



Long-term Coho Salmon and Steelhead Trout Monitoring in Coastal Marin County

2008 Annual Monitoring Report

Natural Resource Technical Report NPS/SFAN/NRTR—2011/460



ON THE COVER

Top Left: Adult coho salmon on John West Fork - Olema Creek

Photograph by: Greg Brown

Top Right: Juvenile coho salmon on Olema Creek

Photo by: Sarah Carlisle

Bottom: Smolt coho salmon on Redwood Creek

Photograph by: Casey Del Real

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Abstract

The National Park Service (NPS) 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 some of the southernmost populations of coho salmon on the Pacific Coast. The NPS Inventory and Monitoring Program and California Department of Fish and Game have supported monitoring of multiple coho salmon life stages in coastal Marin 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) spawning salmonids create;
- *outmigrant smolt trapping*, where the number of smolts (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
- *summer basinwide juvenile coho surveys* 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 coho’s complex life history. 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 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 may be labeled 1, 2, and 3. Cohort 1 was the first to be monitored by NPS in 1997-1998 as one generation returned to spawn in the winter and the next hatched in spring, 1998. These fish were surveyed again when they left the creeks as smolts in 1999 and when they returned as adults in the winter of 2000-2001. Succeeding generations of cohort 1 hatched in 2001, 2004, and 2007. Cohort 2 fish are those that hatched in 1999, 2002, 2005, and 2008, and cohort 3 fish hatched in 2000, 2003, and 2006. This report presents a summary of monitoring results for the 2007-2008 season. The adults and juveniles monitored belong to different generations of cohort 2, while the year-old outmigrating smolts belong to cohort 1.

Adult coho escapement surveys for 2007-2008 revealed a sharp decline in the number of cohort 2 adults returning to spawn compared to the number of smolts from this cohort that left the streams in 2006. Based on estimates of both the summer juvenile population and the outmigrating smolt population, the adult coho escapement during the winter 2007-2008 should have been higher. The total redd production also declined by 77% in the Olema Creek watershed and 98% in the Redwood Creek watershed compared to redd production by the previous generation of this cohort. Of the last five seasons cohort 2 was monitored on Redwood Creek, 2007-2008 had the lowest coho spawning activity. No spawning activity was observed on Pine Gulch. The reduced escapement is probably due to poor ocean productivity when these fish entered the ocean as smolts in the spring of 2006 (McClatchie et al. 2008). Based on regional information (MacFarlane et al 2008) and ocean productivity indexes (Goericke et al. 2007, McClatchie et al. 2008), poor upwelling along the California coast during the summer of 2005 and 2006 has resulted in a decrease in ocean productivity within coho ocean rearing grounds.

This decrease in ocean productivity has caused a decline in coho returns along the entire CCCESU (MacFarlane et al 2008).

The summer 2008 juvenile population estimates for cohort 2 on both Olema Creek ($3,328 \pm 696$) and Redwood Creek (431 ± 271) were lower than average (84% lower on Olema Creek and 93% lower on Redwood Creek), probably as a result of the poor adult returns. No coho were detected during juvenile surveys on Pine Gulch Creek, marking the second missing cohort since the re-colonization of Pine Gulch was documented in 2001.

The smolt production estimate calculated from smolt trapping results on Olema Creek ($2,885 \pm 336$) is the second highest on record and represents a large increase in smolt production from the previous generation (2003-2004) of this cohort (cohort 1). Although the Redwood Creek smolt production estimate ($2,046 \pm 163$) was average, production increased by 4% from the previous generation. It remains to be seen if these higher numbers of smolts will result in a higher number of adult returns in two years. No smolt trapping was done on Pine Gulch Creek during the spring of 2008 due to the absence of juvenile coho there during the summer of 2007.

While 2008 egg-to-juvenile survival rates were average, juvenile-to-smolt survival rates were lower than average for both Olema (a 9% decrease) and Redwood (a 26% decrease) Creek coho. Smolt length was comparable to previous years for both Redwood and Olema Creeks, but Fulton conditions factors (condition scores based on length and weight) and weight were lower than the historical average suggesting limiting environmental conditions such as food and habitat availability in the creeks before the smolt outmigration.

1 Introduction

The mission of the National Park Service is “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of the National Park Service approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Through the Natural Resource Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring networks.

The San Francisco Bay Area Network (SFAN) includes Golden Gate National Recreation Area (GOGA), Muir Woods National Monument (MUWO), and Point Reyes National Seashore (PORE). The network has identified vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent has been to monitor a balanced and integrated “package” of vital signs that meets the needs of current park management, but will also be able to accommodate unanticipated environmental conditions in the future. Salmonids represent a particular high priority vital sign for SFAN because coho salmon are ecologically significant, have endangered status, and are of high interest to the public.

Ongoing monitoring of coho salmon by the National Park Service (NPS) within the Olema Creek, Pine Gulch Creek, and Redwood Creek watersheds in coastal Marin County is supported through the California Department of Fish and Game (CDFG) Contract P0730408 to the Point Reyes National Seashore Association. These monitoring efforts continue salmonid research initiated and conducted by the National Park Service since 1997. The primary focus of this monitoring grant is to document federally and state listed endangered coho salmon (*Oncorhynchus kisutch*) population distribution and trends within these watersheds. In addition, monitoring has been conducted to document information of federally threatened steelhead trout (*O. mykiss*) and other fish species within the monitored watersheds.

The SFAN Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010) documents methods used by the NPS 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 conducted during 2008, 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 Recovery Strategy for Coho Salmon (CDFG 2004) categorizes each of these HSAs as high priority restoration areas for coho salmon. The monitoring efforts conducted through this program contribute to our understanding of population dynamics and condition within the coastal Marin County Area (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 much 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 degrees Fahrenheit) 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 (spawn once) three year life cycle requiring an entire year of residence in the 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 Olema/Lagunitas Creek, Redwood Creek, and Pine Gulch Creek. Some of the factors believed to have contributed to the declines in anadromous fish runs within the parks include:

- 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 and poor ocean productivity.

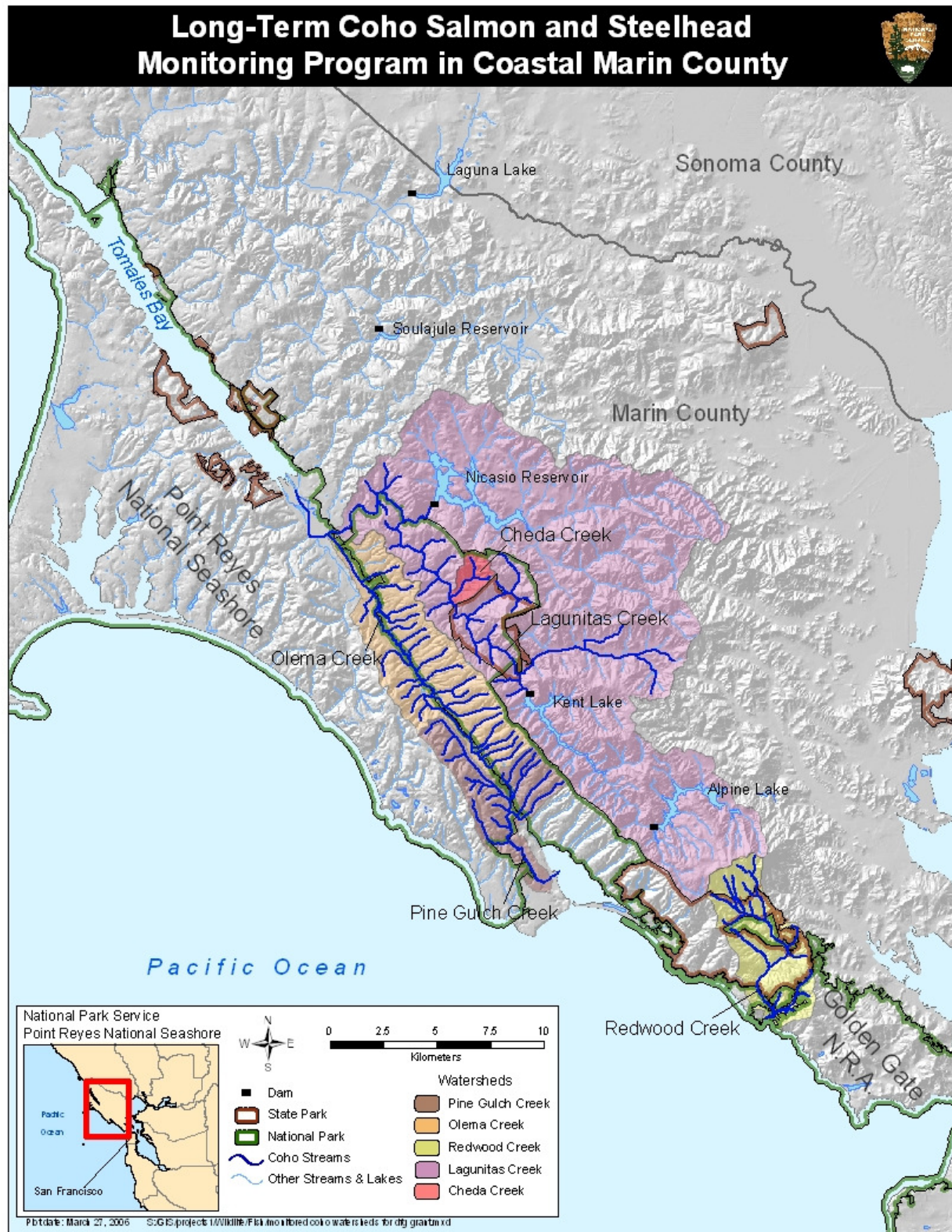


Figure 1. Streams supporting coho salmon in coastal Marin County.

1.2 Fish Resources

The primary species monitored through this program are coho salmon and steelhead trout. However, other aquatic species including sculpin, roach, lamprey, and stickleback are captured and documented through our monitoring efforts.

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from marine water back to freshwater for a single chance at reproduction. Natural populations of coho salmon are known to exist in the Lagunitas, Olema, Pine Gulch, and Redwood Creek watersheds (Brown and Ketcham 2002, Smith 2001). Coho salmon were listed as a threatened species within the central California coast coho salmon evolutionarily significant unit (CCCESU) in 1996 by 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 Fish and Game Commission added coho salmon populations between San Francisco and Punta Gorda to the list of species protected under the Endangered Species Act (areas south of San Francisco were already listed as endangered). This listing became effective in 2005.

Steelhead are the anadromous form of rainbow trout. Steelhead are iteroparous, meaning they can spawn more than once. Steelhead fry reside in near-shore areas, while juveniles tend to use riffles and pool margins. Steelhead 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 DPS 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. The artificially propagated stocks from the Don Clausen Fish Hatchery and the Kingfisher Flat Hatchery/Scott Creek are also included (Federal Register 2006).

1.3 Monitoring Rationale

Salmonid reproduction rates are high, matching the rates of mortality that occur throughout their life cycle. In freshwater systems, mortality rates for coho juveniles typically peak in early summer and stabilize by the fall. 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). In 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 et al 1998).

Our monitoring of multiple life stages will help characterize potential population bottlenecks in the watershed. Observation of adult escapement and redd density, juvenile density in the summer

months, and smolt outmigration allows us to track cohorts through documented bottlenecks and identify if and where watershed-specific limiting factors may exist.

1.3.1 Monitoring Questions

This monitoring program was developed to answer the following questions:

- 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 Point Reyes National Seashore Association (PORE) and Golden Gate National Recreation Area (GOGA)?
- What are the overall population trends of each coho salmon cohort within GOGA and PORE watersheds?

1.3.2 Monitoring Objectives

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 smolt coho salmon by conducting spring smolt trapping near mouths of Olema, Redwood, and Pine Gulch Creeks.
3. Determine long-term trends in distribution and 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 (pool:riffle) 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 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 14.5 square mile watershed is primarily contained within the boundaries of PORE and the GOGA north district. The watershed provides habitat to four federally protected aquatic species (California freshwater shrimp – endangered; coho salmon – endangered; steelhead – threatened; California red-legged frog – threatened). Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within PORE.

Lagunitas Creek and its tributaries (Nicasio Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek, Bear Valley Creek, and Olema Creek) drain more than 230 km² of western Marin County. The headwaters of the Lagunitas Creek mainstem lay within the 53,000 ha watershed lands administered by Marin Municipal Water District (MMWD). The mainstem originally totaled about 40 km of perennial stream draining the northern slope of Mt. Tamalpais, but was reduced by more than 50% by 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. Only one smaller tributary of Lagunitas Creek, Cheda Creek, lies entirely within GOGA lands.

Cheda Creek is a small perennial tributary of the Lagunitas Creek watershed and provides critical habitat for steelhead trout and coho salmon. Past land-use within the Cheda Creek drainage has resulted in serious alterations to the natural hydrologic and riparian condition 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 National Park Service (NPS) to restore the system to a more natural and sustainable condition.

Redwood Creek is a 7.5 square mile coastal watershed in southern Marin County, California. Redwood Creek flows southwest from the flanks of Mt. Tamalpais, through Muir Woods National Monument (MUWO), discharging to the Pacific Ocean through Big Lagoon at Muir Beach, CA. Protected from development, the watershed is primarily contained within the boundaries of Mt. Tamalpais State Park, GOGA and MUWO. The watershed provides habitat to coho salmon – endangered; steelhead – threatened; and the California red-legged frog – threatened. According to the NMFS Genetics Laboratory, the coho salmon found in Redwood Creek represent a genetic outlier within the CCCESU with extreme genetic distance from all

other samples collected within the CCCESU and the Southern Oregon-Northern California Coast ESU (Bjorkstedt et al. 2005).

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

2 Sampling Design and Methods

This program includes strategies to monitor salmonids at a variety of life stages. Detailed methods for winter adult spawner surveys, spring outmigrant smolt trapping, summer juvenile coho basinwide surveys, and index reach surveys are documented in the San Francisco Bay Area Network Salmonid Monitoring Protocol v4.0 (Reichmuth et al. 2010). These methods have been used by the NPS for salmonid monitoring within coastal Marin County since 1997. Many of the methods associated with the project are consistent with draft California Department of Fish and Game biotic monitoring guidelines (Collins 2003). Maps of the Olema, Redwood, and Pine Gulch Creeks are shown in Figures 2-4.

2.1 Adult Salmon Escapement Surveys

Annually, spawner surveys are conducted in watersheds within and adjacent to SFAN Park units, including PORE, GOGA, and MUWO. These surveys concentrate primarily on federally endangered coho salmon (*Oncorhynchus kisutch*) and federally threatened steelhead (*O. mykiss*) 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. Standard Operating Protocols (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 Rationale for sampling design

The methodologies currently used for spawner surveys have been used to estimate escapement for a variety of salmonids throughout the Pacific Northwest (Johnston et al. 1987, Irvine et al. 1992, Anderson and McGuire 1994, Downie and Peterson [undated]). Although both steelhead and coho are present in PORE and GOGA watersheds, the surveys focus on coho because their life history pattern and behavior is more amenable to accurate data collection. Coho spawner survey data tends to be more accurate than steelhead information because: coho spawn earlier than steelhead (typically in December or January), coho remain in the watershed until they die after spawning, which makes carcasses readily collectible, and steelhead spawn over a longer period of time than coho (from January to May) making frequent data collection more difficult.

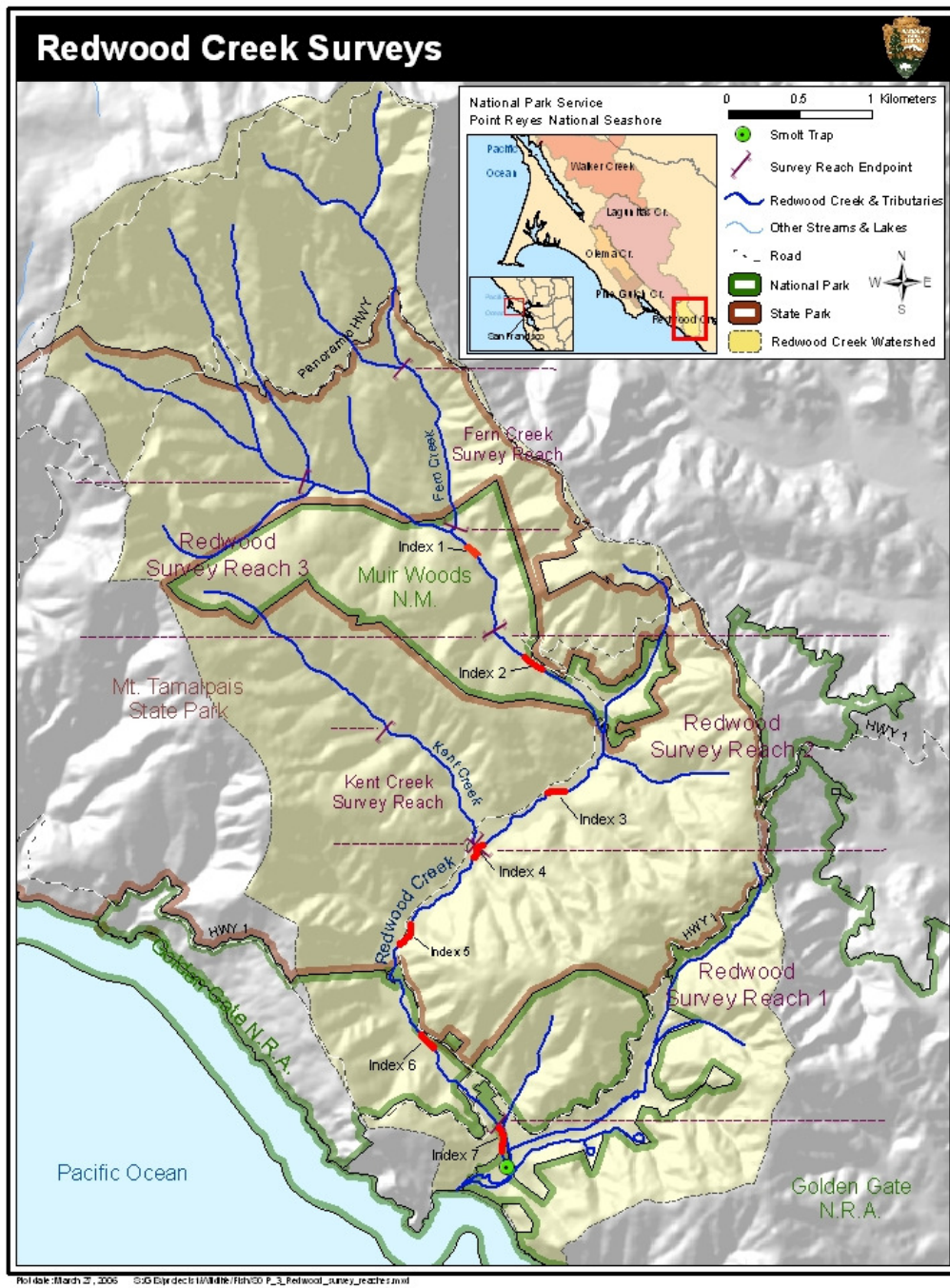


Figure 3. Redwood Creek map. Adult spawner reaches, summer index reaches, and smolt trap locations are shown.

2.1.2 Field Methods

For a detailed description of methods used in the field, please refer to SOP 5, SOP 6, SOP 9 and SOP 11 (Reichmuth et al. 2010). NPS staff and trained volunteers conduct surveys each winter during the coho spawning season to quantify escapement and determine spawning density and distribution. Although surveys focus on coho, steelhead spawners and redds are also observed and counted. Surveys are conducted approximately every week, although storms and high stream flows often dictate less frequent surveys. Teams of two to four observers walk upstream through 2-4 km reaches, along creek margins and banks where possible, and look for live fish, carcasses, and redds. Live fish are identified to species and sex, and lengths are visually estimated. Carcasses are measured (fork length), 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 and marked with flagging. 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 meters along each stream. The survey data is used to generate index values and minimum population estimates for the assessment of long term trends.

2.1.3 Olema Creek

A large section of the mainstem of Olema Creek, 17.6 km, has been surveyed by the Tomales Bay Association (TBA), PORE staff, and volunteers since 1993. The section is currently divided into 7 survey reaches starting 1 km above the confluence with Lagunitas Creek and ending at the Highway 1 culvert at milepost 19.94. Reaches are delineated to facilitate sampling based on access, length, and the existence of permanent landmarks for reach boundaries.

In addition to the mainstem of Olema Creek, surveys are often conducted on some of the larger tributaries. Most tributary surveys conducted in the past were intended only to establish presence or absence of spawning coho and reach lengths varied widely. At present, complete surveys are conducted for the tributaries as personnel and flow conditions allow, based on order of priority. John West Fork, which is the largest tributary to Olema Creek, has the highest priority and abundance of spawning activity. Since 2008 surveys on John West Fork are conducted on the same day as the mainstem of Olema Creek in an attempt to develop a more accurate escapement estimate. For each tributary, survey reaches start at the mouth and generally continue upstream as long as no passage barriers exist or no more spawning activity is detected. Many of the tributaries are unnamed on U.S. Geological Survey (USGS) 7.5 minute maps.

2.1.4 Lagunitas Creek Watershed - Cheda Creek

Cheda Creek, a Lagunitas Creek tributary, has been surveyed since 1996-1997 to detect the presence or absence of coho. The NPS completed a fish passage project in the fall of 2000, coho salmon spawning in the upper part of the creek above the fish passage project site was detected in the 2004-2005 spawning season. Approximately 1.3 km of stream is typically surveyed, including a 0.8 km reach below the fish passage improvement and 0.5 km reach above.

2.1.5 Redwood Creek

Since 1994, the NPS has conducted annual surveys along a 6.7 km section of the mainstem of Redwood Creek between a point 140 m below the Pacific Way Bridge to approximately 500 m above Bridge 4 in Muir Woods. The section encompasses most of the stream length used by coho salmon.

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, were also sampled. The reach on Kent Creek extends from the confluence with Redwood Creek to a waterfall, approximately 1 km upstream, which is impassable to migrating adults. The Fern Creek section has been surveyed since 1994 and extends between the Redwood Creek confluence and a series of steep cascades 1 km upstream.

2.1.6 Pine Gulch Creek

Since 1997, the NPS has conducted surveys along a 9 km section of the mainstem of Pine Gulch Creek. Coho salmon were first spotted during surveys in the winter of 2000-2001. Due to private property access issues and the nature of the watershed, the survey reaches are longer than normal.

The spawner surveys start at the Olema-Bolinas Road Bridge and extend upstream to monument marker 100. The section encompasses most of the stream length that would be potentially used by coho salmon. Although not currently sampled, the McCurdy survey reach was established as a potential survey reach in spawner years when spawner abundance is high and flows allow access to this tributary.

2.1.7 Adult Salmon Escapement Data Analysis

The analysis of spawner survey data is complicated by annual variability in environmental conditions and run characteristics. Accurate abundance estimates are difficult to generate without counting weirs or other intensive sampling techniques (Irvine et al. 1992). The NPS monitoring program is, nonetheless, interested in developing precise indices of abundance for these small watersheds.

Because coho return to spawn over a one to three-month period (November through January, weather dependent) and residence time on the spawning grounds is variable, live fish may be double counted during repeated surveys. Two techniques, Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) are used to compute index values (Beidler and Nickelson 1980, Johnston et al. 1987, Irvine et al. 1992). In addition to calculating the indices, we summarized the live fish, redd, carcass, and environmental data for each stream.

The PLD and AUC estimates provide different types of information. The PLD index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date, and is considered a minimum count. The AUC estimate is calculated using the total number of live fish observed during each survey and the average life of fish on the spawning grounds (residence time). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. Calculating the area under the curve created by plotting the live fish observations for each survey produces a quantity termed total fish-days. The area under the escapement curve was given by:

$$AUC = 0.5 \{ \sum (t_i - t_{i-1}) (p_i + p_{i-1}) \}$$

where t_i is the number of days since the first fish entered the survey area and p_i is the total number of fish observed on the i^{th} day (Irvine et al. 1992). Dividing the total number of fish days by the residence time gives the population estimate. Observer efficiency (OE) is also estimated when possible based on average water clarity over the duration of the spawner season for each creek. When RT and OE values cannot be determined, AUC estimates are calculated based on values

from published coho spawner studies. Because we did not estimate residence time, separate AUC estimates were computed using the range of values presented in the literature, 8 to 17 days (Moring and Lantz 1975, Johnston et al. 1987, Irvine et al. 1992). The most frequently reported values were 11 and 13 days. Two of the eight studies reported OE values between 69 and 76% (Solazzi et al. 1984, Johnston et al. 1987). To consider a wider range of observer efficiencies, AUC estimates were calculated for OE values between 50 and 100%. Data collection typically stops after repeated surveys no longer indicate the presence of live coho. High flows prevented us from conducting surveys during significant portions of some spawner seasons. If fish were observed during the last survey of the season, the last date used for calculating the AUC estimate was arbitrarily set at 10 days after the final survey date. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys.

Redd count and location are used to describe spawning density and spatial distribution. Cumulative redd observations are tallied for the spawner year. Redd location is documented by distance upstream and can be compared annually to determine high density spawning reaches. Redd counts may be limited by observer efficiency and changes to the streambed associated with flow events.

2.1.8 Other Monitoring Programs

NPS conducts escapement monitoring on Pine Gulch Creek, Cheda Creek and Redwood Creek as well as Olema Creek. In addition, the Marin Municipal Water District conducts similar monitoring programs on Lagunitas Creek, San Geronimo Creek, and Devil's Gulch. The Salmon Protection and Watershed Network (SPAWN) program conducts surveys on tributaries of San Geronimo Creek. The aggregate of these monitoring efforts provides for detailed escapement results for two of the five coho salmon genetic subgroups within the central California coast ESU.

2.2 Outmigrant Smolt Trap

For a detailed description of methods used during the outmigrant smolt trapping season, please refer to SOP 3, SOP 4, SOP 6, and SOP 11 (Reichmuth et al. 2010). Outmigrant smolt trapping is performed annually from March through May on Olema, Pine Gulch, and Redwood Creeks. Outmigrant trapping is intended to census the number of coho smolts leaving the watershed. 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 Rationale for Sampling Design

At the time of smoltification, coho have spent more than 14 months in the watershed, and steelhead have spent 1-4 years in the system. The response of coho and steelhead populations to changes in habitat quality cannot be properly assessed without a measure of smolt production.

Smolt trap monitoring, conducted in conjunction with other life stage monitoring activities, allows the NPS to characterize aggregate watershed productivity for salmonids and permits an evaluation of abundance during three of five distinct freshwater salmonid life stages. The smolt trap information can be compared with adult spawner indices to describe potential ocean productivity and survival. Overwintering survival rates can be assessed by comparing smolt

productivity to summer juvenile population estimates. In this manner, change may be detected within each watershed for each monitored salmonid year class. Because coho salmon have a three-year life cycle, monitoring must span this time in order to elicit any type of trend information for the year class. Variation between years of both outmigration and biotic metrics (e.g. weight and length of smolts) can be used to describe the differing conditions and populations of each year class.

2.2.2 Fyke/Pipe 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 effectively result in a census of smolt outmigration. Trap sites were determined by location within each watershed, suitable channel morphology, and access.

Traps are generally installed in mid-March, once winter flows have subsided and stabilized somewhat. In some years, spring rains occasionally raise flows enough to compromise trap operation. Stream flows usually drop substantially by late May or early June, so traps are usually removed at this time. In each of the monitored watersheds, the NPS I&M program maintains a stream gage for measurement of average daily discharge. A Hobo-brand temperature logger is deployed and left in each trap box for the duration of operation.

2.2.3 Fish Handling

Mark-recapture methods were used to estimate trap efficiency and smolt population size using DARR (Darroch Analysis with Rank Reduction). Daily, no more than 30 smolts (or 50% of the catch that day) of coho smolts were anesthetized with carbon dioxide and marked with small but identifiable fin clips, dye on fins using a needleless injector, or implanted with a passive integrated transponder (PIT) tag. A random sub-sample of steelhead parr (juveniles of at least one year of age that show no signs of smoltification), coho and steelhead presmolts (fish of at least one year of age that show early signs of smoltification), coho and steelhead smolts (fish of at least one year of age that undergone physiological changes in preparation for heading out to sea), and coho and steelhead fry (recently hatched and emerged juveniles) are measured and weighed. This sub-sample is normally 10 of each species; however, if fish are anesthetized for mark-recapture purposes, they are also measured.

2.2.4 Site locations

For detailed site descriptions, please refer to SOP 9 (Reichmuth et al. 2010). Smolt traps are located as far downstream as possible in the sampled watershed, preferably near the mouth of the stream, to provide the most accurate smolt productivity index for the watershed upstream of the trap. Channel character, accessibility, and protection are equally important. The site must have adequate vertical gradient to push water through the pipe as well as an area of low energy to house the trap box. The structure should be located in an area where equipment can be easily carried to the site. In addition, it is important that the trap be located in a place where vandalism is not likely.

The Olema mainstem trap was located on NPS lands approximately 400 m upstream of the mouth from 2004-06. Due to high flow failure and the capture of California red-legged frog tadpoles and adults in the trap box during the 2005 and 2006 trapping seasons, the trap was

relocated in 2007 approximately 1 km upstream. NPS staff chose a trap location upstream of the previous location in an attempt to avoid major red-legged frog breeding areas. On Redwood Creek, the trap is located at the most downstream end of the watershed, near the Muir Beach public parking area. Due to the absence of any juvenile coho found within Pine Gulch Creek in the summer of 2007, no smolt trap was constructed during the 2008 smolt trap season.

2.2.5 Sampling period

Past literature was reviewed to determine the appropriate start and ending points for the trapping season. In Waddell and Scott Creeks (Santa Cruz County), outmigration of coho smolts began in mid-March and peaked in mid-May (Shapovalov and Taft 1954). In Lagunitas Creek (Marin Co.), results from smolt trapping from 1983-85 indicated that coho emigration began in early April and ended in late June (Bratovich and Kelley 1988). Steelhead emigration generally begins in early-March and ends by June (Bratovich and Kelley 1988). Based on our trapping experience, we have observed outmigration primarily in April and May, with the peak occurring in late April-early May (Carlisle et al. 2008).

Currently during the trapping season, mid March – May, the traps operate 24 hours per day, and are checked on a daily basis. This frequency was selected to balance excessive labor efforts with the need to prevent injury because of prolonged trap residence. When possible the trap was checked twice-daily to prevent incidental mortality of adult steelhead and steelhead fry. If possible, traps are opened in anticipation of high flows to avoid potential or excess mortality.

In order to minimize impacts to newly emerged fry, the trap box is fitted with a ¼ in mesh screen to allow smaller fish to pass through the box, while still catching smolts.

2.2.6 Smolt Trap Data Analysis

Information produced through this program includes weekly and daily totals of fish captured, including smolts, other age 1+ juveniles, and young-of-year (YOY). Fulton condition factor (K-factor), which is a weight-length relationship, is calculated for smolts and other age 1+ coho salmon and steelhead. Mark/recapture methods are used to estimate trap efficiency and population.

Mark/recapture data is analyzed using DARR (Darroch Analysis with Rank Reduction), a software application developed by Eric Bjorkstedt at the NMFS Southwest Fisheries Science Center (Bjorkstedt 2005, 2010). The software facilitates analysis of temporally stratified mark/recapture data based on methods developed by Darroch (1961).

Using the efficiency method to estimate a population could result in overestimates of the population. Estimates reported through this method would require the following assumptions: 1) there is no mortality of released fish; 2) there is no residualization or behavior change (far more probable in steelhead than coho); and 3) released fish are redistributed and have a constant probability of capture.

For fish biotics including fish weight, length and condition score a contrast is used to preserve the year class effect on the population. The contrast uses the mean across years to test the differences at the year level. A two-sided T-test (alpha 0.05) is then used to for each biotic parameter to test for differences between the current year and previous years. For other data analyses performed, refer to SOP 10 (Reichmuth et al. 2010).

2.3 Juvenile Surveys

Monitoring juvenile salmonids during their freshwater residence phase provides information on overall population trends, particularly when combined with adult spawning data and smolt emigration data (Collins 2003), which are also part of our monitoring program. 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 general systematic surveys (GSS) and index reach monitoring during the summer/fall sampling period. Complete field methods are documented in SOPs 1, 2, 6, and 9 (Reichmuth et al. 2010). 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 should be treated as a standalone survey.

2.3.1 Rational for Sampling Design

Two monitoring efforts are conducted during the summer/fall season to document juvenile salmonids. Index reach monitoring provides density information on all fish species in these reaches, and is comparable to other local and regional watersheds. The implementation of a probabilistic sampling program, including annual habitat surveys and snorkel counts to estimate coho population, began in 2001 for Pine Gulch Creek, 2003 for Olema Creek, and 2004 for Redwood Creek. Index reaches monitored as part of this program include 7-16 years of monitoring data, and are considered a legacy dataset.

2.4 Basinwide General Systematic Survey Methods

Basinwide survey techniques, developed by Hankin and Reeves (Dollof et al 1993), provide a statistically accurate 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.

2.4.1 Habitat Surveys

For a complete description of sites monitored, refer to SOP 9 (Reichmuth et al. 2010). Starting at the bottom of the coho survey area and working upstream, staff numbered, classified, measured the length, and estimated the average width of each habitat unit. Units are classified to level III using the CDFG classification system (Flosi et al 1998) as pool (scour pool, backwater pool, plunge pool, or mid-channel pool), flatwater, or riffle. Side channel and backwater units are also measured. The width of each habitat unit was estimated visually. Every fifth pool unit was flagged for snorkeling and several measured widths were taken for the purpose of calibrating the estimated width. Index reach pools are also flagged for snorkeling. All large woody debris (LWD), alive or dead, providing instream shelter during summer base flow conditions are counted and recorded within each habitat unit.

2.4.2 Basinwide Snorkel Surveys

Project staff surveyed 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 were counted but the presence of steelhead and non-salmonid fish was also noted.

Typically, snorkeling is calibrated by follow-up electrofishing of randomly selected dive pools. These pools are used to create a calibration ratio with which to correct snorkel survey counts.

Because heavy staff effort is invested in the index reach effort, we combined the surveys by using the index reaches for the electrofishing portion of the basinwide survey. When possible, a random subset of snorkeled pools were immediately resampled using the method of bounded counts (Murphy and Willis 1996) to provide an unbiased calibration method. In the pools selected for bounded counts, three additional snorkel passes are performed after the initial pass, allowing a method of calibrating the snorkel survey counts without the use of electrofishing.

2.4.3 Index Reach Monitoring

Index reaches are sampled at SFAN parks during summer/fall base flow periods to assess fish abundance and distribution on the mainstem of Olema Creek, Redwood Creek, and Pine Gulch Creek. Under this technique, established stream reaches approximately 100 m in length, have been surveyed annually since the mid- to late-1990s. 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). Where appropriate, snorkel surveys or seine hauls are used in conjunction with electrofishing. Habitat measurements and assessments are made for the index reaches after fish sampling is completed.

Index reach surveys provide baseline fish distribution information and abundance/density estimates. *MicroFish* software is used to analyze data. The software is based on removal-depletion methods to account for detection error. Measurements of individual fish weight and length are also used to generate biotic condition factors for salmonids in each watershed. Juvenile salmonid year class abundance varies depending on returns of adult spawners and environmental conditions. By comparing the baseline fish density estimates derived from consecutive survey years, the variations in year class abundance can be monitored. Because steelhead often spend in excess of one year in freshwater, annual surveys may provide information on the overwintering success of different year classes.

Index reach monitoring was initiated at seven sites on Olema Creek in 1999. See SOP 9 for detailed index reach locations and maps (Reichmuth et al. 2010). In 2000, Index Reach 8 was added to represent the intermittent portion of the upper mainstem. The stream kilometer (km) location of each index reach is presented in Table 1 and is shown in Figure 2 (p.8). In 2008, seven of the eight index reaches on the mainstem of Olema Creek were sampled. Index reach 1 is no longer sampled due to inconsistent historical monitoring data for this index.

Table 1. Site location and number for Olema Creek index reach sites.

Index site	Name/location	Location stream km
1	Lower Stewarts Pasture/ Olema Flat	1.2
2	Vedanta	3.7
3	Cemetery Pond/Upper Stewart's Pasture	4.9
4	Truttman	6.3
5	Bldg 168/Shook's house	7.6
6	Horse Camp	9.4
7	5 Brooks	10.8
8	Lime Kilns/Upper Olema	13.0

Dr. Jerry Smith of San Jose State University (SJSU) established five index reaches on Redwood Creek in 1992; monitoring of these sites was shared between Dr. Smith and NPS until 2004. Since 2004, all seven index reaches have been monitored by NPS staff. The stream kilometer (km) location of each index reach is presented in Table 2. Two additional index sites, Muir Woods National Monument (MUWO) boardwalk and Banducci, were added by Golden Gate National Recreation Area (GOGA) in 2001 to represent habitat units not being covered by Dr. Jerry Smith.

Table 2. Site location and number for Redwood Creek index reach sites.

