

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

Smolt Trapping 2011 Progress Report

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ON THE COVER

Sculpin on Redwood Creek.

Photograph by: Jessica Weinberg

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Smolt Trapping 2011 Progress Report

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The Long-term Coho and Steelhead Monitoring progress reports are intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols provided by the National Park Service and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the San Francisco Bay Area Network I&M program website (<http://www.sfnps.org/>) on the internet.

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Abstract

The National Park Service has conducted multiple life stage monitoring of coho salmon (*Oncorhynchus kisutch*) in coastal Marin watersheds since 1998. An integrated protocol for monitoring salmonids, including outmigrant trapping, was developed by the National Park Service Inventory and Monitoring program in 2010. Performed in conjunction with winter surveys of spawning adults and summer juvenile surveys, the spring outmigrant surveys permit an evaluation of abundance and survival associated with the freshwater portion of the coho life-cycle. During this period of a salmonid's life they are called "smolts", referring to the process of smoltification which involves a series of transformations in juvenile salmonids in preparation for life in a marine environment. In 2011, smolt trapping was conducted on Olema Creek and Redwood Creek.

Trap installation occurred during Julian week 14 (2 April 2011 – 8 April 2011) on Olema Creek and Redwood Creek. Trapping operations ended during Julian week 22 (28 May 2011 – 3 June 2011). A total of four smolt traps were operated during the 2011 trapping season: one on Olema Creek and three on Redwood Creek.

The peak outmigration for coho smolts was observed during Julian week 18 (30 April – 6 May) for Olema Creek and week 20 (14 May – 20 May) for Redwood Creek. Using a mark/recapture study, a Darroch Analysis with Rank Reduction was performed for Olema Creek, providing an estimate of $1,334 \pm 444$ coho smolts. A comparison of coho smolt production estimates from previous years, suggest a 54% decline in smolt production for this cohort in Olema Creek. On Redwood Creek the calculated Darroch Analysis with Rank Reduction estimate was $3,459 \pm 276$ coho smolts. This represents a 69% increase in smolt production for this cohort in Redwood Creek compared to previous years. In addition to facilitating the mark/recapture study, Passive Integrated Transponder tags were used to track individual coho smolt movements in greater detail than prior to the implementation of Passive Integrated Transponder tags in juvenile coho. Juveniles tagged between July 2010 and February 2011 were recaptured on both traps, during smolt trapping operations. While the majority was recaptured on Redwood Creek, the continuing use of the PIT tags is giving greater clarity to growth rates and movement patterns found in the creeks.

1 - Introduction

The mission of the National Park Service (NPS) 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 NPS 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), John Muir National Historic Site (JOMU), Pinnacles National Monument (PINN), and Point Reyes National Seashore (PORE). The network has identified indicators of ecosystem health, known as Vital Signs, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent is 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 particularly high priority vital sign for SFAN because coho salmon are important indicators of ecosystem health, provide important links between marine and freshwater ecosystems, have endangered status, and garner high public interest.

Smolt trapping is performed in conjunction with winter surveys of adult spawners and summer juvenile surveys as part of an integrated monitoring protocol. The spring outmigrant surveys provide a sample of the salmonid smolts leaving a watershed and permit an evaluation of abundance during three of five distinct freshwater salmonid life history stages. When evaluated as part of a comprehensive monitoring program, the smolt trap information can be compared with adult spawner indices to describe potential ocean productivity and survival and can be compared with summer juvenile population estimates to assess rates of survival through the winter season. This type of comprehensive monitoring information is rare in this region, as most of this research has been in the Pacific Northwest.

The outmigrant program is conducted in selected salmonid-bearing watersheds where the NPS is also performing basinwide population estimates. The program requires intensive monitoring at specific locations for a period of two to three months during the spring of each year. This report documents results of the spring 2011 trapping season at Olema and Redwood Creeks. No trap was installed on Pine Gulch Creek in 2011 due to the lack of observed juvenile coho during the summer of 2010.

1.1 Introduction and History of the Spring Outmigrant Smolt Trapping Program

A significant body of literature documents life-stage bottlenecks and survival rates for salmonid populations. Many of these studies describe how alterations to watershed connectivity and condition affect these species at different freshwater life stages (Moyle 2002, National Marine Fisheries Service 2010). At the time of smoltification, coho salmon (*Oncorhynchus kisutch*) have spent more than 14 months in the watershed, while smolting steelhead trout (*O. mykiss*) can be 1-4 years old. Smolt production, therefore, is the best aggregate measure of watershed condition and fish productivity. 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, in conjunction with other life stage monitoring activities, allows the NPS to characterize aggregate watershed productivity for salmonids, and is a valuable resource for directing long-term management and restoration actions, as well as having direct management utility (California Department of Fish and Game 2004). Trapping results can help quantify dates of migration and growth rates through the winter and spring. Traps also provide presence/absence information and size data for other species during periods not covered by summer/fall monitoring activities.

The NPS has conducted smolt trapping operations at selected sites since 1998. Between 1998 and 2004, the NPS operated an outmigrant trapping on the John West Fork, an important tributary of Olema Creek (PORE), immediately upstream of the State Route 1 culvert. The results of these efforts showed increases in watershed productivity in response to fish passage restoration efforts in summer 1999 (Reichmuth et al. 2006).

In 2002 the NPS initiated smolt trapping on Pine Gulch Creek (PORE) to monitor the size and condition of the coho population that had recently re-colonized this watershed. In order to obtain an estimate of total coho smolt production from the Olema Creek watershed, the NPS initiated trapping at the downstream end of Olema Creek in 2004. In Redwood Creek (GOGA) smolt trapping was first conducted during the spring of 1998 and continued during the spring of 1999. In 2005 smolt trapping operations were once again initiated in Redwood Creek.

In 2006, downstream migrant trapping operations were initiated on Lagunitas Creek as part of a Limiting Factors Analysis grant through the Marin Resource Conservation District. The trapping conducted in 2006 by Stillwater Sciences, Inc. included multiple trapping locations along the mainstem of Lagunitas Creek. Since 2007 Marin Municipal Water District (MMWD) has conducted smolt trapping on the mainstem of Lagunitas Creek at one downstream trapping location. In addition, the Salmon Protection and Watershed Network (SPAWN) has conducted smolt trapping operations on San Geronimo Creek since 2006. Information from all three smolt trapping programs will fill an important information gap linking summer juvenile coho salmon density to adult returns one or two winters later.

1.1.1 Spring Outmigrant Trapping Monitoring Questions

1. What is the relative health/condition factor of salmonid smolts within Olema, Redwood, and Pine Gulch Creeks?
2. What is the annual production of juvenile coho salmon outmigrants in Olema, Redwood, and Pine Gulch Creeks?

1.1.2 Spring Outmigrant Trapping Monitoring Objective

Field and analytical methods used for this report are documented in the Salmonid Monitoring Protocol for the San Francisco Bay Area Network version 4.0 (Reichmuth et al. 2010). This 2011 Spring Outmigrant Smolt Trapping Program Summary addresses Objective 2:

Determine long-term trends in abundance and condition of coho salmon smolts by conducting spring smolt trapping near mouths of Olema, Pine Gulch, and Redwood Creeks.

1.2 Fish Resources

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

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from the marine environment 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 (Smith 2001, Brown and Ketcham 2002). Coho salmon were listed as a threatened species within the central California coast coho salmon evolutionarily significant unit (CCCESU) in 1996 by National Marine Fisheries Service (NMFS) (Federal Register 1996) and the ESU 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.

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 inhabit 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 Distinct Population Segment (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).

2 - Sampling Design and Methods

For a detailed description of methods used during the outmigrant smolt trapping season, please refer to SOP (standard operating procedure) 3, SOP 4, SOP 6, SOP 9, and SOP 11 of the San Francisco Bay Area Network Salmonid Monitoring Protocol version 4.0 (Reichmuth et al. 2010).

2.1 Fyke/Pipe Trap Construction

Trapping is conducted continually for a 2-3 month period during the spring and requires daily visits 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 allow for a thorough sampling of smolt outmigration. Trap sites were determined by location within each watershed, suitable channel morphology, and access (Figure 1).

