



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

2013 Annual Report

Natural Resource Report NPS/SFAN/NRR—2015/956





ON THIS PAGE

Coho fry, Redwood Creek, Marin County, CA
Photograph by: Kelly Church

ON THE COVER

Juvenile salmonid electrofishing, Olema Creek, Marin County, CA
Photograph by: Sarah Carlisle

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Sarah Carlisle¹, Michael Reichmuth²

¹ Point Reyes National Seashore Association, Coho and Steelhead Monitoring Program
1 Bear Valley Road
Point Reyes Station, California 94956

²National Park Service, San Francisco Bay Area Network Inventory and Monitoring Program,
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, California 94956

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Abstract

The San Francisco Bay Area Network (SFAN) monitors populations of coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*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 a population of coho salmon near the southern extent of their range on the Pacific Coast. The National Park Service 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.

Monitoring of multiple life stages presents a more accurate picture of the coho population than monitoring only a single stage, especially given the complex life history of the coho salmon. Coho salmon have a three-year life cycle in which they spend their 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. The first generation that was monitored by the NPS during the winter of 1997-1998 is designated as cohort 1 with the next generation of cohort 1 first sampled as juveniles during the summer of 1998. 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, and 2013. Cohort 2 are those fish that hatched in 1999, 2002, 2005, 2008, and 2011, and cohort 3 fish hatched in 2000, 2003, 2006, 2009, 2012. This report presents a summary of monitoring results for the 2012-2013 spawner season, 2013 smolt trapping season, and 2013 summer juvenile surveys. Adult coho escapement surveys for 2012-2013 show an increase in the number of cohort 1 coho adults returning to spawn on both Olema and Redwood Creeks compared to the previous return of cohort 1 in 2009-2010. No coho spawning was observed on Pine Gulch in 2012-2013.

Olema Creek had a population estimate of 16,599, 95% confidence interval (CI) [13,075; 20,123] coho juveniles, which represents a nine-fold increase when compared to the last time this cohort was observed during the summer of 2010 (1,755, 95% CI [1,062; 2,448]). Redwood Creek had a population estimate of 3,159, 95% CI [2,287; 4,031], a comparable estimate to the last time this

cohort was observed during the summer of 2010. A population estimate was not feasible for Pine Gulch Creek, as no coho juveniles were observed during summer surveys in 2013.

The Olema coho smolt production was calculated using the Chapman modification of the Petersen estimate equation, yielding a production estimate of 99 [standard error (SE) 112]. The raw count of coho smolts in 2013 (49) was approximately five times higher than the total capture in 2010, indicating at least some increase in coho smolt production. Likewise, the 2013 Redwood Creek coho smolt production estimate of 553 [SE 627] showed a 42% increase when compared to the same cohort in 2010 (389 [SE 802]). Based on the absence of juvenile coho during the summer of 2012, no smolt trap was placed in Pine Gulch Creek during the spring of 2013.

List of Acronyms

CCCESU	Central California Coast Evolutionarily Significant Unit
CDFW	California Department of Fish and Wildlife
CI	Confidence Interval
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
PORE	Point Reyes National Seashore
SD	Standard Deviation
SE	Standard Error
SFAN	San Francisco Bay Area Network
SPAWN	Salmon Protection And Watershed Network
YOY	Young of the Year
Year-Year	All year-year references refer to the spawning year

1 Introduction

The San Francisco Bay Area Network (SFAN) 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 changes to environmental conditions in the future. Salmonids represent a particularly high priority vital sign for SFAN because coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) are important indicators of ecosystem health, provide important links between marine and freshwater ecosystems, have endangered or threatened status, and garner high public interest.

Salmonids are monitored at three National Park Service (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 SFAN within the Olema Creek, Pine Gulch Creek, and Redwood Creek watersheds in coastal Marin County is supported through the California Department of Fish and Wildlife (CDFW) Contract P0730408 to the Point Reyes National Seashore Association. These monitoring efforts continue salmonid research initiated and conducted by 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, monitoring has been conducted to document information of federally threatened steelhead trout and other fish species within the monitored watersheds.

The SFAN Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010) documents methods used by SFAN in salmonid monitoring within coastal Marin County since 1997.

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 2013, 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 coastal Marin County (Figure 1).

1.1 Background

Spawning populations of coho salmon and steelhead trout 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 (dams and culverts typically are barriers), cold temperatures (<70°F) and high dissolved oxygen levels (Moyle 2002). 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 historic regional accounts, numbers of coho salmon and steelhead trout have been severely depleted. Coastal Marin County streams and their associated watersheds currently containing populations of coho salmon and steelhead trout include Lagunitas Creek (including Olema Creek tributary), Redwood Creek, and Walker Creek. Coho salmon were documented in Pine Gulch Creek from 2001 through 2010 but have since been extirpated from the watershed. Some of the factors believed to have contributed to the declines in anadromous fish runs within the parks 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.

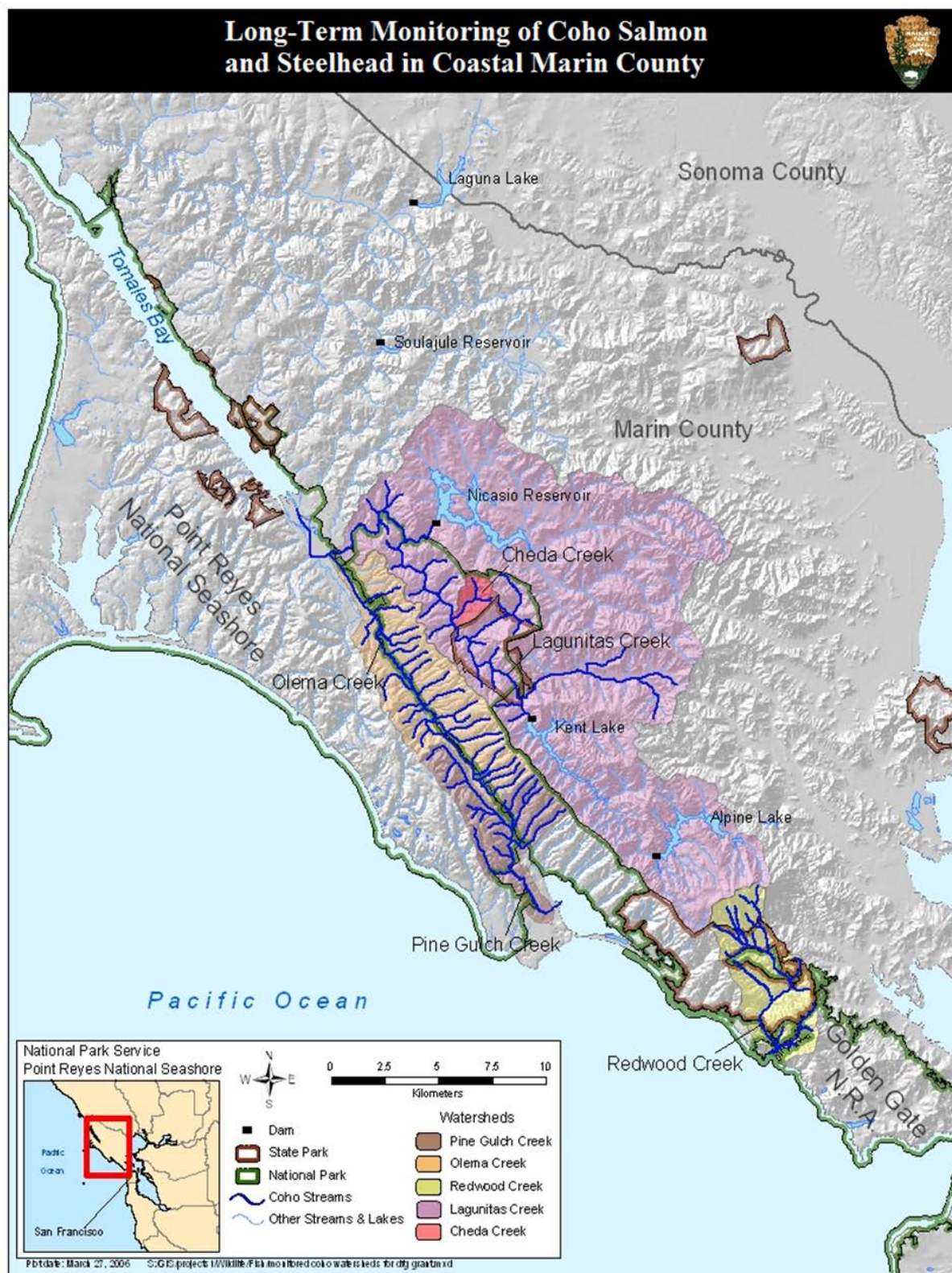


Figure 1. Streams supporting coho salmon in coastal Marin County. The National Park Service monitors streams in Point Reyes National Seashore (Olema and Pine Gulch Creeks) and Golden Gate National Recreational Area (Redwood and Cheda Creeks).

1.2 Fishes Monitored by this Protocol

The primary species monitored through this program are coho salmon and steelhead trout. 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 freshwater to marine water and 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 downgraded in status (upgraded listing protection) to endangered 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 trout is described in detail in Moyle (2002). Steelhead are the anadromous form of rainbow trout. Steelhead are iteroparous, meaning they can spawn more than once. Steelhead trout are known to exist in most perennial watersheds within Marin County. Because of dramatic declines in population numbers, NMFS was petitioned to list this species throughout much of the California coast. 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 California 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 (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 in the spring as fish smolt and move downstream (Chapman 1965, 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 distribution and abundance, 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: endangered California freshwater shrimp (*Syncaris pacifica*); endangered coho salmon; threatened steelhead; and threatened California red-legged frog (*Rana draytonii*). 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 was reduced by more than 50% due to the construction of Alpine Dam in 1918 and Peters Dam in 1953. Because neither dam has provision 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 steelhead trout and coho salmon (Figure 1). Past land-use

within the Cheda Creek drainage has resulted in alterations to the natural hydrology and degraded riparian conditions of the creek. 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 aquatic federally protected species (endangered coho salmon, threatened steelhead, and the threatened California red-legged frog). According to the NMFS Genetics Laboratory, the coho salmon found in Redwood Creek represent a genetic outlier within the CCCESU with extreme 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 km (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 it supported a native self-sustaining population of coho salmon into the 1970s. It is likely the drought of the late 1970s coupled with in-stream damming during the same period 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 that 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 strategies to monitor coho salmon and steelhead trout 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 SFAN for salmonid monitoring within coastal Marin County since 2009. Many of the methods associated with the project are consistent with Fish Bulletin 180 biotic monitoring guidelines (Adams et al. 2011). Maps of Olema, Redwood, and Pine Gulch Creeks with survey locations are shown in Figures 2-4.

2.1 Adult Salmon Escapement Surveys

Spawner surveys are conducted annually 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 salmon escapement. “Escapement” refers to the number of adult fish that successfully pass through a fishery to reach the spawning grounds located in the freshwater streams. Data collected as a part of these surveys contribute to Monitoring Objective 1 and include number of live fish observed (coho and steelhead), number of fish carcasses observed (coho and steelhead), and number of redds observed (coho and steelhead). These surveys were first conducted on Redwood Creek in 1994, Olema Creek in 1997, Cheda Creek in 1998, and Pine Gulch in 2000. SOPs 5, 6, 9, and 11 document field and analytical methods for the adult salmon escapement monitoring efforts ([Reichmuth et al. 2010](#)).

2.1.1 Field Methods

Program staff and trained volunteers conduct surveys for coho and steelhead spawners and redds each winter during the coho spawning season to quantify escapement and determine spawning density and distribution. Steelhead can spawn until late spring and spawner surveys are infrequent after the conclusion of the coho spawning season.

Escapement surveys are conducted within a three-month period starting in late November and continuing through February. Start and end dates for each season vary depending on instream flows, and spawning activity. Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, typically peaking in January (Weitkamp et al. 1995). Surveys are conducted approximately every week, although storms and high stream flows often result in less frequent surveys. Teams of two to four observers walk upstream through 2-4 km creek reaches (Figures 2-4) and along creek margins and banks where possible to look for live fish, carcasses, and redds. Live fish are identified to species and sex, and fork length (FL) are 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. Carcass scales and tissue samples are collected for age and genetic analysis. Redds are measured (total length and average width of both the redd pot and tail spill to the nearest tenth of a meter) and 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.

2.2 Outmigrant 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](#). During the 2013 outmigration season, a total of 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 600 m upstream (just upstream of the Pacific Way bridge). The upstream trap was operated in association with current restoration activities in lower Redwood Creek. 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 estimate 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 Smolt Trap Field Methods

Trapping is conducted continually for a 2-3 month period during the spring and requires daily checking by field 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 each traps efficiency is estimated via mark-recapture techniques resulting in a smolt production estimate calculated using DARR 2.0.2 software (Bjorkstedt 2010). 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, if fish are anesthetized for mark-recapture purposes, they 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 stabilized somewhat. In some years, spring rains occasionally raise 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 gage for measurement of average daily discharge. An Onset-brand temperature logger is deployed in each trap box for the duration of operation.

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 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.

2.4 Basinwide General Systematic Surveys

Basinwide survey techniques, developed by Hankin and Reeves (Dollof et al. 1993), provide a statistically valid estimate of stream habitat or population of a particular fish species 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. Stream habitat sampling units are classified to level III using the CDFW classification system (Flosi et al. 1998) as pool (scour pool, plunge pool, or mid-channel pool), flatwater, or riffle. 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 instream shelter during summer base flow conditions are 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 pools to provide an unbiased calibration method (Dollof et al. 1993).

2.4.1 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. Under this technique, established stream reaches approximately 100 m in length distributed intermittently along the creeks' full length, 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.

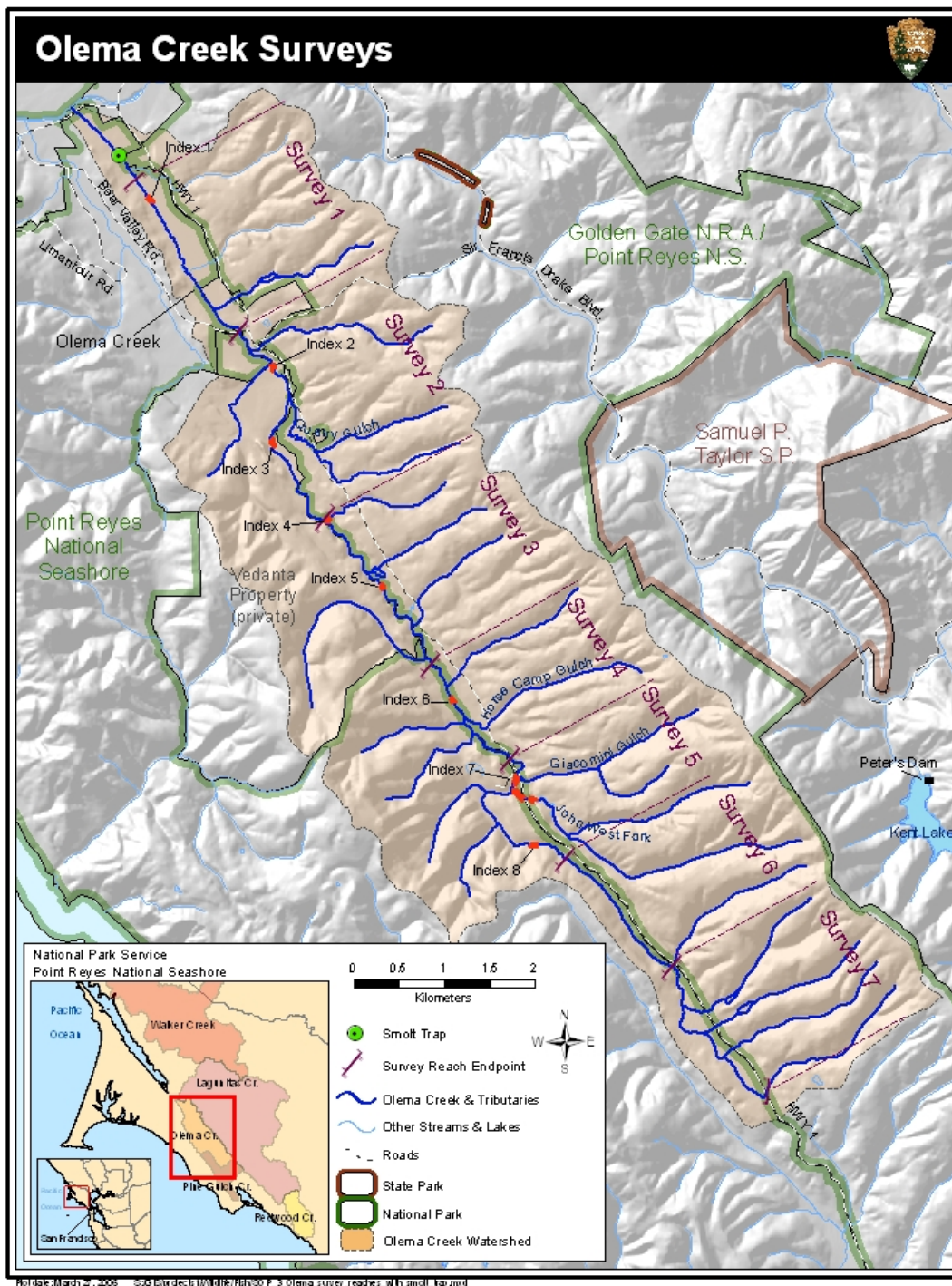


Figure 2. Olema Creek general survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