Index site	Name/location	Location stream km
1	MUWO boardwalk	6.3
2	MUWO restroom	5.2
3	Miwok Trail Crossing	3.8
4	Kent Creek	2.9
5	Frank Valley Road Bridge	1.9
6	Banducci	0.8
7	Pacific Way Bridge	0.1

Index reach monitoring was initiated at eight sites on Pine Gulch Creek in 2000. The stream kilometer (km) location of each index reach is presented in Table 3.

Table 3. Site location and number for Pine Gulch Creek index sites.

Index site	Name/location	Location stream km
1a	Marin County Open Space District (MCOSD)	0.2
1b	Murch	0.4
1c	Weber	0.7
2	Paradise Valley	2.7
3	Pine Gulch Gorge	3.9
4	BCPUD pasture	5.1
5	Lower Teixeira	6.8
6	Upper Teixeira	7.8

2.4.5 Electrofishing/handling

All captured fish are documented as part of the monitoring effort. To reduce fish handling impacts, a subsample of 10 fish per pass, per species is processed. Fish are kept in aerated holding buckets before and after handling, and allowed to recover fully before being released. Processed fish are sedated using carbon dioxide (Alka SeltzerTM), identified to species and age class, measured, and weighed. In some cases, fin clips or scale samples are also collected for age and/or genetic analysis. All other fish are identified to species, counted, and transferred directly to the recovery buckets.

An electrofishing log is kept of all settings, pertinent environmental conditions, fish response, and total catch for each unit. All electrofishing information is reported annually in Section 10 Reports to NOAA Fisheries. Water quality parameters are measured and recorded.

For habitat units sampled by multiple pass electrofishing, maximum likelihood model, *MicroFish* (VanDeventer and Platts 1989) is used to calculate fish population estimates and confidence intervals by species/age class. Total catch is used as the population estimate for species with poor multiple pass depletions or no captures after the first pass, and in units sampled with a single pass.

2.4.6 Juvenile Survey Sample Dates

Index reaches and basinwide surveys for each stream are sampled during the same general time of year on an annual basis. Sampling occurs during summer base flow conditions when intermittent stream flow conditions typically occur. During the 2008 sampling season the Olema Creek sampling period was moved to October to better represent summer base flow conditions. In previous years Olema Creek was sampled in late June before flows reached summer base flow conditions. Table 4 provides the sample dates for the 2008 summer/fall stream fish surveys.

Table 4. Index reach/basinwide survey sample dates, 2008.

Watershed	Stream	# of index reaches	In-stream sample dates
Pine Gulch	Mainstem	6	07/01/08 – 08/06/08
Redwood	Mainstem	6	09/08/08 – 10/07/08
Olema	Mainstem	7	10/08/08 – 11/06/08

3 Monitoring Results

3.1 2007-2008 Adult Coho Escapement Results

Adult coho surveys are conducted within a three month period starting in late November and continuing through early February. Start and end dates for each season vary depending on instream flows, and spawning activity. For more detailed results on individual surveys performed during the 2007-2008 spawner season please see the 2007-2008 Annual Salmon Escapement Report (Carlisle et al. 2008). Historical results for all streams monitored in Marin County by the NPS, MMWD, or SPAWN are presented in Appendix A, Table A1.

3.1.1 Water Year 2008 Rainfall Totals – Bear Valley Headquarters

The data collected at the Bear Valley rain gage shows that the 2008 water year was drier than the average year when compared to the historic data set collected since 1965 (Table 5). The total rainfall for water year 2008 was 31.41 in whereas the average for the last 42 years was 38.66 in. During January, which can be a critical time for spawning activity of coho salmon, the 2008 total of 14.66 in was well over the January average of 8.36 in.

Table 5. Average, maximum, and minimum monthly rainfall at Bear Valley, 1965-2007 compared with 2008.

	Total	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Average	38.66	2.02	5.25	7.34	8.36	6.45	5.36	2.38	1.06	0.22
Min	15.03	0.00	0.61	0.01	0.40	0.47	0.24	0.00	0.00	0.00
Max	79.84	5.74	18.2	22.99	22.39	24.68	24.28	6.60	6.35	1.86
2008	31.41	3.40	1.09	6.76	14.66	4.54	0.49	0.34	0.13	0.00

Figure 5 shows the annual rainfall totals for the last 42 water years. The minimum annual rainfall occurred in 1977 with only 15.03 in of rainfall and the maximum occurred in 1983 with 79.84 in. The graph depicts the large variation that can occur from year to year in this region. Annual rainfall data are not available for 1969 and 1971.

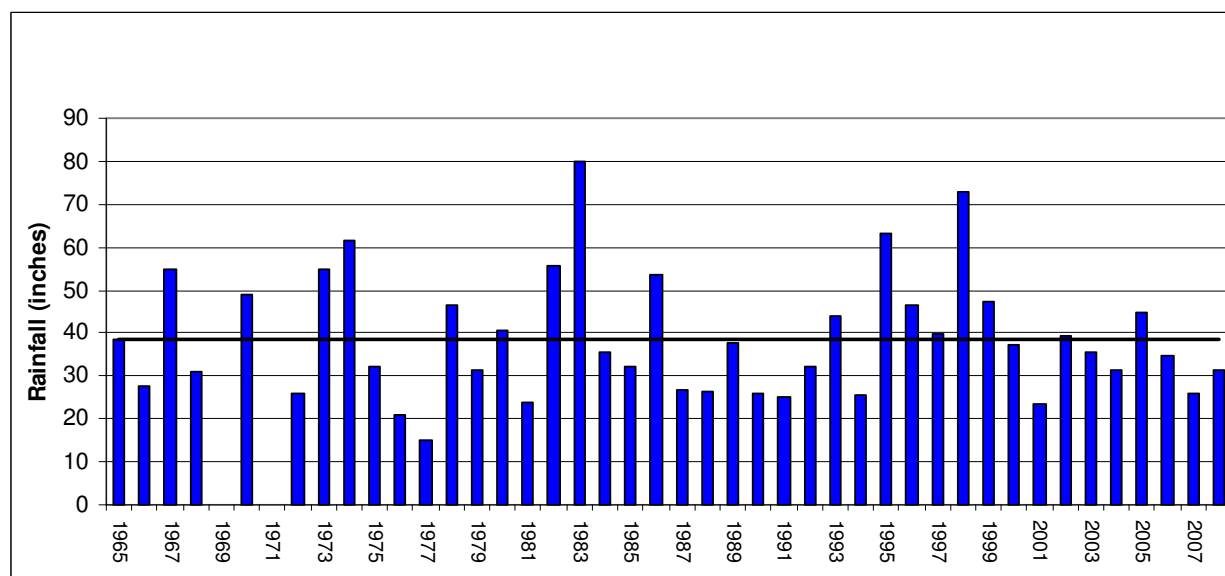


Figure 5. Annual rainfall totals taken at Bear Valley rain gage from 1965 – 2008, missing data from 1969 and 1971. Trend line is average annual rainfall from 1965-2008.

3.1.2 Olema Creek Coho Escapement

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. 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). Freshwater residence time is short (typically less than two weeks), though the NPS program has documented some individuals spending up to 20 days in freshwater under ideal conditions.

Survey Timing and Environmental Conditions: Our monitoring efforts have shown some years where flows necessary to allow entry into the watershed did not occur until mid-January. In those years, fish were observed, stacked 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 earlier than normal. Even when the early entry opportunity has occurred, few coho have been observed. For the most part, peak spawning activity within Olema Creek is between mid-December and mid-January. 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. Figure 6 shows the approximate entry and spawning window monitored for coho salmon for spawner year 2007-2008 compared to the average for 1997-2007. Data on historical timing of the coho run, rainfall during the run, and spawning activity observed on Olema Creek can be found in Appendix A, Table A2.

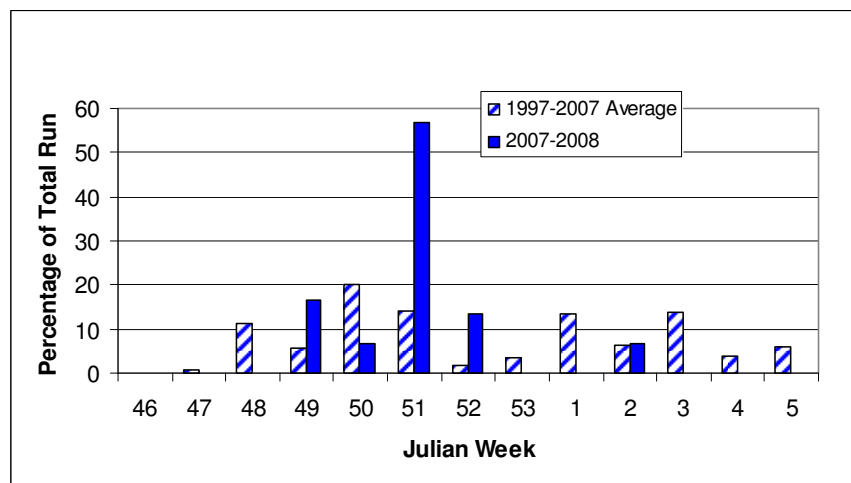


Figure 6. Olema Creek, adult coho run timing, based on number of live fish observed, average of 1997-2007 compared to 2007-2008.

For the 2007-2008 season, eight surveys were conducted in Olema Creek between 29 November 2007 and 8 February 2008. The mean interval between surveys was nine days. Seven-day rainfall totals ranged from a low of 0.02 and 0.01 in during Julian weeks 48 and 6 respectively and a high of 5.82 in during Julian week 4. Average water clarity at the time of surveys ranged from 64-100 cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations (Figure 7).

Historical observations show a bi-modal return, with high returns in Julian weeks 50 and 3, correlating with a mid-December and mid-January return. Figure 6 shows that over 50% of the

returning coho during the 2007-2008 spawning season were observed during Julian week 51 (17-23 December). Based on the past 10 years of data this spawning peak fell within the average spawning time for the Olema Creek watershed. For complete historical results for Olema Creek and John West Fork, refer to Appendix A, Tables A2 and A3.

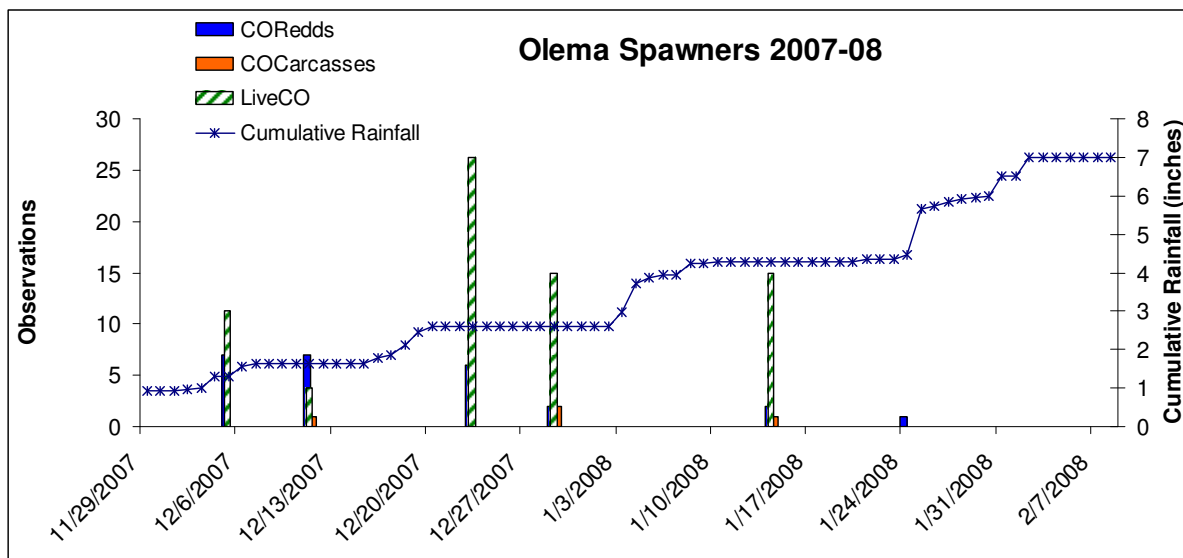


Figure 7. Representation of rainfall totals at Bear Valley and coho adult escapement survey results on Olema Creek mainstem, including live fish, carcasses, and redds, observed during surveys in 2007-2008.

Five surveys were conducted on 2 km in John West Fork (reaches 1-2) between 21 December 2007 and 30 January 2008. The mean interval between surveys was 10 days with a seven day rainfall total low of 0.01 in during Julian week 6 and a high of 5.82 in during Julian week 2. Average water clarity at the time of surveys ranged from 40-100 cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations.

In addition to John West Fork, four other tributaries to the Olema mainstem were surveyed between December and February. The timing of tributary surveys generally preceded the mainstem surveys and were dependent on flow. Sections of Quarry Gulch, Giacomini Gulch, Horse Camp Gulch, and Boundary Gulch were also surveyed.

Live Fish (Coho): While live fish observations do not represent the total number of spawning adults, a total of 47 live adult coho were observed between November and February, 32 coho on mainstem Olema Creek and 15 coho on John West Fork. One peak spawning activity was recorded on the Olema mainstem on 23 December with 17 live coho observed and another peak was recorded on John West Fork on 11 December with a total of 11 coho observed.

No adult spawners were observed in any of the four additional tributaries surveyed.

Live Fish (Steelhead): Although adult steelhead are not a 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 counts are assumed to be much higher than the observed counts. The peak steelhead count on Olema Creek was observed on 8 February 2008 with a count of 14 live adult steelhead. Thirty three percent of the total live adult steelhead counts in the Olema watershed

were observed in survey Reach 3 of the Olema Creek mainstem. A total of 33 adult steelhead were observed on spawner surveys from 14 January to 8 February, representing the second highest total count of steelhead for all monitored years in Olema Creek. In addition, live adult steelhead were observed incidentally into mid-May on the mainstem of Olema Creek while operating a downstream migrant trap.

Carcasses (Coho): A total of five carcasses were found on the mainstem of Olema Creek during the 2007-2008 spawner season. Most carcasses were found in survey Reach 3. The carcass sex ratio was 60% male and 40% female. At least one jack (precocious two-year old male) was recovered, but due to lack of complete carcasses the proportion of jacks within the population was not determined. Scales were collected from all individuals for further age analyses. Only two complete coho carcasses were available for measurement, one of 42 cm in length, and one of 75 cm in length. The results of previous spawner surveys in the Olema Creek watershed suggested that jacks were typically less than 50 cm fork length.

No carcasses were discovered on John West Fork during any of the surveys.

Carcasses (Steelhead): Only two steelhead carcasses were recovered while performing spawner surveys on Olema Creek and none were found on the tributaries. Both were recovered on 24 January. One was unidentifiable while the other was a male with a fork length of 60 cm.

Redds (Coho): 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 the 1997-1998 season. Accumulation of this data show high use areas for spawning within the Olema and John West Fork watersheds.

A total of 26 confirmed redds were observed within the Olema watershed during the 2007-2008 season: 19 coho redds in the mainstem of Olema Creek and 7 coho redds on John West Fork. Redd construction was concentrated in Reaches 1-3 of the Olema mainstem and Reach 2 of John West Fork, with 82% of the redds observed in those four reaches. Most redds were constructed between the 5 December and 28 December surveys. The total density of redds along the mainstem and John West Fork was 2.4 redds/km. The mean surface area of all coho redds was 3.8 m².

The 2007-2008 spawner season was the first season in several years that Reach 1 on Olema Creek mainstem was surveyed. The majority of the redds were found within the first kilometer of the stream in a section rarely surveyed. The 2007-2008 spawner season saw the majority of the redds created before stream kilometer 10, rather than in the higher kilometers of the stream as was found in past years (Figure 8). This may have been due in part to the low water year and late storms.

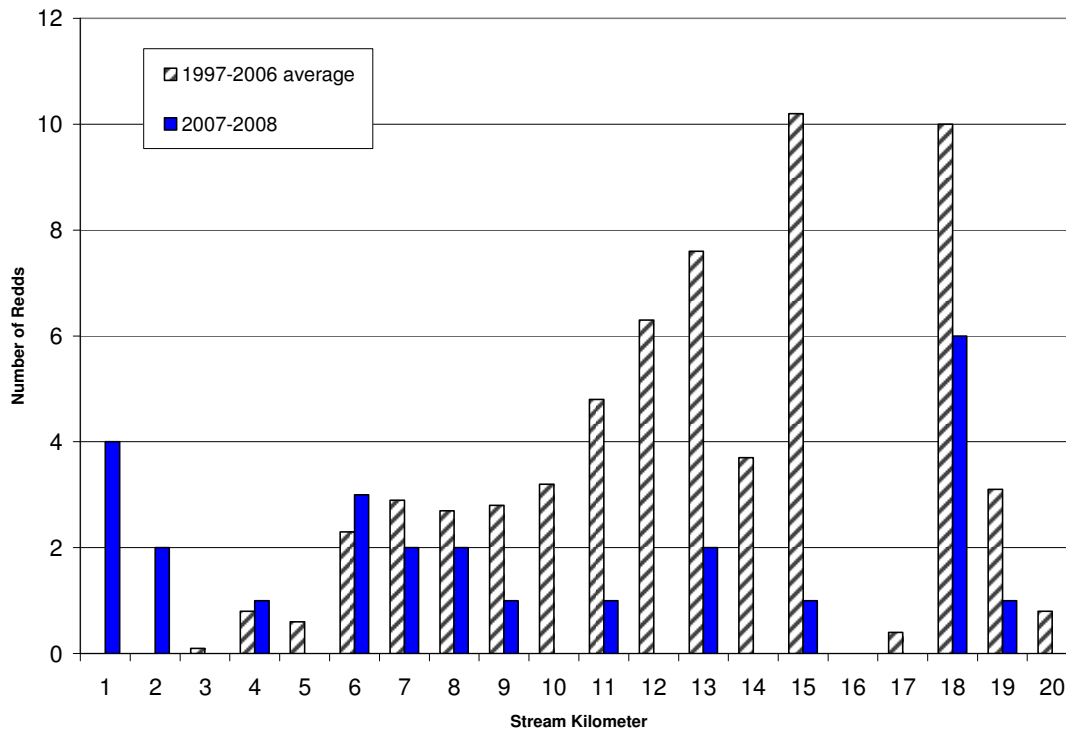


Figure 8. Olema Creek watershed, coho redds per stream kilometer for 2007-2008 compared with the average of 1997-2007. Stream kilometers 1-17 are kilometers along the Olema Creek mainstem, 18-19 are the 2 km of the John West Fork tributary, and 20 is the remaining four Olema tributaries sampled (Boundary Gulch, Giacomini Creek, Horse Camp Creek, Quarry Gulch).

Observers made comments about features of the streambed that could not be positively identified as coho redds and marked them as possible redds instead. A total of six questionable redds were found. The mean surface area of the six questionable coho redds was 2.4 m².

Redds (Steelhead): A total of 23 definite steelhead redds were observed on Olema Creek mainstem and John West Fork. Steelhead redd observations were concentrated in Reaches 2, 5, and 6, representing 70% of observed steelhead redds. The density of redds in the 13.6 km mainstem and John West Fork tributary section surveyed was 1.7 redds/km. The mean surface area of the steelhead redds was 2.1 m².

Figure 9 shows the location of steelhead redds in Olema creek watershed observed in the 2007-2008 season and the average of locations from 2000-2007.

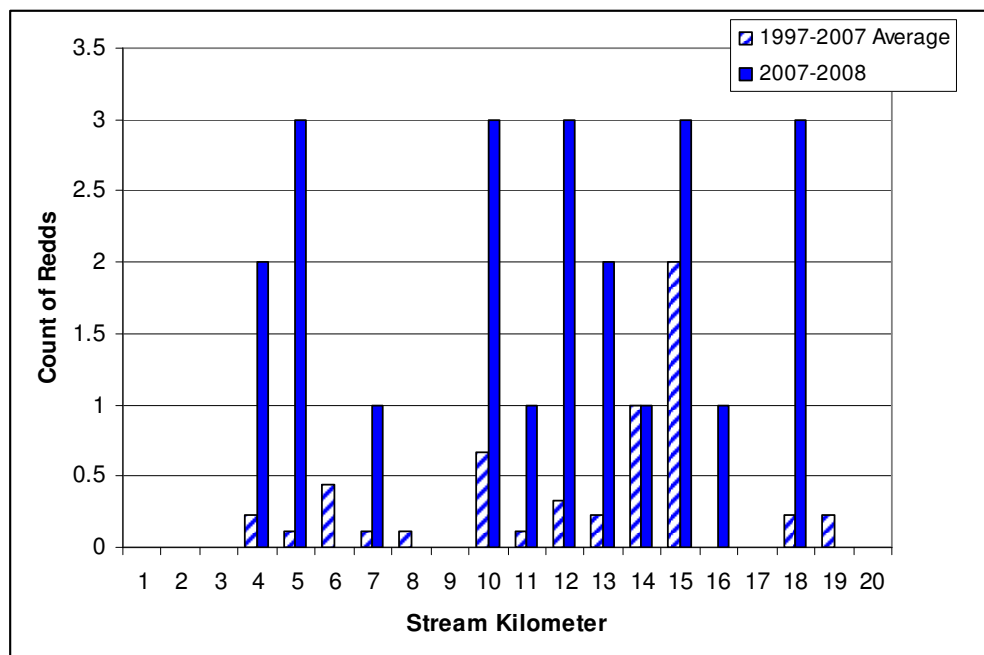


Figure 9. Olema Creek watershed, steelhead redds per kilometer for 2007-2008 compared with the average from 1997-2007. Stream kilometers 1-17 are kilometers along the Olema Creek mainstem, 18-19 are the 2 km of the John West Fork tributary, and 20 is the remaining four Olema tributaries sampled (Boundary Gulch, Giacomini Creek, Horse Camp Creek, Quarry Gulch).

Peak Live plus cumulative Dead Escapement Estimate: The 2007-2008 Peak Live plus cumulative Dead (PLD) index in the Olema Creek mainstem is 22, taken from two peaks, the first on 23 December and the second on 14 January 2008. The 2007-2008 PLD index on John West Fork is 11 coho, taken from the peak on 21 December.

AUC Escapement Estimate: The NPS has also used the AUC method to estimate adult escapement within Olema Creek and the John West Fork tributary. Only live fish are calculated using this technique.

AUC estimates in the Olema Creek section ranged from 18 to 39 coho at 100% OE and 37 to 78 fish at 50% OE (Table 6). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 30 to 40 fish in Olema Creek. Based on our survey OE (70-80%) and estimated RT (13-15 days), AUC estimates for coho salmon in Olema Creek range from 26 to 34. Population estimates in the John West Fork survey section ranged from 3 to 7 coho at 100% OE and 6 to 12 fish at 50% OE. AUC estimates for coho salmon in John West Fork using our survey OE (60-70%) and estimated RT (10-12 days) ranged from 6 to 8. Table 6 summarizes AUC estimates for Olema Creek mainstem and John West Fork for 2007-2008. AUC estimates for Olema Creek mainstem and John West Fork are in Appendix A, Tables A2 and A3. Complete AUC estimates for Olema Creek mainstem and John West Fork can be found in Tables A4 and A5.

Table 6. Coho salmon spawning survey Area Under the Curve (AUC) estimates for Olema Creek mainstem and John West Fork, 2007-2008.

Creek	Number of surveys	Date of entry	Mean survey interval (days)	Survey reaches	Survey area (km)	AUC range 100% OE ^a	AUC range 50% OE ^a	AUC range 70-80% OE ^b	OLM mainstem PLD
Olema mainstem	8	03 Dec 07	8.9	1-6	13.2	18-39	37-78	30-40	22
John West Fork	7	30 Dec 07	5.0	1-2	2.4	3-7	6-12	5-6	11

OE= observer efficiency, PLD = Peak Live plus cumulative Dead

^a RT 8-17 days

^b RT 11 -13 days

Olema Creek Watershed Escapement History: Escapement estimates for adults in Olema Creek have been made using both the PLD and AUC methods. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number due to low OE.

Annual escapement estimates for Olema Creek show a range of 9-184 individuals for the mainstem and a range of 8-86 individuals for John West Fork using the PLD index. Estimates using the AUC method are much higher with estimates reaching beyond 300 adults in some years.

PLD Index Results: The PLD dataset for adult escapement within Olema Creek includes 14 years of survey information but prior to SY 1997-1998, redds and carcasses were not consistently counted. The John West Fork tributary has been the focus of extensive restoration and monitoring and is often used as a proxy of conditions in the mainstem. Tables A2, A3, and A6 in Appendix A show historical PLD estimates for the Olema Creek mainstem, John West Fork, and other Olema Creek tributaries.

Overall trends in coho spawning based on observed redds in the Olema watershed are shown in Figure 10. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year Class 2 shows a rapid increasing trend in spawning over the last three generations before falling off sharply in the current year. Year Class 1 has remained relatively constant over the past three generations and may be the most consistent cohort with an average PLD of 93 adult spawners (22.5 SD). Year Class 3 continues to struggle with a dramatic decline between 2002-2003 and 2005-2006. Each section of the Olema watershed is shown in a different pattern to illustrate the location of spawning activity from year to year as well as within year classes.

Overall trends in coho spawning based on PLD observations in the Olema Creek mainstem are shown in Figure 11. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year Class 1 had shown a steady increase in population size since 1994-1995 until the last generation 2006-2007 in which a major reduction was observed. Year Class 2 shows a rapidly increasing trend in spawning since spawner year 1998-1999 until 2007-2008, when the numbers fell dramatically. Year Class 3 continues to struggle with a dramatic decline beginning with spawner year 1999-2000 and has declined further in the last generation.

Trends in coho spawning for John West Fork based on PLD observations are shown in Appendix A, Figure A1. Year Class 1 peaked in spawner year 2000-2001, declining in the last two returns. Like Olema mainstem, Year Class 2 shows an increasing trend in spawning over four

generations before dropping off sharply in this last spawner year. Year Class 3 continues to struggle but has reestablished itself since the zero count during the 1996-1997 spawner year.

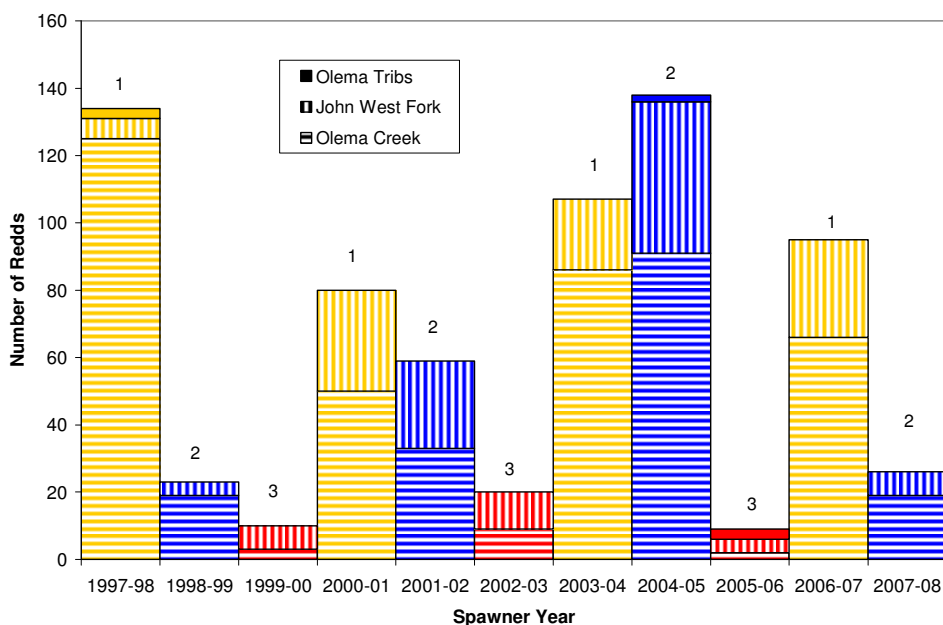


Figure 10. Coho salmon redd results for the Olema Creek watershed by year class for winter 1997-1998 through winter 2007-2008. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red) and creeks are designated by pattern (Olema Creek in horizontal lines, John West Fork in vertical, and other Olema tributaries in a solid color).

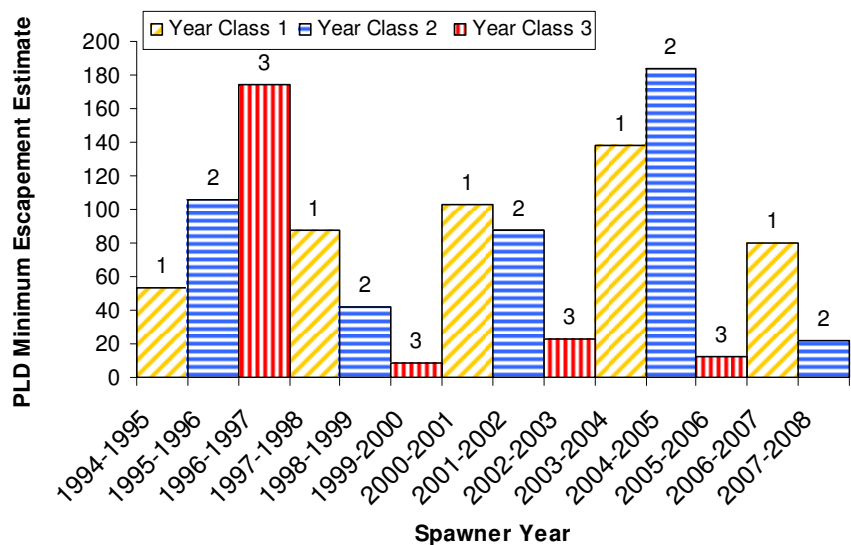


Figure 11. Olema Creek coho salmon PLD index escapement results winter 1994-1995 through winter 2007-2008.

Live Fish and Carcass Biotics: Information on live fish and carcasses were collected during each field survey. Information on sex ratios for live fish is reported in Table 7. While live fish lengths

are estimated, carcasses are handled to definitively determine sex, spawn success, fork length (FL), and for collection of a genetic sample.

Table 7. Sex ratios and size of live coho within the Olema Creek mainstem and John West Fork tributary. Average, maximum, and minimum fork length (FL) of 1997- 2007 compared to 2007-2008.

		Year	Number of Observed Fish	% of measured fish in year	N for FL	Mean FL	FL SD
Average	M	1997-2007				64.3	4.81
	F	1997-2007				59.8	2.05
	J	1997-2007				38.3	1.48
	Unk	1997-2007				58.8	5.60
Max	M	2005-2006	1	6	1	75.0	
	F	2003-2004	97	61	96	63.1	5.25
	J	2006-2007	17	26	17	40.9	5.66
	Unk	1999-2000	1	1	1	70	
Min	M	1999-2000	22	35	9	57.2	7.55
	F	1998-1999	26	39	25	56.6	5.92
	J	2003-2004	10	63	10	36.0	5.68
	Unk	2000-2001	7	11	4	52.5	2.89
Current (2007- 2008)	M	2007-2008	17	36	17	57.8	4.67
	F	2007-2008	25	53	25	56.5	5.97
	J	2007-2008	4	9	4	42.5	2.89
	Unk	2007-2008	1	2	1	60.0	
	All		47		47		

M= Male, F= Female, J=Jack, Unk= Unknown, N= Number of fish measured for FL

Information for carcasses is reported in Table 8. The results of carcass measurements show that males are generally between 56-70 cm, with females averaging 50-67 cm and jacks averaging from 37-49 cm.

Table 8. Sex ratios and size of coho carcasses within the Olema Creek mainstem and John West Fork tributary. Average, maximum, and minimum fork length (FL) of 1997-2007 compared to 2007-2008.

		Year	Number of Observed Fish	% of measured fish in year	N for FL	Mean FL	FL SD
Average	M	1997-2007				67.5	4.93
	F	1997-2007				62.9	3.58
	J	1997-2007				42.7	3.36
	Unk	1997-2007				65.5	3.12
Max	M	2005-2006	7	18	4	74.3	1.50
	F	2003-2004	17	43	16	66.8	5.18
	J	2006-2007	3	23	3	45.7	2.08
	Unk	1999-2000	5	16	1	70.0	
Min	M	1999-2000	3	27	1	57.0	
	F	1998-1999	6	67	6	58.3	8.16
	J	2003-2004	2	13	2	37.5	3.53
	Unk	2000-2001	7	44	3	63.3	10.41
Current (2007- 2008)	M	2007-2008	2	67	1	75.0	
	F	2007-2008	0	0	0		
	J	2007-2008	1	33	1	42.0	
	Unk	2007-2008	0	0	0		
	All		3		3		

M= Male, F= Female, J=Jack, Unk= Unknown, N= Number of fish measured for FL

3.1.3 Cheda Creek Coho 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 1-2 (Figure 4, p.10). Only one definite coho redd was identified in the bottom reach of Cheda Creek.

Survey Timing and Environmental Conditions: Five surveys were conducted in Cheda Creek between 19 December 2007 and 30 January 2008. The mean interval between surveys was 14 days. Seven-day rainfall totals ranged from a low of 0.01 in during Julian week 6 and a high of 5.82 in during Julian week 4. Average water clarity at the time of surveys ranged from 45 cm to 90 cm.

Live Fish (Coho): No live coho spawners were observed during the 2007-2008 season.

Live Fish (Steelhead): Three live steelhead were observed on Cheda Creek on 30 January 2008. All three were in Reach 1, and of the three, two were females and one was male.

Carcasses (Coho and Steelhead): No carcasses were found during the 2007-2008 spawner survey season on Cheda Creek.

Redds (Coho): One confirmed redd was observed in Cheda Creek during the 2007-2008 season (Table 9). It was located in Reach 1 and observed during the 21 December survey.

Redds (Steelhead): Three confirmed steelhead redds were observed on Cheda Creek. All three were found in Reach 1 and observed on 30 January.

Cheda Creek Watershed Escapement History: The dataset for adult escapement within Cheda Creek includes nine years of survey information and has documented the return of coho to the small tributary stream of Lagunitas Creek (Table 9). Due to its small size and presence in the Lagunitas system, Cheda Creek spawner patterns are directly connected to those observed in the mainstem Lagunitas Creek. Our observations of Cheda Creek are intended to determine how a small downstream tributary is used by spawners before and after restoration.

The PLD index ranges from zero adults for the first three survey years to 17 adults observed in SY 2004-2005. The first observed returning year class (SY 2001-2002) appears to be coming back strong with both live adult observations and redd observations. The presence of spawning activity above the fish passage structure constructed in 2000 is a promising sign of recovery and documentation of the projects success.

Table 9. Coho salmon spawning survey including Peak Live plus cumulative Dead (PLD) index, tally of total carcasses, and total redds for Cheda Creek.

Year	Number of surveys	Survey area (km)	PLD Index	Total carcasses	Total new redds
1998/1999	2	N/A	0	0	0
1999/2000	1	N/A	0	0	0
2000/2001	2	1.4	0	0	0
2001/2002	5	1.2	4	0	3
2002/2003	3	1.2	2	1	1
2003/2004	3	1.2	1	0	6
2004/2005	5	1.3	17 ^a	1	6
2005/2006	4	1.3	1	1	2
2006/2007	3	1.3	5	1	7
2007/2008	5	1.3	0	0	1

^a Includes two peaks, 3 weeks apart.

N/A-Survey area not defined

Lagunitas Creek Watershed Escapement History: The PLD index data have not been consistently gathered for all creeks in the project area and can vary in quality depending upon the number of surveys conducted and upon other factors. Data on the number of new redds provides a good overview of recent spawning activity in PRNS watersheds (Table 10). These data indicate the high annual variability in coho spawning activity and the relative importance of Olema Creek to spawning in the Lagunitas Creek drainage. A summary table of redd density within the Lagunitas Creek watershed is provided as Table A1 in Appendix A. Escapement estimates for Olema Creek, which is a tributary to Lagunitas Creek, represent 3-40% of the total escapement estimated for the Lagunitas Creek watershed.

Table 10. Total coho redds in Lagunitas Creek watershed, 1995-2008 (MMWD & PORE).

Year	Lagunitas Creek mainstem	San Geronimo Creek (mainstem+tribs)	Devil's Gulch (+ Cheda)	Olema Creek (mainstem+tribs)	Total new redds	Olema Creek redd proportion
1995/1996	70	6	10	N/A	86	N/A
1996/1997	98	115	42	N/A	255	N/A
1997/1998	80	121	46	134	381	35%
1998/1999	92	60	31	23	206	11%
1999/2000	139	61	3	10	213	5%
2000/2001	119	74	11	80	284	28%
2001/2002	79	145	62	59	345	17%
2002/2003	71	61	26	20	178	11%
2003/2004	124	205	54	109	492	22%
2004/2005	120	158	118	137	533	26%
2005/2006	53	104	35	8	200	4%
2006/2007	128	155	62	95	440	22%
2007/2008	87	46	7	26	166	16%

N/A = not available.

