. mykiss) are important indicators of ecosystem health, provide important links between marine and freshwater ecosystems, have federal endangered or threatened status, and garner high public interest.

Salmonids are monitored at three NPS units within SFAN including Golden Gate National Recreation Area (GOGA), Muir Woods National Monument (MUWO), and Point Reyes National Seashore (PORE). Ongoing monitoring of coho salmon by the SFAN within the Olema Creek (PORE and GOGA), Pine Gulch Creek (PORE), and Redwood Creek (GOGA and MUWO) watersheds in coastal Marin County is supported through the California Department of Fish and Wildlife (CDFW) Contract P1230412 to the Point Reyes National Seashore Association. These monitoring efforts continue salmonid research initiated and conducted by the SFAN since 1997. The primary focus of this monitoring program is to document federally and state listed endangered coho salmon population distribution and trends within these watersheds. In addition, the monitoring was designed to document information on federally threatened steelhead and other fish species within the monitored watersheds.

The SFAN Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010) documents methods used by the SFAN in salmonid monitoring within coastal Marin County since 1997. Any deviations or additions in methodology are highlighted in the Methods section.

This report includes summary results of adult escapement, smolt trapping, habitat surveys, index reach surveys, and basinwide snorkel surveys for Olema Creek, Pine Gulch Creek, and Redwood Creek as well as adult escapement for Cheda Creek, a tributary to Lagunitas Creek, conducted during 2017, and summarized in comparison with all previous years of monitoring. These watersheds are located within the Lagunitas Creek and Bolinas Hydrologic Sub-Areas HSA of the Bodega and Marin Hydrologic Units. The monitoring efforts conducted through this program contribute to our understanding of population dynamics and condition within the coastal Marin County Area (Figure 1).

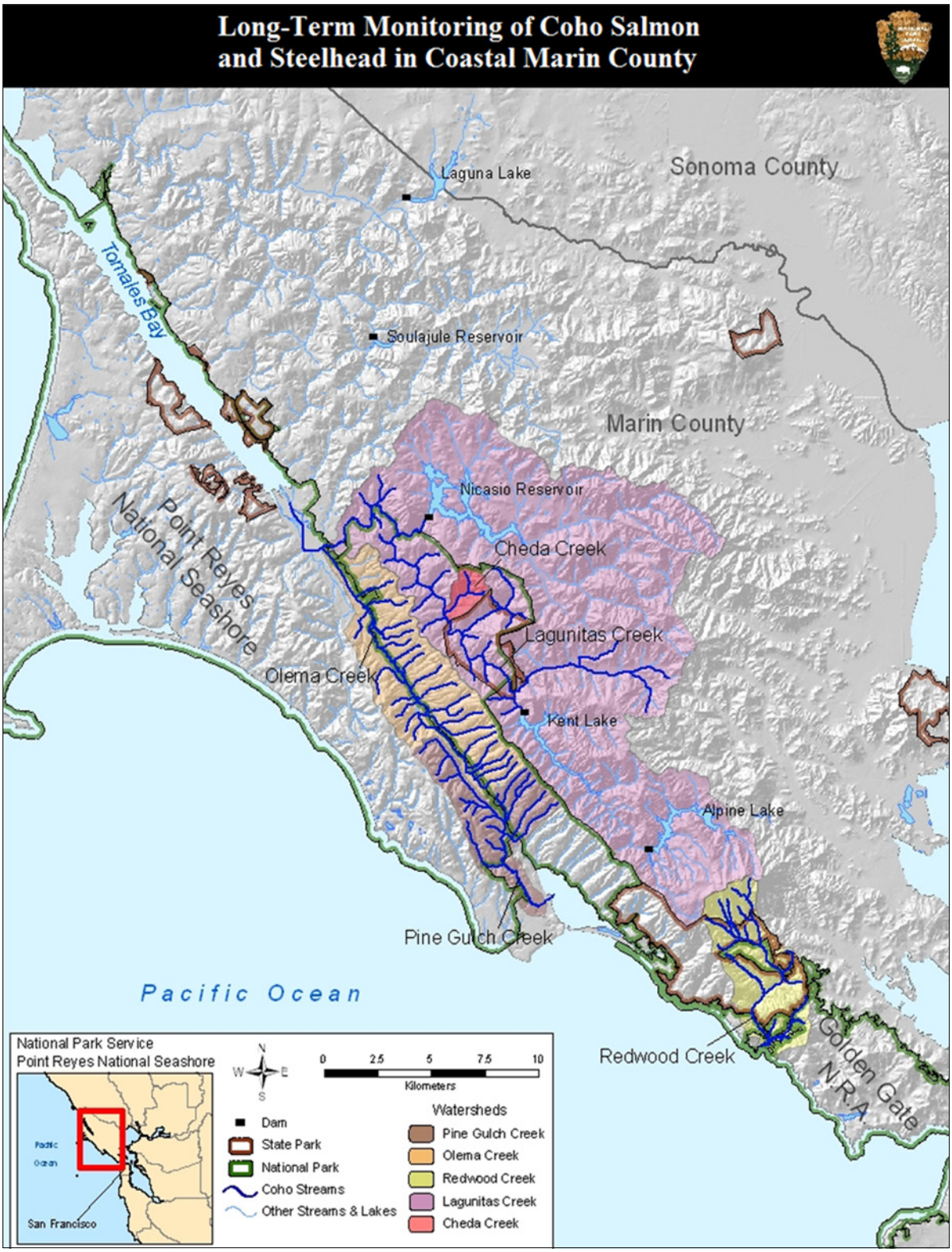

Figure 1. Streams supporting coho salmon in coastal Marin County. The National Park Service monitors streams in Point Reyes National Seashore (Olema and Pine Gulch Creeks) and Golden Gate National Recreational Area (Redwood and Cheda Creeks).

1.1 Background

Spawning populations of coho salmon and steelhead have declined significantly from historic numbers in the coastal streams of central California. It has been estimated that existing naturally spawning coho salmon stocks comprise only 1% of their historical number along the west coast and that as many as 46% of California's coho salmon populations have been extirpated from their watersheds (Brown et al. 1994).

Dramatic declines in salmonid populations throughout coastal watersheds have occurred with changes in watershed condition as a result of land use and development. Salmonids require connected surface flow for migration and dispersal (typical barriers are waterfalls, dams, and culverts), cold temperatures (<70°F) and high dissolved oxygen levels (>4.5 mg/l) (Moyle 2002, Brett and Blackburn 1981). While most salmonids have been affected by watershed development, coho salmon are particularly susceptible due to their semelparous (they spawn only a single time prior to death) three-year life cycle requiring an entire year of residence in freshwater prior to smolting and migrating to the ocean. Although steelhead also require year-round high-quality water, their ability to spawn more than once and to reside in either freshwater or marine systems for variable lengths of time allows the species far greater ability to adjust to changing watershed conditions.

Based on historical regional accounts, numbers of coho salmon and steelhead have been severely depleted. Coastal Marin County streams and their associated watersheds currently containing populations of coho salmon and steelhead include Lagunitas Creek (including Olema Creek tributary), Redwood Creek, and Pine Gulch Creek. Some of the factors believed to have contributed to the declines in anadromous fish runs within these streams include (NMFS 2012):

- dam construction and loss of hydrologic connectivity;
- historic logging and sediment delivery to the channel;
- removal of large woody debris and limited riparian areas;
- stream channel and habitat alteration;
- loss of spawning and rearing habitat;
- water withdrawals, extreme hydrologic and climatic events;
- marine over-harvesting
- changes to ocean food webs, including reduced primary production.

1.2 Fishes Monitored by this Protocol

The primary species monitored through this program are coho salmon and steelhead. However, other aquatic species including sculpin (*Cottus spp.*), California roach (*Hesperoleucus symmetricus*), lamprey (*Lampetra spp.*), and threespine stickleback (*Gasterosteus aculeatus*) are captured and documented through our monitoring efforts.

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from marine water back to freshwater for a single chance at reproduction. Natural populations of coho salmon are known to exist in the Lagunitas (including Olema tributary), Pine Gulch, and Redwood Creek watersheds (Smith 2001, Brown and Ketcham 2002). Coho salmon were listed as a threatened species within the central California coast coho salmon evolutionarily significant unit (CCCESU) in 1996 by the National Marine Fisheries Service (NMFS; Federal Register 1996), and the CCCESU was changed to endangered status in 2005 (Federal Register 2005). The CCCESU includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to, and including, the San Lorenzo River in central California, as well as populations in tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. In 2004, the California Fish and Wildlife Commission added coho salmon populations between San Francisco and Punta Gorda to the list of species protected under the California Endangered Species Act (coho populations south of San Francisco were already listed as endangered). This endangered listing became effective in 2005.

The general biology of steelhead is described in detail in Moyle (2002). Steelhead are the anadromous form of rainbow trout and are iteroparous, meaning they can spawn more than once. Steelhead are known to exist in most perennial watersheds within Marin County. Due to dramatic declines in population numbers, steelhead were listed as a threatened species in 1997 (Federal Register 1997). The central California coast steelhead distinct population segment includes all naturally spawned populations of steelhead (and their progeny) in streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun Bays eastward to Chipps Island at the confluence of the Sacramento and San Joaquin Rivers, excluding the Sacramento-San Joaquin River Basin. The artificially propagated stocks from the Don Clausen Fish Hatchery and the Kingfisher Flat Hatchery are also included (Federal Register 2006).

1.3 Monitoring Rationale

Salmonids produce high numbers of offspring per individual— a life history strategy that offsets high rates of mortality that occur throughout their life cycle. In freshwater systems, there is a large range of mortality rates experienced by coho juveniles during early development due to annual variations in stream condition and habitat quality (Moyle 2002). By winter, mortality rates generally begin to increase with higher flow events, peaking during egg incubation and fry emergence from late winter to early spring (Lestelle 2007, Manning 2001). In Lagunitas Creek, researchers have observed high juvenile densities in the summer, followed by very low smolt outmigration the following spring (Stillwater Sciences 2008). On the north coast of California and Oregon, monitoring has shown that in areas where adult escapement is adequate to seed watersheds, the production of coho smolts is likely limited by winter habitat availability and overwinter survival (Nickelson and Lawson 1998).

Our monitoring of multiple life stages will help characterize potential population bottlenecks in the watershed. Observation of adult escapement and redd density in the winter, juvenile density in the summer months, and smolt outmigration during the spring allows us to track cohorts through documented bottlenecks and identify if and where watershed-specific limiting factors exist.

1.3.1 Monitoring Questions

This monitoring program was developed to answer the following questions excerpted from the SFAN Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010):

- What habitat constraints exist in the parks that currently impede or limit salmon recovery efforts?
- Are parks meeting resource protection mandates relative to salmonid habitat protection?
- Is the condition (e.g., length, weight, presence of abnormalities) of coho salmon changing over time?
- What is the annual production of juvenile coho salmon outmigrants in Redwood, Olema, and Pine Gulch Creeks?
- What is the annual escapement of returning adult coho salmon in Olema, Redwood, Pine Gulch, and Cheda Creeks?
- What is the annual abundance of juvenile coho salmon rearing within Redwood, Olema, and Pine Gulch Creeks at summer base flow conditions?
- What are the changes in salmonid densities at preexisting index reach locations on Redwood, Olema, and Pine Gulch Creeks?

The following questions may be answered in part by this monitoring protocol but additional information will need to be gathered through park or partner efforts:

- What is the survivorship between life stages for each coho cohort within Redwood, Olema, and Pine Gulch Creeks?
- What are the changes in timing and distribution of salmonid spawning, adult sex ratios, and escapement estimates in select streams at PORE and GOGA?
- What are the overall population trends of each coho salmon cohort within GOGA and PORE watersheds?

1.3.2 Monitoring Objectives

This monitoring program was developed to meet the following objectives excerpted from the SFAN Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010):

1. Determine long-term trends in the distribution, abundance, and size (length) of spawning coho salmon by counting numbers of spawners, carcasses, and redds along reaches at Olema, Cheda, Redwood, and Pine Gulch Creeks.
2. Determine long-term trends in abundance and condition of coho salmon smolts by conducting spring smolt trapping near mouths of Olema, Redwood, and Pine Gulch Creeks.

3. Determine long-term trends in distribution, abundance, and condition of juvenile coho salmon by conducting summer basinwide surveys (general systematic surveys [GSS]) at Olema, Redwood, and Pine Gulch Creeks.

4. Determine long-term trends in summer density, size, and age composition of coho salmon at preexisting index reaches at Olema, Redwood, and Pine Gulch Creeks.

5. Identify gross changes in habitat (e.g., pool:riffle ratio) in Olema, Redwood, and Pine Gulch Creeks during basinwide GSS surveys.

1.4 Watershed Background

Olema Creek is the largest undammed watershed in coastal Marin County, California (Figure 1) and an important stream for coho salmon and steelhead within the CCCESU. The 15.9 km stream flows northwest through the Olema Valley, the landward expression of the San Andreas Fault Zone. Its confluence with Lagunitas Creek lies at the head of the ecologically significant Tomales Bay. Protected from development, the 37.6 square km (14.5 square mile) watershed is primarily contained within the boundaries of PORE and the GOGA north district. The watershed provides habitat for four federally protected aquatic species: California freshwater shrimp (*Syncaris pacifica*) – endangered; coho salmon – endangered; steelhead – threatened; and the California red-legged frog (*Rana draytonii*) – threatened. Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within PORE.

Lagunitas Creek and its tributaries (Nicasio Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek, Bear Valley Creek, and Olema Creek) drain more than 230 square km of western Marin County (Figure 1). The headwaters of the Lagunitas Creek mainstem lay within the 53,000 ha watershed lands administered by the Marin Municipal Water District (MMWD). The mainstem originally totaled approximately 40 km of perennial stream draining the northern slope of Mt. Tamalpais, but it was reduced by more than 50% after construction of Alpine Dam in 1918 and Peters Dam in 1953. Because neither dam has provisions for fish passage, their construction resulted in permanent loss of the upper portion of the drainage to anadromous fish.

The portions of the Lagunitas drainage most significant for salmonids are under a number of ownerships. Approximately 12 km of the mainstem is bordered by NPS lands (north district GOGA). A major tributary, San Geronimo Creek, flows through privately held land in San Geronimo Valley. Devil's Gulch lies almost entirely within Samuel P. Taylor State Park with its headwaters in NPS lands.

Cheda Creek, lying entirely within GOGA lands, is a small perennial tributary of the Lagunitas Creek watershed and provides critical habitat for coho salmon and steelhead (Figure 1). Prior land-use practices within the Cheda Creek drainage have resulted in alterations to the natural hydrology and degradation of riparian conditions. These factors have negatively impacted salmonid populations, water quality, and the ability of the aquatic ecosystem to function properly. The construction of a fish passage structure in the fall of 2000 was part of an overall watershed restoration project initiated by the NPS to restore the system to a more natural and sustainable condition.

Redwood Creek is a 19.4 square km (7.5 square mile) coastal watershed in southern Marin County, California (Figure 1). Redwood Creek flows southwest from the flanks of Mt. Tamalpais, through MUWO, discharging to the Pacific Ocean through Big Lagoon at Muir Beach. Protected from development, the watershed is primarily contained within the boundaries of Mt. Tamalpais State Park, GOGA, and MUWO. The watershed provides habitat to three federally protected species (coho salmon – endangered; steelhead – threatened; and the California red-legged frog – threatened). According to the NMFS Genetics Laboratory, the coho salmon found in Redwood Creek represent a genetic outlier within the CCCESU with genetic distance from all other samples collected within the CCCESU and the Southern Oregon-Northern California Coast Evolutionarily Significant Unit (Bjorkstedt et al. 2005).

Pine Gulch Creek drains a 19.4 square kilometer (7.5 square mile) watershed in coastal Marin County, California, and is the primary freshwater input to Bolinas Lagoon (Figure 1). Pine Gulch Creek is located within the CCCESU where coho salmon and steelhead occur. The watershed supports a population of steelhead, and it is generally accepted that Pine Gulch Creek supported a native self-sustaining population of coho salmon into the 1970s (CDFG 1968). It was likely the drought of the late 1970s, coupled with in-stream damming during the same period that severely depleted multiple cohorts and led to unsuitable conditions for continued survival of the species within the Pine Gulch watershed. In 2001, SFAN documented the return of coho salmon to the watershed beginning with the recovery of a coho carcass, and subsequent documentation of coho juveniles in the watershed the following summer (Brown and Ketcham 2002). Based on genetic tests, the coho which have returned to Pine Gulch Creek are likely strays from Redwood Creek, demonstrating a natural expansion of the genetically distinct Redwood Creek stock into a nearby watershed in PORE (Garza and Gilbert-Horvath 2003).

2 Sampling Design and Methods

This program includes four strategies to monitor coho salmon and steelhead at a variety of life stages. All Standard Operating Procedures (SOPs) for winter adult spawner surveys, spring outmigrant smolt trapping, summer juvenile coho basinwide surveys, and summer index reach surveys are documented in the SFAN Salmonid Monitoring Protocol version 4.0 (Reichmuth et al. 2010). The methods described in this report are provided as a summary of detailed methods within the SFAN Salmonid Monitoring Protocol. These methods have been used by the SFAN for salmonid monitoring within coastal Marin County since 2009. Many of the methods associated with the project are consistent with draft CDFW biotic monitoring guidelines (Collins 2003). Maps of Olema, Redwood, and Pine Gulch Creeks with survey locations are shown in Figures 2-4.

2.1 Adult Coho and Steelhead Escapement Surveys

Annually, spawner surveys are conducted in watersheds within and adjacent to SFAN park units, including PORE, GOGA, and MUWO. These surveys concentrate primarily on federally endangered coho salmon and federally threatened steelhead in an attempt to quantify the adult escapement. "Escapement" refers to the number of adult fish that successfully pass through a fishery to reach the spawning grounds located in freshwater streams. Coho and steelhead data collected as a part of these surveys contribute to Monitoring Objective 1 and include number of live adult fish observed, adult fish carcasses observed, and redds observed. These surveys were first conducted on Olema Creek in 1997, Cheda Creek in 1998, Redwood Creek in 1994, and Pine Gulch in 2000. Standard Operating Protocols 5, 6, 9, and 11 document field and analytical methods for the adult salmon escapement monitoring efforts (Reichmuth et al. 2010).

2.1.1 Adult Coho and Steelhead Escapement Survey Field Methods

Program staff and trained volunteers conduct surveys for coho and steelhead spawners and redds each winter and spring during the coho and steelhead spawning season to quantify escapement and determine spawning density and distribution. Surveys conducted during the spring months are conducted to capture the entire steelhead spawning season and are typically performed only after spring freshets, when adult steelhead spawning increases. The adult coho in-stream migration window typically spans from late November to early February, while the window for steelhead spawning begins in late December and usually ends by late April. Start and end dates for each season vary depending on in-stream flows and spawning activity. Adult coho salmon runs within the CCCESU typically peak in January and are compressed into a very short window, because upstream migration coincides with brief yet substantial winter discharges (Weitkamp et al. 1995). Surveys are conducted approximately every week from late November through early February, although storms and high stream flows often dictate less frequent surveys. Redd detection is the key factor in determining adult steelhead abundance, and redds can be detected as a feature within the streambed weeks after they are constructed as long as there are no storm events that lead to increased streambed mobility. Storms are less intense during the spring which allows for more efficient adult steelhead surveys, because redds remain undisturbed and are relatively easy to detect.

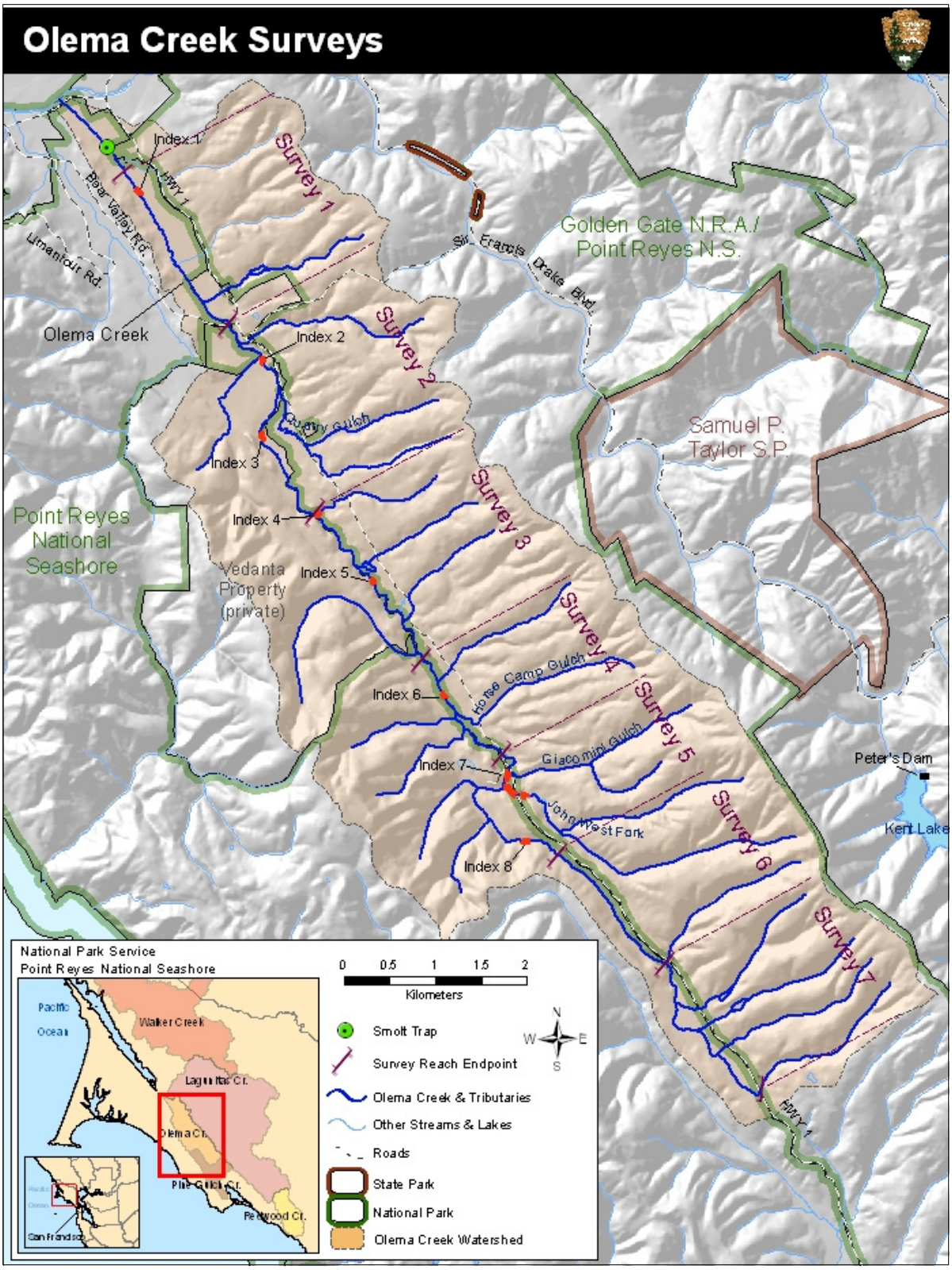

Figure 2. Olema Creek survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

Figure 3. Redwood Creek survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

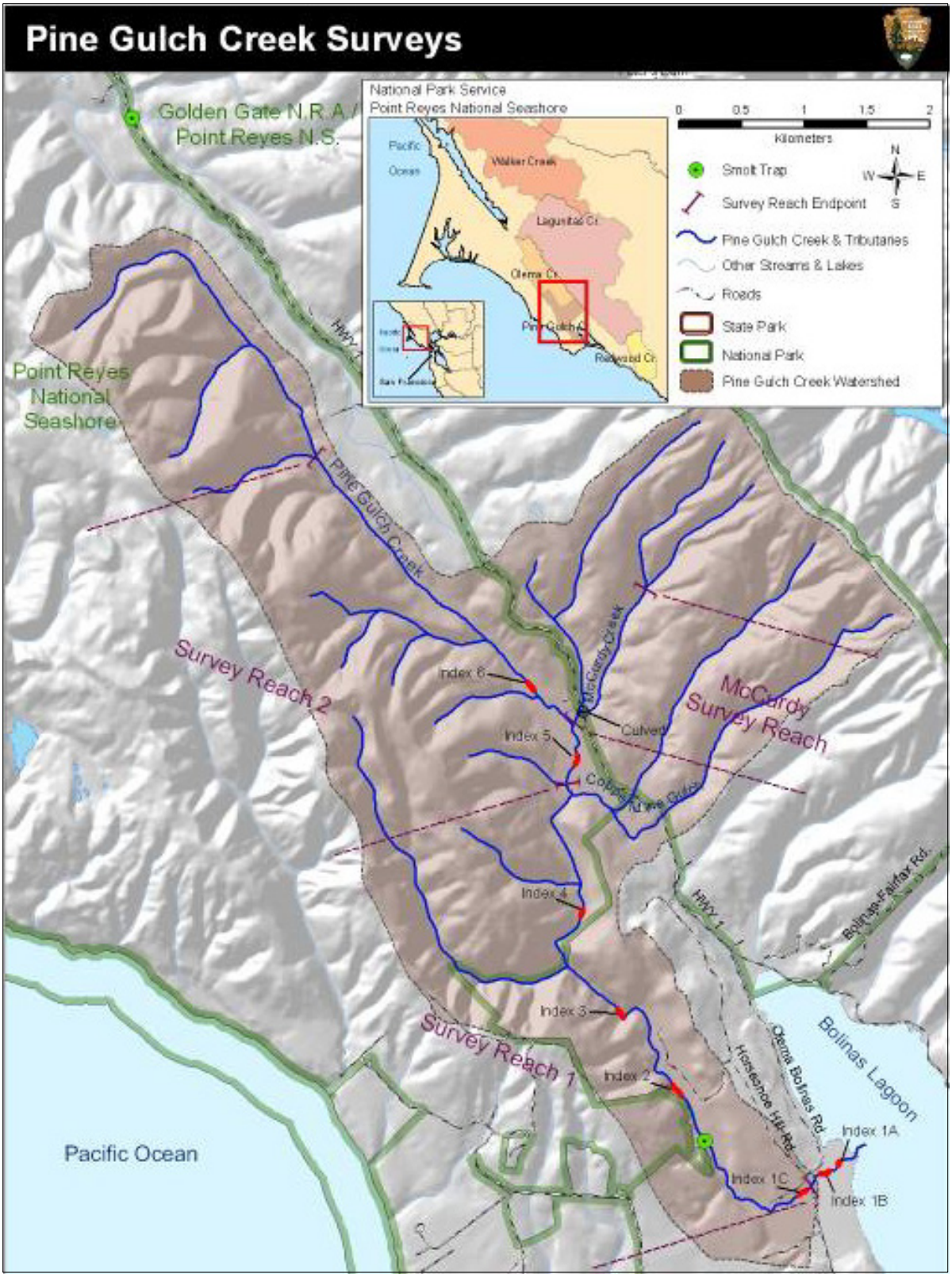

Figure 4. Pine Gulch Creek survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

During spawner surveys, observers walk upstream through 2-3 km creek reaches (Figures 2-4) and along creek margins and banks, where possible, to look for live fish, carcasses, and redds. Although the extent of spawner survey reaches are fairly consistent from year to year, variations in survey extent can occur due to stream access locations, stream conditions, restoration activities, and staff availability (Appendix A, Tables A2 and A5). There is no set minimum or maximum stream distance but reaches must be able to be surveyed completely within one field day. Live fish are identified to species and sex, and fork length (FL) is visually estimated to the nearest 5 cm. Carcasses are measured (FL) to the nearest cm, identified to species and sex, and marked to prevent double counting. Scale and tissue samples are collected from carcasses for age and genetic analysis. Redd measurements are taken to the nearest 0.1 m. Redds are marked with flagging on adjacent vegetation. Because redds are stationary and can be observed over time, redd monitoring is targeted to determine spawning success.