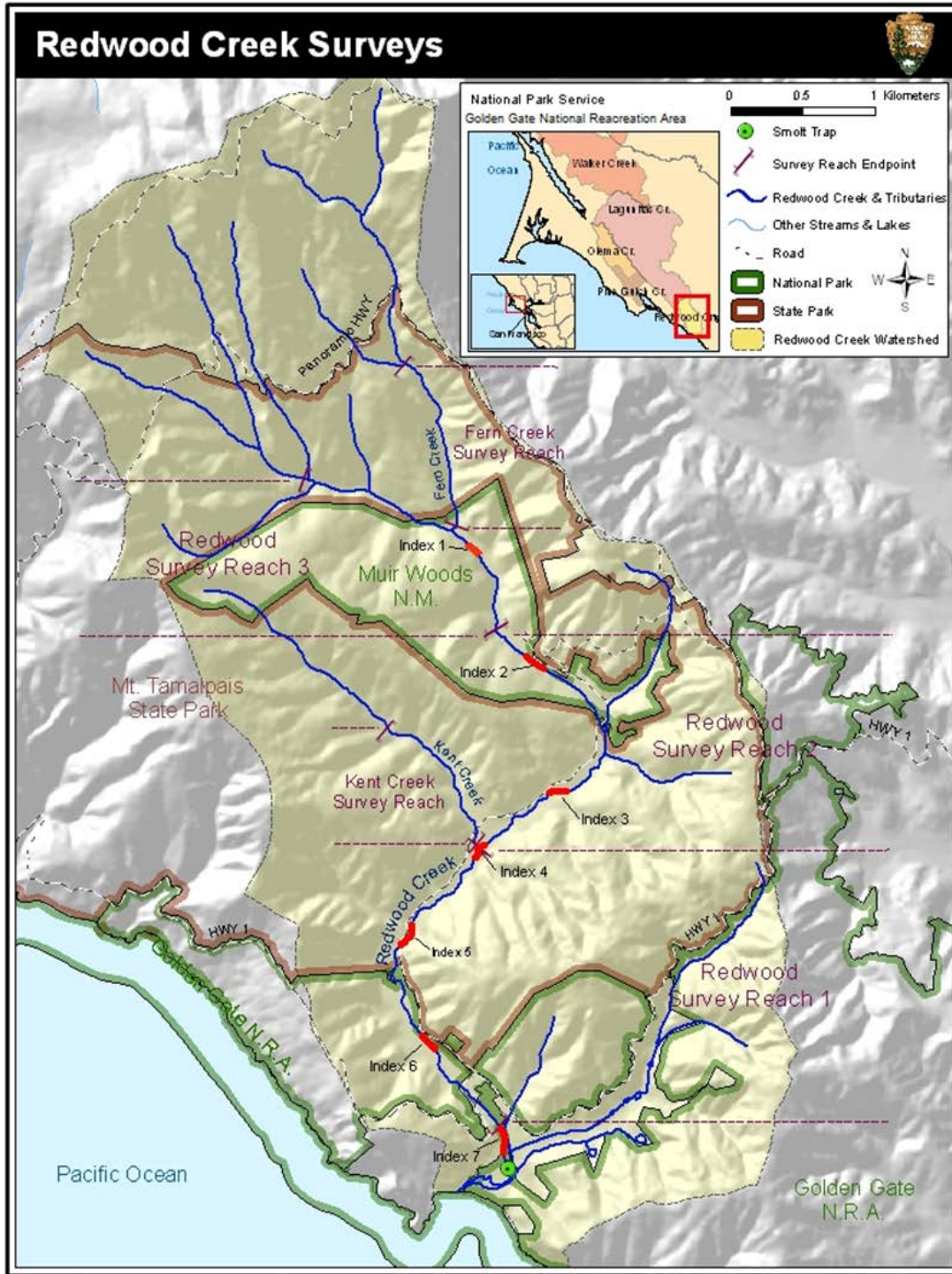


Figure 3. Redwood Creek general survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

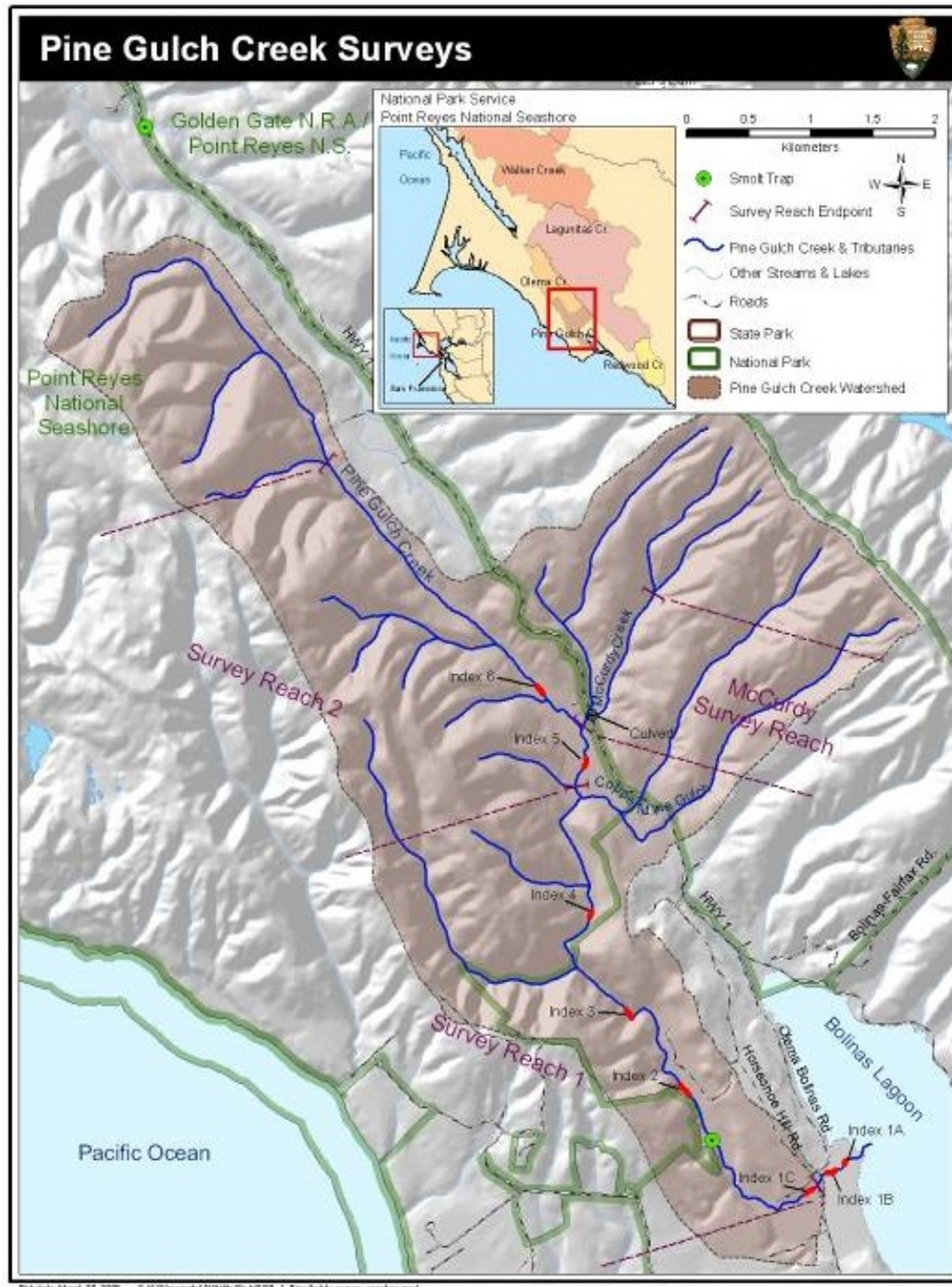


Figure 4. Pine Gulch Creek general survey locations. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

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

The data collected at the Bear Valley rain gage within the Olema Creek watershed shows that the 2013 water year (October 2012-September 2013) had above average rainfall in December, but the other months of the spawning season were well below the historical average. The total rainfall for water year 2013 was 29.62 inches, compared to the historical average for the last 48 years of 38.84 inches. The first pulse of rain came in late October, which had a higher than average monthly rainfall (3.57 inches compared to an average of 2.25 inches). November was only half the historical average, while January had only 13% of the historical average (1.04 inches compared to an average of 8.27 inches), while rainfall for the month of February was at only 11% of the historical average (0.70 inches compared to an average of 6.46 inches).

3.2 Data from Escapement Surveys

In the 2012-2013 spawning year, SFAN conducted escapement surveys starting in late November and continuing through the beginning of March. Surveys were conducted in Olema, Cheda, Redwood, and Pine Gulch Creeks.

These surveys were first conducted on Redwood Creek in 1994, Olema Creek in 1997, Cheda Creek in 1998, and Pine Gulch in 2000. Historical results for all streams monitored in Marin County by SFAN, MMWD, and SPAWN are presented in Appendix A, Table A1.

3.2.1 Olema Creek

Coho escapement monitoring information on 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. Olema Creek watershed spawner survey information includes data collected on 15.1 km of the mainstem of Olema Creek, primarily Reaches 1 through 6, and John West Fork, the largest tributary to Olema Creek (Figure 3). In addition, spawner surveys were conducted on Quarry Gulch, Boundary Gulch (small tributary located between Quarry Gulch and Horse Camp Creek), Horse Camp Creek, and Giacomini Creek. When possible, the mainstem of Olema Creek and the John West Fork tributary are combined for data summaries and analysis.

Adult Coho Survey Timing and Environmental Conditions

Our monitoring efforts have documented some years when flows necessary to allow 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 have resulted in flows that would allow coho access to the watershed. Even when the early entry opportunity has occurred in November, few coho have been observed. For the most part, peak spawning activity within Olema Creek is between mid-December (Julian weeks 50 and 51) and mid-January (Julian weeks 1 through

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. The early storms in October allowed the coho adults access to the creek during their typical time frame for initial spawning (late November through mid-December). 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.

For the 2012-2013 season, the first survey was performed on 5 November 2012 on the lowest reach of Olema Creek. Fifteen surveys were conducted in Olema Creek between 5 November 2012 and 14 February 2013. The mean interval between surveys was 6.6 days. Seven-day rainfall totals during Julian weeks ranged from a low of 0 inches during Julian weeks 5 and 7, and a high of 5.94 inches during Julian week 48. Water clarity encompassing several reaches for a given survey day was calculated by averaging the clarity values obtained from those reaches surveyed on that day. Average water clarity at the time of each survey ranged from 38 cm to over 100 cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations. In an attempt to better capture steelhead spawning numbers, five additional surveys were performed between 25 February and 25 April. New steelhead redds were found into the end of April.

Eight surveys were conducted on John West Fork tributary (reaches 1-2) between 26 November 2012 and 15 January 2013. Six of the eight surveys were conducted on the same day as the Olema Creek mainstem surveys. The mean interval between surveys was 7.3 days. Seven-day rainfall totals during Julian weeks ranged from a low of 0.01 inches during Julian week 53 and 3, and a high of 5.94 inches during Julian week 48. Average water clarity at the time of surveys ranged from 30 cm to 105 cm.

In addition to John West Fork, four other tributaries to the Olema mainstem were surveyed in December and January. The timing of tributary surveys generally preceded the mainstem surveys and were dependent on flow. With the exception of John West Fork, tributaries were surveyed less frequently than the mainstem reaches of Olema Creek. Sections of Giacomini Gulch, Horse Camp Gulch, Boundary Gulch, and Quarry Gulch were surveyed.

Live Coho and Steelhead

Spawner surveys of the Olema Creek mainstem and John West Fork Creek tributary were performed between 5 November 2012 and 13 February 2013. While live coho observations do not represent the total number of spawning adults, a total of 51 live adult coho were observed during seven surveys on the Olema Creek mainstem between November and January. No live adult coho were observed on the John West Fork tributary. The first fish on the Olema Creek mainstem was observed on 19 November.

Four additional tributaries to the Olema mainstem (Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Creek) were surveyed during December. One adult was observed on Horse Camp Gulch on 4 December and one adult was observed on Quarry Gulch on 28 December.

Although adult steelhead are not a primary focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Because of their behavior, actual live adult steelhead

abundance is assumed to be much higher than the observed counts. Surveys were performed on the lower reaches of Olema Creek mainstem until the end of April, in an attempt to better capture steelhead spawning numbers. Five live adult steelhead were observed during the 2012-2013 spawner surveys on the mainstem of Olema Creek only. One unknown adult salmonid was observed on reach 2 on 15 January but could not be positively identified as either a steelhead or a coho.

Coho and Steelhead Carcasses

Nineteen confirmed coho carcasses were recovered on the mainstem of Olema Creek during the 2012-2013 spawner season.

Five steelhead carcasses were observed on Olema Creek mainstem. No steelhead carcasses were seen on John West Fork or the Olema Creek tributaries.

Coho and Steelhead Redds

Redds are the best means of spatially representing spawning densities within the watershed. Within Olema Creek, monitoring efforts have allowed spatial representations of redd density per 100 m section since 1997-1998. Accumulation of this data show high use areas for spawning within the Olema and John West Fork watersheds.

Twenty-nine confirmed coho redds were observed in the mainstem of Olema Creek and two confirmed coho redds were observed on John West Fork during the 2012-2013 season. Coho redds were found on reaches 2-6 on the mainstem and on reach 2 of John West Fork. One coho redd was also observed on Quarry Gulch, an Olema tributary. The average coho redd surface area was 6.38 m² and the density of redds on the mainstem was 1.93 redds/km.

Twenty-six steelhead redds were observed on the mainstem of Olema Creek in reaches 1-6. Three steelhead redds were observed on John West Fork in reaches 1 and 2. The average steelhead redd surface area was 2.00 m² and the density was 1.73 redds/km.

Coho Spawning Trends

Overall trends in coho spawning based on observed redds in the Olema watershed are shown 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 2 shows a rapid increase in spawning over the first three generations before falling off sharply in 2007-2008. It has since held relatively steady. Cohort 3 continued to struggle with a dramatic decline between 2002-2003 and 2005-2006, no adult coho, coho carcasses, or coho redds were observed in 2008-2009. In 2011-2012 redds were observed in low abundance for this cohort. Cohort 1 likewise suffered a sharp decline in 2009-2010, but has since increased in number.

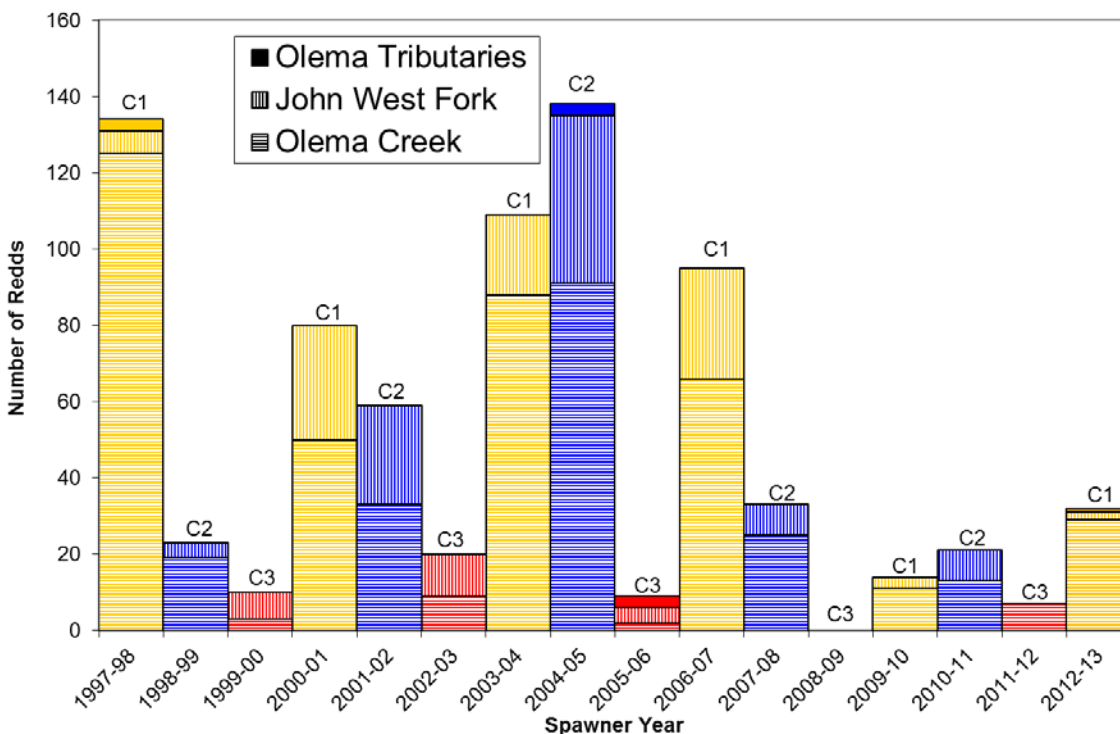


Figure 5. Coho salmon redd results for the Olema Creek watershed by cohort for winter 1997-1998 through winter 2012-2013. Cohorts are designated by color (cohort 1 shown in yellow, cohort 2 shown in blue, cohort 3 shown in red) and creeks are designated by pattern (Olema Creek in horizontal lines, John 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 for the period 1997-2012 compared to 2012-2013.

		Live Coho					
		Year	Sample Size	Sex Ratio%	n for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2012	613	35%	587	62.8	7.30
	F	1997-2012	798	46%	778	60.4	6.2
	J	1997-2012	219	13%	219	38.4	5.14
	Unk	1997-2012	103	6%	67	52.4	10.38
	All		1733	100%			
Current	M	2012-2013	17	32%	17	62	6.6
	F	2012-2013	23	43%	23	63	6.0
	J	2012-2013	7	13%	7	37	9.1
	Unk	2012-2013	6	11%	5	57	0
	All		53	100%			

M= Male, F= Female, J=Jack, Unk= Unknown, n= Number of fish measured for fork length (FL)

SD= Standard Deviation

Table 2. Sex ratio percentages and mean fork length (FL) of coho carcasses within Olema Creek for the period 1997-2012 compared to 2012-2013.

		Carcasses					
		Year	Sample Size	Sex Ratio%	n for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2012	140	36%	108	64	9.1
	F	1997-2012	164	42%	139	65	5.1
	J	1997-2012	29	7%	29	42	3.2
	Unk	1997-2012	60	15%	12	61	10.4
	All		393	100%			
Current	M	2012-2013	6	32%	1	61	
	F	2012-2013	8	42%	2	62	4.2
	J	2012-2013	0	0%	0		
	Unk	2012-2013	5	26%	0		
	All		19	100%			

M= Male, F= Female, J=Jack, Unk= Unknown, n= Number of fish measured for fork length (FL)

SD= Standard Deviation

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 trout. Cheda Creek spawner survey information includes data collected on 1.3 km distributed between reaches 1 and 2

Survey Timing and Environmental Conditions

Five surveys were performed on Cheda Creek during December 2012. The mean interval between surveys was 6 days. Seven-day rainfall totals during Julian weeks ranged from a low of 0.26 inches during Julian week 50 and a high of 4.07 inches during Julian week 52. Average water clarity ranged from 30 cm to over 100 cm.

Live Coho and Steelhead

Three live coho and two live steelhead adults were observed on Cheda Creek during the 2012-2013 season. The coho were seen on 26 December and the steelhead on 28 December.

Coho and Steelhead Carcasses

Two coho carcasses were discovered on Cheda Creek. No steelhead carcasses were found.

Coho and Steelhead Redds

Two coho redds were observed on Cheda Creek during the surveys. The surface area of the one measured redd was 1.53 m², while the redd density was 1.11 redds/km.

No steelhead redds were observed on Cheda Creek in 2012-2013.

Cheda Creek Watershed Coho Escapement History

The dataset for adult escapement within Cheda Creek includes 15 years of survey information and has documented the return of coho to this small tributary stream of Lagunitas Creek (Appendix A, Table A4).