Overall trends in coho spawning based on observed redds in the Lagunitas Creek watershed are shown in Figure 12. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year Class 2 shows an increasing trend in spawning over three generations before this last spawner year, when the year class numbers dropped dramatically. Year Class 1 has remained relatively constant. Year Class 3 has shown a decline in the Lagunitas watershed over the past three generations.

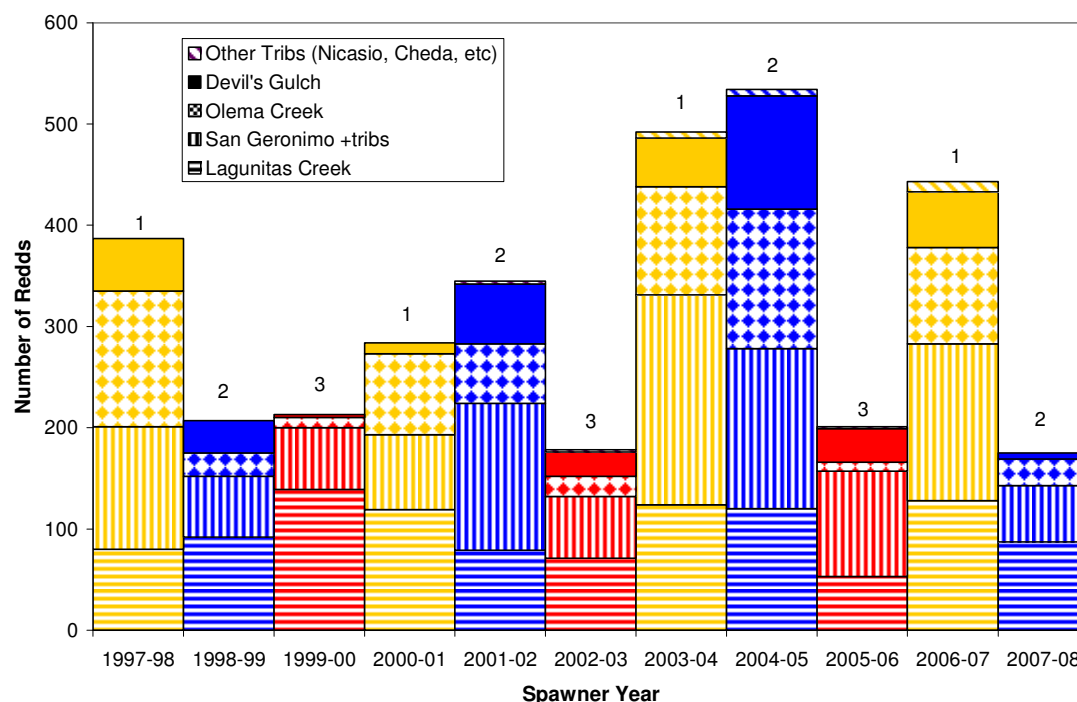


Figure 12. Coho salmon redd results in the Lagunitas watershed by year class winter 1997-1998 through winter 2007-2008. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red) and creeks are designated by pattern (Lagunitas Creek mainstem in horizontal lines, San Geronimo Creek in vertical lines, Olema Creek in checkered, and Devil's Gulch in a solid color).

The contribution of the Lagunitas Creek mainstem to overall spawning activity in the drainage is indicated by data collected by MMWD since 1982 (Appendix A, Table A7) (MMWD 2003, 2005). Coho spawner counts and redd data show that most of the spawning activity takes place on Lagunitas Creek tributaries. Spawning on the mainstem takes place largely in Samuel P. Taylor State Park, upstream of PORE-administered grazing lands.

3.1.4 Redwood Creek Coho Escapement

Survey Timing and Environmental Conditions: Review of the past ten years of coho salmon escapement monitoring information on Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff condition within the watershed (Appendix A, Table A8). Redwood Creek is an unregulated stream with variable environmental conditions that limit flows in the winter season. During most years, access to Redwood Creek depends on the breaching of a sand bar at its confluence with the Pacific Ocean (known as Big Lagoon). Adult coho salmon

upstream migration coincides with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in freshwater under ideal conditions.

The first spawner survey was completed on Redwood Creek on 28 November. With the first major storm event not occurring until the week of December 16, high flows occurred later in the season than previous years. Winter 2007-2008 marked the first spawning season where coho salmon have not been observed in Redwood Creek. Historical information on timing of past runs, rainfall during the run period, spawning activity observed on Redwood Creek can be found in Appendix A, Table A8.

Redwood Creek watershed spawner survey information includes data collected on 9.4 km of the mainstem of Redwood Creek, Reaches 1-3, and two major tributaries, Fern Creek and Kent Creek. No adult coho spawners were observed during the 2007-2008 survey season.

Live Fish (Coho): Spawner surveys of the Redwood Creek watershed were performed between 28 November 2007 and 8 February 2008. No live spawners were observed during any of the surveys.

Live Fish (Steelhead): Steelhead were identified on spawner surveys conducted between 11 January and 7 February. The peak steelhead count in Redwood Creek was observed on 31 January with 12 live adult steelhead. A total of 31 confirmed steelhead adults were seen on the mainstem of Redwood Creek, which is the highest observed number for a spawning season to date. Most live fish (68% of the total count) were observed in survey Reach 2 (Figure 13). Two unidentified fish were seen, one on 31 January and the second on 7 February. In addition, two live adult steelhead and one unidentified live fish were located in the upper reaches of Fern Creek, a tributary to Redwood Creek, the first steelhead and the unknown fish on 31 January and the second steelhead on 7 February. One live adult steelhead was also observed incidentally in late May while operating a downstream migrant trap on Redwood Creek.

Carcasses (Coho): No coho carcasses were observed during surveys within the Redwood Creek watershed. Two unidentified carcasses were also observed during the survey season, one in Reach 1 and one in Reach 2.

Carcasses (Steelhead): Four steelhead carcasses were observed during the Redwood Creek spawner survey season, two in Reach 1 and two in Reach 3. Of the carcasses found, only two were complete enough to sex and measure, both in Reach 3. The first was a male with a length of 85 cm and the second was a female with a length of 80 cm.

Redds (Coho): No confirmed coho redds were observed within the Redwood Creek watershed during the 2007-2008 survey season.

Redds (Steelhead): A total of 12 definite steelhead redds were observed in the mainstem of Redwood Creek between 18 January and 7 February. Steelhead redd observations were primarily concentrated in Reach 2, representing 67% of confirmed steelhead redds. The total density of redds in the 7.4 km mainstem section surveyed was 1.6 redds/km. The mean surface area of the steelhead redds was 3.75 m². There were two definite steelhead redds identified in Fern Creek on

7 February. The number of steelhead redds observed during the 2007-2008 spawning season was higher than the average for the last eight years of surveys (Figure 13).

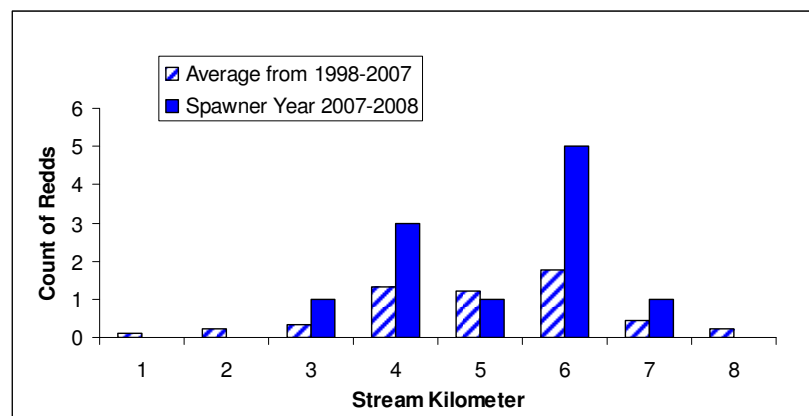


Figure 13. Redwood Creek mainstem steelhead redds per kilometer for 2007-2008 compared with the historical average from 1998-2007.

PLD and AUC Escapement Estimates: As no adult coho were observed during spawner surveys on Redwood Creek, no escapement estimates are available. Historical AUC estimates for Redwood Creek are in Appendix A, Table A8.

Redwood Creek Watershed Escapement History: Escapement estimates for adults in Redwood Creek have been made using both the PLD and AUC methods. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represent the true escapement.

PLD Index Results: The PLD dataset for adult escapement within Redwood Creek includes 16 years of survey information. It should be noted that prior to SY 1997-1998, redds and carcasses were not consistently counted. PLD estimates have ranged from 10 to 171 adults (Appendix A, Table A8). The results of SY 1999-2000, SY 2002-2003, and SY 2005-2006 are not considered representative of actual mainstem escapement due to poor survey conditions. The 2004-2005 spawner surveys had the highest PLD (171 adult coho) in the 16 year survey history. This is believed to be the strongest coho run since documentation of spawners were initiated in SY 1994-1995. This is further supported by the total number of observed redds and carcasses (93 and 76, respectively). The 2007-2008 spawner return was especially disappointing, since the 2004-2005 surveys had such high results, indicating a significant decrease in the year class between returns. Historical coho spawning information for the Redwood Creek watershed, including PLD index, tally of total carcasses, and total redds can be found in Table A8.

Overall trends in coho spawning based on redds observed in the Redwood Creek watershed are shown in Figure 14. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year Class 1 has remained relatively constant over four generations but decreased during spawner year 2006-2007. Year Class 2 shows an increasing trend in spawning since spawner year 1995-1996, with an abrupt crash during the 2007-2008 spawner season. Year Class 3 continues to struggle since a decline beginning with spawner year 1999-2000. Within each year, the data is broken down into the creeks where spawning occurred. Year Class 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. Year Class 2 has a large component of spawning taking place in Kent Creek and Fern Creek. For all years, the majority of spawning occurs in the mainstem of Redwood Creek.

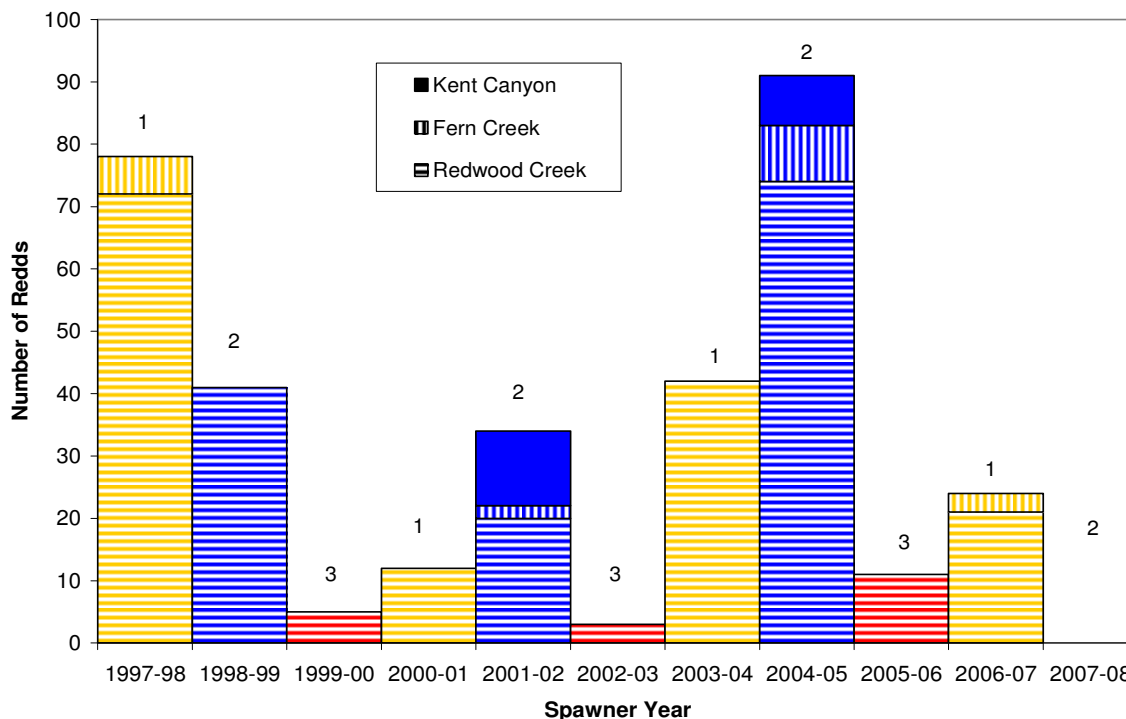


Figure 14. Coho salmon redd results in the Redwood Creek watershed by year class winter 1997-1998 through winter 2007-2008. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red), and creeks are designated by pattern (Redwood Creek in horizontal lines, Fern Creek in vertical, and Kent Creek in a solid color).

Overall trends in coho spawning based on PLD escapement estimates in the Redwood Creek watershed are shown in Figure 15 with similar trends to those observed with number of redds. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year Class 1 has remained relatively constant over the previous four generations but decreased during the spawner year 2006-2007. Year Class 2 shows an increasing trend in spawning since spawner year 1995-1996 until this last spawner year, 2007-2008, when numbers crashed. Year Class 3 continues to struggle since a decline beginning with spawner year 1999-2000, with a slight increase in returning coho observed during the 2005-2006 spawner season.

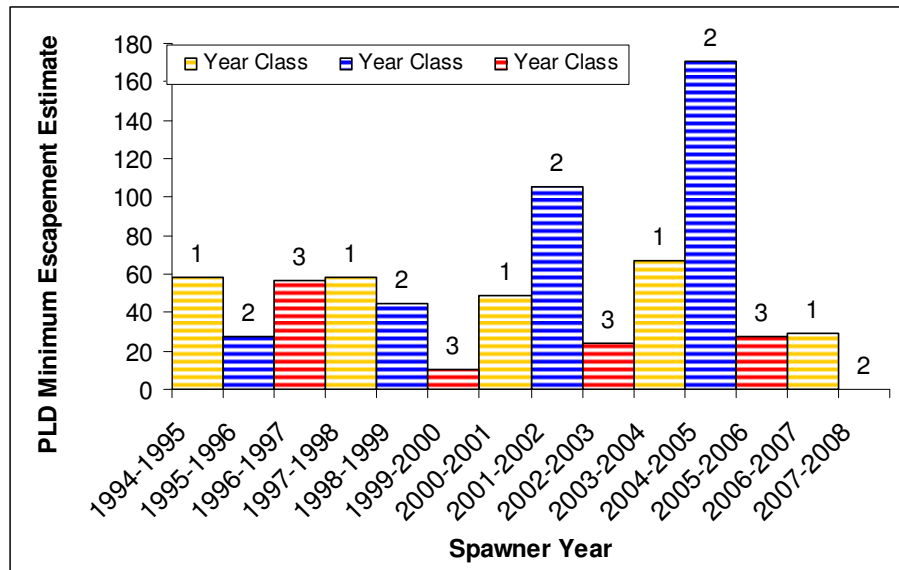


Figure 15. Redwood Creek watershed, coho salmon PLD index escapement results winter 1994-1995 through winter 2007-2008.

Live Fish and Carcass Biotics: Information on live fish and carcasses are collected during each field survey. Sex ratios for live fish are reported for each spawner year in Table 11.

Table 11. Sex ratios and size of live coho within the Redwood Creek watershed, including Redwood Creek mainstem, Fern Creek, and Kent Canyon. Average across years, maximum, and minimum fork length (FL) 1997-2007 compared to 2007-2008.

		Year	Number of Observed Fish	% of measured fish in year	N for FL	Mean FL	FL SD
Average	M	1997-2007				62.0	3.80
	F	1997-2007				57.9	2.80
	J	1997-2007				39.9	3.20
	Unk	1997-2007				56.0	3.37
Max	M	2005-2006	9	24	9	67.2	15.23
	F	2003-2004	42	43	40	60.9	6.39
	J	2006-2007	1	2	1	45	
	Unk	1999-2000	4	25	3	61.7	10.41
Min	M	1999-2000	4	25	4	57.5	9.57
	F	1998-1999	27	33	26	53.5	3.40
	J	2003-2004	22	23	22	36.1	6.71
	Unk	2000-2001	2	3	2	50	0
Current (2007-2008)	M	2007-2008	0				
	F	2007-2008	0				
	J	2007-2008	0				
	Unk	2007-2008	0				
	All		0				

M= Male, F= Female, J=Jack, Unk= Unknown, N= Number of fish measured for FL

The results of carcass measurements show that males are generally between 65-75 cm, with females averaging 57-67 cm and jacks (two year old males) averaging from 37-47 cm. During the 2007-2008 spawner survey season no carcasses were recovered (Table 12).

Table 12. Sex ratios and size of carcasses within the Redwood Creek watershed, including Redwood Creek mainstem, Fern Creek, and Kent Canyon. Average across years, maximum, and minimum fork length (FL) 1997-2007 compared to 2007-2008.

		Year	Number of Observed Fish	% of measured fish in year	N for FL	Mean FL	FL SD
Average	M	1997-2007				63.1	5.36
	F	1997-2007				61.1	5.53
	J	1997-2007				42.2	3.97
	Unk	1997-2007				64.2	3.76
Max	M	2001-2002	19	38	18	71.3	5.23
	F	2000-2001	6	55	5	66.8	2.95
	J	2004-2005	1	2	1	49.0	
	Unk	2004-2005	9	15	1	70	
Min	M	1997-1998	3	13	3	56.0	6.56
	F	1998-1999	4	40	4	52.3	2.63
	J	2002-2003	4	100	4	36.5	8.19
	Unk	1997-1998	7	29	2	60.0	7.07
Current	M	2007-2008	0				
	F	2007-2008	0				
	J	2007-2008	0				
	Unk	2007-2008	0				
	All		0				

M= Male, F= Female, J=Jack, Unk= Unknown, N= Number of fish measured for FL

3.1.5 Pine Gulch Creek Coho Escapement

Survey Timing and Environmental Conditions: Three surveys were conducted in Pine Gulch Creek between 26 December 2007 and 6 February 2008. The mean interval between surveys was 21 days. Seven-day rainfall totals ranged from a low of 0 in during Julian weeks 6 and 7 to a high of 7.93 in during Julian week 4. Average water clarity at the time of surveys ranged from 47 cm to 100 cm.

Live Fish (Coho): One live adult coho female was observed on 14 January.

Live Fish (Steelhead): The peak steelhead count on Pine Gulch Creek was observed on 6 February 2008 with a count of five live adult steelhead. Eighty seven percent of the total live adult steelhead counts were observed in survey Reach 1. Steelhead were observed on spawner surveys from 15 January to 6 February.

Carcasses (Coho and Steelhead): No carcasses were observed on Pine Gulch during any of the surveys.

Redds (Coho): A total of two confirmed redds were observed in the mainstem of Pine Gulch Creek during the 2007-2008 season. Both were observed in Reach 1 on 15 January. The mean surface area of all coho redds was 9.1 m².

Redds (Steelhead): A total of 11 definite steelhead redds were observed on Pine Gulch Creek on 15 January and 6 February. Steelhead redd observations were concentrated in Reach 1, representing 82% of observed steelhead redds. The density of redds in the 9.5 km mainstem section surveyed was 1.2 redds/km. The mean surface area of the steelhead redds was 2.4 m².

PLD and AUC Escapement Estimates: With only one adult coho and no carcasses observed during the spawning season on Pine Gulch Creek, the PLD index for Pine Gulch Creek was one.

Pine Gulch Creek Watershed Escapement History: The dataset for the adult escapement within Pine Gulch Creek includes seven years of survey information following the discovery of one adult coho salmon during the SY 2000-2001. Since this discovery, live adult coho and/or coho spawning activity have been sighted in the watershed during six out of the eight years (Appendix A, Table A9). Summer juvenile coho surveys and spring downstream migrant traps have confirmed that a self-propagating coho run does occur in Pine Gulch Creek, though the last two summer surveys (2007 and 2008) confirmed the absence of any coho juveniles in Pine Gulch Creek.

Pine Gulch Creek Watershed Summary: Year Class 2 appears to be strongest year class on Pine Gulch, followed by Year Classes 3 and 1. Although no returning adults or definite redds were observed during the 2003-2004 spawner year, a basinwide survey conducted on Pine Gulch during the summer of 2004 revealed the presence of juvenile coho in the watershed (Ketcham et al. 2005). While spawning activity was observed in Pine Gulch Creek during the 2007-2008 spawner year, snorkel surveys conducted during the summer of 2008 confirmed the absence of coho from this year class.

3.2 Spring 2008 Outmigrant 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 eleven 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 juveniles observed during the summer 2007 surveys, Pine Gulch Creek was not observed for smolt migration in 2008. Therefore, only Olema Creek data and Redwood Creek data appear below.

3.2.1 Smolt Outmigration Environmental Conditions and Timing

Spring weather patterns, including rainfall and temperature, influence the timing and rate of smolt outmigration. Smolt outmigration historically peaked during Julian weeks 17-19 (late April – early May). On average, the majority of Olema Creek outmigration occurs in weeks 17-18, with the majority of Redwood Creek outmigration occurring during weeks 18-19 (Figures 16 and 17, respectively).

Peak capture for coho smolts/presmolts occurred on Olema Creek in late April during week 17, one week earlier than the historical average (Figure 16). Similarly, during the 2007 season, peak migration occurred two weeks earlier than the average. The earlier migration pattern may be due to the new trapping location, which is approximately 1 km upstream of the trapping location used in years 2004-2006. On Redwood Creek, peak capture of coho smolts occurred in mid-April, during weeks 18 and 19, in accordance with the historical average migration pattern (Figure 17).

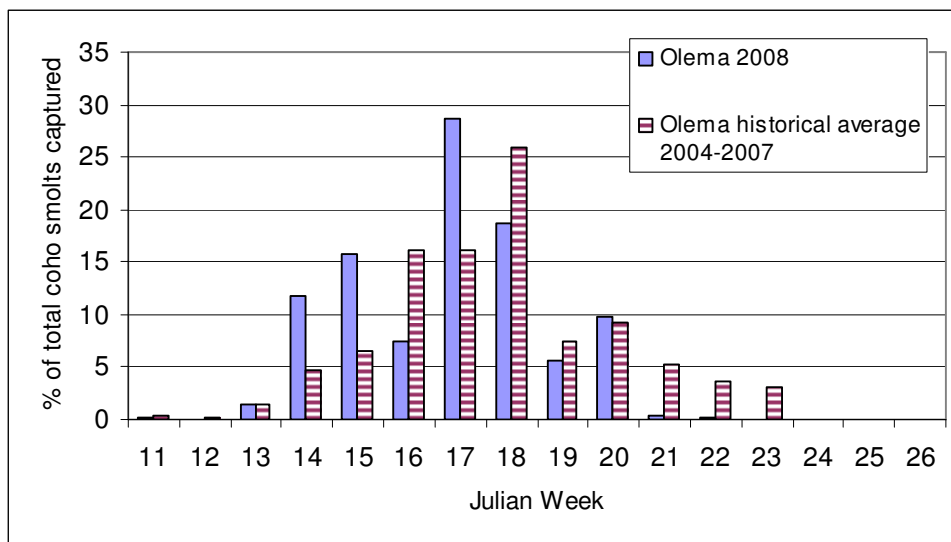


Figure 16. Percent of total smolts captured by Julian week for Olema Creek in 2008 compared to the historical average, 2004-2007.

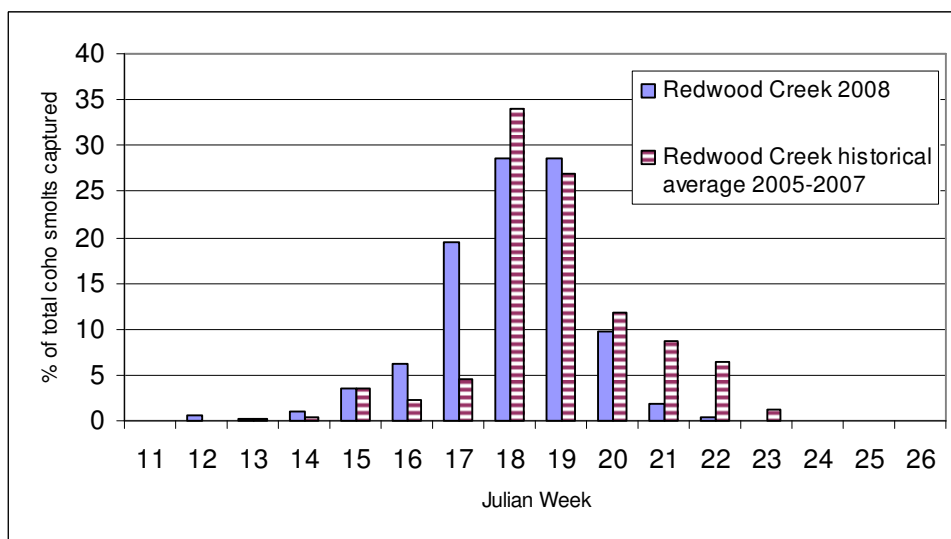


Figure 17. Percent of total coho smolts captured by Julian week for Redwood Creek in 2008 compared to the historical average 2005-2007.

In 2008, downstream migration of coho smolts remained low throughout Julian weeks 11 through 13, with only Olema Creek increasing in smolt capture by Julian week 14. Peak downstream migration occurred at different times for the two creeks sampled. Consistent with the running average, the highest percentage of coho smolts captured in 2008 on Olema Creek occurred during Julian week 17, whereas Redwood Creek smolt capture peaked during Julian weeks 18 and 19.

Spring Outmigration Rainfall: Rainfall amounts were collected from a rain gage located at the Bear Valley Headquarters and represent the rainfall for all trapping operations (Figure 18). In general, conditions remained dry throughout the trapping season, resulting from below-average spring rainfall. Only 0.47 in of rain fell during the observed 2008 season, as opposed to 9.56 in of average precipitation during 1969-2007 seasons.

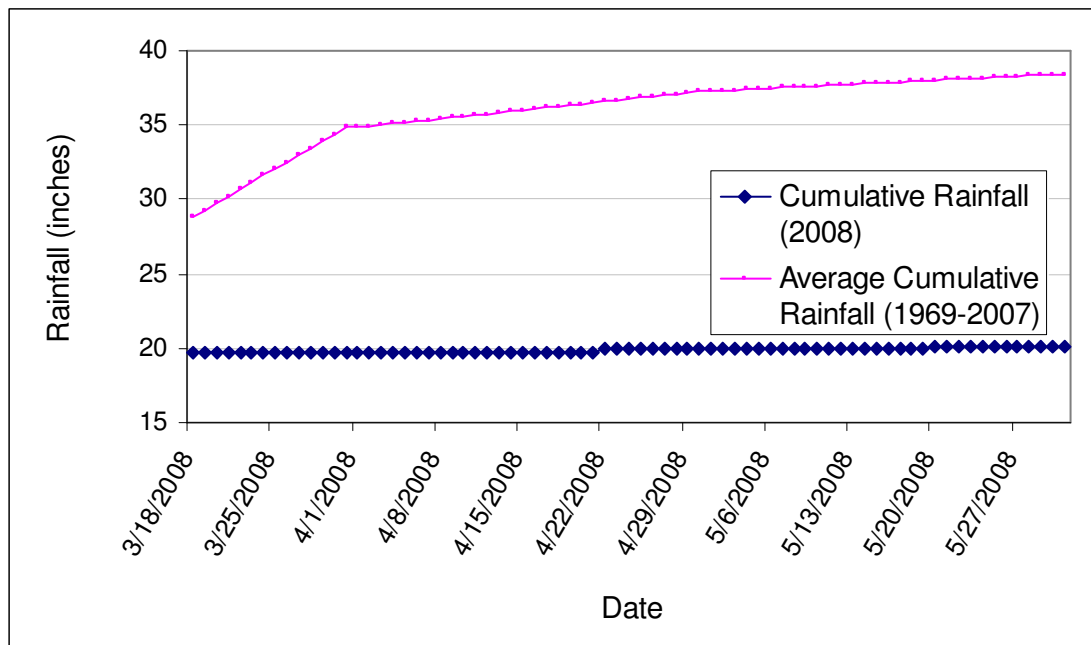


Figure 18. Cumulative rainfall amounts for Bear Valley Headquarters Complex, 18 March-31 May, 2008 compared to average rainfall during the same period, 1969- 2007.

Spring Smolt Trap Water Temperature: Olema Creek had both the highest mean temperature and the greatest range of temperatures in 2008. The mean temperature on Olema Creek was 13.3° C (2.1 SD), compared to a mean of 11.8° C (1.5 SD) on Redwood Creek. Temperatures on Olema Creek ranged from 7.6 to 20.2° C, whereas temperatures on Redwood Creek ranged from 8.2 to 16.6° C.

Water temperatures within trap boxes were within the tolerable temperature range (< 22° C) for coho salmon (Moyle 2002) during the entire trapping season at both trapping locations. However, only Olema Creek had a mean temperature falling within the optimal range for juvenile coho rearing (12 to 14° C) (Moyle 2002), while the average temperature for Redwood (11.8° C) fell just below this range.

3.2.2 Olema Creek Smolt Outmigration Results

During the 2008 outmigrant trapping study, the Olema Creek trap was in place for 74 days (from 18 March through 30 May) and was fully operational for 73 days. A storm caused heavy debris accumulation within the fyke net on 20 April, leaving the trap only partially functional.

The trap captured a total of 934 coho smolts. This is the highest number of coho smolts caught on this trap since trapping began in 2004. Additionally, the trap captured a total of 62 1+ steelhead smolts and nine steelhead parr (Table 13). This is a decline in steelhead smolts compared to 2007. Mark/recapture data stratified by week resulted in an estimated capture probability at 37% throughout the duration of the trapping operation, leading to a total coho smolt estimate of 2,885 ($\pm$ 336 SD) coho smolts.

Also captured during this season were 46 fry, of which 8 were coho and 38 were steelhead. This is a sharp decline from 2007, in which 1,201 fry (62% coho) were trapped. A change in trap mesh size may account for this discrepancy, allowing the smaller fry to escape while the larger

smolts remained trapped. Coho fry capture peaked in mid-May (week 20), and steelhead fry capture peaked in early April (week 15).

A total of three adult steelhead were incidentally captured in the smolt trap during their migration back to the ocean from late March to mid-May. Table 13 shows a summary of all salmonids captured on the Olema Creek trap between 2004 and 2008.

Table 13. Summary of salmonid information for Olema Creeks trap operations, 2004-2008. A coho production estimate was not calculated for 2004 due to insufficient recapture information.

Watershed	Year	Trap operation dates		Steelhead					Coho		Coho production estimate	
		From	To	Juvenile			Adult		Smolt	Fry	Estimate	SD
				Smolt	Parr	Fry	Resident	Ocean-run				
Olema Creek	2004	30-Mar	28-May	13	5	140	0	0	229	32	N/A	N/A
	2005 ^a	1-Apr	9-May	9	8	1,218	0	1	87	14	362	± 145
	2006 ^b	10-Apr	9-Jun	6	19	497	0	0	368	51	3,793	± 784
	2007	14-Mar	27-May	233	134	462	2	12	330	739	1,485	± 207
	2008	18-Mar	30-May	62	9	38	0	3	934	8	2,885	± 336

Coho and steelhead presmolts are included in the coho and steelhead smolt totals.

^a Trapping discontinued May 9 due to high flows and presence of California red-legged frog tadpoles. Trap was not reinstalled.

Estimate is calculated using the Chapman modification of the Petersen estimate equation.

^b Trap was functional 45 of 54 operational days due to high flows.

3.2.3 Redwood Creek Smolt Outmigration Results

During the 2008 outmigrant trapping study, the Redwood Creek trap was in place and fully operational for 73 days (from 18 March through 30 May). The trap captured a total of 890 coho smolts and 18 steelhead smolts (Table 14). Mark/recapture data stratified by week resulted in an estimated capture probability at 39%, resulting in a total coho smolt estimate of 2,046 (± 163 SD).

Also captured during this season were 154 fry, of which 151 (98%) were steelhead. This marks a decline from 2007, in which 682 fry (86% steelhead) were trapped. Again, the change in trap mesh size may account for this change. Coho fry capture peaked in late March (week 13) and steelhead fry capture peaked in late April (week 17). Table 14 shows a summary of all salmonids caught on the Redwood Creek smolt trap between 2005 and 2008.

Table 14. Summary of salmonid results for Redwood Creek trap operations, 2005-2008.

Watershed	Year	Trap operation dates		Steelhead			Adult		Coho		Coho production estimate	
		From	To	Juvenile			Resident	Ocean-run	Smolt	Fry	Estimate	SD
				Smolt	Parr	Fry						
Redwood Creek	2005	27-Mar	31-May	1	1	344	0	0	301	535	1,977	± 430
	2006	18-Apr	9-Jun	18	0	24	0	0	1,048	27	2,502	± 257
	2007	16-Mar	27-May	17	5	585	0	1	330	97	1,353	± 307
	2008	19-Mar	30-May	18	3	151	0	0	890	3	2,046	± 163

Coho and steelhead presmolts are included in the coho and steelhead smolt totals.

3.2.4 Smolt Size and Condition

Length and weight data provide critical information that contributes to the 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 2008 smolt trap operations, staff recorded fork lengths (FL) and weights of a subsample of fish caught in the trap.

The statistical analysis comparing the 2008 mean measurements to historical mean measurements for smolts assumes that there is no correlation between years within each creek. Due to the three-year life cycle of coho, testing for correlation requires a longer dataset than currently exists for smolts in any of the three creeks. Testing for correlation between years will be performed as longer datasets become available. Analyses of fork-length frequency, weight-length relationships, and Fulton Condition Factor are included for coho salmon and steelhead for both smolt trap locations.

Fork Length and Weight: The coho fork lengths recorded throughout the spring monitoring efforts on Olema Creek ranged from 86-145 mm. The highest frequency of fork lengths for coho smolts occurred between 106-110 mm (one length category smaller than that of 2007), representing 23% of the subsample of coho. On Olema Creek, a smaller range of lengths and weights for coho smolts was observed in 2008 compared to previous years, with no coho exceeding 145 mm or 23.2 g. The 2008 mean length of coho smolts was not significantly different ($p=0.55$) from the historical mean length (2004-2007) using a two-sided hypothesis test and an alpha value of 0.05, indicating that the 2008 mean length was consistent with the historical mean length.

Unlike the mean length of coho smolts, however, using a two-sided hypothesis test with the same parameters, the 2008 mean weight was significantly different ($p<0.0001$) than the 2004-2007 mean weight. The point estimate of the difference between the historical mean weight and the 2008 mean weight was -1.52 with a 95% confidence interval of -2.05 to -0.99. These values indicate that the 2008 mean weight was smaller than the historical mean weight. Figures 19 and 20 show representations of fork lengths and fish weights, respectively, for coho caught on Olema Creek.

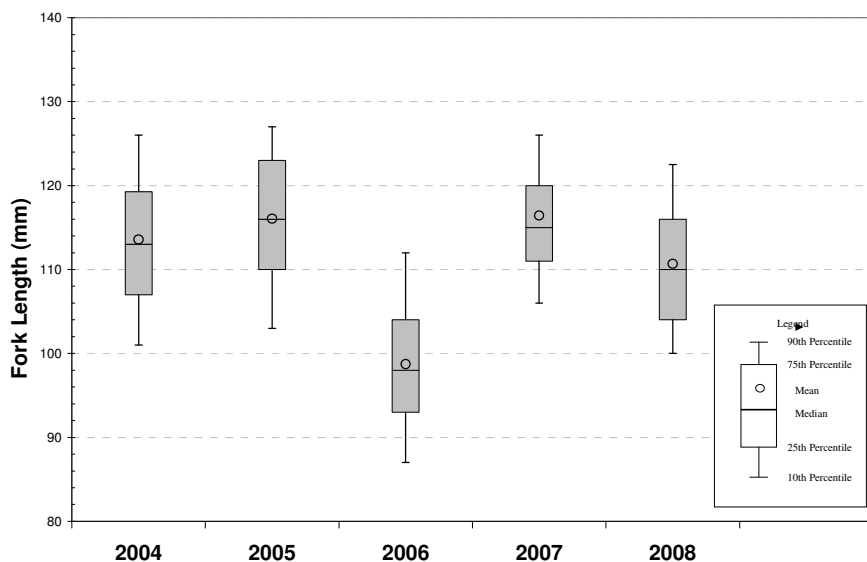


Figure 19. Fork length of coho smolts in Olema Creek, 2004-2008.