Particular care is taken not to disturb redds or actively spawning adults. Locations of all live fish, carcasses, and redds are recorded in reference to permanent tags placed every 100 m along each stream.

2.1.2 Changes to Methodology

The program continues to seek the latest in salmonid monitoring methods and technology. To this end, changes may be made in the program methods that are not currently reflected in the published protocol (Reichmuth et al. 2010). In order to make clear where current methodologies differ from the published protocol, any updates will be included in the annual report until such a time as the published protocols can reflect the updated methods.

In addition to the collection of scale and tissue samples, otoliths are retrieved from all viable carcasses for stable isotope analysis. Carcasses are also scanned using a handheld Passive Integrated Transponder (PIT) tag reader to determine if the carcass contains a PIT tag. The following changes in redd data collection were made in order to increase accuracy of predicting redd salmonid species when a field determination could not be made. Redd measurements are now based on pit and tailspill area, instead of total area as detailed in Reichmuth et al. 2010. Length is recorded for both the pit and the tailspill, as is the average width (average calculated from two width measurements). Redds are assigned an age code for any future mark-recapture studies, which may eventually be used to estimate survey efficiency and provide an alternative method for estimating escapement when survey conditions are unfeasible. In accordance with current methodology, all redd and fish locations are recorded using the nearest downstream monument tag along with the collection of a GPS location for both redd and fish observations. Finally, the program is currently experimenting with different methods of redd identification. Staff members are utilizing both a regression analysis as proposed by Gallagher and Gallagher (2005) and a known-nearest-neighbor algorithm (Garwood and Larson 2014) in an effort to classify unknown redds retroactively. These are both methodologies suggested by the Coastal Monitoring Plan (CMP) technical advisory committee to estimate species for redds in which species could not be determined by staff during field surveys.

2.2 Outmigrant Coho Smolt Trapping

For a detailed description of sampling design rationale, locations, and methods used during the outmigrant smolt trapping season, please refer to SOPs 3, 4, 6, 9 and 11 in Reichmuth et al. 2010.

Outmigrant smolt trapping is performed annually from March through May on Olema and Redwood Creeks. Outmigrant trapping is also performed on Pine Gulch Creek in years when juvenile coho are detected during basinwide juvenile coho surveys performed in July of the previous year. Outmigrant trapping is intended to census the number of coho smolts leaving the watershed, and the smolt data obtained through the trapping contributes to Monitoring Objective 2. Although trapping operations are focused on coho smolts, smolt trapping also provides information on steelhead smolt outmigration. Trapping results can also help quantify dates of fry emergence and growth rates through the spring season. Outmigrant traps provide presence/non-detect information and size data for other aquatic species during periods not covered by summer/fall monitoring activities.

2.2.1 Outmigrant Coho Smolt Trap Field Methods

Trapping is conducted continually for a 2-3 month period during the spring and requires daily field checks by staff. The fyke/pipe traps used by this program are based on methods developed in northern California for trapping small streams (Manning and Roelofs 1996, Manning 2001) and have proven effective for the current monitoring sites. They are designed to catch fish moving downstream and, with efficiency estimated via mark-recapture techniques, result in a smolt production estimate calculated using DARR 2.02_R script in R software (Bjorkstedt 2010) or using Chapman modification of the Petersen equation (Schneider 2000). The Chapman modification of the Petersen equation (Schneider 2000) is only used when the recapture distribution or number of marked coho are not sufficient to produce an estimate using the DARR 2.02_R estimator (Bjorkstedt 2010).

At each site visit a random sub-sample of steelhead parr (juveniles of at least one year of age that show no signs of smoltification), coho and steelhead smolts (fish of at least one year of age that have undergone physiological changes in preparation for heading out to sea), and coho and steelhead fry (recently hatched and emerged juveniles) are measured (FL) to the nearest mm and weighed to the nearest 0.01 g. This sub-sample is normally 10 of each species; however, fish anesthetized for mark-recapture purposes are also measured. Trap site locations within each watershed were determined by suitable channel morphology and access (Figures 2-4).

Traps are generally installed in mid-March, once flows have subsided from winter peaks and have stabilized. In some years, spring rains occasionally increase flows enough to compromise trap operation. Coho smolt migration typically ends by late May or early June coinciding with a drop in stream flows, so traps are usually removed at this time. In each of the monitored watersheds, the SFAN I&M program maintains a stream gauge for measurement of average daily discharge. An Onset-brand temperature logger is deployed in each trap box for the duration of operation.

2.2.2 Changes to Methodology

Smolt outmigrant trapping methods have remained mostly unchanged compared to previous years. Two updates that are not yet included in the protocol are the use of PIT (Passive Integrated Transponder) tags for the mark-recapture studies, and the use of MS-222 (Tricaine

Methanesulfonate) for anesthetizing fish prior to tag implant and handling. PIT tags, because of their unique identification system, allow fish to be tracked on an individual basis enabling a more accurate estimate of outmigrant production. Tag detections recorded by stationary arrays (not part of this protocol) are used to increase the measure of trap efficiency by capturing smolt movement and possible avoidance behavior after traps are removed at the end of the season. Alka-Seltzer® is no longer used by staff during fish processing as the program has transitioned to only using MS-222.

2.3 Juvenile Coho and Steelhead Surveys

Monitoring juvenile salmonids during their freshwater residence phase provides information on overall population trends in distribution, abundance, and condition (Monitoring Objective 3), particularly when combined with adult spawning data and smolt emigration data (Collins 2003). Sampling is most effective during summer and fall base flow conditions, when water clarity is greatest and conditions are more conducive to observation and capture of juvenile salmonids.

The primary activities conducted in the watersheds include basinwide GSS and index reach monitoring during the summer/fall sampling period. Complete published field methods are documented in SOPs 1, 2, 6, and 9 in Reichmuth et al. 2010. The descriptions of field methods for summer juvenile coho and steelhead monitoring are organized by survey type, since a variety of surveys are utilized during the summer juvenile monitoring season. Although multiple survey techniques may be deployed within the same sampling period, each survey type is treated as a standalone survey.

2.3.1 Basinwide General Systematic Surveys

Basinwide survey techniques, developed by Hankin and Reeves (Dollof et al. 1993), provide statistically valid estimates of stream habitat type and salmonid population size for a broad area or entire stream. Basinwide surveys involve a two-stage sampling design using both snorkeling and electrofishing. This two-stage sampling combines labor-intensive data collection for a randomly selected subsample of units correlated with data from a less labor-intensive sampling technique to achieve representation while reducing effort. Sampling units are classified as pool (scour pool, plunge pool, or mid-channel pool), flatwater, or riffle using level III of the CDFW classification system (Flosi et al. 1998). Every fifth pool unit is flagged for snorkeling, and several measured widths are taken for the purpose of calibrating the estimated width. All large woody debris, live or dead, providing in-stream shelter during summer base flow conditions is counted and recorded within each habitat unit. Program staff survey each of the previously determined pools with a single- to triple-pass snorkel count, using dive lights to search under vegetation, woody debris, and undercut banks. Only coho are counted, but the presence of steelhead and non-salmonid fish is also noted. Typically, snorkeling is calibrated by follow-up electrofishing of randomly selected dive units to provide an unbiased calibration method.

2.3.2 Index Reach Monitoring

Index reaches are sampled at SFAN parks during summer/fall base flow periods to assess fish abundance and distribution within each index on Olema Creek, Redwood Creek, and Pine Gulch Creek. Using this technique, established stream reaches approximately 100 m in length and distributed intermittently along the creeks' full lengths have been surveyed annually since the mid- to

late-1990s (Figures 2-4). Index reach surveys include both fish sampling and detailed habitat assessments.

Each index reach contains two to ten contiguous habitat units, which are identified and sampled individually. Each habitat unit is isolated with block nets and sampled separately using standard multiple pass depletion electrofishing methods (Bohlin et al 1989). Habitat measurements and assessments are made for the index reaches after fish sampling is completed.

2.3.4 Changes to Methodology

During snorkel surveys, a handheld GPS device is used to record the location of each snorkeled habitat unit. The GPS device saves each location as a waypoint, and all waypoints should be downloaded in-office immediately following a survey. In recent years, the lower densities of juveniles within the stream have precipitated an increase in sampling frequency. At a minimum, every fifth pool should be sampled. More commonly, every fourth pool and tenth flatwater with a depth greater than 0.2 m is flagged for snorkel surveys. On Redwood Creek mainstem, in an effort to increase accuracy in juvenile estimates, pool units were assigned one of three complexity categories including non-complex, less than 50% open water or depth exceeds ability to electrofish, and less than 20-30% open water. Most of these units of a certain complexity, depth, or size have been skipped in the past, due to an inability to accurately electrofish these units for possible calibration. On Redwood Creek, these pools are snorkeled if feasible, and calibration is performed using repeat snorkel passes. Fish in these units are later seined for biotic information. Juvenile coho of size (≥65 mm) may be anesthetized and marked with a PIT for growth and survival studies. Finally, sampled units are *either* seined or electrofished, not both. If electrofishing is deemed too hazardous in the sampled unit, and that unit must be sampled, a seine will be employed for the surveyed unit.

2.4 Smolt and Juvenile Coho and Steelhead Condition

Length is the principal factor affecting the weight of fishes. In spite of this, there can be significant differences in weight distribution among similar size fish of the same species within a particular watershed. In order to compare length-weight relationships, we applied the Fulton's condition factor (K-factor) to establish comparable indices of condition (Murphy and Willis 1996) to all smolt and juvenile salmonids measured for length and weight. Fulton's condition factor is a ratio relating fish length to fish weight, allowing for the measurement of the relative biomass of a fish. Therefore, only fish with both an associated fork length and weight can be used to calculate K-factor ratios.

3 Monitoring Results

Monitoring data presented below are organized first by monitoring procedure (escapement surveys, outmigrant smolt surveys, basinwide juvenile surveys, and index reach juvenile surveys) and then by watershed. For context, rainfall data are also presented.

3.1 Rainfall

Rainfall data were obtained from the Western Regional Climate Center Olema Valley weather station for Olema Creek during the 2017 water year (October 2016 – September 2017). Total rainfall for water year 2017, as well as the spawning season, was above average. The recorded rainfall amounts for January (16.28 inches) and February (13.33 inches) were both over twice the historical average. Rainfall amounts on Redwood Creek were above average for water year 2017. Redwood Creek experienced one of the wettest Januaries on record (11.34 inches recorded in WY2017), which continued into February (10.06 inches).

3.2 Data from Escapement Surveys

In the 2016-2017 spawning year, escapement surveys were conducted from 2 November and continuing through 13 April in Olema, Cheda, Redwood, and Pine Gulch Creeks, including select associated tributaries.

These surveys were first conducted using the current survey methods on Redwood Creek in 1997, Olema Creek in 1997, Cheda Creek in 1998, and Pine Gulch in 2000. Historical results for coho redd density on all streams monitored in Marin County by the SFAN, MMWD, and the Salmon Protection And Watershed Network (SPAWN) are presented in Appendix A, Table A1.

3.2.1 Olema Creek

Coho escapement data for Olema Creek shows that run timing is highly dependent on the rainfall-runoff conditions within the watershed. Unlike Lagunitas Creek, Olema Creek is an unregulated stream. This makes Olema Creek far more vulnerable to the variable environmental conditions that limit flows in the winter season. Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, which typically occur in December and January (Weitkamp et al. 1995).

Olema Creek watershed spawner survey information includes data collected on 13.7 km of the mainstem of Olema Creek, primarily Reaches 1 through 6, and John West Fork, the largest tributary to Olema Creek (Figure 3). Spawner surveys were also conducted on three smaller tributaries, Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Gulch. When possible, the mainstem of Olema Creek and its tributaries are combined for data summaries and analysis.

<u>Run Timing and Environmental Conditions Background</u>

Our monitoring efforts have documented certain years when flows necessary to allow adult salmonids entry into the watershed did not occur until mid-January. In those years, coho were observed in the estuary waiting for Olema Creek attraction flows. In other years, rains in November generated flows that would allow coho early access to the watershed. Even when this early entry

opportunity has occurred, few coho have been observed migrating upstream. Based on historical data, peak spawning activity in Olema Creek occurs between mid-December (Julian weeks 50 and 51) and mid-January (Julian weeks 1-3). Typically, the peak count will follow a large flow event, encouraging fish that were waiting at the mouth of the watershed to enter and spawn. Data on historical timing of the coho run, rainfall during the run, and spawning activity observed on Olema Creek watershed can be found in Appendix A, Table A2.

Survey Timing and Environmental Conditions

For the 2016-2017 season, the first survey was performed on 3 November 2016 and included Reaches 1 through 4 of Olema Creek. A total of nine surveys were conducted in Olema Creek between 3 November 2016 and 31 January 2017. The mean interval between surveys was 11.1 days during the primary coho spawning season (November through February). Seven day rainfall totals for Julian weeks within peak spawning months (December and January) ranged from a low of 0.01 inches during Julian week 51 and a high of 5.71 inches during Julian week 3. Average water clarity at the time of each survey ranged from 40 cm to over 100 cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations.

Five surveys were conducted on John West Fork tributary between 12 December 2016 and 31 January 2017. Two of the five surveys were conducted on the same day as the Olema Creek mainstem surveys. The mean interval between surveys was 10.4 days. Average water clarity at the time of surveys ranged from 50 cm to 80 cm.

Giacomini Gulch was surveyed on 19 December 2016 and had a visibility of 60 cm. Horse Camp Creek, Boundary Gulch, and Quarry Gulch were surveyed on 27 January 2017; water clarity ranged from 40 cm to 50 cm. Tributary surveys generally preceded the mainstem surveys and were dependent on flow. Historical spawning data for Olema Creek tributaries can be found in Appendix A, Table A3.

Live Coho and Steelhead

While live coho observations do not accurately represent the total number of spawning adults, a total of 18 adult coho were observed during surveys on the Olema Creek mainstem, with an additional two coho adults observed on John West Fork. The first adult coho on the Olema Creek mainstem was not observed until 21 December 2016.

No adult coho or spawning activity was observed during surveys on Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

Although steelhead trout are not a primary focus of this study, observations of live adult steelhead were recorded using the same method for recording live adult coho. Due to the reproductive strategy of adult steelhead, the number of returning spawners is assumed to be much higher than the observed count. Four adult steelhead were observed during the 2016-2017 spawner surveys on the mainstem of Olema Creek. No steelhead adults were observed on John West Fork. Six adult salmonids observed on Olema Creek mainstem could not be positively identified as either coho or steelhead.

Coho and Steelhead Carcasses

No coho carcasses were recovered during the 2016-2017 season on either Olema Creek mainstem or any of its tributaries.

Two steelhead carcasses were recovered on Olema Creek mainstem, and no steelhead carcasses were recovered on John West Fork. One carcass on the Olema Creek mainstem could not be identified to species.

Coho and Steelhead Redds

Redd counts provide the most spatially accurate representation of spawning densities in the watershed. Within Olema Creek, monitoring efforts have allowed for analysis of redd data per 100 m section of stream since 1997-1998. Accumulation of these data show high use areas for spawning within the Olema and John West Fork watersheds.

Ten confirmed coho redds were observed in the mainstem of Olema Creek, and one confirmed coho redd was observed on John West Fork during the 2016-2017 season. Coho redds were found in reaches two through six of the mainstem. Of the 10 confirmed coho redds in the Olema Creek Watershed, eight were measured, and the average surface area was 6.5 m^2. The density of redds on the mainstem was 1.4 redds/km.

One confirmed steelhead redd was observed on the mainstem of Olema Creek. No steelhead activity was observed on John West Fork. The observed surface area was 2.1 m^2. Steelhead redd density on the mainstem was 0.07 redds/km.

A total of four redds in the Olema Creek watershed could not be classified to species due to lack of fish on redd or stream conditions (i.e. high turbidity). These unknown redds were measured for surface area during field surveys. A logistic regression model developed by Gallagher and Gallagher (2005) uses redd surface area and date of redd observation to assign species. The Gallagher model classified two of the three unidentified redds as coho and the other two as steelhead resulting in a total of 12 coho redds and three steelhead redds for the watershed.

The four unknown redds were also classified using the K-nearest neighbor algorithm (kNN) which relies on temporal and spatial data of known redds. Species designation for an unknown redd is based on the three closest known neighbors (Garwood and Larson 2014). The kNN algorithm classified all four as coho, yielding a count of 15 coho redds and one steelhead redd. The K-nearest neighbor method is currently under review by the CMP Technical Team, but results were included for comparison.

Coho Spawning Trends

Overall trends in coho spawning on Olema Creek, based on observed redds, are shown below in Figure 5. The three cohorts are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Cohort 1 suffered a sharp decline and produced its lowest number of redds during the 2009-2010 spawner season. The cohort rebounded slightly in 2012-2013 and continued to show improvement in 2015-2016. The current cohort, cohort 2, shows a rapid increasing trend in spawning over the first three generations before falling off sharply in 2007-2008.

It held relatively steady with a slight increase in 2013-2014 compared to the 2010-2011 season, before a lower number of redds was observed in 2016-2017. Cohort 3 continued to struggle with a dramatic decline in spawning between 2002-2003 and 2005-2006, before no adult coho, coho carcasses, or coho redds were observed in 2008-2009; in 2011-2012, it showed a moderate increase in size that appears to have remained stable through 2014-2015.

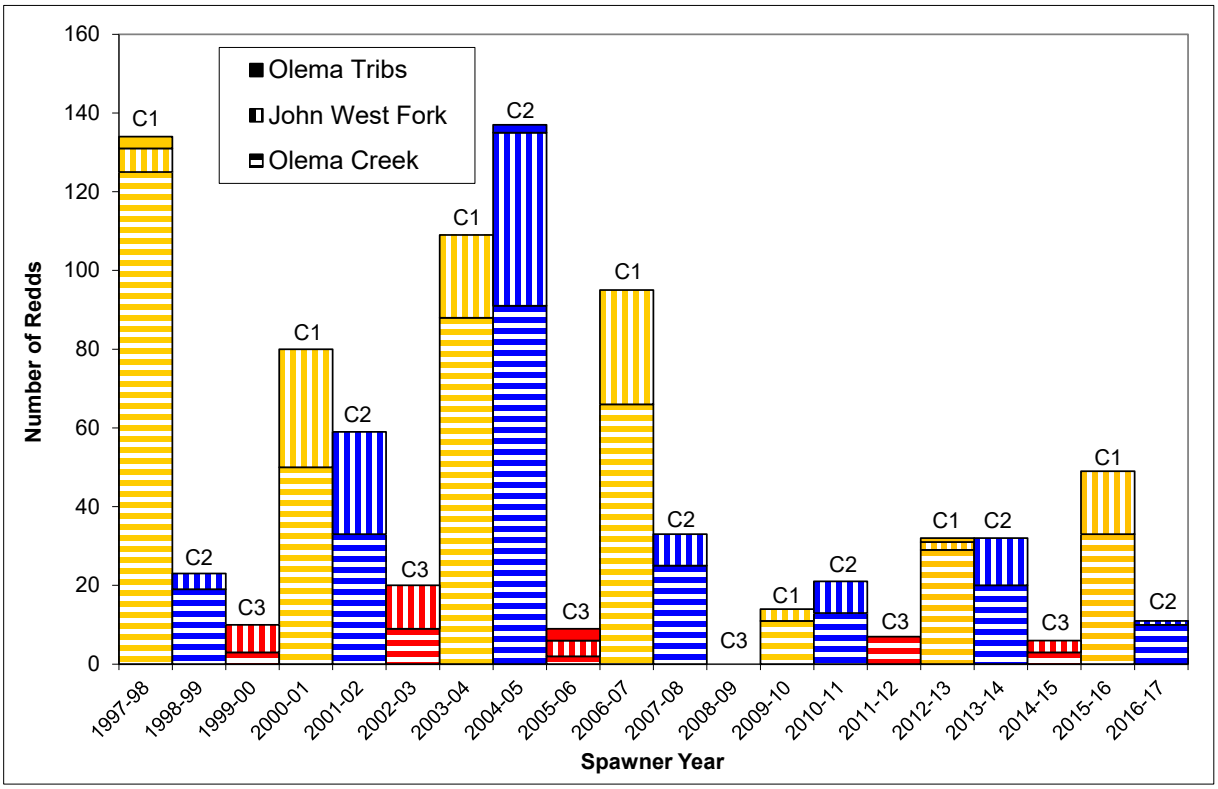

Figure 5. Coho salmon redd results for the Olema Creek watershed by cohort for winter 1997-1998 through winter 2016-2017. Cohorts are designated by color (cohort 1 shown in yellow, cohort 2 shown in blue, cohort 3 shown in red) and creeks are designated by pattern (Olema Creek in horizontal lines, John West Fork in vertical, and other Olema tributaries in a solid color).

Live Coho and Coho Carcass Biotics

Information on live adult coho and coho carcasses were collected during each field survey; information on sex ratios for live fish and carcasses are reported in Tables 1 and 2, respectively.

Table 1. Sex ratio percentages and mean fork length (FL) of live coho within Olema Creek Watershed for the period 1997-2016 compared to 2016-2017. FL = fork length, SD = standard deviation.

Period	Type[a]	Year	Live Coho				
			Sample Size	Sex Ratio %	n[b] for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2016	726	37	699	63	7.3
	F	1997-2016	872	45	850	61	6.0
	J	1997-2016	265	14	265	39	5.3
	Unk	1997-2016	93	5	52	57	7.3
	All	–	1,956	100	–	–	–
Current	M	2016-2017	3	18	3	50	0.0
	F	2016-2017	4	24	4	45	10.8
	J	2016-2017	9	53	9	40	3.5
	Unk	2016-2017	1	5	0	–	–
	All	–	17	100	–	–	–

[a]M = Male, F = Female, J = Jack, Unk = Unknown

[b]n = Number of fish measured for fork length (FL)

Table 2. Sex ratio percentages and mean fork length (FL) of coho carcasses within Olema Creek Watershed for the period 1997-2016 compared to 2016-2017. FL = fork length, SD = standard deviation.