3.2.3 Redwood Creek Coho and Steelhead Escapement

Survey Timing and Environmental Conditions

Review of the past 19 years of coho salmon escapement monitoring information for Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff condition within the watershed (Appendix A, Table A3). 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. Eleven surveys were conducted in Redwood Creek between 6 November 2012 and 22 January 2013. The mean interval between surveys was 6.3 days. Seven-day rainfall totals during Julian weeks ranged from a low of 0.00 inches during Julian weeks 53, 2, and 3 and a high of 4.04 inches during Julian week 48. Average water clarity at the time of each survey ranged from 65 cm to 105 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 A3.

The Redwood Creek mainstem reaches 1 through 3 were consistently sampled during seven of the 11 surveys performed. Fern Creek and Kent Creek were surveyed later in the season when water levels were high enough to allow fish access into the tributaries. Tributary reaches were surveyed on the same day as the mainstem reaches to eliminate the possibility of double counting. In an attempt to better capture steelhead spawning numbers, four additional surveys were performed between 29 January and 2 April. No new steelhead were observed after January.

Live Coho and Steelhead

A total of 56 live adult coho spawners were observed during the 11 spawner surveys on Redwood Creek. No live adult coho were observed in either Kent or Fern Creeks.

A total of seven confirmed steelhead adults were observed in the mainstem of Redwood Creek. No steelhead were observed in either of the tributaries surveyed.

Coho and Steelhead Carcasses

Seventeen coho carcasses were recovered on Redwood Creek during the 2012-2013 spawner season. One additional carcass was observed that could not be identified to species. No coho carcasses were observed on either of the tributaries.

No steelhead carcasses were observed during the spawner survey season.

Coho and Steelhead Redds

Twenty-five coho redds were observed during the 2012-2013 spawner season. Redds were observed in reaches 1- 3 of the mainstem and on the Redwood tributary Fern Creek. The average surface area for coho redds was 3.85 m², while the total density of redds in the mainstem section surveyed was 3.38 redds/km.

A total of six definite steelhead redds were observed in the mainstem of Redwood Creek and were only found in reach 2. The total density of redds in the 7.4 km mainstem section surveyed was 0.81 redds/km. The mean steelhead redd surface area was 2.33 m².

Coho Spawning Trends

Overall trends in coho spawning based on redds observed in the Redwood Creek watershed are shown 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 has remained relatively constant over the past three generations. Cohort 2 shows higher numbers of redds prior to an abrupt decline during the 2007-2008 spawner season and very limited recovery since then. Cohort 3 continues in low abundance since the 1999-2000 spawner year. Within each year, the data is broken down into the creeks where spawning occurred. Cohort 3 redds have been observed only in the mainstem of Redwood Creek, with a noticeable increase in the number of redds during the 2005-2006 spawner season. For all years, the majority of spawning occurs in the mainstem of Redwood Creek.

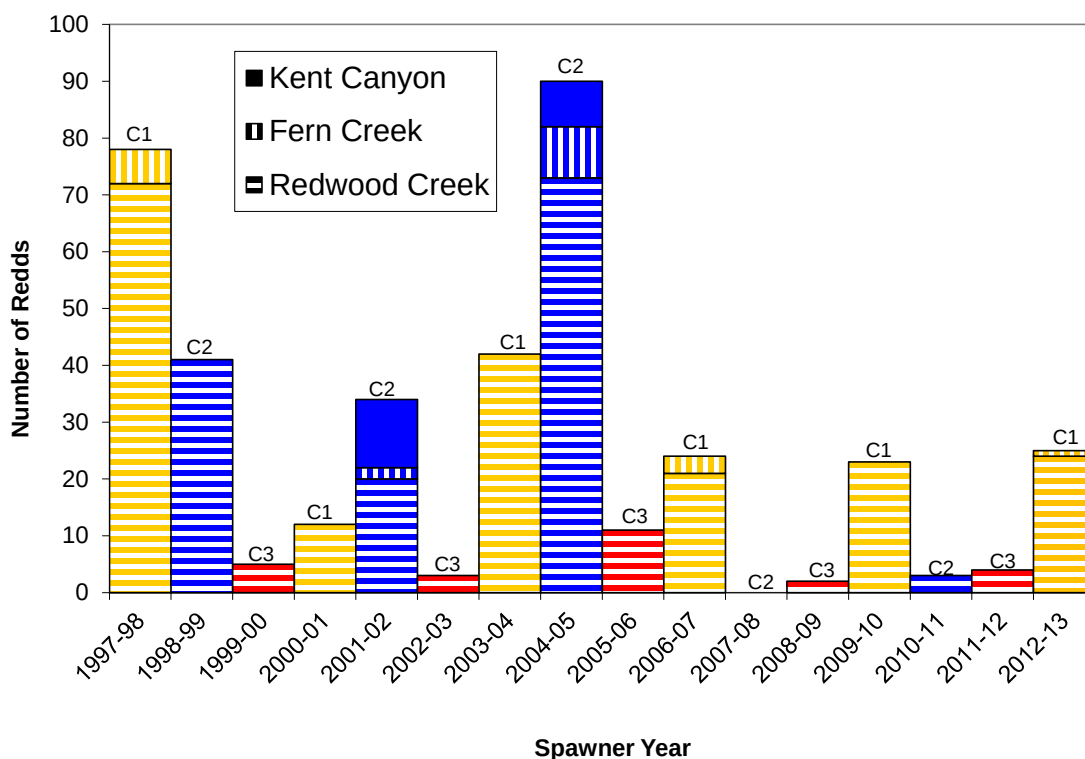


Figure 6. Coho salmon redd numbers in the Redwood Creek watershed by cohort winter 1997-1998 through winter 2012-2013. Cohorts are designated by color (cohort 1 shown in yellow, cohort 2 shown in blue, cohort 3 shown in red), and creeks are designated by pattern (Redwood Creek in horizontal lines, Fern Creek in vertical, and Kent Creek in a solid color).

Live Coho and Coho Carcass Biotics

Information on live coho and coho carcasses are collected during each field survey. Sex ratios for live coho and coho carcasses are reported for 2012-2013 in Tables 3 and 4.

Table 3. Sex ratio percentages and mean fork length (FL) of live coho within the Redwood Creek watershed for the period 1997-2012 compared to 2012-2013.

		Live Coho					
		Year	Sample Size	Sex Ratio%	n for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2012	360	31%	336	62	8.3
	F	1997-2012	481	41%	442	58	6.8
	J	1997-2012	108	9%	108	38	5.2
	Unk	1997-2012	214	18%	106	54	8.5
	All		1163	100%			
Current	M	2012-2013	14	25%	13	66	4.0
	F	2012-2013	24	43%	23	63	5.4
	J	2012-2013	4	7%	4	44	2.5
	Unk	2012-2013	14	25%	10	53	5.9
	All		56	100%			

M= Male, F= Female, J=Jack, Unk= Unknown, n= Number of fish measured for fork length (FL)

SD= Standard Deviation

Table 4. Sex ratio percentages and mean fork length (FL) of coho carcasses within the Redwood Creek watershed for the period 1997-2012 compared to 2012-2013.

		Carcasses					
		Year	Sample Size	Sex Ratio%	n for FL	Mean FL (cm)	FL SD (cm)
Cumulative	M	1997-2012	77	29%	68	64	8.3
	F	1997-2012	118	44%	112	62	5.9
	J	1997-2012	22	8%	22	40	3.1
	Unk	1997-2012	53	20%	19	59	10.7
	All		270	100%			
Current	M	2012-2013	2	12%	0		
	F	2012-2013	12	71%	6	61	3.4
	J	2012-2013	0	0%	0		
	Unk	2012-2013	3	18%	0		
	All		17	100%			

M= Male, F= Female, J=Jack, Unk= Unknown, n= Number of fish measured for fork length (FL)

SD= Standard Deviation

3.2.4 Pine Gulch Creek Coho and Steelhead Escapement

Survey Timing and Environmental Conditions

Two surveys were conducted in Pine Gulch from 3 January 2013 to 25 February 2013 (Table 4). The interval between surveys was 22 days. Seven-day rainfall totals during Julian weeks ranged from a low of 0.00 inches during Julian weeks 53 and 3, and a high of 0.49 inches during Julian week 4. Average water clarity at the time of surveys ranged from 90 cm to over 100 cm.

Live Salmonids and Salmonid Carcasses

No live coho were observed on Pine Gulch Creek during the 2012-2013 spawner season. However, five live steelhead were observed. The first fish was seen 3 January.

No carcasses were discovered on Pine Gulch Creek during any of the surveys.

Coho and Steelhead Redds

No coho redds were discovered on Pine Gulch Creek during the 2012-2013 spawner season.

Twenty steelhead redds were identified on reach 1 of Pine Gulch Creek. The average steelhead redd surface area was 2.87 m² and the density was 2.11 redds/km.

Pine Gulch Creek Watershed Coho Escapement History

The dataset for the adult escapement within Pine Gulch Creek includes 13 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 been sighted in the watershed during six out of the 13 years (Appendix A, Table A5).

3.3 Spring 2013 Outmigrant Coho Smolt Trapping Results

Results for smolt trapping are reported by Julian week (Appendix B) 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 instream flows and coho smolt captures. Trapping operations were initiated on Pine Gulch in 2002, Olema Creek in 2004, and Redwood Creek in 2005. Due to the lack of juvenile coho observed during the summer 2012 surveys, Pine Gulch Creek was not monitored for smolt outmigration in 2013. Therefore, only Olema Creek and Redwood Creek data appear below. Smolt production estimates are only calculated for coho due to differences in outmigration timing between coho and steelhead smolts. Anecdotal steelhead smolt, 1+ steelhead, steelhead fry, and coho fry are also summarized below.

3.3.1 Coho Smolt Outmigration Environmental Conditions and Timing

Spring weather patterns, including variations in rainfall and temperature, changes in stream flow and lunar phases may all influence the timing and rate of coho smolt outmigration. Smolt outmigration historically peaks during Julian weeks 17-19 (late April – early May). On average, the majority of Olema Creek outmigration occurs in weeks 16-18, with the majority of Redwood Creek outmigration occurring during weeks 18 and 19 (Figures 7 and 8, respectively). In 2013, both Olema Creek and Redwood Creek had outmigration peaks that occurred earlier than the historical average (seven weeks early on Olema Creek, one week early on Redwood Creek).

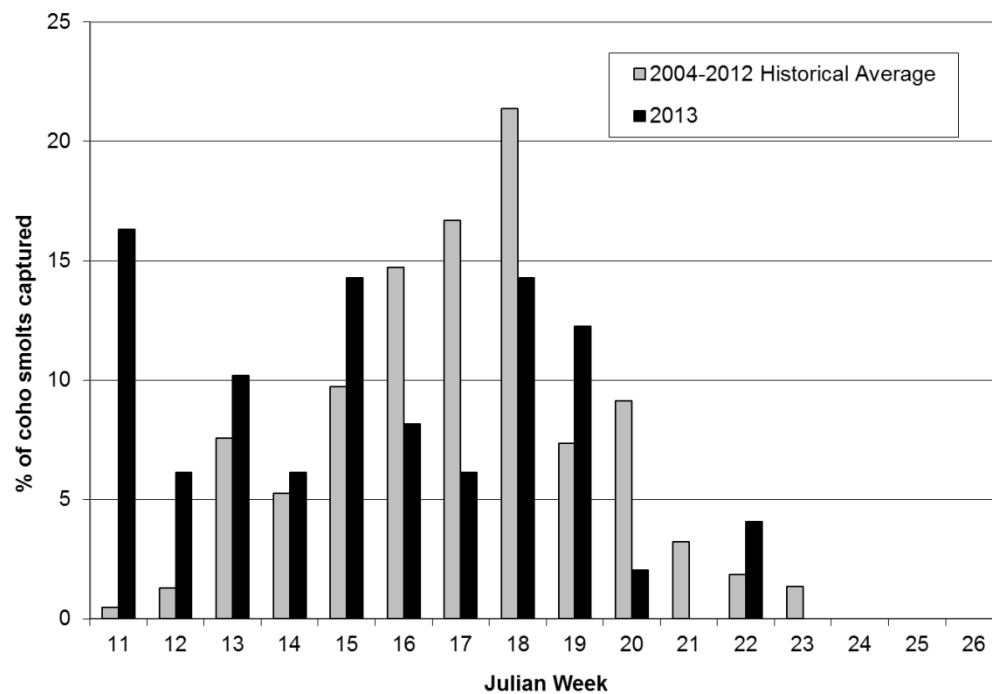


Figure 7. Percent of total coho smolts captured in the trap by Julian week for Olema Creek in 2013 compared to the historical average, 2004-2012.

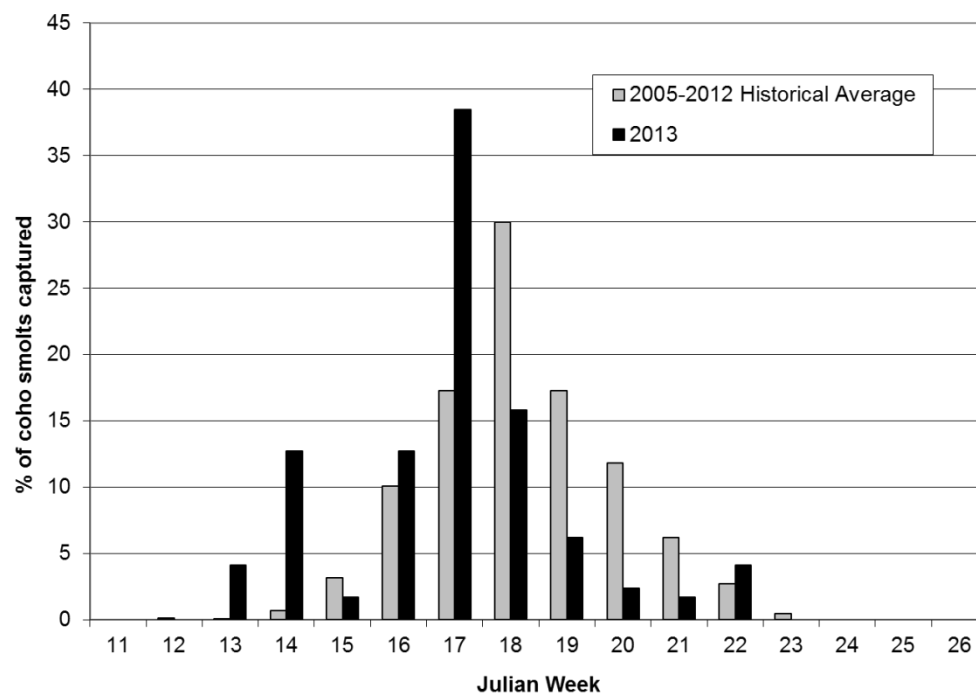


Figure 8. Percent of total coho smolts captured in the trap by Julian week for Redwood Creek in 2013 compared to the historical average 2005-2012.

Spring Coho Outmigration Rainfall

Rainfall amounts were collected from rain gages located at the Bear Valley Visitor Center for Olema Creek and at the Highway One bridge on Redwood Creek. Rainfall data is only available for Olema Creek through the middle of May, after which the gage malfunctioned. Rainfall was lower than the historical average for the entirety of the smolt trapping season.

Spring Coho Smolt Trap Water Temperature

Water temperatures were recorded using a Hobo style data logger. Due to battery issues, no temperatures were recorded for Olema Creek, and data loggers only operated through mid-April on Redwood Creek. Water temperatures within trap boxes on Redwood Creek were within the tolerable temperature range (less than 22°C) for coho salmon (Moyle 2002) during the period when temperature was monitored. The upper Redwood Creek trap had an average temperature of 11.4°C [1.21 (standard deviation (SD))], a maximum temperature of 14.1°C, and a minimum temperature of 8.4°C. The lower Redwood Creek trap had an average of 12.1°C (2.38 SD), a maximum temperature of 17.5°C, and a minimum temperature of 4.6°C.

3.3.2 Olema Creek Smolt Trapping Coho and Steelhead Results

During the 2013 outmigrant trapping study, the Olema Creek trap was in place for 78 days (13 March-31 May 2013) and was fully operational for 74 of those 78 days. The trap was partially operational for one day and not operational for three days.

The trap captured a total of 49 coho smolts. The overall recapture rate for marked coho smolts was 10% (3/30). Due to the low numbers of recaptured fish, no DARR estimate could be calculated for Olema Creek in 2013. An estimate was made using the Chapman modification of the Peterson estimate equation (Ricker 1975). The total Olema Creek coho smolt production estimate using the Chapman modification of the Peterson estimate is 99 [standard error (SE) 112]. Smolt production estimates are calculated for coho smolts only.

Additionally, the trap captured a total of 12 steelhead smolts, 80 steelhead parr, 214 steelhead fry, and 60 coho fry. Coho fry capture peaked early, during week 14, and was low through the rest of the season. Steelhead fry capture also peaked in late March, during Julian week 14. The mortality rate for coho fry was 7% (4/60) and the mortality rate for steelhead fry was 17% (36/214). The high mortality rate for coho and steelhead fry is expected since the trap is designed to let fry pass through the trap. Fry mortality often occurs during storm and wind events that cause the blockage of fry exit routes, subjecting them to high turbulence and potential predation. Six adult steelhead were captured during trapping operations on Olema Creek, and immediately released downstream of the trap.

A total of 30 coho smolts were implanted with passive integrated transponder (PIT) tags during the trapping season on Olema Creek. Recapture data (n=3) show that marked fish spent an average of 27 days above the trap before continuing their outward migration. The time spent upstream of the trap ranged from 1 to 54 days, with a median of 25 days. Tagged individuals had an average fork length of 120 mm with a median fork length of 119 mm and an average weight of 15.5 g with a median weight of 14.7 g. During juvenile surveys in the summer of 2012, 66 juvenile coho were implanted

with PIT tags none of which were recaptured. This is not unexpected given the relatively low number of tagged individuals.