The fyke/pipe trap used on Olema, Redwood, and Pine Gulch Creeks is based on a design used by California Department of Fish and Game (CDFG) on the Noyo River (Gallagher 2000; Barrineau and Gallagher 2001). A 5' x 4' x 20' fyke net is supported by t-posts. Several weir panels are constructed consisting of ½" mesh hardware cloth secured with t-posts and baling wire to direct fish into the mouth of the fyke net. A small gap is left between the weir panels and the streambank on one side as a bypass channel to allow adult steelhead to migrate upstream during higher flows and downstream following spawning. The throat of the fyke net is attached to a series of 6" x 20' PVC pipes, which empty into a plywood trap box.

Traps are generally installed in mid-March, once winter flows have subsided. In some years, spring rains occasionally raise flows enough to compromise trap operation. Stream flows typically drop substantially by late May or early June, so traps are usually removed at this time. A Hobo-brand temperature logger is deployed and left in each trap box for the duration of operation.

2.2 Mark/Recapture Techniques

Mark/recapture methods are used to estimate trap efficiency and smolt population size. Mark-recapture methods are useful for the fyke net trap operations on Olema, Redwood, and Pine Gulch Creeks since fish can avoid the trap and pass through the bypass channel left open for adult steelhead coming back to spawn. Daily, no more than 30 coho smolts (or up to 50% of the catch that day) are anesthetized with carbon dioxide and marked with Passive Integrated Transponder (PIT) tags. Marked smolts are released immediately after recovering from anesthetization at a predetermined site approximately 100 m or at least three habitat units above the trap site. After being measured, all recaptured smolts and unmarked smolts are released immediately in low velocity areas below the trap.

Studies using similar methods of marking and tagging have demonstrated little marking mortality and no fish are held for retention or survival tests (Thedinga et al. 1994, Gries and Letcher 2002). A study using the same trapping methodology on five northwestern California streams revealed that trap mortality was less than one percent for smolts and less than three percent for fry (Manning 2001). The highest mortality rates were associated with high flow.



Figure 1. Location of smolt traps on San Francisco Bay Area Network (SFAN) streams in Marin County, CA. Olema Creek and Pine Gulch Creek are located in Point Reyes National Seashore while Redwood Creek is located in Golden Gate National Recreational Area.

Mark/recapture data is analyzed using Darroch Analysis with Rank Reduction (DARR), 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 population could result in overestimates of population. Estimates reported through this method 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.

2.3 Processing 1+ Aged Fish

Salmonids are identified to species and life stage (fry, parr, smolt, or adult) prior to being measured. Fry are less than one year old and can be identified by the presence of distinct parr marks and small body size. Age 1+ steelhead and coho are separated into the following morphological categories: parr (smaller size, parr marks present) or smolt (faint or absent parr marks, silver body, deciduous scales, black fin margins) (Bratovich and Kelley, 1988; Nelson 1994). Occasional runback steelhead spawners are trapped on their way back out to sea; they are generally greater than 40 cm long and are classified as adults. Any mortality or injury is recorded, as well as the probable cause of death.

Daily, a random sub-sample of up to 10 individuals of coho smolts and steelhead parr and smolts are measured (fork length is measured nose to fork of caudal fin) to the nearest millimeter, and weighed to the nearest 0.01 g using an electronic scale. This sub-sample is normally 10 individuals of each species, however, fish are also measured to the nearest millimeter and weighed if they are anesthetized for mark/recapture purposes. All coho and steelhead 1+ aged fish are identified and counted. Any adult steelhead encountered in the trap is released downstream immediately without being measured.

Selected age 1+ salmonids are sedated using carbon dioxide to facilitate handling and minimize stress to the fish. A clean five-gallon bucket is filled with approximately two inches of fresh stream water and then half of an Alka-Seltzer® tablet is added (plain, unmedicated). The alka-seltzer adds carbon dioxide to the water, effectively sedating the fish. No more than two fish at a time are placed into the treated water. Fish are determined to be adequately sedated when they are sluggish enough for easy handling but before they begin to turn over. The water is changed periodically, particularly on hot days and when processing large numbers of fish.

In general, coho measuring more than 70 mm in the spring are assumed to be one year old and potential smolts. It is the judgment of the field staff to determine whether the fish is a smolt. Typically, coho entering the trap are actively migrating downstream. Smolts undergo physical changes in their body, becoming silvery, and developing black tips on their caudal fin (this is true of both coho and steelhead). Smolts also have looser scales and are losing their parr marks and spots. While the monitoring protocol details descriptions of characteristics of fish in various life stages, a decision in the field is not always obvious. In cases such as these, the decision

between smolt and other life-stages is based on the experience and professional judgment of monitoring staff based on overall field indicators present on the fish.

2.4 Processing Young-of-Year Salmonids

All fry are identified to species and counted. Daily, random sub-samples of 10 coho fry and 10 steelhead fry are measured (fork length to the nearest millimeter) and individuals greater than 40 mm are weighed to the nearest 0.01 g using an electronic scale. Sub-samples are obtained by taking blind scoops out of the holding bucket with a small aquarium dip net.

Although identification of salmonid fry can be difficult, it is important in order to address the objectives of this monitoring program that the species (coho and steelhead) are differentiated. As long as both species are present, it is rather simple to see the distinct differences. Problems may arise when only one or the other is present. The best reference for field identification between species is the “Field Identification of Coastal Juvenile Salmonids” (Pollard et al. 1997). This reference includes color photographs and descriptions of each species at the 40 to 50 mm size. In general, the coho at all sizes have a pinker hue, while steelhead have an orange or yellow hue. In addition, the dorsal and anal fins of coho are longer, sickle-shaped, and more pointed than those of steelhead. For the few individuals that can’t be identified by overall appearance or shape of fins, counting the anal fin rays can differentiate between coho (12 to 17 rays) and steelhead (8 to 12 rays) fry.

2.5 Processing Other Species

Other species encountered through this program are documented. Daily, random sub-samples of 10 individuals of each species are measured and fish over 40 mm are weighed. All other species are counted and released downstream. We have observed that sculpin, as ambush predators, will predate on smolt sized fish in the trap. Once removed from the trap, sculpin are held in a separate bucket to avoid predation.

2.6 Fish Recovery and Release

After processing, each fish is placed in an aerated recovery bucket, keeping larger sculpin in separate buckets to avoid predation on smaller fish. The recovery bucket is a different color (preferably blue or other dark color) and located away from the holding buckets to avoid mixing fish that have and haven’t been processed. The dark colored bucket allows the fish to darken their color, which is beneficial when they are released back into the stream. Fish in the recovery bucket are monitored to insure sedated fish recover fully before being released.

3 - Results

Smolt trapping was conducted between 1 April 2011 (Julian week 13) and 3 June 2011 (Julian week 22). Smolt trapping results are reported using Julian weeks to allow for analysis across years. For specific dates, refer to the Appendix B, Table B1.

3.1 Olema Creek

During the 2011 outmigrant trapping study, the Olema Creek trap was in place for 58 days (6 April—3 June 2011) but was only fully operational for 52 days. Storms occurring in late March delayed installation, while storms that occurred during the trapping season interfered with normal trap operations; the trap was partially operational for a total of five days and was non-operational for one day.

The trap captured a total of 423 coho smolts, 19 steelhead smolts, and 25 steelhead parr. While both coho and steelhead smolts were marked with PIT tags, only coho smolts were recaptured. The overall recapture rate for marked coho smolts was 30% (60/203) and the overall recapture rate for steelhead smolts was 0% (0/9). The mortality rate for coho smolts was 2% (7/423) while the mortality rate for steelhead smolts was 0%.

DARR analysis of the coho smolt data stratified by day (Figure 2) estimated capture probability at approximately 30% for the first six weeks before increasing to 31% for the last four weeks of trapping operations. The total Olema Creek coho smolt production estimate is 1,334 (± 444). Peak capture for coho smolts occurred in early May, during Julian week 18 (Table 1).