Period	Type[a]	Year	Carcasses				
			Sample Size	Sex Ratio %	n[b] for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2016	156	34	113	66	7.9
	F	1997-2016	190	41	152	65	5.1
	J	1997-2016	44	9	44	43	3.7
	Unk	1997-2016	73	16	11	65	7.1
	All	–	463	100	–	–	–
Current	M	2016-2017	0	0	0	–	–
	F	2016-2017	0	0	0	–	–
	J	2016-2017	0	0	0	–	–
	Unk	2016-2017	0	0	0	–	–
	All	–	0	–	–	–	–

[a]M = Male, F = Female, J = Jack, Unk = Unknown

[b]n = Number of fish measured for fork length (FL)

3.2.2 Cheda Creek Coho and Steelhead Escapement

Cheda Creek is a small but important tributary of the Lagunitas Creek watershed and provides critical habitat for coho salmon and steelhead. Cheda Creek spawner survey information includes data collected on 1.7 km.

Survey Timing and Environmental Conditions
Three surveys were performed on Cheda Creek during the 2016-2017 season. Water clarity for the surveys ranged from 25 to 70 cm.

Live Coho and Steelhead
While live coho observations do not accurately represent the total number of spawning adults, only one coho adult was observed on Cheda Creek this season. No live adult steelhead were observed during surveys.

Coho and Steelhead Carcasses
Three coho carcasses were recovered from Cheda Creek during the 2016-2017 spawner season. No steelhead carcasses were recovered.

Coho and Steelhead Redds
One definite coho redd was observed on Cheda Creek. The surface area for the known coho redd was 1.36 m^2. The average redd density for Cheda Creek was 0.6 redds/km.

No steelhead redds were observed on Cheda Creek this season, and six redds were recorded as unknown. The Gallagher model was used to designate species for unknown redds. The model classified three of the unknown redds as coho, and three of the unknown redds as steelhead, with a total of four coho redds and three steelhead redds

The kNN algorithm could not be used to classify unknown redds on Cheda Creek, because steelhead activity was not observed.

Cheda Creek Watershed Coho Escapement History
The dataset for adult escapement within Cheda Creek includes 19 years of survey information and has documented the return of coho to this small tributary of Lagunitas Creek (Appendix A, Table A4).

3.2.3 Redwood Creek Coho and Steelhead Escapement

Run Timing and Environmental Conditions Background
Review of the past 20 years of coho salmon escapement monitoring information for Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff conditions within the watershed. Redwood Creek is an unregulated stream with variable environmental conditions that limit flows in the winter season. During most years, initial fish access to Redwood Creek depends on the breaching of a sand bar at its confluence with the Pacific Ocean. In normal years, adult coho salmon upstream migration coincides with brief peak winter discharges, typically occurring in December and January (Weitkamp et al. 1995).

Survey Timing and Environmental Conditions
Twelve surveys were conducted in Redwood Creek between 2 November 2016 and 8 March 2017. The mean interval between surveys during the primary coho spawning season was 11.6 days. Seven day rainfall totals for Julian weeks within peak spawning months (December and January) ranged from a low of 0.01 inches during Julian week 51 and a high of 5.73 inches during Julian week 3.

Average water clarity at the time of each survey ranged from 35 cm to over 100 cm. Historical information on timing of past runs, rainfall during the run period, and spawning activity observed on Redwood Creek can be found in Appendix A, Table A5.

Green Gulch, Fern Creek, and Kent Canyon are tributaries to Redwood mainstem. Fern Creek was surveyed four times this season on the same day as the mainstem to eliminate the possibility of double counting; water clarity ranged from 60 cm to 100 cm. Surveys on Green Gulch and Kent Canyon were dependent on flow. Lower Green Gulch was surveyed twice (1 January 2017 and 2 February 2017) and Kent Canyon was surveyed once, on 17 January 2017 (water clarity was 60 cm). Water clarity ranged from 20 cm to 65 cm on Green Gulch.

Live Coho and Steelhead

On 8 December 2016, 106 adult coho spawners taken as juveniles from Redwood Creek and raised to maturity, were released as part of an emergency rescue rearing project. Sixty-nine of those fish were adult females, while 34 of those fish were adult males. The remaining three fish were jacks, or precocious males. Forty-seven live adult coho were observed on the mainstem of Redwood Creek during the 2016-2017 spawner season, with 37 of those observed fish displaying hatchery floy-tags (19 pink [female] and 18 green [male] tags). Two adult steelhead and eight unknown salmonids were also observed this season. No adult salmonids were observed in the tributaries.

Coho and Steelhead Carcasses

Two confirmed coho carcasses were recovered on Redwood Creek mainstem, one with a floy tag (green) and one without. One steelhead carcass was also recovered this season. One carcass recovered on the mainstem was not identifiable to species.

Coho and Steelhead Redds

Ten confirmed coho redds were observed during the 2016-2017 spawner season. Redds were documented in reaches 2 and 3 of the mainstem. The average surface area for coho redds was 1.98 m^2, while the total density of redds was 1.28 redds/km. No confirmed coho redds were observed on Fern Creek, Green Gulch, or Kent Canyon tributaries.

Four confirmed steelhead redds were observed with an average measured surface area of 1.5 m^2 on the mainstem of Redwood Creek. Steelhead redd density on the mainstem was 0.51 redds/km. No confirmed steelhead redds were observed on Fern Creek, Green Gulch, or Kent Canyon.

Three redds observed on the mainstem were recorded as unknown, with three unidentified redds observed on Kent Canyon, as well. The Gallagher model classified all three of the unidentified redds as coho resulting in a total count of 13 coho redds and 4 steelhead redds for Redwood Creek mainstem. The Gallagher model classified the three unknown redds on Kent Canyon as coho, as well, resulting in a total of 16 coho redds and four steelhead redds for the Redwood Creek watershed.

The kNN algorithm also classified all of the unknown redds as coho, resulting in 16 coho redds and four steelhead redds for the Redwood Creek watershed. The K-nearest neighbor method is currently under review by the CMP Technical Team, but results were included for comparison.

Coho Spawning Trends

Overall trends in coho spawning on Redwood Creek, based on observed redds, are shown below in Figure 6. The three cohorts are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Cohort 1 spawning had been relatively consistent after 2006-2007, until a decline in redd production was observed during the 2015-2016 season. Cohort 2 shows an increasing trend in spawning since 1995-1996, with an abrupt decline during the 2007-2008 spawner season and very limited recovery since. Cohort 3 redd numbers have consistently been in the single digits with the exception of 2005-2006. Both Cohort 2 and 3 remain at critical levels within the past two generations. Tributary spawning is also represented in Figure 6. For all years, the majority of spawning occurs on the mainstem of Redwood Creek, with limited spawning observed on Fern Creek and Kent Canyon during years with higher abundance.

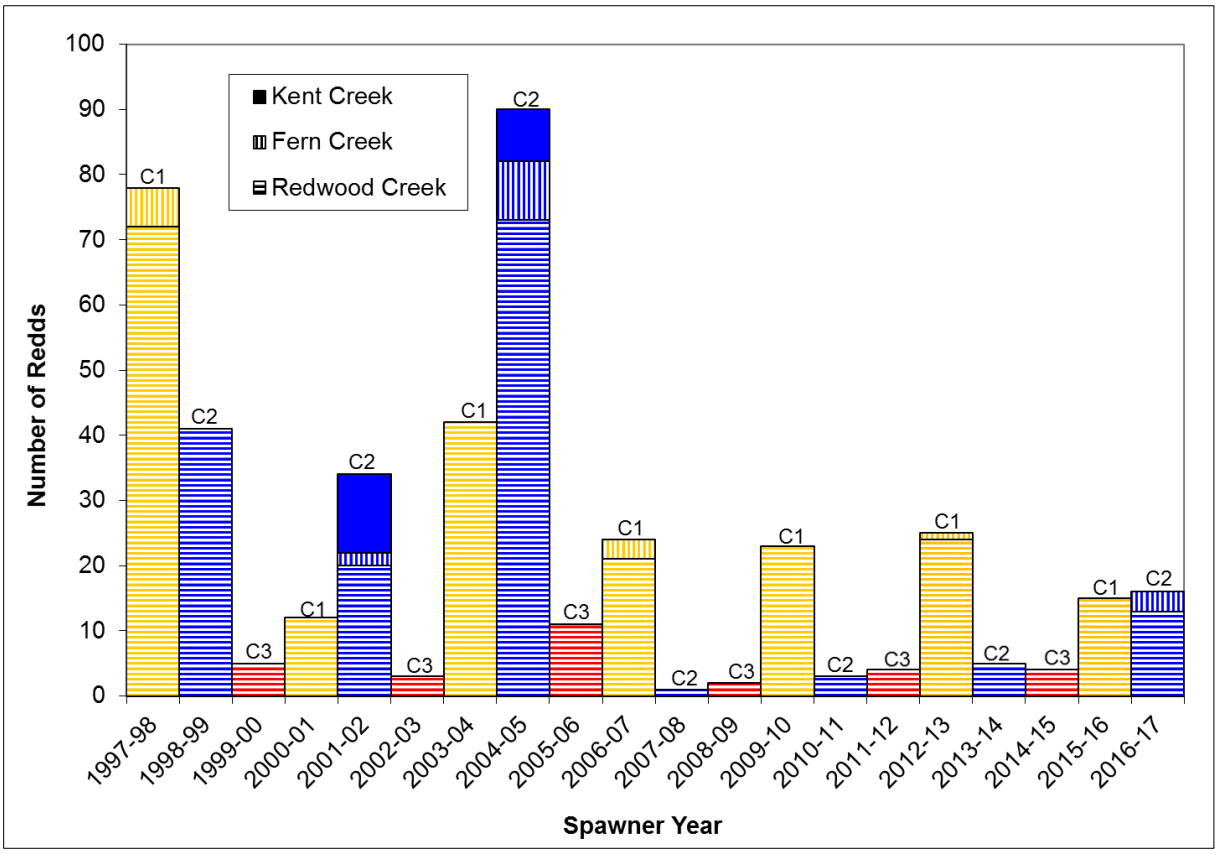

Figure 6. Coho salmon redd numbers in the Redwood Creek watershed by cohort for winter 1997-1998 through winter 2016-2017. Cohorts are designated by color (cohort 1 shown in yellow, cohort 2 shown in blue, cohort 3 shown in red), and creeks are designated by pattern (Redwood Creek in horizontal lines, Fern Creek in vertical, and Kent Creek in a solid color).

Live Coho and Coho Carcass Biotics

Information on live coho and coho carcasses were collected during each field survey. Sex ratios for live coho and coho carcasses are reported for 2016-2017 in Tables 3 and 4. Information presented includes both hatchery reared and wild fish.

Table 3. Sex ratio percentages and mean fork length (FL) of live coho within the Redwood Creek watershed for the period 1997-2016 compared to 2016-2017.

Period	Type[a]	Year	Live Coho				
			Sample Size	Sex Ratio %	n[b] for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2016	354	32	351	62	8.4
	F	1997-2016	475	43	460	59	6.3
	J	1997-2016	144	13	144	41	7.8
	Unk	1997-2016	132	12	104	56	6.1
	All	–	1,105	100	–	–	–
Current	M	2016-2017	10	30	10	60.5	8.3
	F	2016-2017	21	70	21	52.4	15.1
	J	2016-2017	10	0	10	39	7.4
	Unk	2016-2017	6	0	6	50	8.9
	All	–	47	100	–	–	–

[a]M = Male, F = Female, J = Jack, Unk = Unknown

[b]n = Number of fish measured for fork length (FL)

Table 4. Sex ratio percentages and mean fork length (FL) of coho carcasses within the Redwood Creek watershed for the period 1997-2016 compared to 2016-2017.

Period	Type[a]	Year	Carcasses				
			Sample Size	Sex Ratio %	n[b] for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2016	57	24	50	66	7.6
	F	1997-2016	111	47	98	63	8.5
	J	1997-2016	22	10	22	41	4.7
	Unk	1997-2016	44	19	14	64	4.6
	All	–	234	100	–	–	–
Current	M	2016-2017	1	50	0	57	5.8
	F	2016-2017	0	0	0	63	6.8
	J	2016-2017	0	0	0	41	7.2
	Unk	2016-2017	1	50	0	–	–
	All	–	3	100	–	–	–

[a]M = Male, F = Female, J = Jack, Unk = Unknown

[b]n = Number of fish measured for fork length (FL)

3.2.4 Pine Gulch Creek Coho and Steelhead Escapement

Survey Timing and Environmental Conditions

One survey was conducted on Pine Gulch Creek on 1 February 2017. Seven day rainfall totals for Julian weeks within peak spawning months (December and January) ranged from a low of 0.01

inches during Julian week 51 and a high of 5.71 inches during Julian week 3. Average water clarity at the time of surveys was 85 cm.

Live Salmonids and Salmonid Carcasses
No live adult coho spawners were observed on Pine Gulch Creek during the 2016-2017 season.

Coho and Steelhead Redds
No redds of any kind were discovered on Pine Gulch Creek during the 2016-2017 spawner season.

Pine Gulch Creek Watershed Coho Escapement History
The dataset for the adult escapement within Pine Gulch Creek includes 17 years of survey information following the discovery of one adult coho salmon during 2000-2001. Since this discovery, live adult coho and/or coho spawning activity have only been documented in the watershed 6 out of the 17 years (Appendix A, Table A6). The 2011-2012 season is the last time coho spawning was observed on Pine Gulch Creek.

3.3 Spring 2017 Outmigrant Coho Smolt Trapping Results

Results for smolt trapping are reported by Julian week (Appendix B, Table B1) to support analysis between monitoring years and watersheds. In all years, trapping operations were conducted within an 11-week time frame starting in mid-March and ending in early June. Actual start and end dates for each year vary depending on in-stream flows and coho smolt captures. Trapping operations were initiated on Pine Gulch in 2002, Olema Creek in 2004, and Redwood Creek in 2005. Since juvenile coho were not observed in Pine Gulch Creek during the summer 2016 surveys, the stream was not monitored for smolt outmigration. Therefore, only Olema Creek and Redwood Creek data are included in this report. Smolt production estimates are only calculated for coho due to differences in outmigration timing between coho and steelhead smolts. Anecdotal information collected on steelhead smolt, 1+ steelhead (SH 1+), steelhead young-of-year (YoY), and coho (YoY) are also summarized in this section.

3.3.1 Coho Smolt Outmigration Environmental Conditions and Timing

The onset of smoltification is likely controlled by photoperiod but other cues such as spring weather patterns, changes in stream flow, and lunar phases may also influence the timing and rate of coho smolt outmigration (Spence and Hall 2010). Smolt outmigration historically peaks during Julian weeks 17-19 (late April – early May). On average, the majority of Olema Creek outmigration occurs during Julian weeks 16-18, and the majority of Redwood Creek outmigration occurs during weeks 17 and 18 (Figure 7). In 2017, Olema Creek smolt outmigration peaked a week earlier when compared to the historical averages. On Redwood Creek, smolt outmigration peaked a week later when compared to historic averages (Figure 8).

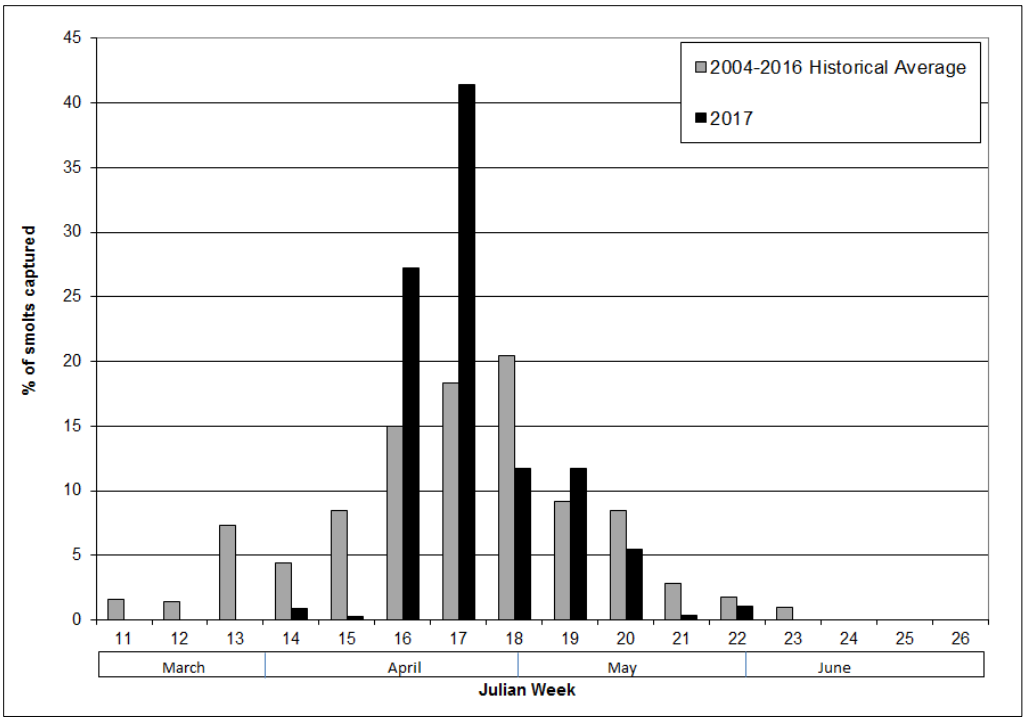

Figure 7. Percent of total coho smolts captured in the trap by Julian week for Olema Creek in 2017 compared to the historical average, 2004-2016.

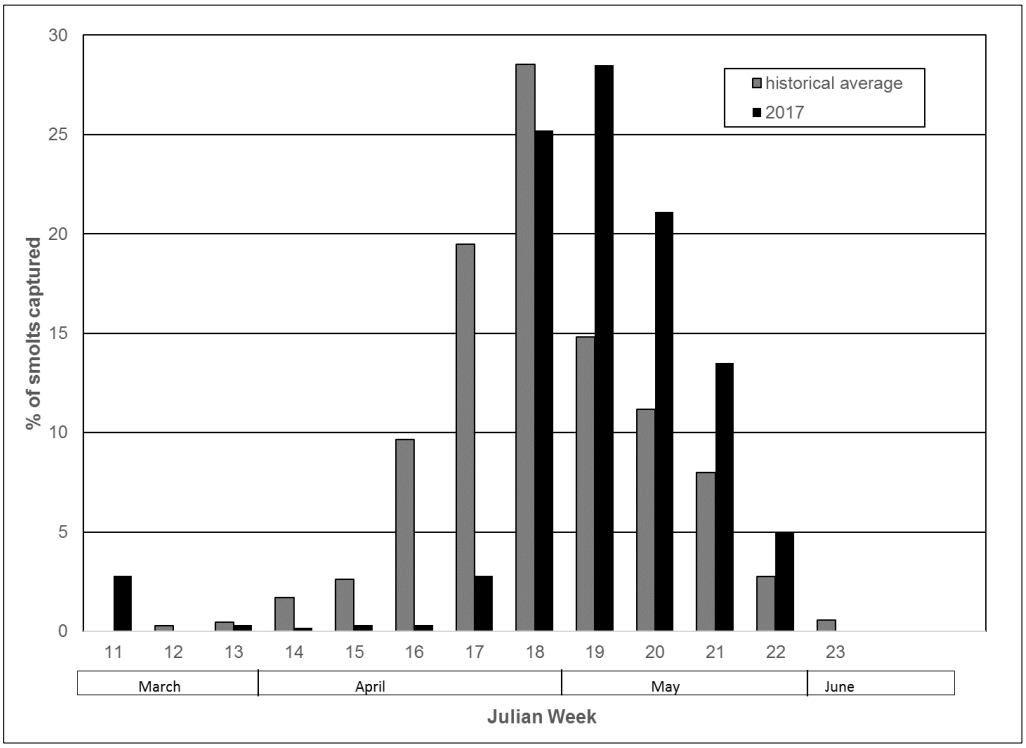

Figure 8. Percent of total coho smolts captured in the trap by Julian week for Redwood Creek in 2017 compared to the historical average, 2005-2016.

Spring Coho Outmigration Rainfall

Rainfall amounts were collected from rain gauges located at the Olema Valley Weather Station near Olema Creek and at the Highway 1 Bridge on Redwood Creek. A total of 7.57 inches of precipitation was recorded at the Olema Valley Weather Station during smolt trapping operations. The rain gauge at the Highway 1 Bridge on Redwood Creek recorded 6.53 inches of precipitation. For the 2017 smolt trapping season, rainfall amounts at the Olema site were slightly lower than the historical average (8.83 inches) while the Redwood site showed slightly higher than the historical average (5.73 inches, respectively).

Spring Coho Smolt Trap Water Temperature

Water temperatures were recorded on a fifteen-minute interval using Onset HOBO® data loggers. Temperatures within the mainstem smolt traps on Olema Creek and Redwood Creek were within the tolerable range (less than 22 ºC) for coho salmon (Moyle 2002) throughout the season. The Olema trap had an average temperature of 13.7 ºC [1.60 standard deviation (SD)], a maximum of 18.0 ºC, and a minimum of 9.5 ºC. The Redwood Creek trap had an average temperature of 13.0 ºC (1.03 SD), a maximum of 17.3 ºC, and a minimum of 10.8 ºC.

3.3.2 Olema Creek Smolt Trapping Coho and Steelhead Results

During the 2017 outmigrant trapping study, the Olema Creek trap was in place for 60 days (16 March—2 June 2017) and fully operational for 59 days. The trap was partially operational for one day.

The trap captured a total of 1,154 coho smolts, with a mortality rate of 1% (6/1,154). The overall recapture rate for marked coho smolts was 20% (86/427). DARR analysis of the coho smolt data stratified by day estimated capture probability at 20% for the duration of the smolt trapping season. The Olema Creek coho smolt production estimate for the 2017 season is 5,677, 95% CI [5,097:6,258]. Figure 9 shows a summary of coho smolt production estimates for Olema Creek traps spring 2005 through 2017; the smolt production estimates are calculated for coho only.

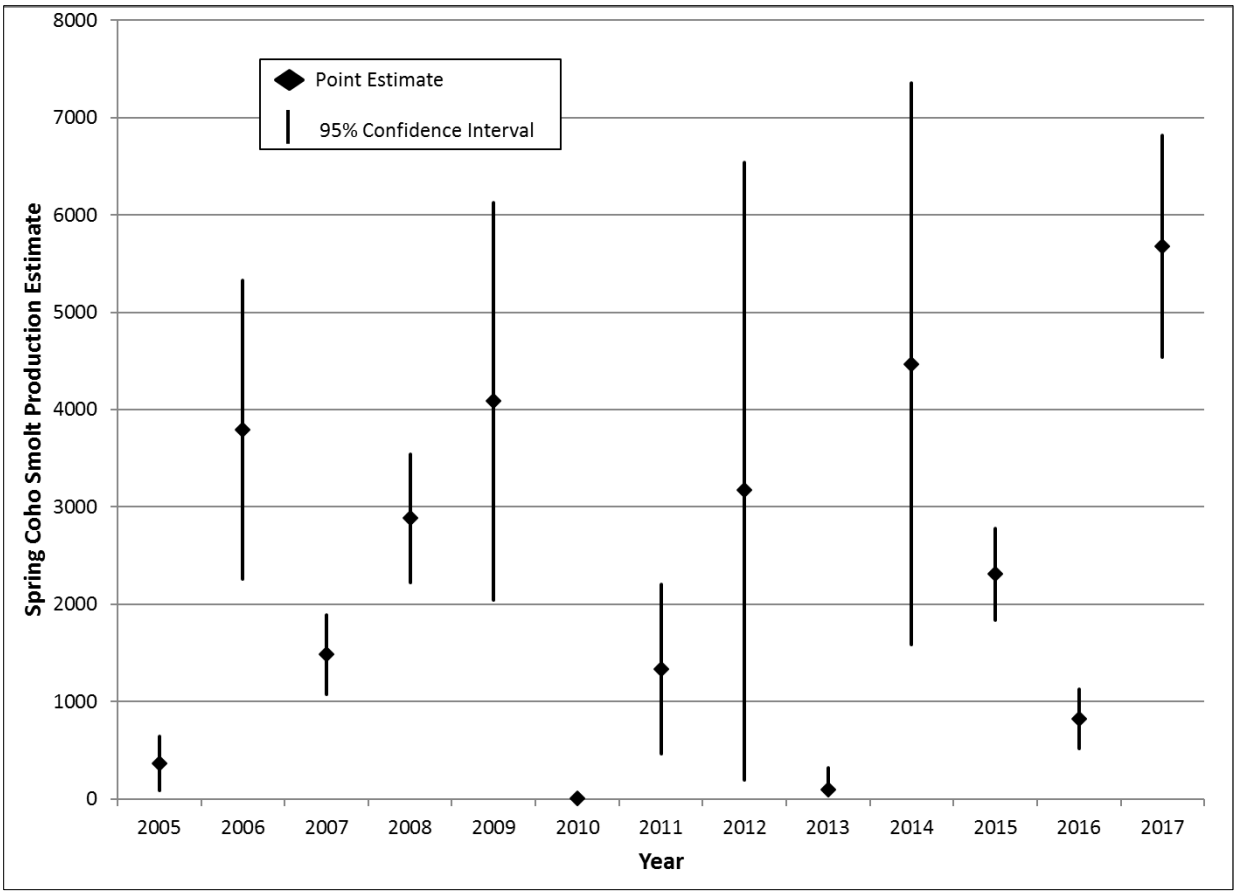

Figure 9. Coho smolt production estimates for Olema Creek, spring 2005-2017. The 2005 and 2013 estimates were calculated using the Chapman modification of the Petersen estimate equation, not using the DARR program.