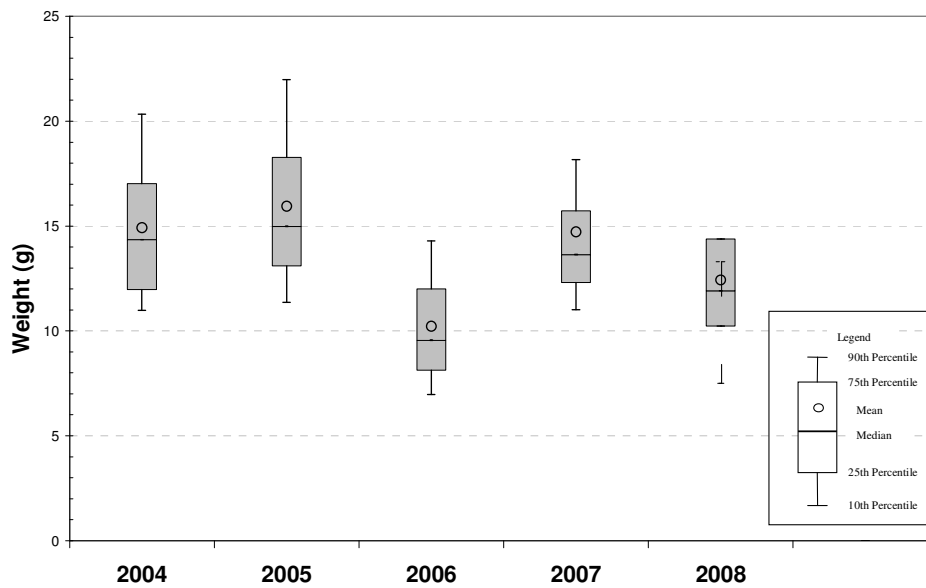


Figure 20. Weight of coho smolts in Olema Creek, 2004-2008.

A histogram is provided for Olema Creek steelhead (Figure 21). Average frequencies are also provided as a comparison between the smolt production in 2008 and the historical average from previous years surveyed. Such comparisons can be used to determine if seasonal or anthropogenic events caused a detrimental effect to the health of the population. The steelhead fork lengths recorded throughout the spring monitoring of Olema Creek ranged from 56-202 mm. The highest frequency of fork lengths for steelhead smolts occurred between 126-130 mm (six length categories smaller than that of 2007), representing 13% of the sample. For Olema Creek steelhead smolts, the 2008 average length was significantly different ($p=0.02$) from the 2004-2007 average length using a two-sided hypothesis test and an alpha value of 0.05. The point estimate of the difference between the historical mean length and the 2008 mean length was -11.88 with a 95% confidence interval of -22.14 to -1.61, indicating that the 2008 mean length was smaller than the historical mean length.

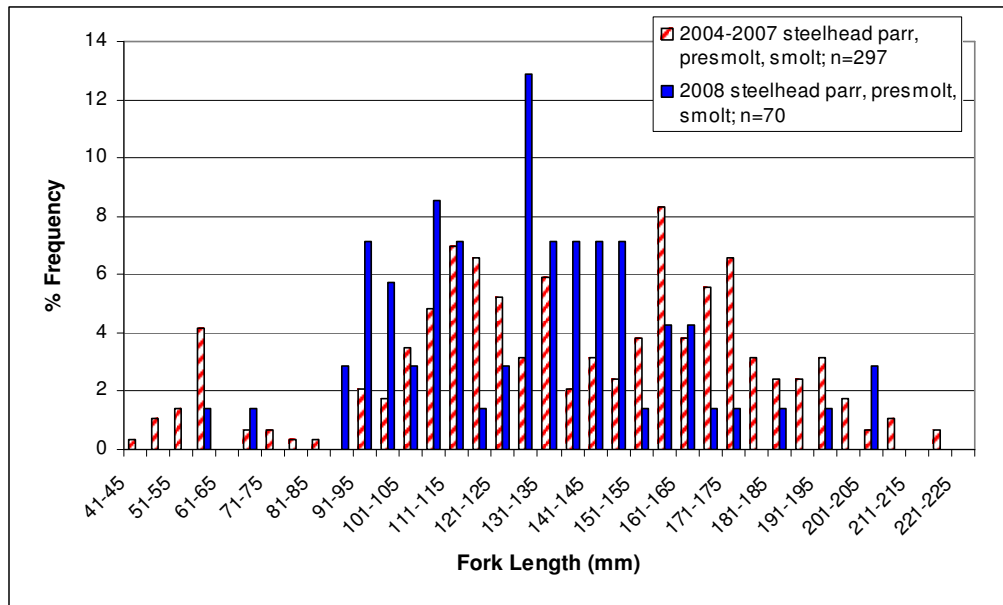


Figure 21. Steelhead smolt fork lengths in 5 mm increments by percent of frequency for Olema Creek in year 2008 compared to the 2004-2007 historical average.

The 2008 average weight was significantly different ($p=0.01$) than the 2004-2007 average steelhead smolt weight. The point estimate of the difference between the historical mean and the 2008 mean was -8.97 with a 95% confidence interval of -15.88 to -2.05. This indicates that the 2008 mean weight was less than the historical mean weight.

The coho fork lengths recorded throughout the spring monitoring of Redwood Creek ranged from 37-171 mm. The highest length frequency for smolts (22%) was observed in the 106-110 mm length category, two length categories larger than the most frequent historical size class (1996, 2005-2007). For Redwood Creek, the 2008 mean length of coho smolts was significantly different ($p<0.0001$) than the 2005-2007 historical mean length using a two-sided hypothesis test and an alpha value of 0.05. The point estimate of the difference between the 2008 mean and the historical mean was 4.78 with a 95% confidence interval of 3.91 to 5.64, indicating that the 2008 mean was larger than the historical mean.

Using the same test, the 2008 mean coho smolt weight was also significantly different ($p=0.007$) than the historical mean value. The point estimate of the difference between the 2008 mean weight and the historical mean weight is 0.60 with a 95% confidence interval of 0.17 to 1.04. This indicates that the 2008 mean weight is larger than the 2005-2007 historical mean weight. This added mass increases the chances of ocean survival. In Redwood Creek, the mean smolt length and weight for coho between 2005 and 2008 were 105 mm and 11.26 g. Length and weight of outmigrating smolts were similar in 2005 and 2006, with much larger smolts observed in 2007 and 2008 (Figures 22 and 23).

Length frequencies for coho fry on Redwood Creek were shorter than those of the historical average; however, the particularly low sample size for 2008 fry may bias this result. Also, most Redwood coho fry were caught earlier in 2008 (Week 13) than usual (Week 16), so they did not have as much time to grow.

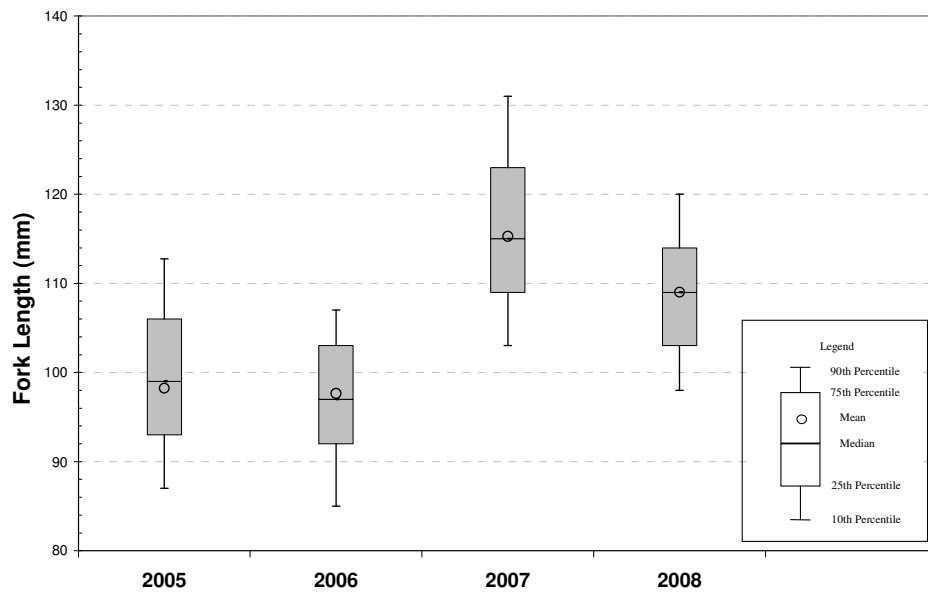


Figure 22. Fork length of coho smolts in Redwood Creek, 2005-2008.

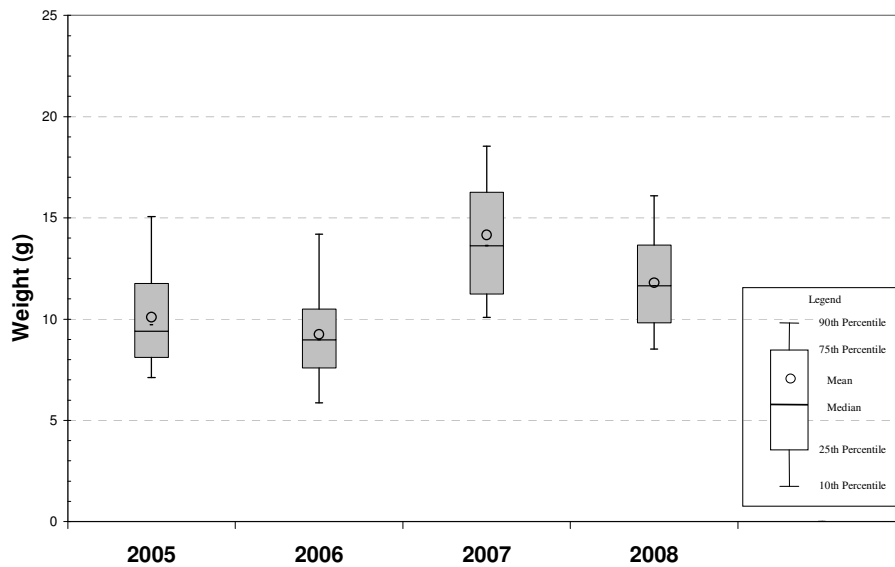


Figure 23. Weight of coho smolts in Redwood Creek, 2005-2008.

Steelhead fork lengths on Redwood Creek ranged from 25-192 mm, with the highest length frequency of smolts (29%) occurring between 161-170 mm (Figure 24). For steelhead smolts, the 2008 mean length was not significantly different ($p=0.45$) than the 2006-2007 historical average using a two-sided hypothesis test with an alpha value of 0.05. The 2008 mean weight also was not significantly different ($p=0.17$) than the historical mean. This indicates that the 2008 mean length and weight were consistent with the historical mean length and weight. The sample sizes were smaller than ideal for a two-sided hypothesis test. No steelhead smolts were measured in

2005 so only 2006-2007 are included in the historical mean. Fewer length categories of steelhead were represented in 2008.

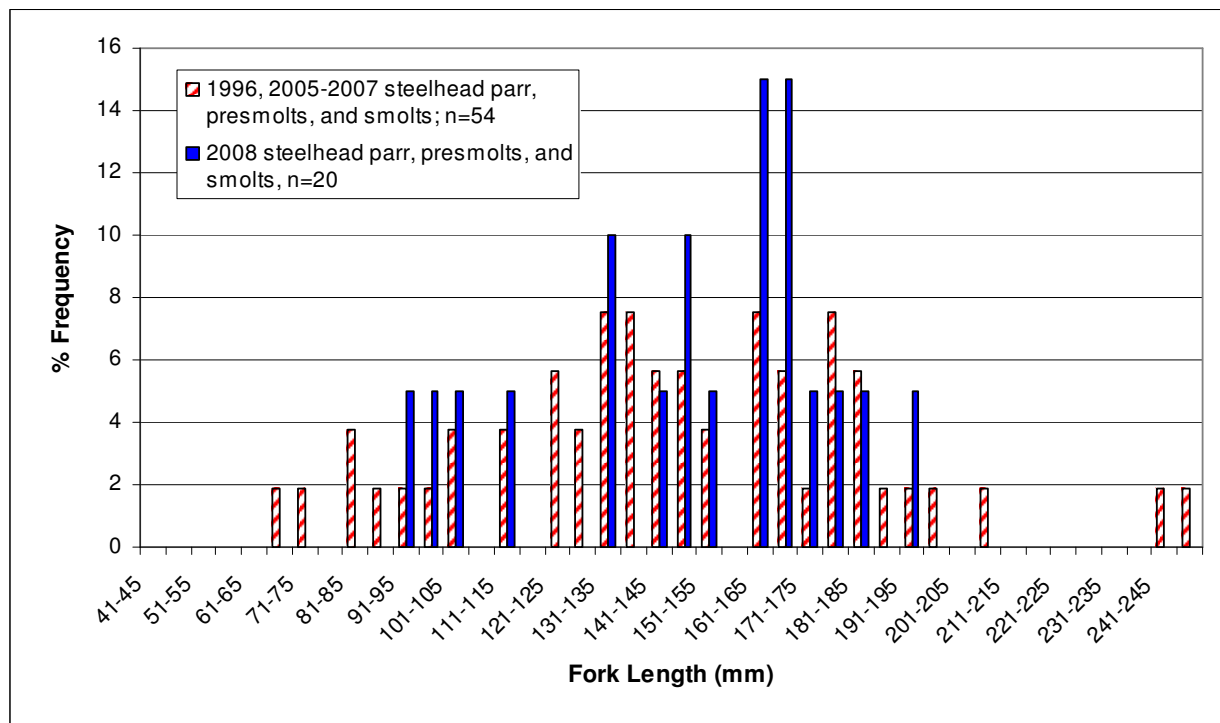


Figure 24. Steelhead smolt and lengths in 5 mm increments by percent of frequency for Redwood Creek in year 2008 compared to the 2005-2007 historical average.

The highest fork length frequencies for coho smolts in both Olema and Redwood Creeks were observed in the 106-110 mm length category. While this is true for 2008, this has not been the pattern for all years. When the running average of all fish measured is compared between both watersheds for all years, the average coho smolt produced from Redwood Creek is approximately 10 mm shorter than the average coho smolt observed in Olema Creek.

No trends were observed when comparing the running average for steelhead between both monitored watersheds. This could be an artifact of the various life cycle strategies of steelhead resulting in captures of multiple life stages within each trapping season. Further data analysis or recording modifications may be required to determine if variations in steelhead fork length frequencies do exist between watersheds.

Fulton Condition Factor: Combined length and weight data provide critical information that contributes to the understanding of fish health and condition at the time of outmigration. Length is the principal factor affecting the weight of fishes, however there can be significant differences in weight distribution between 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 Fulton Condition Factors (K) to establish comparable indices of condition (Murphy and Willis 1996). Table 15 shows the comparison between coho smolt length, weight, and K-factors for all years of trapping on Olema. Historical K-factor tables for Olema and Redwood creeks can be found in Appendix A, Tables A10-A13. Graphs showing the weight-length relationships for coho and steelhead on Olema Creek and Redwood Creek are located in Appendix A, Figures A2-A6.

On Olema Creek, the 2008 mean K-factor was significantly different ($p < 0.0001$) than the historical mean K-factor. The point estimate of the difference between the 2008 mean K-factor and the historical mean K-factor was -0.09 with a 95% confidence interval of -0.10 to -0.08. This test indicates that the 2008 mean K-factor was smaller than the historical mean K-factor.

Table 15. Comparison of mean and median coho smolt length, weight, and K-factor calculated for the trapping location at Olema Creek. Average across years, max, min 2004-2007 compared to 2008.

	Year	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
Average	2004-2007		111.20	8.41		13.95	2.54		0.99	0.06
Max	2007	191	116.43	10.99	115.00	14.72	4.73	13.64	0.91	0.07
Min	2006	205	98.73	9.59	98.00	10.22	3.08	9.55	1.04	0.11
Current	2008	386	110.68	9.19	110.00	12.43	3.20	11.91	0.90	0.09

Table 16 provides a comparison between steelhead smolt length, weight, and K-factors for all years of trapping on Olema Creek. The 2008 mean K-factor for steelhead smolts on Olema Creek was also significantly different ($p = 0.01$) from the 2004-2007 mean K-factor. The point estimate of the difference between the 2008 mean K-factor and the historical mean K-factor was -0.06 with a 95% confidence interval of -0.10 to -0.01. This indicates that the 2008 mean K-factor was smaller than the historical mean K-factor.

Table 16. Comparison of mean and median steelhead smolt length, weight, and K-factor calculated for the trapping location at Olema Creek. Average across years, max, min 2004-2007 compared to 2008.

	Year	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
Average	2004-2007		150.47	25.69		62.29	44.99		0.98	0.02
Max	2004	11	176.55	15.38	176.00	55.31	14.37	50.60	0.99	0.09
Min	2005	6	127.17	32.45	128.50	22.93	15.85	22.25	0.94	0.13
Current	2008	34	141.00	25.74	138.00	27.27	13.01	24.88	0.92	0.09

Table 17 provides a comparison of coho smolt length, weight, and K-factor for coho smolts caught during all years of operation on Redwood Creek. A two-sided hypothesis test with an alpha value of 0.05 shows that the 2008 mean K-factor for coho smolts was significantly different ($p < 0.0001$) than the historical mean K-factor. The point estimate of the difference between the 2008 mean and the historical mean was -0.07 with a 95% confidence interval of -0.08 to -0.06, indicating that the 2008 mean was smaller than the historical mean.

Table 17. Comparison of mean and median coho smolt length, weight, and K-factor calculated for the trapping location at Redwood Creek. Average across years, max, min 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		104.23	9.62		11.26	2.57		0.97	0.02
Max	2007	213	115.28	10.91	115.00	14.16	4.08	13.63	0.90	0.07
Min	2006	412	97.65	8.42	97.00	9.25	2.41	8.98	0.98	0.07
Current	2008	295	108.95	8.79	109.00	11.77	2.71	11.64	0.90	0.10

Table 18 provides a comparison of steelhead smolt length, weight, and K-factor for steelhead smolts caught during all years of trapping operations on Redwood Creek. The 2008 mean K-factor was not significantly different ($p=0.32$) than the 2006-2007 historical average using a two-sided hypothesis test with an alpha value of 0.05. The sample sizes were smaller than ideal for a two-sided hypothesis test. No steelhead smolts were captured on Redwood Creek in 2005 so the historical average includes only fish from 2006 and 2007.

Table 18. Comparison of mean and median steelhead smolt length, weight, and K-factor calculated for the trapping locations at Redwood Creek. Average, max, min 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		154.71	31.97		33.30	14.64		0.88	0.01
Max	2007	16	177.31	13.39	177.00	43.65	12.87	42.00	0.77	0.13
Min	2006	10	132.10	13.91	134.5	22.94	5.91	22.01	0.99	0.11
Current	2008	12	159.33	22.42	163.00	40.47	20.16	41.45	0.96	0.36

The 2008 average coho smolt fork length was 110.68 mm in Olema Creek and 108.95 mm in Redwood Creek. The mean weight of coho smolts was 12.43 g in Olema Creek and 11.77 g in Redwood Creek. The 2008 mean coho smolt K-factor was 0.90 for both Redwood Creek and Olema Creek.

The average steelhead smolt fork length sampled in 2008 was 141.00 mm in Olema Creek and 159.33 mm in Redwood Creek. The mean weight of steelhead smolts ranged was 27.27 g in Olema Creek and 40.47 g in Redwood Creek. Unlike the coho, the 2008 mean K-factor was dissimilar for Redwood Creek (0.96) and Olema Creek (0.92).

3.2.5 Smolt Trap Summary of Non-salmonid Total Catch

A summary of the non-salmonid species captured in the 2008 smolt traps is shown for Olema Creek in Table 19 and Redwood Creek in Table 20. No non-native fish were trapped in either creek during the 2008 smolt trapping season. Historical non-salmonid catch information is in Appendix A, Tables A14 and A15.

On Olema Creek, the majority of the non-salmonid catch was comprised of sculpin species (50%), California roach (34%), and threespine stickleback (7%), which have consistently been the best-represented non-salmonids caught in the Olema Creek smolt trap. The total number of non-salmonids trapped was lower in 2008 compared to the historical average. This decrease was especially pronounced in the threespine stickleback numbers, which represent 53% of the historical average non-salmonid catch and only 7% of the 2008 catch. A change in mesh size on the trap box from one-eighth inch to one-quarter inch mesh might have influenced the number of smaller fish caught. This change in mesh size was made in an effort to allow smaller salmonid fry to pass through the trap while retaining the larger fish in the box. As stickleback tend to be between 30-50 mm long (Moyle 2002), the fish in the smaller size ranges might have had shallow enough bodies to slip through the one-quarter inch mesh and out of the trap.

Sculpin species and rough-skinned newts were the most common of the represented non-salmonid species in 2008 on the Redwood Creek trap, representing 53% and 21% of the catch, respectively. Threespine stickleback (13%) and crayfish (12%) were also caught frequently. Total non-salmonid catch also declined on Redwood Creek, especially for the threespine

stickleback, which made up 94% of the historical average catch. As on Olema Creek, the change in mesh size may have contributed to the lowered non-salmonid catch on Redwood Creek in 2008.

Table 19. Summary of non-salmonid information for Olema Creek trap operations 2008 compared to 2004-2007 historical averages.

Watershed	Year	Trap dates		LAM	RO	SCU	STK	SUC	BF	CRAY	RLF	OTH	WPT	Totals
		From	To											
Olema Creek	2008	18-Mar	30-May	2	158	228	30	2	11	17	7	1	1	460
Average 2004-2007				22	1,223	340	1,960	86	66	9	13	1	2	3,722

Species Code: LAM = lamprey spp., PL = Pacific lamprey, RO = California roach, SCU = sculpin spp., STK = threespine stickleback, SUC = Sacramento sucker, BF = bullfrog (non-native), CRAY = signal crayfish, RLF = California red-legged frog, WPT = western pond turtle, OTH= Chinook salmon, green sunfish (non-native), golden shiner (non-native), rough-skinned newt, and California newt

Table 20. Summary of non-salmonid information for Redwood Creek trap operations 2008 compared to 2005-2007 historical average.

Watershed	Year	Trap dates		LAM	SCU	STK	CRAY	RLF	RSN	CAN	Totals
		From	To								
Redwood Creek	2008	19-Mar	30-May	0	151	38	33	0	61	1	284
Average 2005-2007				0	83	1,839	17	0	19	5	1,963

Species Code: GSH = golden shiner (non-native), LAM = lamprey spp., PL = Pacific lamprey, RO = California roach, SCU = sculpin spp., STK = threespine stickleback, SUC = Sacramento sucker, BF = bullfrog (non-native), CRAY = signal crayfish, RLF = California red-legged frog, RSN = rough-skinned newt, WPT = western pond turtle, CAN = California newt

3.3 Juvenile Coho Salmon Basinwide Survey Results

Juvenile monitoring results are provided for Olema Creek, Redwood Creek, and Pine Gulch Creek. For detailed results at each location, please refer to Reichmuth et al. 2008.

3.3.1 Olema Creek

The 2008 summer habitat survey of Olema Creek was initiated at monument tag 36, at the Vedanta Bridge, and continued upstream to monument tag 115, upstream of the horse crossing at the Five Brooks horse pasture. The measured basinwide survey length for the main channel was 8.3 km. The survey was cut short due to rainfall events at the end of October 2008.

Basinwide snorkel surveys were conducted on 7.8 km of the Olema Creek mainstem starting at the Vedanta Retreat Bridge and ending at the confluence with John West Fork Creek. Snorkel surveys in the area around the town of Olema were avoided based upon water quality conditions not meeting contact recreational use standards near the time of the surveys. This water quality monitoring information has been collected as part of the total maximum daily load (TMDL) monitoring process in collaboration with the Regional Water Quality Control Board. Due to rainfall during the last part of the Olema Creek surveys, the final 0.5 km of the basinwide habitat survey was not snorkeled, as increased flow caused significant changes in habitat and fish movement between units.

Habitat Survey: A total of 531 mainstem habitat units were identified in the 8.3 km Olema Creek survey area. Pool units were the dominant habitat type, measuring a total of 5.4 km. Overall habitat composition was 63% pool, 20% riffle, 15% flatwater, and 2% dry (Table 21). Intermittent conditions were observed approximately 9.8 km upstream from the mouth of Olema Creek. Side channel and backwater units were also measured but not incorporated into the

basinwide habitat analysis. Flatwater and riffle habitat types made up 71% of the total side channel habitat composition. Overall, 408 m of side channel habitat and 347 m of backwater habitat units were measured during the basinwide habitat survey. Total wetted survey length was 8,306 m and was used to calculate side channel density and backwater density, which were 4.9 m per 100 m and 4.2 m per 100 m, respectively. Compared to previous years, the backwater density increased and the side channel density decreased.

Table 21. Habitat composition of Olema Creek coho survey area for 2008. Measured total length is used to calculate percentages rather than established survey length based on monument tags.

Unit Type	Total length (m)	% of length	# of units	% of units
Pool	5,371	63	236	44
Flatwater	1,270	15	104	20
Riffle	1,664	20	172	32
Dry	154	2	19	4
Total	8,459	100	531	100

Woody debris information collected during the basinwide habitat survey is summarized for 2005-2008 (Table 22, Figure 25) and is used to identify trends in woody debris availability and recruitment trends over time. Within Olema Creek, the density of rootwads has increased over the past three years, starting at 0.8 rootwads/100 m in 2005 and maximizing at a density of 1.5 rootwads/100 m in 2008. The density of large woody debris (LWD) jams has decreased, with a maximum of 0.6/100 m in 2005 and a minimum of 0.4/100 m in 2008. The density of 10-20 cm woody debris has fluctuated, with a maximum of 3.7/100 m in 2005 and a minimum of 1.5 in 2007. All other woody debris metrics have not changed dramatically in the past four years of monitoring.

Table 22. Summary of basinwide instream woody debris (WD) per 100 m during summer base flow conditions on Olema Creek; average 2004-2007 compared to 2008. Woody debris must be >2 m in length to be counted.

Field season	Survey length (# 100 m sections)	Rootwads density per 100 m	LWD Jams density per 100 m	SWD Jams density per 100 m	10-20cm WD density per 100 m	20-50cm WD density per 100 m	>50cm WD density per 100 m
Average	79.0	0.8	0.5	0.8	3.5	2.7	0.9
2008	83.1	1.5	0.4	0.5	2.2	1.9	0.3

LWD Jam= large woody debris jam (jams composed of 10 or more pieces of >10 cm diameter woody debris), SWD Jam= small woody debris jam (jams composed of 10 or more pieces of <10 cm diameter woody debris)

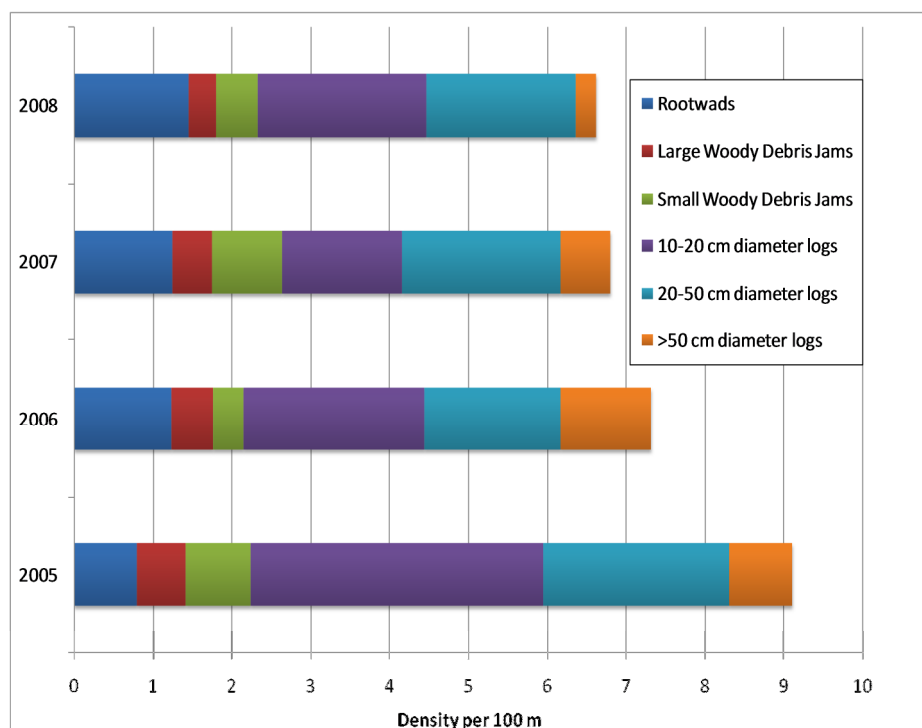


Figure 25. Instream woody debris, by type, per 100 meters in wetted length on Olema Creek, 2005-2008.

Snorkel Counts: In 2008, a total of 474 habitat units were delineated within the 7.8 km Olema Creek snorkel survey area, with pool units representing 63% of all surveyed units. Snorkel surveys were conducted on 25% of the delineated pools with coho being observed in 83% of the sampled pools. A total of 984 coho were counted in the 53 snorkeled pools, giving a raw average of 18.57 coho per pool. Historically, coho have been observed in 69-100% of the pools snorkeled.

Thirteen of the 53 snorkeled pools (25%) were electrofished within a day following the snorkel counts. In addition to the 13 electrofished pools, one pool was resnorkeled 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. A summary of the snorkel counts for Olema Creek in 2008 is presented in Table 23. This table includes both the raw total number of coho counted in the snorkel surveys and the calibrated total number of coho. The calibrated coho count is derived by multiplying the raw coho count by a scaling factor calculated from the comparison of snorkel and electrofishing counts.

Table 23. Summary of coho snorkel counts in Olema Creek, 2004-2008.

Year	Total snorkel survey stream length (km)	Total number of habitat units	Number of Pools			Coho Counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2004	13.3	825	348	69	69	5,751	4,473
2005	11.9	671	318	74	74	8,527	6,955
2006	11.6	859	324	75	52	397	415
2007	11.8	917	368	89	86	6,679	7,811
2008	7.8	474	211	53	44	984	836

Coho Basinwide Estimate: Coho densities (by both pool length and calibrated pool surface area) and a population estimate with 95% confidence interval were calculated for the coho survey area, and are shown in Table 24. The 2008 coho population estimate for Olema Creek is $3,328 \pm 696$. While this is the second lowest population estimate since monitoring began in 2003 and considerably lower than the 2005 estimate of the same year class, it should be noted that this estimate is based on a 7.8 km reach; past years have included estimates based on 11 to 12 km reaches.

Table 24. Coho density and population estimates; Olema Creek coho survey area, 2004-2008.

Year	Total snorkel survey stream length (km)	Avg. Coho per pool		Density		Population estimate	Variance	95% confidence interval
		Raw	Calibrated	Coho/m	Coho/m ²			
2004	13.3	83.3	64.83	3.199	0.864	22,561	14,740,788	$\pm 8,183$
2005	11.9	115.2	93.98	3.613	1.025	29,887	22,537,780	$\pm 9,974$
2006	11.6	5.29	5.53	0.297	0.092	1,793	169,577	± 869
2007	11.8	75.04	87.77	4.175	1.312	32,298	3,771,898	$\pm 4,018$
2008	7.8	18.57	15.77	0.500	0.130	3,328	102,060	± 696

3.3.2 Redwood Creek

The 2008 summer habitat survey of Redwood Creek was initiated at the spring smolt trap site location adjacent to the Muir Beach Picnic Area and continued upstream to monument tag 74, within the Mt. Tamalpais State Park. The measured basinwide survey length for the main channel was 8.5 km. A total of 726 mainstem habitat units were identified within the survey area.

Habitat Survey: Pool units were the primary habitat type, measuring a total of 4.2 km. Overall habitat composition by length was 49% pool, 21% riffle, and 18% flatwater (Table 25). Due to the low water year, Redwood Creek became intermittently dry within the first kilometer of the creek, and 940 m (11% of the surveyed length) was dry. Flatwater and riffle habitat types accounted for 75% of the side channel habitat composition. A total of 115 m of side channel habitat and 55 m of backwater units were also measured during the basinwide habitat survey but were not incorporated into the basinwide habitat analysis. Total wetted length of the surveyed area was 7,521 m and was used to calculate the densities of side channel and backwater habitat, 1.5 m per 100 m and 0.7 m per 100 m, respectively. The density of both side channel habitat and backwater habitat on Redwood Creek in 2008 declined when compared to previous years, possibly due in part to the low water levels at the time of the habitat surveys.

Table 25. Habitat composition of Redwood Creek coho survey area 2008.

	Total length (m)	% of length	# of units	% of units
Pool	4,182	49	244	34
Flatwater	1,525	18	173	24
Riffle	1,814	21	224	31
Dry	940	11	85	12
Total	8,461	99 ^a	726	101 ^a

^a Percents do not add up to 100 due to rounding.

In addition to habitat, woody debris information collected during the basinwide habitat survey is summarized for 2005-07 (Table 26, Figure 26) and is used to identify trends in woody debris availability and recruitment trends over time. Within Redwood Creek, the densities generally

held at previous levels, with a slight decrease in rootwad density and a slight increase in the density of woody debris pieces of 20 to 50 cm in diameter.

Table 26. Summary of basinwide instream woody debris (WD) per 100 m during summer base flow conditions; average 2005-2007 compared to 2008. Woody debris must be >2 m in length to be counted.

Field season	Survey length (# 100 m sections)	Rootwads density per 100 m	LWD Jams density per 100 m	SWD Jams density per 100 m	10-20cm WD density per 100 m	20-50cm WD density per 100 m	>50cm WD density per 100 m
Average	90.4	0.8	0.5	0.7	3.4	2.6	0.8
2008	85.0	0.9	0.6	0.8	2.9	2.9	0.7

LWD Jam= large woody debris jam (jams composed of 10 or more pieces of >10 cm diameter woody debris), SWD Jam= small woody debris jam (jams composed of 10 or more pieces of <10 cm diameter woody debris)

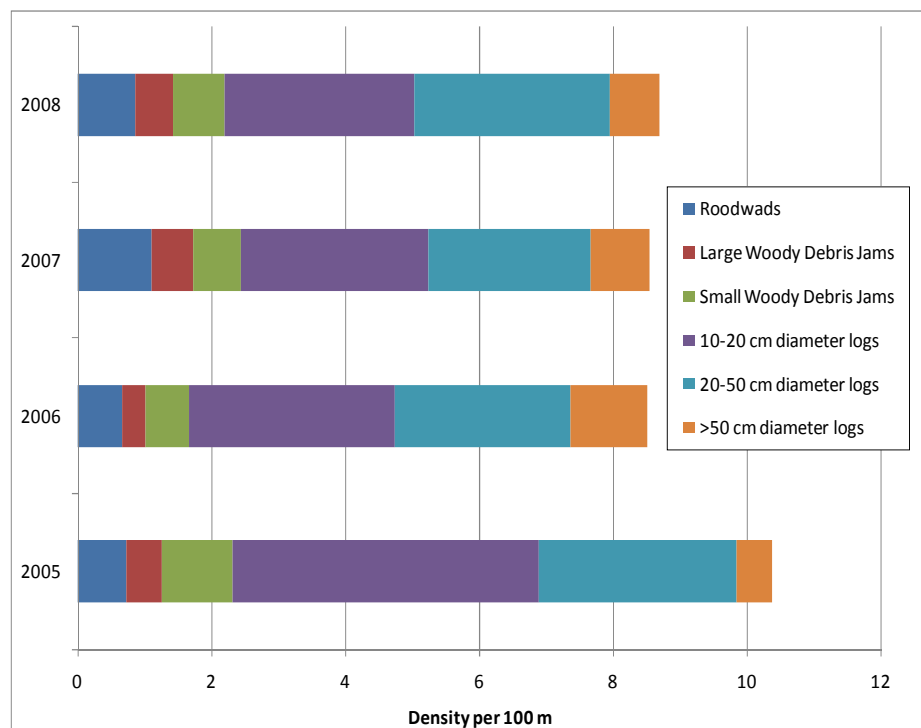


Figure 26. Instream woody debris, by type, per 100 meters in wetted length on Redwood Creek, 2005-2008.

Snorkel Counts: Snorkel surveys were conducted on 27% of the delineated pools with coho being observed in 33% of the sampled pools. A total of 113 coho were counted in the 66 snorkeled pools, giving a raw average of 1.71 coho per pool.

Eighteen of the 66 snorkeled pools (27%) were electrofished within a day following the snorkel counts. *Microfish* population estimates for the electrofished pools were used to calibrate the snorkel counts. A summary of the snorkel counts for Redwood Creek in 2008 is presented in Table 27. This table includes both the raw total number of coho counted in the snorkel surveys and the calibrated total number of coho.

Table 27. Summary of coho snorkel counts in Redwood Creek for 2005-2008.

Year	Total snorkel survey stream length (km)	Total number of habitat units	Number of pools			Coho counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2005	7.7	423	193	61	61	2,737	2,716
2006	7.7	536	228	63	35	198	290
2007	8.1	598	262	81	74	1,976	2,421
2008	8.5	726	244	66	22	113	117

Coho Basinwide Estimate: Coho densities (by both pool length and calibrated pool surface area) and a population estimate with 95% confidence interval were calculated for the coho survey area, and are shown in Table 28. The 2008 coho population estimate for Redwood Creek was 431 ± 271 . This is the smallest population estimate for Redwood Creek since monitoring began, and a major decrease since 2005, the previous cohort of the same year class. In previous years, the population estimate ranged from 1,050 (± 486) juveniles in 2006 to 8,594 ($\pm 1,652$) juveniles in 2005.

Table 28. Coho density and population estimates; Redwood Creek coho survey area, 2005-2008.