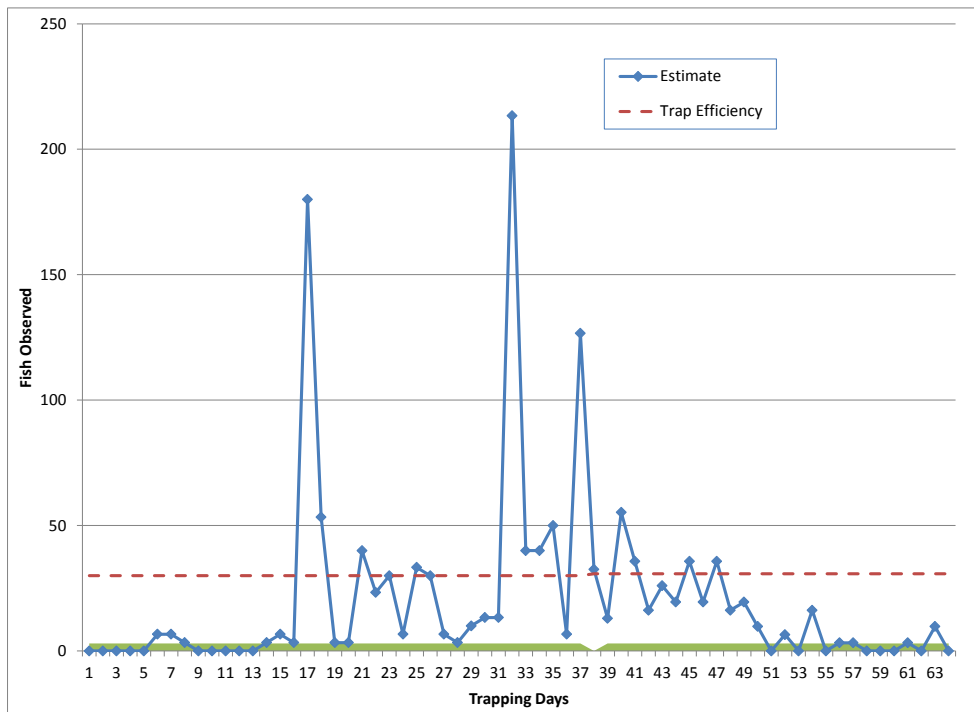


Figure 2. Darroch Analysis with Rank Reduction (DARR) analysis of coho smolt data for Olema Creek, 2011. Estimated number of smolts (solid line) is compared to trap efficiency (dashed line). Darkened bars along bottom show recapture bins.

Table 1. Olema Creek smolt trapping summary, 2 March 2011 – 3 June 2011.

Julian Week #	From	To	Steelhead Juvenile			Steelhead Adult	Coho	
			Smolt	Parr	Fry	Ocean Run	Smolt	Fry
Week 14	2-Apr	8-Apr	2	9	127	2	5	13
Week 15	9-Apr	15-Apr	0	0	82	0	3	4
Week 16	16-Apr	22-Apr	5	4	1	0	92	0
Week 17	23-Apr	29-Apr	3	1	75	0	46	1
Week 18	30-Apr	6-May	2	0	2	0	113	0
Week 19	7-May	13-May	5	3	0	0	103	0
Week 20	14-May	20-May	1	2	2	1	48	0
Week 21	21-May	27-May	1	6	4	0	9	0
Week 22	28-May	3-Jun	0	0	1	0	4	
TOTALS			19	25	294	3	423	18

Totals include mortalities.

Smolt, parr, and fry refer to life stages within the freshwater portion of the salmonid life-cycle.

The trap also captured 18 coho fry and 294 steelhead fry during the trapping season. Coho fry capture peaked early, during week 14, and then was low through the rest of the season. Steelhead fry capture also peaked in late March, during Julian week 14. The mortality rate for coho fry was 0% and the mortality rate for steelhead fry was 1% (4/294). Three adult steelhead were captured in the trap on Olema Creek.

3.2 Redwood Creek

A total of three traps were operated on Redwood Creek during the 2011 season. In addition to the primary outmigrant trap detailed in the approved protocol, a second trap (Banducci Trap) was installed approximately 1 km upstream (just downstream of the Banducci restoration area) to support a mark/recapture study. A third trap (backwater trap) was installed on a backwater downstream of the primary trap with the intent of trapping the large backwater habitat in this section of the watershed. Both the backwater and Banducci traps were operated in association with current restoration activities on lower Redwood Creek.

The primary outmigrant trap in Redwood Creek was in place for 58 days (from 6 April—3 June 2011) and was fully operational for 57 days and partially operational for one day. The Banducci trap was first operational on 1 April and removed on 3 June. It was fully operational for 54 days, partially operational for three days, and non-operational for two days. The numbers reported for Redwood Creek include fish taken from both mainstem traps. The backwater trap was in place for 51 days (7 April – 28 May 2011) and was fully operational for 50 days. Fish collected from the backwater trap were not used for the mark/recapture study.

The mainstem traps captured a total of 1,122 coho smolts, 14 steelhead smolts, and 31 steelhead parr. To avoid double-counting unmarked fish that were caught at both mainstem traps, smolt totals include all fish captured at the bottom mainstem trap and fish that were marked at the upper Banducci trap. For steelhead parr and non-salmonids, all fish captured at both traps are counted because these fish are assumed not to be moving down to the Pacific Ocean. Of the 31 steelhead parr caught on Redwood Creek, 27 (87%) were caught in the Banducci trap. The mortality rate for coho smolts was 0.5% (5/1,122); the mortality rate for steelhead smolts was zero. Both steelhead and coho smolts were marked with PIT tags in the 2011 season. The overall

recapture rate for marked coho smolts, including fish marked and recaptured at the lower mainstem trap and fish marked at the Banducci trap and recaptured at the lower trap, was 41% (262/644). The overall recapture rate for marked steelhead smolts was 0%.

DARR analysis of the coho smolt data stratified by day (Figure 3) estimated capture probability at approximately 18% for the first 4 ½ weeks before rising to approximately 47% for the last four weeks of trapping operations. The total Redwood Creek coho smolt production estimate is 3,459 (± 276). Peak capture for coho smolts occurred in mid-May, during Julian week 20 (Table 2).

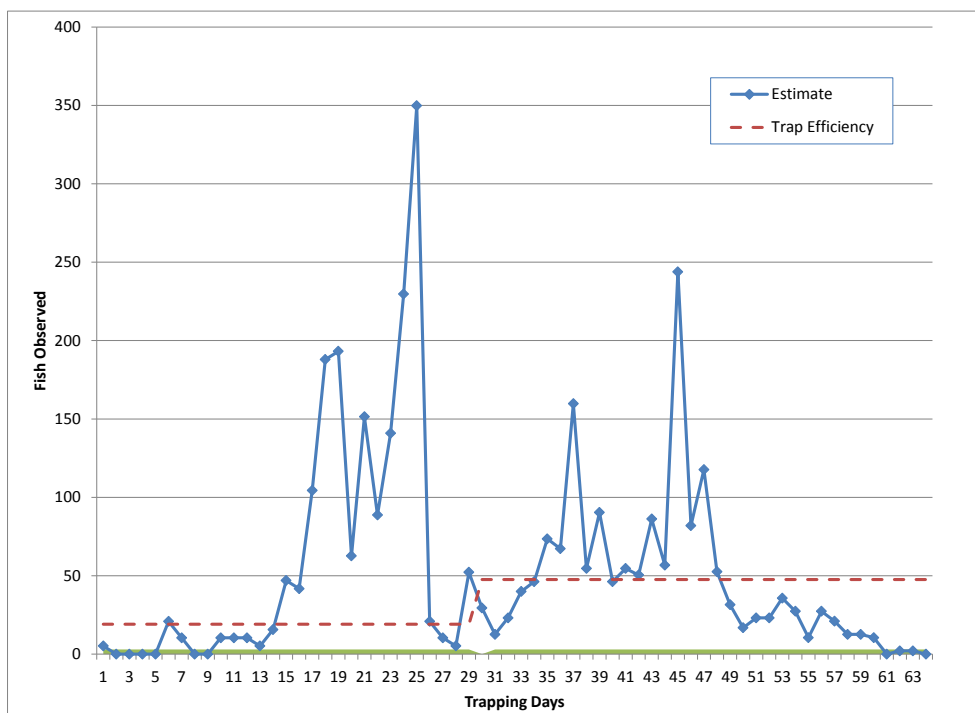


Figure 3. Darroch Analysis with Rank Reduction (DARR) analysis of coho smolt data for Redwood Creek, 2011. Estimated number of smolts (solid line) is compared to trap efficiency (dashed line). Darkened bars along bottom show recapture bins.