Additionally, the trap captured a total of seven steelhead smolts, eight steelhead 1+, 10 coho YoY, and 251 steelhead YoY. The peak coho YoY capture occurred in late April and early May (Julian weeks 18 and 19) while the steelhead YoY and steelhead 1+ were captured throughout the season. The mortality rate was 0% for steelhead smolts, steelhead 1+, and coho YoY, while steelhead YoY had a mortality rate of <1% (1/251).

A total of 427 coho smolts were implanted with passive integrated transponder (PIT) tags during the trapping season on Olema Creek. Recapture data show that fish spent an average of five days in the system after being marked before continuing their outward migration. The time spent upstream of the trap ranged from one day to 17 days, with a median of four days. Tagged individuals had an average and median fork length of 119 mm. The average weight was 15.7 g with a median weight of 15.3 g. Of the 427 tagged coho smolts, 86 were subsequently recaptured with no observed mortality. During the 2016 summer juvenile surveys, 249 juvenile coho were implanted with PIT tags. Nine of these summer tags were recaptured this season at the Olema smolt trap. They showed an average increase in length of 51 mm and an average increase in weight of 8.8 g.

3.3.3 Redwood Creek Smolt Trapping Coho and Steelhead Results

During the 2017 outmigration season, two traps were operated on Redwood Creek. In addition to the primary outmigrant trap detailed in the approved protocol, a second trap was installed approximately 200 m downstream on a backwater system to detect potential use by salmonids. Although monitoring results for the backwater trap are presented in this report, the backwater trap is not part of the salmonids long-term monitoring program. The primary mainstem trap was operated in association with ongoing restoration activities in lower Redwood Creek.

The mainstem trap was in place for 62 days (16 March—2 June 2017). It was fully operational for 58 days, and partially operational for five days. The backwater trap was first operational on 17 March and was opened on 15 May. It was fully operational for 41 days, partially operational for three days, and nonoperational for two days. Only one coho smolt was captured on the backwater trap.

The mainstem trap captured a total of 606 coho smolts and the mortality rate was 1% (8/606). The overall recapture rate for marked coho smolts was 61% (151/247). DARR analysis of the coho smolt data stratified by day estimated capture probability at 89% for the first six week of the smolt trapping season, with the remainder of the season holding at approximately 57%. The total Redwood Creek coho smolt production estimate is 853, 95% CI [606:1,108]. Figure 10 shows a summary of coho smolt production estimates for Redwood Creek traps spring 2005 through 2017; the smolt production estimates are calculated for coho only.

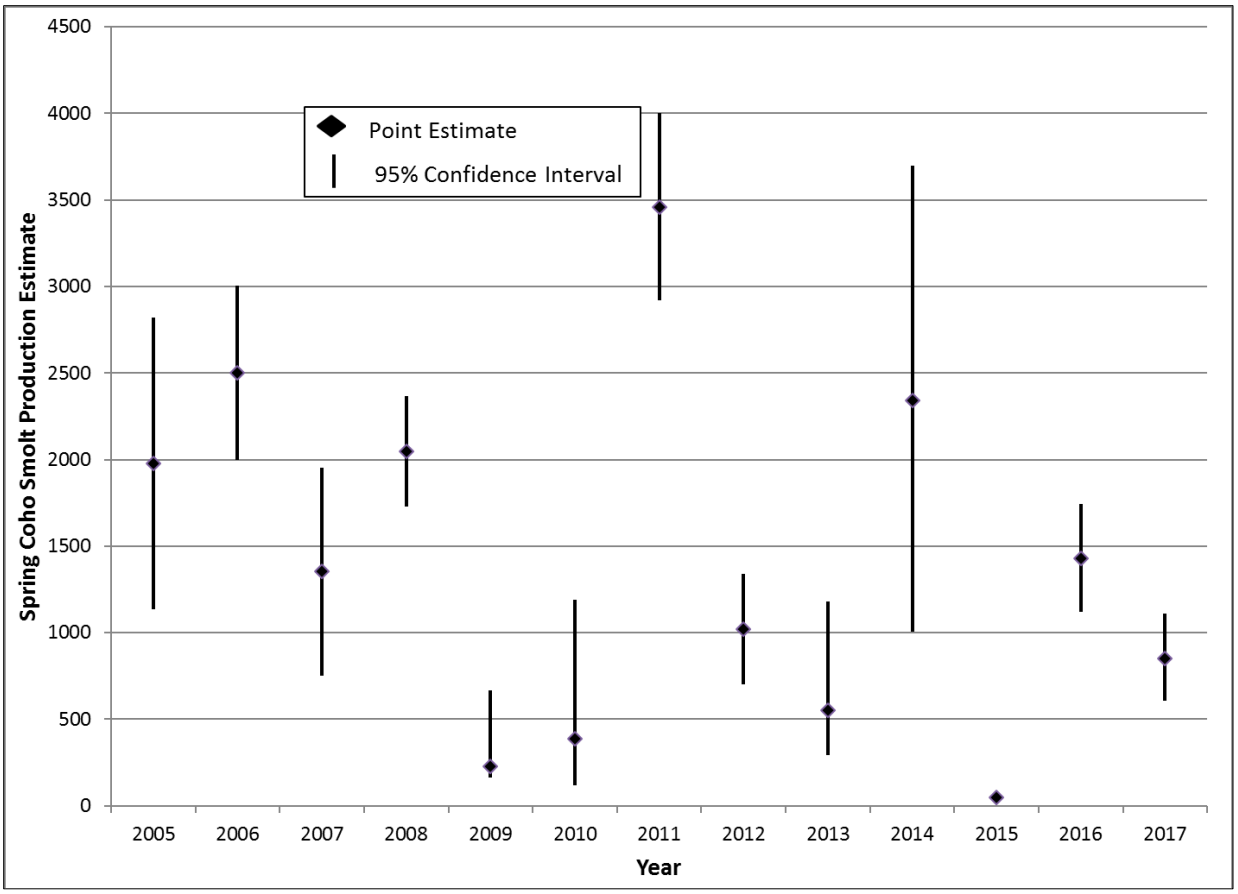

Figure 10. Coho smolt production estimates for Redwood creek, spring 2005-2017. The 2009 estimate was calculated using the Chapman modification of the Petersen estimate equation, not using the DARR program. The 2015 estimate is the raw count.

A total of 41 steelhead smolts and 31 steelhead 1+ were captured, with mortality rates of 0% and 3% (1/31), respectively. Five steelhead YoY were also captured with no observed mortality.

Recapture data show that marked fish spent an average of five days in the system after being marked before continuing their outward migration. The time spent upstream of the trap ranged from one day to 17 days, with a median of five days. Tagged individuals had an average and median fork length of 108 mm. The average weight was 11.7 g with a median weight of 11.4 g. Of the 197 tagged coho smolts, 67 were subsequently recaptured. The mortality rate for recaptured coho was <1% (2/247). During the 2016 summer juvenile surveys, 123 juvenile coho were implanted with PIT tags. Twenty-two of these tagged juveniles were recaptured this season at the Redwood smolt trap. They showed an average increase in length of 31 mm and an average increase in weight of 6.5 g.

3.3.4 Coho and Steelhead Smolt Size and Condition

Length and weight data provide critical information that contributes to an understanding of fish health, survival, and condition factors. In addition, length and weight data allow for estimating fork length frequency, growth rates, and biomass production. Throughout the 2017 smolt trap operations,

staff recorded fork lengths to the nearest mm and weights to the nearest 0.01 g of a subsample of fish caught in each trap.

Olema Creek Coho and Steelhead Smolt Fork Length and Weight

A total of 582 coho smolts were measured for fork length (mm), and 547 of those were also weighed (0.01 g). Coho smolt fork lengths measured throughout the spring 2017 monitoring efforts on Olema Creek ranged from 95 mm to 154 mm, and the highest length frequency was in the 111 mm to 115 mm length interval, representing 22% of the coho smolts measured. The mean coho smolt weight for the duration of the 2017 Olema trapping season was 15.5 g (SD 3.68 g), and the median weight was 15.1 g. Figures 11 and 12 show length and weight data for coho smolts captured during smolt trapping operations spring 2004 through 2017.

Of the seven steelhead smolts captured on Olema Creek, all were measured and weighed. Steelhead smolt fork lengths ranged from 105 mm to 191 mm, and the highest frequency of steelhead smolt fork lengths occurred within the 171 mm to 175 mm length interval, representing 29% of the steelhead smolts measured. Figure 13 shows length information collected from steelhead smolts on Olema Creek.

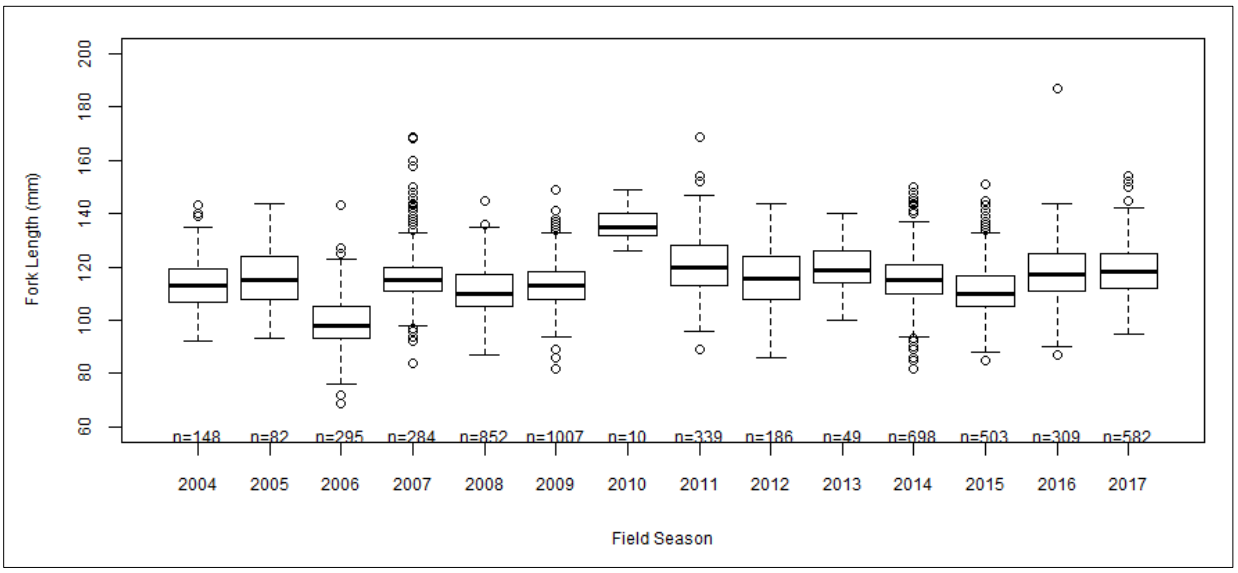

Figure 11. Box and whisker plot of coho salmon smolt fork length for Olema Creek, 2004-2017. Dark lines represent medians, circles represent outliers.

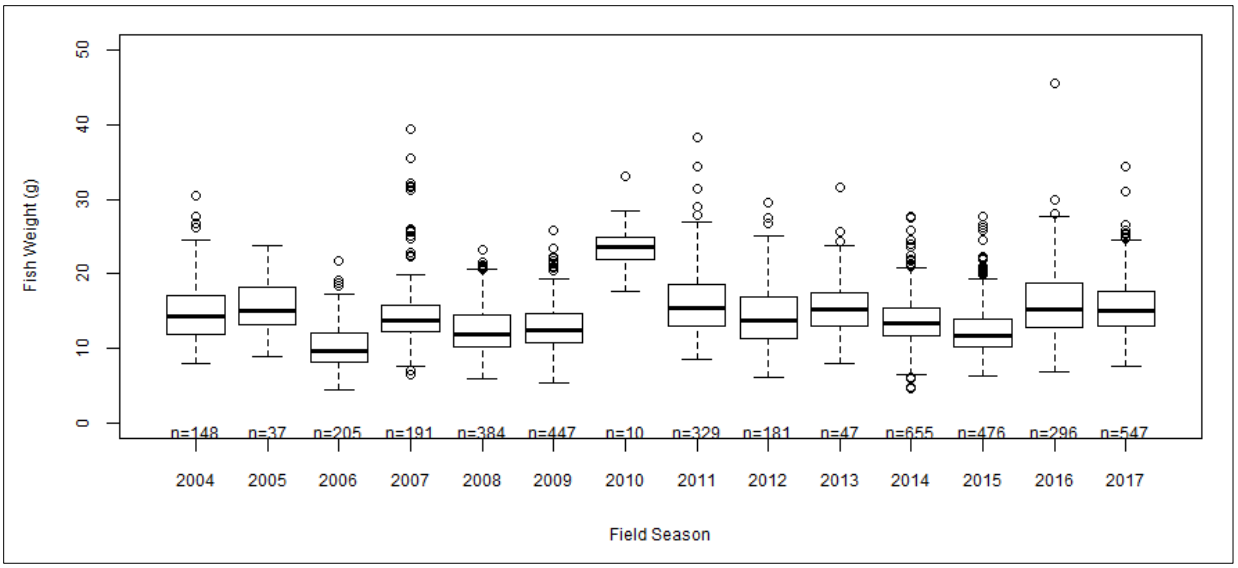

Figure 12. Box and whisker plot of coho salmon smolt weight for Olema Creek, 2004-2017. Dark lines represent medians, circles represent outliers.

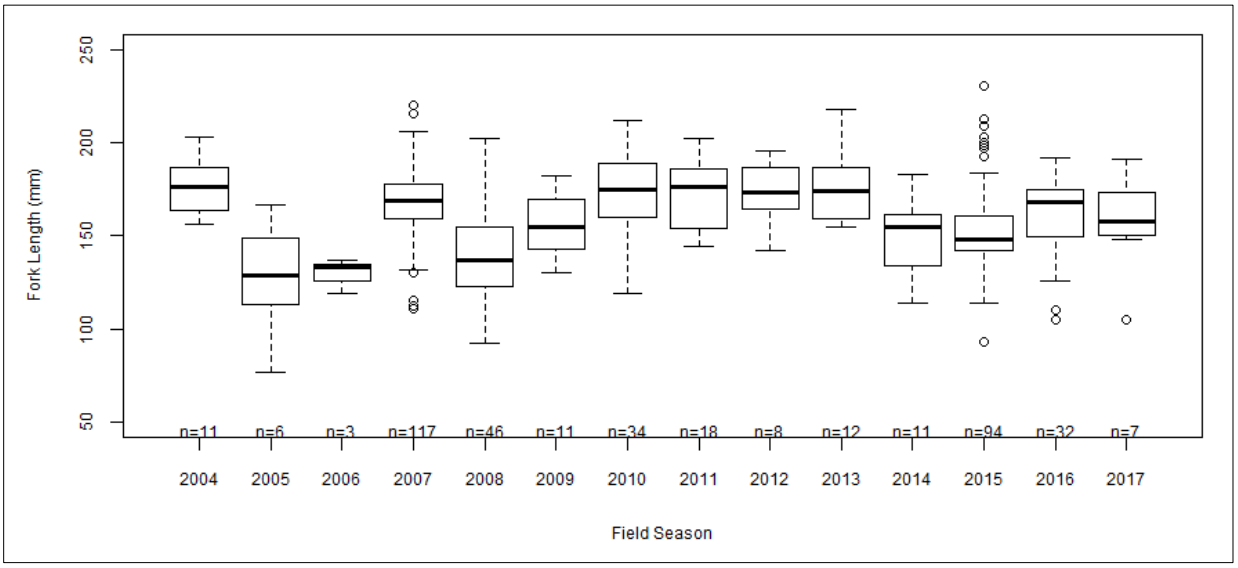

Figure 13. Box and whisker plots for steelhead smolt fork lengths for Olema Creek, 2004-2017. Dark lines represent medians, circles represent outliers.

<u>Redwood Creek Coho and Steelhead Smolt Fork Length and Weight</u>

A total of 365 coho smolts were measured for fork length (mm), and 348 of these fish were also weighed (0.01 g). Coho smolt fork lengths measured throughout the 2017 outmigrant trapping season ranged from 79 mm to 140 mm. The highest length frequency of coho smolts on Redwood Creek was in the 106 mm to 110 mm length interval, representing 25% of the coho smolts measured. The mean coho smolt weight for the duration of the 2017 trapping season was 11.7 g (SD 2.97 g), and the median weight was 11.4 g. Figures 14 and 15 show length and weight data for coho smolts captured on Redwood Creek.

Of the 30 steelhead smolts measured for fork length, 28 were also weighed. Steelhead smolt fork lengths ranged from 100 to 184 mm. The highest frequency of steelhead smolt fork lengths occurred within the 156 to 160 mm length interval, accounting for 24% of the steelhead smolts measured. Figure 16 shows fork length information for steelhead smolts captured on Redwood Creek.

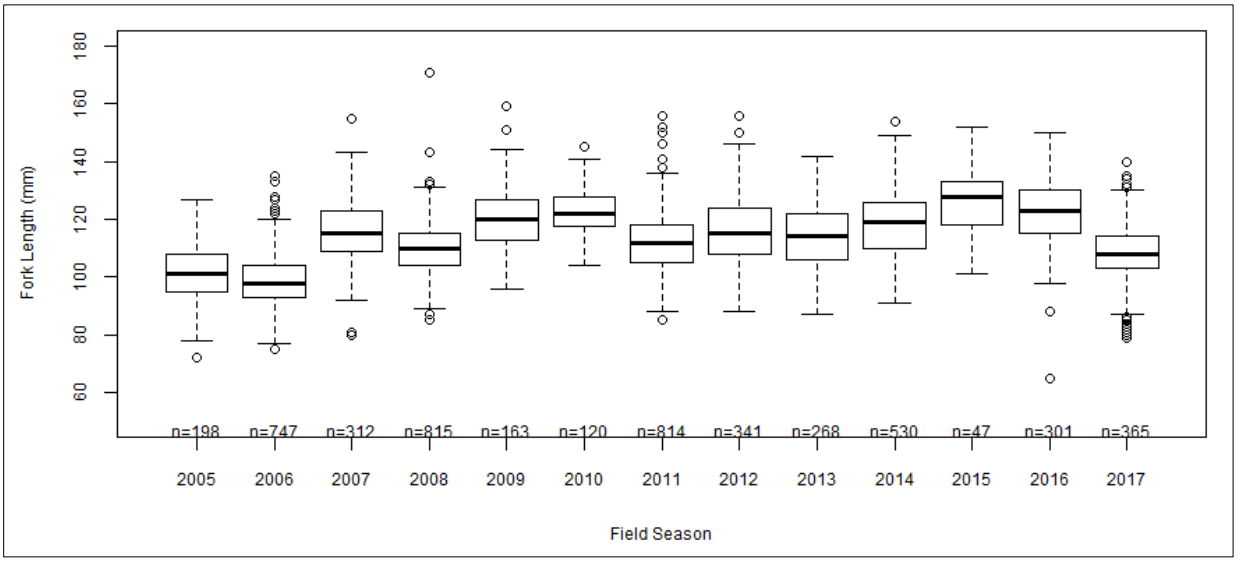

Figure 14. Box and whisker plots for coho salmon smolt fork lengths for Redwood Creek, 2005-2017. Dark lines represent medians, circles represent outliers, n= sample size.

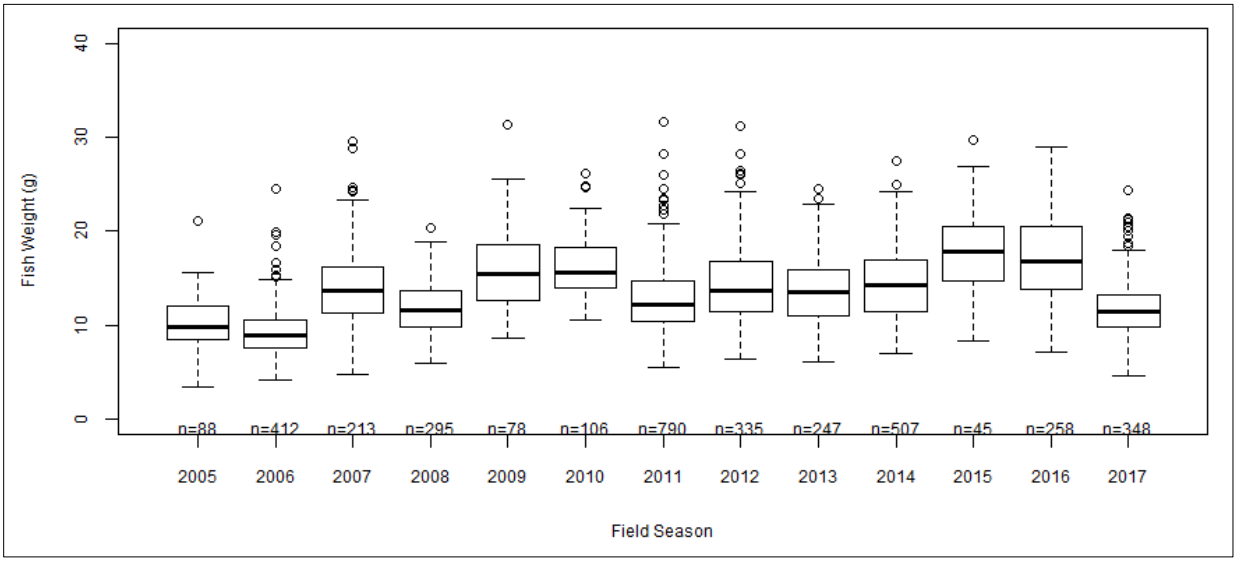

Figure 15. Box and whisker plots for coho salmon smolt weights for Redwood Creek, 2005-2017. Dark lines represent medians, circles represent outliers, n= sample size.

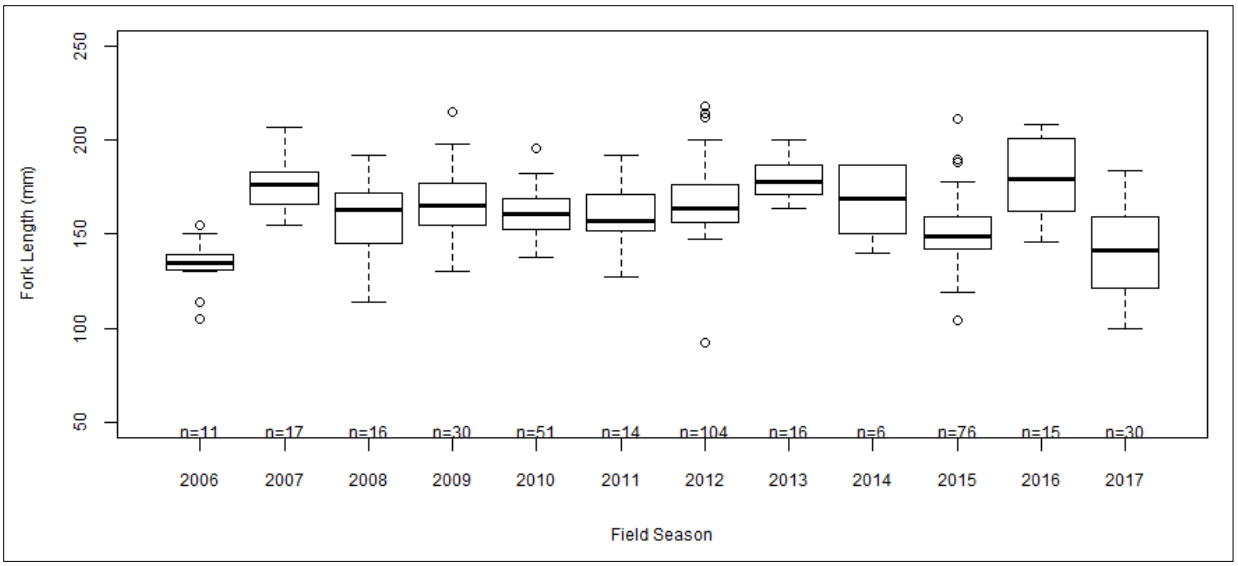

Figure 16. Box and whisker plots for steelhead smolt fork lengths for Redwood Creek, 2006-2017. No steelhead smolts were measured in 2005. Dark lines represent medians, circles represent outliers, n= sample size.

Coho and Steelhead Fulton's Condition Factor

Table 5 shows length, weight, and K-factor for coho smolts captured during 2017 smolt trap sampling on Olema and Redwood Creeks, while Table 6 shows the fork length, weight, and K-factor for steelhead smolts caught during smolt trap sampling on Olema and Redwood Creeks. Historical fork length, weight, and K-factor data for salmonid smolts on Olema and Redwood Creeks is in Appendix A, Tables A7 through A10.

Table 5. Coho smolt mean and median fork length, weight, and K-factor calculated during 2017 for the trapping locations on Olema and Redwood Creeks. FL = fork length, SD = standard deviation.