Year	Total snorkel survey stream length (km)	Avg. Coho per pool		Density		Population estimate	Variance	95% confidence interval
		Raw	Calibrated	Coho/m	Coho/m ²			
2005	7.7	44.87	44.53	1.937	0.458	8,594	606,987	$\pm 1,652$
2006	7.7	3.14	4.61	0.297	0.072	1,050	54,241	± 486
2007	8.1	24.40	29.89	1.857	0.482	7,832	621,780	$\pm 1,640$
2008	8.5	1.71	1.77	0.091	0.025	431	16,439	± 271

3.3.3 Pine Gulch Creek

Both the 2008 summer habitat and basinwide snorkel surveys of Pine Gulch Creek were initiated at monument tag 00, at the bridge within the Marin County Open Space District, and continued upstream to monument tag 95, above the Teixeira ranch within the Point Reyes National Seashore. The measured basinwide habitat survey length for the main channel was 10.1 km. A total of 826 mainstem habitat units were identified in the survey area.

Habitat Survey: Pool and riffle units comprised the majority of the habitat types, measuring a total of 8.8 km. Overall habitat composition was 43% pool, 45% riffle, and 12% flatwater by length (Table 29). Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Flatwater and riffle habitat types made up 87% of the total side channel habitat composition. Overall, 956 m of side channel habitat and 216 m of backwater habitat units were measured during the basinwide habitat survey, with a side channel density of 9.5 m/100 m of wetted survey length and a backwater density of 2.1 m/100 m. No dry units were observed on Pine Gulch Creek so the total wetted survey length is equal to the total survey length. The density of side channel habitat and backwaters increased in 2008 on Pine Gulch Creek when compared to previous years.

Table 29. Habitat composition of Pine Gulch coho survey area, 2008.

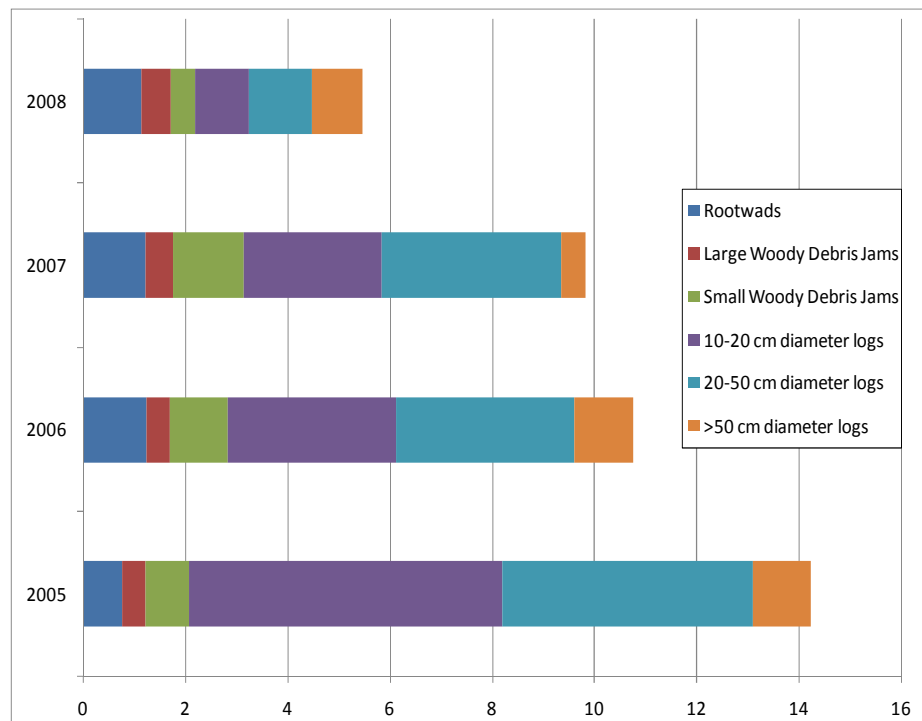
	Total length (m)	% of length	# of units	% of units
Pool	4,303	43	363	44
Flatwater	4,553	45	121	15
Riffle	1,244	12	342	41
Dry	0	0	0	0
Total	10,100	100	826	100

Woody debris information is collected during the basinwide habitat survey is summarized for 2005-2008 (Table 30, Figure 27) and is used to identify trends in woody debris availability and recruitment trends over time. Within Pine Gulch Creek, the density of small woody debris (SWD) jams and woody debris pieces up to 50 cm in diameter decreased in the last year, while rootwads and LWD jams maintained previous levels. In contrast, woody debris pieces over 50 cm in diameter increased.

Table 30. Summary of basinwide instream woody debris (WD) per 100 m during summer base flow conditions in Pine Gulch Creek; average 2005-2007 compared to 2008. Woody debris must be >2 m in length to be counted.

Field season	Survey length (# 100 m sections)	Rootwads density per 100 m	LWD Jams density per 100 m	SWD Jams density per 100 m	10-20cm WD density per 100 m	20-50cm WD density per 100 m	>50cm WD density per 100 m
Average	99.0	1.1	0.5	1.1	4.0	4.0	0.9
2008	101.0	1.1	0.6	0.5	1.1	1.2	1.0

LWD Jam= large woody debris jam (jams composed of 10 or more pieces of >10 cm diameter woody debris), SWD Jam= small woody debris jam (jams composed of 10 or more pieces of <10 cm diameter woody debris)

**Figure 27.** Instream woody debris, by type, per 100 meters in wetted length on Pine Gulch Creek, 2005-2008.

Snorkel Counts: Snorkel surveys were conducted on 21% (67 of 309 pools) of the delineated pools. No coho were observed in any of the 78 snorkeled pools.

Historically, coho have been present within 20 to 63% of the pools snorkeled. Sixteen of the 78 snorkeled pools (20.5%) were electrofished within a day following the snorkel counts. No coho salmon were detected throughout the electrofishing surveys on Pine Gulch. A summary of the 2008 Pine Gulch Creek snorkel survey is presented in Table 31.

Table 31. Summary of coho snorkel counts in Pine Gulch Creek, 2005-2008.

Year	Total snorkel survey stream length (km)	Total number of habitat units	Number of pools			Coho counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2005	9.9	616	309	67	42	219	249
2006	10.3	844	357	104	21	58	86
2007	10.3	860	339	95	0	0	0
2008	10.1	826	363	78	0	0	0

Coho Basinwide Estimate: The 2008 basinwide estimate for coho salmon in Pine Gulch Creek is zero, based on extensive electrofishing and snorkeling effort distributed throughout the watershed. Historical density and population estimates are presented in Table 32. In previous years, the population estimate has ranged from 0 juveniles in 2007 to $1,150 \pm 554$ juveniles in 2005. This year class was fairly strong in 2005 but in spring 2006, only 98 coho smolts were observed leaving the watershed.

Table 32. Coho density and population estimates; Pine Gulch coho survey area, 2005-2008.

Year	Total snorkel survey stream length (km)	Avg. Coho per pool		Density		Population Estimate	Variance	95% confidence interval
		Raw	Calibrated	coho/m	coho/m ²			
2005	9.9	3.27	3.72	0.219	0.072	1,150	66,615	± 554
2006	10.3	0.56	0.83	0.073	0.030	295	9,419	± 201
2007	10.3	0.00	0	0	0	0	0	0
2008	10.1	0.00	0	0	0	0	0	0

3.4 Index Reach Monitoring Results

Juvenile monitoring results are provided for Olema, Redwood, and Pine Gulch Creeks. For detailed results at each location, please refer to Reichmuth et al. 2008.

3.4.1 Olema Creek

During the summer of 2008, seven of the eight index reaches on the mainstem of Olema Creek were sampled.

Index Reach Habitat and Total Catch: The results presented in Table 33 represent the real catch documented through electrofishing activities for 2008 on Olema Creek. Coho juveniles, steelhead young-of-the-year (YOY), and steelhead one year or older (1+) are listed. Historical catch numbers can be found in Appendix A, Table A16. Salmonid density results are determined based upon the total catch determined from the multiple pass depletion method.

Table 33. Summary of total catch for coho (CO), steelhead young-of-the-year (SH YOY), and steelhead age 1+ (SH 1+) within Olema Creek mainstem index reach sample locations 2008.

Year	Species and Age	Index reach								Total
		1	2	3	4	5	6	7	8	
2008	CO	Not Sampled	3	42	12	22	9	7	0	95
	SH YOY		113	145	181	103	40	23	2	607
	SH 1+		3	9	13	6	4	1	1	37

In 2008, all surveyed index reaches except for Index Reach 8 included the presence of coho and steelhead.

In 2008, the habitat surveys of the index reaches showed a lower percentage of habitat made up by pools for all of the index reaches when compared to historical averages. Flatwater habitat percentages, however, were above or near to historical averages. This may have been due to the late sampling period or the low water year. Index reach habitat composition for 2008 can be found in Appendix A, Table A17.

Salmonid Density by Habitat Type: The results of our monitoring efforts show distinct differences in salmonid numbers and densities based on habitat type. Table 34 is a summary of coho salmon catch and densities by habitat unit type using data from the electrofishing surveys performed between 2004 and 2008. Densities are calculated using the best available catch estimate, either total catch from electrofishing surveys or catch calculated using *Microfish*. The results show distinct use of pools by coho; in 2008, there were fish densities of 0.24 fish/m and 0.07 fish/m² occurring in pool habitat. This density is roughly comparable to the 2006 densities displayed, when a similarly low number of fish were found during the summer survey. Overall average densities for the summer of 2008 are the lowest in the ten year monitoring history when all habitat units are taken into account (Table 34). The data, taken from 2004 through 2008, show a marked preference by coho for pool habitat, ranging as high as 4.56 fish/m. Flatwater habitat rarely had densities higher than 1.0 fish/m. Only limited use of riffle habitat by coho juveniles was observed during the surveys. For historical data on coho densities by habitat type, refer to Appendix A, Table A18.

Table 34. Summary catch and densities from electrofishing surveys for coho salmon by habitat unit on Olema Creek; 2004-2007 compared to 2008.

Year	Habitat type	Year	# of habitat units	Catch	Density	
					Fish/m	Fish/m ²
Average	Pool	2004-2007	55	4,568	3.32	0.75
	Riffle	2004-2007	13	6	0.04	0.02
	Flatwater	2004-2007	14	167	0.51	0.15
Max	Pool	2007	16	1,452	4.56	1.10
	Riffle	2005	4	3	0.07	0.02
	Flatwater	2004	5	156	1.38	0.27
Min	Pool	2006	14	120	0.24	0.05
	Riffle	2006	3	0	0.00	0.00
	Flatwater	2006	4	0	0.00	0.00
2008	Pool		16	90	0.24	0.07
	Riffle		14	0	0.00	0.00
	Flatwater		6	5	0.03	0.02

Table 35 shows a summary of densities of steelhead YOY per habitat type for years 2004 through 2008. Steelhead YOY were found in all habitats; in 2008, the highest densities were observed in pool habitat (1.51 fish/m), as opposed to riffle habitat (0.30 fish/m). This may be indicative of low coho densities in pool habitat during the summer of 2008. Because steelhead are less discriminating about depth as a feature of habitat choice, they tend to occur in most stream habitats, even at very shallow depths, when coho densities are higher. While coho juveniles strongly favor pool habitat, steelhead show less discrimination between habitat types, perhaps due in part to competition from coho for available pool habitat. For historical data on steelhead densities by habitat type, refer to Appendix A, Table A19.

Table 35. Summary of catch and densities from electrofishing surveys for steelhead young-of-the-year (YOY) by habitat unit on Olema Creek index reaches, 2004-2007 compared to 2008.

Year	Habitat type	Year	# of habitat units	Catch	Density	
					Fish/m	Fish/m ²
Average	Pool	2004-2007	55	2,119	1.55	0.36
	Riffle	2004-2007	13	72	0.33	0.10
	Flatwater	2004-2007	14	260	0.96	0.30
Max	Pool	2007	16	719	2.31	0.59
	Riffle	2007	6	19	0.48	0.20
	Flatwater	2004	5	190	1.63	0.32
Min	Pool	2006	14	120	1.14	0.25
	Riffle	2006	3	2	0.11	0.04
	Flatwater	2005	2	2	0.22	0.08
2008	Pool		16	448	1.51	0.49
	Riffle		14	57	0.30	0.09
	Flatwater		6	133	0.98	0.36

Densities used in Figure 28 were determined from all habitat units surveyed within each index reach in 2008. Coho densities are highest in Index Reach 3 while steelhead densities are highest in Index Reaches 2 through 4. At no point did the coho densities exceed or even match steelhead densities during the 2008 summer survey. For 2008 densities based on index reach electrofishing, refer to Appendix A, Table A20.

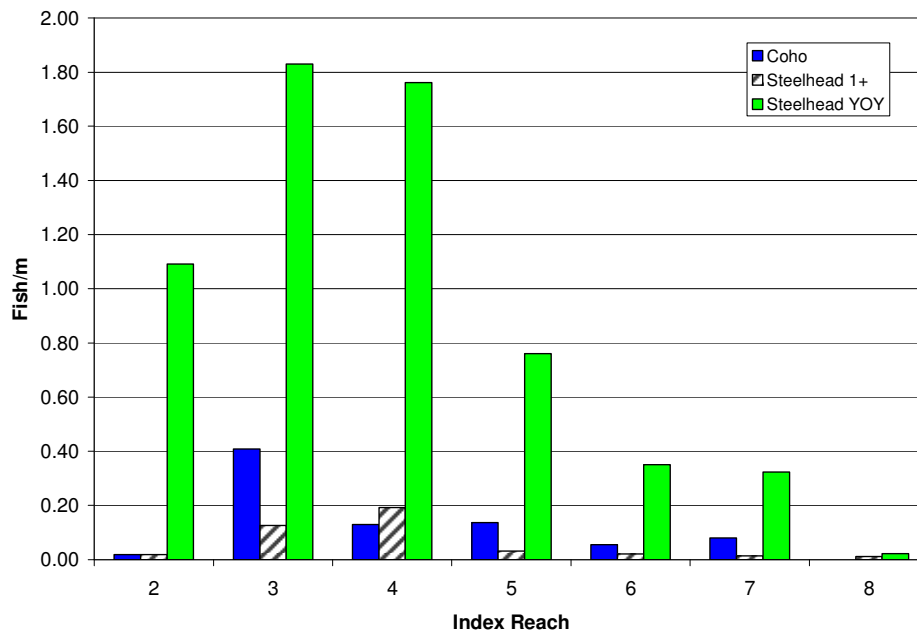


Figure 28. Coho and steelhead densities according to index reach on Olema Creek, 2008.

Juvenile Fish Length and Weight: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure 29), showing the percentage of fish in each fork length bin of 5 mm. Figures 30 and 31 show the distribution across years for coho fork length (Figure 30) and coho weight (Figure 31). Graph representations of the weight-length relationships for both coho and steelhead juveniles are provided in Appendix A, Figures A7 and A8. Within the Olema Creek sample, 80 coho salmon (84% of the total index reach catch) were weighed and measured. The size range for coho was observed to be 61 to 100 mm.

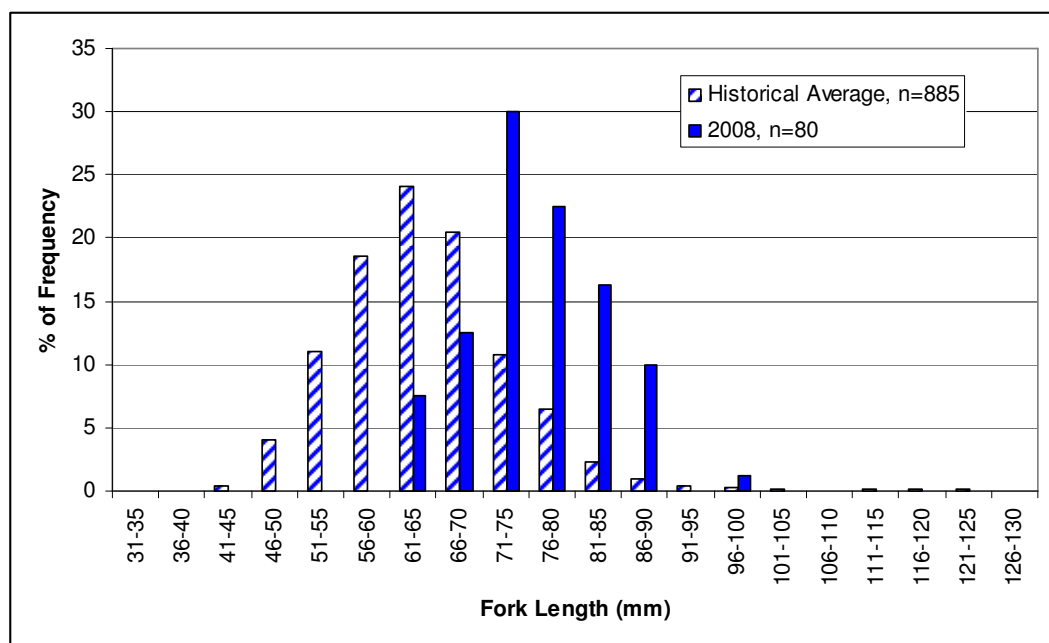


Figure 29. Coho histogram for fish measured in the seven Olema Creek index reaches, 2008 showing percentage of fish in each fork length bin. Average length percentages (2004-2007) are shown for comparison. Fork length is represented in 5 mm bins.

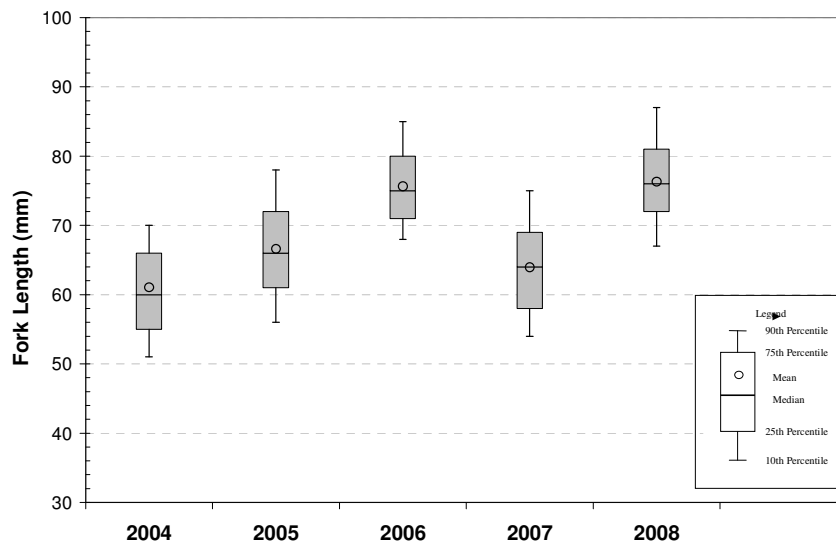


Figure 30. Fork length distribution for coho measured in Olema Creek index reaches, 2004-2008.

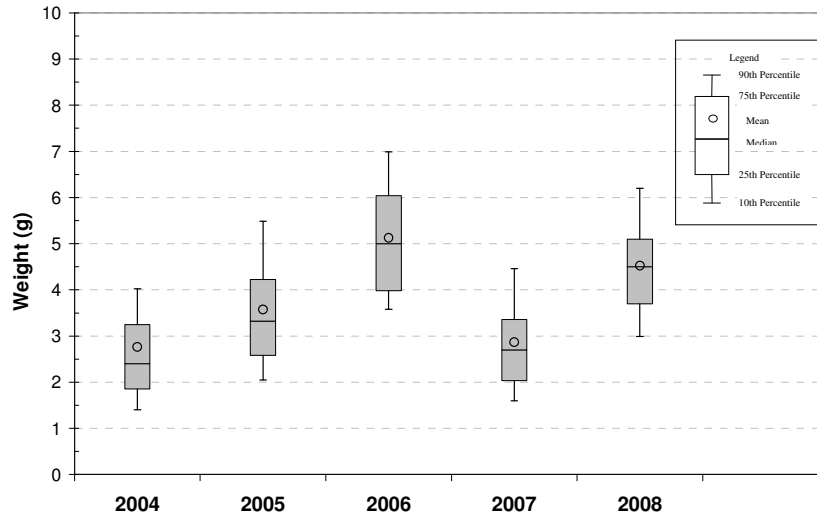


Figure 31. Weight distributions for coho measured in Olema Creek index reaches, 2004-2008.

Histograms are presented for steelhead (Figure 32), showing the percentage of fish in each fork length bin of 5 mm. A total of 358 steelhead trout (56% of the total index reach catch) were weighed and measured. The size range for steelhead trout was 46 to 205 mm.

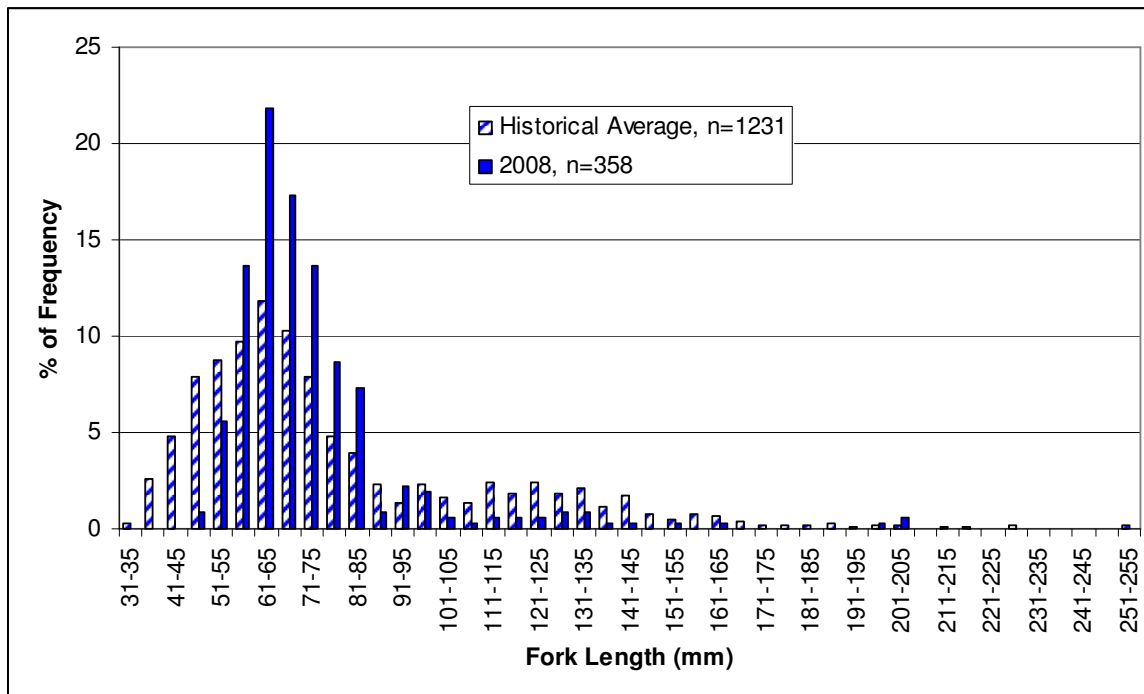


Figure 32. Steelhead histogram for fish measured in the seven Olema Creek index reaches, 2008 showing percentage of fish in each fork length bin. Fork length is represented in 5 mm bins. Multiple peaks represent multiple year classes of *O. mykiss*. Average fork length percentages for steelhead from years 2004-2007 shown for comparison.

In order to compare length-weight relationships, we applied the Fulton Condition Factors (K) to establish comparable indices of condition (Murphy and Willis 1996). Table 36 shows coho

lengths, weights, and K-factors for Olema Creek index reaches, also showing the years with maximum and minimum mean fork length. Tables 37 and 38 show the comparisons between steelhead YOY and steelhead 1+ lengths, weights, and K-factors for Olema Creek.

The 2008 mean K-factor (0.99) for coho in Olema Creek was the lowest observed in comparison to previous years with the minimum of 1.13 in 2004 and a maximum of 1.15 in 2006. For steelhead YOY, the 2008 K-factor (1.05) was also lower than the 2004-2007 average but it was very close to the previous low of 1.04 recorded in 2007. As with coho, the 2008 steelhead K-factors for 1+ steelhead were the lowest observed since monitoring began (0.94). Tables depicting historical K-factors on Olema Creek can be found in Appendix A, Tables A21-A23.

Table 36. Mean coho length, weight, and K-factor calculated for coho measured and weighed in the Olema Creek index reaches. Average across years, max, and min based on fork length from 2004-2007 compared to 2008.

	Year	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
Average	2004-2007		66.21	6.41		3.48	1.11		1.12	0.05
Max	2006	81	75.63	7.23	75.00	5.13	1.60	5.00	1.15	0.08
Min	2004	175	61.26	10.21	60.00	2.80	1.80	2.50	1.13	0.12
Current	2008	80	76.29	7.09	75.50	4.52	1.29	4.50	0.99	0.07

Table 37. Mean steelhead length, weight, and K-factor calculated for steelhead young-of-the-year (YOY) measured and weighed in the seven Olema Creek index reaches. Average across years, max, and min based on fork length from 2004-2007 compared to 2008.

	Year	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
Average	2004-2007		61.29	7.79		2.87	1.05		1.13	0.08
Max	2005	239	68.59	10.14	67.00	3.90	1.90	3.41	1.13	0.12
Min	2007	241	54.08	7.82	53.00	1.74	0.78	1.52	1.04	0.12
Current	2008	321	67.51	9.08	66.00	3.38	1.53	3.01	1.05	0.10

Table 38. Mean steelhead length, weight, and K-factor calculated for steelhead age 1+ measured and weighed in the seven Olema Creek index reaches. Average across years, max, and min based on fork length from 2004-2007 compared to 2008.

	Year	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
Average	2004-2007		125.19	13.61		23.22	7.27		1.06	0.06
Max	2005	53	140.92	27.52	137.00	32.77	22.49	26.66	1.05	0.07
Min	2006	137	108.55	25.88	101.00	16.53	12.19	11.28	1.14	0.19
Current	2008	35	113.86	24.89	104.00	15.38	10.50	11.18	0.94	0.08

3.4.2 Redwood Creek

In 2008, six of seven reaches on the mainstem of Redwood Creek were sampled. Historical average salmonid density estimates from electrofishing surveys completed by Dr. Jerry Smith on Redwood Creek from 1992-2001 are located below in Table 39. Survey results from 1999-2003 in Table 39, represent combined efforts between Dr. Jerry Smith and NPS.

Table 39. Summary of historical average salmonid density estimates from electrofishing surveys completed by Dr. Jerry Smith on Redwood Creek index reaches, 1992-2003.

Year	Total # of sampled indexes	Length sampled (m)	Density		
			CO/m	SH YOY/m	SH 1+/m
1992	4 ^a	314.6	1.48	0.75	0.13
1993	4	289.9	1.51	1.84	0.13
1994	7	392.3	0.07	2.26	0.46
1995	4	242.6	1.38	3.18	0.13
1996	3	184.1	1.28	1.08	0.36
1997	5 ^a	299.9	0.75	0.49	0.16
1998	5	357.8	1.05	1.54	0.13
2000	6	328.3	0.04	1.28	0.49
2001	5 ^a	291.4	0.89	0.20	0.20
2002	4	239.9	1.87	0.36	0.10
2003	4	213.7	0.89	0.98	0.26

CO= coho, SH= steelhead, YOY= young of year, 1+ = one year of age or older

^a One or both of the sites downstream of the well were intermittent or dry.

Index Reach Habitat and Total Catch: The results presented in Table 40 are the real catch documented through electrofishing activities in the Redwood Creek index reaches for 2008. For historical index reach catch, refer to Appendix A, Table A24.

Table 40. Summary of total catch for coho (CO), steelhead young-of-the-year (SH YOY), and steelhead age 1+ (SH 1+) by reach within Redwood Creek mainstem index reach sample locations, 2008.

Year	Species	Index Reach							total
		1	2	3	4	5	6	7	
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

In 2008, all sampled index reaches except Index Reach 4 included the presence of coho and steelhead.

In 2008, six of the seven index reaches had a lower than average percentage of pool habitat. Riffles and flatwater percentages were also generally higher than the historic average. Index reach habitat composition for 2008 can be found in Appendix A, Table A25.

Salmonid Density by Habitat Type: The results of our monitoring efforts show distinct differences in salmonid numbers and densities based on habitat type (Table 41). While the total number of fish observed was extremely low, the results show distinct use of pools by coho with fish densities of 0.10 fish/m and 0.03 fish/m² occurring in this habitat. Only rarely did coho occur in either riffle or flatwater habitat units within the survey reaches. For historical coho densities based on habitat type, refer to Appendix A, Table A26. Densities are calculated using best available catch estimates, from either total catch from electrofishing surveys or a catch estimate calculated by *Microfish*.

Table 41. Summary of catch and densities from electrofishing surveys for coho salmon by habitat unit on Redwood Creek index reaches, 2005-2007 compared to 2008.

Year	Habitat type	Year	# of habitat units	Catch	Density	
					Fish/m	Fish/m ²
Average	Pool	2005-2007	63	1,914	1.45	0.36
	Riffle	2005-2007	31	3	0.02	0.02
	Flatwater	2005-2007	19	24	0.08	0.03
Max	Pool	2005	19	1,050	2.04	0.52
	Riffle	2007	13	2	0.05	0.06
	Flatwater	2005	3	12	0.24	0.10
Min	Pool	2006	22	103	0.29	0.07
	Riffle	2006	13	0	0.00	0.00
	Flatwater	2007	6	0	0.00	0.00
2008	Pool		18	33	0.10	0.03
	Riffle		11	0	0.00	0.00
	Flatwater		13	2	0.01	0.00

Historically, steelhead YOY chose pool habitat over flatwater or riffle habitat, and in 2008, steelhead YOY again showed a strong preference for pool habitats with densities of 1.52 fish/m (Table 42). However, they show less discrimination than coho, and thus occupy a wider variety of habitats than coho. Flatwaters were a secondary choice, with densities of 0.89 fish/m. For historical steelhead YOY densities based on habitat type, refer to Appendix A, Table A27. Densities are calculated using the best available catch estimates, from either total catch from electrofishing surveys or a catch estimate calculated by *Microfish*.

Table 42. Summary of total catch from electrofishing for steelhead young-of-the-year (YOY) by habitat unit on Redwood Creek index reaches, 2005-2007 compared to 2008.

Year	Habitat type	Year	# of habitat units	Catch	Density	
					Fish/m	Fish/m ²
Average	Pool	2005-2007	63	1,866	1.51	0.39
	Riffle	2005-2007	31	93	0.21	0.09
	Flatwater	2005-2007	19	311	0.63	0.25
Max	Pool	2007	22	1,200	3.05	0.79
	Riffle	2007	13	57	0.43	0.22
	Flatwater	2007	10	255	1.47	0.57
Min	Pool	2006	22	151	0.46	0.10
	Riffle	2005	5	18	0.10	0.02
	Flatwater	2006	6	19	0.29	0.09
2008	Pool		18	433	1.52	0.47
	Riffle		11	27	0.10	0.05
	Flatwater		13	119	0.89	0.43

Densities used in Figure 33 are determined from all habitat units surveyed within each index reach. Coho densities were highest in Index Reaches 3 and 5, and they were completely absent from Index Reach 4. Steelhead YOY densities were highest in Index Reaches 3 and 4. It should also be noted that steelhead YOY had a higher density than coho in every index reach surveyed. Index Reach 7 was not sampled in 2008. For a table depicting 2008 index reach fish densities, refer to Appendix A, Table A28.

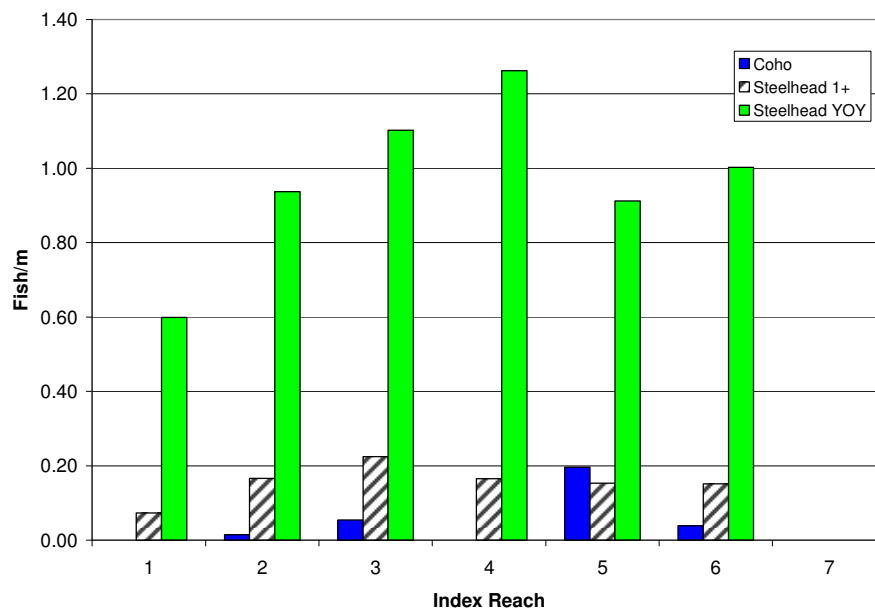


Figure 33. Fish densities by index reach for steelhead YOY, steelhead 1+, and coho during survey season 2008 on Redwood Creek.

Juvenile Fish Length and Weight: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure 34), showing the percentage of fish in each fork length bin of 5 mm. Figures 35 and 36 show distribution across the years of fork length (Figure 35) and weight (Figure 36) for coho measured in Redwood Creek index reaches. Graphs depicting weight-length relationships for coho and steelhead found in Appendix A, Figures A9-A10.

Within the Redwood Creek 2008 sample, 33 coho salmon (97% of the total index reach catch) were weighed and measured. The size range for juvenile coho was observed to be 31 to 110 mm.

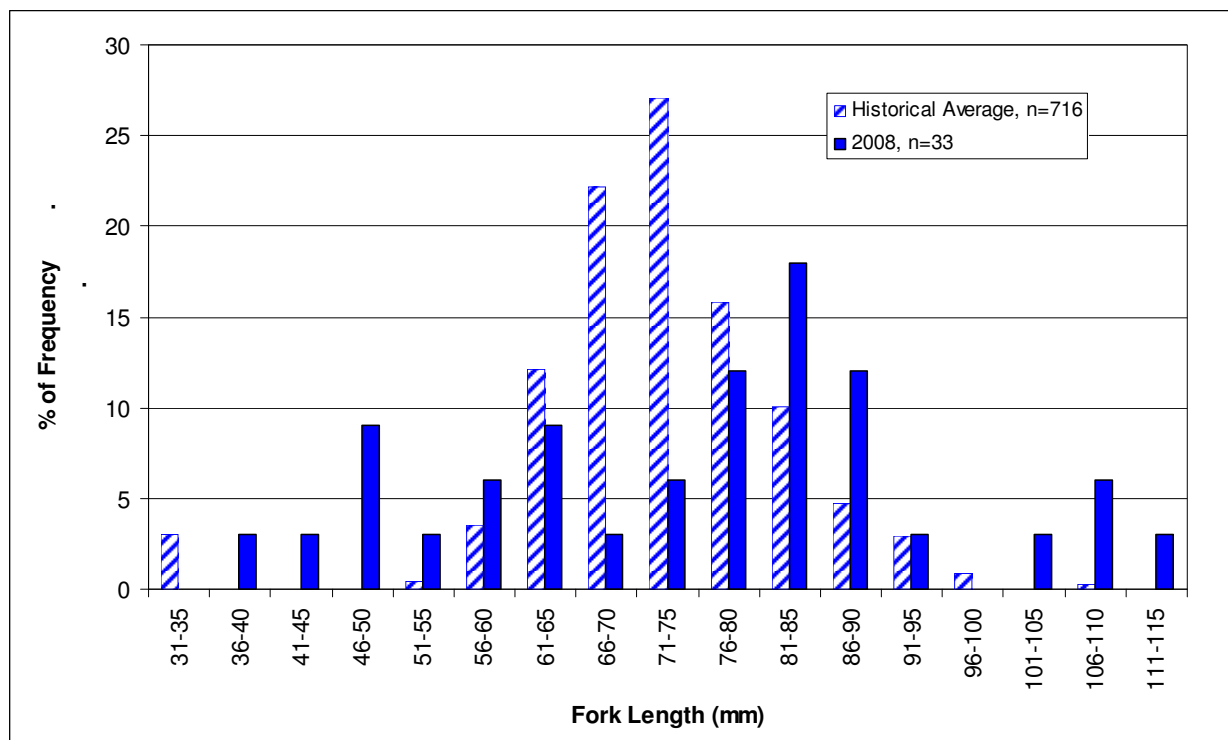


Figure 34. Coho histogram for fish measured in the seven Redwood Creek index reaches, 2008 showing the percentage of fish in each fork length bin. Historical averages (2005-2007) are shown for comparison. Fork length is represented in 5 mm bins.