Table 2. Redwood Creek mainstem smolt trapping summary, 26 March 2011 – 3 June 2011.

Julian			Steelhead Juvenile			Steelhead Adult	Coho	
Week #	From	To	Smolt	Parr	Fry	Ocean Run	Smolt	Fry
Week 13	26-Mar	1-Apr	0	2	0	0	1	0
Week 14	2-Apr	8-Apr	1	5	0	0	12	0
Week 15	9-Apr	15-Apr	5	3	0	1	32	0
Week 16	16-Apr	22-Apr	4	10	0	0	341	0
Week 17	23-Apr	29-Apr	3	6	9	0	178	0
Week 18	30-Apr	6-May	0	2	0	1	204	0
Week 19	7-May	13-May	0	1	0	0	325	0
Week 20	14-May	20-May	1	2	0	0	348	0
Week 21	21-May	27-May	0	0	0	0	107	1
Week 22	28-May	3-Jun	0	0	1	0	29	0
TOTALS			14	31	10	2	1577	1

Totals include mortalities and fish captured on the two mainstem traps.

Smolt, parr, and fry refer to life stages within the freshwater portion of the salmonid life-cycle.

The mainstem traps also captured one coho fry and 10 steelhead fry. All of the fry were captured at the Banducci trap. The mortality rate for both coho and steelhead fry over the entire trapping season was 0%. Steelhead fry capture peaked in late April, during Julian week 17. Two adult steelhead were caught in either mainstem trap during the 2011 trapping season.

Smolts captured on the backwater trap were not included in the total counts or population estimate. A total of 500 coho smolts and 17 steelhead smolts were captured on the backwater trap, along with 87 steelhead parr and one coho fry. The mortality rate for coho smolts was 0.4% (2/500), while the mortality rate for steelhead smolts was 6% (1/17). The mortality rates for both steelhead parr and coho fry were 0%.

3.3 Timing

Both Olema Creek and Redwood Creek had early outmigration surges in Julian week 16, followed by reduced captures during Julian week 17. During Julian week 18, Olema Creek peaked at 113 coho smolts captured with a similar one week total during Julian week 19, before steadily decreasing in coho smolt captures for the remaining trapping period. In contrast Redwood Creek coho smolt captures steadily increased until a peak was reached during Julian week 20 with a total of 348 coho smolts captured (Figure 4).

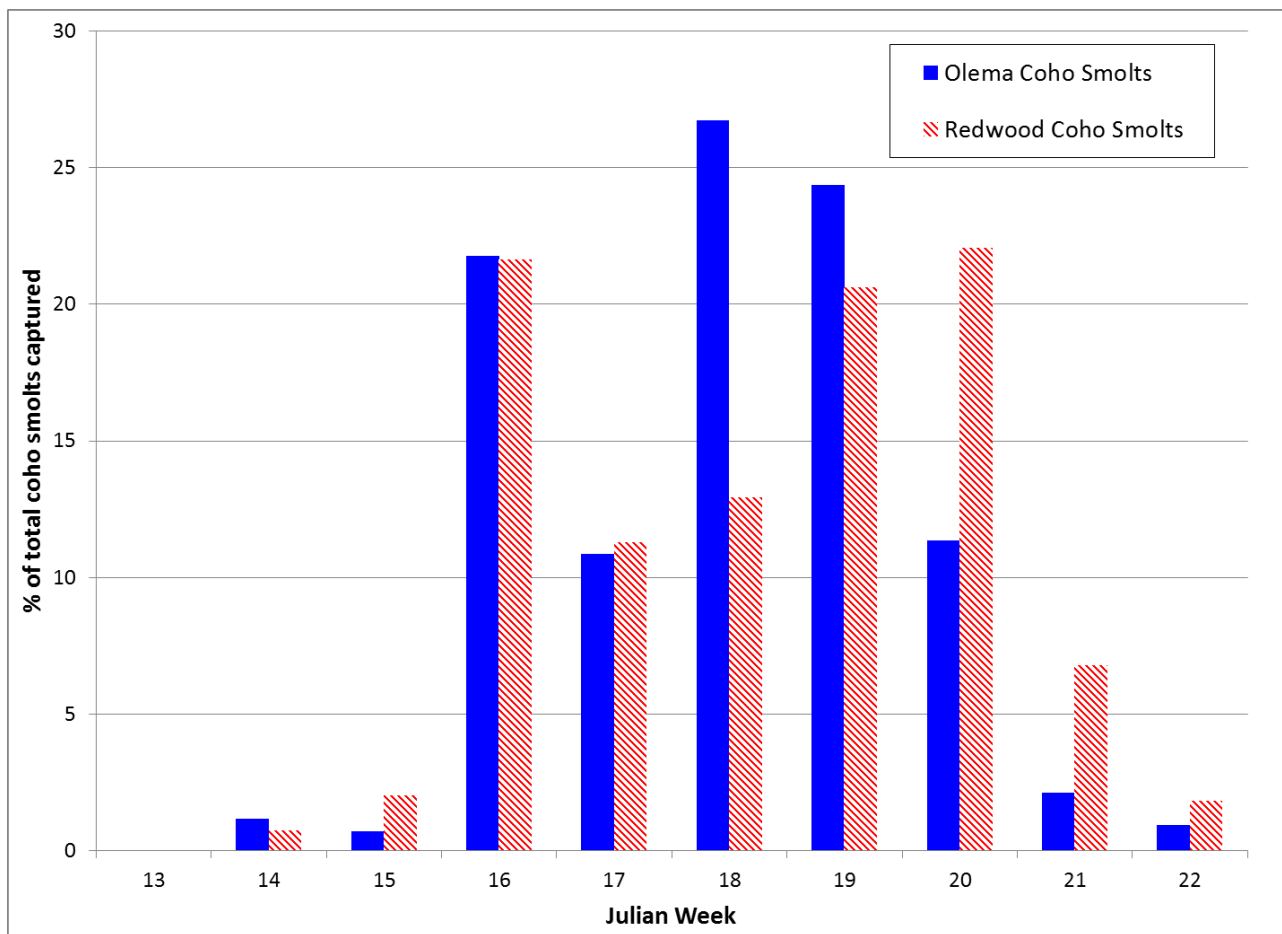


Figure 4. Percent of total coho smolts captured by Julian week for Olema and Redwood Creeks, 2011.

3.5 Rainfall

Rainfall amounts were collected from rain gages located at the Bear Valley Visitor Center for Olema Creek and at the Highway One bridge on Redwood Creek. The following graphs are representations of rainfall amounts at the two rain gage locations (Figure 5 and Figure 6). Rainfall was lower than the historical average during April, but higher than the historical average in May and June. For May and June, the 2011 monthly totals were more than twice the monthly average total with May 2011 totaling 2.96 in compared to a 1965-2009 average of 1.03 in and June 2011 totaling 2.60 in compared to a 1965-2009 average of 0.19 in. While only 1.85 in of that rain in June fell during the actual smolt trapping period, it is still well above the historical average.