Watershed	Sample Size	Mean FL (mm)	Median FL (mm)	Mean FL SD	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Olema Creek	582	118	118	9.6	15.5	3.68	15.1	0.93	0.08
Redwood Creek	365	108	108	9.7	11.7	2.97	11.4	0.91	0.07

Table 6. Steelhead smolt mean and median fork length, weight, and K-factor calculated during 2017 for the trapping locations on Olema and Redwood Creeks. FL = fork length, SD = standard deviation.

Watershed	Sample Size	Mean FL (mm)	Median FL (mm)	Mean FL SD	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Olema Creek	7	157	158	27.4	37.2	14.9	37.0	0.93	0.12
Redwood Creek	30	141	142	23.7	27.4	10.9	25.7	0.92	0.08

3.3.5 Smolt Trap Summary of Non-salmonid Total Catch

On Olema Creek, a total of 1,290 non-salmonid aquatic vertebrates were captured during the 2017 trapping season. The majority of the non-salmonid catch was comprised of three-spined stickleback (55%). Of the 1,089 non-salmonid aquatic vertebrates captured in the mainstem Redwood Creek trap, 943 (87%) were three-spined stickleback. In the backwater trap on Redwood Creek, a total of 840 non-salmonids were captured. California newts (*Taricha torosa*) and rough-skinned newts (*Taricha granulosa*) accounted for 99% of the non-salmonid. Historical non-salmonid catch information is in Appendix A, Tables A11 and A12.

3.4 Juvenile Coho and Steelhead Basinwide 2017 Results

Summer juvenile monitoring results are provided for Olema Creek, Redwood Creek, and Pine Gulch Creek.

3.4.1 Olema Creek

The 2017 summer habitat survey and basinwide snorkel surveys of Olema Creek were initiated at monument tag 15, the current Olema Creek smolt trapping site, and surveyed to monument tag 150, adjacent to the Randall Ranch House. The measured basinwide survey length for the main channel was 13.1 km. Stream segments totaling approximately 1.0 km in length were not sampled as they were deemed inaccessible due to dense vegetation, deemed as marsh lands with no defined channel, or because we had concerns with water quality, specifically high concentrations of fecal coliform.

<u>Habitat Survey</u>

A total of 1,164 mainstem habitat units were identified in the 13,115 m Olema Creek survey reach. Pool units were the dominant habitat type available to fish, measuring 7,374 m and accounting for 56% of the total mainstem length. Habitat composition data for Olema Creek are located below in Table 7. Intermittent conditions were observed approximately 9.7 km upstream from the mouth of Olema Creek. Dry sections of streambed accounted for 10% of the total length surveyed. Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Overall, 772 m of side channel habitat and 322 m of backwater habitat was measured during the survey. Flatwater and riffle habitat types accounted for 87% of the total side channel habitat length.

Total wetted mainstem survey length was 11,826 m and was used to calculate side channel and backwater density, 6.5 m per 100 m and 2.7 m per 100 m, respectively. Compared to previous years,

side channel density increased (2004 to 2016 average of 5.4 m per 100 m), while backwater density decreased (2004 to 2016 average of 2.9 m per 100 m).

Table 7. Habitat composition of Olema Creek coho survey reach for 2017. Measured total length is used to calculate percentages of length per habitat type.

Unit Type	Total length (m)	% of length	# of units	% of units
Pool	7,374	56	424	36
Flatwater	1,907	15	272	23
Riffle	2,545	19	344	30
Dry	1,289	10	124	11
Total	13,115	100	1,164	100

Woody debris information collected during the basinwide habitat survey is summarized for 2005 to 2017 (Table 8) and may be used to identify trends in woody debris availability and recruitment. When compared to historical averages, root wad density decreased by more than fifty percent. The only categories that showed an increase in density for 2017 were 10-20 cm and 20-50 cm woody debris.

Table 8. Summary of basinwide in-stream woody debris (WD) per 100 m on Olema Creek during base flow conditions. Average 2005-2016 compared to 2017.

Field season	Survey length (# 100 m sections)	Root Wads per 100 m	LWD[a] Jams per 100 m	SWD[b] Jams per 100 m	10-20cm WD[c] per 100 m	20-50cm WD[c] per 100 m	>50cm WD[c] per 100 m
2005-2016 Average	115.2	1.3	0.5	0.6	2.7	2.5	0.8
2017	118.3	1.0	0.4	0.4	2.8	3.0	0.4

[a]LWD Jams = 10 or more pieces of large woody debris

[b]SWD Jams = 10 or more pieces of small woody debris

[c]10-20 cm, 20-50 cm, >50 cm refer to diameter of individual pieces of woody debris

Coho Snorkel Counts and Basinwide Estimate

Snorkel surveys were conducted on 20% of the delineated pools, with coho being found in 26% (22 of 84). The raw count of juvenile coho was 68, giving an estimate of <1 coho per snorkel pool. Seventeen (20%) of the 84 pools were electrofished within a day following the snorkel counts. One (1%) of the 84 pools was re-snorkeled immediately following the initial pass using the method of bounded counts. *Microfish* and bounded count population estimates for the resampled pools were used to calibrate the snorkel counts. Summer coho population estimates with 95% confidence interval were calculated for the basinwide survey reach from 2004 to 2017 (Figure 17). The 2017 basinwide estimate for juvenile coho was 400, 95% CI [181; 619].

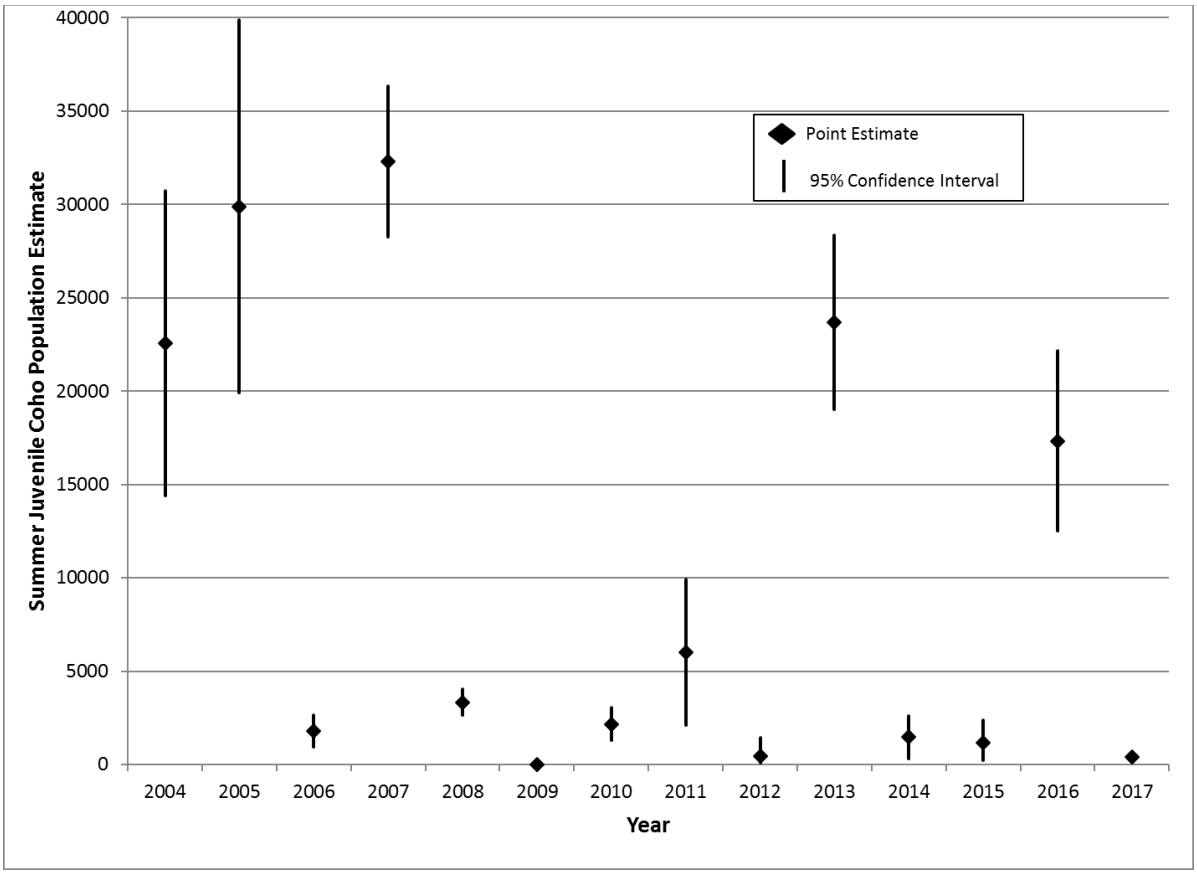

Figure 17. Summer juvenile coho basinwide population estimates for Olema Creek, 2004 through 2017.

Summer Coho and Steelhead Measurement Information

As part of the summer monitoring program, a subsample of fish were weighed and measured within each sampled habitat unit during the basinwide surveys. A total of 20 juvenile coho were measured for fork length (mm) and weighed (0.01 g). Coho fork lengths measured throughout the summer 2017 monitoring efforts on Olema Creek ranged from 72 mm to 90 mm. The highest frequency of fork lengths for coho juveniles occurred within the 71 mm to 75 mm length interval and the 76 mm to 80 mm length interval, representing 80% of the subsample of coho measured in 2017. The Olema Creek mean and median coho weight was 5.2 g (SD 0.97 g). Figure 18 shows representations of fork lengths (a) and fish weights (b) for coho juveniles caught on Olema Creek during summers 2010 through 2017.

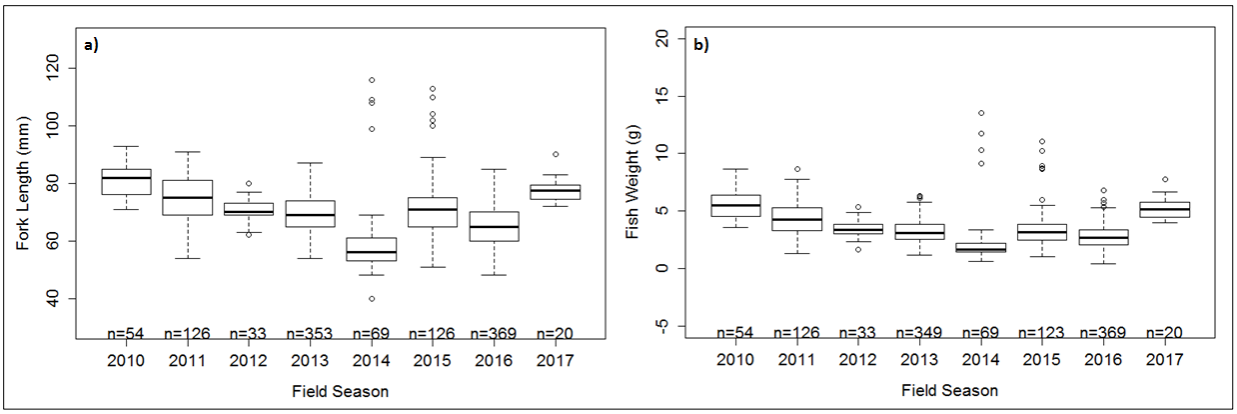

Figure 18. Box and whisker plots for juvenile coho lengths (a) and weights (b) for basinwide Olema Creek, summer 2010-2017 (no coho captured in 2009). Dark Lines represent medians, circles represent outliers.

Within the Olema Creek sample, 356 steelhead were measured for fork length. Of those 356 fish, 349 were also weighed. The size range for steelhead was 38 to 208 mm. Fork length frequencies were used to establish year class bins. The highest frequency of fork lengths for steelhead occurred within 61 to 65 mm length intervals, representing 18% of the sample. The Olema Creek mean steelhead YoY weight was 3.6 g (SD 1.80 g) and the median coho weight was 3.3 g. The mean steelhead 1+ weight was 29.2 g (SD 16.69 g) and the median steelhead 1+ weight was 22.5 g.

Figure 19 shows length information collected from Olema Creek steelhead YoY (a) and 1+ (b) for summers 2009 through 2017.

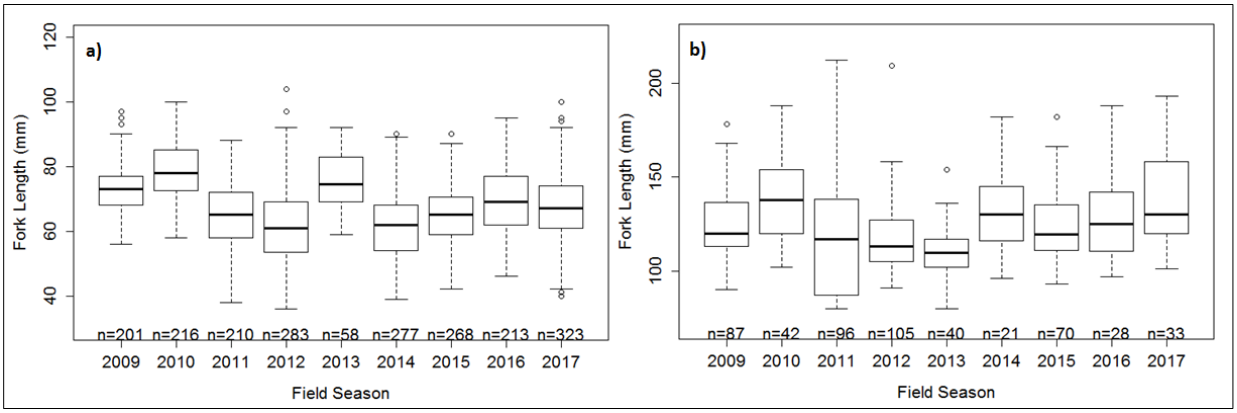

Figure 19. Box and whisker plots for young of year steelhead (a) and 1+ steelhead (b) lengths for basinwide Olema Creek, summer 2009-2017. Dark Lines represent medians, circles represent outliers.

<u>Coho and Steelhead Fulton's Condition Factor</u>

Table 9 shows length, weight, and K-factor data for coho captured during 2017 basinwide sampling on Olema Creek. Table 10 shows the length, weight, and K-factor data for steelhead YoY and steelhead 1+ caught during 2015 basinwide sampling on Olema Creek.

Table 9. Mean and median fork length, weight, and K-factor calculated for coho measured and weighed in the basinwide calibration pools on Olema Creek mainstem, summer 2017. FL = fork length, SD = standard deviation.

Species	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Coho	20	78	4.3	78	5.2	0.97	5.2	1.10	0.07

Table 10. Mean and median fork length, weight, and K-factor calculated for steelhead measured and weighed in the basinwide calibration pools on Olema Creek mainstem, summer 2017. FL = fork length, SD = standard deviation, YoY = young-of-year, 1+ = one year or older.

Species and Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Steelhead YoY	323	67	11.2	67	3.6	1.80	3.3	1.09	0.13
Steelhead 1+	33	139	27.9	131	29.2	16.69	22.5	1.04	0.09

3.4.2 Redwood Creek

The 2017 summer habitat and basinwide snorkel surveys of Redwood Creek were initiated at the confluence of Redwood Creek and the Pacific Ocean, and continued upstream to monument tag 74, within Mt. Tamalpais State Park. The measured basinwide survey length for the main channel was 8.6 km. An additional 0.8 km was surveyed on Fern Creek, a tributary to Redwood Creek.

Habitat Survey

A total of 662 mainstem habitat units were identified within the 8,626 m Redwood Creek survey reach. Pool units were the primary habitat type accounting for 5,349 m and 62% of the total mainstem length. Dry units were not observed on the mainstem during surveys. Habitat composition data for Redwood creek can be found below in Table 11. Overall, 615 m of side channel habitat and 219 m of backwater habitat units were measured during the basinwide survey. Riffle units accounted for 35% of the side channel habitat length.

An additional 824 m were surveyed in Fern Creek, a tributary to Redwood Creek. Riffle units accounted for the majority (54%) of the length. Pool units represented 24% of the length, while flatwater units accounted for the remaining 21%.

The total mainstem survey length was used to calculate the density of side channel and backwater habitat, 7.3 m per 100 m and 2.6 m per 100 m, respectively. The density of side channel and backwater habitats in 2017 were considerably higher than the historical averages (2004 to 2016 side channel average of 4.3 m per 100 m, 2004 to 2016 backwater average of 1.7 m per 100 m).

Table 11. Habitat composition of Redwood Creek coho survey reach, summer 2017. Measured length is used to calculate percentages of length per habitat type.

Unit Type	Total length (m)	% of length	# of units	% of units
Pool	5,349	62	286	43
Flatwater	1,026	12	112	17
Riffle	2,251	26	264	40
Dry	0	0	0	0
Total	8,626	100	662	100

Woody debris information collected during the basinwide habitat survey is summarized for 2005 to 2017 (Table 12) and may be used to identify trends in woody debris availability and recruitment. The only two categories of woody debris to exceed the historical averages were the categories of root wads and 20-50 cm wood.

Table 12. Summary of mainstem Redwood Creek basinwide in-stream woody debris (WD) per 100 m during summer base flow conditions. Average 2005-2016 compared to 2017.

Field season	Survey length (# 100 m sections)	Root Wads per 100 m	LWD[a] Jams per 100 m	SWD[b] Jams per 100 m	10-20cm WD[c] per 100 m	20-50cm WD[c] per 100 m	>50cm WD[c] per 100 m
2005-2016 Average	81.4	1.1	0.4	0.8	3.4	2.7	1.3
2017	86.3	1.4	0.4	0.6	3.4	4.0	1.1

[a]LWD Jams = 10 or more pieces of large woody debris

[b]SWD Jams = 10 or more pieces of small woody debris

[c]10-20 cm, 20-50 cm, >50 cm refer to diameter of individual pieces of woody debris

Woody debris information was also collected on Fern Creek. The category of 20-50 cm woody debris had the highest density at 3.3 per 100 m. Root wad density was the lowest at 0.5 per 100 m.

Coho Snorkel Counts

Snorkel surveys were conducted on 26% of the delineated pools with coho observed in 67% (55 out of 82) of the sampled pools. A total of 356 coho were counted in the 82 snorkeled pools, giving a raw average of 3.8 coho per snorkel pool. An additional 12 pools were snorkeled on Fern Creek. No coho juveniles were observed on Fern Creek pools during the snorkel surveys. Twenty-two of the 94 snorkeled pools (23%) were electrofished or resnorkeld using the bounded count method within a day following the snorkel counts. *Microfish* population estimates for the electrofished pools and bounded count estimates were used to calibrate the snorkel counts. On Fern Creek, one pool with snorkel counts of zero coho were subsequently electrofished for calibration, and no coho were captured. The 2017 basinwide estimate for juvenile coho was 1,106, 95% CI [785; 1,427].

In an attempt to better capture coho juvenile numbers and produce a more accurate production estimate, crew members began snorkeling pools that had been previously skipped due to complexity.

In prior years, units deemed too complex to successfully electrofish for calibration units were skipped when identifying units to be surveyed via snorkeling. This year, units identified as too complex to successfully electrofish were broken into two categories. The first category included any unit that was too complex to electrofish, but not too complex to snorkel. The second category included any unit that was too complex or hazardous to snorkel. Randomly selected units of the first category were sampled at the same time as the basinwide units, and calibrated using a method of repeat snorkeling. The 2017 basinwide estimate for juvenile coho including complex pool units was 911, 95% CI [669; 1,153]. Summer coho population estimates with 95% confidence interval were calculated for the basinwide survey reach from 2005 through 2017 (Figure 20). However, only the 2017 estimate includes complex pools as described above.

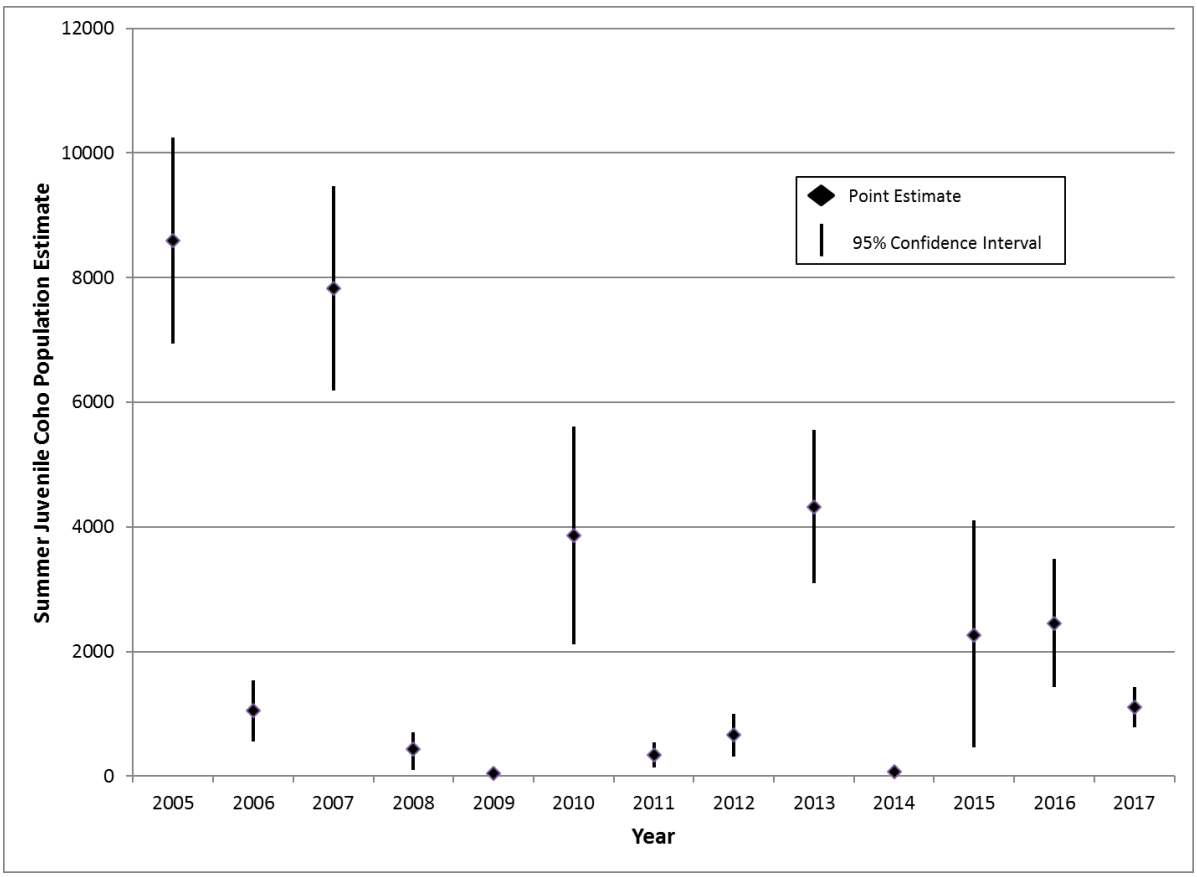

Figure 20. Summer juvenile coho basinwide population estimates for Redwood Creek, 2005-2017.

Summer Coho and Steelhead Measurement Information

A total of 65 juvenile coho were measured for fork length (mm) and of those fish 64 were weighed (0.01 g). Coho fork lengths measured during 2017 summer monitoring of Redwood Creek ranged from 50 mm to 83 mm. The highest fork length frequencies for coho occurred within the 61 to 65 mm length interval, representing 21% of the sample, and within the 76 to 80 mm length interval, representing 29 % of the sample. The Redwood Creek mean and median coho weight was 4.2 g (SD

1.29 g). Coho juvenile length (a) and weight (b) information collected from Redwood Creek during basinwide sampling is represented in Figure 21.

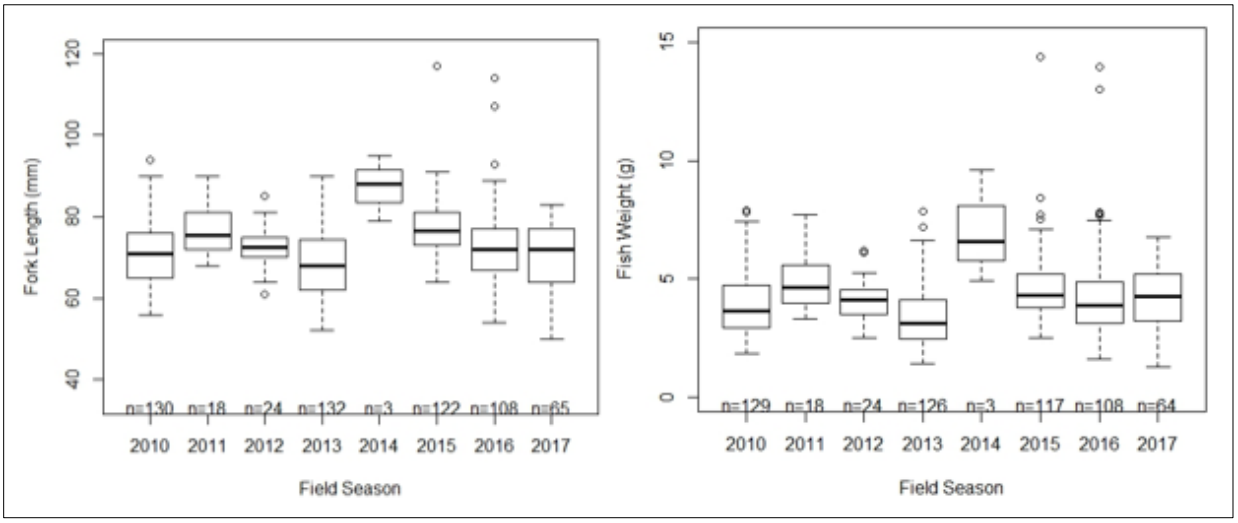

Figure 21. Box and whisker plots for juvenile coho lengths (a) and weights (b) for basinwide Redwood Creek, summer 2010-2017 (no coho captured in 2009). Dark Lines represent medians, circles represent outliers.