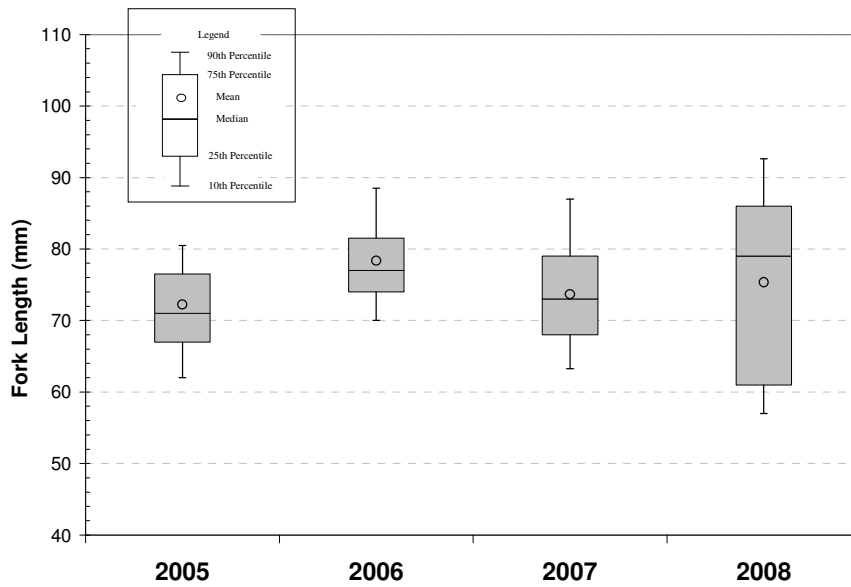


Figure 35. Fork length distribution for coho measured in Redwood Creek index reaches, 2005-2008.

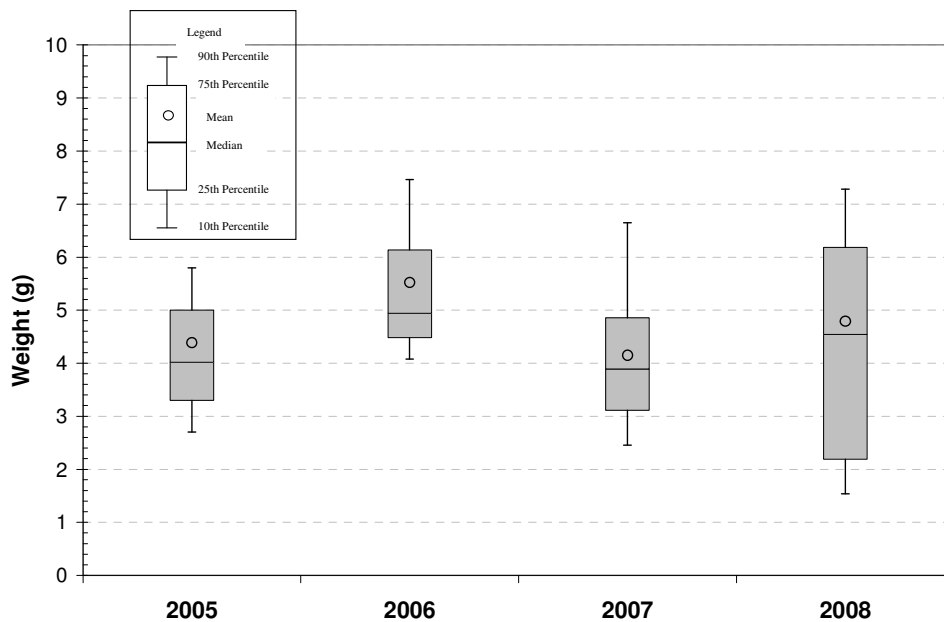


Figure 36. Weight distributions for coho measured in Redwood Creek index reaches, 2005-2008.

Histograms are presented for steelhead (Figure 37), showing the percentage of fish in each fork length bin of 5 mm. A total of 465 steelhead (82% of the total index reach catch) were weighed and measured. The size range for steelhead caught was 36 to 180 mm.

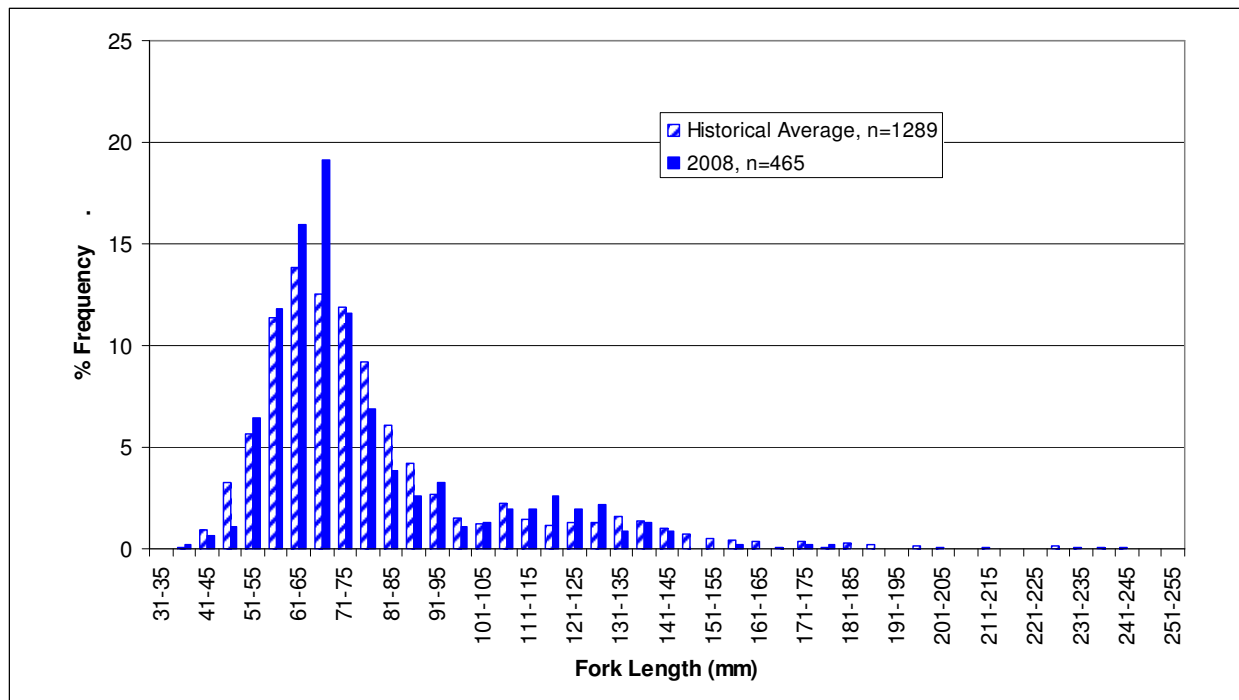


Figure 37. Steelhead histogram for fish measured in the seven Redwood Creek index reaches, 2008 showing the percentage of fish in each fork length bin. Average historical percentages are added for comparison (2005-2007). Fork length is represented in 5 mm bins. Multiple peaks represent multiple year classes of steelhead.

Table 43 shows the coho length, weight, and K-factor for Redwood Creek between 2005 and 2008. Tables 44 and 45 show the comparisons between steelhead YOY and steelhead 1+ length, weight, and K-factors for Redwood Creek between 2005 and 2008. The 2008 mean K-factor of 0.90 for coho fell below the previous minimum K-factor of 1.00 recorded in 2007. For historical K-factors on Redwood Creek, refer to Appendix A, Tables A29-A31.

Table 43. Mean length, weight, and K-factor calculated for coho measured and weighed in the seven Redwood Creek index reaches. Average across years, max, and min from 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		72.26	5.44		4.39	0.98	1.11	1.09	0.10
Max	2006	79	78.36	7.32	77.00	5.52	1.65	4.94	1.13	0.10
Min	2005	241	67.58	9.11	67.00	3.63	1.51	3.50	1.12	0.10
Current	2008	32	76.53	18.73	79.50	4.79	3.14	4.54	0.90	0.09

Steelhead YOY in Redwood Creek had a mean K-factor of 0.96, as compared to a historical minimum of 1.00 recorded in 2007. The steelhead 1+ had an average K-factor of 0.92, which was lower than the previous minimum K-factor of 0.95 recorded in 2007.

Table 44. Mean length, weight, and K-factor calculated for steelhead YOY measured and weighed in the seven Redwood Creek index reaches. Average across years, max, and min from 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		68.08	5.29		3.90	0.87		1.11	0.05
Max	2006	156	77.99	9.60	78.00	5.43	2.03	5.20	1.10	0.11
Min	2007	547	63.52	9.61	62.00	2.76	1.30	2.42	1.00	0.11
Current	2008	372	66.83	9.15	67.00	3.03	1.26	2.86	0.96	0.08

Table 45. Mean length, weight, and K-factor calculated for steelhead 1+ measured and weighed in the seven Redwood Creek index reaches. Average across years, max, and min from 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		129.64	7.71		26.55	5.52		1.05	0.05
Max	2005	64	133.66	28.01	128.00	29.00	21.02	23.21	1.08	0.07
Min	2007	79	121.72	26.32	119.00	19.38	13.12	15.07	0.95	0.11
Current	2008	93	116.45	18.09	116.00	15.40	7.26	14.62	0.92	0.06

3.4.3 Pine Gulch Creek

In 2008, seven of eight index reaches on the mainstem of Pine Gulch Creek were sampled. No coho were present in any of the reaches sampled. This is the second consecutive year since the return of coho was documented in 2001 that no juveniles were observed through the index reach surveys. In addition, no coho were observed during the basinwide snorkel surveys.

Index Reach Habitat and Total Catch: The results presented in Table 46 are the real catch documented through electrofishing activities on Pine Gulch Creek in 2008. Historical catch results can be found in Appendix A, Table A32.

Table 46. Summary of total catch for each species by reach within Pine Gulch Creek mainstem index reach sample locations, 2008.

Year	Species	Index Reach								total
		1a	1b	1c	2	3	4	5	6	
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

Index Reach Habitat Information: In 2008, no coho were found within the index reaches, though steelhead were present in all index reaches. Other aquatic species sampled at each index reach are documented.

Pine Gulch Creek Index Reaches 1a through 1c were established to represent the lower reaches of the watershed where the stream flows through organic agricultural cropland. The NPS and other agencies are working with these landowners to enhance operations to protect instream flow for the benefit of coho salmon and steelhead trout. Sampling in these private lands is done with the cooperation of the landowners.

During the 2008 summer monitoring season, only two of the six surveyed index reaches had a higher than average percentage of pool habitat, ranging from 6.1% higher (Index 1c) to 8.6% higher (Index 2). Index reach habitat composition for 2008 can be found in Appendix A, Table A33.

Salmonid Density by Habitat Type: Pools are typically the best habitat for both coho salmon and steelhead trout, and consistently support higher densities than flatwater and riffle units. As observed in Olema Creek, steelhead occurred in all habitat types, though in varying densities. Without the presence of the coho, they favor pool habitats over riffles and flatwaters. Historical Pine Gulch coho numbers and densities based on habitat type are not included in this report due to low annual catch totals. For historical steelhead YOY densities based on habitat type, refer to Appendix A, Table A34.

Table 47 shows the breakout of habitat units and fish densities for steelhead YOY. Densities were calculated using the best available catch estimate, either total catch from electrofishing surveys or catch calculated by *Microfish*. Steelhead YOY densities for pool units have previously ranged from 0.66 fish/m to 1.57 fish/m, and summer 2008 fell within the upper end of that range. No coho were observed within the six sampled Pine Gulch Creek index reaches in 2008; historically, they were spread across the length of the creek, and were particularly concentrated in the upper reaches. Likewise, steelhead distribution in 2008 was more concentrated than the historical distribution. The highest steelhead densities were observed in Index Reaches 2 and 3, whereas highest historical densities for steelhead YOY have occurred in Index Reaches 1b through 4 (Figure 38). For 2008 densities based on index reach, refer to Appendix A, Table A35.

Table 47. Summary of catch and densities from electrofishing surveys for steelhead young-of-the-year (YOY) by habitat unit in Pine Gulch Creek index reaches, 2005- 2008.

	Habitat type	Year	# of habitat units	Catch	Density	
					Fish/m	Fish/m ²
Average	Pool	2005-2007	43	784	1.05	0.32
	Riffle	2005-2007	27	103	0.63	0.30
	Flatwater	2005-2007	18	62	1.38	1.12
Max	Pool	2007	16	404	1.57	0.48
	Riffle	2005	6	15	0.94	0.61
	Flatwater	2007	4	44	0.83	0.24
Min	Pool	2006	15	147	0.66	0.20
	Riffle	2006	11	9	0.07	0.03
	Flatwater	2006	5	15	0.32	0.12
2008	Pool		17	292	1.51	0.45
	Riffle		8	81	0.75	0.32
	Flatwater		3	8	0.15	0.08

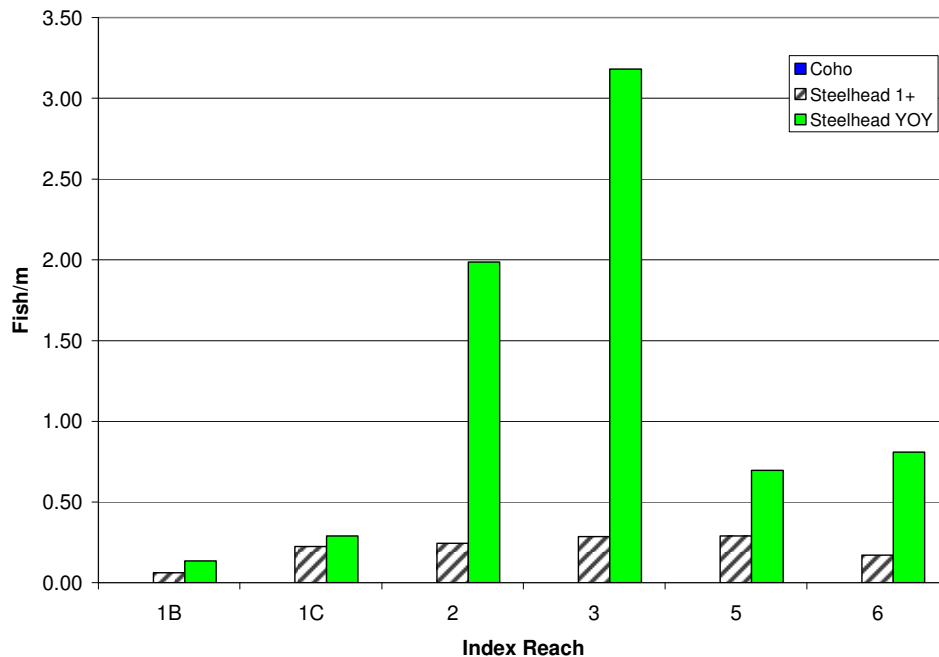


Figure 38. Fish density by index reach on Pine Gulch Creek, 2008.

Juvenile Fish Length and Weight: As part of the summer monitoring program, a sub-sample of fish are weighed and measured within each sampled habitat unit. A fork length histogram is presented for steelhead in Figure 39 showing the percentage of fish in each fork length bin of 5 mm. Within the Pine Gulch Creek sample, 326 steelhead (77% of the total index reach catch) were weighed and measured. The size range for steelhead trout was 36 to 225 mm. A graph depicting weight-length relationships for steelhead trout can be found in Appendix A, Figure A11.

A condition factor is a ratio relating fish length to fish weight, serving to quantify the relative biomass of a fish. Tables 48 and 49 show the comparisons between steelhead YOY and steelhead 1+ length, weight, and K-factors for Pine Gulch Creek, taken from survey years 2005-2008. For steelhead YOY, the 2008 average length and weight were both lower than the 2005-2007 average. The 2008 mean K-factor for steelhead YOY was 1.02, lower than the 2005-2007 average, but just above the previous low (1.00 in 2007). The 2008 mean length of steelhead 1+ was higher than the historical mean but the 2008 mean weight did not differ much from the 2005-2007 average. The mean K-factor of 0.93 for steelhead 1+ also fell below the previous low mean (0.99 in 2007) and was also lower than the 2005-2007 average. For historical K-factors on Pine Gulch Creek, refer to Appendix A, Tables A36-A38.

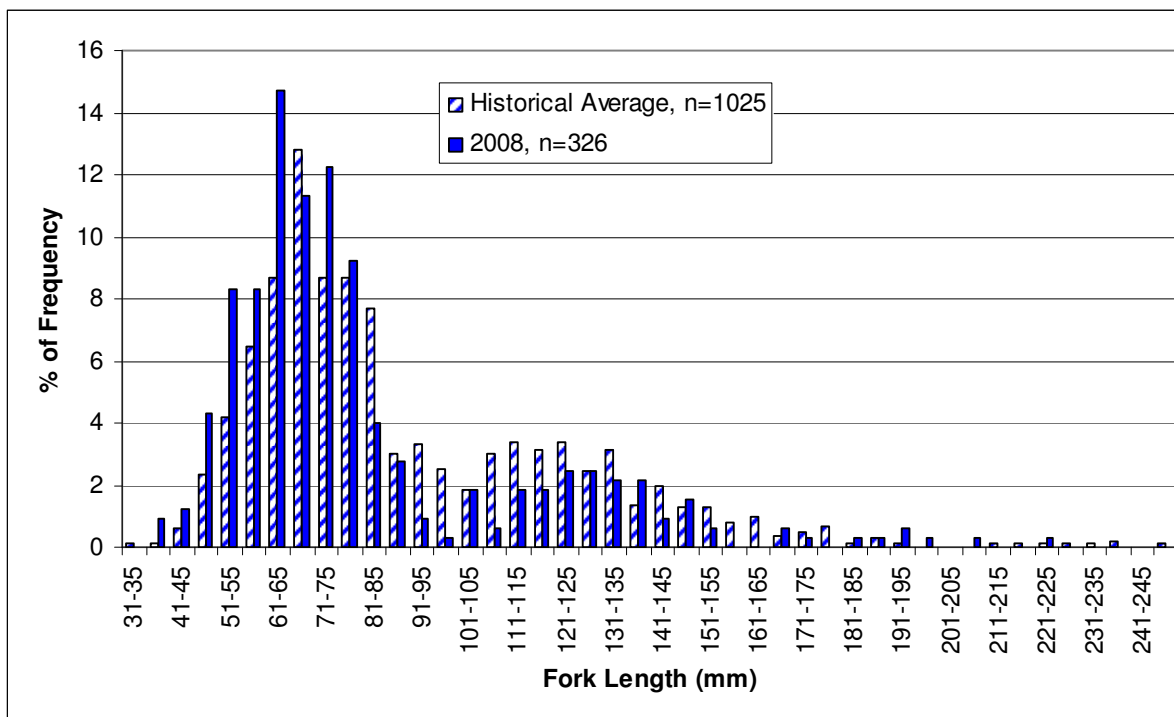


Figure 39. Steelhead histogram for fish measured in the seven Pine Gulch Creek index reaches, 2008 showing percentage of fish in each fork length bin. Shown for comparison are the historic averages taken during previous years (2005-2007). Fork length is represented in 5 mm bins. Multiple peaks represent multiple year classes of *O. Mykiss*.

Table 48. Mean length, weight, and K-factor calculated for steelhead YOY measured and weighed in the seven Pine Gulch Creek index reaches. Average across years, max, and min based on fork length from 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		71.54	7.00		4.42	1.44		1.09	0.10
Max	2006	157	77.99	9.60	78.00	5.43	2.03	5.20	1.10	0.11
Min	2007	300	64.73	10.42	65.00	2.97	1.46	2.77	1.00	0.10
Current	2008	252	66.47	11.07	66.00	3.23	1.63	2.92	1.02	0.19

Table 49. Mean length, weight, and K-factor calculated for steelhead 1+ measured and weighed in the seven Pine Gulch Creek index reaches. Average across years, max, and min based on fork length from 2005-2007 compared to 2008.

	Year	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
Average	2005-2007		128.58	4.51		24.58	2.60		1.05	0.06
Max	2007	117	131.79	21.05	129.00	24.32	12.26	20.92	0.99	0.06
Min	2006	123	123.43	26.21	120.00	22.12	13.42	18.46	1.09	0.12
Current	2008	72	134.46	26.99	129.00	25.34	18.16	19.71	0.93	0.09

4 Multiple Life Stage Comparisons

Through multiple life stage monitoring, the NPS is able to develop survival estimates for each stage of the coho life history. While we are able to derive an extrapolated survival rate estimate using this method, we still do not have a means of developing a confidence interval at this time.

Analysis of these integrated data allow for two types of summary analyses. These monitoring methods support a means of tracking survival rates between life stages. When compared between watersheds, we are able to identify if observed trends between life stages are likely based on localized or regional conditions. The analyses of these data also allow for comparison to determine whether the observed results are dependent on year class conditions, or habitat conditions. In cases where habitat is limiting, then we would predict that results would be observed on an annual basis.

Figure 40 provides a graphical representation of the population fluctuations in the 2004-2005 year class for Olema, Redwood, and Pine Gulch Creeks through the life cycle of the cohort.

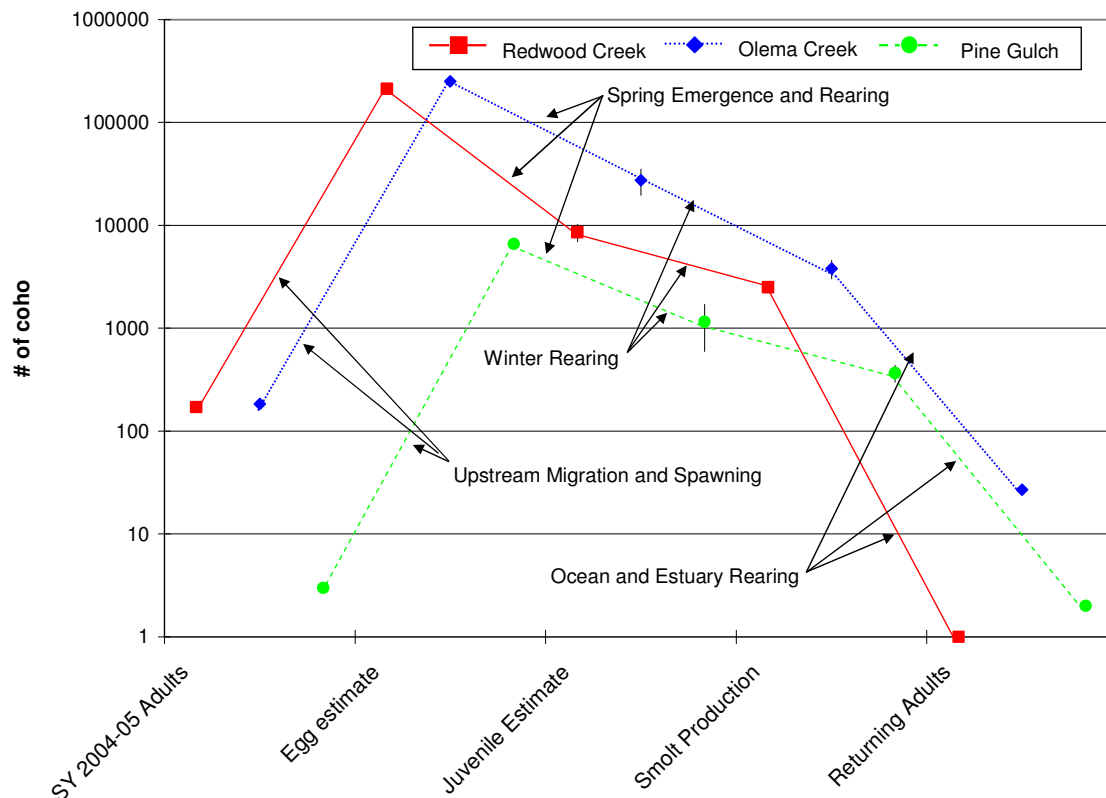


Figure 40 Survival rate between monitored life stages in Olema, Pine Gulch, and Redwood Creeks for spawner year 2004-2005.

4.1 Coastal Marin Watershed Observations

4.1.1 Egg-to-Juvenile Survival

The egg-to-juvenile survival rates may be used to understand habitat differences between monitored watersheds. The egg-to-juvenile survival rate is calculated from the estimated number of eggs and the basinwide juvenile estimate conducted in the fall of the following summer. The egg estimate is determined from number of documented redds multiplied by the estimated number of eggs per female using the Shapavolov and Taft (1954) formula based on female fork length (where the average female fork length for that year is used to calculate egg production).

Factors that may affect the rate of egg-to-juvenile survival include winter and spring peak discharge events, redd scour, and side channel/backwater habitat availability for newly emerged juveniles. Estimated egg-to-juvenile survival has ranged from 7–46% in Olema Creek (SY 2002-2003 to SY 2007-2008), 4-14% in Redwood Creek (SY 2003-2004 to SY 2007-2008), and 5-27% in Pine Gulch Creek (SY 2000-2001 to SY 2007-2008). The variability in Pine Gulch Creek may be accounted for by the very small population size and low spawner detection levels (maximum number of redds detected in the watershed is 3). The 2002-2003 spawner year survival rate (46%) on Olema Creek is most likely an overestimate of the juvenile survival, caused by low redd detection levels during the 2002-2003 spawning seasons. Therefore, they will be excluded from all subsequent analysis.

In Lagunitas Creek, MMWD has developed a predictive model to estimate the number of juveniles that will be observed during summer sampling, based on the number of redds and peak April discharge (Stillwater Sciences 2008). This best-fit model indicates that summer survival is highly dependent on spring runoff conditions, likely during the time of newly emergent fry (March – April). Side channel and backwater habitat availability is likely important for fry when they are newly emerged and most susceptible to higher flows (Bell et al. 2001).

In summer 2008, lower than average egg-to-juvenile survival was observed in Olema Creek (4% lower than average), while the Redwood Creek survival rate was slightly higher (1%) than average. The decrease in the Olema Creek egg-to-juvenile survival rate was likely caused by the below average rainfall experienced during WY 2008 and a decreased survey area due to the onset of fall rains. During the winter of 2007-2008, Marin County experienced below average rainfall, receiving only 32 in of rain compared to the average of 39 in per year. In particular, the spring of 2008 was exceptionally dry with less than 1 in of rain occurring after February. The reduced spring rainfall, combined with the second consecutive year of below average rainfall, resulted in intermittent stream conditions in the upper 16% of the surveyed area. The basinwide survey on Olema Creek was halted approximately 4 km early due to the onset of an early fall rain starting on 30 October 2008. This resulted in the completion of only 73% of the typical area surveyed. In Pine Gulch, a survival estimate was not obtained due to the absence of coho fry in the watershed.

Our investigations have raised a question about the causes for the differences in egg-to-juvenile survival rates between Olema and Redwood Creek. During four of the past five years of monitoring, Redwood Creek has had a lower egg-to-juvenile survival rate than Olema Creek. During the survey period of 2004-2006, which had normal to high rainfall and runoff, including high spring flows, Redwood juvenile survival rates were low. In 2007 when the spring had well below normal rainfall totals, however, the Redwood Creek egg-to-juvenile survival rate was similar to that of the Olema and Pine Gulch Creek watersheds. Information provided by

Kamman Hydrology and Engineering, Inc. and the NPS has indicated channel confinement in lower Redwood Creek (Jones and Stokes 2007) as a possible cause for the lower survival rate. The channel is also confined in upper Redwood Creek through Muir Woods National Monument where historic bank armoring was installed by the Civilian Conservation Corps. Observations during summer habitat surveys show that the average density of side channel and backwater habitat for Redwood Creek is approximately 50% of that observed in Olema and Pine Gulch Creeks. The Redwood Creek estuary known as “Big Lagoon” is a fraction of its historic size and provides limited habitat for salmonids before entering the Pacific Ocean.

The lack of emergent fry habitat is further evidenced by coho fry captures at the Redwood Creek downstream migrant trap during the spring of 2005 and 2006. Coho fry captures in the downstream extent of the watershed suggests that a large number of coho fry are prematurely forced downstream due to the lack of available refugia during spring storm events. Recent restoration projects on Redwood Creek, including Phase I and II of the Banducci restoration which installed woody debris and altered bank slope, as well as the proposed Big Lagoon restoration which will remove stream bank levies and expand the tidal lagoon, have been designed to expand and enhance side channel and backwater habitat to reduce this potential habitat and population constraint.

4.1.2 Juvenile-to-Smolt Survival

The juvenile-to-smolt survival rate is determined based on the spring outmigration estimate divided by the juvenile population estimate documented the previous summer. The juvenile-to-smolt survival rate is indicative of the overwinter survival, and may reflect on the availability of overwintering habitat within the watershed. Spring outmigrant trapping is problematic to conduct. High spring flows often wash out the trap, resulting in missed monitoring days. In these cases, the smolt trapping often underestimates the rate of outmigration; however the resulting estimate remains an important aggregate measure of watershed habitat quality. In addition, aggregate smolt size information, including average fork length and weight of outmigrating coho salmon, indicate differences between watersheds, which is important with respect to ocean survival and adult returns.

Factors that may affect the rate of juvenile-to-smolt survival include winter and spring peak discharge events, overwintering (floodplain) refugia, and predation. Estimated juvenile-to-smolt survival has ranged from 1-83% in Olema Creek between 2004 and 2008. The low of 1% survival was calculated in Spawner Year 2003-2004, and the high estimate was calculated in SY 2005-2006. In Pine Gulch Creek, the estimated juvenile-to-smolt survival was 32% in SY 2004-2005 and 98% in SY 2005-2006. For Redwood Creek, the estimates for juvenile-to-smolt survival ranged from 26% (SY 2006-2007) to 31% (SY 2003-2004). The notable exception to that range is for SY 2005-2006, where the survival was 129%. This number could be influenced by several factors. The smolt production estimate is an estimate based on the entire watershed, as opposed to the juvenile estimate which is taken from a designated reach within the mainstem of Redwood. Also, due to the small size of the population being monitored, uncertainties within the population estimate can have a bigger impact on survival rates than with a population that is larger in size. When combined with environmental influences, such as a mild winter with low mortality, these other uncertainties can result in an inflated survival estimate.

During the spring of 2008, both Olema and Redwood Creeks experienced lower juvenile-smolt survival rates than in previous years. The highest survival rate was observed in Redwood Creek

with an estimated survival rate of 26%, while the survival rate observed in Olema Creek was much lower at 9%.

Although Olema Creek had a lower smolt survival rate from juvenile-to-smolt (9% for SY 2006-2007), total smolt production increased by almost eight times when compared to the previous cohort (SY 2003-2004), producing the second highest smolt production estimate on record. The increased number of smolts produced will increase the likelihood of a strong returning run during the winter of 2009-2010 on Olema Creek. Likewise, Redwood Creek observed a minor increase (4%) in smolt production from the previous cohort (SY 2003-2004), thus increasing the chances for increased escapement numbers in 2009-2010. However, smolt condition scores on both Redwood and Olema Creek were both significantly different than previous years, with both streams showing a lower K-factor than the historical average.

4.1.3 Smolt-to-Adult Survival

The smolt-to-adult survival estimates correlate with the ocean phase of the coho salmon life-cycle. The smolt condition factors, including length and weight, at the time of outmigration (Miller and Sandros 2003), as well as the estuarine habitat condition and availability at the mouth of these watersheds, likely affects the adult returns. In addition, the ocean productivity metrics that have been developed and refined over the past decade have dramatically increased the ability of scientists to be predictive about the ocean conditions and therefore potential rates of return for these salmonid populations. In both 2005 and 2006, it has been documented that the ocean conditions in the Central California coast area were abnormal, with warmer water conditions and reduced upwelling throughout the region (McClatchie et al. 2008). In future years, the smolt-to-adult survival may be analyzed against documented ocean indicators.

The 2007-2008 adult returns were reduced from the previous return of this year class. In Olema Creek, the mainstem experienced a 77% decline in coho redds for the 2007-2008 year class compared to 2004-2005 year class. Total Olema Creek watershed redd numbers, which takes into account John West Fork, declined by 79%. The most dramatic decline occurred on Redwood Creek with a 98% decline in total coho redd production from the previous year class. On Pine Gulch Creek, one adult coho was observed but no viable redds were produced. Based on smolt production estimates, the 2007-2008 year class should have produced much stronger returns. However, due to poor ocean productivity (McClatchie et al. 2008) ocean survival rates were low, which resulted in a catastrophic decline in coho population regionally (MacFarlane et al 2008). Tables 50, 51, and 52 represent life stage comparisons and survival rates for coho salmon within Olema Creek, Redwood Creek, and Pine Gulch, respectively.

Table 50. A comparison of multiple life stage observations of coho salmon within the Olema Creek mainstem for Spawner Year (SY) 2004-2005 and SY 2007-2008.

	SY	
	2004-2005	2007-2008
PLD Index	184	22
Redds (watershed redd total) ^d	91 (136)	19 (26)
Average female fork length	65.7	64 ^a
Estimated number of eggs	234,317 ^b	44,802 ^b
Basinwide juvenile estimate	29,887±9,974	3,328±696
Estimated survival rate egg-to-juvenile	12.8%	7.4%
Watershed smolt production estimate	3,793 ± 784	-
Mean smolt length (mm)	99	-
Mean smolt weight (g)	10.27	-
Estimated survival rate juvenile-to-smolt	12.7%	-
Estimated survival rate egg to smolt	1.6%	-
Estimated survival rate smolt-to-adult ^c	1.4%	Spawner Year 2010-2011

^a Average female length based on female carcass lengths on Olema Creek for spawner years 2003-2004 thru 2007-2008.

^b Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.

^c Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the total watershed redd count (in parentheses)) divided by the estimated number of outmigrating smolts for previous cohort

^d Includes John West Fork redd count

Table 51. A comparison of multiple life stage observations of coho salmon within the Redwood Creek mainstem for Spawner Year (SY) 2004-2005 and SY 2007-2008.

	SY	
	2004-2005	2007-2008
PLD Index	171	0
Redds	72	2 ^b
Average female fork length	63.3	62.5 ^c
Estimated number of eggs	164,376 ^a	4,398 ^a
Basinwide juvenile estimate	8,594± 1,652	431± 271
Estimated survival rate egg-to-juvenile	5.2%	9.8 %
Watershed smolt production estimate	2,502± 257	-
Mean smolt length (mm)	98	-
Mean smolt weight (g)	9.25	-
Estimated survival rate juvenile-to-smolt	29.1%	-
Estimated survival rate egg to smolt ^d	1.5%	-
Estimated survival rate smolt-to-adult ^c	0.2%	Spawner Year 2010-2011

^a Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.

^b Estimated based on distribution of juvenile coho observed during the summer of 2008.

^c Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-1998 through 2006-2007.

^d Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the redd count) divided by the estimated number of outmigrating smolts for previous cohort

Table 52. A comparison of multiple life stage observations of coho salmon within the Pine Gulch Creek mainstem for Spawner Year (SY) 2001-2002, SY 2004-2005, and SY 2007-2008.

	SY		
	2001-2002	2004-2005	2007-2008
PLD Index	2	3	0
Redds	2	3	0
Average female fork length	62.5 ^a	62.5 ^a	-
Estimated number of eggs	4,398 ^b	6,597 ^b	-
Basinwide juvenile estimate	1,205±337	1,150± 554	0
Estimated survival rate egg-to-juvenile	27.4%	17.4%	-
Watershed smolt production estimate	-	367±69	-
Mean smolt length (mm)	112	100	-
Mean smolt weight (g)	14.03	9.78	-
Estimated survival rate juvenile-to-smolt	-	31.9%	-
Estimated survival rate egg to smolt	-	5.56%	-
Estimated survival rate smolt-to-adult ^c	-	0%	Spawner Year 2010-2011

^a Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-1998 thru 2006-2007.

^b Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length

^c Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the redd count) divided by the estimated number of outmigrating smolts for previous cohort

5 Conclusion

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the CCCESU. In addition to our NPS/CDFG funded monitoring efforts on Olema Creek, Redwood Creek, Pine Gulch Creek and Cheda Creek, extensive monitoring is conducted by Marin Municipal Water District (MMWD) on Lagunitas Creek, Devils Gulch, and mainstem of San Geronimo Creek, and by the Salmon Protection and Watershed Network (SPAWN) on tributaries of San Geronimo Creek. Through these combined monitoring efforts, we have documented significant information about coho salmon behavior, distribution, and use of these small coastal watersheds.

Information summarized in this report indicates a dramatic decline in the 2007-2008 coho salmon spawner year class from the last return of this cohort, with evidence pointing to poor ocean conditions in the spring of 2006 (McClatchie et al. 2008) when these fish entered the ocean as smolts. This observed decline was also observed on a regional scale (MacFarlane et al. 2008). The results also show an effect of stream environmental conditions. For summer 2008, we observed lower rates of egg-to-juvenile survival (7-10%), for coho juveniles, as well as lower overwintering survival (9-26%) for the smolts outmigrating in spring 2008. These rates of survival were lower than expected given the mild winter and dry spring conditions. Fulton Condition Factors (K-factors), which provides a weight-length indecies, were also significantly lower than average for both Redwood and Olema Creeks and for both coho and steelhead. This suggests limitations in both food and habitat availability. In particular fish may have had limited food and rearing habitat during the late summer and early fall months. The observed summer fish lengths on both Olema and Redwood Creek suggests that although fish may have had adequate food and habitat during the spring and early summer months, the dry stream conditions during the late summer and early fall caused added stress to the population.