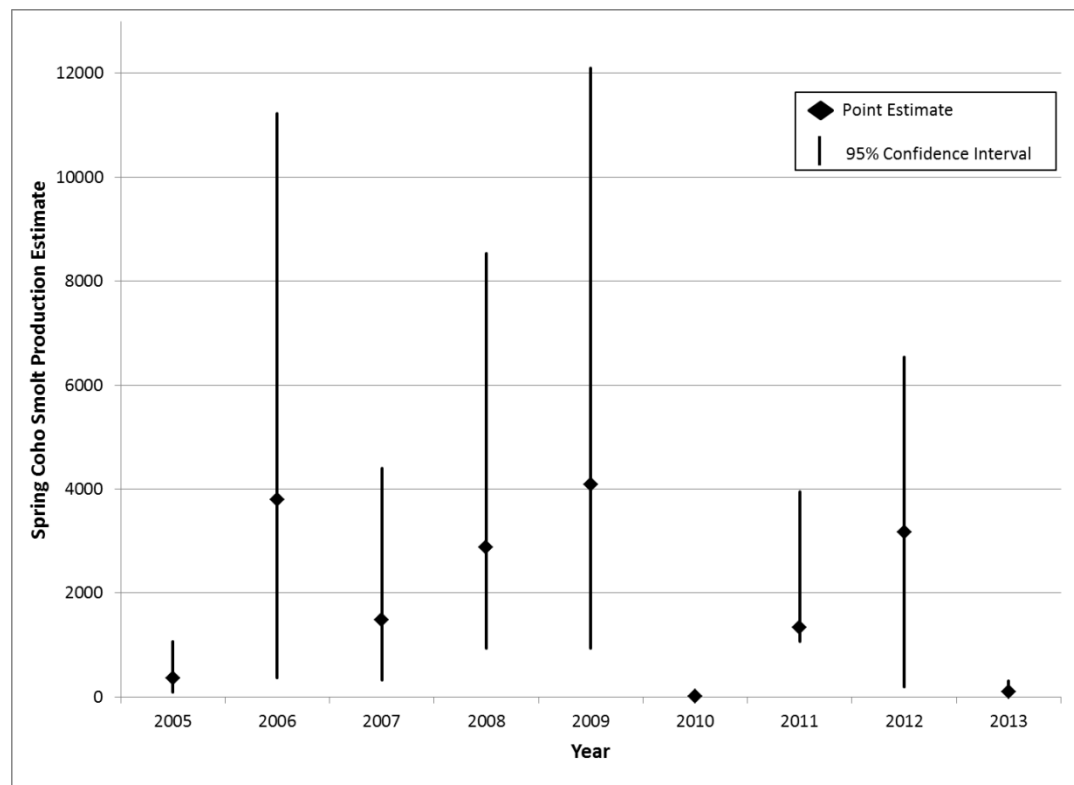


Figure 9. Coho smolt production estimates for Olema creek, spring 2005-2013. The 2005 and 2013 estimates were calculated using the Chapman modification of the Petersen estimate equation (Ricker 1975), not using the DARR program.

3.3.3 Redwood Creek Smolt Trapping Coho and Steelhead Results

The downstream trap in Redwood Creek was in place for 72 days (14 March-31 May 2013) and was fully operational for 66 days and partially operational for six days. The upstream trap was first operational on 20 March and removed on 31 May. It was fully operational for 68 days, partially operational for three days, and non-operational for one day. The data summaries and analysis reported for the 2013 smolt trapping season on Redwood Creek include fish captured in both mainstem traps.

The mainstem traps captured a total of 293 coho smolts. To avoid double-counting unmarked fish captured at the upper trap, all unmarked smolts were released below the downstream trap. The mortality rate for coho smolts was 0.5% (1/293). Only coho smolts were marked during the 2013 season. The overall recapture rate for marked coho smolts at both traps combined was 35% (49/140).

DARR analysis of the coho smolt data stratified by day estimated capture probability at approximately 73% for the first six weeks before falling to approximately 20% for the last four weeks of trapping operations. The total Redwood Creek coho smolt production estimate is 553 [SE 320]. Total peak capture for coho smolts on both Redwood Creek traps occurred in late April, during

Julian week 17. Figure 10 shows a summary of coho smolt production estimates on Redwood Creek smolt traps between 2005 and 2013. Smolt production estimates are calculated for coho only.

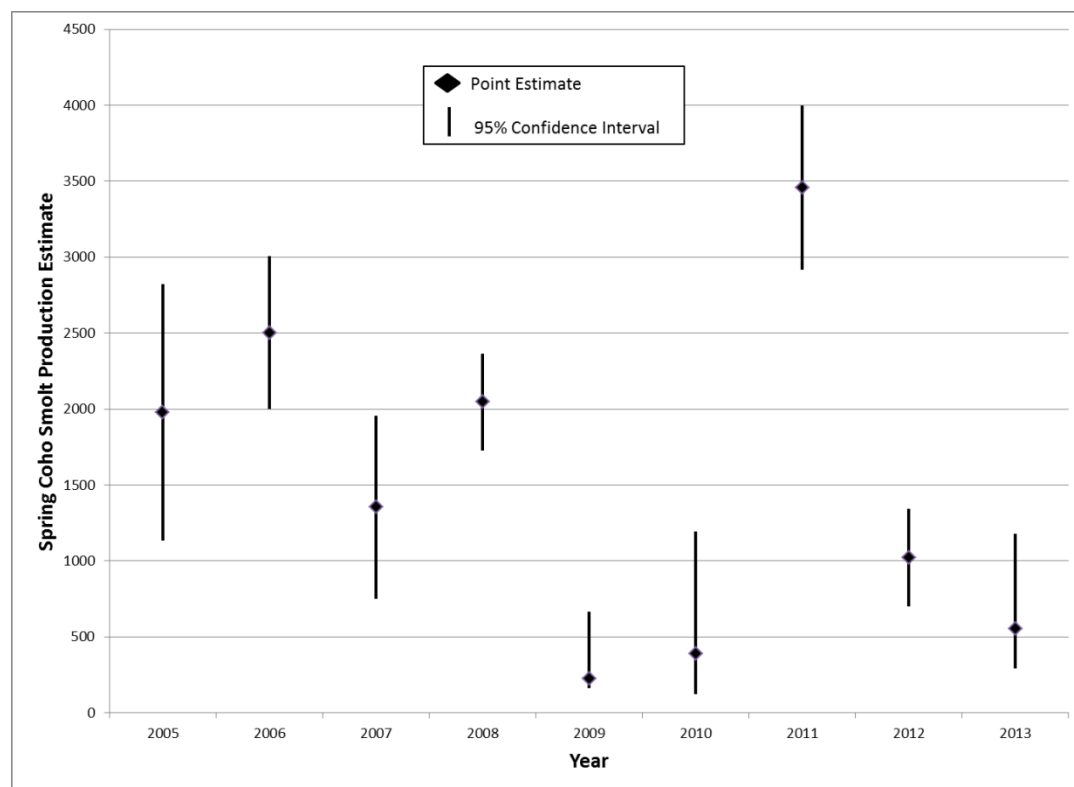


Figure 10. Coho smolt production estimates for Redwood Creek, spring 2005-2013. The 2009 estimate was calculated using the Chapman modification of the Petersen estimate equation (Ricker 1975), not using the DARR program.

A total of 16 steelhead smolts, and 55 steelhead parr, along with six coho fry and two steelhead fry, were captured on Redwood Creek in 2013. All of the fry were captured at the upstream trap. For steelhead parr and non-salmonids, all fish captured at both traps are counted because these fish are assumed to be residing in the vicinity of each trapping location and not migrating to the Pacific Ocean. There was no steelhead mortality and a mortality rate of 67% (4/6) for coho fry. Both coho and steelhead fry were captured at the upstream trap with peak capture occurring in early April, during Julian week 14. Of the 55 steelhead parr caught on Redwood Creek, 39 (60%) were caught in the downstream trap.

On the mainstem Redwood Creek traps, a total of 140 coho smolts were marked with PIT tags and 49 smolts were subsequently recaptured. Recapture data show that marked fish spent an average of 16 days in the system after being marked before continuing their outward migration. The time spent upstream of the trap ranged from 2 to 35 days, with a median of 12 days. Individuals tagged at the lower mainstem trap had an average fork length of 117 mm with a median fork length of 116 mm and an average weight of 14.2 g with a median weight of 13.8 g. Individuals tagged at the upper mainstem trap had an average and median fork length of 113 mm and an average weight of 13.8 g with a median weight of 13.1 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 2013 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 49 coho smolts were measured for fork length with 47 of the 49 coho also weighed. Coho fork lengths measured throughout the spring 2013 monitoring season on Olema Creek ranged from 100 mm to 140 mm, and the highest length frequency was in the 116 mm to 120 mm length interval, representing 27% of the coho smolts measured. The mean coho weight for the duration of the 2013 Olema trapping season was 15.8 g (SD 4.66 g) and the median coho weight was 15.3 g. Figures 11 and 12 show lengths and weights for coho smolts captured during smolt trapping from 2004 through 2013.

Steelhead fork lengths measured throughout the 2013 spring monitoring of Olema Creek ranged from 151 mm to 220 mm, and the highest frequency of steelhead smolt fork lengths were in the 171 mm to 175 mm length interval, representing 25% of the steelhead smolts measured. Figure 13 shows length information collected from steelhead smolts on Olema Creek.

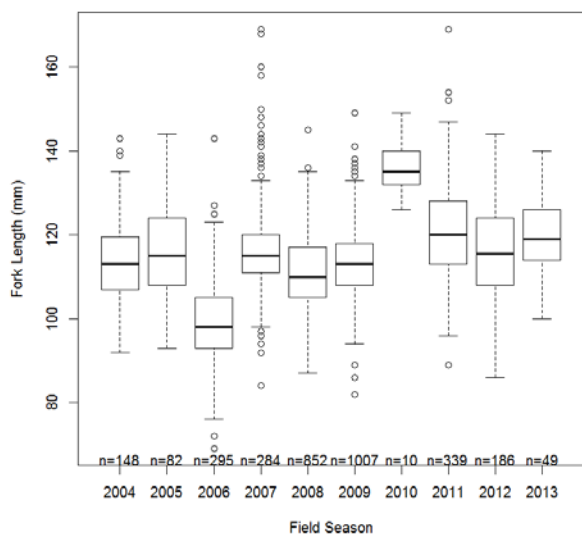


Figure 11. Box and whisker plots of coho salmon smolt fork lengths for Olema Creek, 2004-2013. Dark lines represent medians, circles represent outliers.

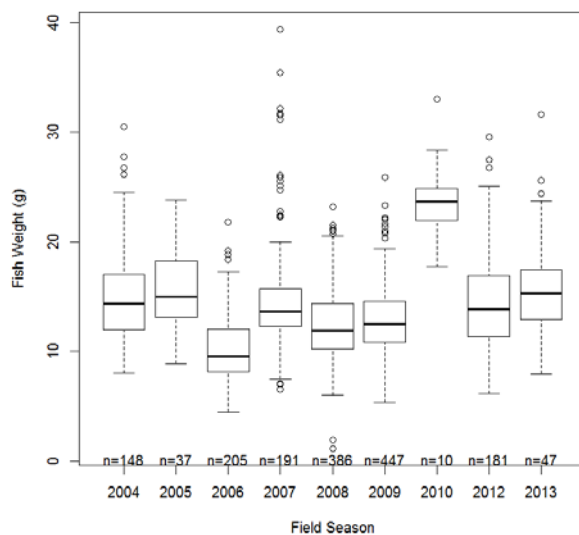


Figure 12. Box and whisker plots of coho salmon smolt fish weights for Olema Creek, 2004-2013. Dark lines represent medians, circles represent outliers.

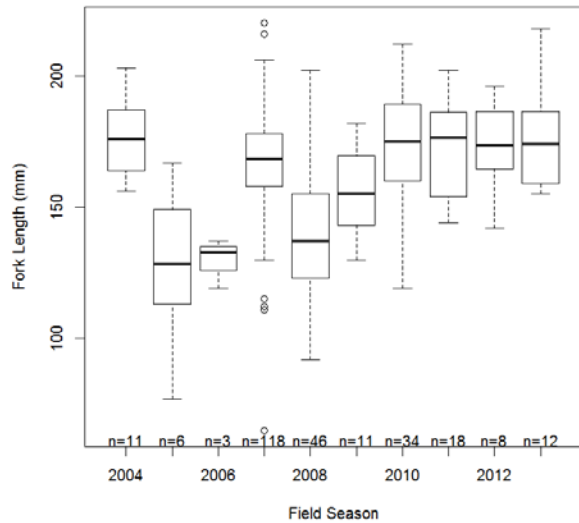


Figure 13. Box and whisker plots of steelhead trout smolt fork lengths for Olema Creek, 2004-2013. Dark lines represent medians, circles represent outliers.

Redwood Creek Coho and Steelhead Smolt Fork Length and Weight

A total of 268 coho smolts were measured for fork length (mm) with 247 of the 268 coho also weighed (0.01 g). Coho fork lengths measured throughout the 2013 spring monitoring of Redwood Creek ranged from 86 mm to 145 mm. The highest length frequency of coho smolts on Redwood Creek was in the 121 mm to 125 mm length interval, representing 18% of the coho smolts measured. The mean coho weight for the duration of the 2013 Redwood trapping season was 13.7 g (SD 3.54 g) and the median coho weight was 13.5 g. Figures 14 and 15 show lengths and weights for coho smolts captured on Redwood Creek.

Steelhead fork lengths on Redwood Creek ranged from 161 mm to 200 mm. The highest frequency of steelhead smolt fork lengths for Redwood Creek occurred in the 176 mm and 180 mm length interval, accounting for 25% total of the steelhead smolts measured. Figure 16 shows fork length information from steelhead smolts captured on Redwood Creek.

Figures 14-16 appear on the following page.

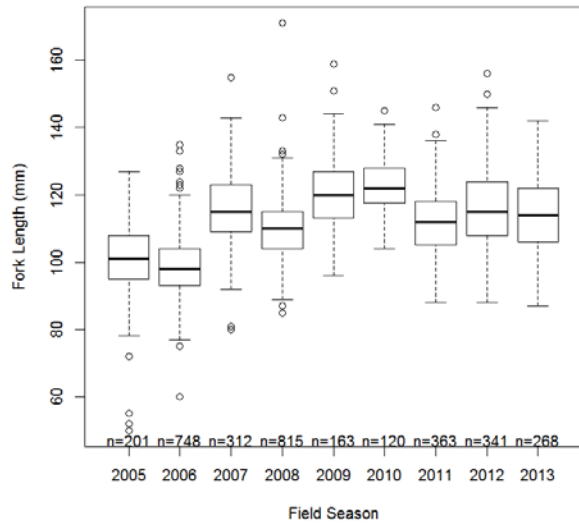


Figure 14. Box and whisker plots of coho salmon smolt fork lengths for Redwood Creek, 2005-2013. Dark lines represent medians, circles represent outliers.

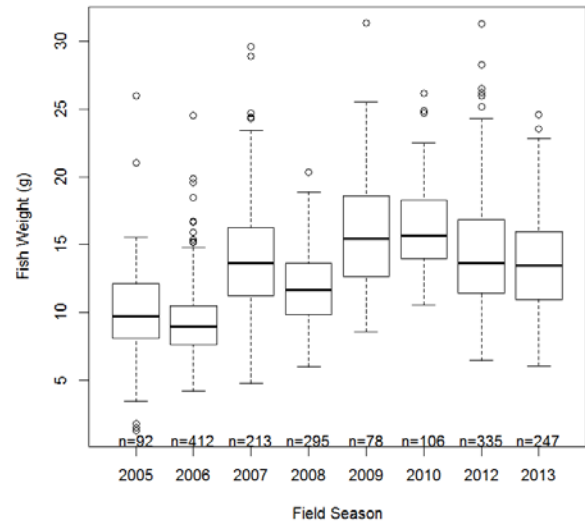


Figure 15. Box and whisker plots of coho salmon smolt weights for Redwood Creek, 2005-2013. Dark lines represent medians, circles represent outliers.

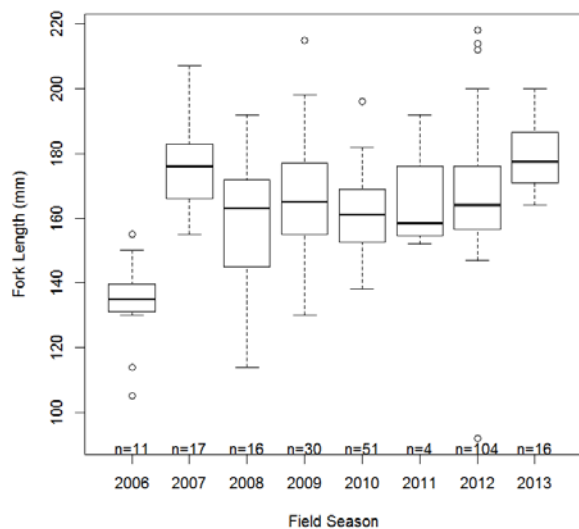


Figure 16. Box and whisker plots of steelhead trout smolt fork lengths for Redwood Creek, 2006-2013. No steelhead smolts were measured in 2005. Dark lines represent medians, circles represent outliers.

Coho and Steelhead Fulton's Condition Factor

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 and within the surrounding region. In order to compare length-weight relationships, we applied the Fulton's condition factor (K) to establish comparable indices of condition (Murphy and Willis 1996). Fulton's condition factor is a ratio relating fish length to fish weight, allowing for the measurement of the relative biomass of a fish.

Table 5 shows length, weight, and K-factor for coho smolts captured during 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 for salmonid smolts on Olema and Redwood Creeks is in Appendix A, Tables A6 through A9.

Table 5. Coho smolt mean and median fork length, weight, and K-factor calculated during 2013 for the trapping locations at Olema and Redwood Creeks.

Watershed	Sample Size	Mean Fork Length (mm)	Median Fork Length (mm)	Fork Length Standard Deviation	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Olema Creek	47	120	119	9.1	15.8	4.66	15.3	0.91	0.11
Redwood Creek	247	114	114	10.5	13.7	3.54	13.5	0.92	0.09

Table 6. Steelhead smolt mean and median fork length, weight, and K-factor calculated during 2013 for the trapping locations at Olema and Redwood Creeks.

Watershed	Sample Size	Mean Fork Length (mm)	Median Fork Length (mm)	Fork Length Standard Deviation	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Olema Creek	12	177	174	20.2	48.5	17.44	44.8	0.84	0.06
Redwood Creek	16	178	178	10.4	46.3	7.99	45.2	0.82	0.04

3.3.5 Smolt Trap Summary of Non-salmonid Total Catch

On Olema Creek, the majority of the non-salmonid catch was comprised of sculpin spp. (54%), threespine stickleback (29%), and California roach (16%). These three taxa have consistently been the best-represented non-salmonids caught in the Olema Creek smolt trap. The total number of non-salmonids trapped, 733, was 73% lower in 2013 compared to the historical average. A change in mesh size on the trap from one-eighth inch to one-quarter inch mesh starting in 2008 has allowed smaller non-salmonids the ability to escape the trap. As stickleback tend to be between 1.2 and 2.0 inches (30-50mm) long (Moyle 2002), the fish in the smaller size ranges have shallow enough bodies to slip through the one-quarter inch mesh and out of the trap.

On the two mainstem Redwood Creek traps, 536 rough-skinned newts (*Taricha granulosa*) were captured. Of the 3,315 non-salmonid fish captured on the mainstem Redwood Creek, 2,241 (68%) were threespine stickleback and the other 1,074 (32%) were sculpin spp. One non-native bullfrog

(*Rana catesbeina*) was caught on Olema Creek while no non-native species were captured on Redwood Creek. Historical non-salmonid catch information is in Appendix A, Tables A10 and A11.