Within the Redwood Creek sample, 562 steelhead were measured for fork length and 547 of those 562 steelhead were also weighed. The size range for steelhead was 34 mm to 228 mm. Fork length frequencies were used to determine year class bins. The highest fork length frequencies for steelhead occurred within the 66 to 70 mm and 71 to 75 mm length interval, representing 23% of the sample. The Redwood Creek mean steelhead YoY weight was 3.8 g (SD 1.78 g), and the median weight was 3.5 g. The mean steelhead 1+ weight was 23.2 g (SD 12.69 g), and the median weight was 20.5 g. Figure 22 shows representations of fish lengths for steelhead YoY and 1+ captured on Redwood Creek for summers 2009 through 2017.

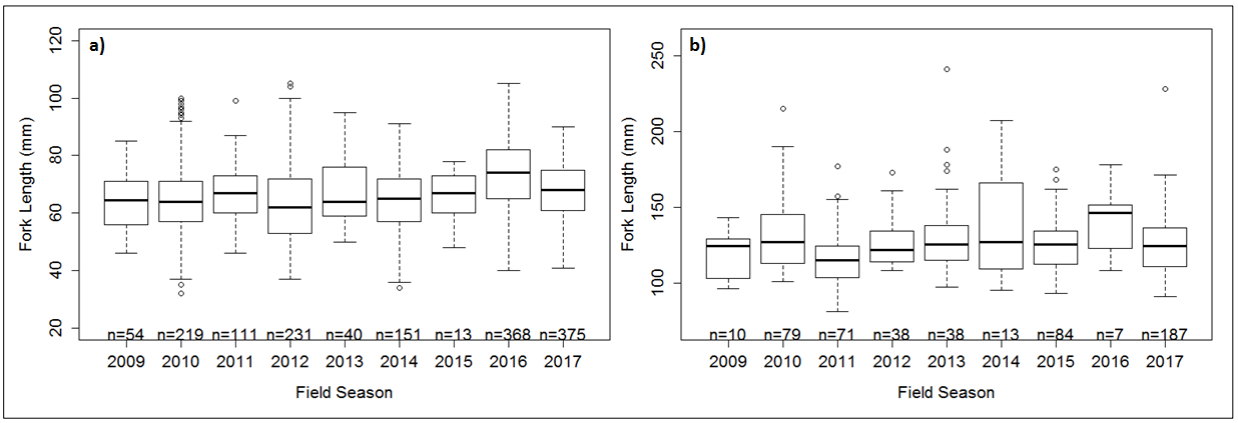

Figure 22. Box and whisker plots for young of year steelhead (a) and 1+ steelhead (b) lengths for basinwide Redwood Creek, summer 2009-2017. Dark Lines represent medians, circles represent outliers.

Coho and Steelhead Fulton's Condition Factor

Table 13 shows length, weight, and K-factor for coho captured during basinwide sampling on Redwood Creek in summer 2017. Table 14 shows the comparisons between steelhead YoY and steelhead 1+ length, weight, and K-factors for Redwood Creek.

Table 13. Mean and median fork length, weight, and K-factor for coho measured and weighed in the basinwide and complex calibration pools on Redwood Creek mainstem, 2017. FL = fork length, SD = standard deviation.

Species	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Coho	65	71	7.5	72	4.2	1.29	4.2	1.16	0.07

Table 14. Mean and median fork length, weight and K-factor calculated for steelhead measured and weighed in the basinwide and complex calibration pools on Redwood Creek mainstem, 2017. FL = fork length, SD = standard deviation, YoY = young-of-year, 1+ = one year or older.

Species and Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Steelhead YoY	375	68	11.0	69	3.8	1.78	3.5	1.10	0.09
Steelhead 1+	187	126	19.9	124	23.2	12.69	20.5	1.08	.07

3.4.3 Pine Gulch Creek

The 2017 summer habitat and basinwide surveys of Pine Gulch Creek were initiated at monument tag 15 and continued upstream to monument tag 94, above the Teixeira Ranch within PORE. The measured basinwide habitat survey length for the main channel was 8.1 km.

Habitat Survey

A total of 703 mainstem habitat units were identified in the 8,136 m Pine Gulch Creek survey reach. Pool and riffle units comprised the majority of the habitat types measuring a total of 7,116 m. Overall habitat composition by unit was 50% pool, 37% riffle, and 13% flatwater (Table 15). No dry units were observed on Pine Gulch Creek. Side channel and backwater units were also measured but not incorporated into the basinwide habitat calculations. Overall, 698 m of side channel habitat and 149 m of backwater habitat units were measured during the basinwide habitat survey. Riffle habitat units represented 51% of the total side channel habitat length.

The total survey length was used to calculate the densities of side channel and backwater habitat, 8.6 m per 100 m and 1.8 m per 100 m, respectively. The density of side channel and backwater habitats in 2017 were comparable to the historical averages (2005 to 2016 side channel average of 8.3 m per 100 m, 2005 to 2016 backwater average of 1.9 m per 100 m).

Table 15. Habitat composition of Pine Gulch Creek coho survey reach, 2017. Measured length is used to calculate percentages of length per habitat type.

Unit Type	Total length (m)	% of length	# of units	% of units
Pool	4,095	50	323	46
Flatwater	1,020	13	96	14
Riffle	3,021	37	284	40
Dry	0	0	0	0
Total	8,136	100	703	100

Woody debris information collected during the basinwide habitat survey is summarized for summers 2005 through 2017 (Table 16) and may be used to identify trends in woody debris availability and recruitment over time. None of the categories observed exceeded historical densities.

Table 16. Summary of basinwide in-stream woody debris (WD) per 100 m during summer base flow conditions in Pine Gulch Creek. Average 2005-2016 compared to 2017.

Field season	Survey length (# 100 m sections)	Root Wads per 100 m	LWD[a] Jams per 100 m	SWD[b] Jams per 100 m	10-20cm WD[c] per 100 m	20-50cm WD[c] per 100 m	>50cm WD[c] per 100 m
2005-2016 Average	92.1	0.9	0.4	0.8	3.4	3.0	1.2
2017	81.4	0.9	0.4	0.3	3.2	2.2	0.9

[a]LWD Jams = 10 or more pieces of large woody debris

[b]SWD Jams = 10 or more pieces of small woody debris

[c]10-20 cm, 20-50 cm, >50 cm refer to diameter of individual pieces of woody debris

Coho Snorkel Counts

Snorkel surveys were conducted on 19% of the delineated pools (62 of 323), with no coho observations in any of the 62 snorkeled pools. Nine of the snorkeled pools (15%) were electrofished within a day following the snorkel counts, and no coho were captured. In addition to the nine electrofished pools, four pools (6%) were re-snorkeled immediately following the initial pass using the method of bounded counts. *Microfish* and bounded count population estimates for the resampled pools were used to calibrate the snorkel counts. Since 2009 no summer coho population estimates with 95% confidence interval have been calculated due to the apparent extirpation of the species from the Pine Gulch watershed.

Summer Steelhead Measurement Information

A total of 169 steelhead were measured for fork length during the summer surveys on Pine Gulch Creek. Of those 169 steelhead, 151 were also weighed. The size range for steelhead was 32 mm to 188 mm. Fork length frequencies were used to determine year class intervals. The highest frequency of fork lengths for steelhead occurred within the 46 to 50 mm, 56 to 60 mm, and 71 to 75 mm length intervals, representing 38% of the sample. The Pine Gulch Creek mean steelhead YoY weight was 2.6 g (SD 1.43 g), and the median weight was 2.1 g. The Pine Gulch Creek mean steelhead 1+ weight

was 23.7 g (SD 13.69 g), and the median weight was 20.2 g. Figure 23 shows summer steelhead YoY and steelhead 1+ length information collected from Pine Gulch Creek for summers 2009 through 2017.

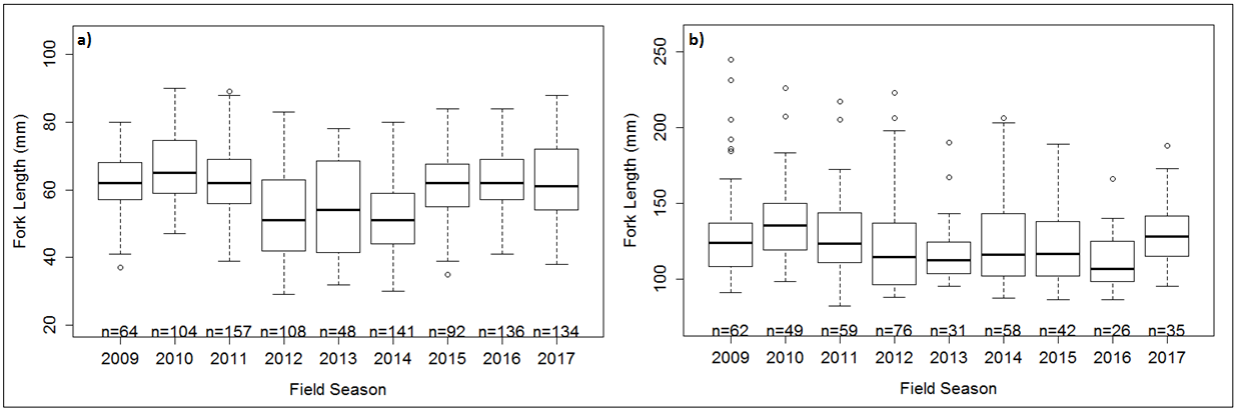

Figure 23. Box and whisker plots for young of year steelhead (a) and 1+ steelhead (b) lengths for basinwide Pine Gulch Creek, summer 2009-2017. Dark Lines represent medians, circles represent outliers.

Steelhead Fulton's Condition Factor

Table 17 shows a summary of steelhead YoY and steelhead 1+ fork length, weight, and K-factors for basinwide monitoring on Pine Gulch Creek.

Table 17. Mean and median fork length, weight, and K-factor calculated for steelhead measured and weighed in the basinwide calibration pools on Pine Gulch Creek mainstem, 2017. FL = fork length, SD = standard deviation, YoY = young-of-year, 1+ = one year or older.

Species and life stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
Steelhead YoY	134	62	11.2	61	2.6	1.43	2.1	0.97	0.12
Steelhead 1+	35	130	22.2	128	23.7	13.69	20.2	0.98	0.07

3.5 Coho and Steelhead 2015 Index Reach Monitoring Results

Index reach juvenile monitoring results are provided for Olema Creek, Redwood Creek, and Pine Gulch Creek.

3.5.1 Olema Creek

Index reach 1 has not been sampled in the past ten years. In 2009, Index Reaches 4 and 8 were removed from the sampling regime due to access and staffing considerations.

Index Reach Habitat and Total Salmonid Catch

The results presented in Table 18 are the summer 2017 total catch documented through index reach electrofishing activities and show salmonid sample size variation between reaches. Total salmonid

catch along with habitat information described in the next section is used for additional density calculations in this report. Historical catch numbers can be found in Appendix A, Table A13.

Table 18. Summary of total catch by species within Olema Creek mainstem index reach sample locations, summer 2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year or older, NS = not sampled.

	Index Reach								total
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**–**
CO	NS	2	7	NS	2	0	9	NS	20
SH YoY	NS	87	167	NS	238	73	60	NS	625
SH 1+	NS	5	8	NS	16	3	3	NS	35

In 2017, both coho and steelhead were found in all index reaches sampled, with the exception of Index Reach 6, where no coho were observed.

Index Reach Habitat Information

In 2017, the index reach habitat surveys showed that pools accounted for the highest percentage of habitat surface area within each sampled reach with the exception of Index Reach 5, where flatwater units were the dominant habitat types. Flatwater and riffle habitat types represented a much lower percentage of the total habitat surface area. Index reach habitat composition for 2017 can be found in Appendix A, Table A14.

Salmonid per Meter by Index Reach

The results of our monitoring efforts show distinct differences in salmonid numbers and fish per meter based on index reach. Number of fish per meter is calculated using total catch from electrofishing surveys. Data presented in Figure 24 are based on all habitat units surveyed within each index reach in 2017, and can be viewed in Appendix A, Table A15. Coho per meter was highest in Index Reach 7, steelhead YoY and 1+ per meter were highest in Index Reach 5.

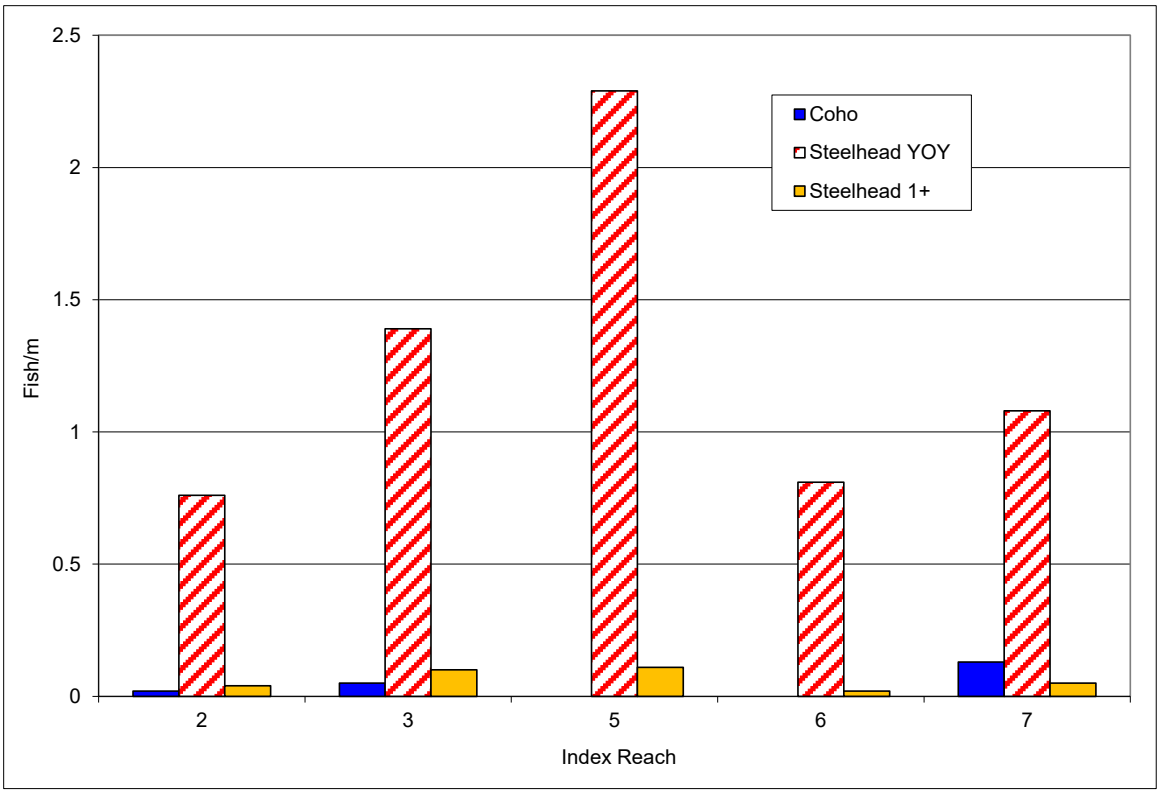

Figure 24. Coho and steelhead juvenile fish per meter according to index reach on Olema Creek, 2017.

Juvenile Coho and Steelhead Measurements

As part of the summer monitoring program, a subsample of fish were weighed (0.01 g) and measured for fork length (mm) within each surveyed habitat unit. Fork length was recorded for 19 coho captured during index reach electrofishing activities. The size range for coho was 65 mm to 82 mm. Steelhead age is based on fork length frequencies, and each sample year has a different fork length size range. Within the 2017 Olema Creek sample, 433 steelhead were measured for fork length. The size range for steelhead young of year was 38 mm to 100 mm (n=400), while the size range for the steelhead 1+ was 101 mm to 195 mm (n=33). Mean and median fork length for coho were 75 mm (SD 4.7 mm). The mean coho weight was 4.8 g (SD 0.91 g), and the median weight was 4.7 g. Mean fork length for steelhead YoY was 68 mm (SD 11.2 mm) and median fork length for steelhead YoY was 67 mm. The mean steelhead YoY weight was 3.7 g (SD 1.89 g) and median weight was 3.2 g. Mean fork length for steelhead 1+ was 135 mm (SD 22.3 mm), with a median fork length of 130 mm. The mean steelhead 1+ weight was 26.8 g (SD 14.85 g), and the median weight was 20.7 g.

3.5.2 Redwood Creek

In 2017, six of the seven index reaches were surveyed by SFAN staff. Index 7 no longer exists due to restoration activities.

Index Reach Habitat and Total Salmonid Catch

The results presented in Table 19 are the total catch documented through electrofishing activities in the Redwood Creek index reaches for 2017. Coho were found in all of the sampled index reaches. For historical index reach catches 2004 through 2016, refer to Appendix A, Table A16.

Table 19. Summary of total catch by species within Redwood Creek mainstem index reach sample locations, summer 2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year or older, NS = not sampled.

	Index Reach							total
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**–**
CO	15	20	2	5	16	3	NS	61
SH YoY	140	272	93	95	138	59	NS	797
SH 1+	9	67	68	113	88	49	NS	394

Index Reach Habitat Information

In 2017, pool habitat was identified as the dominant habitat type by length and surface area within Index Reaches 2 through 6. Riffle habitat units accounted for the majority of the habitat in Index Reach 1. Index reach habitat composition for 2017 can be found in Appendix A, Table A17.

Salmonid fish per meter by Index Reach

Number of fish per meter is calculated using the total catch from electrofishing surveys. Data presented in Figure 25 are based on all habitat units surveyed within each index reach in 2017 and can be viewed in Appendix A, Table A18. Coho YoY per meter was highest in Index Reach 5, while steelhead YoY per meter was highest in Index Reach 2. Steelhead 1+ per meter was highest in Index Reach 4.

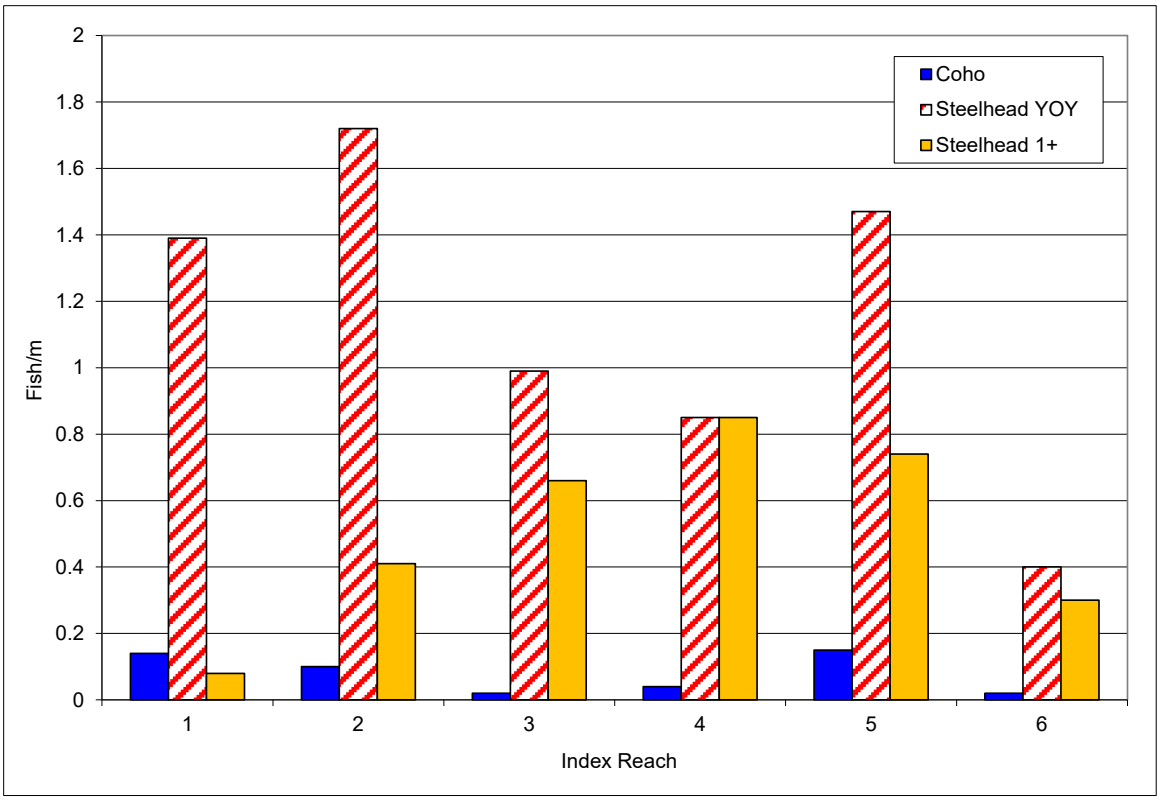

Figure 25. Coho and steelhead juvenile fish per meter according to index reach on Redwood Creek, 2017.

Juvenile Coho and Steelhead Measurements

As part of the summer monitoring program, a subsample of fish are weighed (0.01 g) and measured for fork length (mm) within each sampled habitat unit. Age classes for steelhead were determined using fork length frequencies. Within the Redwood Creek sample, 59 coho salmon were measured for fork length. The size range for juvenile coho was 55 mm to 109 mm. A total of 847 steelhead were measured. The size range for steelhead YoY was 31 mm to 100 mm (n=584), while the size range for steelhead 1+ was 101 mm to 200 mm (n=253). Mean fork length for coho was 72 mm (SD 9.8 mm) and median fork length was 72 mm. The mean coho weight was 4.4 g (SD 1.96 g), and the median weight was 4.2 g. Mean fork length for steelhead YoY was 67 mm (SD 13.3 mm) and median fork length for steelhead YoY was 68 mm. The mean fish weight for steelhead YoY was 3.9 g (SD 2.3 g) and the median weight was 3.6 g. Mean fork length for steelhead 1+ was 128 mm (SD 18.8 mm), with a median fork length of 123 mm. The mean steelhead 1+ weight was 23.8 g (SD 11.1 g), and the median weight was 20.3 g.

3.5.3 Pine Gulch Creek

In 2017, four of eight index reaches on the mainstem of Pine Gulch Creek were sampled. Index 4 has not been sampled since 2000 because of access limitations. Indexes 1A and 1B were removed from the sampling regime due to their proximity to Index 1C. Monitoring of Index 1C has not been permissible by the landowner since 2011.

Index Reach Habitat and Total Salmonid Catch

The results presented in Table 20 are the 2017 real catch documented through electrofishing activities and show salmonid sample size variation between reaches. No coho were captured in any of the index reaches. Historical catch results can be found in Appendix A, Table A19.

Table 20. Summary of total catch by species within Pine Gulch Creek mainstem index reach sample locations, summer 2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year or older, NS = not sampled.

	Index Reach								total
Species	**1a**	**1b**	**1c**	**2**	**3**	**4**	**5**	**6**	**–**
CO	NS	NS	NS	0	0	NS	0	0	0
SH YoY	NS	NS	NS	37	33	NS	69	42	181
SH 1+	NS	NS	NS	5	9	NS	10	5	29

Index Reach Habitat Information

During the 2017 summer monitoring season riffle or flatwater habitat types were the dominant types found within all sampled index reaches, with the exception of Index Reach 5, where pool habitat was the dominant habitat type. Index reach habitat composition for 2015 can be found in Appendix A, Table A20.

Salmonid Fish per Meter by Index Reach

Number of fish per meter, shown in Figure 26, is calculated using the total catch from electrofishing surveys and can be viewed in Appendix A, Table A21. The highest steelhead YoY per meter was observed in Index Reach 6 while the highest steelhead 1+ per meter were observed in Index Reach 3.