The intensity of our life-cycle monitoring program allows for larger scale characterization of patterns observed in the area. Though a relatively small geographic area, the coastal Marin watersheds support a significant proportion of the CCCESU coho salmon, as well as two genetically distinct subpopulations. Genetic evaluations suggest that coho salmon occurring in Olema Creek and Cheda Creek constitute part of the Lagunitas/Olema genetic subgroup that would likely encompass the entire Tomales Bay watershed. Genetic evaluation also suggests that the Pine Gulch Creek population represents an expansion of the Redwood Creek coho population to a new watershed (Garza and Gilbert 2003).

Based on smolt production estimates for this coho salmon cohort, the 2007-2008 year class should have produced strong returns; however, only a few returns were actually observed. The total Olema Creek watershed redd count, including John West Fork, declined by 77%. Redwood Creek mainstem had a 98% decline in total coho redd production from the previous year class. Of the four consecutively monitored years of this cohort on Redwood Creek, 2007-2008 had the lowest coho spawning activity. This year also represented the non-return of coho to Pine Gulch Creek. Although one adult coho was observed, no viable redds were constructed. Subsequent summer surveys did not document coho juveniles in Pine Gulch Creek.

Our review of redd count and escapement information collected over the past decade indicates annual fluctuations in spawning for each returning cohort in Olema, Cheda, Pine Gulch, and Redwood Creeks. The patterns represented in our monitoring data suggest a regional influence on the coho salmon escapement observed over the past decade. Overall coho escapement within

Marin County watersheds has fluctuated dramatically since the 1997-1998 ENSO event, which likely triggered the Pacific Decadal Oscillation (PDO) shift of dominant productivity from the Alaska Current to the California Current in the late 1990s (Goericke et al. 2005). This event caused high flows during the winter of 1997-1998, which may have resulted in low overwinter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the overwintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class.

From 1999 to 2005, all three coho year classes in Olema Creek and Redwood Creek showed a strong response to these changing ocean productivity patterns. The upward trend was most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed during the winter of 2000-2001. Since 2005 there has been a sharp downward trend in observed coho returns. Based on regional information (MacFarlane et al 2008) and ocean productivity indexes (Goericke et al. 2007, McClatchie et al. 2008), poor upwelling along the California coast during the summer of 2005 and 2006 has resulted in a decrease in ocean productivity within coho ocean rearing grounds. This decrease in ocean productivity has caused a decline in coho returns along the entire CCCESU (MacFarlane et al 2008). Continued monitoring efforts will allow for better characterization of year classes and annual productivity of coho salmon within coastal Marin County watersheds.

Up until this spawner season, the emerging picture from 13 winters of coho spawner surveys on Olema Creek reveals the presence of two strong year classes (Year Class 1 and 2) and one weak year class (Year Class 3). Year Class 3 was probably the strongest of the three, with a PLD index (used as a minimum escapement estimate) of 180 during the 1996-1997 spawning run. Although low spawner counts for the last three runs of this year class may be due in part to poor survey conditions, juvenile density observations support the notion that this became, and now remains, the weakest year class. With the poor numbers from this year's spawner run, that picture may change. While Year Class 2 had been the strongest, high ocean mortality for the adults may have a lasting impact on the cohort, leaving Year Class 1 as the strongest year class.

On John West Fork Creek, 11 winters of coho spawning surveys has revealed a dramatic increase in coho spawners above the State Route 1 culvert (MP 22.67) since the completion of the culvert modification to improve fish passage. In spawner year 2006-07, there was an increase in redd construction but a decrease in the PLD index for Year Class 1, which may be due in part to poor survey conditions. In the 1999-2000 and 2002-2003 spawning years, John West Fork counts exceeded mainstem results, likely due in part to lower flows and better survey conditions on the tributary. As with the mainstem in spawner year 2007-2008, the return numbers were below those expected.

Results from 14 winters of coho spawner surveys on Redwood Creek revealed the presence of two year classes (Year Class 2 and 3) that are currently in low numbers and one moderate year class that may be in decline (Year Class 1). Previously, Year Class 3 was probably comparable to Year Class 1, with a PLD index of 57 during the 1996-1997 spawning run. However, the resulting cohort likely suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-1998 (McClatchie et al. 2008). However, with the high oceanic mortality and the apparent lack of any adult spawners on Redwood in 2007-2008, the strongest year class (Year Class 2) may have been relegated to the weakest year class.

The 2008 smolt production estimates on both Olema and Redwood Creek watersheds were lower than expected based on the juvenile population estimates calculated during the summer of 2007, indicating reduced overwinter survival (9% on Olema Creek and 26% on Redwood Creek). There are several causes that could have contributed to the low observed overwinter survival rate including: limited food and habitat availability in late fall 2007, lack of winter refugia during the high flow events in December 2007, limited food availability during the spring of 2008, migrational barriers caused by low spring flows, and predation.

This summary also documents extensive information on size 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 at surviving to adulthood. Based on these data, we have identified that the spring 2006 outmigrants from all watersheds were approximately 10 mm and 3 g smaller than average when compared with other years. Second, Redwood Creek tends to have smaller smolt outmigration sizes than the Olema or Pine Gulch Creek watersheds. The smaller smolt sizes likely contributed to high ocean mortality and the resulting poor return rates observed during the 2004-2005 spawner season. Comprehensive smolt trapping is in its fifth year of operation at both Olema and Redwood Creeks. Additional years of data will help refine the general size of smolts leaving these coastal Marin watersheds.

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Appendix A

Table A1. Coho Spawner Survey Redd Density History for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek, John West Fork, Redwood Creek, and Pine Gulch including total redds, survey length and redd density.

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek			John West Fork			Redwood Creek			Pine Gulch		
	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density	Total redds	Survey length	Redd density
1997-1998	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	125	13.4	9.3	6	1.3	4.6	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	19	11.6	1.6	4	1.2	3.3	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	3	7.2	0.4	7	1.1	6.4	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	50	11.6	4.3	30	1.9	15.8	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	33	11.6	2.9	26	1.9	13.7	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	9	11.6	0.8	10	1.3	7.7	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	86	11.6	7.4	21	2.4	8.8	42	7.4	5.7	0	9.5	0
2004-2005	120	12.8	9.4	138	7.0	19.7	112	3.7	30.6	91	11.6	7.9	45	2.4	18.8	72	7.4	10.0	3	9.5	0.3
2005-2006	53	12.8	4.1	48	7.0	6.9	33	3.7	8.9	2	11.6	0.2	4	2.4	1.7	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	66	11.6	5.7	29	2.4	12.1	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	19	15.1	1.3	7	2.4	3.3	0	7.4	0	2	9.5	0.2

Table A2. Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2007-2008 on the Olema Creek mainstem, plus Peak Live plus Cumulative Dead (PLD) and Area Under the Curve (AUC) estimates.

Spawner year	Run timing				Total monthly rainfall (in)				Olema Creek spawner summary					
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey area (km)	# surveys	Total carcass counts	Total redds	PLD	AUC range 70-80% OE RT 11-13 days
1997-1998 ^e					10.32	3.47	16.49	24.68	13.4	8	39	125	88	91-123
1998-1999					7.48	2.21	7.66	15.61	11.6	6	13	19	42 ^a	57-77
1999-2000					5.2	0.99	7.15	12.77	7.2	2	9	3	9 ^b	N/A
2000-2001					1.54	1.31	6.45	8.07	11.6	4	65	50	103	122-165
2001-2002					9.81	15.03	5.08	3.55	11.6	4	26	33	88 ^c	172-232
2002-2003					3.3	17.33	3.75	2.34	11.6	4	16	9	23 ^b	N/A
2003-2004					2.71	12.14	5.13	7.68	11.6	6	33	86	138 ^d	225-304
2004-2005					0.65	10.13	4.85	5.33	11.6	6	60	91	184 ^d	243-328
2005-2006					3.27	19.9	7.94	4.76	11.6	3	11	2	12 ^b	N/A
2006-2007					5.54	6.43	1.09	9.93	11.6	6	27	66	80 ^d	131-177
2007-2008					1.09	6.76	14.66	N/A	13.2	8	5	19	22 ^d	30-40

a/ Includes two peaks, 7 weeks apart.

b/ Surveys missed peak numbers.

c/ Includes two peaks, 4 weeks apart.

d/ Includes two peaks, 3 weeks apart.

e/ Data source Manning 1999.

N/A = not available or survey data was not adequate to develop AUC estimate.

Table A3. Coho salmon run timing, average total rainfall by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2007-2008 on the John West Fork tributary to Olema Creek, plus Peak Live plus Cumulative Dead (PLD) and Area Under the Curve (AUC) estimates.

Spawner year	Run timing				Total monthly rainfall (in)*				John West Fork spawner summary					
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey area (km)	# surveys	Total carcass counts	Total redds	PLD	AUC range 70-80% OE RT 11-13 days
1997-1998					10.32	3.47	16.49	24.68	1.3	5	0	6	12	N/A
1998-1999					7.48	2.21	7.66	15.61	1.2	2	0	4	9	N/A
1999-2000					5.2	0.99	7.15	12.77	1.1	3	0	7	18 ^a	12-16
2000-2001					1.54	1.31	6.45	8.07	1.9	4	31	30	58	69-94
2001-2002					9.81	15.03	5.08	3.55	1.9	6	4	26	20	41-55
2002-2003					3.3	17.33	3.75	2.34	1.3	7	0	10	27 ^b	23-31
2003-2004					2.71	12.14	5.13	7.68	2.4	6	7	21	41	49-67
2004-2005					0.65	10.13	4.85	5.33	2.4	7	12	45	86 ^c	98-132
2005-2006					3.27	19.9	7.94	4.76	2.4	7	0	4	8	14-19
2006-2007					5.54	6.43	1.09	9.93	2.4	7	5	29	28 ^d	26-35
2007-2008					1.09	6.76	14.66	N/A	2.4	7	0	7	11	5-6

a/ Surveys missed peak numbers

b/ Includes two peaks, 4 weeks apart

*/ Same rainfall data as for Olema Creek mainstem.

c/ Includes two peaks, 3 weeks apart

d/ Includes two peaks, 2 weeks apart

N/A = not available or survey data was not adequate to develop AUC estimate.

Table A4. Area Under the Curve (AUC) population estimates for coho salmon adults in Reaches 2-6 of Olema Creek during 2007-2008. Observer efficiency is based on average clarity of the surveys.

Residence time (days)	Observer efficiency					
	100%	90%	80% ^f	70% ^c	60%	50%
8 ^a	39	43	49	55	65	78
9 ^b	35	38	43	49	58	69
10 ^c	31	35	39	44	52	62
11 ^{d,e,f}	28	31	35	40	47	56
12	26	29	32	37	43	52
13 ^{a,e,f,g}	24	27	30	34	40	48
14 ^g	22	25	28	32	37	44
15 ^a	21	23	26	30	35	41
16	19	22	24	28	32	39
17 ^a	18	20	23	26	30	37

a/ Irvine et al. (1992)

b/ van der Berghe and Gross (1986)

c/ Flint (1984)

d/ Beidler and Nickelson (1980)

e/ Johnston et al. (1987): 69% observer efficiency

f/ Crone and Bond (1976)

g/ Koski (1966)

h/ Solazzi et al. (1984): 76% observer efficiency

Table A5. Area Under the Curve (AUC) population estimates for coho salmon adults in John West Fork during 2007-08. Observer efficiency is based on average clarity of the surveys.

Residence time (days)	Observer efficiency					
	100%	90%	80% ^f	70% ^c	60%	50%
8 ^a	7	8	9	9	10	12
9 ^b	6	7	8	8	9	11
10 ^c	5	6	7	7	8	10
11 ^{d,e,f}	5	6	6	6	7	9
12	5	5	6	6	7	8
13 ^{a,e,f,g}	4	5	5	5	6	8
14 ^g	4	4	5	5	6	7
15 ^a	4	4	5	5	5	7
16	3	4	4	4	5	6
17 ^a	3	4	4	4	5	6

a/ Irvine et al. (1992)

b/ van der Berghe and Gross (1986)

c/ Flint (1984)

d/ Beidler and Nickelson (1980)

e/ Johnston et al. (1987): 69% observer efficiency

f/ Crone and Bond (1976)

g/ Koski (1966)

h/ Solazzi et al. (1984): 76% observer efficiency

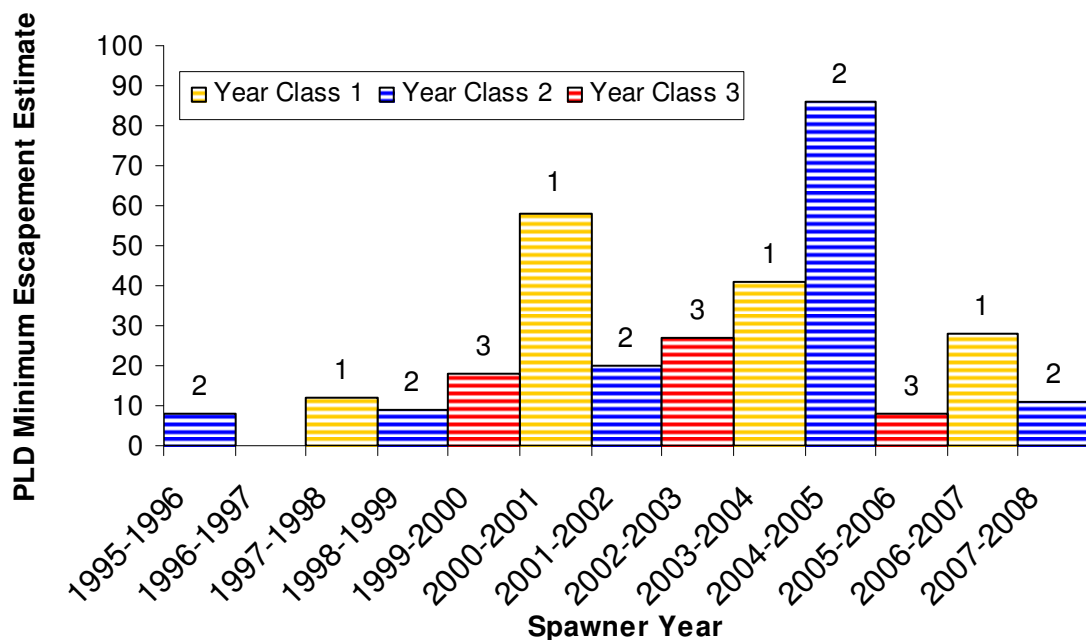


Figure A1. John West Fork Creek coho salmon PLD index escapement results winter 1995-1996 through winter 2007-2008.

Table A6. Coho salmon spawning survey including Peak Live plus cumulative Dead (PLD) index, tally of total carcasses, and total redds for all of the tributaries of the Olema Creek watershed excluding John West Fork. These tributaries include Quarry Gulch, Giacomini Creek, Horse Camp Creek, and Boundary Gulch, 1997-2008.

Year	Number of surveys	Total live	Total carcasses	Total new redds	Source
1997/1998	6	4	1	3	NPS-PRNS
1998/1999	0	0	0	0	NPS-PRNS
1999/2000	2	0	0	0	NPS-PRNS
2000/2001	4	0	0	0	NPS-PRNS
2001/2002	4	1	0	0	NPS-PRNS
2002/2003	0	0	0	0	NPS-PRNS
2003/2004	2	0	0	1	NPS-PRNS
2004/2005	6	2	3	3	NPS-PRNS
2005/2006	4	3	0	3	NPS-PRNS
2006/2007	3	3	0	0	NPS-PRNS
2007/2008	4	0	0	0	NPS-PRNS

Table A7. Coho salmon spawning survey data for Lagunitas Creek mainstem, 1982-2008.

Year	Number of surveys	PLD Index	Total carcasses	Total new redds	Source
1982/1983	6	N/A	N/A	65	Bratovich & Kelly 1988
1983/1984	6	N/A	N/A	26	Bratovich & Kelly 1988
1991/1992	1	N/A	N/A	34	Wise 1992
1995/1996	10	129 ^a	N/A	70	Trihey & Assoc. 1996
1996/1997	8	170 ^a	23	98	Trihey & Assoc. 1997
1997/1998	10	46	27	80	MMWD
1998/1999	8	56 ^b	6	92	MMWD
1999/2000	14	371 ^b	37	139	MMWD
2000/2001	14	181 ^b	18	119	MMWD
2001/2002	15	214 ^b	25	79	MMWD
2002/2003	13	283 ^b	18	71	MMWD
2003/2004	17	270 ^b	23	124	MMWD
2004/2005	17	448 ^b	37	120	MMWD
2005/2006	20	152	4	53	MMWD
2006/2007	19	166	44	128	MMWD
2007/2008	17	59	13	87	MMWD

a/ Peak live fish counts only, no cumulative dead.

b/ Corrected live fish observations reported by MMWD, may include repeat sightings of same fish

N/A= not available.

MMWD = Marin Municipal Water District data

Table A8. Coho salmon run timing, average daily discharge by month, total carcasses and redds documented in surveys for spawner years 1997-1998 through 2007-2008 on the Redwood Creek watershed, plus Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) estimates.

Spawner year	Run timing				Total monthly rainfall (in)				Redwood Creek spawner summary					
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey area (km)	# surveys	Total carcass counts	Total redds	PLD	AUC range 70-80% OE RT 11-13 days
1997-1998									9.4 ^a	7	24	72	54	145-195
1998-1999					3.28	1.49	5.27	8.47	9.4 ^a	11	10	41	39 ^c	64-87
1999-2000					2.72	0.59	5.95	0.00	8.4 ^b	6	1	5	10	13-18
2000-2001					0.00	0.00	4.39	6.07	9.4 ^a	5	11	12	49	121-163
2001-2002					0.00	0.00	0.83	3.56	9.4 ^a	5	50	20	94	190-257
2002-2003					2.18	13.04	1.23	1.83	9.4 ^a	5	3	3	24 ^e	35-48
2003-2004					2.62	3.45	7.21	6.38	9.4 ^a	5	25	42	67	70-94
2004-2005					0.8	7.59	3.66	3.09	9.4 ^a	7	63	72	171	276-373
2005-2006					2.19	12.57	0.00	3.48	9.4 ^a	5	5	11	27	45-61
2006-2007					2.58	4.27	0.63	3.63	9.4 ^a	9	6	21	28 ^g	39-51
2007-2008					1.79	7.84	16.23	2.23	9.4 ^a	8	0	0	0	N/A

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

b/ Includes the mainstem of Redwood Creek and Fern Creek.

c/ Includes two peaks, 7 weeks apart.

d/ Includes two peaks, 22 days apart.

e/ Includes two peaks, 33 days apart.

f/ Includes two peaks, 25 days apart.

g/ Includes three peaks, 26 and 24 days apart.

Table A9. Coho salmon spawning survey including Peak Live plus cumulative Dead (PLD) index, tally of total carcasses, and total redds for the Pine Gulch Creek mainstem.

Year	Year class	Number of surveys	Survey area (km)	PLD Index	Total carcasses	Total new redds	Source
2000/2001	1	3	7.0	1	0	0	NPS-PRNS
2001/2002	2	2	9.0	2	0	2	NPS-PRNS
2002/2003	3	2	8.0	2	2	1	NPS-PRNS
2003/2004	1	6	9.0	0	0	0	NPS-PRNS
2004/2005	2	3	10.0	3	0	3	NPS-PRNS
2005/2006	3	4	9.5	1	0	1	NPS-PRNS
2006/2007	1	4	9.5	0	0	0	NPS-PRNS
2007/2008	2	3	9.5	1	0	2	NPS-PRNS

Using the data collected, fish length can be plotted against weight, and a power function curve can be calculated, providing an idea of the fitness of the sample of measured fish. The calculated power function curve is also known as the weight-length regression curve. Weight-length relationships are presented for Olema Creek coho smolts (Figure A2) and steelhead smolts (Figure A3), as well as for Redwood Creek coho (Figure A4) and steelhead (Figure A5). Additionally, comparisons of the average weight-length relationships from both watersheds for coho (Figure A6) are provided to determine if variations in relative health between these key populations exist.

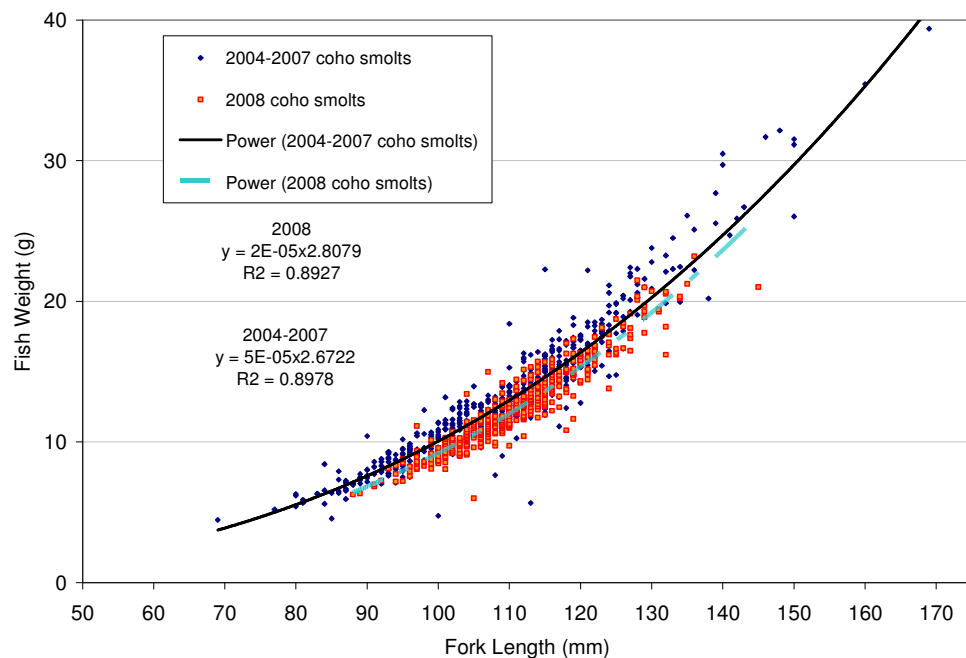


Figure A2. Weight-length comparisons between coho smolts of Olema Creek in 2008 compared to the historical average from years 2004-2007. Power regression lines shown for both 2008 smolts and 2004-2007 smolts.

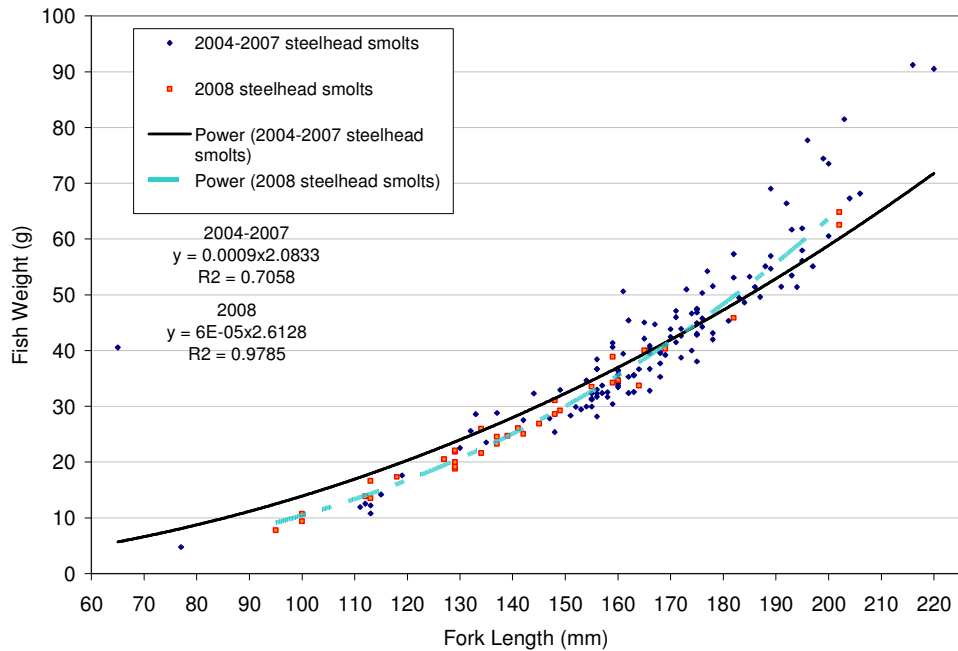


Figure A3. Weight-Length comparison between steelhead smolts of Olema Creek in 2008 compared to the historical average from years 2004-2007. Power regression lines shown for both 2008 smolts and 2004-2007 smolts.

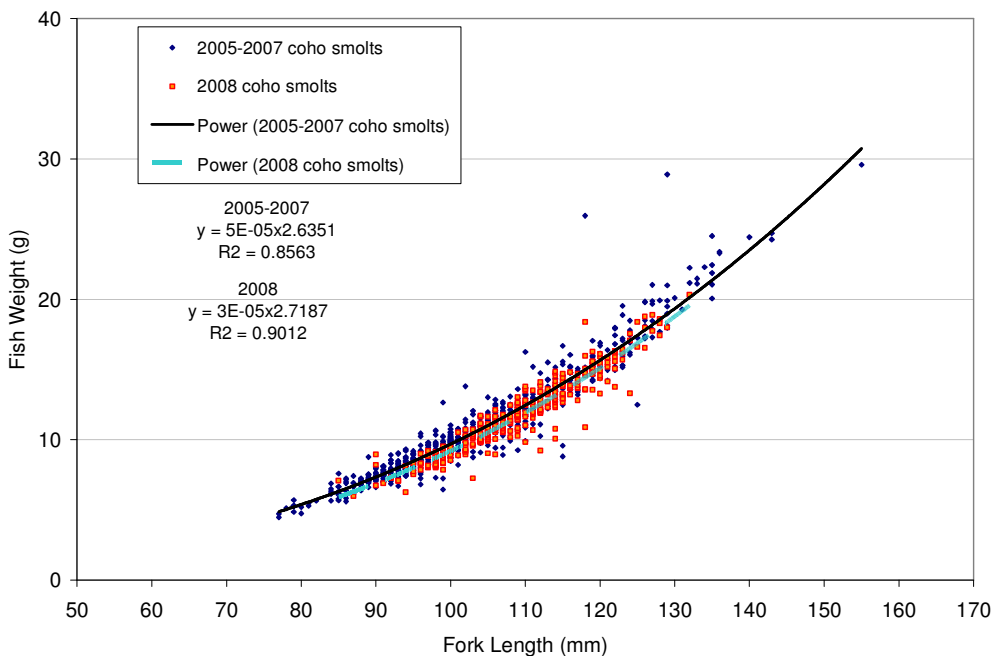


Figure A4. Weight-Length comparison between coho smolts of Redwood Creek in 2008 compared to the historical average from years 2005-2007. Power regression lines shown for both 2008 smolts and 2004-2007 smolts.

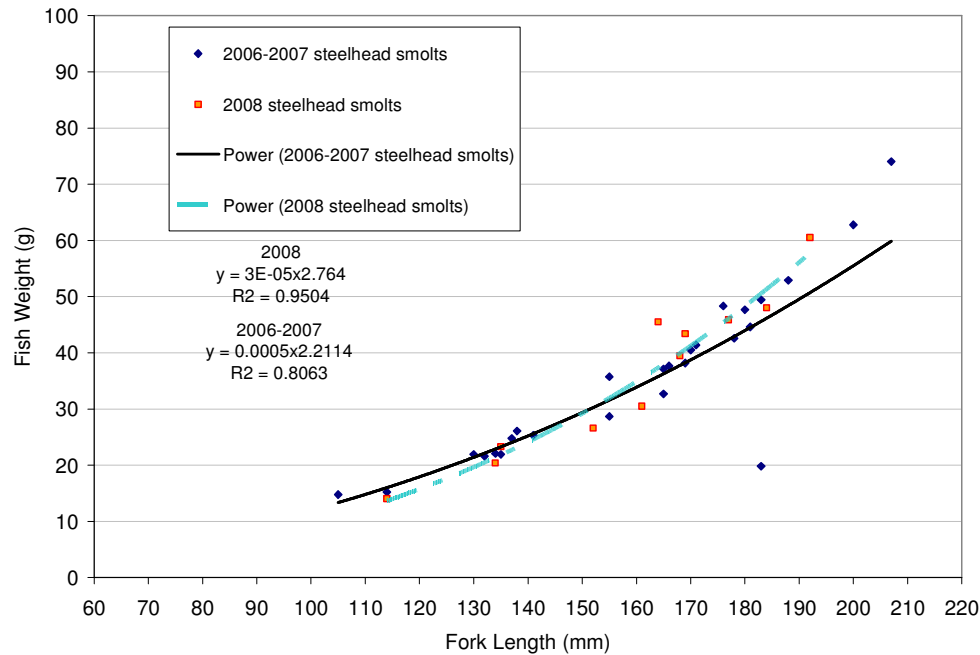


Figure A5. Weight-Length comparisons between steelhead smolts of Redwood Creek in 2008 compared to the historical average from years 2006-2008 (no steelhead smolts caught in 2005). Power regression lines shown for both 2008 smolts and 2004-2007 smolts.

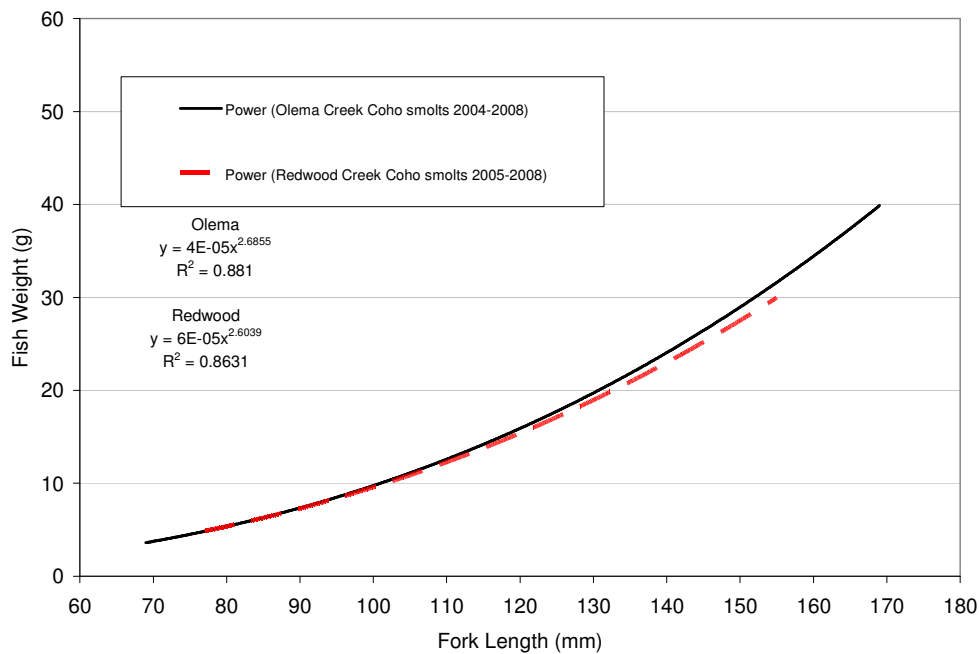


Figure A6. Weight Length comparison between coho smolts of Olema and Redwood Creeks for 2004-2008 (Olema Creek) and 2005-2008 (Redwood Creek). Power regression lines shown for both Olema and Redwood Creeks.

Table A10. Mean coho length, weight, and K-factor calculated for coho measured and weighed in the Olema Creek smolt trap 2004-2008.

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	113.58	9.72	113.00	14.35	4.03	14.35	1.00	0.07
2005	Smolt	37	116.05	9.53	116.00	15.95	3.89	14.98	1.01	0.08
2006	Smolt	205	98.73	9.59	98.00	10.22	3.08	9.55	1.04	0.11
2007	Smolt	191	116.43	10.99	115.00	14.72	4.73	13.64	0.91	0.07
2008	Smolt	386	110.68	9.19	110.00	12.43	3.20	11.91	0.90	0.09

Table A11. Mean steelhead length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Olema Creek smolt trap 2004-2008.

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	176.55	15.38	176.00	55.31	14.37	50.60	0.99	0.09
2005	Smolt	6	127.17	32.45	128.50	22.93	15.85	22.25	0.94	0.13
2006	Smolt	3	129.67	9.45	133.00	24.99	6.39	28.59	1.13	0.09
2007	Smolt	109	168.49	19.21	166.00	41.71	13.59	39.69	0.85	0.08
2008	Smolt	34	141.00	25.74	138.00	27.27	13.01	24.88	0.92	0.09

Table A12. Mean length, weight, and K-factor calculated for coho smolts measured and weighed in the Redwood Creek smolt trap, 2005-2008.

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	93	98.25	12.49	99.00	10.10	3.45	9.79	1.02	0.11
2006	Smolt	412	97.65	8.42	97.00	9.25	2.41	8.98	0.98	0.07
2007	Smolt	213	115.28	10.91	115.00	14.16	4.08	13.63	0.90	0.07
2008	Smolt	295	108.95	8.79	109.00	11.81	2.71	11.64	0.90	0.07

Table A13. Mean length, weight, and K-factor calculated for steelhead smolts measured and weighed in the Redwood Creek smolt trap, 2006-2008 (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	132.10	13.91	134.50	22.94	5.91	22.01	0.99	0.11
2007	Smolt	16	177.31	13.39	177.00	43.65	12.87	42.00	0.77	0.13
2008	Smolt	12	159.33	22.42	163.00	40.47	20.16	41.45	0.96	0.36

Table A14. Summary of non-salmonid information for Olema Creek trap operations, 2004-2008.

Watershed	Year	Trap dates		CH	GSF	GSH	LAM	PL	RO	SCU	STK	SUC	BF	CRAY	RLF	RSN	WPT	CAN	Totals
		From	To																
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
Total average				<1	<1	<1	18	<1	1,010	319	1,574	69	55	10	12	<1	2	0	3,074

Species Code: CH = Chinook salmon, GSF = green sunfish (non-native), GSH = golden shiner (non-native), LAM = lamprey spp., PL = Pacific lamprey, RO = California roach, SCU = sculpin spp., STK = threespine stickleback, SUC = Sacramento sucker, BF = bullfrog (non-native), CRAY = signal crayfish, RLF = California red-legged frog, RSN = rough-skinned newt, WPT = western pond turtle, CAN = California newt

Table A15. Summary of non-salmonid information for Redwood Creek trap operations, 2005-2008.

Watershed	Year	Trap dates		GSH	LAM	PL	SCU	STK	BF	CRAY	RLF	RSN	WPT	CAN	Totals
		From	To												
Redwood Creek	2005	27-Mar	31-May	0	0	0	24	5,343	0	0	0	0	0	11	5,378
	2006	18-Apr	9-Jun	0	0	0	133	117	0	7	0	8	0	2	267
	2007	18-Mar	26-May	0	0	0	93	57	0	44	0	48	0	2	244
	2008	19-Mar	30-May	0	0	0	151	38	0	33	0	61	0	1	284
Total average				0	0	0	100	1,389	0	21	0	29	0	4	1,543

Species Code: GSH = golden shiner (non-native), LAM = lamprey spp., PL = Pacific lamprey, RO = California roach, SCU = sculpin spp., STK = threespine stickleback, SUC = Sacramento sucker, BF = bullfrog (non-native), CRAY = signal crayfish, RLF = California red-legged frog, RSN = rough-skinned newt, WPT = western pond turtle, CAN = California newt

Table A16. Summary of total catch by species within Olema Creek mainstem index reach sample locations, 2004-2008. 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			Not					
	SH 1+	Sampled	147	231	Sampled	182	44	20	39	663
2005	SH 1+		6	10		26	24	10	8	84
	CO		206	255		269	361	191	186	1,468
	SH YOY	Not			Not					
2006	SH 1+	Sampled	72	97	Sampled	180	67	38	44	498
	SH 1+		10	5		13	15	7	7	57
	CO		92	36	0	4	2	9	18	161
2007	SH YOY	Not			93	80	65	37	43	450
	SH 1+	Sampled	37	67	24	54	32	6	20	240
	CO		123	170	233	332	217	156	160	1,391
2008	SH YOY	Not			241	120	51	10	36	705
	SH 1+	Sampled	9	22	16	19	15	3	8	92
	CO		3	42	12	22	9	7	0	95
2008	SH YOY	Not			181	103	40	23	2	607
	SH 1+	Sampled	113	145	13	6	4	1	1	37

CO= coho, SH= steelhead, YOY= young-of-the-year, 1+ = age one year or older

Table A17. Summary of habitat composition; shows extent of area sampled and variation between reaches; Olema Creek, 2008.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	Sampled (m ²)	% of total
1			Not Sampled			
2	Pool	2	45.3	55.93	147.18	59.56
	Riffle	1	7.9	9.75	26.86	10.87
	Flatwater	2	27.8	34.32	73.08	29.57
	TOTAL	5	81	100	247.12	100
3	Pool	3	69.5	74.49	245.3	73.19
	Riffle	0	0	0	0	0
	Flatwater	1	23.8	25.51	89.85	26.81
	TOTAL	4	93.3	100	335.14	100
4	Pool	4	43.3	42.12	139.06	44.79
	Riffle	3	34.2	33.27	84.78	27.31
	Flatwater	1	25.3	24.61	86.65	27.91
	TOTAL	8	102.8	100	310.49	100
5	Pool	2	69.4	59.78	338.41	70.1
	Riffle	3	46.7	40.22	144.37	29.9
	Flatwater	0	0	0	0	0
	TOTAL	5	116.1	100	482.78	100
6	Pool	1	45.2	53.55	231.42	70.19
	Riffle	3	15.2	18.01	54.51	16.53
	Flatwater	1	24	28.44	43.8	13.28
	TOTAL	5	84.4	100	329.73	100
7	Pool	2	33.4	51.31	141.81	54.82
	Riffle	3	31.7	48.69	116.88	45.18
	Flatwater	0	0	0	0	0
	TOTAL	5	65.1	100	258.69	100
8	Pool	2	42.4	78.23	136.63	87.2
	Riffle	1	6.5	12	11.05	7.05
	Flatwater	1	5.3	9.78	9.01	5.75
	TOTAL	4	54.2	100	156.69	100
Total	Pool	16	348.5	58.38	1379.81	65.07
	Riffle	14	142.2	23.82	438.45	20.68
	Flatwater	6	106.2	17.8	302.39	14.25
	TOTAL	36	596.9	100	2120.65	100

Table A18. Summary of total catch from electrofishing surveys for coho salmon by habitat unit on Olema Creek index reaches, 2004-2008.