3.4 Juvenile Coho and Steelhead Basinwide 2013 Results

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

3.4.1 Olema Creek

The 2013 summer habitat survey and basinwide snorkel surveys of Olema Creek were initiated at monument tag 15, at the current Olema Creek smolt trapping site. Accessible areas were surveyed through monument tag 150, adjacent to the Randall Ranch House. The measured basinwide survey length for the main channel was 13.5 km. Stream segments totaling approximately 1.0 km were not sampled as they were deemed inaccessible due to water quality concerns or dangerous stream conditions.

Habitat Survey

A total of 1,140 mainstem habitat units were identified in the 13,498 m within the Olema Creek survey reach. Pool units were the dominant habitat type available to fish, measuring a total of 7,630 m. Overall habitat composition by number of units was 34% pool, 28% riffle, 26% flatwater, and 12% dry (Table 7). Intermittent conditions were observed approximately 9.8 km upstream from the mouth of Olema Creek. Dry sections of streambed accounted for 9% of the total length surveyed. Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Flatwater and riffle habitat types made up 80% of the total side channel habitat composition. Overall, 813 m of side channel habitat and 218 m of backwater habitat units were measured during the basinwide habitat survey.

Total wetted survey length was 12,306 m and was used to calculate side channel density and backwater density, which were 6.6 m per 100 m and 1.8 m per 100 m, respectively. Compared to previous years side channel density increased (2004 to 2012 average of 5.5 m per 100 m for side channels) while backwater density decreased (2004 to 2012 average of 2.1 m per 100 m for backwaters).

Table 7. Habitat composition of Olema Creek coho survey reach for 2013. 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	7,630	57	394	34
Flatwater	2,448	18	294	26
Riffle	2,228	6	320	28
Dry	1,192	9	132	12
Total	13,498	100	970	100

Woody debris information collected during the basinwide habitat survey is summarized for 2005 to 2013 (Table 8) and may be used to identify trends in woody debris availability and recruitment trends over time. All of the categories were at or below historical densities, with the exception of 20 to 50 cm diameter logs.

Table 8. Summary of basinwide in-stream woody debris (WD) per 100 m on Olema Creek during base flow conditions. Average 2004-2012 compared to 2013.

Field Season	Survey Length (# 100 m sections)	Root Wads per 100 m	LWD Jams per 100 m	SWD Jams per 100 m	10-20cm WD per 100 m	20-50cm WD per 100 m	>50cm WD per 100 m
2004-2012 Average	115.7	1.4	0.6	0.7	2.6	2.2	0.8
2013	123.1	1.4	0.4	0.4	2.4	2.9	0.7

LWD Jams= 10 or more pieces of large woody debris

SWD Jams= 10 or more pieces of small woody debris

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 94% (74 of 79). In the 79 delineated pools, 2,634 coho were counted, producing a raw estimate of 33 coho per pool. Twelve of the 79 (15%) pools were electrofished within a day following the snorkel counts. One additional pool was re-snorkeled immediately following the initial pass using the method of bounded counts. *Microfish* and bounded count population estimates for the electrofished pools were used to calibrate the snorkel counts. Summer coho population estimates with 95% confidence intervals have been calculated for the coho survey reach since 2004 (Figure 17). The 2013 basinwide estimate for juvenile coho was 16,599, 95% CI [13,075; 20,123].

Figure 17 appears on the following page.

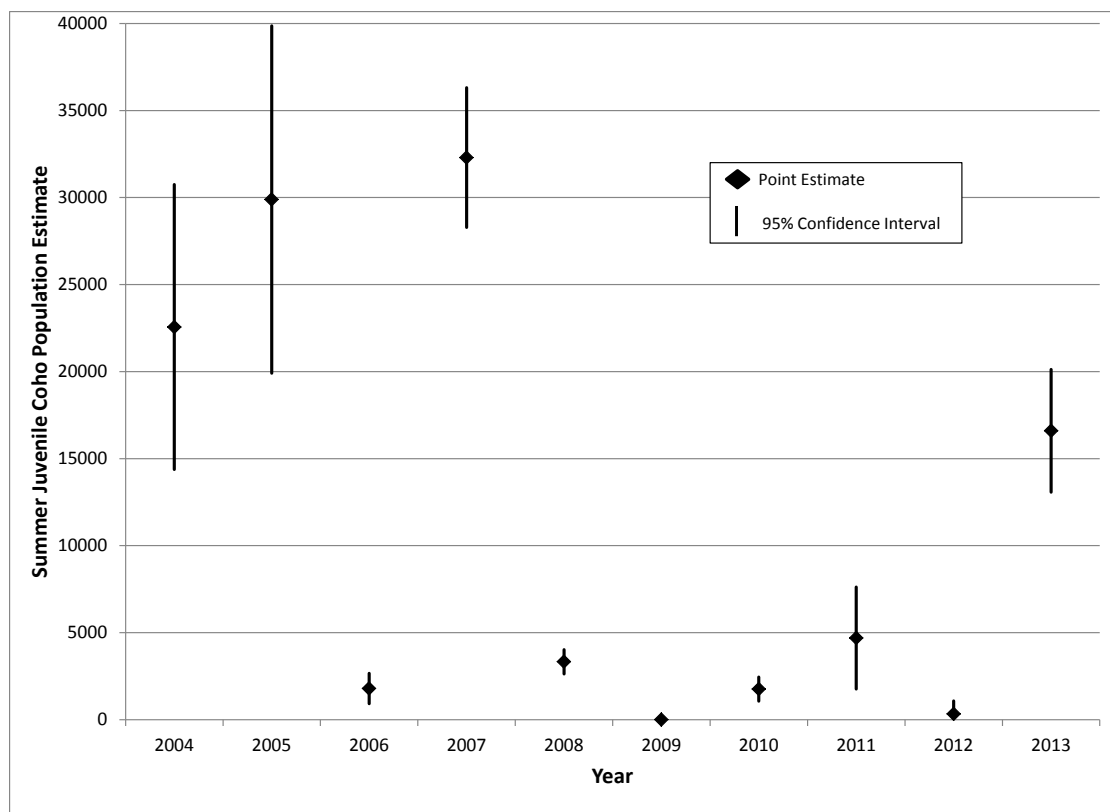


Figure 17. Summer juvenile coho basinwide population estimates for Olema Creek, 2004 through 2013.

Summer Coho and Steelhead Measurement Information

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit during the basinwide surveys. A total of 353 juvenile coho were measured for fork length (mm) with 349 of the 353 coho also weighed (0.01 g). Coho fork lengths measured throughout the summer 2013 monitoring efforts on Olema Creek ranged from 51 mm to 90 mm. The highest frequency of fork lengths for coho juveniles occurred within the 66 mm to 70 mm length interval, representing 30% of the subsample of coho measured in 2013. The Olema Creek mean coho weight was 3.3 g (SD 1.02 g) and the median coho weight was 3.1 g. Figure 18 shows representations of fork lengths and fish weights, respectively, for coho caught on Olema Creek for summers 2010 through 2013.

Within the Olema Creek sample, 98 steelhead were measured for fork length. Of those 98, 97 steelhead were also weighed. The size range for steelhead was 56 mm to 155 mm. Fork length frequencies were used to establish year class bins. The highest frequency of fork lengths for steelhead occurred within the 66 mm to 70 mm length interval representing 15% of the sample. Figure 19 shows steelhead length information collected on Olema Creek for summers 2009 through 2013.

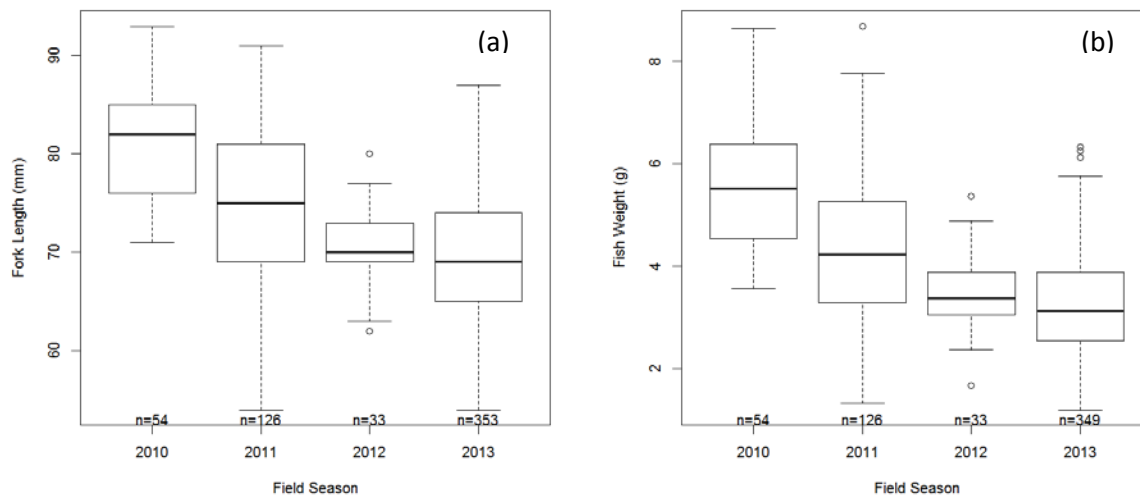


Figure 18. Box and whisker plots for juvenile coho lengths (a) and weights (b) for basinwide Olema Creek, summer 2010-2013. (no coho captured in 2009). Dark lines represent medians, circles represent outliers.

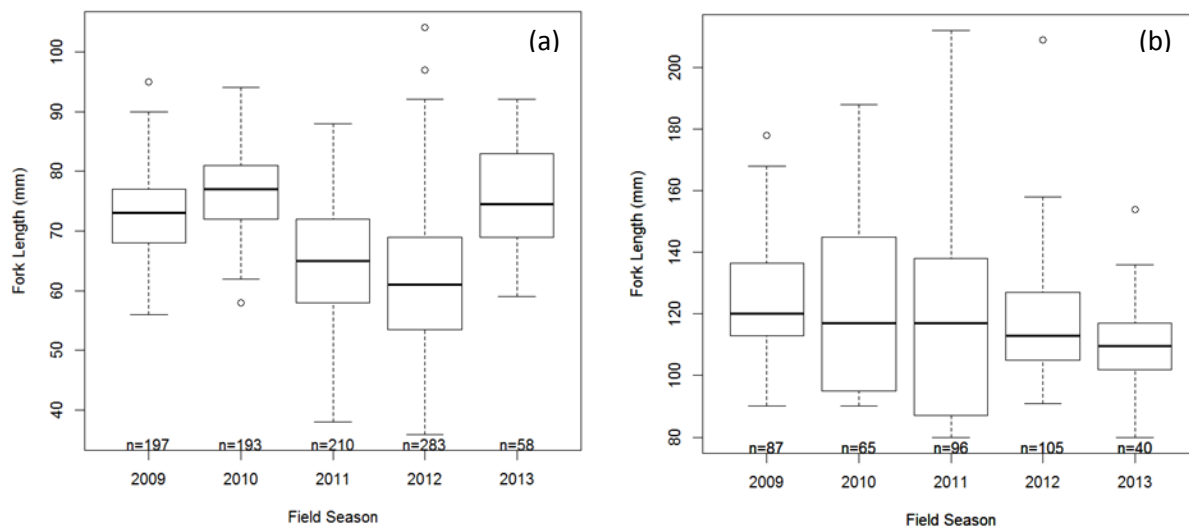


Figure 19. Box and whisker plots for young of year (a) and 1+ (b) steelhead lengths for basinwide Olema Creek, summer 2009-2013. Dark lines represent medians, circles represent outliers.

Coho and Steelhead Fulton's Condition Factor

Table 9 shows length, weight, and K-factor for coho captured during basinwide sampling on Olema Creek. Table 10 shows the length, weight, and K-factor for steelhead YOY and steelhead 1+ caught during 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 2013.

Species	Sample Size	Mean Fork Length (mm)	Fork Length Standard Deviation	Median Fork Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Coho	349	70	6.7	75	3.3	1.02	3.1	0.95	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 2013.

Species and Life Stage	Sample Size	Mean Fork Length (mm)	Fork Length Standard Deviation	Median Fork Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Steelhead YOY	57	76	7.6	74	4.4	1.31	4.2	1.00	0.07
Steelhead 1+	40	111	14.2	110	13.0	12.95	11.8	0.92	0.10

YOY= young of the year, 1+ = one year of age or older

3.4.2 Redwood Creek

The 2013 summer habitat and basinwide snorkel surveys of Redwood Creek were initiated at the downstream smolt trap site (just downstream of the Muir Beach pedestrian bridge) and continued upstream to monument tag 74, within the Mt. Tamalpais State Park. The measured basinwide survey length for the main channel was 8.7 km. An additional 0.8 km was surveyed on Fern Creek, a tributary to Redwood Creek.

Habitat Survey

A total of 713 mainstem habitat units were identified within the 8,679 m Redwood Creek survey reach. Pool units were the primary habitat type measuring a total of 4,720 m. Overall habitat composition by habitat unit was 39% pool, 39% riffle, and 22% flatwater (Table 11). Flatwater habitat types accounted for 52% of the side channel habitat composition. Overall, 402 m of side channel habitat and 249 m of backwater units were measured during the basinwide habitat survey. Total wetted length of the surveyed area was 8,676 m and was used to calculate the densities of side channel and backwater habitat, 4.6 m per 100 m and 2.9 m per 100 m, respectively. The density of side channel and backwater habitat on Redwood Creek in 2013 was higher than the historical average (2004 to 2012 side channel average was 3.8 m per 100 m, 2004 to 2012 backwater average was 1.3 m per 100 m).

Table 11 appears on the following page.

Table 11. Habitat composition of Redwood Creek coho survey reach, summer 2013. Measured length is used to calculate percentages of length per habitat type.

	Total Length (m)	% of Length	# of Units	% of Units
Pool	4,720	54	279	39
Flatwater	1,628	19	156	22
Riffle	2,328	27	276	39
Dry	3	0	2	0
Total	8,679	100	713	100

An additional 818 m were surveyed in Fern Creek, a tributary to Redwood Creek. Riffle units made up the majority (75%) of the length. Pools made up 12% of the length, while flatwaters made up 11%.

In addition to habitat, woody debris information collected during the basinwide habitat survey is summarized from 2005 through 2013 (Table 12) and may be used to identify trends in woody debris availability and recruitment trends over time. The only metrics that were not above historical densities were the densities for root wads and large woody debris jams.

Table 12. Summary of mainstem Redwood Creek basinwide in-stream woody debris (WD) per 100 m during summer base flow conditions. Average 2005-2012 compared to 2013.

Field Season	Survey Length (# 100 m sections)	Root Wads per 100 m	LWD Jams per 100 m	SWD Jams per 100 m	10-20cm WD per 100 m	20-50cm WD per 100 m	>50cm WD per 100 m
2005-2012 Average	79.4	1.1	0.5	0.8	3.0	2.5	1.2
2013	86.8	0.8	0.4	0.9	5.0	3.7	1.8

LWD Jams= 10 or more pieces of large woody debris

SWD Jams= 10 or more pieces of small woody debris

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 highest density was 2.8 per 100m for 10 to 20 cm woody debris. The lowest density was 0.9 per 100 m for root wads and small woody debris jams.

Coho Snorkel Counts and Basinwide Estimate

Snorkel surveys were conducted on 24% of the delineated pools with coho observed in 79% of the sampled pools. A total of 637 coho were counted in the 66 snorkeled pools, giving a raw average of 9.7 coho per pool. An additional two pools were snorkeled on Fern Creek. No coho juveniles were observed in any of the pools on Fern Creek. Thirteen of the 58 snorkeled pools (20%) were electrofished within a day following the snorkel counts. *Microfish* population estimates for the electrofished pools were used to calibrate the snorkel counts. On Fern Creek, one pool with a snorkel count of zero coho was subsequently electrofished for calibration resulting in no coho captured. Summer coho population estimates with 95% confidence intervals have been calculated for the coho

survey reach since 2005 (Figure 20). The 2013 basinwide estimate for juvenile coho was 3,159, 95% CI [2,287; 4,031].

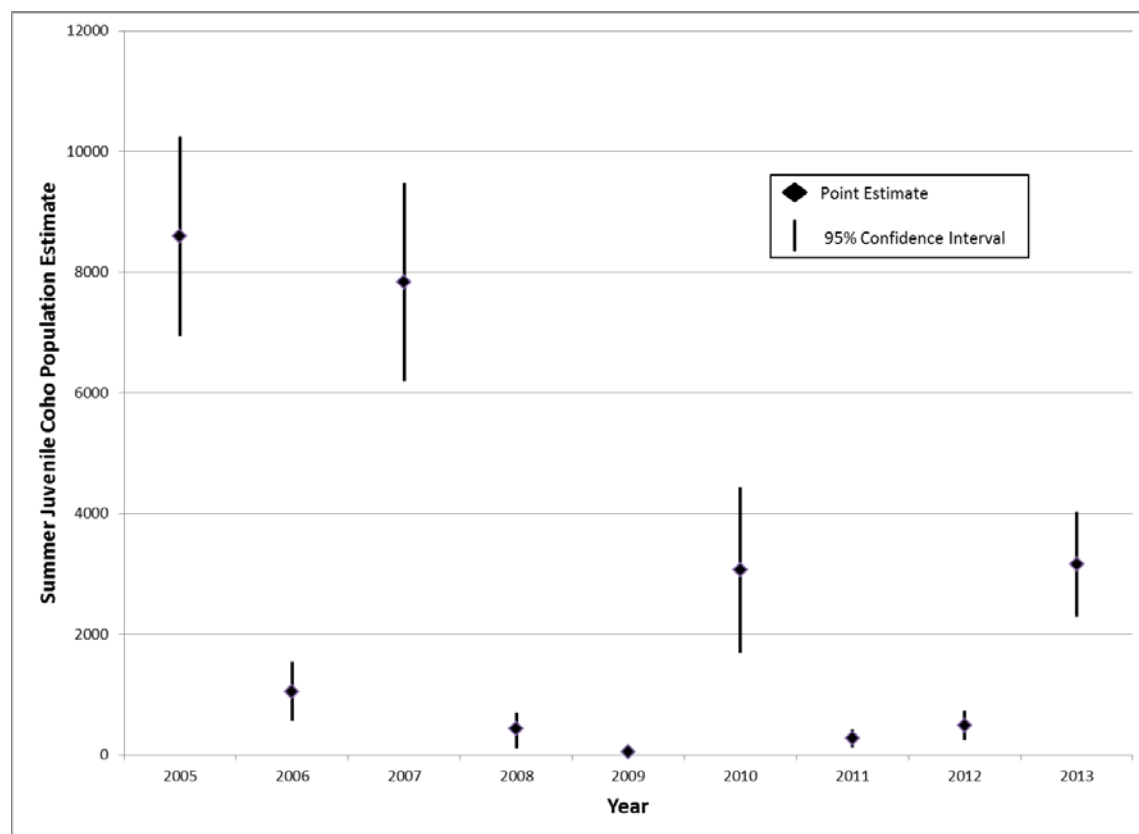


Figure 20. Summer juvenile coho basinwide population estimates for Redwood Creek, 2005-2013.