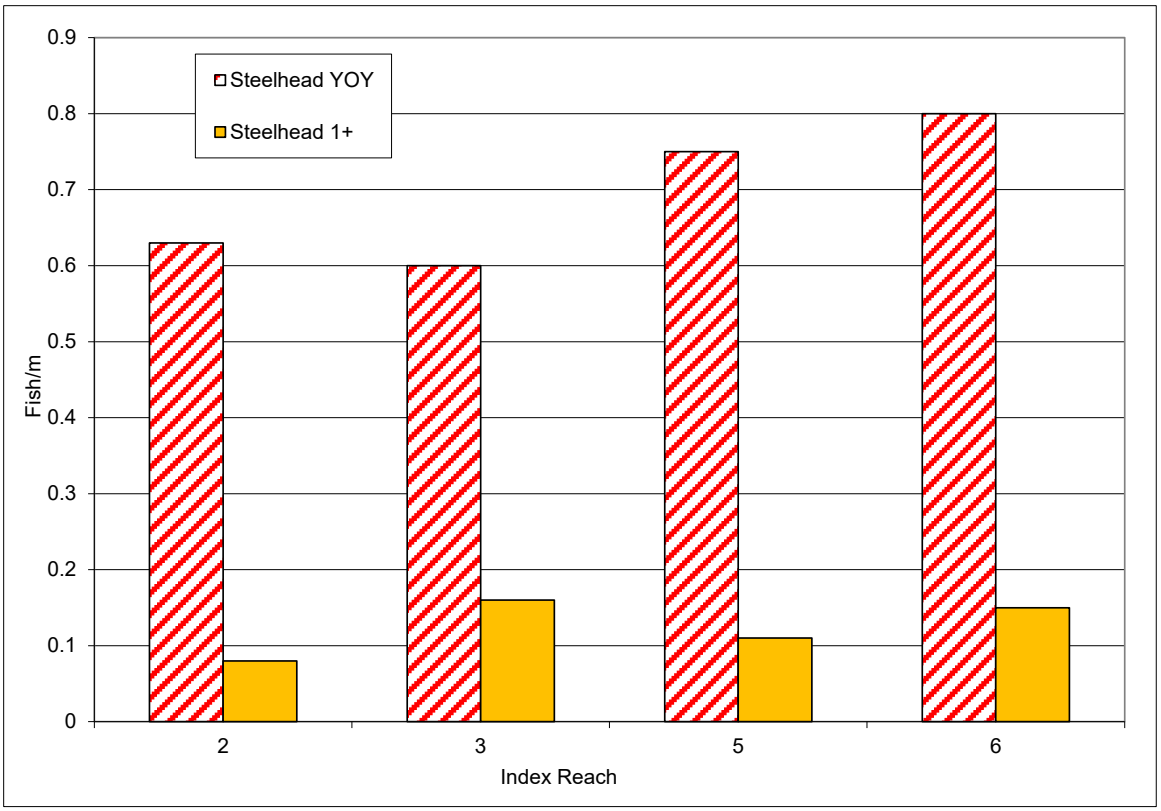

Figure 26. Steelhead juvenile fish per meter according to index reach on Pine Gulch Creek, 2017.

Juvenile Steelhead Measurements

As part of the summer monitoring program, a subsample of fish were weighed (0.01 g) and measured (mm) for fork length within each sampled habitat unit. Fork length was recorded for 190 steelhead captured during index reach electrofishing activities on Pine Gulch Creek. The size range for steelhead YoY was 36 mm to 92 mm (n=160), while the size range for steelhead 1+ was 102 mm to 176 mm (n=29). Mean fork length for steelhead YoY was 63 mm (SD 13.1 mm) and median fork length was 65 mm. The Pine Gulch Creek mean steelhead YoY weight was 3.5 g (SD 1.81 g), and the median weight was 3.2 g. Mean fork length for steelhead 1+ was 143 mm (SD 35.4 mm) and median fork length for steelhead 1+ was 131 mm. The mean steelhead 1+ weight was 30.7 g (SD 20.46 g), and the median weight was 19.8 g.

4 Discussion

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the CCCESU. In addition to SFAN/CDFW funded monitoring of coho on Olema Creek, Redwood Creek, Pine Gulch Creek, and Cheda Creek, extensive monitoring is conducted by MMWD on Lagunitas Creek, Devils Gulch, and the mainstem of San Geronimo Creek, and by SPAWN on tributaries of San Geronimo Creek. Through SFAN monitoring efforts, significant information has been documented regarding coho salmon behavior, life history, distribution, and population trends. Though a relatively small geographic area, the coastal Marin County watersheds support a significant proportion of the CCCESU coho salmon. The scope of this life-cycle monitoring program allows for characterization of regional patterns observed in the CCCESU.

The Olema Creek count of 15 coho salmon redds for 2016-2017 was a 50% decrease compared to the 2013-2014 return (32 redds). The Redwood Creek redd count of sixteen redds was a 200% increase when compared to the 2013-2014 return (five redds). No adult coho were observed in Pine Gulch Creek, marking the eighth consecutive season coho spawning was not observed in this watershed.

The 2017 smolt production estimate on Olema Creek watershed showed an increase from the spring of 2014, when cohort 1 smolts were last in the system. The coho smolt production estimate of 5,677, 95% CI [4,538:6,816] was lower than expected given the summer 2016 juvenile estimate of 17,337, 95% CI [12,527:22,147]. A decreased rate of overwinter survival due to an extremely wet winter and under-detection of coho smolts during the spring of 2017 due to late trap installation are just two factors that may have contributed to the higher estimate. On Redwood Creek, the 2017 smolt estimate was 853, 95% CI [606:1,108] and represents a decrease of over 70% from 2014 (2,342, 95% CI [1,005:3,700]).

This report also includes fork length and weight data for coho smolts captured during spring 2017 outmigrant monitoring. Smolt size is directly related to ocean survival (Miller and Sandros 2003), with smolts of larger size at the time of ocean entrance having a higher chance of surviving to adulthood. On both Olema and Redwood Creeks, the mean coho smolt fork length, weight, and K-factor were lower than the historical average but within one standard deviation of the historical average (Appendix A Table A7, A9). Comprehensive smolt trapping is in its fourteenth year of operation at Olema Creek and thirteenth year at Redwood Creek. Additional years of data will help refine our understanding of variation and the range in size of smolts leaving these coastal Marin County watersheds.

On Olema Creek, a basinwide population estimate of 400, 95% CI [181:619] was calculated. The population estimate for Redwood Creek was 1,106, 95% CI [785:1,427] coho juveniles. While the Olema Creek cohort saw a decrease of approximately 60% between 2014 and 2017, the Redwood Creek cohort saw an increase of over 90%. No coho juveniles were observed on Pine Gulch Creek.

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Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek[a]			Redwood Creek[a]			Pine Gulch		
	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km
1997-1998	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	134	20.8	6.4	78	9.2	8.5	N/A	N/A	N/A
1998-1999	92	10.7	8.6	46	7.0	6.6	32	3.2	10	23	17	1.4	41	9.2	4.5	N/A	N/A	N/A
1999-2000	139	10.7	13.0	58	7.0	8.3	3	3.2	0.9	10	12.8	0.8	5	8.2	0.6	N/A	N/A	N/A
2000-2001	119	12.8	9.3	56	7.0	8.0	11	3.2	3.4	80	19.3	4.1	12	9.2	1.3	0	9.5	0
2001-2002	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	59	15.4	3.8	34	9.2	3.7	2	9.5	0.2
2002-2003	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	20	17	1.2	3	9.2	0.3	1	9.5	0.1
2003-2004	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	109	15	7.3	42	9.2	4.6	0	9.5	0
2004-2005	120	12.8	9.4	140	7.0	19.7	112	3.7	30.6	138	20.9	6.6	90	9.6	9.4	3	9.5	0.3
2005-2006	53	12.8	4.1	48	7.0	6.9	33	3.7	8.9	9	17	0.5	11	9.6	1.1	1	9.5	0.1
2006-2007	128	12.8	10	117	7.0	16.7	55	3.7	14.9	95	18	5.3	24	9.2	2.6	0	9.5	0
2007-2008	87	12.8	6.8	46	7.0	6.6	6	3.7	1.6	33	18	1.8	1[b]	9.6	0.1	2	9.5	0.2
2008-2009	25	12.8	2.0	1	7.0	0.1	0	3.7	0	0	18	0	2	8.6	0.2	0	9.5	0

[a] Includes redds from all surveyed tributaries.

[b] No redd was observed during spawner surveys. Subsequent summer basinwide surveys determined that at least one coho redd was constructed but not observed during spawner surveys.

Table A1 (continued). Coho spawner survey redd density history for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek, Redwood Creek, and Pine Gulch including total redds, survey length (km) and redd per km for spawner years 1997-1998 through 2016-2017.

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek[a]			Redwood Creek[a]			Pine Gulch		
	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km	Total redds	Survey length	Redd per km
2009-2010	42	12.8	3.3	7	7.0	1	0	3.7	0	14	18.3	0.8	23	9.2	2.5	0	9.5	0
2010-2011	32	12.8	2.5	40	7.0	5.7	0	3.7	0	21	18	1.2	3	9.6	0.3	0	9.5	0
2011-2012	94	12.8	7.3	19	7.0	0.4	4	3.7	0	7	18	0.4	4	9.6	0.4	1	9.5	0.1
2012-2013	108	12.8	8.4	59	7.0	8.4	2	3.7	0.5	32	18	1.8	25	9.6	2.6	0	8.0	0
2013-2014	171	12.8	13.4	7	7.0	1.0	5	3.7	1.4	32	18	1.8	5	8.6	0.6	0	8.0	0
2014-2015	79	12.8	6.2	37	7.0	5.3	20	3.7	5.4	6	18	0.3	4	8.6	0.5	0	8.0	0
2015-2016	79	12.8	6.2	37	7.0	5.3	20	3.7	5.4	49	18	2.7	6	9.9	0.6	0	7.3	0
2016-2017	49	12.8	3.8	78	7.0	11.1	31	3.7	8.4	15	18	0.8	16	9.9	1.6	0	7.3	0

[a] Includes redds from all surveyed tributaries.

[b] No redd was observed during spawner surveys. Subsequent summer basinwide surveys determined that at least one coho redd was constructed but not observed during spawner surveys.

Table A2. Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2016-2017 on the Olema Creek watershed. N/A = Data not available for this time period.

		Total monthly rainfall (in)				Olema Creek spawner summary			
Spawner Year	**Run timing**	**Nov**	**Dec**	**Jan**	**Feb**	**Survey reach (km)**	**# surveys**	**Total carcass counts**	**Total redds**
1997-1998[a]	Nov 16-Jan 8	10.32	3.47	16.49	24.68	20.8[b]	8	39	134
1998-1999	Dec 8- Jan 30	7.48	2.21	7.66	15.61	17.0[c]	6	13	23
1999-2000	Dec 2-Feb 1	5.20	0.99	7.15	12.77	12.8[d]	2	9	10
2000-2001	Jan 16- Feb 8	1.54	1.31	6.45	8.07	19.3[e]	4	96	80
2001-2002	Nov 27- Jan 11	9.81	15.03	5.08	3.55	15.4[f]	4	30	59
2002-2003	Jan 7- Jan 21	3.30	17.33	3.75	2.34	17.0[c]	4	16	20
2003-2004	Dec 17- Feb 10	2.71	12.14	5.13	7.68	15.0[a]	6	40	109
2004-2005	Dec 15- Feb 9	0.65	10.13	4.85	5.33	20.9[g]	6	72	138
2005-2006	Dec 6- Jan 26	3.27	19.90	7.94	4.76	17.0[h]	3	11	9
2006-2007	Dec 18- Feb 16	5.54	6.43	1.09	9.93	18.0[i]	6	32	95
2007-2008	Dec 5- Jan 24	1.09	6.76	14.66	N/A	18.0[i]	8	5	33
2008-2009	Dec 27 & Feb 20	3.14	3.16	1.22	11.12	18.0[i]	11	0	0

[a] Includes the mainstem of Olema Creek (Reaches 2-6), Headwaters Tributary, John West Fork, Giacomini Gulch, and Horse Camp Creek.

[b] Includes the mainstem of Olema Creek (Reaches 1-7), Headwaters Tributary, Eucalyptus Gulch, Randall Gulch, John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[c] Includes the mainstem of Olema Creek (Reaches 1-6) and John West Fork.

[d] Includes the mainstem of Olema Creek (Reaches 2-5), John West Fork, Giacomini Gulch, Horse Camp Creek, Water Tank Creek, and Boundary Gulch.

[e] Includes the mainstem of Olema Creek (Reaches 1-7), John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[f] Includes the mainstem of Olema Creek (Reaches 2-6), Randall Gulch, John West Fork, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[g] Includes the mainstem of Olema Creek (Reaches 1-7), Headwaters Tributary, Randall Gulch, John West Fork North, John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[h] Includes the mainstem of Olema Creek (Reaches 2-7), Headwaters Tributary, John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[i] Includes the mainstem of Olema Creek (Reaches 1-6), John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

Table A2 (continued). Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2016-2017 on the Olema Creek watershed. N/A = Data not available for this time period.

		Total monthly rainfall (in)				Olema Creek spawner summary			
Spawner Year	**Run timing**	**Nov**	**Dec**	**Jan**	**Feb**	**Survey reach (km)**	**# surveys**	**Total carcass counts**	**Total redds**
2009-2010	Dec 14- Jan 29	1.41	5.15	12.51	7.23	18.3[j]	9	6	14
2010-2011	Dec 10- Jan 20	5.21	12.28	2.09	6.97	18.0[i]	11	13	21
2011-2012	Jan 26- Feb 23	5.58	0.63	6.97	2.29	18.0[i]	14	12	7
2012-2013	Nov 19- Jan 30	9.20	12.16	1.04	0.70	18.0[i]	15	19	32
2013-2014	Feb 13- Mar 5	N/A	N/A	N/A	N/A	18.0[i]	28	18	32
2014-2015	Dec 9- Jan 6	4.92	17.88	0.12	3.47	18.0[i]	16	10	6
2015-2016	Dec 16- Feb 3	2.20	11.17	11.22	1.38	18.0[i]	12	32	49
2016-2017	Nov 30- Jan 16	3.76	7.33	16.28	13.35	18.0[k]	9	0	15

[i] Includes the mainstem of Olema Creek (Reaches 1-6), John West Fork, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[j] Includes the mainstem of Olema Creek (Reaches 1-6), John West Fork, John West Fork North, Giacomini Gulch, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

[k] Includes the mainstem of Olema Creek (Reaches 1-6), John West Fork, Horse Camp Creek, Boundary Gulch, and Quarry Gulch.

Table A3. Coho salmon spawning survey including number of tributaries surveyed, total live adults counted, total carcasses, and total redds for the Olema Creek watershed excluding the John West Fork. These tributaries include Boundary Gulch, Giacomini Creek, Horse Camp Creek, and Quarry Gulch, spawner years 1997-1998 through 2016-2017.

Year	Number of tributaries surveyed	Total live	Total carcasses	Total redds
1997-1998	6	4	1	3
1998-1999	0	0	0	0
1999-2000	2	0	0	0
2000-2001	4	0	0	0
2001-2002	44	1	0	0
2002-2003	0	0	0	0
2003-2004	2	0	0	0
2004-2005	6	2	3	3
2005-2006	4	3	0	3
2006-2007	3	3	0	0
2007-2008	4	0	0	0
2008-2009	4	0	0	0
2009-2010	3	0	0	0
2010-2011	4	1	0	0
2011-2012	4	0	0	0
2012-2013	4	2	0	1
2013-2014	4	0	0	0
2014-2015	2	0	0	0
2015-2016	3	0	0	0
2016-2017	4	0	0	0

Table A4. Coho salmon spawning survey including number of surveys, survey length, total carcasses, and total redds for Cheda Creek, spawner years 1998-1999 through 2016-2017. N/A = Survey Length Not Defined.

Year	Number of surveys	Survey length (km)	Total carcasses	Total redds
1998-1999	2	N/A	0	0
1999-2000	1	N/A	0	0
2000-2001[a]	2	1.4	0	0
2001-2002	5	1.2	0	3
2002-2003	3	1.2	1	1
2003-2004	3	1.2	0	6
2004-2005	5	1.3	1	6
2005-2006	4	1.3	1	2
2006-2007	3	1.3	1	7
2007-2008	5	1.3	0	1
2008-2009	1	1.3	0	0
2009-2010	3	1.3	0	0
2010-2011	5	1.3	0	0
2011-2012	4	1.3	1	4
2012-2013	5	1.3	2	2
2013-2014	1	1.3	0	1
2014-2015	2	1.3	2	4
2015-2016	4	1.7	5	5
2016-2017	4	1.7	3	4

[a] First winter after fish passage project was completed

Table A5. Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2016-2017 on the Redwood Creek watershed. N/A = Data not available for this time period.

Spawner year	Run timing	Total monthly rainfall (in)				Redwood Creek spawner summary			
		Nov	Dec	Jan	Feb	Survey reach (km)	# surveys	Total carcass counts	Total redds
1997-1998	Nov 25- Jan 23	N/A	N/A	N/A	N/A	9.2[a]	7	24	78
1998-1999	Dec 5-Feb 24	3.28	1.49	5.27	8.47	9.2[a]	11	10	41
1999-2000	Jan 19- Feb 18	2.72	0.59	5.95	0.00	8.2[b]	6	1	5
2000-2001	Dec 21- Mar 8	0.00	0.00	4.39	6.07	9.2[a]	5	11	12
2001-2002	Dec 8- Feb 6	0.00	0.00	0.83	3.56	9.2[a]	5	50	34
2002-2003	Jan 1- Feb 5	2.18	13.04	1.23	1.83	9.2[a]	5	3	3
2003-2004	Dec 4-Feb 6	2.62	3.45	7.21	6.38	9.2[a]	5	25	42
2004-2005	Dec 11-Feb 3	0.8	7.59	3.66	3.09	9.6[c]	7	63	90
2005-2006	Dec 7- Feb 9	2.19	12.57	0.00	3.48	9.6[c]	5	5	11
2006-2007	Nov 20- Jan 23	2.58	4.27	0.63	3.63	9.2[a]	9	6	24
2007-2008	NA	1.79	7.84	16.23	2.23	9.6[c]	8	0	1[e]
2008-2009	Dec 31-Feb 10	N/A	3.62	1.03	8.92	8.6[d]	10	2	2
2009-2010	Dec 14- Feb 9	1.15	4.01	9.33	3.96	9.2[a]	8	10	23
2010-2011	Dec 2- Jan 21	2.62	10.27	1.90	5.90	9.6[c]	13	1	3
2011-2012	Nov 29- Feb 8	2.31	0.52	4.45	1.75	9.6[c]	14	8	4
2012-2013	Nov 6- Jan 17	5.56	8.98	0.99	0.59	9.6[c]	11	17	25

[a] Includes the mainstem of Redwood Creek, Fern Creek, and Kent Creek.

[b] Includes the mainstem of Redwood Creek and Fern Creek.

[c] Includes the mainstem of Redwood Creek, Fern creek, and the lower Redwood Creek restoration area.

[d] Includes the mainstem of Redwood Creek, Fern Creek, Kent Creek, and the lower Redwood Creek restoration area.

[e] No redd was observed during spawner surveys. Subsequent summer basinwide surveys determined that at least one coho redd was constructed but not observed during spawner surveys.

[f] Includes the mainstem of Redwood Creek, Fern Creek, lower Green Gulch, Kent Creek, and the lower Redwood Creek Restoration area.

Table A5 (continued). Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2016-2017 on the Redwood Creek watershed. N/A = Data not available for this time period.

Spawner year	Run timing	Total monthly rainfall (in)				Redwood Creek spawner summary			
		Nov	Dec	Jan	Feb	Survey reach (km)	# surveys	Total carcass counts	Total redds
2013-2014	Feb 12- Feb 19	3.14	0.61	0.38	14.27	8.6[d]	13	1	5
2014-2015	Dec 8- Jan 7	3.67	13.56	0.01	2.15	8.6[d]	11	0	4
2015-2016	Dec 26- Jan 26	1.42	6.15	8.11	1.14	9.9[f]	12	3	6
2016-2017	Dec 9- Jan 30	3.60	5.61	11.34	10.06	9.9[f]	12	2	16

[a] Includes the mainstem of Redwood Creek, Fern Creek, and Kent Creek.

[b] Includes the mainstem of Redwood Creek and Fern Creek.

[c] Includes the mainstem of Redwood Creek, Fern creek, and the lower Redwood Creek restoration area.

[d] Includes the mainstem of Redwood Creek, Fern Creek, Kent Creek, and the lower Redwood Creek restoration area.

[e] No redd was observed during spawner surveys. Subsequent summer basinwide surveys determined that at least one coho redd was constructed but not observed during spawner surveys.

[f] Includes the mainstem of Redwood Creek, Fern Creek, lower Green Gulch, Kent Creek, and the lower Redwood Creek Restoration area.

Table A6. Coho salmon spawning survey including number of surveys, survey length, total carcasses, and total redds on the Pine Gulch Creek mainstem for spawner years 2000-2001 through 2016-2017.

Year	Year class	Number of surveys	Survey reach (km)	Total carcasses	Total redds
2000-2001	1	3	7.0	0	0
2001-2002	2	2	9.0	0	2
2002-2003	3	2	8.0	2	1
2003-2004	1	6	9.0	0	0
2004-2005	2	3	10.0	0	3
2005-2006	3	4	9.5	0	1
2006-2007	1	4	9.5	0	0
2007-2008	2	3	9.5	0	2
2008-2009	3	1	9.5	0	0
2009-2010	1	1	9.5	0	0
2010-2011	2	1	9.5	0	0
2011-2012	3	1	9.5	0	1
2012-2013	1	2	8.0	0	0
2013-2014	2	2	8.0	0	0
2014-2015	3	3	8.0	0	0
2015-2016	1	3	7.3	0	0
2016-2017	2	1	7.3	0	0

Table A7. Mean and median fork length, weight, and K-factor calculated for coho smolts measured and weighed in the Olema Creek smolt trap 2004-2017. FL = fork length, SD = standard deviation.

Year	Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2004	Smolt	148	114	9.7	113	14.4	4.03	14.4	1.00	0.07
2005	Smolt	37	116	9.5	116	16.0	3.89	15.0	1.01	0.08
2006	Smolt	205	99	9.6	98	10.2	3.08	9.6	1.04	0.11
2007	Smolt	191	116	11.0	115	14.7	4.73	13.6	0.91	0.07
2008	Smolt	386	111	9.2	110	12.4	3.20	11.9	0.90	0.09
2009	Smolt	447	113	8.1	113	12.9	2.79	12.5	0.89	0.06
2010	Smolt	10	136	6.7	135	24.1	4.17	23.6	0.94	0.06
2011	Smolt	376	122	10.7	121	16.2	4.24	15.5	0.89	0.06
2012	Smolt	180	117	10.7	115	14.6	4.40	13.8	0.89	0.06
2013	Smolt	47	120	9.3	119	15.8	4.66	15.3	0.91	0.11
2014	Smolt	698	115	9.9	115	13.6	3.15	13.3	0.88	0.08
2015	Smolt	503	111	9.6	110	12.3	3.31	11.7	0.88	0.06
2016	Smolt	311	118	11.3	117	16.1	4.81	15.1	0.95	0.06
2017	Smolt	582	118	9.6	118	15.5	3.68	15.1	0.93	0.08

Table A8. Mean and median fork length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Olema Creek smolt trap 2004-2017. FL = fork length, SD = standard deviation.

Year	Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2004	Smolt	11	177	15.4	176	55.3	14.37	50.6	0.99	0.09
2005	Smolt	6	127	32.5	129	22.9	15.85	22.3	0.94	0.13
2006	Smolt	3	130	9.5	133	25.0	6.39	28.6	1.13	0.09
2007	Smolt	109	168	19.2	166	41.7	13.59	39.7	0.85	0.08
2008	Smolt	34	141	25.7	138	27.3	13.01	24.9	0.92	0.09
2009	Smolt	11	156	17.4	155	33.6	10.43	32.6	0.87	0.54
2010	Smolt	31	174	22.7	175	48.2	17.80	44.9	0.88	0.07
2011	Smolt	15	172	18.8	174	42.3	13.16	42.2	0.80	0.04
2012	Smolt	8	173	17.6	174	40.0	8.70	40.2	0.77	0.11
2013	Smolt	12	177	20.2	174	48.5	17.44	44.8	0.84	0.06
2014	Smolt	11	148	21.9	155	32.1	10.77	34.0	0.85	0.06
2015	Smolt	94	153	21.2	148	32.7	15.50	28.3	0.86	0.07
2016	Smolt	32	161	20.7	169	41.3	13.17	45.7	0.98	0.08
2017	Smolt	7	157	158	27.4	37.2	14.9	37.0	0.93	0.12

Table A9. Mean and median fork length, weight, and K-factor calculated for coho smolts measured and weighed in the Redwood Creek smolt trap, 2005-2017. FL = fork length, SD = standard deviation.

Year	Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2005	Smolt	90	100	9.4	99	10.4	3.12	9.8	1.02	0.11
2006	Smolt	412	98	8.4	97	9.3	2.41	9.0	0.98	0.07
2007	Smolt	213	115	10.9	115	14.2	4.08	13.6	0.90	0.07
2008	Smolt	295	109	8.8	109	11.8	2.84	11.6	0.90	0.10
2009	Smolt	83	120	11.0	120	15.8	4.18	15.3	0.89	0.05
2010	Smolt	106	123	7.7	123	16.2	3.16	15.7	0.86	0.05
2011	Smolt	1,262	112	9.4	111	12.5	3.06	12.0	0.88	0.07
2012	Smolt	169	119	11.6	117	15.3	4.38	14.8	0.90	0.08
2013	Smolt	247	114	10.5	114	13.7	3.54	13.5	0.92	0.09
2014	Smolt	530	118	10.9	119	14.5	3.54	14.3	0.86	0.07
2015	Smolt	47	127	10.1	128	17.9	4.15	17.8	0.86	0.05
2016	Smolt	301	123	10.9	123	17.2	4.44	16.8	0.93	0.13
2017	Smolt	365	108	9.7	108	11.7	2.97	11.4	0.91	0.07

Table A10. Mean and median fork length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Redwood Creek smolt trap, 2006-2017 (no steelhead smolts caught in 2005). FL = fork length, SD = standard deviation.