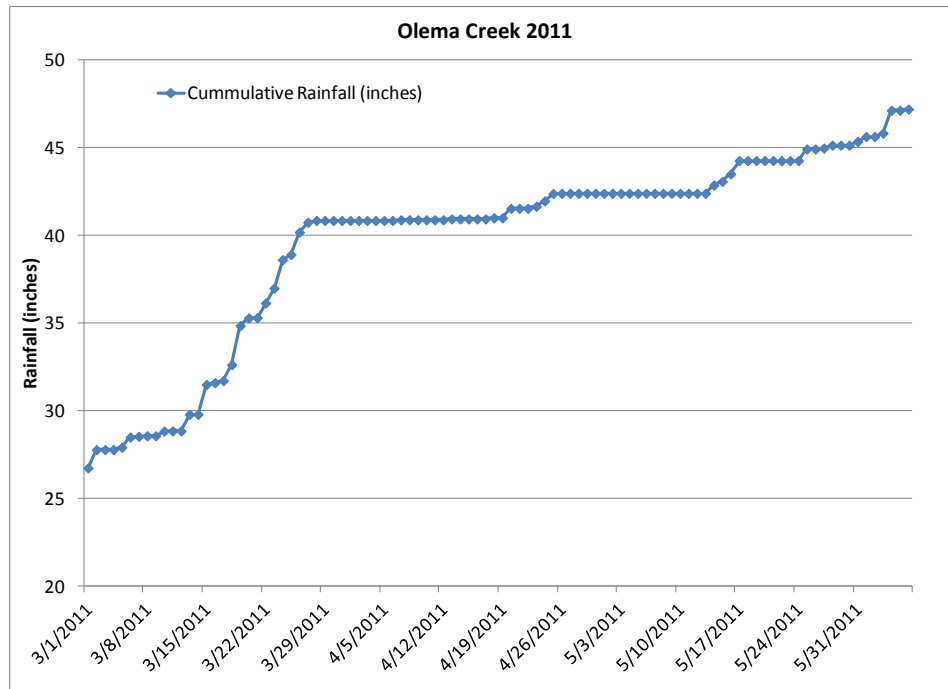


Figure 5. Cumulative daily rainfall totals for Water Year 2011, starting in October 2010, for Olema Creek during the 2011 smolt trapping season, 6 April – 3 June 2011.

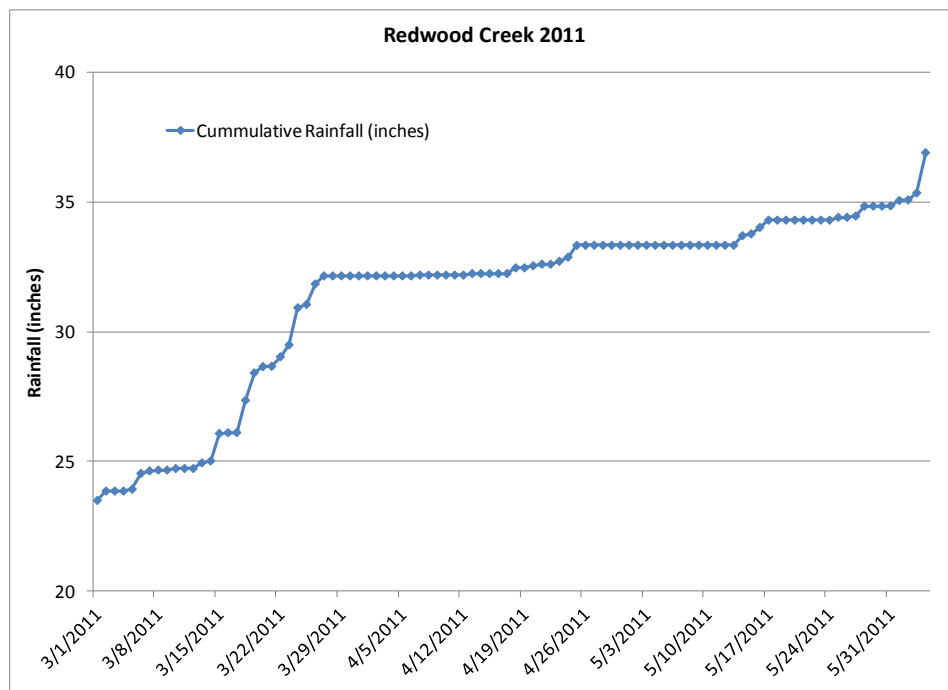


Figure 6. Cumulative daily rainfall totals for Water Year 2011, starting in October 2010, for Redwood Creek during the 2011 smolt trapping season, 6 April – 3 June 2011.

3.6 Water Temperature

Water temperatures within trap boxes were within the tolerable temperature range (less than 22 °C) for coho salmon (Moyle 2002) during the entire trapping season at both trapping locations (Figures 7 and 8). Olema Creek was the warmer of the two creeks, with the highest average temperature of 12.6 °C (1.2 SD), the highest maximum temperature of 15.7 °C, and the highest minimum temperature of 9.0 °C for the trapping season. Redwood Creek had an average temperature of 11.7 °C (1.0 SD), a maximum temperature of 14.3 °C, and a minimum temperature of 8.7 °C.

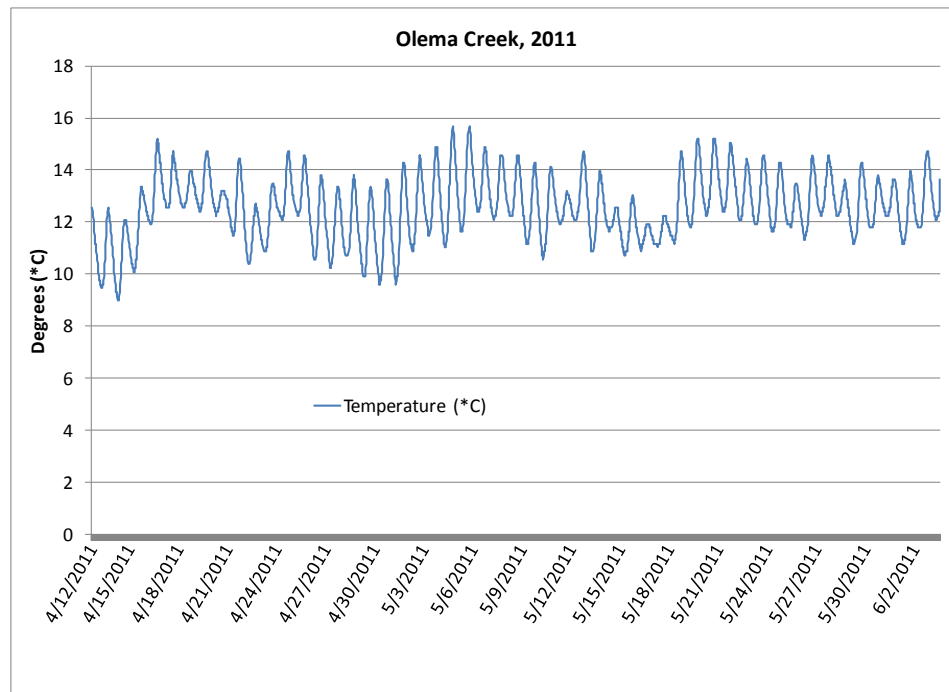


Figure 7. Olema Creek trap box Hobo temperature logger readout, spring 2011. The logger was installed on 12 April 2011 and removed on 3 June 2011 when the trap was removed for the season.

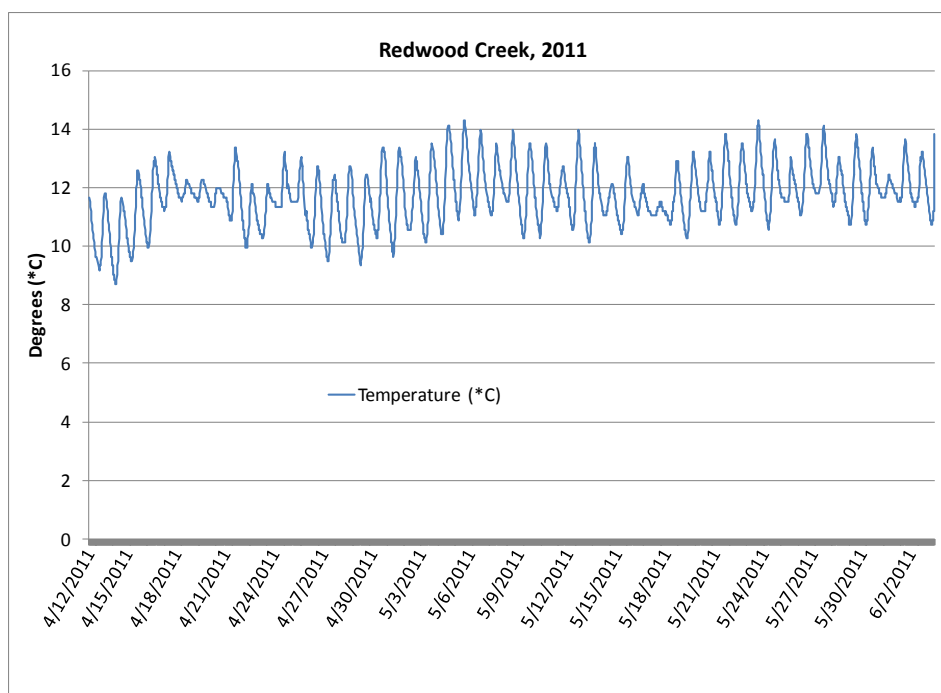


Figure 8. Redwood Creek trap box Hobo temperature logger readout, spring 2011. The logger was installed on 12 April 2011 and removed on 3 June 2011 when the trap was removed for the season.