Year	Habitat type	# of habitat units	Total catch # of fish	Density	
				Fish/m	Fish/m ²
2004	Pool	14	1,434	4.47	0.99
	Riffle	5	Not Sampled		
	Flatwater	5	156	1.38	0.27
2005	Pool	11	1,562	4.01	0.87
	Riffle	4	3	0.07	0.02
	Flatwater	2	1	0.11	0.04
2006	Pool	14	120	0.24	0.05
	Riffle	3	0	0.00	0.00
	Flatwater	4	0	0.00	0.00
2007	Pool	16	1,452	4.56	1.10
	Riffle	6	3	0.06	0.03
	Flatwater	3	10	0.56	0.27
2008	Pool	16	90	0.24	0.07
	Riffle	14	0	0.00	0.00
	Flatwater	6	5	0.03	0.02

Table A19. Summary of total catch from electrofishing surveys for steelhead young-of-the-year (YOY) by habitat unit on Olema Creek index reaches, 2004-2008.

Year	Habitat type	# of habitat units	Total catch # of fish	Density	
				Fish/m	Fish/m ²
2004	Pool	14	537	1.57	0.34
	Riffle	5	Not Sampled		
	Flatwater	5	190	1.63	0.32
2005	Pool	11	466	1.19	0.27
	Riffle	4	51	0.39	0.07
	Flatwater	2	2	0.22	0.08
2006	Pool	14	397	1.14	0.25
	Riffle	3	2	0.11	0.04
	Flatwater	4	46	0.70	0.21
2007	Pool	16	719	2.31	0.59
	Riffle	6	19	0.48	0.20
	Flatwater	3	22	1.29	0.61
2008	Pool	16	448	1.51	0.49
	Riffle	14	57	0.30	0.09
	Flatwater	6	133	0.98	0.36

Table A20. Summary of total catch and density estimates for each species by reach on Olema Creek, summer 2008 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	CO SH YOY SH (1+)	Not Sampled		
2	CO SH YOY SH (1+)	3 113 3	0.04 1.40 0.04	0.01 0.46 0.01
3	CO SH YOY SH (1+)	42 145 9	0.45 1.56 0.10	0.13 0.43 0.03
4	CO SH YOY SH (1+)	12 181 13	0.12 1.76 0.13	0.04 0.59 0.04
5	CO SH YOY SH (1+)	22 103 6	0.19 0.89 0.05	0.05 0.21 0.01
6	CO SH YOY SH (1+)	9 40 4	0.11 0.47 0.05	0.03 0.12 0.01
7	CO SH YOY SH (1+)	7 23 1	0.11 0.35 0.02	0.03 0.09 0.004
8	CO SH YOY SH (1+)	0 2 1	0 0.04 0.02	0 0.01 0.01
	Average density	CO SH YOY SH (1+)	0.16 1.02 0.06	0.04 0.29 0.02

CO= coho, SH= steelhead, YOY= young-of-the-year, 1+ = one year of age or older

Using the data collected, fish length can be plotted against weight, and a power function curve can be calculated, providing an idea of the fitness of the sample of measured fish. Weight-length relationships are shown for coho (Figures A7) and steelhead (Figure A8). For comparison, fork lengths and weight-length relationships from previous years are also presented. Historical data prior to 2004 are not currently available due to an inconsistency in data collection techniques used prior to 2004.

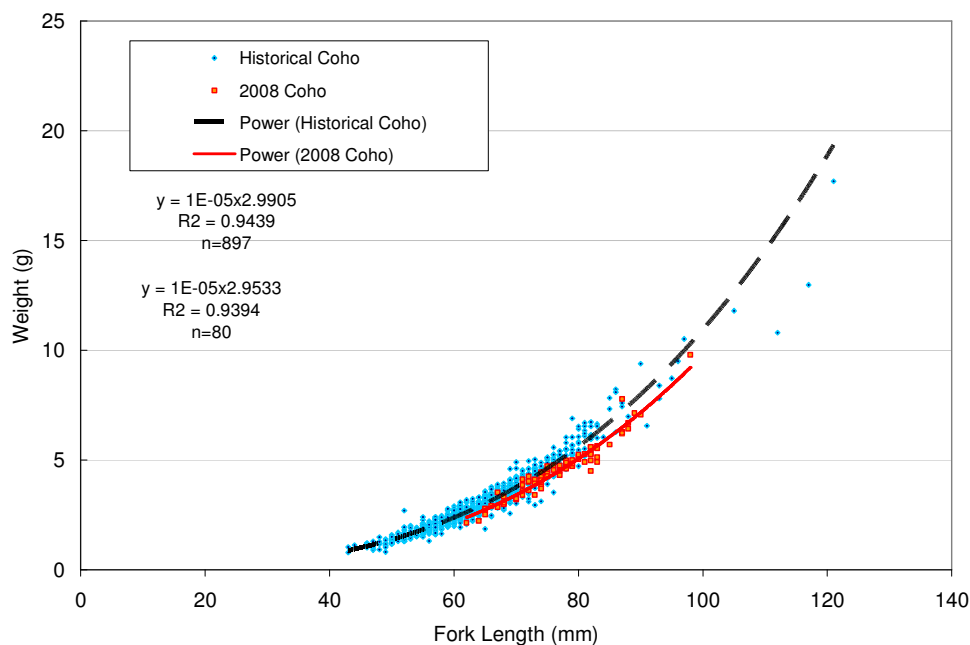


Figure A7. Coho weight-length relationships for fish measured in the seven Olema Creek index reaches, 2008. Weight-length relationship for coho from 2004-2007 shown for comparison. Power regression lines shown for both 2008 and historical juveniles.

The steelhead data points for 2008 fit a power regression line, whereas the steelhead from previous years (2004-2007) fit a linear regression line.

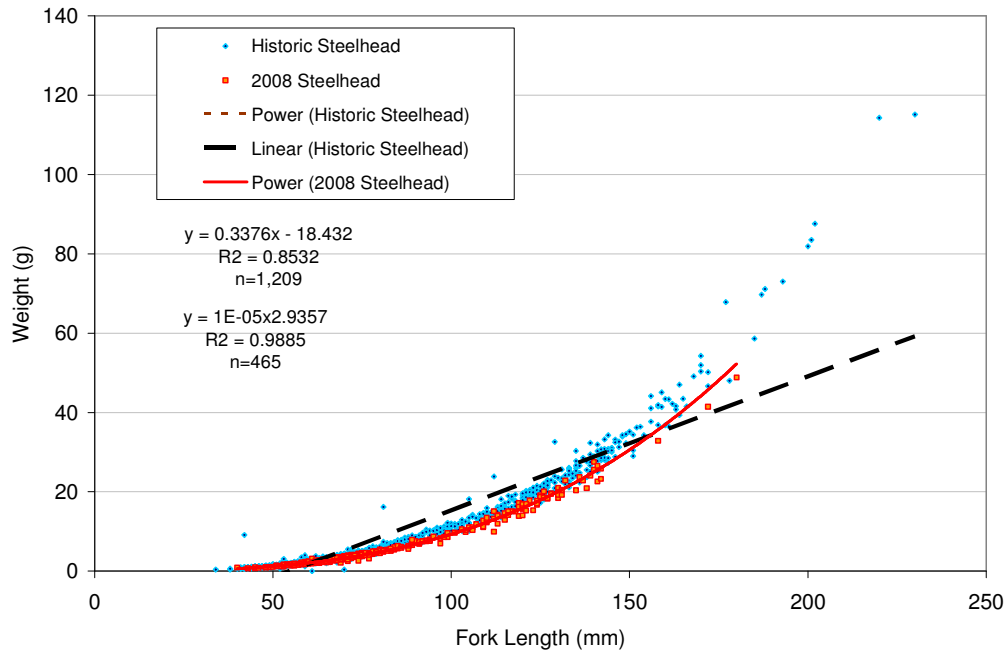


Figure A8. Steelhead weight-length relationships for fish measured in the seven Olema Creek index reaches, 2008. Weight-length relationships for steelhead 2004-2007 are shown for comparison. Power and linear regression lines shown for both 2008 and historical juveniles.

Table A21. Mean coho length, weight, and K-factor calculated for coho measured and weighed in the Olema Creek index reaches 2004-2008.

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	YOY	175	61.26	10.21	60.00	2.80	1.80	2.50	1.13	0.12
2005	YOY	287	64.00	7.09	64.00	3.14	1.07	3.01	1.16	0.08
2006	YOY	81	75.63	7.23	75.00	5.13	1.60	5.00	1.15	0.08
2007	YOY	335	63.95	8.80	64.00	2.86	1.28	2.70	1.04	0.20
2008	YOY	80	76.29	7.09	75.50	4.52	1.29	4.50	0.99	0.07

Table A22. Mean steelhead length, weight, and K-factor calculated for steelhead young-of-the-year (YOY) measured and weighed in the Olema Creek index reaches 2004-2008.

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	YOY	150	55.05	10.70	53.00	2.23	1.53	1.70	1.23	0.92
2005	YOY	239	68.59	10.14	67.00	3.90	1.90	3.41	1.13	0.12
2006	YOY	218	67.44	7.95	68.00	3.62	1.23	3.67	1.13	0.10
2007	YOY	241	54.08	7.82	53.00	1.74	0.78	1.52	1.04	0.12
2008	YOY	321	67.51	9.08	66.00	3.38	1.53	3.01	1.05	0.10

Table A23. Mean steelhead length, weight, and K-factor calculated for steelhead age 1+ measured and weighed in the Olema Creek index reaches in 2004-2008.

Year	Life	Sample	Mean	Length	Median	Mean	Weight	Median	Mean	K-Factor
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	Stage	Size	Length (mm)	Standard Deviation	Length (mm)	Weight (g)	Standard Deviation	Weight (g)	K- Factor	Standard Deviation
2004	1+	68	129.56	25.15	125.50	24.83	14.89	21.30	1.05	0.09
2005	1+	53	140.92	27.52	137.00	32.77	22.49	26.66	1.05	0.07
2006	1+	137	108.55	25.88	101.00	16.53	12.19	11.28	1.14	0.19
2007	1+	80	121.73	17.51	118.00	18.74	8.13	16.49	0.99	0.12
2008	1+	35	113.86	24.89	104.00	15.38	10.50	11.18	0.94	0.08

Table A24. Summary of total catch (not including Dr. Jerry Smith information) for each species by reach within Redwood Creek mainstem index reach sample locations, 2004-2008.

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

Table A25. Summary of habitat composition; shows extent of area sampled and variation between reaches; Redwood Creek, summer 2008.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	sampled (m ²)	% of total
1	Pool	2	29.4	24.89	84.26	21.02
	Riffle	4	52.4	44.37	174.84	43.61
	Flatwater	2	36.3	30.74	141.83	35.38
	TOTAL	8	118.1	100	400.93	100
2	Pool	3	26.6	40.61	93.05	45.65
	Riffle	2	15.8	24.12	45.5	22.32
	Flatwater	2	23.1	35.27	65.29	32.03
	TOTAL	7	65.5	100	203.85	100
3	Pool	4	58.1	72.08	199.15	81.4
	Riffle	2	14.2	17.62	31.81	13.00
	Flatwater	1	8.3	10.3	13.7	5.6
	TOTAL	7	80.6	100	244.66	100
4	Pool	4	60.6	69.98	160.11	89.21
	Riffle	1	8.9	10.28	6.82	3.80
	Flatwater	3	13.5	15.59	12.54	6.99
	Dry	1	3.6	4.16	0	0
	TOTAL	9	86.6	100	179.47	100
5	Pool	3	73.3	70.89	283.17	76.78
	Riffle	1	5.6	5.42	15.96	4.33
	Flatwater	2	24.5	23.69	69.68	18.89
	TOTAL	6	103.4	100	368.81	100
6	Pool	2	26.3	21.74	99.34	48.73
	Riffle	1	2.5	2.07	2.5	1.23
	Flatwater	3	36.7	30.33	102.01	50.04
	Dry	5	55.5	45.87	0	0
	TOTAL	6	121	100	203.85	100
7	Pool		Not Sampled			
	Riffle					
	Flatwater					
	TOTAL					
Total	Pool	18	274.3	47.69	919.08	57.39
	Riffle	11	99.4	17.28	277.44	17.32
	Flatwater	13	142.4	24.76	405.05	25.29
	Dry	6	59.1	10.27	0	0
	TOTAL	43	575.2	100	1601.55	100

Table A26. Summary of total catch from electrofishing surveys for coho salmon by habitat unit on Redwood Creek index reaches, 2004-2008.

Year	Habitat type	# of habitat units	Total catch # of fish	Density	
				Fish/m	Fish/m2
2004	Pool	13	424	1.98	0.54
	Riffle		Not Sampled		
	Flatwater	7	23	0.23	0.10
2005	Pool	19	1,050	2.04	0.52
	Riffle	5	1	0.005	0.001
	Flatwater	3	12	0.24	0.10
2006	Pool	22	103	0.29	0.07
	Riffle	13	0	0	0
	Flatwater	6	0	0	0
2007	Pool	22	761	2.03	0.49
	Riffle	13	2	0.05	0.06
	Flatwater	10	12	0.09	0.04
2008	Pool	18	33	0.10	0.03
	Riffle	11	0	0	0.00
	Flatwater	13	2	0.01	0.005

Table A27. Summary of total catch from electrofishing surveys for steelhead young-of-the-year (YOY) by habitat unit on Redwood Creek index reaches, 2004-2008.

Year	Habitat type	# of habitat units	Total catch # of fish	Density	
				Fish/m	Fish/m ²
2004	Pool	13	60	0.26	0.08
	Riffle		Not Sampled		
	Flatwater	7	16	0.15	0.06
2005	Pool	19	515	1.03	0.28
	Riffle	5	18	0.10	0.02
	Flatwater	3	37	0.75	0.33
2006	Pool	22	151	0.46	0.10
	Riffle	13	18	0.10	0.03
	Flatwater	6	19	0.29	0.09
2007	Pool	22	1,200	3.05	0.79
	Riffle	13	57	0.43	0.22
	Flatwater	10	255	1.47	0.57
2008	Pool	18	443	1.52	0.47
	Riffle	11	27	0.35	0.10
	Flatwater	13	119	0.89	0.43

Table A28. Summary of total catch and density estimates for each species by reach on Redwood Creek, summer 2008 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
1	CO	0	0	0
	SH YOY	84	0.71	0.21
	SH (1+)	10	0.08	0.02
2	CO	2	0.03	0.01
	SH YOY	79	1.21	0.39
	SH (1+)	19	0.29	0.09
3	CO	6	0.07	0.02
	SH YOY	103	1.28	0.42
	SH (1+)	23	0.29	0.09
4	CO	0	0	0
	SH YOY	120	1.39	0.67
	SH (1+)	20	0.23	0.11
5	CO	23	0.22	0.06
	SH YOY	101	0.98	0.27
	SH (1+)	21	0.20	0.06
6	CO	3	0.02	0.01
	SH YOY	79	0.65	0.39
	SH (1+)	12	0.10	0.06
7	CO	Not Sampled		
	SH YOY			
	SH (1+)			
	Average density	CO	0.06	0.02
		SH YOY	0.98	0.35
		SH (1+)	0.18	0.07

CO= coho, SH= steelhead, YOY= young-of-the-year, 1+ = one year of age or older

Weight-length relationships are shown for coho (Figures A9) and steelhead (Figure A10), with historical measurements included for comparison.

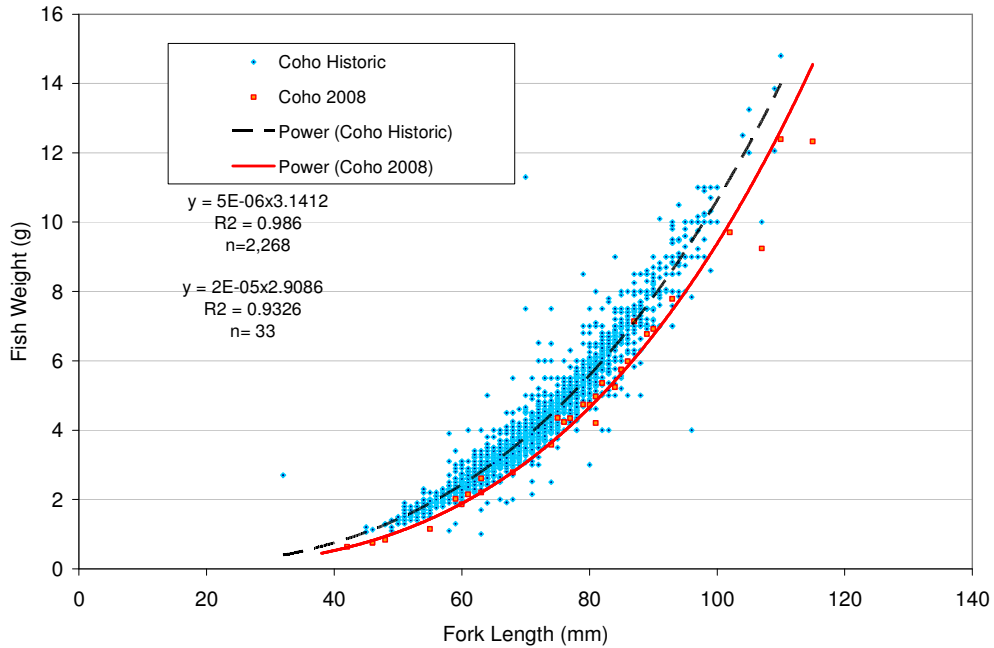


Figure A9. Coho weight-length relationships for fish measured in the seven Redwood Creek index reaches, 2008. Historical relationships added for comparison (1998-2007). Power regression lines shown for both 2008 and historical juveniles.

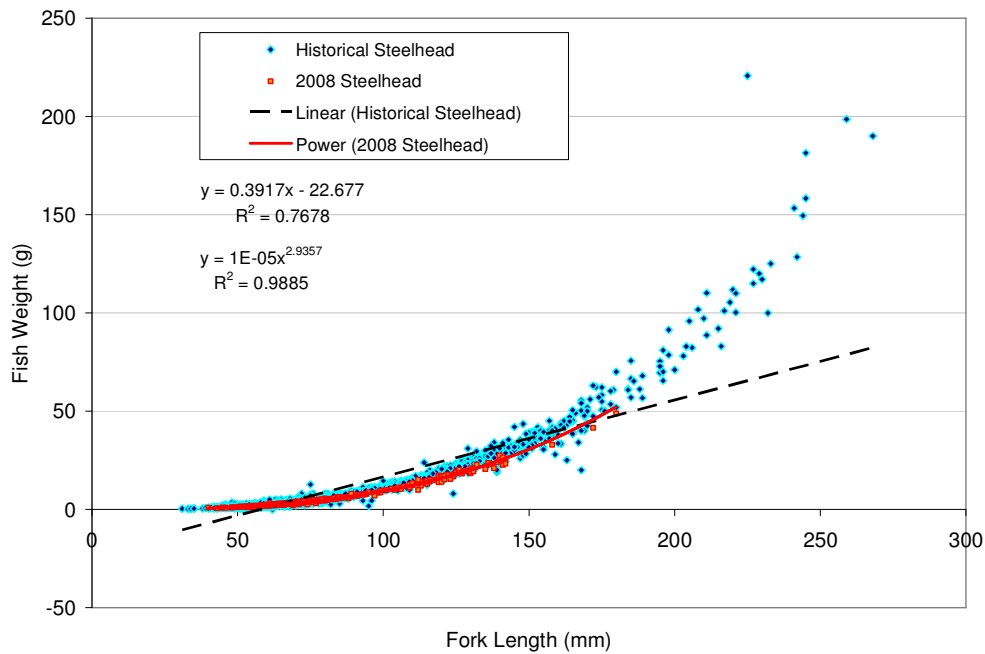


Figure A10. Steelhead weight-length relationships for fish measured in the seven Redwood Creek index reaches. Sample year 2008 is compared to all previous sample years (1998-2007). Power and linear regression lines shown for both 2008 and historical juveniles.

Table A29. Mean length, weight, and K-factor calculated for coho measured and weighed in the Redwood Creek index reaches, 2005-2008.

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	YOY	337	72.15	8.04	71.00	4.39	1.58	4.02	1.13	0.07
2006	YOY	79	78.35	7.32	77.00	5.52	1.65	4.94	1.13	0.10
2007	YOY	294	73.73	8.38	73.00	4.15	1.49	3.89	1.00	0.08
2008	YOY	32	76.53	18.73	79.50	4.79	3.14	4.54	0.90	0.09

Table A30. Mean length, weight, and K-factor calculated for steelhead young-of-the-year (YOY) measured and weighed in the Redwood Creek index reaches, 2005-2008.

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	YOY	340	72.16	10.85	72.00	4.50	2.00	4.20	1.12	0.07
2006	YOY	156	77.99	9.60	78.00	5.43	2.03	5.20	1.10	0.11
2007	YOY	547	63.52	9.61	62.00	2.76	1.30	2.42	1.00	0.11
2008	YOY	372	66.83	9.15	67.00	3.03	1.26	2.86	0.96	0.08

Table A31. Mean length, weight, and K-factor calculated for steelhead age 1+ measured and weighed in the Redwood Creek index reaches, 2005-2008.

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	1+	64	133.66	28.01	128.00	29.00	21.02	23.21	1.08	0.07
2006	1+	89	130.53	26.13	128.00	26.38	21.04	22.58	1.06	0.09
2007	1+	79	121.72	26.32	119.00	19.38	13.12	15.07	0.95	0.11
2008	1+	93	116.45	18.09	116.00	15.40	7.26	14.62	0.92	0.06

Table A32. Summary of total catch for each species by reach within Pine Gulch Creek mainstem index reach sample locations, 2005-2008.

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

CO= coho, SH= steelhead, YOY= young-of-the-year, 1+ = age one year or older

Table A33. Summary of habitat composition; shows extent of area sampled and variation between reaches; Pine Gulch Creek, 2008.

Index reach	Habitat type	# of units	Length		Surface area	
			sampled (m)	% of total	Sampled (m ²)	% of total
1a	Pool					
	Riffle					
	Flatwater					
	TOTAL			Not Sampled		
1b	Pool	1	12.7	21.53	39.37	28.52
	Riffle	0	0	0.00	0	0.00
	Flatwater	3	46.3	78.47	98.67	71.48
	TOTAL	4	59	100.00	138.04	100.00
1c	Pool	4	54.5	91.91	161.2	89.12
	Riffle	1	4.8	8.09	19.68	10.88
	Flatwater	0	0	0.00	0	0.00
	TOTAL	5	59.3	100.00	180.88	100.00
2	Pool	4	51.6	80.00	214.6	80.23
	Riffle	1	12.9	20.00	52.89	19.77
	Flatwater	0	0	0.00	0	0.00
	TOTAL	5	64.5	100.00	267.49	100.00
3	Pool	2	26.4	46.73	120.83	58.64
	Riffle	2	30.1	53.27	85.21	41.36
	Flatwater	0	0	0.00	0	0.00
	TOTAL	4	56.5	100.00	206.04	100.00
4	Pool					
	Riffle					
	Flatwater					
	TOTAL			Not Sampled		
5	Pool	3	30.6	60.36	83.17	63.86
	Riffle	2	20.1	39.64	47.07	36.14
	Flatwater	0	0	0.00	0	0.00
	TOTAL	5	50.7	100.00	130.24	100.00
6	Pool	3	30.6	46.36	72	60.05
	Riffle	2	35.4	53.64	47.9	39.95
	Flatwater	0	0	0.00	0	0.00
	TOTAL	5	66	100.00	119.89	100.00
Total	Pool	17	206.4	57.82	691.15	63.41
	Riffle	8	103.3	29.11	252.77	24.68
	Flatwater	3	46.3	13.07	98.67	11.91
	TOTAL	28	356	100.00	1042.57	100.00

Table A34. Summary of total catch from electrofishing surveys for steelhead young-of-the-year (YOY) by habitat unit in Pine Gulch Creek index reaches, 2005-2008.

Year	Habitat type	# of habitat Units	Total catch # of fish	Density	
				Fish/m	Fish/m ²
2005	Pool	12	233	0.91	0.27
	Riffle	6	15	0.94	0.61
	Flatwater	6	0	0.00	0.00
2006	Pool	15	147	0.66	0.20
	Riffle	11	9	0.07	0.03
	Flatwater	5	15	0.32	0.12
2007	Pool	16	404	1.57	0.48
	Riffle	10	79	0.88	0.27
	Flatwater	4	44	0.83	0.24
2008	Pool	17	292	1.51	0.45
	Riffle	8	81	0.75	0.32
	Flatwater	3	8	0.15	0.08

Table A35. Summary of total catch and density estimates for each species by reach on Pine Gulch Creek, summer 2008; 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
1a	CO SH YOY SH (1+)	Not Sampled		
1b	CO SH YOY SH (1+)	0 9 4	0 0.15 0.07	0 0.07 0.03
1c	CO SH YOY SH (1+)	0 20 15	0 0.34 0.25	0 0.11 0.08
2	CO SH YOY SH (1+)	0 87 12	0 1.35 0.19	0 0.33 0.04
3	CO SH YOY SH (1+)	0 147 16	0 2.60 0.28	0 0.71 0.08
4	CO SH YOY SH (1+)	Not Sampled		
5	CO SH YOY SH (1+)	0 37 15	0 0.73 0.30	0 0.28 0.12
6	CO SH YOY SH (1+)	0 53 10	0 0.80 0.15	0 0.44 0.08
	Average density	CO SH YOY SH (1+)	0 1.00 0.20	0 0.34 0.07

CO= coho, SH= steelhead, YOY= young-of-the-year, 1+ = age one year or older

Steelhead weight-length relationships are shown in Figure A11. Historical numbers are included for comparison.

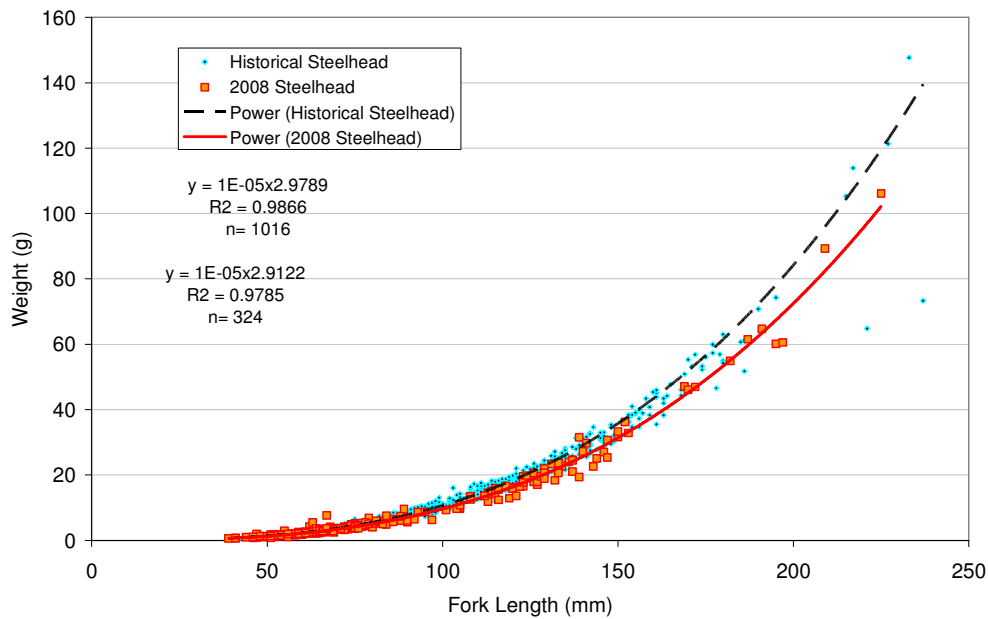


Figure A11. Steelhead weight-length relationships for fish measured in the seven Pine Gulch Creek index reaches, 2008. Shown for comparison are historic data taken from previous years (2005-2007). Power regression lines shown for both 2008 and historical juveniles.

Table A36. Mean length, weight, and K-factor calculated for coho measured and weighed in the Pine Gulch Creek index reaches 2005-2008.

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	YOY	40	80.48	4.71	80.50	5.84	1.10	5.67	1.11	0.06
2006	YOY	14	81.14	5.64	83.50	5.85	1.18	6.10	1.09	0.12
2007	YOY	0	0	0	0	0	0	0	0	0
2008	YOY	0	0	0	0	0	0	0	0	0

Table A37. Mean length, weight, and K-factor calculated for steelhead young-of-the-year (YOY) measured and weighed in the Pine Gulch Creek index reaches 2005-2008.

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	YOY	213	71.17	9.68	70.00	4.45	1.83	4.04	1.17	0.07
2006	YOY	157	77.99	9.60	78.00	5.43	2.03	5.20	1.10	0.11
2007	YOY	300	64.73	10.42	65.00	2.97	1.46	2.77	1.00	0.10
2008	YOY	252	66.47	11.07	66.00	3.23	1.63	2.92	1.02	0.19

Table A38. Mean length, weight, and K-factor calculated for steelhead age 1+ measured and weighed in the Pine Gulch Creek index reaches 2005-2008.

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	1+	106	130.52	27.44	120.00	27.29	22.45	19.51	1.08	0.08
2006	1+	123	123.43	26.21	120.00	22.12	13.42	18.46	1.09	0.12
2007	1+	117	131.79	21.05	129.00	24.32	12.26	20.92	0.99	0.06
2008	1+	72	134.46	26.99	129.00	25.34	18.16	19.71	0.93	0.09

Table A39. A comparison of multiple life stage observations of coho salmon within the Olema Creek mainstem for SY 2002-2003 through SY 2007-2008. Shaded years represent year classes (Year Class 1= light blue, Year Class 2= grey, Year Class 3= white).

Spawner Year	PLD Index	Redds (watershed redd total) ^f	Average female fork length	Estimated number of eggs	Basinwide juvenile estimate	Estimated survival rate egg to juvenile	Watershed smolt production estimate	Mean smolt length (mm)	Mean smolt weight (g)	Estimated survival rate juvenile to smolt	Estimated survival rate egg to smolt	Estimated survival rate smolt to adult ^e
2002-03	22	11 ^a (22)	64 ^b	25,938 ^c	11,926±3,244	46.0%	831±167 ^d	114	14.35	7.0%	3.2%	1.4%
2003-04	138	88 (109)	66.3	235,556 ^c	25,857±1,499	11.2%	362±145	116	15.95	1.4%	0.2%	52.5% ^d
2004-05	184	91 (137)	65.7	234,317 ^c	29,887±9,974	12.8%	3,793±784	99	10.27	12.7%	1.6%	1.4%
2005-06	12	6 ^a (12)	58.7	10,973 ^c	1,793 ±869	16.3%	1,485±206	116	14.72	82.8%	13.5%	2.8%
2006-07	80	66 (95)	65.3	165,106 ^c	32,298±4,018	19.6%	2,885±336	111	12.44	8.9%	1.8%	1.0%
2007-08	22	19 (26)	64 ^b	44,802	3,328±696	7.4%						SY2010-2011

^a Due to poor observer efficiency, the PLD index was used to estimate the Olema mainstem redd count based on two spawners per redd.

^b Average female length based on female carcass lengths on Olema Creek for spawner years 2003-2004 thru 2007-2008.

^c Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.

^d The Spawner Year 2003-2004 watershed production estimate is artificially low since trapping operations were suspended early due to the capture of Red-legged frog tadpoles. The actual watershed production estimate was likely four to five times higher based on regional smolt production estimates. For these reasons, the smolt-to-adult survival rate is likely artificially high.

^e Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the total watershed redd count (in parentheses)) divided by the estimated number of outmigrating smolts for previous cohort

^f Includes John West Fork redd count

Table A40. A comparison of multiple life stage observations of coho salmon within the Redwood Creek mainstem for SY 2003-2004 through SY 2007-2008. Shaded years represent year classes (Year Class 1= light blue, Year Class 2= grey, Year Class 3= white).

Spawner Year	PLD Index	Redds	Average female fork length	Estimated number of eggs	Basinwide juvenile estimate	Estimated survival rate egg to juvenile	Watershed smolt production estimate	Mean smolt length (mm)	Mean smolt weight (g)	Estimated survival rate juvenile to smolt	Estimated survival rate egg to smolt	Estimated survival rate smolt to adult ^d
2003-04	67	42	64.2	99,960 ^a	6,415±1,367	6.4%	1,977±430	98	10.10	30.8%	2.0%	2.1%
2004-05	171	72	63.3	162,155 ^a	8,594± 1,652	5.3%	2,502± 257	98	9.25	29.1%	1.5%	0.2%
2005-06	27	11	62	23,628 ^a	1,050±486	4.4%	1,353± 307	115	14.16	128.9%	5.7%	0.3%
2006-07	28	21	66	54,207 ^a	7,832± 1,640	14.4%	2,046±163	109	11.81	26.1%	3.8%	2.2%
2007-08	0	2 ^b	62.5 ^c	4,398 ^a	431± 271	9.8%						SY2010-11

^a Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.

^b Estimated based on distribution of juvenile coho observed during the summer of 2008.

^c Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-1998 thru 2006-2007.

^d Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the total watershed redd count) divided by the estimated number of outmigrating smolts for previous cohort

Table A41. A comparison of multiple life stage observations of coho salmon within the Pine Gulch Creek mainstem for SY 2000-2001 through SY 2007-2008. Shaded years represent year classes (Year Class 1= light blue, Year Class 2= grey, Year Class 3= white).

Spawner Year	PLD Index	Redds	Average female fork length	Estimated number of eggs	Basinwide juvenile estimate	Estimated survival rate egg to juvenile	Watershed smolt production estimate	Mean smolt length (mm)	Mean smolt weight (g)	Estimated survival rate juvenile to smolt	Estimated survival rate egg to smolt	Estimated survival rate smolt to adult ^c
2000-01	1	1	62.5 ^a	2,199 ^b	589±329	26.8%	-	113	14.31	-	-	-
2001-02	2	2	62.5 ^a	4,398 ^b	1,205±337	27.4%	-	112	14.03	-	-	-
2002-03	2	1	62.5 ^a	2,199 ^b	585±236	26.6%	737±144	112	14.01	N/A	33.5%	0.3%
2003-04	0	1	62.5 ^a	2,199 ^b	108	4.9%	8	114	14.33	7.4%	0.4%	0.0%
2004-05	3	3	62.5 ^a	6,597 ^b	1,150± 554	17.4%	367±69	100	9.78	32.0%	5.6%	0.0%
2005-06	0	1	62.5 ^a	2,199 ^b	295 ±201	13.4%	290±62	113	13.57	98.3%	13.2%	1.4%
2006-07	0	0	-	-	0	-	-	-	-	-	-	-
2007-08	1	0	-	-	0	-	-	-	-	-	-	-

^a Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-1998 thru 2006-2007.

^b Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length

^c Estimated smolt-to-adult calculated by dividing number of adult spawners (estimated based on 2 times the total watershed redd count) divided by the estimated number of outmigrating smolts for previous cohort

^d Estimated based on distribution of juvenile coho observed during the summer of 2008.

Appendix B – Julian Week Table

Table B1. List of Julian weeks and their calendar equivalents leap year.

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

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