Year	Life Stage	Sample Size	Mean FL (mm)	Mean FL SD	Median FL (mm)	Mean Weight (g)	Mean Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2006	Smolt	10	132	13.9	135	22.9	5.91	22.0	0.99	0.11
2007	Smolt	16	177	13.4	177	43.7	12.87	42.0	0.77	0.13
2008	Smolt	12	159	22.4	163	40.5	20.16	41.5	0.96	0.36
2009	Smolt	26	169	17.6	168	39.5	12.17	37.1	0.80	0.06
2010	Smolt	46	160.	11.2	160	34.5	7.10	34.7	0.83	0.06
2011	Smolt	13	157	17.6	157	32.0	10.42	31.1	0.80	0.08
2012	Smolt	30	163	12.7	162	33.8	6.69	33.0	0.77	0.07
2013	Smolt	14	178	11.0	176	46.3	7.99	45.2	0.82	0.04
2014	Smolt	6	167	19.3	169	40.5	12.84	39.4	0.85	0.04
2015	Smolt	76	150	17.2	149	28.5	9.37	27.3	0.82	0.09
2016	Smolt	15	180	22.7	179	53.1	20.76	48.5	0.87	0.05
2017	Smolt	30	141	142	23.7	27.4	10.9	25.7	0.92	0.08

Table A11. Summary of non-salmonid information for Olema Creek trap operations, 2004-2017.

Watershed	Year	Trap dates		CH[a]	GSF[a]	BG[a]	GSH[a]	LAM[a]	PL[a]	RO[a]	SCU[a]	STK[a]	SUC[a]	BF[a]	CRAY[a]	RLF[a]	RSN/ CAN[a]	WPT[a]	MF[a]	Totals
		From	To																	
Olema Creek	2004	30-Mar	28-May	2	1	0	1	15	0	274	243	3,083	144	19	14	0	0	0	0	3,796
	2005	1-Apr	9-May	0	0	0	0	33	0	1,006	117	648	58	234	0	0	0	1	0	2,097
	2006	10-Apr	9-Jun	0	0	0	0	6	1	420	644	2,998	3	4	5	52	0	5	0	4,138
	2007	15-Mar	26-May	0	0	0	0	35	0	3,190	364	1,110	140	6	16	1	0	2	0	4,864
	2008	18-Mar	30-May	0	0	0	0	2	3	158	228	30	2	11	17	7	1	1	0	460
	2009	12-Mar	29-Mar	0	0	0	0	109	0	554	335	782	8	1	12	77	1	2	3	1,884
	2010	19-Mar	21-May	0	0	0	0	27	0	3,187	110	1,353	7	1	3	44	2	0	0	4,734
	2011	6-Apr	3-Jun	0	0	0	0	1	1	677	212	485	6	0	4	1	0	0	1	1,388
	2012	3-Apr	31-May	0	0	0	0	0	0	195	217	234	0	0	13	57	2	1	0	719
	2013	12-Mar	31-May	0	0	0	0	5	0	118	399	211	0	1	24	5	1	0	0	764
	2014	21-Mar	30-May	0	0	0	0	0	0	189	244	256	0	0	15	1	2	1	0	708
	2015	10-Mar	5-Jun	0	0	1	0	0	0	233	241	126	0	2	4	3	2	1	0	613
	2016	24-Mar	26-May	0	0	0	2	0	0	460	88	523	1	3	6	293	1	1	0	1,378
	2017	16-Mar	2-Jun	0	0	2	1	0	0	421	144	704	0	2	9	7	0	0	0	1,290
Historical average				**<1**	**<1**	**<1**	**<1**	**19**	**<1**	**850**	**280**	**943**	**31**	**23**	**11**	**21**	**<1**	**1**	**<1**	**2,180**

[a] Species Code: CH = Chinook salmon (*O. tshawytcha*), GSF = green sunfish (*Lepomis cyanellus*, non-native), BG = bluegill (*Lepomis macrochirus*, non-native), GSH = golden shiner (*Notemigonus cyrsoleucas*, non-native), LAM = lamprey spp. (*Lampetra* spp.), PL= Pacific lamprey, RO = California roach, SCU = sculpin spp., STK = threespine stickleback, SUC = Sacramento sucker (*Catostomus occidentalis*), BF = bullfrog (*Rana catesbeina*, non-native), CRAY = signal crayfish (*Pacifastacus leniusculus*), RLF = California red-legged frog (*Rana draytonii*), RSN = rough-skinned newt (*Taricha granulosa*), CAN = California newt (*Taricha torosa*), WPT = western pond turtle (*Clemmys marmorata*), MF = mosquito fish (*Gambusia affinis*, non-native).

Table A12. Summary of non-salmonid information for Redwood Creek trap operations, 2005-2017.

Watershed	Year	Trap dates		SCU[a]	STK[a]	CRAY[a]	RLF[a]	RSN/ CAN[a]	Totals
		From	To						
Redwood Creek	2005	27-Mar	31-May	24	5,343	0	0	11	5,378
	2006	18-Apr	9-Jun	133	117	7	0	10	267
	2007	18-Mar	26-May	93	57	44	0	50	244
	2008	19-Mar	30-May	151	38	33	0	62	284
	2009	11-Mar	29-May	360	116	17	0	742	1,235
	2010	19-Mar	28-May	407	394	15	0	429	1,245
	2011	1-Apr	3-Jun	912	103	9	1	1,415	2,440
	2012	4-Apr	31-May	764	1,051	11	0	268	2,094
	2013	14-Mar	31-May	1,074	2,241	16	2	536	3,869
	2014	20-Mar	5-Jun	777	184	9	6	307	1,283
	2015	5-Mar	5-Jun	133	311	10	5	595	1,054
	2016	25-Mar	26-May	110	539	1	3	1,081	1,734
	2017	16-Mar	2-Jun	30	943	5	3	108	1,089
Historical average				**439**	**905**	**16**	**1**	**402**	**1,763**

[a] Species Code: SCU = sculpin spp., STK = threespine stickleback, CRAY = signal crayfish (*Pacifastacus leniusculus*), RLF = California red-legged frog (*Rana draytonii*), RSN = rough-skinned newt (*Taricha granulosa*), CAN = California newt (*Taricha torosa*)

Table A13. Summary of total salmonid catch by species within Olema Creek mainstem index reach sample locations, 2004-2017. Shows variation between years and distribution within watershed. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index reach								Total
Year	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**–**
2004	CO	NS	186	352	NS	295	239	175	164	1,411
	SH YoY	NS	147	231	NS	182	44	20	39	663
	SH 1+	NS	6	10	NS	26	24	10	8	84
2005	CO	NS	206	255	NS	269	361	191	186	1,468
	SH YoY	NS	72	97	NS	180	67	38	44	498
	SH 1+	NS	10	5	NS	13	15	7	7	57
2006	CO	NS	92	36	0	4	2	9	18	161
	SH YoY	NS	55	77	93	80	65	37	43	450
	SH 1+	NS	37	67	24	54	32	6	20	240
2007	CO	NS	123	170	233	332	217	156	160	1,391
	SH YoY	NS	112	135	241	120	51	10	36	705
	SH 1+	NS	9	22	16	19	15	3	8	92
2008	CO	NS	3	42	12	22	9	7	0	95
	SH YoY	NS	113	145	181	103	40	23	2	607
	SH 1+	NS	3	9	13	6	4	1	1	37
2009	CO	NS	0	0	NS	0	0	0	NS	0
	SH YoY	NS	11	16	NS	48	21	25	NS	121
	SH 1+	NS	12	19	NS	6	6	5	NS	48
2010	CO	NS	28	9	NS	8	10	41	NS	96
	SH YoY	NS	91	42	NS	69	61	61	NS	324
	SH 1+	NS	45	16	NS	4	11	11	NS	87
2011	CO	NS	31	19	NS	28	29	94	NS	201
	SH YoY	NS	40	90	NS	101	75	30	NS	336
	SH 1+	NS	34	28	NS	27	13	9	NS	111
2012	CO	NS	1	0	NS	1	0	0	NS	2
	SH YoY	NS	84	194	NS	39	27	39	NS	383
	SH 1+	NS	12	15	NS	5	9	15	NS	56
2013	CO	NS	20	91	NS	82	120	147	NS	460
	SH YoY	NS	5	16	NS	75	4	1	NS	101
	SH 1+	NS	9	18	NS	27	10	4	NS	68
2014	CO	NS	3	4	NS	19	21	17	NS	64
	SH YoY	NS	98	213	NS	346	39	18	NS	714
	SH 1+	NS	6	4	NS	3	5	0	NS	18

Table A13 (continued). Summary of total salmonid catch by species within Olema Creek mainstem index reach sample locations, 2004-2017. Shows variation between years and distribution within watershed. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index reach								Total
Year	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**–**
2015	CO	NS	0	64	NS	0	80	1	NS	145
	SH YoY	NS	21	74	NS	231	35	22	NS	383
	SH 1+	NS	11	27	NS	6	9	9	NS	62
2016	CO	NS	119	131	NS	98	83	80	NS	511
	SH YoY	NS	56	68	NS	73	19	2	NS	218
	SH 1+	NS	8	9	NS	7	4	2	NS	30
2017	CO	NS	2	7	NS	2	0	9	NS	20
	SH YoY	NS	87	167	NS	238	73	60	NS	625
	SH 1+	NS	5	8	NS	16	3	3	NS	35

Table A14. Summary of habitat composition; shows extent of area sampled and variation between reaches; Olema Creek, 2017. NS = not sampled.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	Sampled (m^2)	% of total
1	NS	NS	NS	NS	NS	NS
2	Pool	2	77.2	97.47	333.85	98.23
	Riffle	1	2.0	2.53	6.00	1.77
	Flatwater	0	0.0	0	0	0
	TOTAL	3	79.2	–	339.85	–
3	Pool	3	52.3	58.05	234.72	63.56
	Riffle	4	32.4	35.96	119.74	32.42
	Flatwater	1	5.4	5.99	14.85	4.02
	TOTAL	8	90.1	–	369.31	–
4	NS	NS	NS	NS	NS	NS
5	Pool	3	27.2	29.50	93.33	26.93
	Riffle	0	0	0	0	0
	Flatwater	3	65.0	70.50	253.19	73.07
	TOTAL	6	92.2	–	346.52	–
6	Pool	2	42.6	62.65	212.98	71.65
	Riffle	2	18.7	27.50	53.13	17.87
	Flatwater	1	6.7	9.85	31.16	10.48
	TOTAL	5	68.0	–	297.26	–
7	Pool	3	35.7	75.80	216.48	84.37
	Riffle	1	3.6	7.64	5.40	2.10
	Flatwater	1	7.8	16.56	34.71	13.53
	TOTAL	5	47.1	–	256.59	–
8	NS	NS	NS	NS	NS	NS
Total	Pool	13	235.0	60.83	1,091.37	58.53
	Riffle	8	56.7	14.68	184.27	9.88
	Flatwater	6	84.9	21.98	333.90	17.91
	TOTAL	27	376.6	–	1,609.54	–

Table A15. Summary of total salmonid catch and density estimates for each species by reach on Olema Creek; summer 2017; illustrates variation between reaches and provides a general idea of distribution within watershed. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

Index reach	Species (age)	Total catch # of fish	Density	
			Fish/m	Fish/m^2
1	NS	NS	NS	NS
2	CO	2	0.02	0.00
	SH YoY	87	0.76	0.18
	SH (1+)	5	0.04	0.01
3	CO	7	0.05	0.01
	SH YoY	167	1.39	0.35
	SH (1+)	8	0.10	0.03
4	NS	NS	NS	NS
5	CO	1	0.00	0.00
	SH YoY	208	2.29	0.60
	SH (1+)	12	0.11	0.03
6	CO	0	0.00	0.00
	SH YoY	73	0.81	0.20
	SH (1+)	3	0.02	0.00
7	CO	9	0.13	0.02
	SH YoY	60	1.08	0.18
	SH (1+)	3	0.05	0.01
8	NS	NS	NS	NS

Table A16. Summary of total salmonid catch (not including Dr. Smith information) by species within Redwood Creek mainstem index reach sample locations, 2004-2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index Reach							Total
Year	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**–**
2004	CO	NS	42	95	74	158	71	NS	440
	SH YoY	NS	6	22	19	24	4	NS	75
	SH 1+	NS	19	8	17	15	13	NS	72
2005	CO	23	59	77	93	164	236	339	991
	SH YoY	44	38	41	70	77	178	82	530
	SH 1+	5	12	12	10	14	9	4	66
2006	CO	6	21	21	38	3	9	0	98
	SH YoY	36	77	26	20	5	17	4	185
	SH 1+	2	23	21	20	11	20	1	98
2007	CO	54	138	215	120	146	89	8	770
	SH YoY	90	161	305	170	212	392	144	1,474
	SH 1+	8	43	10	11	7	11	7	97
2008	CO	0	2	6	0	23	3	NS	34
	SH YoY	84	79	103	120	101	79	NS	566
	SH 1+	10	19	23	20	21	12	NS	105
2009	CO	0	5	2	27	5	0	0	39
	SH YoY	104	87	85	55	27	21	25	404
	SH 1+	14	7	20	40	15	2	3	101
2010	CO	0	19	53	34	69	49	NS	224
	SH YoY	63	125	92	93	102	51	NS	526
	SH 1+	14	45	38	26	29	33	NS	185
2011	CO	0	14	6	2	2	0	NS	24
	SH YoY	79	71	20	38	39	15	NS	262
	SH 1+	13	55	24	33	29	25	NS	179
2012	CO	13	11	16	8	1	2	NS	51
	SH YoY	85	79	32	84	64	22	NS	366
	SH 1+	5	16	7	17	13	7	NS	65
2013	CO	38	86	26	21	25	5	NS	201
	SH YoY	3	6	13	2	2	0	NS	26
	SH 1+	4	9	6	15	9	6	NS	49
2014	CO	0	1	2	1	3	3	NS	10
	SH YoY	58	78	91	112	148	72	NS	559
	SH 1+	1	4	8	3	4	0	NS	20

Table A16 (continued). Summary of total salmonid catch (not including Dr. Smith information) by species within Redwood Creek mainstem index reach sample locations, 2004-2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index Reach							Total
Year	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**–**
2015	CO	0	4	1	28	11	29	NS	73
	SH YoY	0	1	0	5	0	3	NS	9
	SH 1+	4	36	19	62	20	13	NS	154
2016	CO	7	73	34	30	10	13	NS	167
	SH YoY	30	126	68	118	120	109	NS	571
	SH 1+	1	14	3	2	13	23	NS	56
2017	CO	15	20	2	5	16	3	NS	61
	SH YoY	140	272	93	95	138	59	NS	797
	SH 1+	9	67	68	113	88	49	NS	394

Table A17. Summary of habitat composition; shows extent of area sampled and variation between reaches; Redwood Creek 2017. NS = not sampled.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	sampled (m^2)	% of total
1	Pool	2	24.4	24.45	94.86	27.35
	Riffle	4	47.0	47.09	159.32	45.93
	Flatwater	3	28.4	28.46	92.70	26.72
	TOTAL	9	99.8	–	346.88	–
2	Pool	3	81.2	56.94	444.76	61.92
	Riffle	3	32.9	23.07	148.67	20.70
	Flatwater	2	28.5	19.99	124.80	17.38
	TOTAL	8	142.6	–	718.23	–
3	Pool	5	64.0	77.86	320.36	86.42
	Riffle	3	18.2	22.14	50.33	13.58
	Flatwater	0	0.0	0	0	0
	TOTAL	8	82.2	–	370.69	–
4	Pool	6	76.4	78.60	268.80	87.34
	Riffle	2	13.1	13.48	22.78	7.40
	Flatwater	1	7.7	7.92	16.17	5.25
	TOTAL	9	97.2	–	307.75	–
5	Pool	3	64.6	67.64	336.24	70.88
	Riffle	2	30.9	32.36	138.12	29.12
	Flatwater	0	0.0	0	0	0
	TOTAL	5	95.5	–	474.36	–
6	Pool	3	70.2	80.05	310.77	84.95
	Riffle	3	11.4	13.00	38.60	10.55
	Flatwater	1	6.1	6.96	16.47	4.50
	TOTAL	7	87.7	–	365.84	–
7	NS	NS	NS	NS	NS	NS
Total	Pool	22	380.8	62.74	1,775.79	68.73
	Riffle	17	153.5	25.29	557.82	21.59
	Flatwater	7	70.7	11.65	205.14	9.68
	TOTAL	46	605	–	2,583.75	–

Table A18. Summary of total salmonid catch and density estimates for each species by reach on Redwood Creek; summer 2017; illustrates variation between reaches and provides a general idea of distribution within watershed. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

Index reach	Species (age)	Total catch # of fish	Density	
			Fish/m	Fish/m^2
1	CO	15	0.14	0.04
	SH YoY	140	1.39	0.41
	SH (1+)	9	0.08	0.02
2	CO	20	0.10	0.02
	SH YoY	272	1.72	0.40
	SH (1+)	67	0.41	0.09
3	CO	2	0.02	0.00
	SH YoY	93	0.99	0.22
	SH (1+)	68	0.66	0.14
4	CO	5	0.04	0.01
	SH YoY	95	0.85	0.30
	SH (1+)	113	0.85	0.25
5	CO	16	0.15	0.03
	SH YoY	138	1.47	0.35
	SH (1+)	88	0.74	0.14
6	CO	3	0.02	0.00
	SH YoY	59	0.40	0.11
	SH (1+)	49	0.30	0.07
7	NS	NS	NS	NS

Table A19. Summary of total salmonid catch by species within Pine Gulch Creek mainstem index reach sample locations, 2005-2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index reach								Total
Year	**Species**	**1a**	**1b**	**1c**	**2**	**3**	**4**	**5**	**6**	**–**
2005	CO	3	1	0	2	15	NS	16	8	45
	SH YoY	25	18	44	78	41	NS	40	33	279
	SH 1+	8	5	33	18	17	NS	24	7	112
2006	CO	0	0	0	0	0	NS	4	10	14
	SH YoY	9	22	17	17	45	NS	39	20	169
	SH 1+	31	28	38	13	18	NS	17	18	163
2007	CO	0	0	0	0	0	NS	0	0	0
	SH YoY	3	39	61	145	153	NS	55	52	508
	SH 1+	2	21	29	23	13	NS	23	14	125
2008	CO	NS	0	0	0	0	NS	0	0	0
	SH YoY	NS	9	22	87	147	NS	37	53	355
	SH 1+	NS	4	15	12	16	NS	15	10	72
2009	CO	NS	NS	0	0	0	NS	3	0	3
	SH YoY	NS	NS	3	3	26	NS	6	8	46
	SH 1+	NS	NS	14	7	12	NS	5	5	43
2010	CO	NS	NS	0	0	0	NS	0	0	0
	SH YoY	NS	NS	18	53	52	NS	40	22	185
	SH 1+	NS	NS	19	24	14	NS	16	6	79
2011	CO	NS	NS	NS	0	0	NS	0	0	0
	SH 1+	NS	NS	NS	32	42	NS	47	38	159
	SH YoY	NS	NS	NS	20	18	NS	16	7	61
2012	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	19	37	NS	18	28	102
	SH 1+	NS	NS	NS	25	24	NS	16	23	88
2013	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	26	41	NS	14	12	93
	SH 1+	NS	NS	NS	26	19	NS	11	10	66
2014	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	30	46	NS	34	35	145
	SH 1+	NS	NS	NS	10	20	NS	10	6	46
2015	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	43	62	NS	25	17	147
	SH 1+	NS	NS	NS	17	19	NS	14	9	59

Table A19 (continued). Summary of total salmonid catch by species within Pine Gulch Creek mainstem index reach sample locations, 2005-2017. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

		Index reach								Total
Year	**Species**	**1a**	**1b**	**1c**	**2**	**3**	**4**	**5**	**6**	**–**
2016	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	30	41	NS	13	23	107
	SH 1+	NS	NS	NS	12	16	NS	9	8	45
2017	CO	NS	NS	NS	0	0	NS	0	0	0
	SH YoY	NS	NS	NS	37	33	NS	69	42	181
	SH 1+	NS	NS	NS	5	9	NS	10	5	29

Table A20. Summary of habitat composition; shows extent of area sampled and variation between reaches; Pine Gulch Creek, 2017. NS = not sampled.

			Length		Surface area	
Index reach	**Habitat type**	**# of units**	**sampled (m)**	**% of total**	**Sampled (m^2)**	**% of total**
1A-1C	NS	NS	NS	NS	NS	NS
2	Pool	2	15.8	31.98	47.54	28.93
	Riffle	2	12.9	26.11	39.02	23.74
	Flatwater	2	20.7	41.90	77.77	47.33
	TOTAL	6	49.4	–	164.32	–
3	Pool	1	14.3	26.29	73.93	44.33
	Riffle	2	21.6	39.71	49.75	29.83
	Flatwater	1	18.5	34.01	43.11	25.84
	TOTAL	4	54.4	–	166.79	–
4	NS	NS	NS	NS	NS	NS
5	Pool	4	53.5	77.2	148.97	30.38
	Riffle	2	9.4	13.56	26.77	14.44
	Flatwater	1	6.4	9.24	9.60	5.18
	TOTAL	7	69.3	–	185.34	–
6	Pool	3	18.4	33.03	41.95	22.37
	Riffle	3	35.3	63.38	142.20	75.82
	Flatwater	1	2.0	3.59	3.40	1.81
	TOTAL	7	55.7	–	187.55	–
Total	Pool	10	102.0	168.50	312.39	176.00
	Riffle	9	79.2	142.76	257.74	143.84
	Flatwater	5	47.6	88.74	133.88	80.16
	TOTAL	24	228.8	–	704.00	–

Table A21. Summary of total salmonid catch and density estimates for each species by reach on Pine Gulch Creek, summer 2017; illustrates variation between reaches and provides a general idea of distribution within watershed. CO = coho salmon, SH = steelhead, YoY = young-of-year, 1+ = one year of age or older, NS = not sampled.

Index reach	Species (age)	Total catch # of fish	Density	
			Fish/m	Fish/m^2
1a-1C	NS	NS	NS	NS
2	CO	0	0.00	0.00
	SH YoY	37	0.63	0.21
	SH (1+)	5	0.08	0.03
3	CO	0	0.00	0.00
	SH YoY	33	0.60	0.20
	SH (1+)	9	0.16	0.04
4	NS	NS	NS	NS
5	CO	0	0.00	0.00
	SH YoY	69	0.75	0.28
	SH (1+)	10	0.11	0.04
6	CO	0	0.00	0.00
	SH YoY	42	0.80	0l34
	SH (1+)	5	0.15	0.06

Appendix B. Julian Week Numbers

Table B1. List of Julian weeks and their calendar equivalents in a non-leap year.

Julian Week Number	Inclusive Dates
1	Jan 01 - Jan 07
2	Jan 08 - Jan 14
3	Jan 15 - Jan 21
4	Jan 22 - Jan 28
5	Jan 29 - Feb 04
6	Feb 05 - Feb 11
7	Feb 12 - Feb 18
8	Feb 19 - Feb 25
9	Feb 26 - Mar 04
10	Mar 05 - Mar 11
11	Mar 12 - Mar 18
12	Mar 19 - Mar 25
13	Mar 26 - Apr 01
14	Apr 02 - Apr 08
15	Apr 09 - Apr 15
16	Apr 16 - Apr 22
17	Apr 23 - Apr 29
18	Apr 30 - May 06
19	May 07 - May 13
20	May 14 - May 20
21	May 21 - May 27
22	May 28 - Jun 03
23	Jun 04 - Jun 10
24	Jun 11 - Jun 17
25	Jun 18 - Jun 24
26	Jun 25 - Jul 01
27	Jul 02 - Jul 08
28	Jul 09 - Jul15
29	Jul 16 - Jul 22
30	Jul 23 - Jul 29
31	Jul 30 - Aug 05
32	Aug 06 - Aug 12
33	Aug 13 - Aug 19
34	Aug 20 - Aug 26
35	Aug 27 - Sep 02
36	Sep 03 - Sep 09

Table B1 (continued). List of Julian weeks and their calendar equivalents in a non-leap year.

Julian Week Number	Inclusive Dates
37	Sep 10 - Sep 16
38	Sep 17 - Sep 23
39	Sep 24 - Sep 30
40	Oct 01 - Oct 07
41	Oct 08 - Oct 14
42	Oct 15 - Oct 21
43	Oct 22 - Oct 28
44	Oct 29 - Nov 04
45	Nov 05 - Nov 11
46	Nov 12 - Nov 18
47	Nov 19 - Nov 25
48	Nov 26 - Dec 02
49	Dec 03 - Dec 09
50	Dec 10 - Dec 16
51	Dec 17 - Dec 23
52	Dec 24 - Dec 31

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