3.7 Watershed Production Estimate

On Olema Creek, a total of 423 coho smolts were captured, with a calculated production estimate of 1,334 (± 444). On Redwood Creek 1,577 coho smolts were captured with a calculated production estimate of 3,459 (± 276) coho smolts. The majority of the steelhead fry and steelhead smolts were captured on Olema Creek (Table 3). For a summary of salmonid information for smolt trapping operations from 1999 to 2010 see Table A1 in Appendix A.

Table 3 Summary of salmonid information for Olema Creek and Redwood Creek trap operations, 2011.

Watershed	Year	Trap Operation Dates		Steelhead				Coho		Coho Production Estimate	
		From	To	Juvenile		Adult		smolt	fry	Estimate	Standard Error
				smolt	parr	Fry	ocean-run				
Olema Creek	2011	6-Apr	3-Jun	19	25	294	3	423	18	1,334	444
Redwood Creek ^a	2011	1-Apr	3-Jun	12	31	10	2	1,577	1	3,459	276

^a Includes totals from both mainstem trap sites.

3.8 Non-salmonid Captures

An annual summary of total catch for non-salmonid species is represented in Table 4. Non-native mosquito fish (*Gambusia affinis*) were found in the Olema Creek trap for the first time in 2009; only one was captured in 2011. The majority of the non-salmonids captured on Olema Creek were California Roach with a total of 677 captured during the trapping season. No non-native species were trapped in either Redwood or Olema Creeks. In the backwater trap on Redwood Creek, a total of 1,193 rough-skinned newts (*Taricha granulosa*) and 195 California newts (*Taricha torosa*) were captured. Twenty-five rough-skinned newts and two California newts were captured in the two mainstem Redwood Creek traps. Of the 408 non-salmonid fish captured on Redwood Creek, 397 were sculpin. For a summary of non-salmonid species information for trapping operations from 1999 to 2010 see Table A2 in Appendix A.

Table 4 Summary of non-salmonid information for Olema Creek and Redwood Creek trap operations, 2011.

Watershed	Year	Trap Dates		LAM	RO	SCU	STK	SUC	Totals
		From	To						
Olema Creek	2011	6-Apr	3-Jun	1	677	212	485	6	1,381
Redwood Creek ^a	2011	1-Apr	3-Jun	0	0	397	11	0	408

Species Code: LAM = Lamprey spp., RO = California Roach, SCU = Sculpin spp., STK = Threespine Stickleback, SUC = Sacramento Sucker.

^a Includes totals from both mainstem trap sites.

3.9 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 2011 smolt trap operations, staff recorded fork lengths and weights of a subsample of fish captured in the trap. Histograms of salmonid fork length frequencies are presented for Olema Creek coho (Figure 9) and steelhead smolts (Figure 10) and Redwood Creek coho (Figure 11) and steelhead smolts (Figure 12).

On Olema Creek, the coho fork lengths ranged from 86 mm to 170 mm and the peak length frequency was in the 116 mm to 120 mm range, representing 20% of the coho smolts measured. On Redwood Creek, coho smolt fork lengths ranged from 81 mm to 160 mm. The peak length frequency of coho smolts on Redwood Creek was in the 106 mm to 110 mm range, representing 21% of the coho smolts measured.

Olema Creek steelhead smolt fork lengths ranged from 141 to 205 mm and the highest frequency of steelhead smolt fork lengths were in the 161 to 165 mm range, representing 17% of the steelhead smolts measured. Steelhead smolt fork lengths on Redwood Creek ranged from 126 to 195 mm. The highest frequencies of steelhead smolt fork lengths on Redwood Creek occurred between 151 mm and 160 mm range, accounting for 43% total of the steelhead smolts measured.

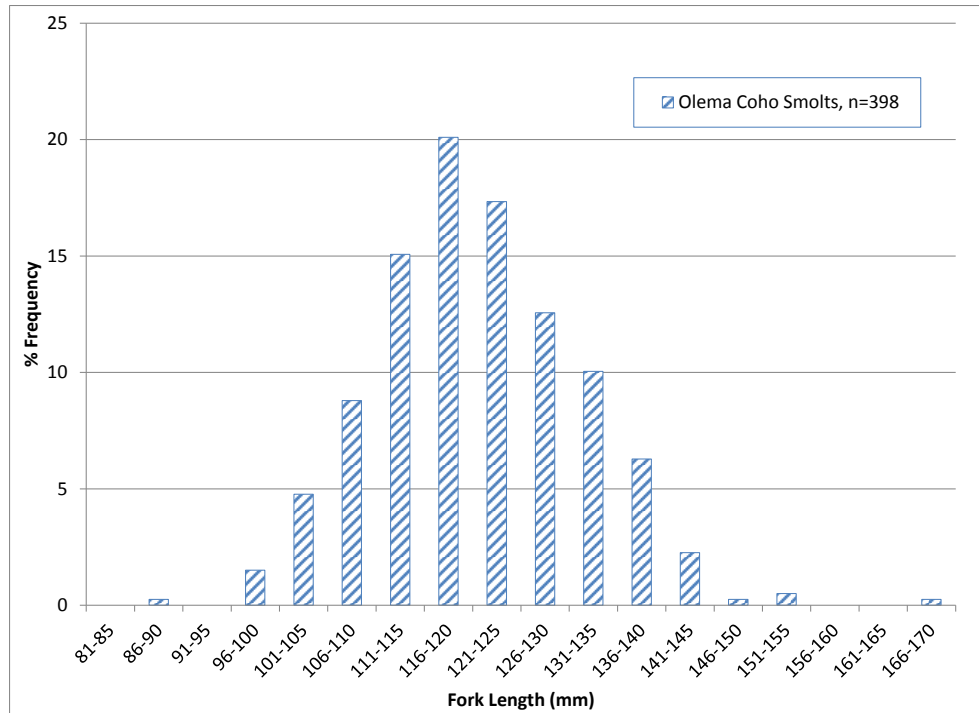


Figure 9. Coho smolt fork lengths in 5 mm bins for Olema Creek, 2011.

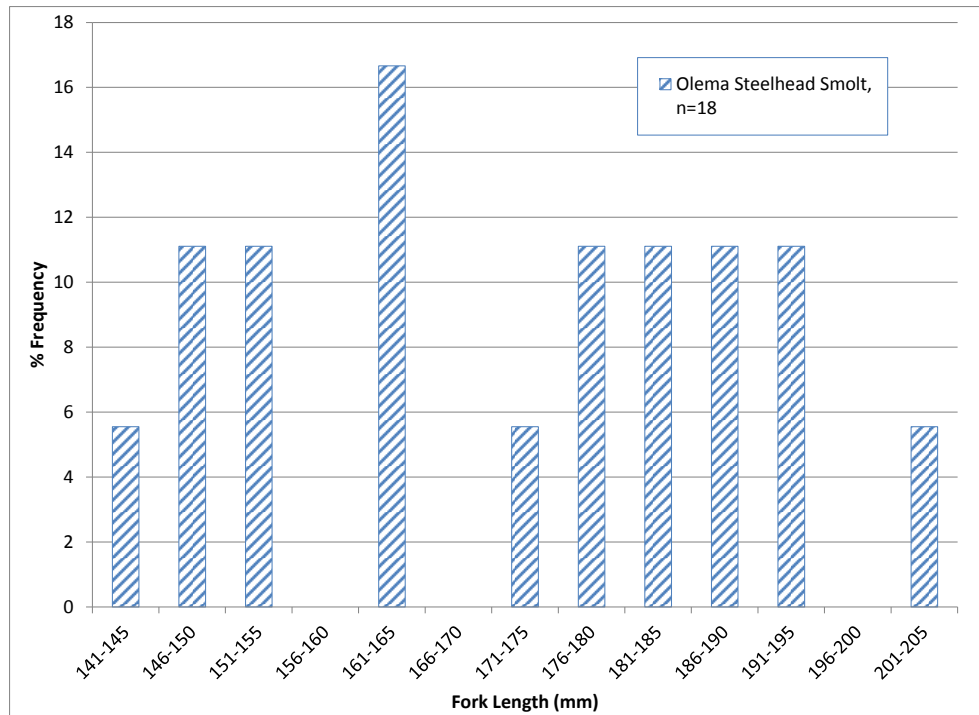


Figure 10. Steelhead smolt fork lengths in 5 mm bins for Olema Creek, 2011.