Summer Coho and Steelhead Measurement Information

A total of 128 juvenile coho were measured for fork length (mm) with 122 of the 128 coho also weighed (0.01 g). Coho fork lengths measured throughout the 2013 summer monitoring of Redwood Creek ranged from 51 mm to 90 mm. The highest length frequency for juveniles (28%) was observed in the 61 mm to 65 mm length interval. The Redwood Creek mean coho weight was 3.5 g (SD 1.37 g) and the median coho weight was 3.2 g. Coho juvenile length and weight information collected from Redwood Creek during basinwide sampling is represented in Figure 21. Within the Redwood Creek sample, 78 steelhead were measured for fork length with 75 of the 78 steelhead also weighed. The size range for steelhead was 46 mm to 245 mm. Fork length frequencies were used to determine year class bins. The highest frequency of fork lengths for steelhead occurred within the 61 mm to 65 mm length interval, representing 12% of the sample. Figure 22 shows representations of fish lengths for steelhead YOY and 1+ captured on Redwood Creek for summers 2009 through 2013.

Figures 21 and 22 appear on the following page.

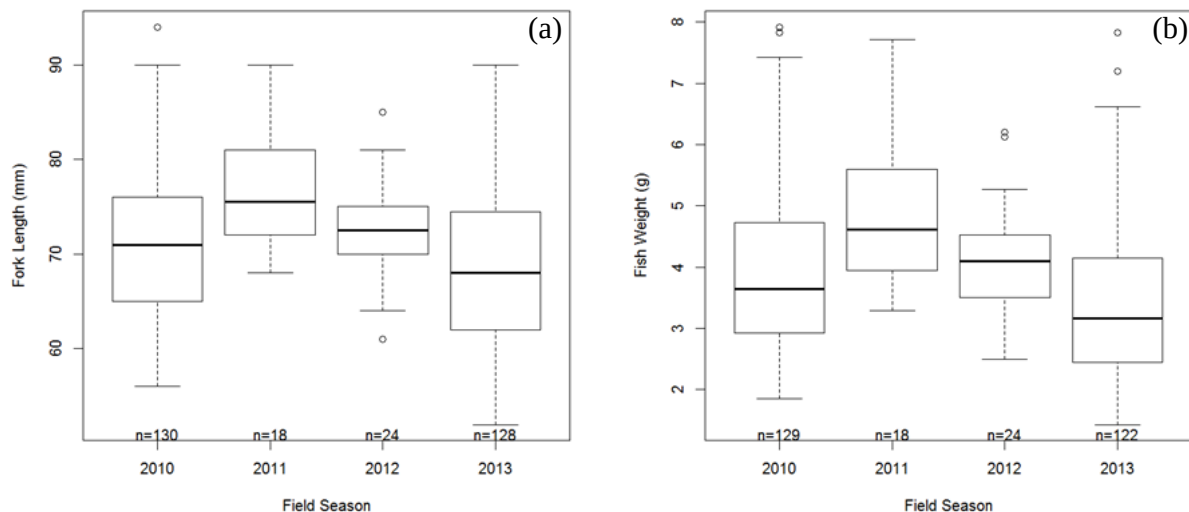


Figure 21. Box and whisker plots for juvenile coho lengths (a) and weights (b) for basinwide Redwood Creek, summer 2010-2013. (no coho captured in 2009). Dark lines represent medians, circles represent outliers.

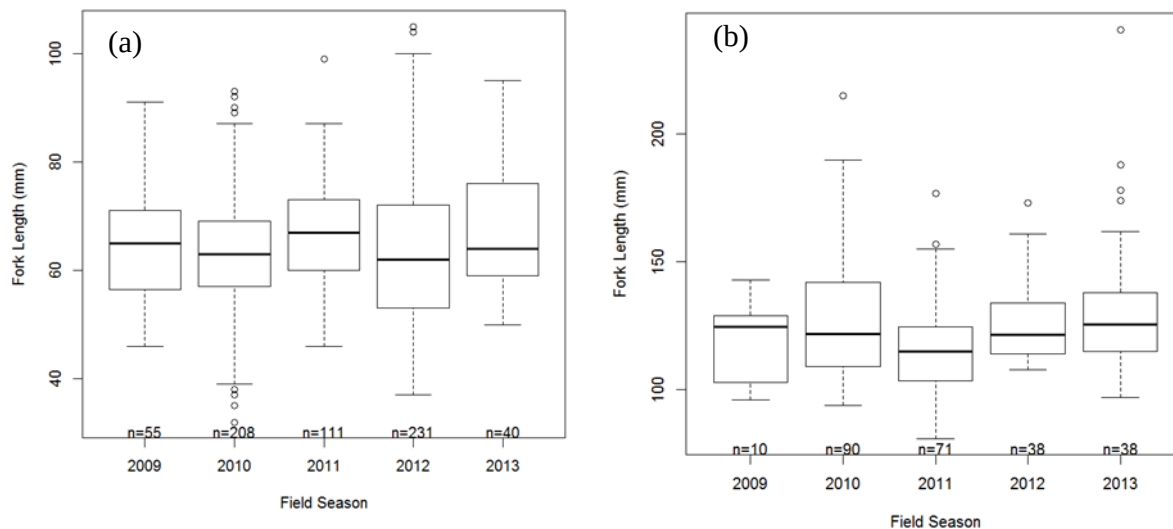


Figure 22. Box and whisker plots for young of year (a) and 1+ (b) steelhead lengths for basinwide Redwood Creek, summer 2009-2013. Dark lines represent medians, circles represent outliers.

Coho and Steelhead Fulton's Condition Factor

Table 13 shows length, weight, and K-factors for coho captured during basinwide sampling on Redwood Creek in summer 2013. 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 calibration pools on Redwood Creek mainstem, 2013.

Species	Sample Size	Mean Fork Length (mm)	Fork Length Standard Deviation	Median Fork Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Coho	122	69	8.9	68	3.5	1.37	3.2	1.01	0.08

Table 14. Mean and median fork length, weight and K-factor calculated for steelhead measured and weighed in the basinwide calibration pools on Redwood Creek mainstem, 2013.

Species and Life Stage	Sample Size	Mean Fork Length (mm)	Fork Length Standard Deviation	Median Fork Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Steelhead YOY	39	67	11.7	65	3.3	1.68	2.7	1.01	0.15
Steelhead 1+	36	127	21.9	125	21.2	12.18	18.4	0.96	0.06

YOY= young of the year, 1+ = one year of age or older

3.4.3 Pine Gulch Creek

The 2013 summer habitat and basinwide surveys of Pine Gulch Creek were initiated at monument tag 15 and continued upstream to monument tag 95, above the Teixeira Ranch within PORE. The measured basinwide habitat survey length for the main channel was 8.6 km.

Habitat Survey

A total of 658 mainstem habitat units were identified in the 8,600 m Pine Gulch Creek survey reach. Pool and riffle units comprised the majority of the habitat types measuring a total of 6,611 m. Overall habitat composition by habitat unit was 40% riffle, 37% pool, and 23% flatwater (Table 15). No dry units were observed on Pine Gulch Creek, so the total wetted survey length was equal to the total survey length of 8,600 m. Side channel and backwater units were also measured but not incorporated into the basinwide habitat calculations. Flatwater and riffle habitat types made up 93% of the total side channel habitat composition. Overall, 851 m of side channel habitat and 161 m of backwater habitat units were measured during the basinwide habitat survey, with a side channel density of 9.9 m per 100 m of wetted survey length and a backwater density of 1.9 m per 100 m. Both side channel density and backwater density were higher in 2013 than the historical averages (summers 2005 through 2012, average side channel density 8.1 m per 100 m and backwater density 1.5 m per 100 m).

Table 15 appears on the following page.

Table 15. Habitat composition of Pine Gulch Creek coho survey reach, 2013. Measured length is used to calculate percentages of length per habitat type.

	Total Length (m)	% of Length	# of Units	% of Units
Pool	3,457	40	244	37
Flatwater	1,989	23	151	23
Riffle	3,154	37	263	40
Dry	0	0	0	0
Total	8,600	100	658	100

Woody debris information collected during the basinwide habitat survey is summarized for summers 2005 through 2013 (Table 16) and may be used to identify trends in woody debris availability and recruitment over time. Complex woody debris (root wads, large woody debris jams, and small woody debris jams) decreased in density, while simple woody debris density (10-20 cm diameter logs, 20-50 cm diameter logs, and >50 cm diameter logs) was higher than the historical average.

Table 16. Summary of basinwide in-stream woody debris (WD) per 100 m during summer base flow conditions in Pine Gulch Creek. Average 2005-2012 compared to 2013.

Field Season	Survey Length (# 100 m sections)	Root Wads per 100 m	LWD Jams per 100 m	SWD Jams per 100 m	10-20cm WD per 100 m	20-50cm WD per 100 m	>50cm WD per 100 m
2005-2012 Average	97.4	1.0	0.5	0.9	3.2	2.9	1.3
2013	86.0	0.6	0.3	0.8	5.4	4.2	1.8

LWD Jams= 10 or more pieces of large woody debris

SWD Jams= 10 or more pieces of small woody debris

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 22% of the delineated pools. No coho were observed in any of the 54 snorkeled pools. Eight of the 54 snorkeled pools (15%) were electrofished within a day following the snorkel counts and no coho were caught. In addition to the eight electrofished pools, four pools (7%) were re-snorkeled immediately following the initial pass using the method of bounded counts. *Microfish* and bounded count population estimates for the electrofished pools were used to calibrate the snorkel counts. Summer coho population estimates with 95% confidence interval have been calculated for the coho survey reach since 2005 (Figure 23). The 2013 basinwide estimate for juvenile coho was zero as no juvenile coho were detected by survey crews.

Figure 23 appears on the following page.

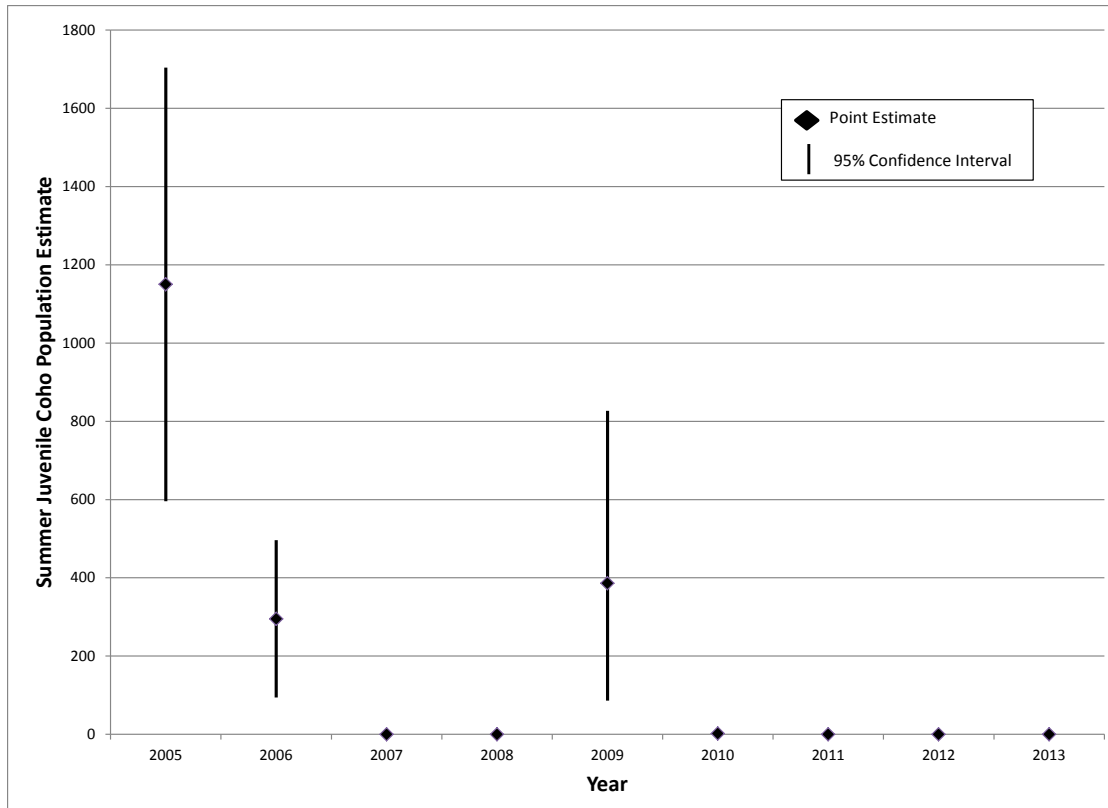


Figure 23. Summer juvenile coho basinwide population estimates for Pine Gulch Creek, 2005 through 2013.

Summer Steelhead Measurement Information

A total of 79 steelhead were measured for fork length during the summer surveys on Pine Gulch Creek. Of those 79, 70 steelhead (89% of the total basinwide steelhead catch) were also weighed. The size range for steelhead was 31 mm to 190 mm. Fork length frequencies were used to determine year class intervals. The highest frequency of fork lengths for steelhead occurred within the 41 mm to 45 mm length interval, representing 11% of the sample. Figure 24 shows steelhead YOY length information and Figure 25 shows steelhead 1+ length information collected from Pine Gulch Creek for summers 2009 through 2013.

Figures 24 and 25 appear on the following page.

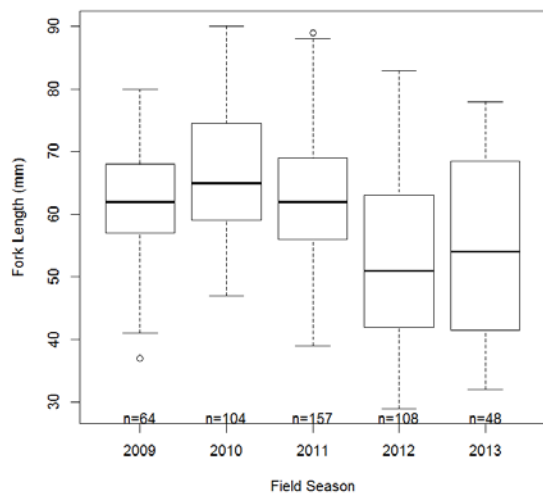


Figure 24. Box and whisker plots for steelhead young of the year fork lengths for basinwide Pine Gulch Creek, summer 2009-2013. Dark lines represent medians, circles represent outliers.

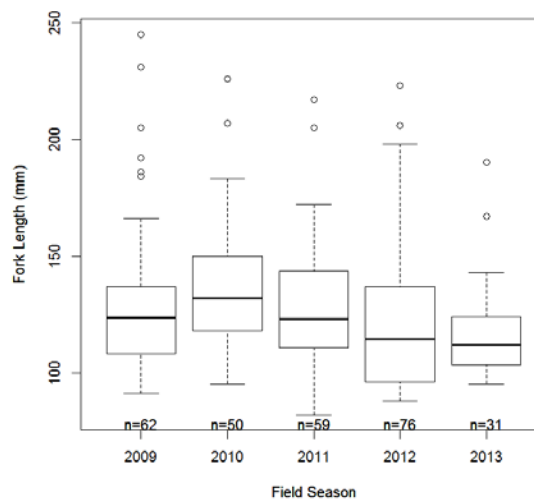


Figure 25. Box and whisker plots for steelhead aged 1+ fork lengths for basinwide Pine Gulch Creek, summer 2009-2013. Dark lines represent medians, circles represent outliers.

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 weighed and measured in the basinwide calibration pools on Pine Gulch mainstem, 2013.

Species and Life Stage	Sample Size	Mean Fork Length (mm)	Fork Length Standard Deviation	Median Fork Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
Steelhead YOY	39	59	13.2	59	2.3	1.47	2.0	0.97	0.07
Steelhead 1+	31	117	21.1	112	17.0	13.8	13.4	0.95	0.15

YOY= young of the year, 1+ = one year of age or older

3.5 Coho and Steelhead Index Reach Monitoring Results

Index reach juvenile monitoring results are provided for Olema Creek, Redwood Creek, and Pine Gulch Creek. As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Age classes for steelhead were determined using fork length frequencies.

3.5.1 Olema Creek

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

Index Reach Habitat and Total Salmonid Catch

The results presented in Table 18 are the 2013 total catch per index reach documented through electrofishing activities, which are used for additional density calculations in this report. Salmonid density results are calculated based upon the habitat information described in the next section and the total catch is determined using a multiple pass depletion method. In 2013, both coho and steelhead were found in all sampled indexes. 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 2013.

Year	Species	Index Reach								Total
		1	2	3	4	5	6	7	8	
2013	CO		20	91		82	120	147		460
	SH YOY	Not sampled	5	16	Not sampled	75	4	1	Not sampled	101
	SH 1+		9	18		27	10	4		68

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Index Reach Habitat Information

In 2013, the habitat surveys of the index reaches showed a majority of pool habitats followed by riffle and flatwater habitat types. Index reach habitat composition for 2013 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 habitat type. Fish numbers are calculated using the best available catch estimate, either total catch from electrofishing surveys or catch calculated by *Microfish*. Fish per m used in Figure 26 were calculated from all habitat units surveyed within each index reach in 2013, and can be viewed in Appendix A, Table A15. Coho numbers were highest in Index Reach 7, while steelhead YOY and 1+ numbers were highest in Index Reach 5.

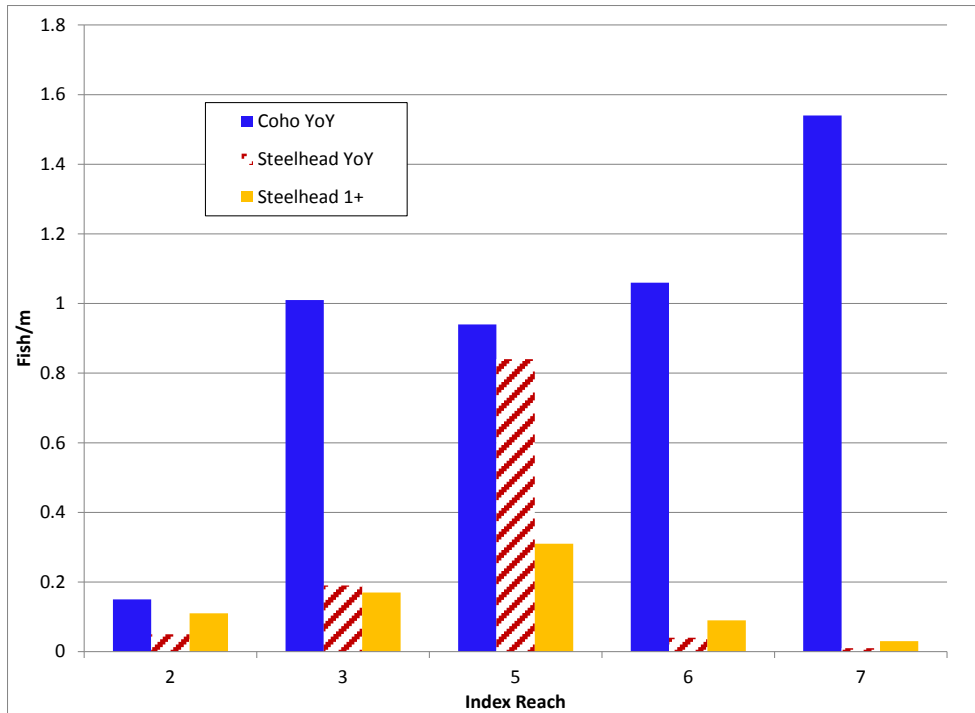


Figure 26. Coho and steelhead juvenile fish per meter according to index reach on Olema Creek, 2013.