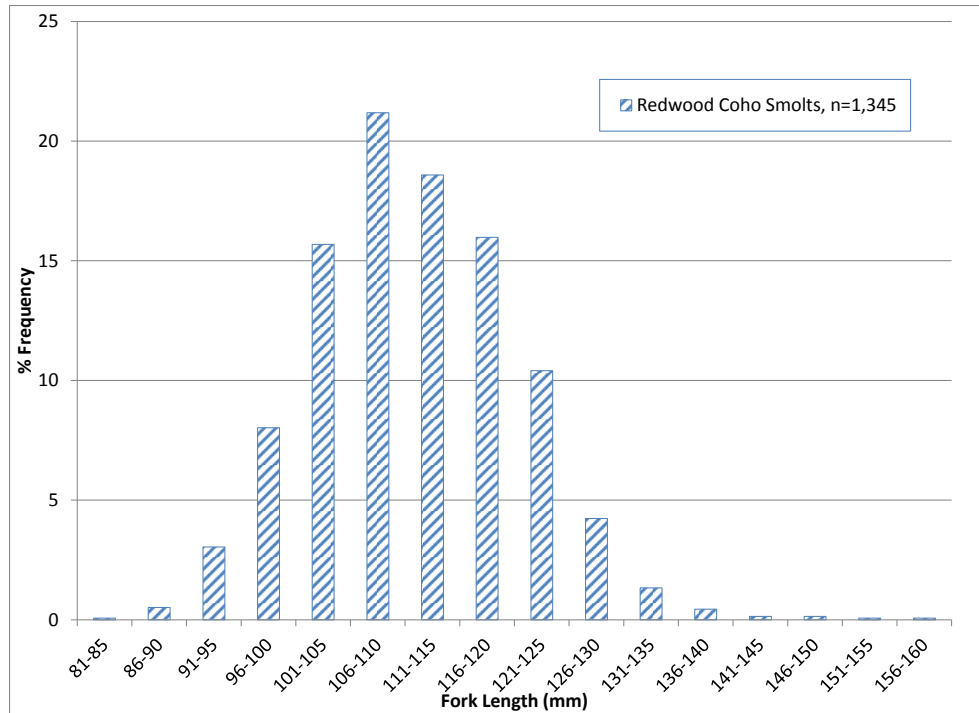


Figure 11. Coho smolt fork lengths in 5 mm bins for Redwood Creek, 2011.

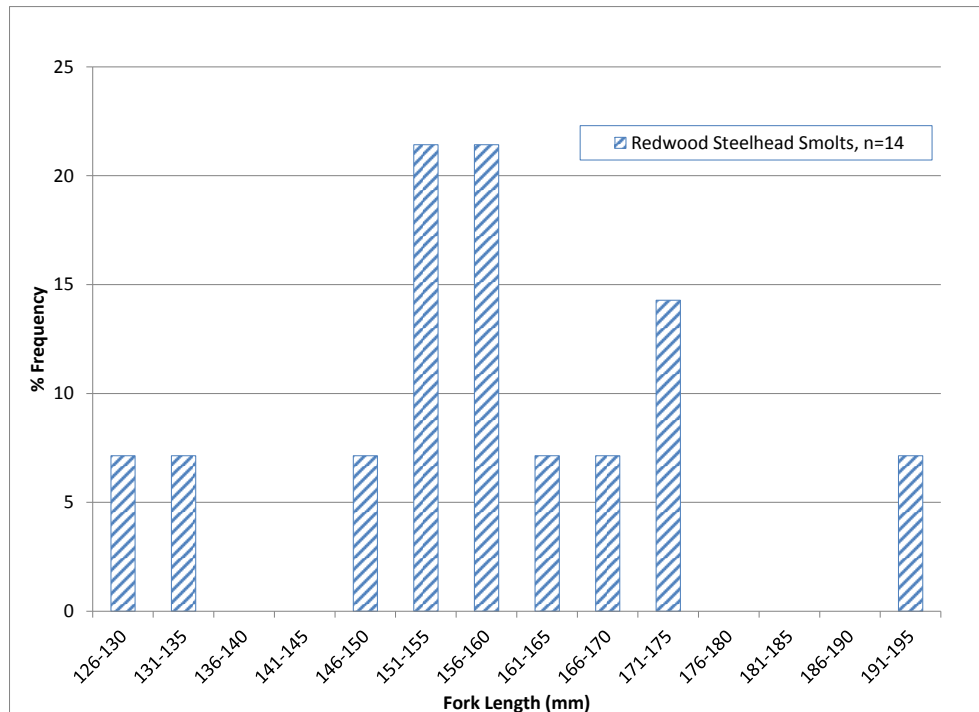


Figure 12. Steelhead smolt fork lengths in 5 mm bins for Redwood Creek, 2011.

Length is the principal factor affecting the weight of fishes. In spite of this, there can be significant differences in weight distribution between similar size fish of the same species within a particular watershed and surrounding region. In order to compare length-weight relationships, we applied the Fulton Condition Factors (K) to establish comparable indices of condition

(Murphy and Willis 1996). Condition factors are a ratio relating fish length to fish weight therefore measuring the relative biomass of a fish, with a higher length to weight ratio denoting a better over-all condition. Table 5 shows the comparisons between coho smolt length and K-factors at Olema and Redwood Creeks. Table 6 shows the comparisons between steelhead smolt length and K-factors at Olema and Redwood Creeks.

In 2011, the average coho smolt fork length was 121.51 mm in Olema Creek and 111.54 mm in Redwood Creek. The mean weight of coho smolts was 16.23 g in Olema Creek and 12.46 g in Redwood Creek. The mean K-factor was 0.89 in Olema Creek and 0.88 in Redwood Creek.

Table 5. Coho mean and median length, weight, and K-factor calculated during 2011 for the trapping locations at Olema and Redwood Creeks.

Watershed	Sample Size	Mean Length (mm)	Median Length (mm)	Length Standard Deviation	Mean Weight (g)	Median Weight (g)	Weight Standard Deviation	Mean K-Factor	K-Factor Standard Deviation
Olema Creek	376	121.51	121.00	10.65	16.23	15.51	4.24	0.89	0.06
Redwood Creek	1,262	111.54	111.00	9.39	12.46	12.04	3.06	0.88	0.07

The average steelhead smolt fork length was 172.27 mm in Olema Creek and 157.15 mm in Redwood Creek. The mean weight of steelhead smolts was 42.27 g in Olema Creek and 31.95 g in Redwood Creek. The mean K-factor was 0.80 for both Olema and Redwood Creeks.

Table 6. Steelhead mean and median length, weight, and K-factor calculated during 2011 for the trapping locations at Olema and Redwood Creeks.

Watershed	Sample Size	Mean Length (mm)	Median Length (mm)	Length Standard Deviation	Mean Weight (g)	Median Weight (g)	Weight Standard Deviation	Mean K-Factor	K-Factor Standard Deviation
Olema Creek	15	172.27	174.00	18.84	42.27	42.23	13.16	0.80	0.04
Redwood Creek	13	157.15	157.00	17.61	31.95	31.13	10.42	0.80	0.08

3.9.1 Coho Smolt Passive Integrated Transponder Summary

During the course of the trapping operation, 203 coho smolts were implanted with PIT tags on Olema Creek as part of the smolt trapping mark/recapture study. Passive integrated transponder tag recapture data show that marked fish spent an average of 11.7 days in the system after being marked before continuing their outward migration. The time spent upstream of the trap ranged from 1 to 32 days, with a median of 10 days. Tagged individuals had an average fork length of 123 mm with a median fork length of 121 mm and an average weight of 16.88 g and a median weight of 16.26 g. Of the 203 coho smolts, 59 were subsequently recaptured. During juvenile surveys in the summer of 2010, 59 juvenile coho were implanted with PIT tags. Three of those coho were recaptured during smolt trapping. They showed an average increase in length of 34.7 mm and an average increase in weight of 8.13 g.

For Olema Creek smolts tagged during the spring, the average length at tagging was not significantly different ($p=0.4774655$) from the average length at recapture using a two-sided hypothesis test and an alpha value of 0.05. The point estimate of the difference between the pre-

tagging mean length and the post-tagging mean length was 1.37 with a 95% confidence interval of -2.43 to 5.16. The mean weight for coho smolts at tagging on Olema Creek was not significantly different ($p=0.9092323$) than the mean smolt weight at recapture using a two-sided hypothesis test with an alpha value of 0.05. The point estimate of the difference between the pre-tagging mean weight and the post-tagging mean weight was 0.08, with a 95% confidence interval of -1.34 to 1.51.

On the mainstem Redwood Creek traps, a total of 644 coho salmon were marked with PIT tags and 345 fish were subsequently recaptured. Tagged individuals implanted at the lower mainstem trap had an average fork length of 113.0 mm and a median fork length of 112 mm. They had an average weight of 12.90 g and a median weight of 12.45 g. Individuals tagged at the Banducci trap had an average and median fork length of 112 mm and an average weight of 12.56 g with a median weight of 12.15 g. An additional 159 coho smolts were marked at the backwater trap. They had an average and median fork length of 123 mm and an average weight of 16.66 g with a median weight of 16.52 g.

For Redwood Creek smolts, the average length at tagging was not significantly different ($p=0.5445705$) from the average length at recapture using a two-sided hypothesis test and an alpha value of 0.05. The point estimate of the difference between the pre-tagging mean length and the post-tagging mean length was 0.45 with a 95% confidence interval of -1.02 to 1.93. The mean weight for coho smolts at tagging on Redwood Creek was not significantly different ($p=0.5127361$) than the mean smolt weight at recapture using a two-sided hypothesis test with an alpha value of 0.05. The point estimate of the difference between the pre-tagging mean weight and the post-tagging mean weight was -0.16, with a 95% confidence interval of -0.63 to 0.32.

Between July 2010 and February 2011, 125 juvenile coho were PIT tagged on Redwood Creek. Sixty five were tagged during the summer season and an additional 29 juveniles were tagged during winter habitat surveys. Fifty-two of these fish were later captured during the 2011 smolt trap season; 40 were originally tagged during the summer surveys and 12 had been tagged during the winter habitat surveys. Information about the growth of these coho is provided below (Table 7). It should be noted that the fish tagged during the summer surveys had a minimum size limit, which may have led to a skewed sample in that only the largest juveniles were tagged. During the winter surveys, juveniles had all reached the minimum size limit for tagging. In addition to providing information about the growth of fish tagged prior to the outmigrant season, PIT tags also showed movement patterns during the trapping time period.

Along with the expected downstream movement, fish were also observed moving upstream from the lower mainstem trap to the Banducci trap, as well as from the backwater trap upstream to both the lower mainstem trap and the Banducci trap. Finally, five different tagged fish were observed multiple times on the same trap, indicating that they were moving through the trap before migrating back upstream around the trap to be captured again. Passive Integrated Transponder tag recapture data show that marked fish spent an average of 6.9 days in the system after being marked before continuing their outward migration. The time spent upstream of the lower mainstem trap ranged from 1 to 47 days, with a median of 5 days.

Table 7. Measurements of Redwood Creek coho tagged as juveniles during summer and winter surveys and recaptured as smolts in spring 2011.

Season tagged	Number of coho recaptured	Average Juvenile Fork Length (mm)	Average Juvenile Weight (g)	Average Smolt Fork Length (mm)	Average Smolt Weight (g)	Average Change in Fork Length (mm)
Summer	40	84.00	6.45	118.06	14.61	30.67
Winter	12	89.67	N/A	110.75	12.29	21.08

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Appendix A. Annual Catch Totals

Table A1. Summary of salmonid information for Olema and Redwood Creeks trap operations, 1999-2010.

Watershed	Year	Trap Operation Dates		Days In Operation ^c	Steelhead			Adult ocean-run	Coho		Coho Production Estimate	
		From	To		smolt	parr	fry		smolt	fry	Estimate	Standard Error
Olema Creek	2004	30-Mar	28-May	28	13	5	140	0	228	31	831	167
	2005 ^a	1-Apr	9-May	31	9	8	1,218	1	88	14	362	145
	2006	10-Apr	9-Jun	45	6	19	497	0	368	51	3,793	784
	2007	14-Mar	27-May	66	233	135	462	12	330	739	1,485	207
	2008	18-Mar	30-May	72	62	9	38	3	934	8	2,885	336
	2009	12-Mar	29-May	62	117	104	32	0	1,072	1	4,088	1,041
	2010	19-Mar	21-May	42	34	26	858	0	10	13	N/A	N/A
Redwood Creek	2005	27-Mar	31-May	35	1	1	344	0	299	535	1,977	430
	2006	18-Apr	9-Jun	49	18	0	24	0	1,048	27	2,502	257
	2007	16-Mar	27-May	66	17	5	585	1	330	97	1,353	307
	2008	19-Mar	30-May	70	18	3	151	0	890	3	2,046	163
	2009 ^b	11-Mar	29-May	65	69	16	199	2	163	4	N/A	N/A
	2010 ^d	19-Mar	28-May	59	51	62	53	0	120	98	389	409

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

^a Trapping discontinued May 9 due to high flows. Trap was not reinstalled. Population estimate calculated using Chapman (1951)

^b During 2009 coho smolts were marked at both the Banducci and mainstem traps on Redwood Creek. The smolt total presented in this table includes all unmarked fish caught at the mainstem trap, including those that were then marked, and the fish marked at Banducci to avoid double-counting fish that were not marked at Banducci and later caught downstream in the mainstem trap. A population estimate is not available for Redwood Creek in 2009 due to the lack of variation in timing of recaptured smolts.

^c Does not include days where trap was only partially functioning.

^d Includes fish captured at both mainstem traps, as detailed in comment above.

Table A2. Summary of non-salmonid information for Olema and Redwood Creeks trap operations, 1999-2010.

Watershed	Year	Trap Dates		CH	GSF	GSH	LAM	PL	RO	SCU	STK	SUC	Totals
		From	To										
Olema Creek	2004	30-Mar	28-May	2	1	1	15	0	274	243	3,083	144	3,763
	2005	1-Apr	9-May	0	0	0	33	0	1,006	117	648	58	1,862
	2006	10-Apr	9-Jun	0	0	0	5	1	420	644	2,998	3	4,071
	2007	15-Mar	26-May	0	0	0	35	0	3,190	356	1,110	140	4,839
	2008	18-Mar	30-May	0	0	0	2	3	158	228	30	2	423
	2009	12-Mar	29-May	0	0	0	109	0	554	335	782	8	1,788
	2010	19-Mar	21-May	0	0	0	27	0	3,187	110	1,353	7	4,674
Redwood Creek	2005	27-Mar	31-May	0	0	0	0	0	0	24	5,343	0	5,367
	2006	18-Apr	9-Jun	0	0	0	0	0	0	133	117	0	250
	2007	18-Mar	26-May	0	0	0	0	0	0	93	57	0	150
	2008	19-Mar	30-May	0	0	0	0	0	0	151	38	0	189
	2009 ^a	11-Mar	29-May	0	0	0	0	0	0	220	74	0	294
	2010 ^a	19-Mar	28-May	0	0	0	0	0	0	340	193	0	533

Species Code: CH = Chinook Salmon (*Oncorhynchus tshawytscha*), GSF = Green Sunfish (non-native), GSH = Golden Shiner (*Notemigonus crysoleucas*, non-native), LAM = Lamprey spp., PL = Pacific Lamprey (*Lampetra tridentata*), RO = California Roach, SCU = Sculpin spp., STK = Threespine Stickleback, SUC = Sacramento Sucker.

^a Includes Banducci trap site.

Appendix B. Julian Week Table

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

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