Juvenile Coho and Steelhead Fork Length per Index Reach

A total of 318 coho were measured for fork length, with 314 of those fish also weighed. The size range for coho was 46 mm to 90 mm. The ages of the steelhead are based on fork length frequencies, with each sample year having different fork length size ranges. Within the Olema Creek sample, 132 steelhead were measured for fork length. The size range for steelhead young of year was 66 mm to 100 mm (n=83), while the size range for the steelhead 1+ was 101 mm to 180 mm (n=50).

3.5.2 Redwood Creek

In 2013, 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 2013. In 2013, both coho and steelhead were found in all sampled index reaches. For historical index reach catch from 2004 through 2013, refer to Appendix A, Table A16.

Table 19. Summary of total catch by each species within Redwood Creek mainstem index reach sample locations, summer 2013.

Year	Species	Index Reach							Total
		1	2	3	4	5	6	7	
2013	CO	38	86	26	21	25	5	Not Sampled	175
	SH YOY	3	6	13	2	2	0		26
	SH 1+	4	9	6	15	9	6		49

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Index Reach Habitat Information

In 2013, pools were the dominant habitat type identified within Index Reaches 2 through 6. In Index Reach 1, riffle units were the dominant habitat type. Index reach habitat composition for 2013 can be found in Appendix A, Table A17.

Salmonid Fish per Meter by Index Reach

Number of fish per meter were calculated using the best available catch estimate, either total catch from electrofishing surveys or catch estimate calculated by *Microfish*. Fish per m used in Figure 27 were calculated from all habitat units surveyed within each index reach and can be viewed in Appendix A, Table A18. Coho numbers were highest in Index Reach 2. Steelhead YOY numbers were highest in Index Reaches 2 and 3, while steelhead 1+ densities were highest in Index Reaches 4 and 6.

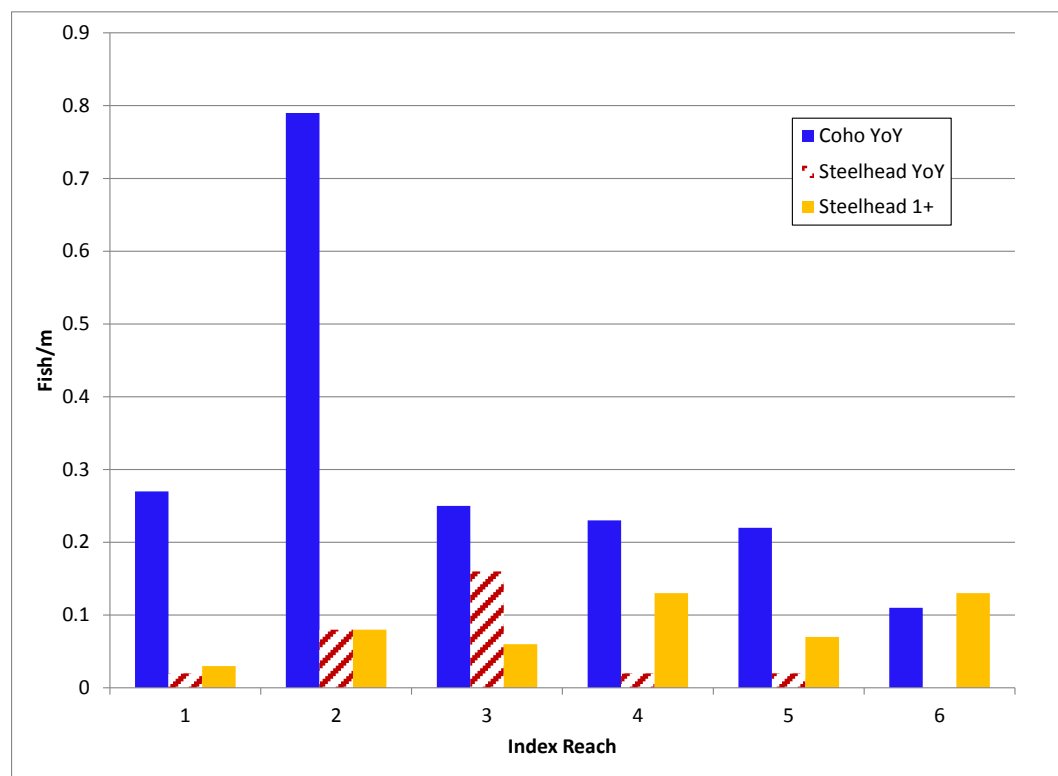


Figure 27. Coho and steelhead juvenile densities according to index reach on Redwood Creek, 2013.

Juvenile Coho and Steelhead Fork Length per Index Reach

Within the Redwood Creek sample, 187 coho salmon were measured for fork length, with 162 (87%) of the 187 fish also weighed. The size range for juvenile coho was 46 mm to 95 mm. A total of 61 steelhead trout (86% of the total index reach catch) were measured for fork length, with 51 of the 61 fish also weighed. The size range for steelhead YOY was 51 mm to 90 mm (n=25) while the size range for steelhead 1+ was 96 mm to 180 mm (n=46).

3.5.3 Pine Gulch Creek

In 2013, four of eight index reaches on the mainstem of Pine Gulch Creek were sampled. Index Reach 4 has not been sampled since 2000 because of no available road access. Index Reaches 1a and 1b were removed from the sampling regime due to their proximity to Index Reach 1c. Monitoring of Index Reach 1c has not been permitted by the landowner since 2011.

Index Reach Habitat and Total Salmonid Catch

The results presented in Table 20 are the 2013 total catch per index reach documented through electrofishing activities. 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 for each species by reach within Pine Gulch Creek mainstem index reach sample locations, summer 2013.

Year	Species	Index Reach								Total
		1a	1b	1c	2	3	4	5	6	
2013	CO				0	0		0	0	0
	SH YOY	Not sampled	Not Sampled	Not Sampled	26	41	Not sampled	14	12	93
	SH 1+				26	19		11	10	66

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Index Reach Habitat Information

During the 2013 summer monitoring season, pool units were the dominant habitat type within three of the four surveyed index reaches (reaches 2, 5, and 6) followed by riffle and flatwater habitat types. In Index Reach 3, the dominant habitat type was flatwater, followed by riffle and pool habitats. Index reach habitat composition for 2013 can be found in Appendix A, Table A20.

Salmonid Fish per Meter by Index Reach

Densities used for Figure 28 are calculated using the best available catch estimate, either total catch from electrofishing surveys or catch calculated by *Microfish*, and can be viewed in Appendix A, Table A21. The highest steelhead YOY numbers were observed in Index Reach 3, whereas steelhead 1+ numbers were highest in Index Reach 2.

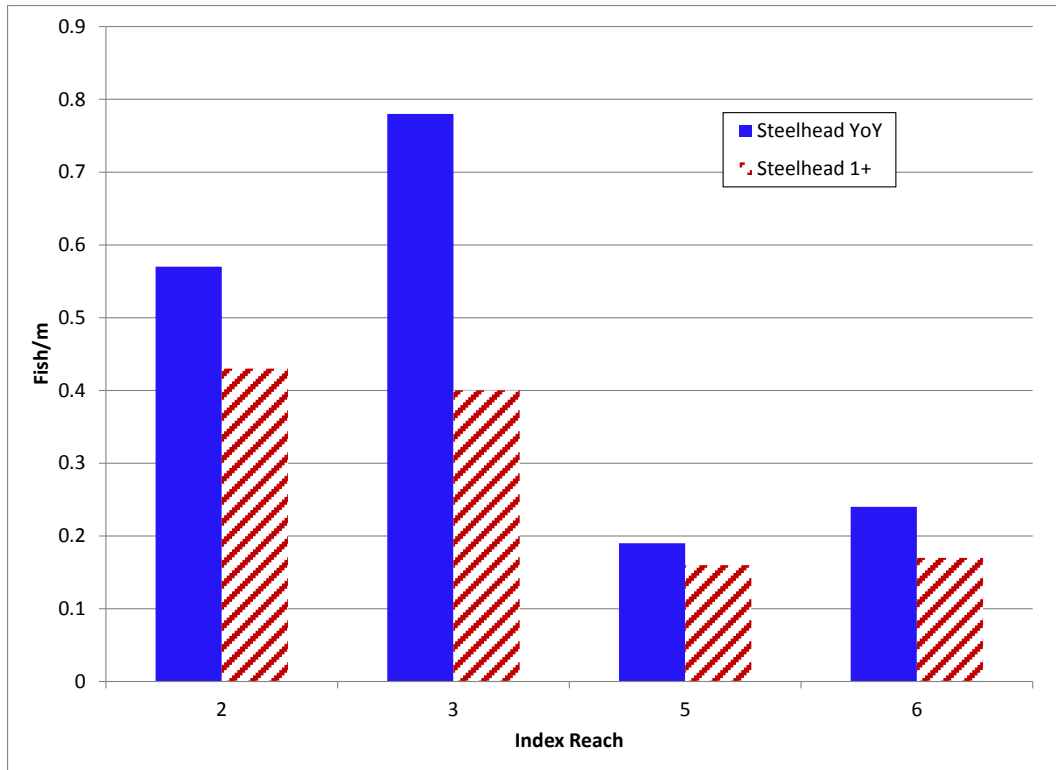


Figure 28. Steelhead juvenile densities according to index reach on Pine Gulch Creek, 2013.

Juvenile Steelhead Fork Length per Index Reach

A total of 151 steelhead trout were measured for fork length. The size range for steelhead YOY was <20 mm to 90 mm (n=87), while the size range for steelhead 1+ was 91 mm to 215 mm (n=64).

4 Discussion

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the CCCESU. In addition to our SFAN/CDFW funded monitoring efforts on Olema Creek, Redwood Creek, Pine Gulch Creek, and Cheda Creek, extensive monitoring is conducted by MMWD on Lagunitas Creek, Devil's Gulch, and the mainstem of San Geronimo Creek, and by SPAWN on tributaries of San Geronimo Creek. Through our SFAN monitoring efforts, we have documented significant information about coho salmon abundance, life history, distribution, and use of Olema Creek, Pine Gulch Creek, and Redwood Creek watersheds. The intensity of our life-cycle monitoring programs allow for larger scale characterization of patterns observed in the area. Though a relatively small geographic area, the coastal Marin County watersheds support a significant proportion of the CCCESU coho salmon.

The count of 31 coho salmon redds for 2012-2013 was a 120% increase compared to the 2009-2010 coho redd count (14 redds) for Olema Creek watershed. The Redwood Creek redd count was similar to what was observed during the winter of 2009-2010 (25 redds compared to 23 redds in 2009-2010). No adult coho were observed in Pine Gulch Creek.

The 2013 smolt production estimates on both Olema Creek and Redwood Creek watersheds showed increases from the spring of 2010, when the cohort was last observed in coastal watersheds of western Marin County. The Olema Creek coho smolt production estimate of 99 [SE 112] was within the expected range given the summer 2012 juvenile coho estimate of 330, 95% CI [65; 1,074]. The smolt estimate for Redwood Creek of 553 [SE 320] was higher than expected, based on the summer 2012 juvenile coho estimate of 484, 95% CI [235; 733]. Potential factors contributing to this higher estimate include but are not limited to: an increased rate of overwinter survival, under-detection of juveniles during the summer of 2012, and violations in marking assumptions used to determine smolt production estimates.

This summary also documents extensive information on length and weight of outmigrating coho salmon observed leaving the monitored watersheds. 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. In seven of the nine years of sampling, Redwood Creek has had smaller smolt outmigration sizes than Olema Creek. Comprehensive smolt trapping is in its tenth year of operation at Olema Creek and ninth year of operation at Redwood Creek. Coho smolts, migrating downstream on Olema Creek, were both longer and heavier when compared to the average from the previous nine years of monitoring. Both coho smolt length and weight were average at Redwood Creek when compared to the previous eight years of monitoring. Additional years of data will help refine our understanding of variation and the range in size of smolts leaving these coastal Marin County watersheds.

The juvenile basinwide counts performed during the summer of 2013 on Olema and Redwood creeks support the higher adult escapement observations during the 2012-2013 coho spawning season. On Olema Creek, a basinwide population estimate of 16,599, 95% CI [13,075; 20,123] was calculated.

The population estimate for Redwood Creek was 3,159, 95% CI [2,287; 4,031] coho juveniles. No coho juveniles were observed on Pine Gulch Creek.

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Appendix A. Historic Data Tables

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Table A1. 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.

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek ^a			Redwood Creek			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	14.7	9.1	72	7.4	6.9	N/A	N/A	N/A
1998-1999	92	10.7	8.6	46	7.0	6.6	32	3.2	10	23	12.8	1.8	41	7.4	5.5	N/A	N/A	N/A
1999-2000	139	10.7	13.0	58	7.0	8.3	3	3.2	0.9	10	8.3	1.2	5	7.4	0.7	N/A	N/A	N/A
2000-2001	119	12.8	9.3	56	7.0	8.0	11	3.2	3.4	80	13.5	5.9	12	7.4	1.6	0	9.5	0
2001-2002	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	59	13.5	4.4	20	7.4	2.7	2	9.5	0.2
2002-2003	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	20	12.9	1.6	3	7.4	0.4	1	9.5	0.1
2003-2004	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	109	14.0	7.8	42	7.4	5.7	0	9.5	0
2004-2005	120	12.8	9.4	140	7.0	19.7	112	3.7	30.6	138	14.0	9.9	73	7.4	9.9	3	9.5	0.3
2005-2006	53	12.8	4.1	48	7.0	6.9	33	3.7	8.9	9	14.0	0.6	11	7.4	1.5	1	9.5	0.1
2006-2007	128	12.8	10	117	7.0	16.7	55	3.7	14.9	95	14.0	5.8	21	7.4	2.8	0	9.5	0
2007-2008	87	12.8	6.8	46	7.0	6.6	6	3.7	1.6	33	17.5	1.9	1 ^b	7.4	0	2	9.5	0.2
2008-2009	25	12.8	2.0	1	7.0	0.1	0	3.7	0	0	17.5	0	2	7.4	0.3	0	9.5	0
2009-2010	42	12.8	3.3	7	7.0	1	0	3.7	0	14	17.5	0.8	23	7.4	3.1	0	9.5	0
2010-2011	32	12.8	2.5	40	7.0	5.7	0	3.7	0	21	17.5	1.2	3	7.4	0.4	0	9.5	0
2011-2012	94	12.8	7.3	19	7.0	0.4	4	3.7	0	7	17.5	0.4	4	7.4	0.5	1	9.5	0.1
2012-2013	108	12.8	8.4	59	7.0	8.4	2	3.7	0.5	32	17.5	1.8	25	7.4	3.4	0	9.5	0

^a Olema Creek includes redds from all surveyed tributaries to Olema Creek.

^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 2012-2013 on the Olema Creek watershed.

Spawner year	Run timing				Total monthly rainfall (in)				Olema Creek spawner summary			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey reach (km)	# surveys	Total carcass counts	Total redds
1997-1998 ^e					10.32	3.47	16.49	24.68	13.4	8	39	134
1998-1999					7.48	2.21	7.66	15.61	11.6	6	13	23
1999-2000					5.2	0.99	7.15	12.77	7.2	2	9	10
2000-2001					1.54	1.31	6.45	8.07	11.6	4	96	80
2001-2002					9.81	15.03	5.08	3.55	11.6	4	30	59
2002-2003					3.3	17.33	3.75	2.34	11.6	4	16	20
2003-2004					2.71	12.14	5.13	7.68	11.6	6	40	109
2004-2005					0.65	10.13	4.85	5.33	11.6	6	72	138
2005-2006					3.27	19.9	7.94	4.76	11.6	3	11	9
2006-2007					5.54	6.43	1.09	9.93	11.6	6	32	95
2007-2008					1.09	6.76	14.66	N/A	13.2	8	5	33
2008-2009					3.14	3.16	1.22	11.12	13.2	11	0	0
2009-2010					1.41	5.15	12.51	7.23	17.5	9	6	14
2010-2011					5.21	12.28	2.09	6.97	17.5	11	13	21
2011-2012					5.58	0.63	6.97	2.29	17.5	14	12	7
2012-2013					9.20	12.16	1.04	0.70	17.5	15	19	32

N/A = not available

Table A3. Coho salmon spawning survey including tally of total carcasses and total redds for all of the tributaries of the Olema Creek watershed excluding the John West Fork. These tributaries include Quarry Gulch and Giacomini Creek, Horse Camp Creek, Boundary Gulch, 1997-2013.

Year	Number of creeks 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	4	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

Table A4. Coho salmon spawning number of surveys, survey length, tally of total carcasses, and total redds for Cheda Creek.

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

^a First winter after fish passage project was completed

N/A - Survey Length Not Defined

Table A5. Coho salmon run timing, average daily discharge by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2012-2013 on the Redwood Creek watershed.

Spawner year	Run timing				Total monthly rainfall (in)				Redwood Creek spawner summary			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey reach (km)	# surveys	Total carcass counts	Total redds
1997-1998									9.4 ^a	7	24	78
1998-1999					3.28	1.49	5.27	8.47	9.4 ^a	11	10	41
1999-2000					2.72	0.59	5.95	0.00	8.4 ^b	6	1	5
2000-2001					0.00	0.00	4.39	6.07	9.4 ^a	5	11	12
2001-2002					0.00	0.00	0.83	3.56	9.4 ^a	5	50	34
2002-2003					2.18	13.04	1.23	1.83	9.4 ^a	5	3	3
2003-2004					2.62	3.45	7.21	6.38	9.4 ^a	5	25	42
2004-2005					0.8	7.59	3.66	3.09	9.4 ^a	7	63	90
2005-2006					2.19	12.57	0.00	3.48	9.4 ^a	5	5	11
2006-2007					2.58	4.27	0.63	3.63	9.4 ^a	9	6	24
2007-2008					1.79	7.84	16.23	2.23	9.4 ^a	8	0	1 ^c
2008-2009					N/A	3.62	1.03	8.92	8.4 ^b	10	2	2
2009-2010					1.15	4.01	9.33	3.96	9.4 ^a	8	10	23
2010-2011					2.62	10.27	1.90	5.90	9.4 ^a	13	1	3
2011-2012					2.31	0.52	4.45	1.75	9.4 ^a	14	8	4
2012-2013					5.56	8.98	0.99	0.59	9.4 ^a	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 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 A6. Coho salmon spawning survey including number of surveys, survey length, tally of total carcasses, and total redds for the Pine Gulch Creek mainstem.

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	9.5	0	0

Table A7. Mean and median length, weight, and K-factor calculated for coho smolts measured and weighed in the Olema Creek smolt trap 2004-2013.

Year	Life Stage	Sample Size	Mean Length (mm)	Length Standard Deviation	Median Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
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

Table A8. Mean and median length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Olema Creek smolt trap 2004-2013.

Year	Life Stage	Sample Size	Mean Length (mm)	Length Standard Deviation	Median Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
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

Table A9. Mean and median length, weight, and K-factor calculated for coho smolts measured and weighed in the Redwood Creek smolt trap, 2005-2013.

Year	Life Stage	Sample Size	Mean Length (mm)	Length Standard Deviation	Median Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
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

Table A10. Mean and median length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Redwood Creek smolt trap, 2006-2013 (no steelhead smolts caught in 2005).

Year	Life Stage	Sample Size	Mean Length (mm)	Length Standard Deviation	Median Length (mm)	Mean Weight (g)	Weight Standard Deviation	Median Weight (g)	Mean K-Factor	K-Factor Standard Deviation
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

Table A11. Summary of non-salmonid information for Olema Creek trap operations, 2004-2013.

Trap dates																			
Watershed	Year	From	To	CH	GSF	GSH	LAM	PL	RO	SCU	STK	SUC	BF	CRAY	RLF	RSN	WPT	MF	Totals
Olema Creek	2004	30-Mar	28-May	2	1	1	15	0	274	243	3,083	144	19	14	0	0	0	0	3,796
	2005	1-Apr	9-May	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	6	1	420	644	2,998	3	4	5	52	0	5	0	4,138
	2007	15-Mar	26-May	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	2	3	158	228	30	2	11	17	7	1	1	0	460
	2009	12-Mar	29-Mar	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	27	0	3,187	110	1,353	7	1	3	44	2	0	0	4,734
	2011	6-Apr	3-Jun	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	195	217	234	0	0	13	57	2	1	0	719
	2013	12-Mar	31-May	0	0	0	5	0	118	399	211	0	1	24	5	1	0	0	764
Total average				<1	<1	<1	23	1	978	287	1,093	37	28	11	24	1	1	<0	2,481

Species Code: CH = Chinook salmon (*O. tshawytscha*), GSF = green sunfish (*Lepomis cyanellus*, non-native), GSH = golden shiner (*Notemigonus crysoleucas*, 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 catesbeiana*, non-native), CRAY = signal crayfish (*Pacifastacus leniusculus*), RLF = California red-legged frog (*Rana draytonii*), RSN = rough-skinned newt (*Taricha granulosa*), 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, 2005-2013.

Trap dates											
Watershed	Year	From	To	SCU	STK	CRAY	RLF	RSN	CAN	Totals	
Redwood Creek	2005	27-Mar	31-May	24	5,343	0	0	0	11	5,378	
	2006	18-Apr	9-Jun	133	117	7	0	8	2	267	
	2007	18-Mar	26-May	93	57	44	0	48	2	244	
	2008	19-Mar	30-May	151	38	33	0	61	1	284	
	2009	11-Mar	29-May	220	74	9	0	49	0	352	
	2010	19-Mar	28-May	407	394	15	0	425	4	1,245	
	2011	1-Apr	3-Jun	912	103	9	1	1,218	197	2,440	
	2012	4-Apr	31-May	764	1,051	11	0	268	0	2,094	
	2013	14-Mar	31-May	1,074	2,241	16	2	536	0	3,869	
Total average				420	1,046	16	<1	290	24	1,797	

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, 2004-2013. Shows variation between years and distribution within watershed.

Year	Species	Index reach								Total
		1	2	3	4	5	6	7	8	
2004	CO		186	352		295	239	175	164	1,411
	SH YOY	Not	147	231	Not	182	44	20	39	663
	SH 1+	Sampled	6	10	Sampled	26	24	10	8	84
2005	CO		206	255		269	361	191	186	1,468
	SH YOY	Not	72	97	Not	180	67	38	44	498
	SH 1+	Sampled	10	5	Sampled	13	15	7	7	57
2006	CO		92	36	0	4	2	9	18	161
	SH YOY	Not	55	77	93	80	65	37	43	450
	SH 1+	Sampled	37	67	24	54	32	6	20	240
2007	CO		123	170	233	332	217	156	160	1,391
	SH YOY	Not	112	135	241	120	51	10	36	705
	SH 1+	Sampled	9	22	16	19	15	3	8	92
2008	CO		3	42	12	22	9	7	0	95
	SH YOY	Not	113	145	181	103	40	23	2	607
	SH 1+	Sampled	3	9	13	6	4	1	1	37
2009	CO		0	0		0	0	0		0
	SH YOY	Not	11	16	Not	48	21	25	Not	121
	SH 1+	Sampled	12	19	Sampled	6	6	5	Sampled	48
2010	CO		28	9		8	10	41		96
	SH YOY	Not	91	42	Not	69	61	61	Not	324
	SH 1+	Sampled	45	16	Sampled	4	11	11	Sampled	87
2011	CO		31	19		28	29	94		201
	SH YOY	Not	40	90	Not	101	75	30	Not	336
	SH 1+	Sampled	34	28	Sampled	27	13	9	Sampled	111
2012	CO		1	0		1	0	0		2
	SH YOY	Not	84	194	Not	39	27	39	Not	383
	SH 1+	sampled	12	15	sampled	5	9	15	sampled	56
2013	CO		20	91		82	120	147		460
	SH YOY	Not	5	16	Not	75	4	1	Not	101
	SH 1+	sampled	9	18	sampled	27	10	4	sampled	68

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Table A14. Summary of habitat composition; shows extent of area sampled and variation between reaches; Olema Creek, 2013.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	Sampled (m ²)	% of total
1			Not Sampled			
	Pool	2	45.2	71.63	186.83	84.66
2	Riffle	2	9.6	15.21	11.86	5.37
	Flatwater	1	8.3	13.15	22.00	9.97
	TOTAL	5	63.1		220.68	
	Pool	2	75.5	91.63	351.84	89.08
3	Riffle	1	6.9	8.37	43.13	10.92
	Flatwater	0	0.0	0.00	0.00	0.00
	TOTAL	3	82.4		394.96	
4			Not Sampled			
	Pool	2	51.2	60.88	187.70	63.90
5	Riffle	1	4.9	5.83	14.21	4.84
	Flatwater	1	28.0	33.29	91.84	31.26
	TOTAL	4	84.1		293.75	
	Pool	2	44.8	73.81	188.36	80.60
6	Riffle	2	10.7	17.63	28.43	12.16
	Flatwater	1	5.2	8.57	16.90	7.23
	TOTAL	5	60.7		233.69	
	Pool	3	46.7	73.20	155.78	72.92
7	Riffle	3	17.1	26.80	57.87	27.08
	Flatwater	0	0.0	0.00	0.00	0.00
	TOTAL	6	63.8		213.65	
8			Not Sampled			
	Pool	11	263.4	74.39	1,070.51	78.90
Total	Riffle	9	49.2	13.89	155.49	11.46
	Flatwater	3	41.5	11.72	130.74	9.64
	TOTAL	23	354.1		1,356.73	

Table A15. Summary of total salmonid catch and density estimates for each species by reach on Olema Creek; summer 2013 illustrates variation between reaches and provides a general idea of distribution within watershed.

Index reach	Species (age)	Total catch # of fish	Fish/m	Density Fish/m ²
1		Not Surveyed		
	CO	20	0.32	0.09
2	SH YOY	5	0.08	0.02
	SH (1+)	9	0.14	0.04
	CO	91	1.10	0.23
3	SH YOY	16	0.19	0.04
	SH (1+)	18	0.22	0.05
4		Not Surveyed		
	CO	82	0.94	0.28
5	SH YOY	75	0.84	0.26
	SH (1+)	27	0.32	0.09
	CO	120	1.98	0.51
6	SH YOY	4	0.07	0.02
	SH (1+)	10	0.16	0.04
	CO	147	2.30	0.69
7	SH YOY	1	0.02	<0.01
	SH (1+)	4	0.06	0.02
8		Not Surveyed		

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Table A16. Summary of total salmonid catch (not including Dr. Smith information) for each species by reach within Redwood Creek mainstem index reach sample locations, 2004-2013.

Year	Species	Index Reach							total
		1	2	3	4	5	6	7	
2004	CO		42	95	74	158	71		440
	SH YOY	Not sampled	6	22	19	24	4	Not sampled	75
	SH 1+		19	8	17	15	13		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		34
	SH YOY	84	79	103	120	101	79	Not sampled	566
	SH 1+	10	19	23	20	21	12		105
2009	CO	0	5	2	27	5	0	0	36
	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		224
	SH YOY	63	125	92	93	102	51	Not sampled	526
	SH 1+	14	45	38	26	29	33		185
2011	CO	0	14	6	2	2	0		24
	SH YOY	79	71	20	38	39	15	Not sampled	262
	SH 1+	13	55	24	33	29	25		179
2012	CO	13	11	16	8	1	2		51
	SH YOY	85	79	32	84	64	22	Not Sampled	366
	SH 1+	5	16	7	17	13	7		65
2013	CO	38	86	26	21	25	5		175
	SH YOY	3	6	13	2	2	0	Not Sampled	26
	SH 1+	4	9	6	15	9	6		49

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Table A17. Summary of habitat composition; shows extent of area sampled and variation between reaches; Redwood Creek 2013.

Index reach	Habitat type	# of units	Length sampled (m)	% of total	Surface area sampled (m ²)	% of total
1	Pool	2	32.2	28.88	105.62	28.12
	Riffle	6	58.6	52.56	198.97	52.98
	Flatwater	3	20.7	18.57	71.00	18.90
	TOTAL	11	111.5		375.58	
2	Pool	2	34.6	39.32	166.52	39.18
	Riffle	2	15.6	17.73	64.55	15.19
	Flatwater	3	37.8	42.95	193.95	45.63
	TOTAL	7	88.0		425.02	
3	Pool	3	45.4	61.27	188.48	70.46
	Riffle	3	17.2	23.21	37.25	13.92
	Flatwater	1	11.5	15.52	41.78	15.62
	TOTAL	7	74.1		267.51	
4	Pool	4	57.9	62.46	194.81	83.97
	Riffle	3	34.8	37.54	37.19	16.03
	Flatwater	0	0.0	0.00	0.00	0.00
	TOTAL	7	92.7		232.00	
5	Pool	4	76.1	74.03	339.26	74.38
	Riffle	1	21.2	20.62	102.82	22.54
	Flatwater	1	5.5	5.35	14.03	3.07
	TOTAL	6	102.8		456.11	
6	Pool	4	78.9	88.65	298.90	88.40
	Riffle	1	2.1	2.36	4.41	1.30
	Flatwater	1	8.0	8.99	34.80	10.29
	TOTAL	6	89.0		338.11	
7				Not Sampled		
Total	Pool	19	325.1	58.25	1,293.59	61.77
	Riffle	16	149.5	26.79	445.18	21.26
	Flatwater	9	83.5	14.96	355.55	16.98
	TOTAL	44	558.1		2,094.33	

Table A18. Summary of total salmonid catch and density estimates for each species by reach on Redwood Creek; summer 2013 illustrates variation between reaches and provides a general idea of distribution within watershed.

Index reach	Species (age)	Total catch	Density	
		# of fish	Fish/m	Fish/m ²
1	CO	38	0.34	0.10
	SH YOY	3	0.03	0.01
	SH (1+)	4	0.04	0.01
	CO	86	0.98	0.20
2	SH YOY	6	0.07	0.01
	SH (1+)	9	0.10	0.02
	CO	26	0.35	0.10
3	SH YOY	13	0.18	0.05
	SH (1+)	6	0.08	0.02
	CO	21	0.23	0.09
4	SH YOY	2	0.02	0.01
	SH (1+)	15	0.16	0.06
	CO	25	0.24	0.05
5	SH YOY	2	0.02	<0.01
	SH (1+)	9	0.09	0.02
	CO	5	0.06	0.01
6	SH YOY	0	0.00	0.00
	SH (1+)	6	0.07	0.02
7	Not Sampled			

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Table A19. Summary of total salmonid catch for each species by reach within Pine Gulch Creek mainstem index reach sample locations, 2005-2013.

Year	Species	Index Reach								total
		1a	1b	1c	2	3	4	5	6	
2005	CO	3	1	0	2	15	Not Sampled	16	8	45
	SH YOY	25	18	44	78	41		40	33	279
	SH 1+	8	5	33	18	17		24	7	112
2006	CO	0	0	0	0	0	Not Sampled	4	10	14
	SH YOY	9	22	17	17	45		39	20	169
	SH 1+	31	28	38	13	18		17	18	163
2007	CO	0	0	0	0	0	Not Sampled	0	0	0
	SH YOY	3	39	61	145	153		55	52	508
	SH 1+	2	21	29	23	13		23	14	125
2008	CO	Not Sampled	0	0	0	0	Not Sampled	0	0	0
	SH YOY		9	22	87	147		37	53	355
	SH 1+		4	15	12	16		15	10	72
2009	CO	Not Sampled	Not Sampled	0	0	0	Not Sampled	3	0	3
	SH YOY			3	3	26		6	8	46
	SH 1+			14	7	12		5	5	43
2010	CO	Not Sampled	Not Sampled	0	0	0	Not Sampled	0	0	0
	SH YOY			18	53	52		40	22	185
	SH 1+			19	24	14		16	6	79
2011	CO	Not Sampled	Not Sampled	Not Sampled	0	0	Not Sampled	0	0	0
	SH 1+				32	42		47	38	159
	SH YOY				20	18		16	7	61
2012	CO	Not sampled	Not Sampled	Not Sampled	0	0	Not sampled	0	0	0
	SH YOY				19	37		18	28	46
	SH 1+				25	24		16	23	43
2013	CO	Not sampled	Not Sampled	Not Sampled	0	0	Not sampled	0	0	0
	SH YOY				26	41		14	12	93
	SH 1+				26	19		11	10	66

CO= coho salmon

SH= steelhead trout

YOY= young of the year

1+ = one year of age or older

Table A20. Summary of habitat composition; shows extent of area sampled and variation between reaches; Pine Gulch Creek, 2013.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	Sampled (m ²)	% of total
1a			Not Sampled			
1b			Not Sampled			
1c			Not Sampled			
	Pool	3	48.3	95.08	169.09	96.44
	Riffle	1	2.5	4.92	6.25	3.56
2	Flatwater	0	0.0	0.00	0.00	0.00
	TOTAL	4	50.8		175.34	
	Pool	1	14.8	27.56	74.49	34.40
	Riffle	1	18.7	34.82	67.32	31.09
3	Flatwater	1	20.2	37.62	74.74	34.51
	TOTAL	3	53.7		216.55	
4			Not Sampled			
	Pool	3	37.3	66.25	89.94	70.82
	Riffle	2	5.6	9.95	10.70	8.42
5	Flatwater	1	13.4	23.80	26.35	20.75
	TOTAL	6	56.3		126.99	
	Pool	3	27.9	51.96	75.23	62.21
	Riffle	1	14.0	26.07	20.53	16.98
6	Flatwater	1	11.8	21.97	25.17	20.82
	TOTAL	5	53.7		120.93	
	Pool	10	128.3	59.81	408.75	63.89
	Riffle	5	40.8	19.02	104.80	16.38
Total	Flatwater	3	45.4	21.17	126.27	19.73
	TOTAL	18	214.5		639.81	

Table A21. Summary of total salmonid catch and density estimates for each species by reach on Pine Gulch Creek, summer 2013; illustrates variation between reaches and provides a general idea of distribution within watershed.

Index reach	Species (age)	Total catch # of fish	Density	
			Fish/m	Fish/m ²
1a		Not Sampled		
1b		Not Sampled		
1c		Not Sampled		
	CO	0	0.00	0.00
2	SH YOY	26	0.51	0.15
	SH (1+)	26	0.51	0.15
	CO	0	0.00	0.00
3	SH YOY	41	0.76	0.19
	SH (1+)	19	0.35	0.09
4		Not Sampled		
	CO	0	0.00	0.00
5	SH YOY	14	0.25	0.11
	SH (1+)	11	0.20	0.09
	CO	0	0.00	0.00
6	SH YOY	12	0.22	0.10
	SH (1+)	10	0.19	0.08

CO= coho salmon; SH= steelhead trout; YOY= young of the year; 1+ = one year of age or older

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	Julian week number	Inclusive dates
1	Jan 01 - Jan 07	27	Jul 02 - Jul 08
2	Jan 08 - Jan 14	28	Jul 09 - Jul15
3	Jan 15 - Jan 21	29	Jul 16 -Jul 22
4	Jan 22 - Jan 28	30	Jul 23 - Jul 29
5	Jan 29 - Feb 04	31	Jul 30 - Aug 05
6	Feb 05 - Feb 11	32	Aug 06 - Aug 12
7	Feb 12 - Feb 18	33	Aug 13 - Aug 19
8	Feb 19 - Feb 25	34	Aug 20 - Aug 26
9	Feb 26 - Mar 04	35	Aug 27 - Sep 02
10	Mar 05 - Mar 11	36	Sep 03 - Sep 09
11	Mar 12 - Mar 18	37	Sep 10 - Sep 16
12	Mar 19 -Mar 25	38	Sep 17 - Sep 23
13	Mar 26 - Apr 01	39	Sep 24 - Sep 30
14	Apr 02 - Apr 08	40	OCT 01 - Oct 07
15	Apr 09 - Apr 15	41	Oct 08 - Oct 14
16	Apr 16 - Apr 22	42	Oct 15 - Oct 21
17	Apr 23 - Apr 29	43	Oct 22 - Oct 28
18	Apr 30 - May 06	44	Oct 29 - Nov 04
19	May 07 - May 13	45	Nov 05 - Nov 13
20	May 14 - May 20	46	Nov 14 - Nov 18
21	May 21 - May 27	47	Nov 19 - Nov 25
22	May 28 - Jun 03	48	Nov 26 - Dec 02
23	Jun 04 - Jun 10	49	Dec 03 - Dec 09
24	Jun 11 - Jun 17	50	Dec 10 - Dec 16
25	Jun 18 - Jun 24	51	Dec 17 - Dec 23
26	Jun 25 - Jul 01	52	Dec 24 - Dec 31

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Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov