



**OLEMA CREEK WATERSHED SUMMARY MONITORING REPORT,
MARIN COUNTY, CA
1997-2003**



PORE/NR/WR/04-02

Prepared by:

Brannon J. Ketcham (Hydrologist)¹
Gregory G. Brown (Biologist)¹
Odessa Wolff (Biologist)²

¹Point Reyes National Seashore
Point Reyes Station, CA 94956

² Point Reyes National Seashore Association
Point Reyes Station, CA 94956

Prepared for:

California Department of Fish and Game Fisheries Restoration Grant Program Contract # P0130434
National Park Service – San Francisco Area Network – Inventory and Monitoring Program

May 7, 2004
Version 3.0

**OLEMA CREEK WATERSHED SUMMARY MONITORING REPORT,
MARIN COUNTY, CA
1997-2003**

PORE/NR/WR/04-02

Ketcham, B.J., Brown G.G., and Wolff, O.G. 2004. Olema Creek Watershed Summary Monitoring Report, Marin County, CA. 1997-2003. PORE/NR/WR/04-02. 80pp plus appendices.

ABSTRACT

Olema Creek is the largest undammed watershed in coastal Marin County, California and an important stream for threatened coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) within the central California coast Evolutionarily Significant Unit (CCCESU). Though dramatically reduced from the mid-1900s populations, the Lagunitas Creek watershed (including Olema) supports at least 10% of coho salmon (Brown et.al. 1994) and is considered a keystone population of the CCCESU. The National Park Service (NPS) has conducted adult escapement surveys, smolt trapping, and summer juvenile index reach monitoring in the Olema Creek watershed since 1998. NPS results show that this watershed has supported annual runs of coho ranging from less than 50 to more than 200, with associated juvenile densities (95% CI) ranging from 0.297 ($\pm$ 0.029) coho per meter in 1999 to 2.172 ($\pm$ 0.215) coho per meter in 2002. Expanded monitoring efforts beginning in 2003 will allow managers to quantify basinwide juvenile estimates as well as overwinter survival. The Olema Creek fisheries monitoring program will continue with support through the NPS Inventory and Monitoring Program and the California Department of Fish and Game Salmonid Restoration funds. In addition, these data will be integrated into future watershed scale limiting factors assessments that may help identify biotic bottlenecks within the system and will complement existing wetland restoration and water quality monitoring within the Lagunitas Creek and Tomales Bay watersheds.

This report presents and analyzes results from adult escapement surveys between 1997 and 2004, outmigrant smolt trapping between 1998 and 2003, summer index reach monitoring between 1999 and 2003 and a modified Hankin-Reeves coho juvenile population estimate for 2003. Recommendations related to the monitoring protocols and analyses are also provided.

ACKNOWLEDGEMENTS

Monitoring efforts on Olema Creek date back to 1994, with the institution of winter adult spawner surveys by volunteers of the Tomales Bay Association in cooperation with NPS staff. This effort evolved into a five-year National Park Service funded Coho and Steelhead Restoration Project (CSRP). The current monitoring program was initiated under the CSRP with original development by David Manning, Ron Smith, Brannon Ketcham and David Press. A great number of people were integral to the continued development and implementation of this program including Jesse Wechsler, Ken Kundargi, John Brunzell, Jessica Scheeter, Jim Whitlock, and Jef Parr. Through the years, volunteers have contributed thousands of hours to these programs assisting with all aspects of our monitoring efforts.

We also would like to express our appreciation to Darren Fong, Aquatic Ecologist at Golden Gate National Recreation Area, who has provided continual technical review and assistance for the program since drafting the original proposal in 1996. This research is conducted under the Endangered Species Act Section 10 Permit #1046 authorization managed by NOAA - Fisheries.

Funding to support monitoring activities between 1997 and 2002 was provided through a National Park Service Natural Resources Preservation Program grant. Additional NPS funding has been provided through various sources, including base funding as well as support through the Point Reyes National Seashore Association. In 2003, funding was provided through the National Park Service - San Francisco Area Network Inventory and Monitoring Program and the California Department of Fish and Game Fisheries Restoration Grant Program Contract P0130434.

For additional copies or information related to this document, please contact Brannon Ketcham, Water Resources and Restoration Branch Chief at (415) 464-5192 or brannon_ketcham@nps.gov.

TABLE OF CONTENTS

ABSTRACT	3
ACKNOWLEDGEMENTS	4
TABLE OF CONTENTS	5
1.0 INTRODUCTION	7
1.1 BACKGROUND	7
1.2 FISH RESOURCES	8
1.2.1 Coho Salmon	8
1.2.2 Steelhead	9
1.3 MONITORING RATIONALE	11
1.4 PHYSICAL SETTING	11
1.4.1 Watershed Description	11
1.4.2 Watershed History	12
1.4.3 Geomorphic Response to Historic Actions (discussion adapted from Niemi and Hall 1996)	12
1.4.4 Olema Creek Hydrologic Response	14
1.4.4 Rainfall Information	15
1.4.5 Water Quality	16
2.0 METHODS	17
2.1 ADULT ESCAPEMENT SURVEYS	17
2.1.1 Adult Escapement Monitoring Objectives & Questions	17
2.1.2 Field Methods	17
2.1.3 Analysis	18
2.1.4 Other Monitoring Programs	19
2.2 OUTMIGRANT SMOLT TRAP	19
2.2.1 Monitoring Objectives and Questions	20
2.2.2 Field Methods	20
2.2.3 Analysis	21
2.3 INDEX REACH SURVEYS	21
2.3.1 Rationale for Sampling Design	22
2.3.2 Monitoring Objectives and questions	22
2.3.3 Site Location and Field Methods	23
2.3.4 Data Analysis	24
2.4 HANKIN REEVES POPULATION ESTIMATES	24
2.4.1 1999 Juvenile Fish Abundance, Distribution, and Mortality in Isolated Pools	25
2.4.2 2003 Summer Mainstem Coho Population Estimate	25
2.5 GENETIC ANALYSIS	26
2.6 DATA MANAGEMENT	26
3.0 RESULTS	29
3.1 ADULT ESCAPEMENT SURVEYS	29
3.1.1 Survey Timing and Environmental Conditions	29
3.1.2 Watershed Escapement History and Estimates	30
3.1.3 Live Fish, Carcass, and Redd Observations	34
3.2 OUTMIGRANT SMOLT TRAP	37
3.2.1 Smolt outmigration timing	37
3.2.2 Smolt size and condition	38
3.2.3 Fish passage performance at the John West Fork	40
3.3 INDEX REACH SURVEYS	42
3.3.1 Index reach total salmonid catch	43
3.3.2 Index Reach Habitat Information	43

3.3.3	<i>Salmonid density by habitat type</i>	45
3.3.4	<i>Salmonid Index Reach Density</i>	45
3.3.5	<i>Summer fish measurement information</i>	48
3.4	POPULATION ESTIMATES.....	51
3.4.1	<i>1999 Juvenile Fish Abundance, Distribution, and Mortality in Isolated Pools</i>	51
3.4.2	<i>Summer 2003 Hankin Reeves Survey</i>	53
3.5	EXTRAPOLATED COHO SALMON POPULATION ESTIMATES COMPARING INDEX REACH MONITORING AND SNORKEL SURVEY ESTIMATES.....	56
3.6	GENETICS AND RECOVERY	56
4.0	ANALYSIS	59
5.0	RECOMMENDATIONS	68
5.1	ADULT ESCAPEMENT	69
5.2	SMOLT TRAP OPERATIONS.....	69
5.3	INDEX REACH MONITORING	70
5.4	BASINWIDE POPULATION ESTIMATE.....	71
6.0	REFERENCES	73
APPENDICES		79

APPENDIX A – HABITAT, SNORKEL, AND ELECTROFISHING SURVEY RESULTS

APPENDIX B – ELECTROFISHING LOG

APPENDIX C – GENETIC SAMPLE SUMMARY TABLE

APPENDIX D – OUTMIGRANT SMOLT TRAP OPERATIONS INFORMATION

1.0 INTRODUCTION

Olema Creek is the largest undammed watershed in coastal Marin County, California (Figure 1.1) and an important stream for threatened coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) within the central California coast Evolutionarily Significant Unit (Figure 1.2). 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 Point Reyes National Seashore and the Golden Gate National Recreation Area North District. The watershed provides habitat to four federally protected aquatic species (California freshwater shrimp – endangered; coho salmon – threatened; steelhead – threatened; California red-legged frog – threatened). Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within Point Reyes National Seashore.

In 1997 the National Park Service (NPS) initiated the Coho Salmon and Steelhead Trout Restoration Project (CSRP) to assess watershed and fishery condition in Marin County, and develop recommendations to enhance local populations of these anadromous species. The project watersheds including Redwood Creek, Pine Gulch Creek, and tributaries of Lagunitas Creek (Olema Creek, Cheda Creek, and Devil's Gulch) are located in western Marin County, and within the National Marine Fisheries Service (NMFS) designated central California coast Evolutionarily Significant Unit (CCCESU). Anadromous fish populations throughout the state of California are estimated to be 1% of historic populations. Though dramatically reduced from the mid 1900s, the Lagunitas Creek watershed contains 10% of the remaining fish (Brown and Moyle 1991) and is considered the keystone population of the CCCESU.

This report represents a comprehensive summary of monitoring data for various life stages of coho salmon and steelhead trout collected by the National Park Service since 1998 in the Olema Creek watershed. It includes summaries of adult escapement, smolt trapping, and juvenile index reach monitoring efforts initiated through the NPS Coho Salmon and Steelhead trout Restoration Project (CSRP) and continued through support by the San Francisco Area Network Inventory and Monitoring Program and a California Department of Fish and Game Salmonid Restoration grant to the Point Reyes National Seashore Association (P0130434).

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). The latest status review update for coho salmon states that within the central California coast Evolutionarily Significant Unit (CCCESU) states that the “decision to list coho as ‘threatened’ in this ESU may have been overly optimistic” (NMFS 2001).

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 Fahrenheit) and high dissolved oxygen levels. 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. Major NPS 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; and
- Marine over-harvesting and poor productivity during El Niño events.

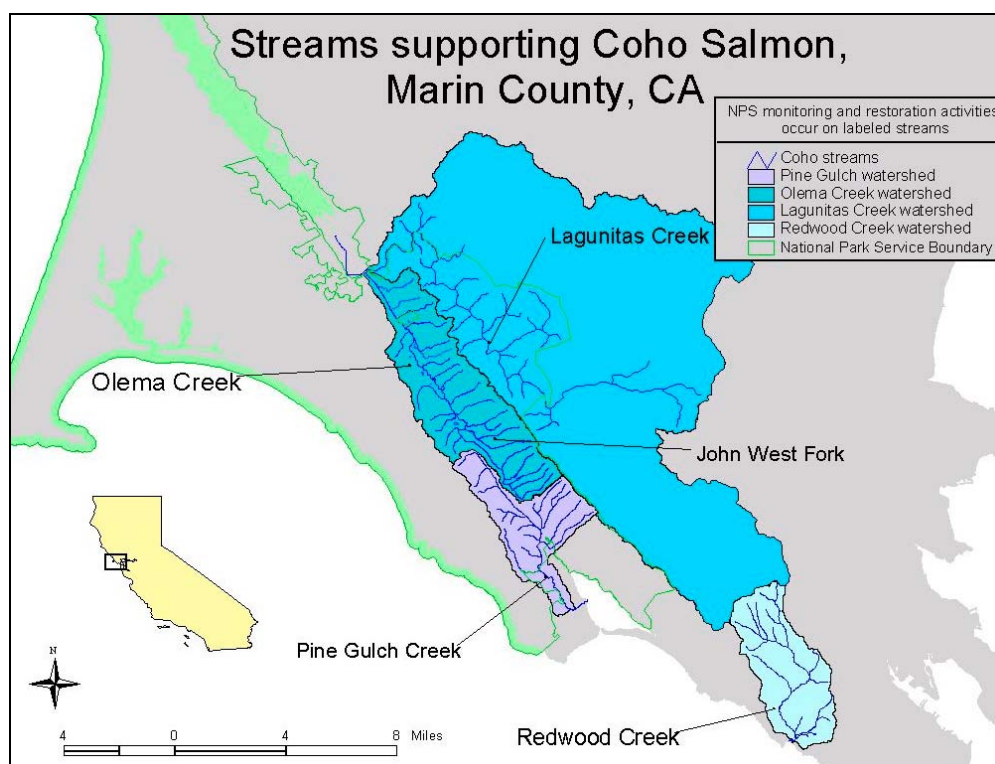


Figure 1.1 Streams supporting coho salmon in coastal Marin County.

1.2 Fish Resources

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

1.2.1 Coho Salmon

Biology

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. Coho generally return to natal streams after spending two years in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sandbars at the mouth of coastal streams allowing the fish to move upstream. Spawning occurs in small to medium sized gravel at aerated sites, typically near the head of a riffle (Moyle 1976). These streams have summer temperatures seldom exceeding 21 degrees Centigrade (70 degrees Fahrenheit). Emergent fry use shallow near-shore areas, whereas optimal habitat conditions for juveniles and sub-adults are deep pools associated with rootwads, woody debris, and boulders in shaded stream sections (Laufle et al 1986). The distribution and habitat of coho juveniles partially overlaps with that of the California red-legged frog.

Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species coastwide (NMFS 1996). Several runs were listed along the central California coast and include regions occupied by California red-legged frogs. Causes of coho salmon declines in California include incompatible landuse practices such as logging and urbanization, loss of wild stocks, introduced diseases, over harvesting, and climactic changes.

Coho salmon are known to exist in watersheds including Lagunitas, Olema, Pine Gulch (Brown and Ketcham 2002), and Redwood Creeks. Walker Creek, which flows into Tomales Bay, likely supported coho salmon and is part of a larger coho recovery program conducted by the California Department of Fish and Game and NOAA-Fisheries.



Regulatory Protection

NOAA-Fisheries

Coho salmon were listed as a threatened species within the central California coast coho salmon ESU (CCCESU) on October 31, 1996 by the National Marine Fisheries Service (NOAA-Fisheries) (Federal Register 1996). The CCCESU (Figure 1.2) 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 association with the coho threatened listing NOAA-Fisheries designated critical habitat for coho salmon on May 5, 1999. The critical habitat is designated to include all river reaches accessible to listed coho salmon from Punta Gorda in northern California south to the San Lorenzo River in central California, including Mill Valley (Arroyo Corte Madera Del Presidio) and Corte Madera Creeks, tributaries to San Francisco Bay. Excluded are areas above specific dams or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Major river basins containing spawning and rearing habitat for this ESU comprise approximately 4,152 square miles in California. The following counties lie partially or wholly within these basins: Lake, Marin, Mendocino, San Mateo, Santa Clara, Santa Cruz, and Sonoma.

NOAA-Fisheries has acknowledged that within the CCCESU, the decision to list coho salmon as threatened may have been overly optimistic and concludes that the ESU population is presently endanger of extinction (NMFS 2001). This said, it has been noted through personal communication that the Lagunitas/Olema Creek watershed population is the largest, and most stable south of the Noyo River and may represent a much larger percentage of the remaining wild coho in the ESU than the 10% quoted in the 1997 listing.

California Department of Fish and Game

On April 5, 2001, the Fish and Game Commission accepted the petition to list coho salmon north of the Golden Gate as endangered under the State Endangered Species Act. As a response to this petition, the DFG prepared a status review of California which concluded that the coho salmon within the central California coast ESU (as designated by NOAA Fisheries – Figure 1.2) are in serious danger of becoming extinct throughout all or a significant portion of its range, and that the endangered listing is warranted (CDFG 2002). As a response, the CDFG released a draft Recovery Strategy for coho salmon in November 2003, which was adopted as revised by the Fish and Game Commission on February 6, 2004.

1.2.2 Steelhead

Biology

Steelhead are the anadromous form of rainbow trout; adult steelhead typically spawn in gravel riffles in the spring, from February to June. Steelhead are multiparous, meaning they can spawn more than once. Research conducted in the 1950s documented female steelhead returning to spawn in multiple years (Shapavolov and Taft 1954). Optimum

temperatures for growth range from 13 to 21 degrees Centigrade (55 to 70 degrees Fahrenheit) (Moyle 1976). It is also noted that steelhead may persist in a broad range of pH (from 5.8 to 9.6) but prefer a pH between 7 and 8 (Moyle 1976). Steelhead fry reside in near-shore areas. Steelhead juveniles tend to use riffles and pool margins, potentially overlapping with California red-legged frog tadpoles. Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species throughout much of the California coast.

Steelhead trout are known to exist in most perennial watersheds within Marin County.

Regulatory Protection

Steelhead were listed as a threatened species on August 17, 1997 (Federal Register 1997). The central California coast steelhead ESU (Figure 1.2) includes all naturally spawned populations of steelhead (and their progeny) in California streams from the Russian River to Aptos Creek, and the drainages of San Francisco and San Pablo Bays eastward to the Napa River (inclusive), excluding the Sacramento-San Joaquin River Basin. Critical habitat for steelhead is under development. On April 30, 2002, the U.S. District Court for the District of Columbia approved a NMFS consent decree withdrawing a February 2000 critical habitat designation for this and 18 other ESUs.

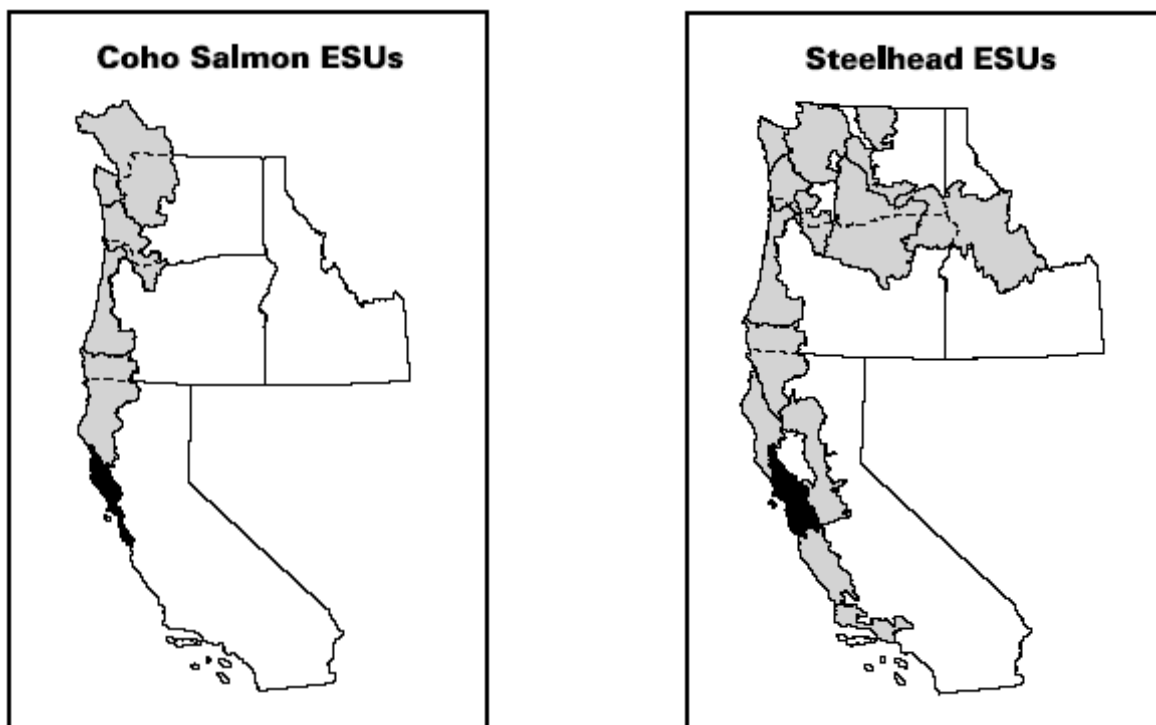


Figure 1.2 Coho salmon and Steelhead Evolutionarily Significant Units as identified by NOAA Fisheries. Marin County is included within the Central California Coast ESU for coho salmon (left) and steelhead (right).

Historical Fishery Resources

Review of the historical background information shows that fisheries resources have declined dramatically since the turn of the century. As early as 1892, reports of declines in fish abundance within the streams of western Marin County were circulated. Response to declines and recreational demand included planting of a variety of salmonid species within the Lagunitas Creek watershed including coho salmon, chinook salmon, steelhead trout, and eastern brook trout. Direct plants to Olema Creek included eastern brook trout in 1892, and chinook salmon in 1897 and 1910.

Interviews with long time residents and former as well as present fisheries resource managers support the contention that fisheries resources within the area have been declining for years and that the most significant and noticeable changes have occurred since the mid-1950's. It is well established that both the abundance and distribution of coho salmon and steelhead trout has declined throughout the area. Interestingly, though most of the changes in fish

populations have occurred within the past 50 years, the majority of the most exploitive land use practices (dairy and logging) ended more than seventy years ago.

There is little doubt that historic exploitation of the forest, grassland, and fisheries associated with the Olema Valley has severely impacted the extent of existing coho salmon and steelhead trout populations.

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 the north coast of California and Oregon, researchers have observed high juvenile densities in the summer, followed by very low smolt outmigration the following spring (Duffy 2004 personal communication). 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 1992).

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.

1.4 Physical Setting

The Olema Valley has a rich and varied land use history. Beginning in the early 1800s traditional hunting and burning by the Coast Miwok shifted to intensive livestock production. The first major Mexican land grants included livestock and sheep grazing as well as extractive uses such as logging. In the later 1800s production converted primarily to dairy operations, and western Marin County became one of the state leaders in dairy production. The dairy business lost appeal in the mid-1900s with many of the operations converting to beef cattle production. Acquisition of the land in the Olema Valley by the National Park Service's Point Reyes National Seashore and Golden Gate National Recreation Area began in the mid 1970s. Currently, 35% of the Olema Creek watershed is within the designated Pastoral Zone and managed for beef cattle. Agricultural land use is primarily limited to the east side of Olema Valley and the Bolinas Ridge. The exception to this is the private lands operated by the Vedanta Society.

1.4.1 Watershed Description

Olema Creek's hydrologic regime is inextricably linked to the San Andreas Fault and the area's Mediterranean climate. East of the fault, intermittent tributaries flow from the serpentine bedrock and thin soils of Bolinas Ridge and across the alluvial valley bottom. West of the fault, perennial tributaries draining the deep marine sedimentary deposits of Inverness Ridge to the west follow much steeper stream gradients before joining the mainstem of Olema Creek. The intermittent Bolinas Ridge tributaries provide the most significant fisheries habitat and watershed area, while the perennial but steep Inverness Ridge tributaries supply the important summer base flow to the mainstem, which contains the majority of the aquatic habitat within the watershed.

The Olema Valley was dramatically affected by the 1906 San Francisco earthquake. The quake resulted in surface ruptures from Bolinas Lagoon to Tomales Bay with lateral offsets measured up to 20 feet. Geologic investigations have shown that such events reoccur on this section of the fault on the order of once every 300 years (Niemi 2002 personal communication). The location and actions along the fault insure some level of instability within the watershed.

The watershed condition reflects impacts of more than a century of intensive agricultural land use, combined with the instability of its location along the highly active San Andreas Fault. The effects of past land-use practices (logging, agriculture, and grazing) have changed the condition of the watershed, altering its ability to support fish populations at their historic levels. Although land-use activities have been greatly reduced and upgraded to a more environmentally

sustainable land-use ethic, present land-use continues to influence water quality conditions within the watershed. Loss of native perennial vegetation, soil compaction and loss, hillside trailing, gullying, and incision of swales and meadows have changed the runoff patterns and reduced the capacity of the watershed to attenuate pollutant loading and surface runoff.

1.4.2 Watershed History

The landforms observed throughout western Marin County have been formed by a combination of extreme climactic events and plate tectonics. While the geologic setting and climate have been described, it is the extremes associated with these conditions that have played the greatest role in shaping the valley, stream channel, and habitat for the anadromous fisheries known to prefer this watershed. The Olema Valley was the site of a surface rupture trending to the northwest following the 1906 San Francisco earthquake, with extensive land rupture of up to 21 feet occurring along the central shutter ridge feature (Gilbert 1908). In many other ways, the fault zone has resulted in very unusual geomorphic features, including parallel streams flowing opposite directions within the same valley (Olema and Pine Gulch Creeks).

Discounting the cumulative impacts of human alteration and ocean conditions, and assuming that anadromous fish populations were relatively strong in the mid 1960s as the NPS began acquiring land, it is the extreme climactic events that have impacted the habitat and ultimately populations of coho salmon and steelhead trout.

The last thirty years have been marked by two major droughts (1976-77 and 1985-90), two El Nino events (1983 and 1998), and a 500 year storm event (1982). While the drought weakened fish populations throughout the coastal watersheds, it was the 500 year flood followed the next year by the first documented El Nino event that severely impacted habitat and fish populations for 2/3 of the coho salmon year class. The major storm events resulted in catastrophic debris flows and delivery of sediment to the channel. In some areas we are still observing major sediment deposition resulting from the mobilization of materials deposited in the channels in 1982 and 1983. In addition to these issues, abandoned road facilities within the Seashore persist as sources of sediment to the stream.

1.4.3 Geomorphic Response to Historic Actions (discussion adapted from Niemi and Hall 1996)

Like many of the watersheds in coastal California, there are a series of periods bounded by regional shifts in resource extraction. Within the Olema Valley major land use shifts, alterations to the channel and climactic events are connected to the geomorphic character of the existing stream channel and habitat condition. The discussion of the historic channel conditions and alignments is best illustrated in Figure 1.3.

Prior to European influence on the Olema Valley, it is likely that the east side drainages deposited most of their bed load and sediment on alluvial fans (Dietrich 1997). Disconnection of these tributary channels to the mainstem was effective at metering sediment into the main channel. The tributaries were likely prime spawning areas with extensive and well conditioned spawning gravels. With more intensive land uses over the last 150 years, disturbance has resulted in incision of the tributaries through their alluvial fans. This has increased the sediment source network to include tributaries. The scenario described would imply that the east side tributaries always did include some intermittent habitat.

Between 1860 and 1918, land use consisted primarily of logging and intensive agricultural production. The lower section of the stream channel meandered across a floodplain beginning south of Olema and covering the entire valley bottom. Sediment entrainment and transport to the head of Tomales Bay contributed to the progradation of the tidal marsh more than one kilometer to the northwest.

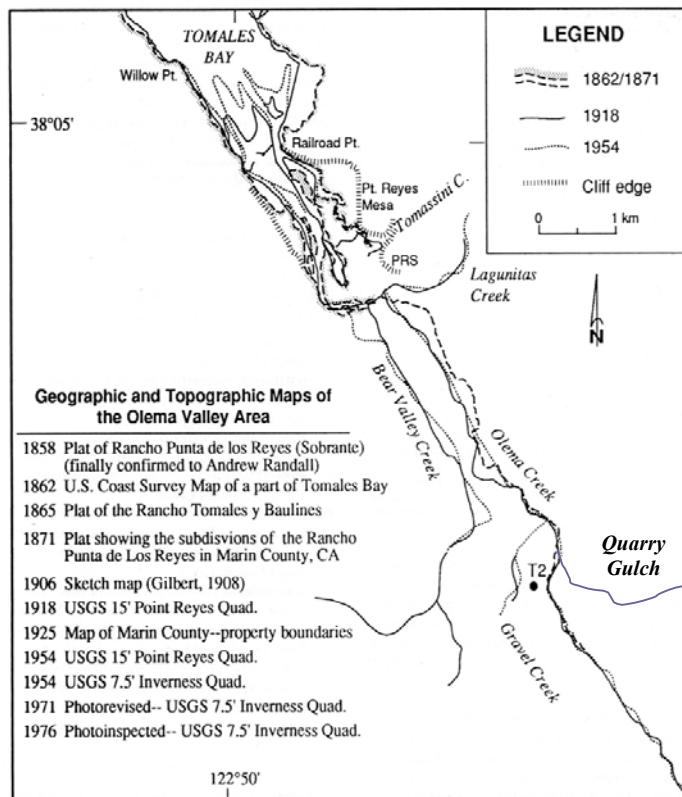


Figure 1.3. Comparison of the 1862/1871, 1918, and 1954 maps of Tomales Bay and the northern reach of Olema Creek (adapted from Niemi and Hall 1996).

In 1921 a canal was excavated between Sir Francis Drake Boulevard and the town of Olema. This area, adjacent to Highway 1 between Olema and Point Reyes Station (currently referred to as the Olema Pasture) was once a willow thicket regularly flooded by stormflow events. Clearing of the willows for charcoal and dredging the channel to an estimated depth of two to three meters below the floodplain significantly altered the hydrology within Olema Creek. Aside from initiating a process of incision and instability to the lower reach of the stream, loss of connectivity to the floodplain resulted in increased the sediment transport to the head of Tomales Bay.

Several pre-1920s historical accounts noted the “Arroyo Olemus Lake” (Livingston 1991). Besides the 1982 flood event, this area did not begin flooding again regularly until 1995 when a combination of major storms, restored riparian corridor (woody debris) and sediment deposition resulted in the avulsion of Olema Creek and the regular formation of the Olema Lake. The process that resulted in the reconnection of this section of the channel to its floodplain is prevalent in many of the coastal watersheds within the Point Reyes National Seashore. Excessive sediment mobilized during episodic rainfall conditions is deposited in the lower reaches of a channelized and/or leveed stream channel. Accumulation of these sediments is now allowing many of these channels to reoccupy the former floodplains, enhancing the quality and condition of the stream channel and estuarine system downstream.

The 1921 channelization initiated the development and migration of a knickpoint within the system. While the section of channel that was dredged remains relatively straight, the section of the channel beginning at the Bear Valley Bridge is characterized by entrenched meanders and extreme bank instability (as observed following El Nino 1998). Fieldwork completed by Niemi and Hall in 1992 indicated that the knickpoint was migrating upstream. The knickpoint currently lies approximately 200 meters upstream of the confluence with Quarry Gulch. It is a site of extreme streambank instability, high energy within the channel, and a major source of sediment to the channel downstream. Besides impacting the mainstem of Olema Creek, migration of this knickpoint past the Quarry Gulch resulted in bifurcation of the impact, with the incision and instability transferred to the tributary.

In the 1940s Waldo Giacomini constructed a series of levees at the head of Tomales Bay in order to conduct a major dairy operation. Besides eliminating more than 500 acres of estuarine and freshwater marsh habitat, construction of the levees changed the hydrologic circulation of the estuary at the confluence of Olema Creek and Bear Valley Creek with Lagunitas Creek. In larger events, the levees act as a dam to pond waters of the smaller tributaries, Olema and Bear Valley Creek. Currently, the National Park Service is in the planning stages to restore natural process to this property.

Throughout the rest of the watershed logging and intensive dairying continued their prominence until the middle of the century. As most of the accessible trees were logged and the dairy economy changed, much of the watershed was converted to beef grazing operations. Though still intensive, the actions were much less impacting than those of the later 1800s and early 1900s.

Beginning in the 1960s and 1970s, with the establishment of Point Reyes National Seashore and Golden Gate National Recreation Area, the intensity of land use has been greatly reduced. Currently less than 40% of the watershed is managed for grazing activities.

1.4.4 Olema Creek Hydrologic Response

Within the Olema Creek system, hydrologic response is rapid and short-lived. In this Mediterranean climate, the flow of Olema Creek ranges from less than 0.5 cubic feet per second (cfs) in the summer to more than 2,500 cfs in the winter. An indicator often used to describe stream channel condition is the bankfull or effective discharge. This is a flow that occurs approximately on a two-year repeat interval and is calculated at approximately 500 cfs (Dunne & Leopold 1978). The 14.5 square mile watershed is quite linear with a measured lag time between peak rainfall and runoff at the Bear Valley Bridge on the order of three to four hours. The rainfall-runoff response time in most tributaries is between 15 to 45 minutes, depending on watershed size.

Past land use has altered the hydrologic response of Olema Creek. Incision through meadow and floodplain features has reduced the lag time and increased peak flows within the watershed. The result of these physical alterations and increased winter discharge is a reduced groundwater storage capacity in the tributary floodplains and meadows. The alterations to the wetland systems have resulted in a greater range of flow between winter and summer.

Seven to nine inches of cumulative rainfall are required to initiate significant response and connectivity of the entire system. If this rainfall is spread across more than 60 days, additional precipitation is necessary to saturate the watershed. Once tributaries are connected to the mainstem, runoff response at the Bear Valley Bridge increases dramatically.

This event is considered the first flush water quality event, delivering accumulated sediment and pollutants from land-based source areas. This runoff event often coincides with the initial upstream migration by coho salmon into the stream system. Until most of the intermittent tributaries are flowing, response in the main channel is not adequate to accommodate fish passage to most of the spawning habitat within the system.

The most significant tributaries with regard to water, habitat, and fish are the John West Fork, Quarry Gulch, Giacomini Creek, Randall Gulch, and Boundary Gulch. These tributaries provide some perennial habitat sections in the upper and middle portions of the channel, while going intermittent as the creek stretches across the alluvial valley bottom. Habitat within these streams is viable for both coho salmon and steelhead trout.

Tributaries draining Inverness Ridge are perennial, and are significant contributors to the summer base flow. In normal years the upper 30% of the Olema mainstem, lacking connection to Inverness Ridge, is intermittent. Beginning just south of five Brooks and progressing north, these steep tributaries join the mainstem. While ripe with water supply, most of these steep drainages provide little to no habitat. Where there is habitat, it primarily fits the needs of steelhead trout for both access and rearing (riffle dominated). Most significant of these watersheds are Davis/Boucher and Vedanta Creeks.

Table 1.1 Monthly Watershed Production for Olema Creek (acre-feet)

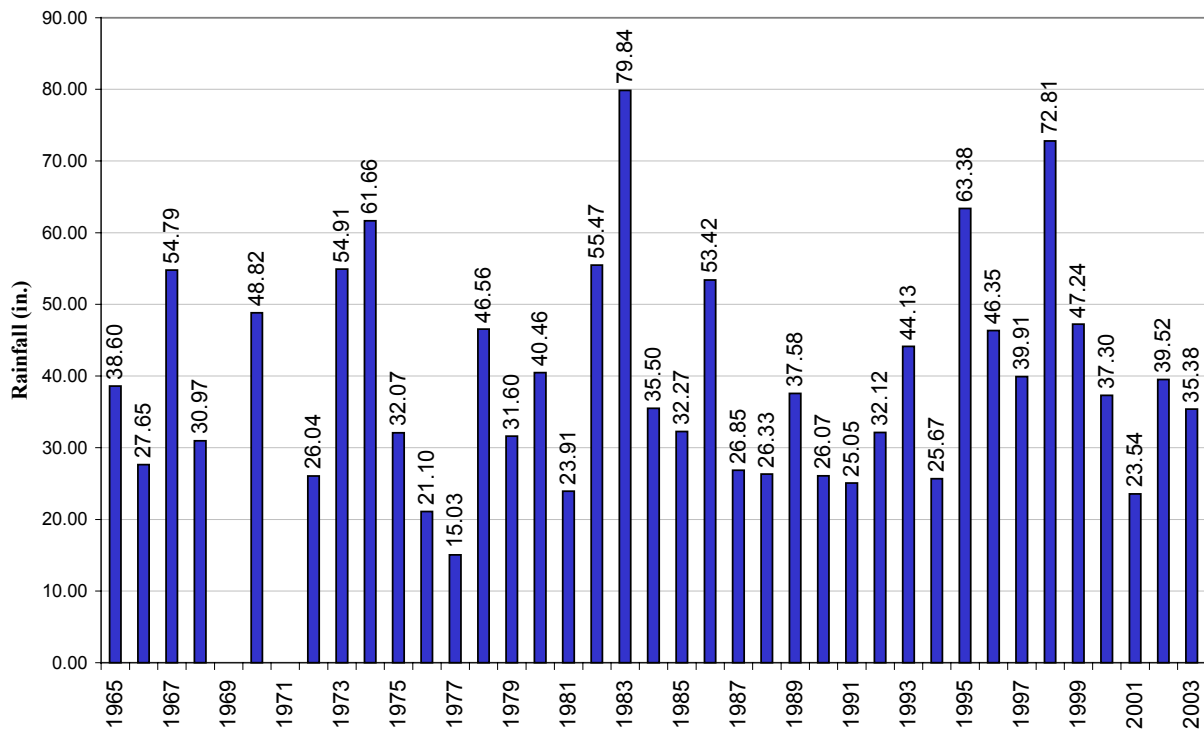
Month		WY98	WY99	WY00	WY01	WY02	WY03		Normal
-------	--	------	------	------	------	------	------	--	--------

October	69	79	83	149	198	52	105
November	1,443	572	122	109	1,290	136	612
December	1,750	1,441	115	146	6,326	7,177	2,826
January	10,346	3,236	2,321	1,845	6,277	3,996	4,670
February	20,644	6,233	6,874	4,606	2,527	1,206	7,015
March	1,915	3,481	2,286	1,204	2,000	1,006	1,982
April	1,492	1,555	831	226	425	774	884
May	737	494	468	99	186	945	488
June	456	136	136	60	121	171	180
July	183	42	77	45	81	117	91
August	95	57	48	44	74	74	65
September	51	87	72	50	45	59	61
Total	39,181	17,413	13,433	8,583	19,550	15,713	18,979
Percent Normal Discharge	206%	92%	71%	45%	103%	83%	

1.4.4 Rainfall Information

Daily rainfall totals have been recorded at the Bear Valley Headquarters since 1968. In 1997, the Seashore installed a weather station to collect and compile hourly weather information. Annual rainfall for the period 1968 to the present is 38.35 inches at Bear Valley headquarters, with approximately 95% of that occurring between November and April. Of the past 38 years, 17 have exceeded the rainfall normal.

Annual Rainfall Totals at Bear Valley, Point Reyes National Seashore



	Total	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Average	38.95	1.97	5.65	6.92	8.34	6.50	5.52	2.44	1.05	.19	.09	.13	.33

Min	15.03	1.73	4.18	4.88	5.75	5.28	4.75	1.74	1.57	.27	.41	.38	.59
Max	79.84	5.74	18.20	17.33	22.39	24.68	24.28	6.60	6.35	1.02	2.58	1.82	2.54

Table 1.2 Annual Rainfall Monthly Averages at Bear Valley, 1965-2003

1.4.5 Water Quality

Regulatory Framework and Water Quality Monitoring Efforts

Olema Creek flows into Lagunitas Creek and Tomales Bay, both of which have been identified by the San Francisco Bay Regional Water Quality Control Board (RWQCB) as impaired by nutrients, sediment, and pathogens (CRWQCB 2001). The RWQCB is required to develop TMDLs for these pollutants in accordance with Section 303(d) of the Clean Water Act. The final pathogen TMDL has been released for Tomales Bay, and includes an extensive monitoring program. Point Reyes National Seashore is conducting TMDL pathogen sampling at six sites in Olema Creek to support the Regional Water Quality Control Board (RWQCB) Tomales Bay Pathogen TMDL program. The NPS proposes monitoring at six sites for the concentrated pathogen TMDL sampling program in Olema Creek. In addition to the monthly sample regime, weekly sampling will be conducted during the wettest month of the year (one month December – March). Olema TMDL pathogen sampling sites have been identified in order to represent pathogen source and transport through the watershed. The standardized monitoring frequency on Olema Creek has improved our understanding of both temporal and spatial watershed process and response to different land uses. Olema Creek monitoring represents a variety of land uses including livestock grazing, development, and wilderness.

In 2004, the NPS expanded the TMDL monitoring plan to include two additional sites within the Olema Creek watershed (NPS 2004) as a reasonable and prudent measure necessary to monitor incidental take of listed salmonids within the watershed (NOAA Fisheries – in draft 2004). Within Olema Creek, the grazing/TMDL monitoring plan includes monthly sampling at 8 locations within the watershed. For one month in the winter samples will be collected on a weekly basis to determine the geometric mean of the monitored water quality parameters. One of the major constituents for monitoring is suspended sediment and turbidity. Collection of this information applies directly to the sub-lethal and potentially lethal effects of sediment to fish.

Point Reyes National Seashore Water Quality Monitoring Program

Since 1999, water quality sampling has been conducted on more than 28 sites within the Seashore. The intent of this threats-based monitoring program was to identify source areas, and address problems at the watershed or sub-watershed scale. Data collected between 1999 and 2001 are reported in the Point Reyes National Seashore Water Quality Monitoring Report (NPS 2001a). The Seashore sampling program currently conducts quarterly sampling, plus collection of the first flush event. Standardization of the sampling regime from storm-event based, to a quarterly basis has reduced the loading bias observed in the first two years of data and shows results representative of all seasons.

Results from ongoing quarterly monitoring indicate pathogen loading associated with nonpoint source winter runoff is high throughout the pastoral zone. Summer pathogen levels are far lower, as most perennial riparian areas are excluded from direct livestock access. Potential pollutant sources in the monitoring watersheds include horse and cattle manure, contamination from septic systems, and “natural” (wild) sources (namely warm-blooded animals).

Olema Creek Turbidity Threshold Sampling Program

Turbidity Threshold Sampling (TTS) involves methodology and instrumentation developed by the U.S. Forest Service Redwood Sciences Laboratory. TTS operates with an OBS3 sensor calibrated to measure turbidity. Point samples are collected at turbidity thresholds with an Isco sampler integrated into the system. The data resulting from TTS can be used to determine suspended sediment loads by establishing a relationship between sediment concentration and turbidity. In December 2002, the TTS unit was installed at the Olema Creek stream gauge at the Bear Valley Road Bridge (near the park headquarters). The TTS unit and associated data will improve our understanding of watershed sediment response and duration.

2.0 METHODS

This program includes strategies to monitor salmonids at a variety of life stages. Methods for adult spawner surveys, outmigrant smolt trapping, summer juvenile index reach surveys, and a modified Hankin-Reeves coho juvenile population estimate are documented in the draft San Francisco Area Network Stream Aquatic Resource Monitoring Protocol (NPS 2003b). These methods have been used by the National Park Service (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).

2.1 *Adult Escapement Surveys*

Beginning in the winter of 1997-98, the CSRP conducted spawner surveys in portions of the Lagunitas, Olema, and Redwood Creek watersheds. NPS staff and volunteers counted redds, live fish, and carcasses in an attempt to better understand trends in adult coho salmon abundance and distribution.

2.1.1 Adult Escapement Monitoring Objectives & Questions

Monitoring Objectives

1. to develop an index and/or total escapement estimate of adult coho salmon for the analysis of long-term population trends;
2. to determine the distribution of spawning activity by collecting georeferenced redd location data;
3. to determine population characteristics of coho adults including fish size, age, sex and redd size; and
4. to collect tissue and scale samples for genetic and age analysis by National Marine Fisheries Service Genetics Laboratory in Santa Cruz, CA.

Monitoring Questions

1. What is the distribution of spawning coho salmon within Olema Creek?
2. Can the NPS develop and use methods to estimate escapement using redd number and size information?
3. What are the long term trends associated with populations of coho salmon in coastal Marin County watersheds?

2.1.2 Field Methods

The methodology used in these protocols 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 the watershed, the studies have focused on coho because their spawning behavior and timing are more amenable to accurate data collection.. Coho spawner survey data tends to be more accurate than steelhead information because:

1. coho spawn earlier than steelhead, when flows and water turbidity tend to be lower, which makes live fish and redds easier to observe;
2. unlike steelhead, all coho inevitably die after spawning which makes carcasses readily collectible;
3. steelhead spawn over a longer period than coho, from January to May, which makes the frequent collection of data more difficult.

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, occasional steelhead spawners and redds are observed and counted incidental to coho observations. Surveys are spaced approximately every two weeks,

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. 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 are used to generate index values and minimum population estimates for the assessment of long term trends. A more detailed description of the survey procedure and monument tags can be found in San Francisco Area Network Stream Aquatic Resource Monitoring Protocol (NPS 2003b).

Environmental conditions are also monitored throughout the spawning season. Before beginning each survey, observers noted weather conditions and measured water clarity using a graduated rod. Rainfall data was logged continuously from tipping bucket gages at two locations along Olema Creek (Bear Valley and Hagmaiers Ranch). Stream stage was monitored continuously by pressure transducers at the Bear Valley Bridge on Olema Creek.

On the mainstem of Olema Creek spawner surveys are conducted along a 17.6 km section beginning approximately 1.0 km above the confluence with Lagunitas Creek and ending at the Hwy 1 culvert at milepost 19.94. The section is divided into seven survey reaches to facilitate sampling. These seven reaches were adopted from volunteer based surveys between 1994 and 1997. Reaches were chosen based on access, length, and the existence of permanent landmarks for reach boundaries (Figure 2.1). The existing seven reaches extend from:

1. one kilometer above the confluence with Lagunitas Creek to the Bear Valley Road Bridge in the town of Olema (1.6 km);
2. The Bear Valley Bridge to the confluence with Truttman Creek (3.2 km);
3. Truttman Creek to the horse trail crossing at the Stewart Ranch (2.6 km). Note; the storms of 1997-98 washed out the trail crossing;
4. Stewart Ranch to the first Hwy. 1 bridge at Five Brooks (1.3 km);
5. Five Brooks to the abandoned Lime Kilns (2.8 km);
6. The Lime Kilns to the abandoned Randall ranch house (1.7 km);
7. The Randall House to the Hwy. 1 culvert at milepost 19.94 (4.1 km);

In addition to the mainstem of Olema Creek, surveys are often conducted on six 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. For each tributary, survey reaches start at the mouth and generally continue upstream as long as no passage barriers exist. Surveys on the John West Fork of Olema Creek are repeated most often. Results are used by staff as an indicator of activity in the mainstem when flow conditions do not allow for regular surveys. Surveys on the John West Fork extend approximately 2.2 kilometers upstream from the confluence with Olema Creek.

2.1.3 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. 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). 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. While the PLD index produces a minimum instantaneous estimate, the AUC method is used to calculate a total population estimate. The PLD index is computed as the name suggests. The peak number of live fish observed during a single day of the spawning season is added to the cumulative number of unmarked carcasses observed prior to that date. 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). 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. Because we did not estimate residence time, separate AUC estimates were computed using the range of values, 8 to 17 days, presented in the literature (Moring and Lantz 1975; Johnston et al. 1987; Irvine et al. 1992). 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.

Because the necessary conditions for accurate AUC estimates are not always met, we also quantified spawning runs using the Peak Live + Cumulative Dead (PLD) index. This 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. Redd count and location is used to describe spawning density and spatial distribution.

2.1.4 Other Monitoring Programs

NPS conducts escapement monitoring on Pine Gulch 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

The NPS has conducted smolt trapping using the pipe trap method on the John West Fork since 1998. The intent of this trapping was to document production from this tributary, at a location upstream of an impediment to fish passage at State Route 1. Trapping was also conducted on two additional tributaries in 1999. In 2004 the NPS has also initiated trapping at the lower end of Olema Creek near the confluence with Lagunitas Creek.

Performed in conjunction with winter spawner surveys and summer juvenile surveys, the spring outmigrant surveys permit an evaluation of abundance during three of five distinct freshwater salmonid life stages. A significant body of literature has documented 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 the different freshwater life stages. At the time they smolt, coho have spent more than 14 months in the watershed, while steelhead can be 1-4 years old. Smolt production, therefore, is the best aggregate measure of watershed condition and productivity. The response of coho and steelhead populations to changes in habitat quality can not be properly assessed without a measure of smolt production.

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 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 focused in the Pacific Northwest. The habitat and climate supporting salmonids in this area have not been well studied, meaning that local adaptations by these species are not well understood. 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. Although smolt trapping is focused on salmonids, it also provides presence absence information and size data for other aquatic species during periods not covered by summer/fall monitoring activities.

Aside from the large scale benefits associated with the trapping program, results associated with trapping on the John West Fork have allowed the program to quantify dates of fry emergence and rates of growth through the spring season. Through smolt trapping, the NPS has documented downstream movement of both smolts and fry in the spring season as flow in this intermittent tributary recedes. Our monitoring has documented anywhere from 1,000 to 6,000 fry heading downstream from the spawning grounds, towards more perennial flow and suitable summer habitat

Smolt trapping on the John West Fork has also shown a dramatic response in smolt productivity in response to adult passage improvements through the State Route 1 culvert. The information that is being developed around the Pine Gulch Creek watershed shows how this information can be used to characterize overall watershed condition and survival through the winter season

Data collected through smolt trapping also has direct management utility. An understanding of the environmental factors and dates that result in cessation of downstream smolt movement may be used to determine instream construction windows that would not impair movement of smolts.

2.2.1 Monitoring Objectives and Questions

Monitoring Objectives

1. Estimate coho and steelhead smolt yields,
2. Determine length and weight characteristics of coho and steelhead smolt, presmolt, and parr populations,
3. assess juvenile overwinter survival rates, and
4. Measure environmental factors thought to govern outmigration of fish.

Monitoring questions

1. What is the aggregate watershed productivity for coho salmon?
2. How does smolt productivity relate to associated adult spawner counts for the year class?
3. What are estimated winter survival rates for juvenile salmonids within the west Marin County watersheds, as measured through comparison with summer surveys?
4. What is the ocean survival and return, as related to watershed smolt production?
5. Are measured environmental factors linked to patterns in downstream migration and are they consistent with scientific literature?
6. How does smolt condition compare between fish from perennial vs intermittent streams?

2.2.2 Field Methods

The pipe-style 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. The pipe trap is designed to minimize impingement under high flows and in-trap predation of fry by larger juvenile salmonids and other fish. The trap is installed in mid-March and removed at the end of May. The pipe-style trap operates by impounding water behind a weir constructed of 1/2 inch mesh hardware cloth, fence posts, rocks, and sand bags that span the entire width of the stream. Flow is directed into a series of 8-inch diameter, 20 ft. long PVC pipes. To decrease water velocity, the pipe empties onto a slanted, perforated metal ramp. The ramp is connected to a 125 x 74 x 50 centimeter live box constructed of plywood and 1/8 inch mesh hardware cloth. The live box is situated in a shaded pool, and contains rocks, vegetation, and a 1/2 inch mesh divider screen to provide a refugium for fry. In addition, the weir contains several vents that allow any late spawning adult steelhead to migrate upstream unimpeded during higher flows.

The trap is checked daily and all captured fish are processed and released.... All 1+ salmonids are anesthetized using Alkaseltzer™. The fork length is measured to the nearest mm, and fish are weighed to the nearest 0.1 gram. Anesthetized fish are allowed to recover fully in an aerated “recovery bucket” before release. Fry are identified to species, counted, and a subsample measured. The trap targets salmonid smolts, parr, and fry but the numbers and lengths of all captured species are recorded

Environmental conditions are also noted, including stream water level, weather, and instantaneous water temperature. For more detailed data on the water temperature regime, a temperature logger (Onset Optic Stowaway) is deployed and left in the trap box for the duration of operation

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 1983-1985 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). Peak outmigration within Olema Creek occurs mid-April into early May.

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. Twice-daily trap visits on Lagunitas Creek were abandoned because few or no fish were captured between the morning and afternoon (Bratovich and Kelley 1988). We have observed similar trends, with most movement into the traps occurring at night. Under high flow events, the trap is checked frequently during the day to remove accumulated debris within the trap and at the weir.

2.2.3 Analysis

Information produced through this program will include weekly and daily totals of fish captured, including smolts, other age 1+ juveniles, and young of year. Weight-length relationships for smolts and other age 1+coho salmon and steelhead may also be reported.

In addition, tissue and scale samples are collected from a subsample of fish moving through the smolt trap during each year. This will allow for further genetic analysis of central California coast salmonids, as well as age-length relationships and determination of smolt age for both coho and steelhead.

Within the monitored watersheds, this technique is intended to estimate the number of smolts leaving the watershed. 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 can be used to describe the differing conditions and populations of each year class.

2.3 Index Reach Surveys

Index reach surveys will include both fish sampling and detailed habitat assessments, including habitat unit size, substrate, instream shelter, and riparian condition. The results of the index reach surveys provide baseline fish distribution information and abundance/density estimates. It is likely that juvenile salmonid year class abundance will vary 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 also may provide information on the overwintering success of different year classes.

The limitations of index reach surveys are well known. Sample site selection is not systematic, sample size is small relative to the overall number of habitat units, and distribution of fish throughout stream reaches is not necessarily consistent. The fish and habitat parameters collected via index reach surveys can be very accurate for the sampled area, but are not necessarily applicable to the rest of the stream or watershed. Although total fish population may be extrapolated from density estimates within index reaches, it is not possible to determine the statistical accuracy of such extrapolated estimates (Dollof et al 1993).

When a statistically accurate estimate of stream habitat or population of a particular fish species is needed for a broader area or an entire stream, basinwide survey techniques developed by Hankin and Reeves (Dollof et al 1993) will also be used. The results of such surveys yield estimates of total stream habitat surface area and total fish population size and will include calculated statistical error. Since basinwide surveys involve a two stage sampling design using both snorkeling and electrofishing, and the index reach surveys use primarily electrofishing, we attempted to reduce sampling effort by using the index reaches for the electrofishing portion of the basinwide surveys.

2.3.1 Rationale for Sampling Design

Salmonid monitoring has occurred in Marin County streams for several decades, and most of the past and current juvenile sampling efforts have utilized some variant of index reach methodology. MMWD and Dr. Jerry Smith of SJSU have monitored index reaches on the Lagunitas and Redwood Creek watersheds, respectively, for a decade or more. GOGA and CSRP staff have sampled index reaches on various NPS watersheds since the late 1990's. Continuing these methods will allow comparison of data with an established long term dataset on abundance, density, and distribution of juvenile salmonid and other fish within Marin County streams.

By focusing intensive sampling over small portions of the creek, index reach monitoring allows for collection of detailed fish and habitat information when personnel, budget, and time are limited. Overall species composition and biomass can be assessed since all species present in a selected reach can be effectively sampled, particularly when electrofishing. Length and weight measurements of individual fish, as well as scale and tissue samples, can also be easily collected. Since a small area is being sampled, transporting the additional equipment associated with more intensive sampling is minimized.

The advantages of basinwide surveys are well established (Dollof et al 1993). Combining the two allows for both the intensive sampling data derived from the index reach surveys and the extensive sampling and statistically valid population estimates of basinwide surveys, and eliminate the additional electrofishing that would be needed if both were conducted independently. This is especially important when dealing with the permitting issues associated with sampling ESA listed salmonids.

This sampling design is consistent with the three-tiered approach outlined by Moyle et al (1998) for assessing fish condition. Under this approach "good condition" is defined as "healthy individual fish in healthy populations that [are] part of healthy biotic communities". The length and weight measurements collected in the index reach surveys allow us to assess relative health of individual fish. Index reach abundance/density indices and basinwide survey population estimates provide a means to track the population of each species. And the range of species sampled in index reach surveys indicates the composition and relative condition of the overall fish community.

2.3.2 Monitoring Objectives and questions

Monitoring Objectives

1. Conduct monitoring to sample general fish population parameters and minimize impact on fish (handling and harassment) in a manner that allows for collection of repeatable and robust data.
2. Describe stream habitat condition and trends
3. Evaluate abundance, distribution, and biomass of juvenile salmonids and co-occurring fish against baseline information in order to document significant changes within and between watersheds over time;
4. Establish baseline information on fish age structure, condition, and population in order to document significant changes within and between watersheds over time;
5. Evaluate fish utilization of various habitat types;
6. Evaluate effectiveness of management actions on habitat conditions and fish populations.
7. Contribute to salmonid monitoring, restoration, research, and recovery planning at the local and regional levels.

Monitoring Questions

1. What is the distribution and density of salmonids and other fish species within the monitored watersheds?
2. How does observed fish density in Olema Creek (namely coho juvenile density) compare with densities in other watersheds within coastal Marin County and the CCCESU?

3. How do salmonids and other fish use different stream habitat?
4. What are survival strategies and success in intermittent tributaries?
5. What sort of biomass production do fish species (salmonid and non-salmonid) represent within the watershed?

2.3.3 Site Location and Field Methods

Index reaches are situated at somewhat regular intervals throughout the mainstem of each creek, and generally correspond to stream reaches determined by Rosgen channel type, land use patterns, other habitat characteristics, and professional judgement and knowledge of the watersheds. Where possible, water quality and aquatic invertebrate monitoring sites coincide with the location of the index reaches. The composition of habitat types within the index reaches is intended to reflect the overall habitat conditions of the stream segments they represent, as determined by the habitat typing surveys that have been completed for each watershed. Using similar criteria, tributary index reaches are situated upstream, downstream, and in some cases within restoration sites.

Olema Creek Mainstem

Eight index sites were established in 1999 and 2000 within the mainstem of Olema Creek for long-term annual monitoring of juvenile salmonids and other fish (Figure 2.2). Additional index reaches are located on the John West Fork and Quarry Gulch, two tributaries with planned or completed restoration projects.

Table __. Olema Creek Rosgen Stream Reach and Index Section Locations.

Rosgen Stream Reach Number	Rosgen Stream Type	Stream kms.	Location Description	Index Section (Section Name, km)
1	Da	0-2.3	Confluence w/ Lagunitas Creek to Single Channel at Monument 23	1 (Lower Stewart's, 1.2 km)
2	B	2.3-3.2	Single channel to tributary at Olema Ranch Campground	
3	F	3.2-9.6	OL-21 to Horse Camp Creek	2 (Vedanta, 3.7), 3 (Quarry/Upper Stewart's, 4.9), 4 (Truttman 6.2), 5 (Shook's, 7.6)
4	B	9.7-11.9	Horse Camp Creek to tributary OL-07	6 (Horse Camp 9.4), 7 (Five Brooks 10.8)
5	F	11.9-15.0	OL-07 to Randall Gulch	8 (Lime Kilns 13.0)
6	C	15.0-16.2	Randall Gulch to South Hagmaier	Dry
7	E/C	16.3-17.4	South Hagmaier to Hwy. 1	Dry

Each index reach consists of a 30-100 meter reach, containing from three to ten contiguous habitat units, which are identified and sampled individually. Habitat units are isolated with seine nets and electrofished separately using standard multiple pass depletion methods. Most riffle units are sampled with a single pass. Captured fish are sedated using carbon dioxide (Alka Seltzer™), identified to species and age class, measured, and weighed. Some individuals are handled to collect fin clips or scale samples for age and/or genetic analysis. Fish are kept in aerated holding buckets before and after handling, and allowed to recover fully before being released.

Habitat measurements and assessments are made for the index reaches after fish sampling is completed. The length, average width and depth, substrate composition, and instream shelter complexity (Flosi et. al. 1998) are quantified in each habitat unit. Transects are set up across each habitat unit and depth and substrate type recorded at points along the transects. Instream shelter complexity values are estimated for pool and flatwater units. Additional habitat parameters including bank erosion, riparian cover, and woody debris are then determined for the index site as a whole. Ideally the habitat portion of index reach monitoring will be completed the same day as fish sampling, but may be conducted up to two weeks afterwards if necessary as long as habitat conditions do not change significantly.

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 also measured and recorded.

2.3.4 Data Analysis

For habitat units sampled by multiple pass electrofishing, fish population estimates and confidence intervals for each species/age class are generated by *Microfish* (VanDeventer and Platts 1989) using the maximum likelihood model. 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. Confidence intervals for each habitat unit were established by developing a correlation between estimated population and standard error for the habitat units where multiple electrofishing passes and estimates were completed. Though we anticipated separate correlation values by year, the available data resulted in correlation equations for each salmonid species and age class from the watershed. The correlation was derived based on sampling results collected between 1999 and 2003. This resulted in development of a 95% confidence interval population estimate for each habitat unit. Population estimate and 95% CI for each index reach presented in Section 3 are derived from adding each individual result (95%CI low, population estimate, and 95%CI high). The density calculations for each index reach including fish per meter and fish per square meter are derived from the summary index results, and not an average of each habitat unit.

Biotic condition results are also reported including the weight-length power curve relationship for both salmonid species evaluated, as well as the Fulton Condition factor. The power curve relationship (below) is reported for each species and each index reach with an r^2 value where W=weight, FL=fish fork length, a=derived coefficient, and b=power relationship.

$$W=aFL^b$$

Fish condition can be assessed using Fulton's condition factor as well as weight-length power function (Anderson and Gutreuter 1983). Fulton's condition factor (K) is represented by:

$$K = \frac{Weight \ (g)}{Length \ (mm)^3} \times 100,000$$

and will be calculated automatically by the database for all fish with both length and weight. Mean K can then be calculated for each species/age class within a reach or habitat type. Typically, "plumper" fish have higher K and b values than "skinny" fish.

Standing biomass for each habitat unit is calculated by extrapolating the mean weight per individual (from weighed individuals of each species/age class) to the population estimate for each species/age class. Biomass estimates for the salmonid components of the sample are reported as information within the document.

Complete field methods are documented in SOP 1 of the draft San Francisco Area Network Stream Aquatic Resource Monitoring Protocol (NPS 2003b).

2.4 Hankin Reeves Population Estimates

2.4.1 1999 Juvenile Fish Abundance, Distribution, and Mortality in Isolated Pools

During August 1999 a Hankin-Reeves type Basinwide Visual Estimation Technique (BVET) (Dolloff, et. al. 1993) survey was employed on the upstream isolated pool reach of Olema Creek between the mainstem confluences of John West Fork and Randall Gulch (11.8-15.0 km) in order to better understand the contribution of isolated pools to the overall carrying capacity of Olema Creek. The survey was repeated in the last week of October 1999 in order to assess the change in available fish habitat and survival/growth of threatened salmonids in isolated pools.

Specific objectives of the 1999 fish abundance and distribution survey in isolated pool habitats in upper Olema Creek were to:

- Evaluate fish species composition, abundance, and distribution;
- document changes in available juvenile rearing habitat during periods of low flow;
- estimate survival and growth rates of juvenile salmonids in intermittent pool habitat; and
- assess the value of isolated pool habitats to overall salmonid populations.

2.4.2 2003 Summer Mainstem Coho Population Estimate

In summer 2003, through DFG grant monitoring support, the NPS conducted a basinwide snorkel estimate (Dolloff et. al. 1993) on Olema Creek for the first time. This increased level of monitoring effort is intended to match the ongoing efforts in Pine Gulch Creek, and allow for comparison of the index reach monitoring information collected in the watershed since 1999.

The summer 2003 habitat survey covered 9.2 kilometers of Olema Creek, from the Olema Ranch Campground to stream km 11.5. The snorkel surveys covered approximately 7.8 km of the mainstem starting at stream km 3.7, located at the Vedanta Bridge, and continuing upstream to stream km 11.5, the Five Brooks horse pasture. This represents most of the perennial mainstem habitat for Olema Creek.

Specific objectives of the 2003 coho population estimate within the mainstem of Olema Creek were to:

- Evaluate distribution and density of juvenile coho salmon within Olema Creek for comparison with similar work conducted on Pine Gulch Creek;
- Estimate a population of coho salmon for comparison with Lagunitas Creek (MMWD 2003) and Pine Gulch Creek (Ketcham and Brown 2003) reported information;
- Compare results of population estimates derived using the Hankin-Reeves method with extrapolated estimates from index reach surveys (See Section 2.5); and
- Determine juvenile coho population to evaluate against smolt production within the watershed.

Snorkel surveys in the area around the town of Olema were avoided because upon water quality conditions did not meet contact recreational use standards near the time of survey. This water quality monitoring information has been collected as part of the TMDL monitoring process in collaboration with the Regional Water Quality Control Board.

Habitat Typing

Starting at the bottom of the coho survey area and working upstream, project staff number, classify, measure the length, and estimate the average width of each habitat unit. Units are classified as pool (scour pool, backwater pool, plunge pool, or mid-channel pool), flatwater, or riffle. The width of each habitat unit is estimated visually. Every fifth pool unit is flagged for snorkeling and several measured widths are taken for the purpose of calibrating the estimated width.

Snorkel Counts

Project staff surveyed each of the previously determined pools with one or more snorkel passes, 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. The number of divers in the water varied from 1 to 3, depending on the width and complexity of the unit. Strategies were used to divide the fish between the divers and filter them in such a way that the divers could be confident of their counts. This represents a more comprehensive effort than in years past, when only one diver was in the water at a time.

Pools from all index reaches within the survey area were also included in the snorkel surveys. These pools were electrofished the day after each snorkel survey. Calibration for the snorkel surveys is normally conducted using electrofishing results. However, the numbers of coho seen during this year's snorkel surveys were consistently higher than the number of coho caught while electrofishing the same pools. Data gathered over the summer will be analyzed to determine whether the snorkel counts represent the more accurate number of coho for the pools surveyed.

2.5 Genetic Analysis

Tissue samples have been collected for genetic analysis by the NOAA - Fisheries Genetics Lab in Santa Cruz, California. Sample collection follows NOAA - Fisheries protocol and is performed as part of the Section 10 permit 1046. Samples are collected mostly from adult carcasses and smolts, though samples from some young of year salmon have been collected.

The genetics of coho salmon within the CCCESU have become more well-defined in the past year in association with the completion of analysis of coho salmon genetic samples from across the state of California (Hedgecock et. al. 2002). In conjunction with the Russian River Broodstock Reintroduction Program, the NOAA-Fisheries Genetics Lab has conducted extensive genetic characterization on samples from more than 300 fish per year for development of a spawning matrix (Garza and Gilbert-Horvath 2003).

2.6 Data Management

Analytical techniques for each of the monitoring program components are described in the sections above. Field data are currently recorded on survey specific sheets, and entered and stored in a Microsoft Access database. Staff is working to reconfigure our database to meet design standards recommended through the NPS Inventory and Monitoring Program.

Other NPS programs are beginning to employ handheld PDA units in the field, allowing for direct entry of data into the database. The NPS fisheries program will explore the feasibility and utility of these units for field based data entry beginning in summer 2004.

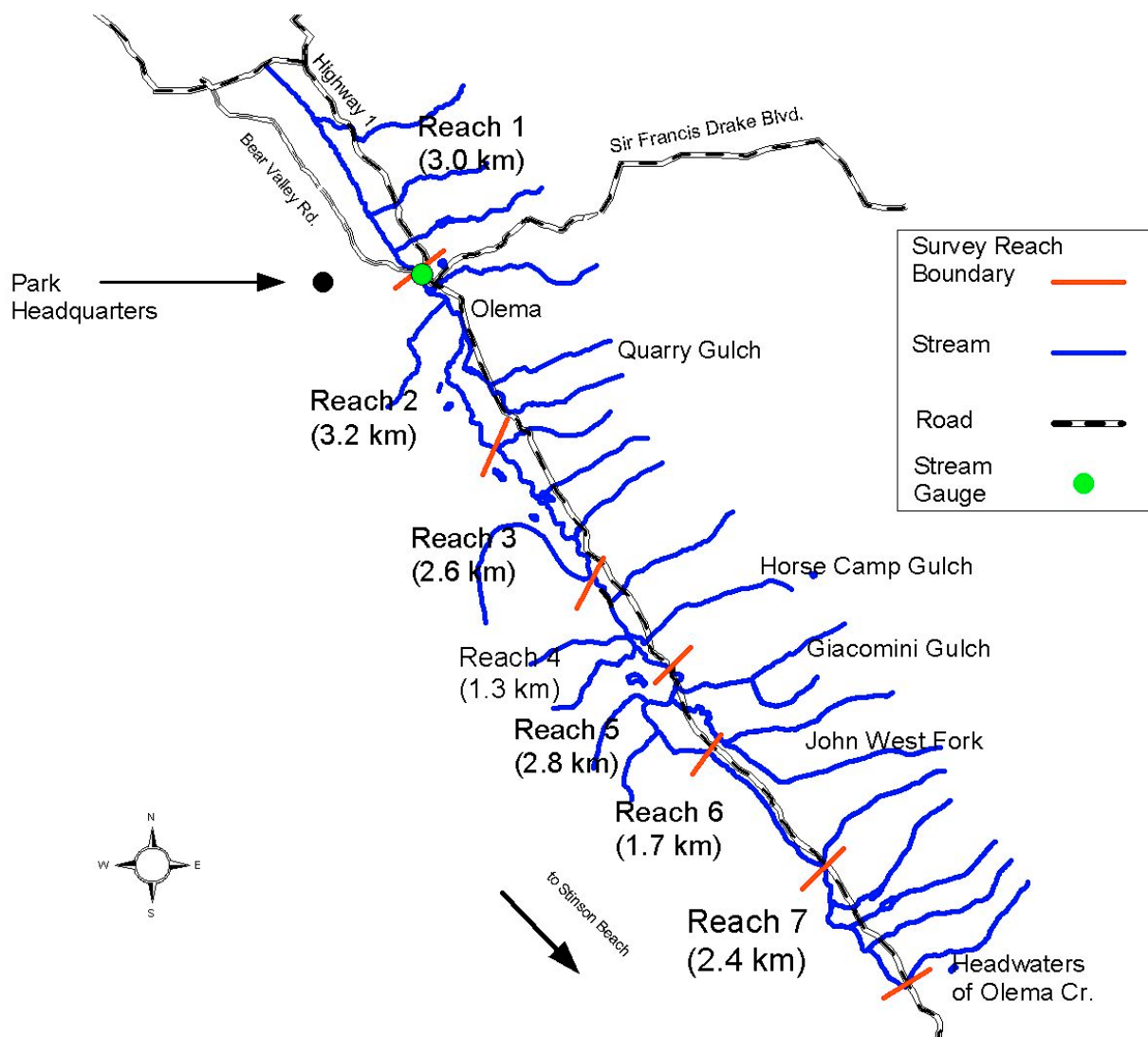


Figure 2.1 Olema Creek Winter Adult Escapement Survey Reach Map



Figure 2.2 Olema Creek Index Reach Location Map

3.0 RESULTS

3.1 Adult Escapement Surveys

Efforts dating back to the mid-1980s by the Tomales Bay Association (TBA) documented coho salmon spawning in Olema Creek, though comprehensive surveys were not initiated until the winter of 1994-95. Spawner surveys were led by the TBA between 1994 and 1996. Beginning in 1997, monitoring efforts have been coordinated by National Park Service fisheries staff. A comprehensive report of adult escapement information for west Marin County watersheds was compiled in 1999 by David Manning of the NPS (Manning 1999). The results of all NPS monitoring, 1998-99 through 2003-2004 are reported in the Olema Creek Annual Adult Escapement Report (Appendix A).

3.1.1 Survey Timing and Environmental Conditions

Review of the seven years of escapement monitoring information on Olema Creek shows that run timing is highly dependent on the rainfall-runoff condition within the watershed (table 3.1). Unlike Lagunitas Creek, Olema Creek is an unregulated stream. This makes conditions 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 2 weeks), though the NPS program has documented some individuals spending up to 20 days in the freshwater under ideal conditions.

Table 3.1 Monthly environmental and physical factors monitored in Olema Creek for spawner years 1997-98 through 2003-04.

Spawner Year	Total Rainfall (in)				Mean Daily Discharge (cfs)				Max Daily Discharge (cfs)			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
1997-1998	10.32	3.47	16.49	24.68	24.2	28.5	168.7	372.6	207.6	93.5	663	1339.6
1998-1999	7.48	2.21	7.66	15.61	9.6	23.5	52.8	98.2	140	132	218	311
1999-2000	5.2	0.99	7.15	12.77	2.1	1.9	37.8	120	4.5	3.7	278	777
2000-2001	1.54	1.31	6.45	8.07	1.8	2.4	30.1	83.1	2.6	4	193.4	423.1
2001-2002	9.81	15.03	5.08	3.55	21.7	103.1	103.5	45.4	169.4	373.7	840.2	165.3
2002-2003	3.3	17.33	3.75	2.34	2.3	117	65.1	21.8	5.4	383.9	177.3	110.3
2003-2004	2.71	12.14	5.13	7.68	1.9	109.1	N/a	N/a	2.9	1018.3	N/a	N/a

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 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. Even when the early entry opportunity has occurred in November, few coho have been observed. For the most part, peak of spawning 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. Table 3.2 shows the approximate entry and spawning window monitored for coho salmon between spawner year (SY) 1997-98 and SY 2003-04.

Conditions where Olema Creek run timing was far different than that observed in Lagunitas Creek occurred in 1999-2000 and 2000-2001, where Olema entry flow was delayed by 2 months, and in 2002-2003 and 2003-2004, where Olema entry flows were delayed by one month. Surveys indicated that coho did indeed wait to enter the watershed, and that once in the stream, spawning occurred almost immediately. This behavior has raised an important question regarding how populations maintain themselves in a watershed with regulated and unregulated channels. The escapement and timing within the unregulated Olema Creek watershed may be affected negatively by outside influences. Under State Water Resources Control Board Order 95-17, the Marin Municipal Water District is required to release winter attraction flows (>25 cfs for three days) through Lagunitas Creek prior to December 1 each year. Such releases in a low-flow year could attract fish that would otherwise move up Olema Creek. In addition, the estuary at the mouth of Olema Creek is highly constrained by levees associated with Sir Francis Drake Blvd and the Giacomini Dairy. For fish that do remain near the mouth of Olema Creek for an attraction flow, the shallow, exposed pools may make

adult salmon susceptible to both temperature effects and predation. Each of these factors may play in to the escapement in years where natural rainfall runoff conditions are temporally distinct from the winter reservoir releases.

Table 3.2 Coho salmon run timing, average daily discharge by month, and Olema Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1997-98 through 2003-04 within the Olema Creek mainstem.

Spawner Year (SY)	Run Timing				Average Daily Discharge (cfs)				Olema Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds
1997-1998					24.2	28.5	168.7	372.6	13.4	88	39	126
1998-1999					9.6	23.5	52.8	98.2	11.6	42 ^a	13	42
1999-2000					2.1	1.9	37.8	120	7.2	9	9	10
2000-2001					1.8	2.4	30.1	83.1	11.6	103	65	86
2001-2002					21.7	103.1	103.5	45.4	11.6	90 ^c	28	58
2002-2003					2.3	117	65.1	21.8	11.6	20	17	5
2003-2004					1.9	109.1	Greg	Greg	11.6	138 ^d	34	88

Initial findings in the Lagunitas Creek watershed based on information gathered by the MMWD imply that juvenile densities are directly related to peak winter flow (inverse correlation) and redd production in tributaries (Ettlinger 2004 personal communication). This implies that in wet years, redd success and juvenile production is higher in the tributaries since redds in the mainstem are subject to scour and other impacts related to high flow conditions.

3.1.2 Watershed Escapement History and Estimates

Escapement estimates for adults in Olema Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number. The AUC method is dependent on two variables, observer efficiency (OE) and fish residence time (RT) in the freshwater following entry. In years where flows were high, both OE and RT were assumed to be lower than normal.

Annual escapement estimates for the Olema Creek watershed, including the John West Fork, show a range of 27-180 using the PLD index. Estimates using the AUC method are much higher with estimates reaching beyond 300 adults in some years. The Olema Creek escapement estimates represent 20-40% of the total escapement estimated for the Lagunitas Creek watershed.

PLD Index Results

The PLD dataset for adult escapement within Olema Creek includes 10 years of survey information. It should be noted that prior to SY 1997-98, redds and carcasses were not consistently counted. Olema Creek mainstem (Table 3.3) and the John West Fork tributary (JWF) (Table 3.4) are reported separately. PLD estimates have ranged from 9 to 174 for the mainstem and 8-58 for JWF. The John West Fork tributary has been the focus of extensive restoration and monitoring, and is often used as the proxy of conditions in the mainstem. In the SY 1999-00 and SY 2002-03, PLD estimates and live fish observations on the 2 kilometer survey area of JWF exceeded those of the 13 kilometer mainstem. Due to poor survey conditions in the Olema mainstem during these years, the results of SY 1999-00 and SY 2002-03 are not considered representative of actual mainstem escapement.

Table 3.3. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Olema Creek mainstem.

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1994/95	3	13.4	53	1	9	Tomales Bay Association (TBA)
1995/96	2	13.4	106	37	n.a.	Manning 1999
1996/97	2	15.6	174	16	n.a.	Manning 1999
1997/98	8	13.4	88	39	126	Manning 1999
1998/99	6	11.6	42 ^a	13	42	NPS-PRNS
1999/00 ^b	2	7.2	9	9	10	NPS-PRNS
2000/01	4	11.6	103	65	86	NPS-PRNS
2001/02	4	11.6	90 ^c	28	58	NPS-PRNS
2002/03 ^b	4	11.6	20	17	5	NPS-PRNS
2003/04	6	11.6	138 ^d	34	88	NPS-PRNS

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

n.a. = not available.

Table 3.4. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the John West Fork of Olema Creek

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1995/96	NA	<1.0	8 ^a	NA	NA	NPS-PRNS
1996/97	NA	NA	NA	NA	NA	NPS-PRNS
1997/98	5	1.3	12	0	7	NPS-PRNS
1998/99	2	1.2	9	0	1	NPS-PRNS
1999/00 ^b	3	1.1	18	0	7	NPS-PRNS
2000/01	4	1.9	58	30	48	NPS-PRNS
2001/02	6	1.9	20	5	31	NPS-PRNS
2002/03	7	1.3	27 ^c	0	12	NPS-PRNS
2003/04	6	2.4	41	7	21	NPS-PRNS

a/ Includes live fish only, no carcass data.

b/ Surveys missed peak numbers.

c/ Includes two peaks, 4 weeks apart

NA = not available.

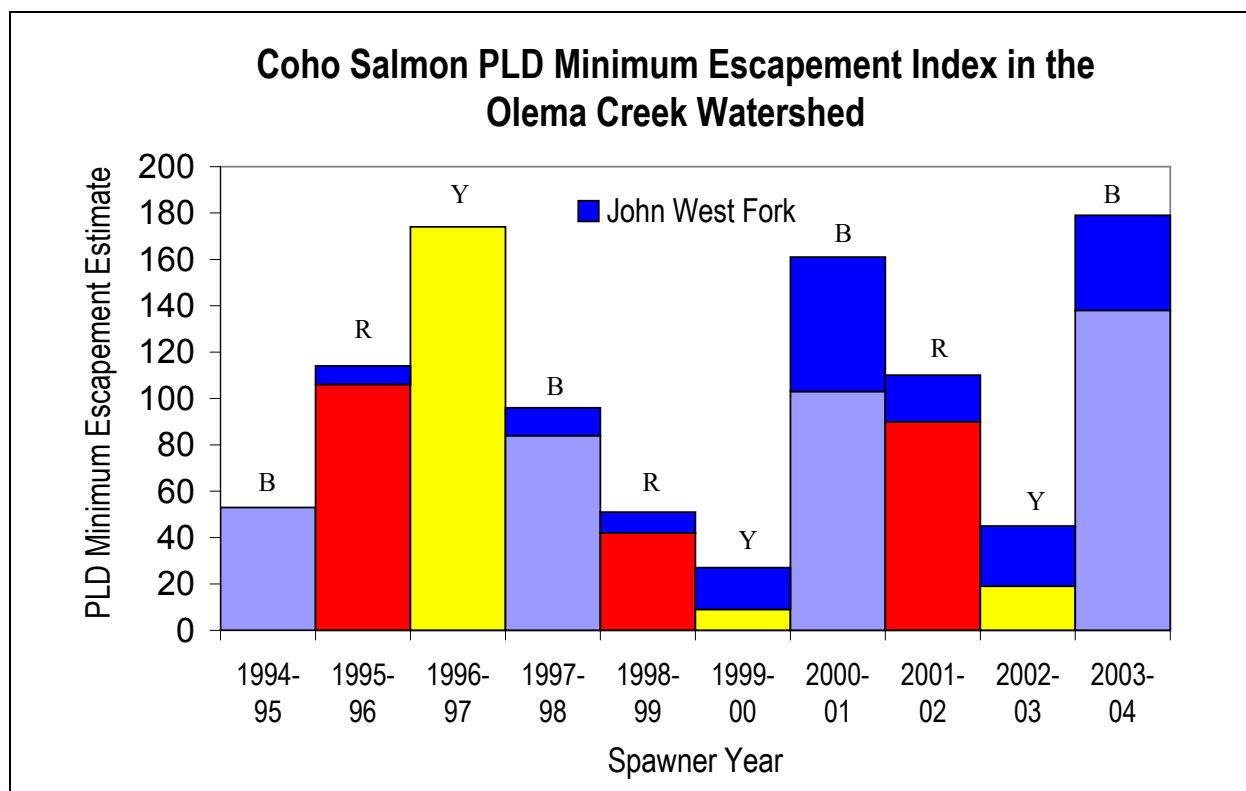


Figure 3.1 Olema Creek & John West Fork Coho Salmon PLD Index Escapement results winter 1994-1995 through winter 2003-2004.

Overall trends in the PLD indices for coho in the Olema watershed are shown in figure 3.1. The three year classes are represented as primary colors (blue-B, red-R, and yellow-Y) to show relationships between spawning runs. The blue year class shows an increasing trend in PLD over the last four generations. The other strong year class, red, rebounded to past levels, while the yellow year class may be starting to recover after a dramatic decline between the 1996-97 and 1999-2000 runs.

Escapement Estimate

The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Olema Creek (Table 3.5) and the John West Fork (Table 3.6). 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. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique. Detailed results of the AUC estimates are included in the Olema Creek Annual Escapement Monitoring Report.

Summary AUC results for Olema Creek and the John West Fork are presented in tables 3.5 and 3.6, respectively. AUC estimates are reported for a range (8-17 days) of fish residence time (RT) at 100%¹ and 50%² observer efficiency (OE), where the low estimate represents 17 day survival, and the high estimate represents 8 day survival. Estimates using commonly reported values for OE (70-80%) and RT (11-13 days) are compared to locally observed conditions in years where environmental factors reduced/increased average RT or allowed for high/low OE for that specific survey year. The PLD index for each year is included for reference.

Table 3.5. Coho salmon spawning survey Area Under the Curve (AUC) estimates for Olema Creek, 1997-98 through 2003-04.

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Reaches	Survey Area (km)	AUC Range 100% OE ¹	AUC Range 50% OE ²	AUC Range for OE & RT reported in literature	AUC for locally observed conditions	OLM Mainstem PLD
1997/98	7	15 Nov 97	7.9	2-4	4.5	56-118	112-236	91-123	Same	88
1998/99	5	19 Nov 98	12.1	2-6	11.6	35-74	69-148	57-77	Same	42 ^d
1999/00	NA	18 Jan 00								9
2000/01	2	10 Jan 01	7.3	2-6	11.6	75-159	149-317	122-165	101-132 ^a	103
2001/02	3	24 Nov 01	12.3	2-6	11.6	105-224	210-447	172-232	186-256 ^b	90 ^e
2002/03	NA	13 Dec 02								20
2003/04	4	14 Dec 03	11.8	2-6	11.6	138-293	275-585	225-304	217-293 ^c	138 ^f

NA – Survey data for mainstem not adequate to develop AUC estimate.

a- OE 80-90% / RT 12-14 days

b- OE 70-80% / RT 10-12 days

c- OE 80-90% / RT 10-12 days

d- Surveys missed peak numbers.

e- Includes two peaks, 4 weeks apart

f- Includes two peaks, 3 weeks apart

Table 3.6. Coho salmon spawning survey Area Under the Curve (AUC) estimates for John West Fork, 1997-98 through 2003-04.

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Reaches	Survey Area (km)	AUC Range 100% OE	AUC Range 50% OE	AUC Range for OE & RT reported in literature	AUC for locally observed conditions	John West Fork PLD
1997/98	NA	15 Nov 97	7.9							12
1998/99	NA	19 Nov 98	12.1							9
1999/00	3	18 Jan 00	4.7	1-2	1.1	7-15	14-30	12-16	16-22 ^a	18
2000/01	4	10 Jan 01	9.4	1-2	1.9	42-90	85-180	69-94	57-75 ^b	58
2001/02	6	24 Nov 01	7.4	1-2	1.9	25-53	50-107	41-55	44-61 ^c	20
2002/03	6	13 Dec 02	6.9	1-2	1.3	14-30	28-61	23-31		27 ^d
2003/04	4	14 Dec 03	9.6	1-3	2.4	30-64	60-129	49-67		41

NA – Survey data for mainstem not adequate to develop AUC estimate.

a- OE 60-70% / RT 9-11 days

b- OE 80-90% / RT 12-14 days

c- OE 70-80% / RT 10-12 days

d- Includes two peaks, 4 weeks apart

Summary

The emerging picture from 10 winters of coho spawner surveys (Figure 3.1) reveals the presence of two strong year classes (red and blue) and one weak year class (yellow). Previously, the yellow year class was probably the strongest of the three, with a PLD index of 180 during the 1996-97 spawning run. However, the resulting cohort probably suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-98. This event caused high flows during the winter of 1997-98 which may have resulted in low overwinter survival for the juvenile coho. It is likely, however, that the most acute impact to coho populations actually occurred during the summer of 1997, when high ocean temperatures and very low productivity along the California coast would have resulted in high mortality rates of the coho smolts entering the ocean that spring. Although low spawner counts for the last two runs of this year class may be due in part to poor survey conditions during the winters of 1999-2000 and 2002-03, juvenile density observations support the notion that this became, and now remains the weakest year class.

Results from the JWF are represented and reported separately. Coho spawning activity in this important tributary has increased dramatically in the four winters since culvert modifications improved fish passage. In the 1999-2000 and 2002-2003 spawning years, JWF counts exceeded mainstem results, likely due in part to lower flows and better survey conditions on the tributary.

Overall coho escapement within Olema Creek has been trending upward since the 1997 ENSO event likely triggered the observed regime shift in the Pacific Decadal Oscillation (PDO) patterns across the California Coast. For the past two generations, all year classes have shown an increasing trend in the number of returning adults. This upward trend has been documented in other coastal Marin County watersheds, and is most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed in winter 2000-2001. Increases in adult escapement have translated into large shifts in juvenile coho density and smolt production at all monitoring locations. Continued monitoring efforts will allow for better characterization of year classes and annual productivity of coho salmon within Olema Creek and other coastal Marin County watersheds.

3.1.3 Live Fish, Carcass, and Redd Observations

Survey protocol collects information on live fish, carcasses, and redds. Information on sex ratios for live fish and carcasses are reported in table 3.7. 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. The results of carcass measurements show that males are generally between 65 – 75 cm, with females averaging 57-67 cm.

Table 3.7. Sex ratios of live coho and carcasses, and size observations of carcasses within Olema Creek.

		Live Coho				Carcasses	
		#		#		mean FL	FL SD
97-98	M	71	30%	16	47%	63.9 (n=15)	5.1
	F	95	40%	12	35%	59.1 (n=11)	3.1
	J	42	18%	5	15%	45.4 (n=5)	4.3
	Unk	29	12%	1	3%		
	All	237	100%	34	100%		
98-99	M	11	21%	4	31%	64.0 (n=2)	1.4
	F	25	47%	4	31%	61.0 (n=4)	3.4
	J	7	13%	3	23%	45.7 (n=3)	2.1
	Unk	10	19%	2	15%		
	All	53	100%	13	100%		
99-00	M	1	50%	2	22%	65 (n=1)	
	F	1	50%	6	67%	58.3 (n=6)	8.2
	J	0	0%	1	11%		
	Unk	0	0%	0	0%		
	All	2	100%	9	100%		
00-01	M	42	34%	22	34%	66.3 (n=22)	6.4
	F	61	50%	35	54%	65.4 (n=35)	4.7
	J	17	14%	8	12%	44.9 (n=8)	2.0
	Unk	3	2%	0	0%		
	All	123	100%	65	100%		
01-02	M	38	40%	8	30%	72.5 (n=6)	2.7
	F	46	48%	12	44%	66.7 (n=6)	6.3
	J	6	6%	1	4%	45 (n=1)	
	Unk	5	5%	6	22%		
	All	95	100%	27	100%		
02-03	M	0	0%	7	41%	68.8 (n=4)	6.3
	F	2	67%	0	0%		
	J	1	33%	2	12%	37.5 (n=2)	3.5

03-04	Unk	0	0%	8	47%	57.5 (n=4)	14.4
	All	3	100%	17	100%		
	M	37	26%	7	21%	74.3 (n=4)	1.5
	F	68	48%	11	32%	66.3 (n=10)	6.3
	J	31	22%	6	18%	45.2 (n=6)	2.0
	Unk	5	4%	10	29%	60.0 (n=4)	12.2
	All	141	100%	34	100%		

As a measure of the overall watershed, escapement, carcass, and redd information is reported as density per kilometer. This measure will be used for comparative purposes with the juvenile and smolt densities observed within the monitored areas. Density per kilometer for parameters measured or estimated during the spawner surveys are included for Olema Creek (Table 3.8) and John West Fork (Table 3.9). It should be noted that the survey areas used to calculate PLD, carcass and redd densities may be different from the survey area used to calculate the AUC estimate.

Table 3.8. Density information (per kilometer) for parameters measured or estimated during spawner surveys for Olema Creek. Survey areas used to calculate PLD, carcass and redd densities may be different from the survey area used to calculate the AUC estimate.

Olema Creek		Density (# / km)			
	PLD Index	AUC OE=80% RT=13 days	AUC OE=70% RT= 11 days	Total Carcasses	Total Redds
1997/98	7	20	27	2.9	9.4
1998/99	4	5	7	1.1	3.6
1999/00*	1*			1.3	1.4
2000/01	9	11	14	5.6	7.4
2001/02	8	15	20	2.4	5.0
2002/03*	2*			1.5	0.4
2003/04	12	20	26	2.9	7.6

*Survey data for mainstem not adequate to develop AUC estimate

Table 3.9. Density information (per kilometer) for parameters measured or estimated during spawner surveys for John West Fork. Survey areas used to calculate PLD, carcass and redd densities may be different from the survey area used to calculate the AUC estimate.

John West Fork		Density (# / km)			
	PLD Index	AUC OE=80% RT=13 days	AUC OE=70% RT= 11 days	Total Carcasses	Total Redds
1997/98	9	11	15	0.0	5.4
1998/99	8	36	50	0.0	0.8
1999/00	16	22	29	0.0	6.4
2000/01	31	18	24	15.8	25.3
2001/02	11	20	28	2.6	16.3
2002/03	21	11	15	0.0	9.2
2003/04	17	36	50	2.9	8.8

3.2 Outmigrant smolt trap

3.2.1 Smolt outmigration timing

The outmigrant traps are operated between mid-March and June of each year. While it is likely that smolts are moving past the trap location beginning in February, the results show that the peak of outmigration occurs in early April of each year. Outmigration within the John West Fork is affected by weather patterns, typically showing an increase with rainfall and runoff events. In the John West Fork, young of year salmon have also been observed to move with storm or foggy conditions.

Evaluation of the annual data for the John West Fork shows a dramatic increase in smolt and juvenile production in association with the SY 2000-01 and SY 2001-02.

Table 3.10. Summary information for John West Fork trap operations spring 1998 – spring 2003.

Trap Operation Dates			SH						CO	
			Juvenile				Adult		Fry	smolt
			smolt	presmolt	Parr	fry	Resident	Ocean-run		
1998	20-Mar	20-Aug	30	12	2	6599 ^a	8	0	1,061 ^a	21
1999*	12-Mar	1-Jul	15	22	14	228	2	6	0	0
2000*	29-Mar	19-Jul	2	25	22	6620	2	1	14	0
2001*	14-Mar	4-Jun	10	19	72	481	1	0	6563	3
2002*	19-Mar	11-Jun	18	5	8	269	0	0	5711	104
2003	22-Mar	30-May	18	25	3	1962 ^b	3	1	1561 ^b	181

^a 1,061 fry originally identified as coho were probably steelhead

^b number does not include 62 unidentified fry

*includes totals from upper trap

For the John West Fork trap observations are evaluated as production per kilometer, assuming that the habitat area upstream of the trap area is 2.0 kilometers. Results presented in tables 3.10 and 3.11 show a wide variability in juvenile production for both coho salmon and steelhead trout, as well as an increasing trend in coho smolt production since fish passage restoration in 1999.

Table 3.11. John West Fork trap density estimates (fish per meter) resulting from spring trapping operations 1998 – 2003.

	Steelhead (SH)					Coho (CO)	
	Juvenile density / m					density / m	
	smolt	presmolt	Parr	fry		Fry	smolt
1998	0.015	0.006	0.001	3.299 ^a		0.530 ^a	0.011
1999*	0.008	0.011	0.007	0.114		0	0
2000*	0.001	0.013	0.011	3.310		0.007	0
2001*	0.005	0.010	0.036	0.241		3.282	0.002
2002*	0.009	0.003	0.004	0.135		2.856	0.052
2003	0.009	0.013	0.002	0.981 ^b		0.755 ^b	0.091

^a fry originally identified as coho were probably steelhead

^b number does not include 62 unidentified fry

*includes totals from upper trap

3.2.2 Smolt size and condition

A variety of research has shown that ocean survival of smolts is dependent on fish size as they enter the ocean. Within intermittent stream systems such as the John West Fork, fish tend to grow in the spring and early summer when feeding conditions are best. In the summer, as surface flow recedes supporting isolated, intermittent pools, water temperatures increase and the food supply decreases dramatically. We have observed pools becoming isolated between June and October, and yet supporting salmonid survival (both coho and steelhead). We also frequently observed temperature and dissolved oxygen stratification in these pool units, with cool water and adequate DO near the bottom. As part of the California Department of Fish and Game - Russian River coho salmon broodstock reintroduction program (RRCBRP), coho were captured from intermittent sections of Olema Creek and John West Fork in 2001-2003. The fish condition at the time they were captured (late summer - September) was marginal. Fish were observed to be very small and skinny compared with fish captured from areas with perennial flow. It is our deduction that feeding rates are reduced during these low flow summer months, and that the John West Fork reared fish must quickly catch up in the late fall – prior to major winter storms, and spring, before outmigrating to the ocean. It is clear that these fish have the capacity to “catch up” as shown in growth patterns of the fish captured through the RRCBRP, where undersized Olema watershed fish caught up to their counterparts within the first few months of hatchery feeding operations (Wilson 2004 personal communication).

Staff record length and weight of the fish captured in the traps. Smolts outmigrating through the John West Fork over the past six years have ranged from 80-130 mm in size. Figure 3.2 shows the mean, median, and range of coho smolt lengths leaving John West Fork during the monitoring seasons 1998 through 2003.

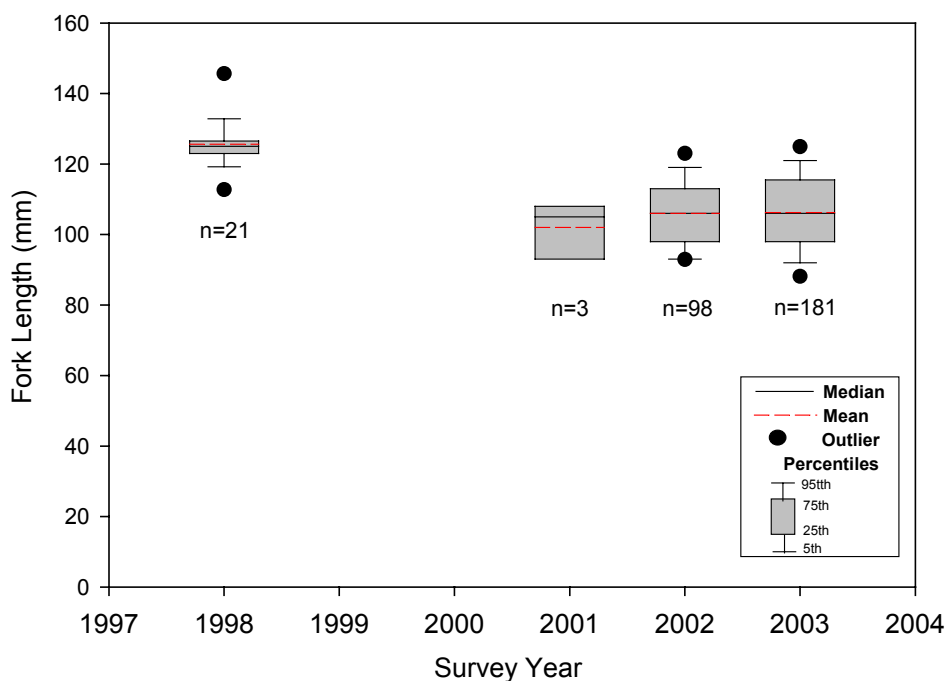


Figure 3.2. Coho smolt fork length box and whisker plots depicting mean, median, 5th, 25th, 75th and 95th percentiles, as well as outliers from John West Fork, Olema Creek during the monitoring seasons 1998 through 2003.

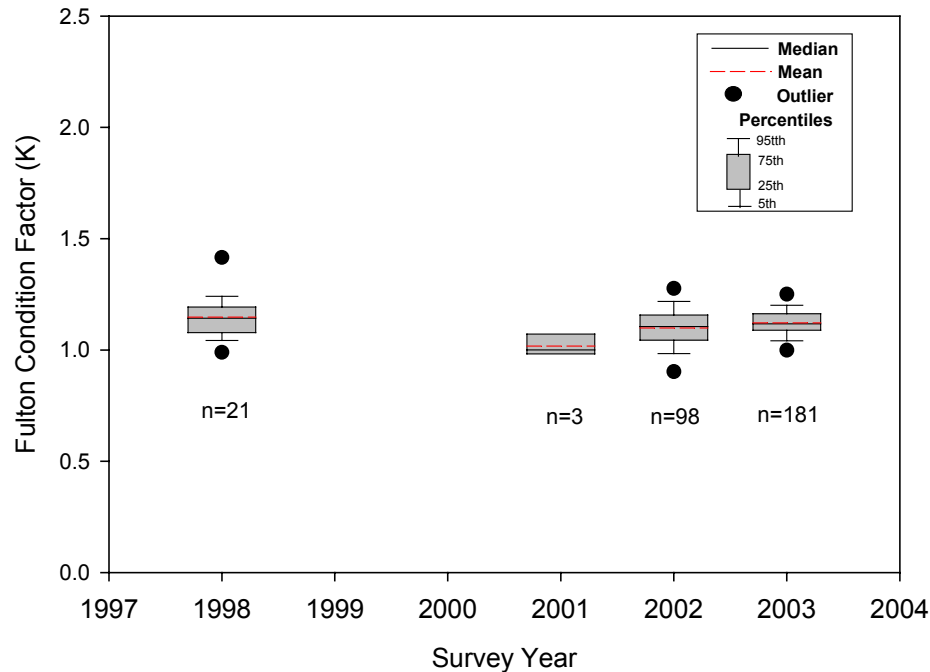


Figure 3.3. Coho smolt Fulton Condition Factor (K) box and whisker plots depicting mean, median, 5th, 25th, 75th and 95th percentiles, as well as outliers from John West Fork, Olema Creek during the monitoring seasons 1998 through 2003.

Despite the intermittent summer habitat conditions in the John West Fork, the size of coho observed emigrating through trap is not all that different from the smolts emigrating through the Pine Gulch Creek trap station. The John West Fork coho smolts were 1-2 grams heavier than the Pine Gulch Creek coho (Figure 3.4), although productivity is assumed to be higher in the perennial system. The greater variability of weight-length condition of the John West Fork coho smolts is indicative of the variable rearing conditions that occur in this intermittent tributary.

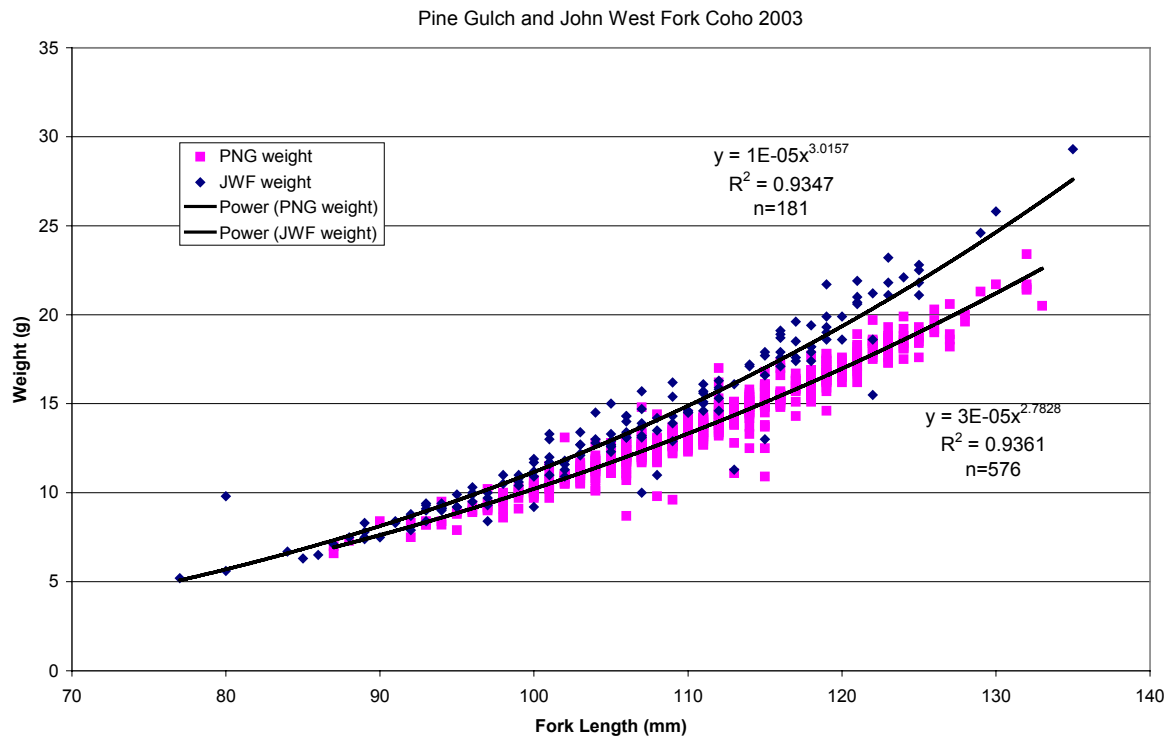


Figure 3.4 Comparison of coho smolt weight length relationships in Pine Gulch Creek and John West Fork of Olema Creek, Marin County, CA spring 2003.

3.2.3 Fish passage performance at the John West Fork

Culverts often create temporal, partial or complete barriers for anadromous salmonids on their spawning migrations (adapted from Robison et al. 1999). In most cases, problem culverts that impede fish passage occur in smaller watersheds, often tributaries of larger systems. Individually, the habitat upstream of these problem culverts is not large, but cumulatively, the loss of these tributary resources as spawning, rearing, and winter refugia habitat is detrimental to salmonid populations. Recent research on watershed restoration considers the identification, prioritization, and treatment of migration barriers to restore ecological connectivity for salmonids a vital step towards recovering depressed populations (Roni et al. 2002).

While adult migration was long recognized as a problem with culverts, and many restoration actions were designed to address this specific issue, far more culverts are barriers to juvenile migration. A common strategy for over-wintering juvenile coho is to migrate out of larger river systems into smaller tributaries during late-fall and early-winter storms to seek refuge from higher flows and potentially higher turbidity levels in mainstem channels (Skeesick 1970; Cederholm and Scarlett 1981; Tripp and McCart 1983; Tschaplinski and Hartman 1983; Scarlett and Cederholm 1984; Sandercock 1991; Nickelson et al. 1992). Recent research conducted in coastal northern California watersheds suggests that juvenile salmonids migrate into smaller tributaries in the fall and winter to feed on eggs deposited by spawning adults carcasses of spawned-out adults (Roelofs, pers. comm).

Within the Olema Creek watershed, State Route 1 runs parallel to the mainstem, with each of the eastern tributaries crossing under the road through culverts. Most of these culverts were constructed in the 1930s – 1950s, and were not designed to accommodate either adult or juvenile passage. The County of Marin contracted an assessment of road crossings, which identified three current crossings in Olema Creek as impediments or barriers to fish migration and movement within the watershed (Taylor and Associates 2003).

The Marin County culvert assessment identified the John West Fork culvert as the #1 priority for restoration based on its assumed ability to pass adults and juveniles (Taylor and Associates 2003). Our monitoring efforts indicate that the work conducted in 1999 has been highly effective at moving adults through the site, but it is likely that very few if any juvenile salmon are able to negotiate the culvert. While we have observed smaller fish (often steelhead) jumping at the culvert, the juvenile passage of the culvert remains questionable. Because of this, we assume the coho production information observed in the John West Fork trap to be derived solely from areas upstream of the culvert.

Monitoring efforts on the John West Fork have been synthesized to show the overall response to the riparian exclusion and fish passage restoration activities in 1997 and 1999. Table 3.12 depicts the annual monitoring results upstream of the State Route 1 culvert for multiple life stages of each year class. Since restoration in 1999, 83.7% (139 of 166) of the live fish and 80.8% (97 of 120) of redds observed in the watershed have been located above the culvert. In the two years that monitoring was conducted prior to fish passage restoration, only 14% (3 of 21) of the coho adults and 0% (0 of 8) coho redds were observed above the culvert. In addition, over the past three years, the NPS has observed increases in the number of coho smolts leaving the watershed and thousands of coho salmon young of year leaving the watershed as a response to highly productive spawning the prior winter.

Table 3.12. Multiple life stage observations of coho salmon within the John West Fork above the restored culvert since spring 1998. Note culvert fish passage enhancement (restoration) completed summer 1999.

	Spawner Year (SY)								
	1996-97	1997-98	1998-99	R E S T O R A T I O N	1999-00	2000-01	2001-02	2002-03	2003-04
Adult	n/a	3	0		9	50	13	26	40
Redds	n/a	0	0		3	40	25	12	19
Young of Year Coho passing through trap	n/a	1061*	0		14	6,563	5,711	1,561	1,582
Summer index reach density [coho/meter]	n/a	0.0 ^a	n/a		0. 0 ^b	8.4 ^b	9.7 ^b	0. 6 ^b	Summer 2004
Smolt outmigration (year old coho)	21	0	0		3	104	181	112	Spring 2005

*fry identified as coho were probably steelhead

^a counts conducted in 10 pool units above the culvert

^b counts conducted in 3 pool units and two riffles above the culvert

3.3 Index Reach Surveys

Index reach monitoring was initiated at seven sites on Olema Creek in 1999. In 2000, Index Reach 8 was added to represent the intermittent portion of the upper mainstem. The location of each index reach is shown in Figure 2.1 and Table 3.13. In 2003, 7 of 8 index reaches on the mainstem of Olema Creek were sampled.

Table 3.13 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

*not surveyed in 2003

3.3.1 Index reach total salmonid catch

The index reach total catch (Table 3.14) provides a general sense of the annual variation in fish numbers within and distribution between index reaches monitored since 1999. The summer monitoring information shows a dramatic increase in coho numbers in 2001 and 2002. These higher juvenile numbers correspond to similar patterns observed in adult spawner survey and spring outmigrant smolt trapping efforts conducted by the NPS.

The results presented in Table 3.14 are the total number of fish captured during electrofishing surveys. *Microfish* population estimates are used to calculate fish density and other derived data. Index reach population estimates and fish density for each species/age class are reported with 95% confidence. Density results presented in Section 3.3.3 are determined based upon the habitat information measured for the given year of monitoring. The detailed annual reports are included in the Olema Creek Summer Monitoring Summary Report included as Appendix X.

Table 3.14 Summary of total catch for each species by reach within Olema Creek mainstem index reach sample locations between 1999 and 2003; (NPS 2001b, , 2002a, 2002b, 2003a).

Year	Species	Index Reach								total
		1	2	3	4	5	6	7	8	
1999	CO	4	25	23	36	15	51	62	not sampled	216
	SH YOY	65	222	200	341	220	159	192		1,399
	SH 1+	17	19	27	39	46	31	17		196
2000	CO	1	64	21	140	34	76	23	0	359
	SH YOY	99	342	376	232	256	190	168	209	1,872
	SH 1+	24	19	11	24	22	12	19	6	137
2001	CO	39	23	73	257	213	205	241	156	1,207
	SH YOY	22	132	202	151	354	40	30	20	951
	SH 1+	15	26	17	37	34	29	26	7	191
2002	CO	3	114	123	not sampled	260	323	332	310	1,465
	SH YOY	26	102	439		267	118	139	203	1,294
	SH 1+	7	7	9		16	7	5	0	51
2003	CO	not sampled	22	5	60	210	152	202	72	723
	SH YOY		35	111	26	134	139	136	79	660
	SH 1+		8	7	11	27	21	9	9	92

3.3.2 Index Reach Habitat Information

Table 3.15 shows the average habitat composition for each index reach, the extent of area sampled, and variation between reaches. Sample area boundaries and the number and types of habitat units may vary from year to year to track changes in the stream channel within each index reach. Occasional large changes in index reaches occur, for example the stream channel encompassed by index reach 5 has migrated laterally more than 50 feet since it was established in 1999.

Table 3.15 Summary of habitat composition; Olema Creek Summer Index Reaches 1999-2003.

Index Reach	Habitat Type	# of Units	SD	Length		Surface area	
				Sampled (m)	SD	Sampled (m²)	SD
1	Pool	4.0	0.0	65.9	3.0	219.3	19.6
	Riffle	0.8	0.5	5.4	4.2	13.3	14.3
	Flatwater	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	4.8	0.5	71.3	6.7	232.6	21.5
2	Pool	2.8	0.4	65.8	17.3	312.7	94.3
	Riffle	1.2	0.4	18.7	9.2	37.1	16.6
	Flatwater	0.8	0.8	23.4	26.4	117.8	121.4
	TOTAL	4.8	0.4	107.8	8.7	467.5	35.0
3	Pool	1.8	1.3	38.5	23.7	164.1	100.3
	Riffle	0.2	0.4	1.9	4.2	4.8	10.6
	Flatwater	1.8	0.8	43.0	22.2	190.9	148.9
	TOTAL	3.8	1.6	83.4	13.8	359.8	81.2
4	Pool	2.3	0.5	85.2	27.7	412.5	139.7
	Riffle	0.8	1.0	8.2	9.6	24.0	27.7
	Flatwater	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	3.0	1.4	93.4	34.6	436.5	162.1
5	Pool	2.2	1.6	42.5	20.7	168.4	83.7
	Riffle	1.8	0.4	24.3	7.7	91.1	31.6
	Flatwater	1.4	0.9	24.3	14.9	89.9	52.2
	TOTAL	5.4	1.5	91.1	10.4	349.5	50.8
6	Pool	2.8	0.8	67.0	23.3	296.2	104.0
	Riffle	0.8	0.4	7.0	5.7	19.2	17.3
	Flatwater	0.4	0.5	11.2	15.4	43.5	59.6
	TOTAL	4.0	0.7	85.2	13.8	358.9	58.4
7	Pool	4.0	1.0	61.6	14.8	215.9	72.8
	Riffle	1.8	1.5	29.6	17.6	69.8	46.1
	Flatwater	0.6	0.5	5.8	5.7	16.2	17.3
	TOTAL	6.4	2.3	97.0	23.7	301.9	75.9
8	Pool	3.8	1.0	53.9	13.9	133.2	49.3
	Riffle	0.3	0.5	1.5	3.0	2.3	4.6
	Flatwater	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	4.0	0.8	55.4	15.5	135.5	52.9
Total	Pool	23.6		480.4		1922.4	
	Riffle	7.6		96.6		261.5	
	Flatwater	5.0		107.7		458.3	
	TOTAL	36.2		684.7		2642.2	

3.3.3 Salmonid density by habitat type

The results of our monitoring efforts show distinct differences in salmonid numbers and densities based on habitat type. Coho salmon primarily use pool habitat, while steelhead densities have ranged dramatically through the years, with high densities observed in pools and flatwater units within the index reaches.

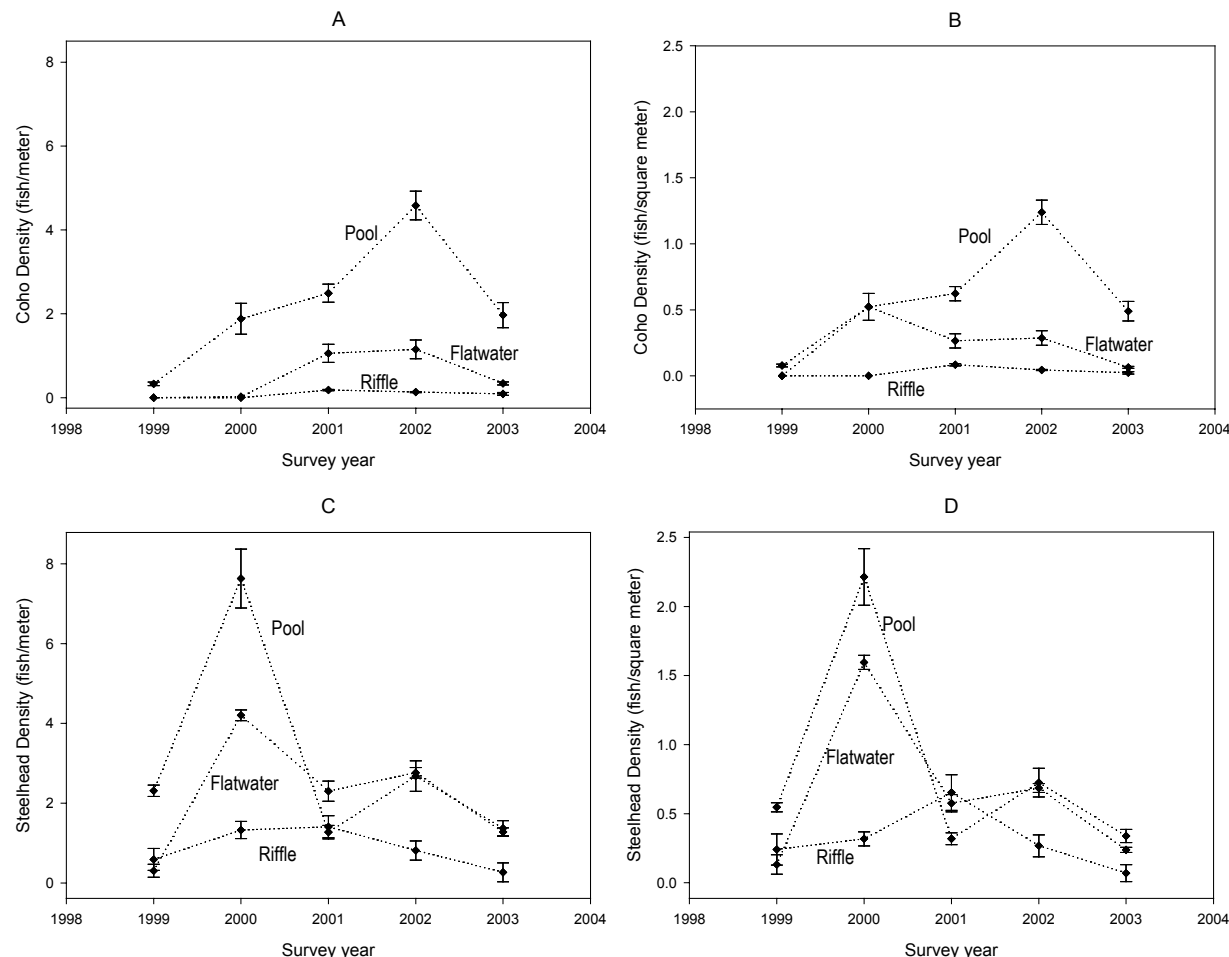


Figure 3.5 Temporal change in salmonid density for pool, flatwater, and riffle habitat observed within eight Olema Creek index reaches, Summer 1999-2003. Error bars show 95% confidence intervals.

- Density of juvenile coho per meter.
- Density of juvenile coho per square meter.
- Density of YOY steelhead per meter.
- Density of YOY steelhead per square meter.

3.3.4 Salmonid Index Reach Density

Densities shown in Figures 3.6 and 3.7 are determined from all habitat units surveyed within each index reach. Juvenile coho densities have tended to be highest in index reaches 5, 6, and 7. High coho densities were also present in index 8 during the summers of 2001 and 2002, corresponding to high levels of spawning activity in the area during the previous winters.



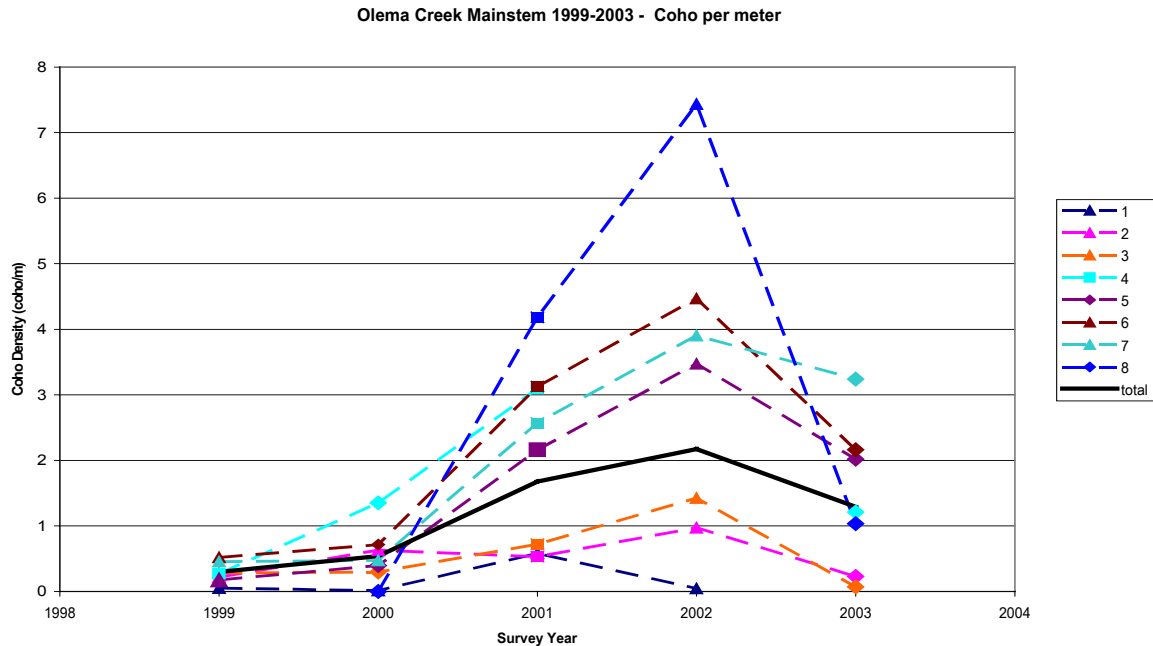


Figure 3.6. Summer juvenile coho salmon densities (coho/meter) for eight index sites in Olema Creek from 1999-2003. Heavy line without symbols indicates means for all sites. Symbols represent cohort year classes.

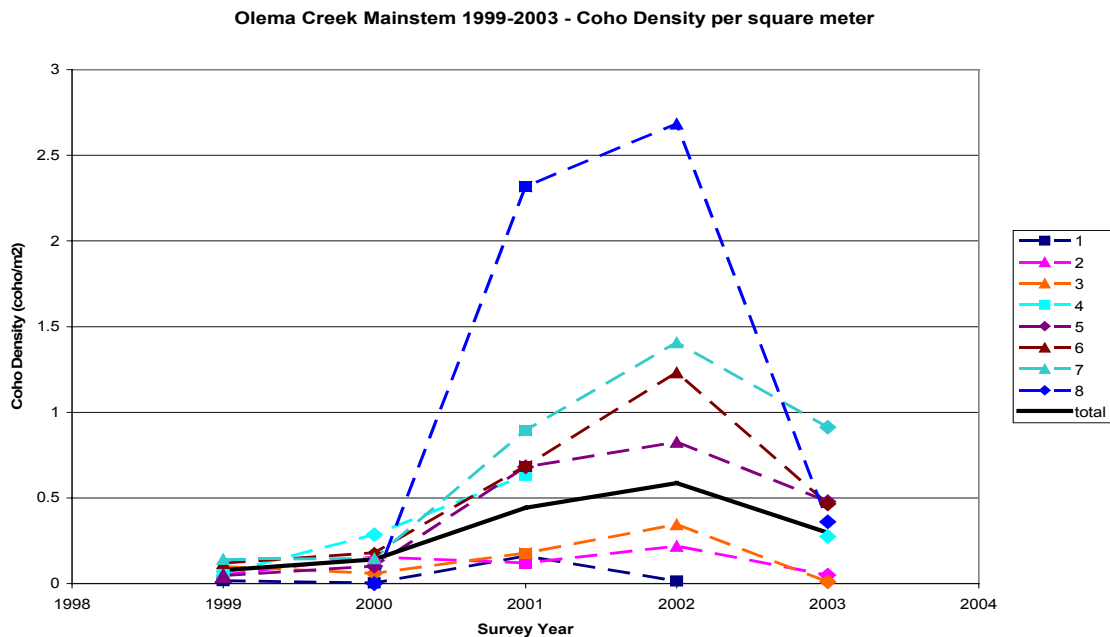


Figure 3.7. Summer juvenile coho salmon densities (coho/square meter) for eight index sites in Olema Creek from 1999-2003. Heavy line without symbols indicates means for all sites. Symbols represent cohort year classes.

Overall densities for coho, steelhead YOY, and steelhead 1+ are shown in figure 3.8. Juvenile coho density seems to be on the rise, ranging from 0.297 (± 0.029) fish/m and 0.079 (± 0.008) fish/m² in 1999 to 2.172 (± 0.215) fish/m and 0.587 (± 0.058) fish/m² in 2002. Monitoring shows a subtle decline in young of year steelhead density from 2.464 (± 0.257) fish/m and 0.641 (± 0.067) fish/m² in 2000 to 1.111 (± 0.162) fish/m and 0.256 (± 0.037) fish/m² in 2003. Steelhead 1+ density has shown little variation over the years, averaging around 0.2 fish/m and 0.05 fish/m².

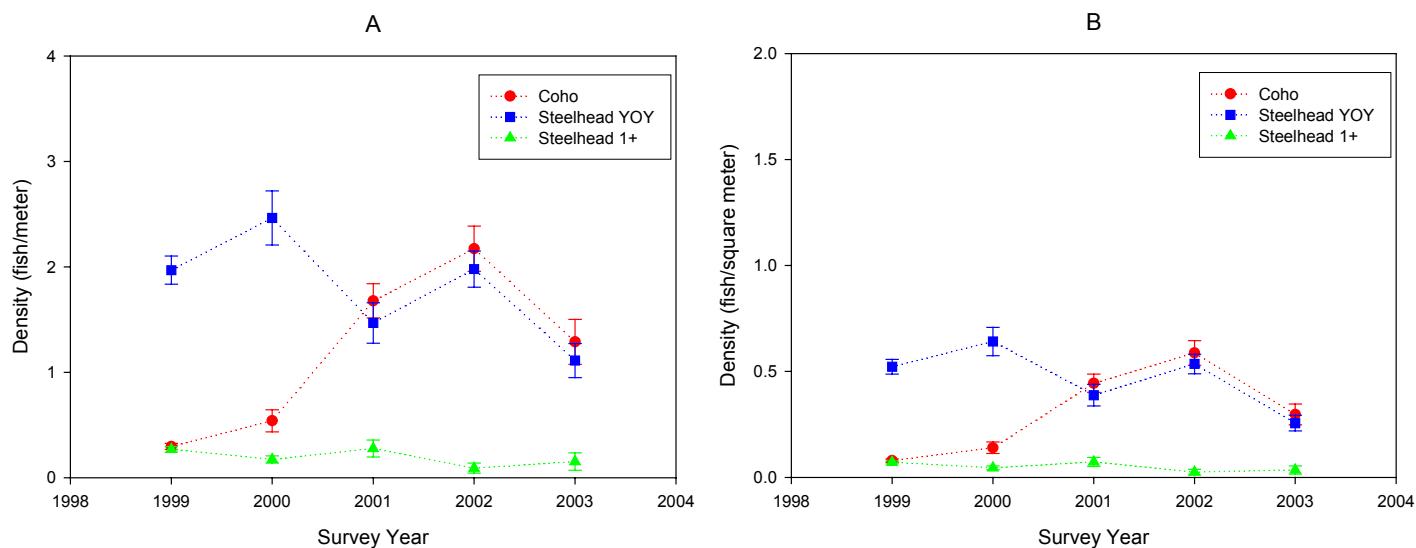


Figure 3.8. Presents the average density (with 95% CI) of salmonids monitored through the summer program, 1999 - 2003. A) fish/m and B) fish/m²

3.3.5 Summer fish measurement information

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Annual results including histograms, weight-length charts, as well as Fulton condition factor, mean weight, and biomass for each of the salmonid species and steelhead age classes are included in the Annual Index Reach Monitoring Summary (Appendix C).

Synthesis of this detailed information is presented in Figure 3.9 and 3.10 in box and whisker plots. The charts show the size range of coho salmon both spatially, between index reaches, and temporally, between monitoring years. There is clearly a trend of shorter fork length in relation to location in the watershed. The largest coho juveniles on average have been documented in the lower reaches of the watershed. This is reasonable considering the lower reaches likely include larger habitat units and warmer water, resulting in increased productivity and fish growth.

The range of coho juvenile fork length in fish captured through the summer monitoring efforts (July – August of each summer) is 37 to 99 millimeters, with most fish at this age grouped in the 60 to 80 millimeter FL.

Figure 3.9 Box and whisker plots depicting mean, median, 5th, 25th, 75th and 95th percentiles, as well as outliers of juvenile coho salmon fork length within the eight Olema Creek index reaches, summers 1999 – 2003.

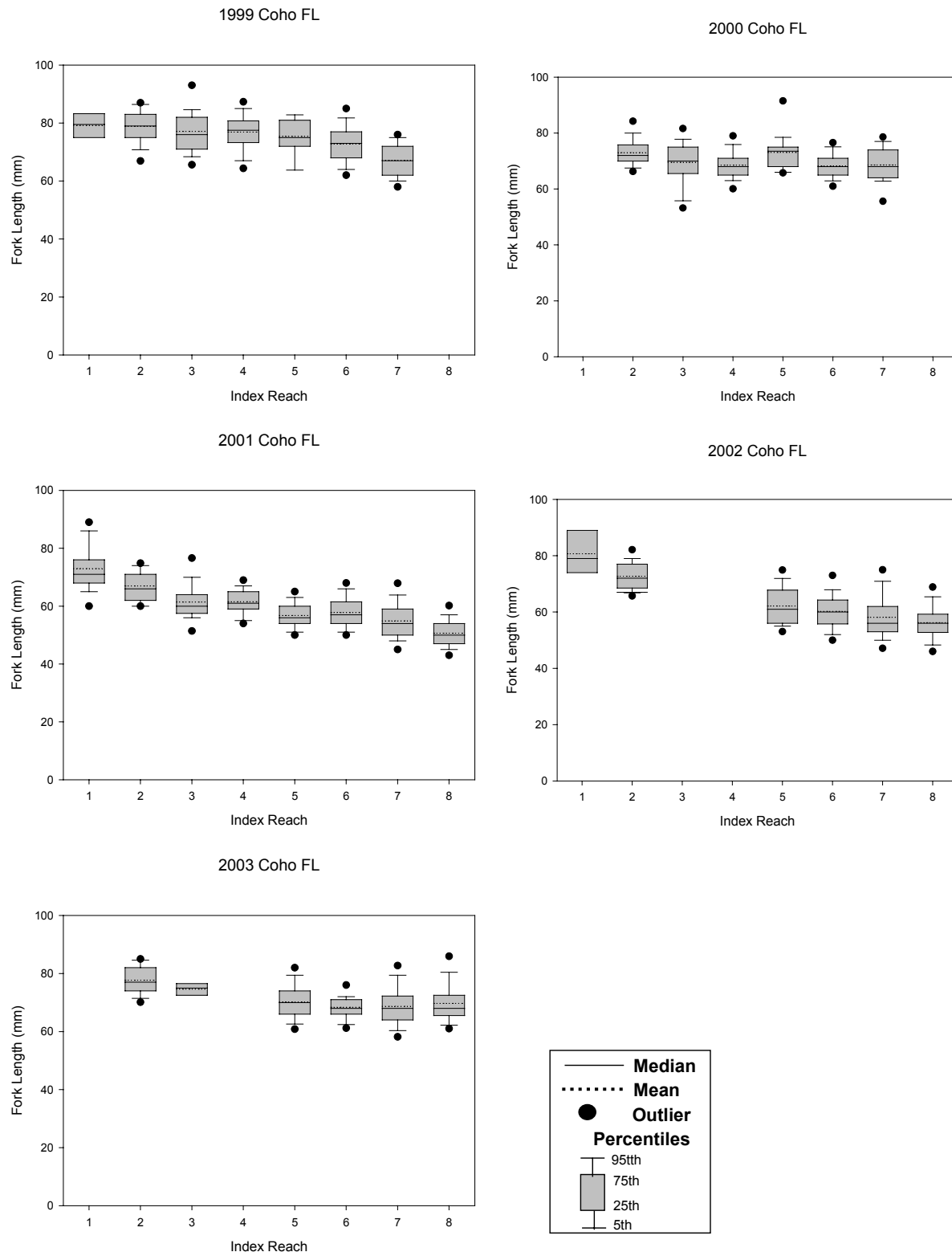
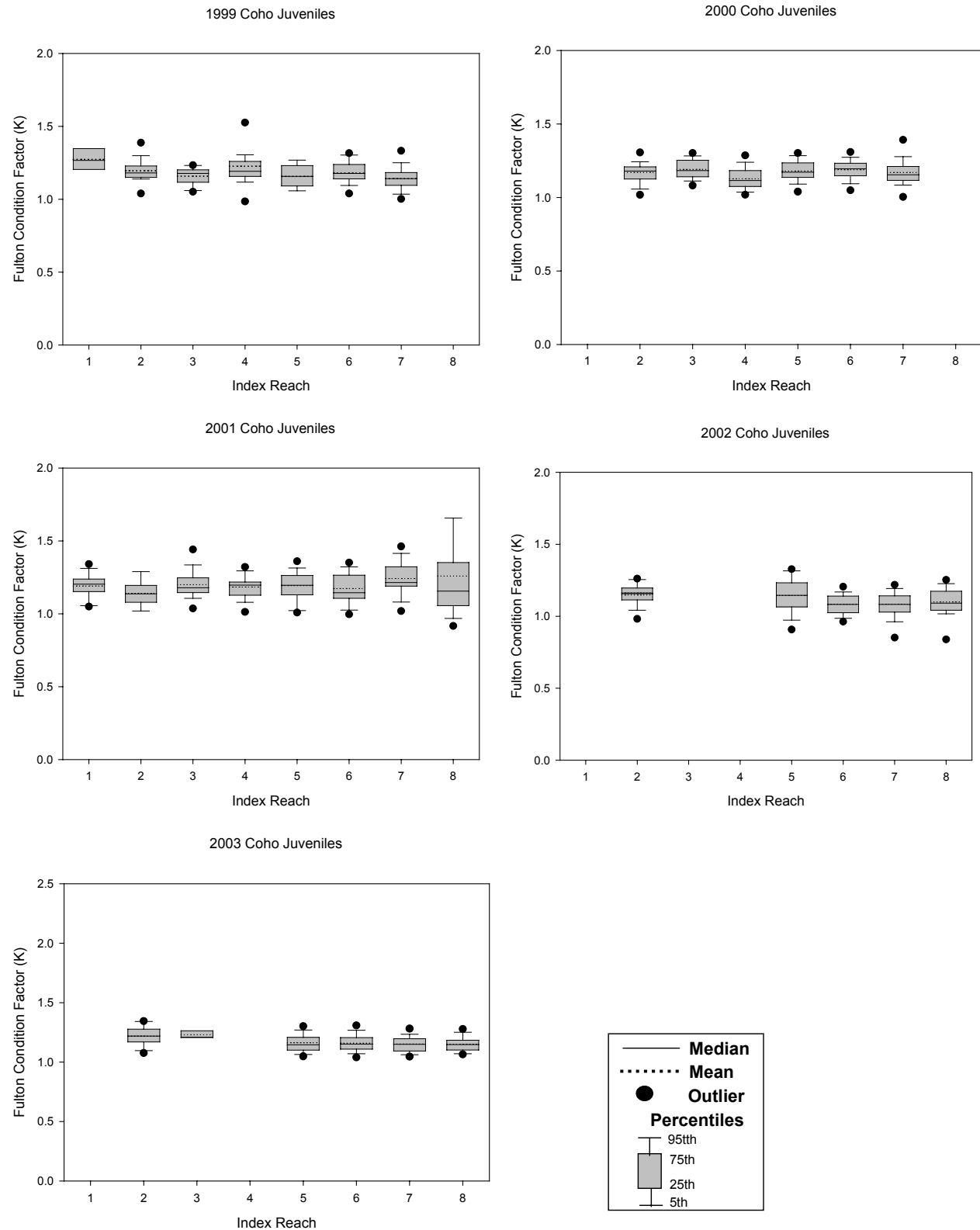


Figure 3.10 Box and whisker plots depicting mean, median, 5th, 25th, 75th and 95th percentiles, as well as outliers of juvenile coho salmon Fulton Condition Factor within the eight Olema Creek index reaches, summers 1999 – 2003.



3.4 Population estimates

3.4.1 1999 Juvenile Fish Abundance, Distribution, and Mortality in Isolated Pools

The upper reaches of Olema Creek were targeted for evaluation in 1999 because of typical high winter spawning densities and drying conditions in the summer. The intent of the investigation was to determine the level of use during summer conditions before and after the low flow period. Snorkel surveys were conducted initially, but comparison with electrofishing results showed that counting high numbers of coho, steelhead and steelhead 1+ resulted in problems with calibration. The correlation between diver counts and the electrofishing estimates for CO 0+, SH 0+, and SH 1+ were 0.76, 0.82, and 0.47 respectively. The results of the survey indicated significant use of this habitat by juvenile salmonids. High mortality and low growth rates occur throughout the summer/fall low flow period. Mortality is mainly the result of lowered water quality and/or complete desiccation of habitat units. Evidence of mammalian and avian predation was evident along the margins of habitat units as well.

The comparison between August and October resulted in some marked contrast in habitat availability and quality, in addition to distribution and connectivity. Total habitat units assessed during the survey was down from 307 in August 1999 to 304 that October (Table 3.16). The length of these surveys varied due to the change in thalweg in the drying sections from 3,431 meters in August down to 3,042 meters in October. In August, habitat units were well represented, with pool, dry channel, and riffle units most dominant; 165 pool units comprised 58% of the total length, while 71 dry channel and 62 riffle units accounted for 25% and 14% of the unit lengths respectively. By October, 153 dry channel units comprised 49% of the total length of the survey area with 118 pool and 28 riffle units accounting for 41% and 9% of the total length respectively.

Table 3.16. Tier 1 habitat type composition by length (m) and surface area (m²). Upper Olema Creek, Marin County, CA. Habitat survey, August and October 1999.

Habitat Type	Number of Units	Total Length per Habitat Type	Percent of Total Length	Average Length per Habitat Type	Total Surface Area per Habitat Type	Percent of Total Surface Area	Average Surface Area per Habitat Type
August 1999							
Pool	165	1984.4	58	12.0	4693.1	87	28.0
Dry Channel	71	874.8	25	12.3	n.a.	n.a.	n.a.
Riffle	62	473	14	7.6	513.8	9	8.3
Flatwater	4	55	2	13.8	80.7	1	20.2
Pocket Water	1	23.2	<1	23.2	93.7	2	93.7
Backwater	4	21.4	<1	5.4	29.1	<1	7.3
Totals	307	3431.7	100		5410.4	100	
October 1999							
Dry Channel	153	1480.5	49	9.68			
POOL	118	1259.9	41	10.68	2963.1	92	23
Riffle	28	236	8	8.43	189	6	6.7
Flatwater	2	33.6	1	16.80	62.2	2	31
Pocket Water	1	23.2	<1	23.20	n.a.	n.a	n.a.
Backwater	2	9.1	<1	4.55	4.5	<1	2.3
Totals	304	3042.25	100		3219	100	

The correlation between visually estimated and measured surface areas was high ($R = 0.97$) and a calibration ratio of 1.01 was used to correct visually estimated surface area. The total surface area of Upper Olema Creek in August was 5410.4 m². Due to the drying patterns between August and October, approximately 40% of the total surface area was lost between the August and October surveys. In the August survey pools represented 87% of the total wetted surface area. With the loss of shallower riffle and flatwater habitat under drying conditions, pools represented a total of 92% of the wetted surface area in the October survey.

Electrofishing density estimates were used in Simple Random Sampling Ratio Estimation (Bohlin, et. al. 1989) to estimate total fish abundance. Total population estimates were derived from densities developed in association with electrofishing estimates on approximately 20% of the habitat units in the reach. The density estimates for August and October are shown in Table 3.17. In October, a second habitat survey was conducted showing a loss of approximately 40% of the calculated surface area within the survey reach. Approximately 30% of the previously sampled habitat units were resampled, and many others were assessed for condition. Observations associated with this survey show that the density of fish in the habitat units sampled between August and October did not change significantly, rather the large reduction in population occurred as part of the loss in habitat associated with drying conditions. As an example, between August and October, sampled densities of coho dropped from 0.51 fish per square meter to 0.43 fish per square meter. However, the overall surface area of habitat in October represented just 60% of that measured in August. In addition, while the steelhead young of year density was observed to drop from 1.17 to 0.34 fish per square meter, we actually observed a slight increase in year old steelhead from 0.10 to 0.17 fish per square meter in October. This increase can be accounted for by potential behavioral response of these older fish. Those that survive are clearly successful at taking up residence in pools that remain wet through the year. Because these older fish are likely dominant, they probably remain in residence full time to defend their perennial habitat. Population estimates for the reach were extrapolated using the detailed habitat surveys and fish densities. The results are presented, but problems with such extrapolation techniques are documented in Sections 2.5 and 3.5.

Table 3.17. Estimated number of fish, density, standard error, and 95% confidence interval from fish/m² and fish/m. Upper Olema Creek, California. Electrofishing survey, August and October 1999.

August 1999						
	Fish/m ²				Fish/m	
	CO (0+)	SH (0+)	SH (1+)		CO (0+)	SH (1+)
Number of Fish	2395	5482	481		2106	4821
Density	0.51	1.17	0.10		1.06	0.21
Standard Error	170.38	1238.16	58.75		192.31	667.51
95% CI	340	2468	117		383	1330
October 1999						
	Fish/m ²				Fish/m	
	CO (0+)	SH (0+)	SH (1+)		CO (0+)	SH (1+)
Number of Fish	1261	995	492		1273	1005
Density	0.43	0.34	0.17		1.01	0.39
Standard Error	396.66	456.27	248.88		323.33	332.35
95% CI	823	946	516		671	689

The results of fish abundance surveys on the isolated pool section of Upper Olema Creek indicate that this reach is significant to the overall juvenile salmonid population in Olema Creek. Much like the intermittent tributaries, this portion of the watershed is not subject to excessive flows, provides limited winter refugia and good habitat for spawning. As we have observed in other tributaries, the number of fish using these intermittent habitat units is high.

3.4.2 Summer 2003 Hankin Reeves Survey

A total of 537 habitat units were identified (275 pool, 69 flatwater, and 193 riffle units). Overall habitat composition was 51% pool, 13% flatwater, and 36% riffle (Table 3.18). A comparison between visually estimated and measured surface area was conducted for 68 pools to determine a surface area correction factor. The correlation between the estimated surface area and measured surface area was adequate ($R^2=0.93$). Based on this, a calibration ratio of 1.03 was used to correct the estimated surface area of all units (Figure 3.11).

Table 3.18 Habitat composition of Olema Creek coho survey area, July-August, 2003

Unit type		2003		2004		2005	
		# of units	%	# of units	%	# of units	%
pool		275	51				
flatwater		69	13				
riffle		193	36				
total		537					
Survey length		9.2 km					

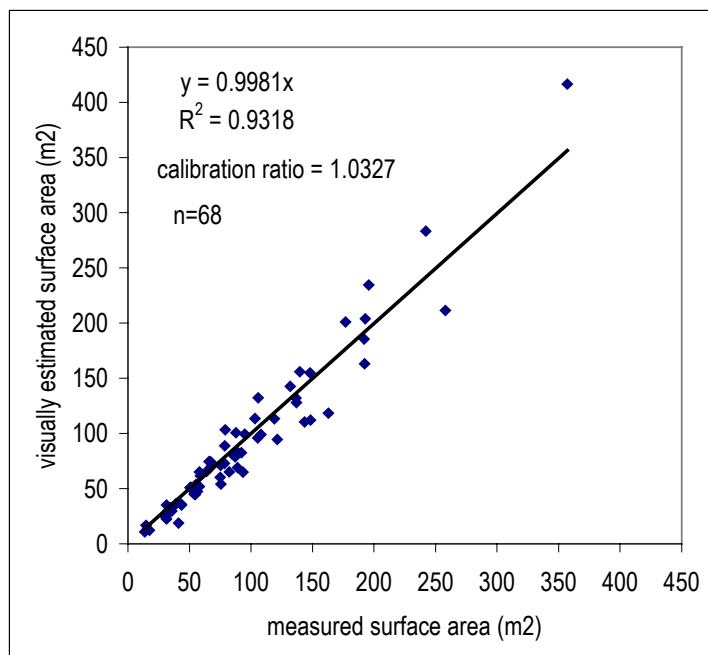


Figure 3.11 Correlation between measured and visually estimated surface area of 68 pools; Olema Creek, July-August 2003

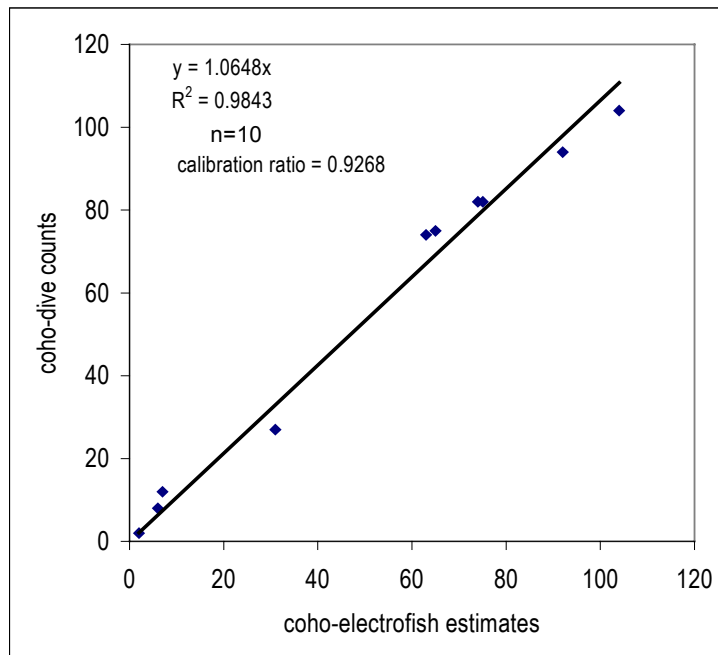


Figure 3.12 Correlation between electrofishing estimates and snorkel counts for 10 pools; Olema Creek, July-August 2003

Snorkel counts

We snorkeled 46 of the 275 pools, and counted a total of 2,153 juvenile coho. Coho were present in all but two of the snorkeled pools. Ten of the 46 dive pools were electrofished within a day following the dive counts (Appendix B [electrofishing log included in final watershed report]). *Microfish* population estimates for the electrofished pools were used to calibrate the snorkel counts. Correlation between electrofishing and snorkel counts was adequate ($R^2=0.98$) and a calibration ratio of 0.93 was used to correct the snorkel counts for all pools (Figure 3.12). A summary of the snorkel counts is shown in Table 3.19. Coho densities (by both pool length and calibrated surface area), population estimate, and 95% confidence interval were calculated for the coho survey area as a whole (Table 3.20). The highest number of coho individuals counted in one pool was 140, and the highest observed coho density was 1.630 coho/m² (based on calibrated surface area and calibrated snorkel counts).

Table 3.19 Summary of coho snorkel counts in Olema Creek, July-August 2003

Year	Total stream length surveyed (km)	Total number of habitat units	Number of Pools			Coho Counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2003	9.2	537	275	46	44	2153	1995

Table 3.20 Coho density and population estimates; Olema Creek coho survey area, July-August 2003

Year	Avg. Coho per pool		Density		Population Estimate	Variance	95% confidence Interval
	Raw	Calibrated	coho/m	Coho/m ²			
2003	46.79	43.36	1.934	0.441	11,926	2,057,080	± 3,244

The total coho salmon population estimate for Olema Creek in 2003 is $11,926 \pm 3,244$. This is the first population estimate conducted on Olema Creek. Densities observed in the summers of 2001 and 2002, were much higher than in 2003, and would have resulted in basinwide estimates far higher than those reported in this section.

3.5 Extrapolated coho salmon population estimates comparing index reach monitoring and snorkel survey estimates

This section includes three extrapolated population estimates for coho salmon in Olema Creek and Pine Gulch Creek. This includes estimates based on index reach derived densities of coho per meter and coho per square meter. While standard error and confidence intervals can be developed for the index reach fish densities, it is important to note that this error is calculated on the quality of the estimate within each habitat unit. The weakness of extrapolating these densities into a basinwide estimate is that it does not account for the natural variability of fish between pools within the basin.

In order to address this issue, we have developed fish estimates on the number of fish per pool, derived from the pools included in the index reach sample process. While we are able to derive an extrapolated estimate using this method, we still do not have a means of developing a confidence interval at this time.

Table 3.21 shows the results for Olema Creek, and extrapolated estimates for the survey area described in Section 3.2.1. These calculations also extrapolate fish numbers for flatwater and riffle habitat units. These habitat units are not included in the Hankin-Reeves analysis used in Section 3.2. This is not an issue in Pine Gulch Creek as no coho juveniles were sampled within either flatwater or riffle habitat units.

It should be noted that despite the fact that these extrapolated population values are not supported with an error range, all three methods of estimating provide a result that is within the reported range using the Hankin-Reeves analysis. We present this information as conditional, and hope that it leads to some investigations that could allow us to present these types of estimates with statistical support.

Table 3.21 Extrapolated population estimates for Olema Creek using three density based methods (Coho per unit, coho per meter, and coho per square meter) multiplied by habitat results. The estimates reported in this table are for information only, as they do not contain any error estimates. Basinwide results should be reported as $11,926 \pm 3,244$ as shown in Table 3.13.

Unit type	Habitat Units from Hankin Reeves/Basinwide Survey			Coho densities from Index Reach Surveys			Coho population estimate based on Index Reach densities		
	# of units	length (m)	surface area (m ²)	coho/unit	coho/m	coho/m ²	by # (coho/unit)	by length (coho/m)	by surface area (coho/m ²)
pool	275	6,192	27,274	50.3	2.19	0.54	13,832	13,560	14,728
flatwater	69	1,240	4,321	7.3	0.34	0.06	504	422	259
riffle	193	2,207	6,707	0.8	0.09	0.02	154	199	134
total	537	9,639	38,302	31.6	1.57	0.36	14,490	14,181	15,121

3.6 Genetics and Recovery

NOAA Fisheries has conducted extensive genetic analysis on CCCESU coho salmon and CCCESU steelhead over the past three years. The NPS has participated in these efforts through the collection and submission of multiple genetic samples through the years. Additional detailed genetic studies were conducted on approximately 300 coho salmon collected as juveniles for participation in the Russian River Coho Broodstock Reintroduction Program, a cooperative effort led by the California Department of Fish and Game.

The first coho salmon genetic investigations were conducted through the University of California Bodega Marine Lab. Analysis of coho salmon genetic samples collected from multiple year classes observed in 14 watersheds within the CCCESU and Southern Oregon/Northern California (SONC) ESU found that the genetics generally supported the ESU structure, with statistically significant clusters of samples corresponding to CCC and SONC ESUs (Hedgecock et. al. 2002). In addition, they found correlations among samples collected from watersheds south of the Golden Gate (state endangered at the time of publication). Analysis of coho samples collected from Olema Creek in 1996, 1997, and 1998

showed their closest affinity to Lagunitas Creek, and also an influence from Noyo River coho. This is a result that reflects extreme recovery efforts taken in the early 1980s by Trout Unlimited in Lagunitas Creek (R. Plant 2004, personal communication), and likely means that the Olema Creek populations was primarily derived from this same hatch-box recovery effort. The results of the Bodega Marine Lab investigation showed that the Redwood Creek (Marin County) and Russian River – Green Valley coho were genetically distinct from the coho of all the other watersheds. The persistence of these remnant populations and potential genetic link remains a mystery.

This investigation also found significant departures from random mating and suggestion of potential inbreeding depression in many of the smaller populations. Temporal comparisons of different year classes from the same watershed showed that in Olema Creek the 1996 year class was significantly different from the 1997 and 1998 year classes (which were considered homogeneous) (Hedgecock et. al. 2002). Some adult samples analyzed for Olema Creek from winter 1996-97 showed excesses of individuals with homozygous multi-loci genotypic categories, implying general departure from random mating (e.g. inbreeding).

Russian River Coho Broodstock Recovery Program

In 2001, as a result of very low rainfall and loss of habitat for the remaining coho in the Russian River, the CDFG initiated a broodstock recovery program for coho salmon in the watershed. Based on best available information, coho from the remaining habitat in the Green Valley portion of the Russian River, and coho from drying portions of Olema and John West Fork were collected for inclusion in the new program. The fish were reared in the Warm Springs Hatchery with the intent of conducting genetic analysis and matching breeding pairs to optimize fitness of fish for the broodstock population. NPS documentation of high coho densities made the Olema fish a resource considered for inclusion as part of the Russian River Coho Broodstock Reintroduction Program.

As part of the Russian River Coho Broodstock Recovery Program, the NOAA-Fisheries Genetics Laboratory at the Pacific Southwest Fisheries Center in Santa Cruz, CA conducted detailed analysis of samples from individuals collected as part of the broodstock program. Because inbreeding depression and potential genetic bottlenecks were already recognized as a problem for breeding the Green Valley fish together, the CDFG and NOAA-Fisheries proposed collection of coho from drying portions of Olema and John West Fork to augment the broodstock program on the Russian River. Garza and Gilbert-Horvath (2003) reported their analysis of the first year class collected for this program. The report provides a highly detailed analysis and comparison of the Olema Creek coho population and the Russian River Green Valley coho, known to be genetically distinct from all others observed within the CCCESU, but subject to potential inbreeding depression and showing a recent population bottleneck (Hedgecock et.al. 2002).

A total of 308 coho samples were analyzed including 114 collected from drying sections of the Olema Creek mainstem and John West Fork in September 2001 and 189 from the Russian River Green Valley watershed. A total of 18 microsatellite loci were analyzed as part of this program. Analysis of heterozygosity found that the Olema coho had high heterozygosity and had not recently gone through a population bottleneck. In addition, the number of alleles per gene in the Olema Creek individuals was twice that observed within the Russian River Green Valley fish. The result of standardized variance in allele frequencies between populations, measure of genetic distance between populations found that approximately 13% of the observed genetic variation was partitioned between populations. This level of variation is comparable to that observed in steelhead populations between the Smith River (Klamath steelhead ESU) and the Santa Ynez River (Southern California steelhead ESU) (Garza et.al. in prep). Garza and Gilbert-Horvath (2003) conclude that the Russian River Green Valley coho and Lagunitas Olema coho constitute two separate populations with no contemporary gene flow between the two, and that the Lagunitas/Olema Creek coho appear to have been influenced by stocks of fish from the Noyo River (speculation is through hatchbox outplanting).

In addition to the detailed analysis, Garza and Gilbert-Horvath (2003) released a phylogeographic tree which estimated the frequency of 401 alleles using the Cavalli-Sforza/Edwards Chord distance bootstrap method for genetics information in the CCCESU. The results depict the presence of five genetic subgroups within the ESU that are geographically and oceanographically based. This includes:

- Santa Cruz County subgroup which shows some influence from the Noyo stock;
- Redwood/Pine Gulch Creek subgroup which does not show genetic relationship with any other CCCESU coho;
- Lagunitas/Olema subgroup (potentially Tomales Bay) which shows an influence from the Noyo River stock;

- Russian River Green Valley subgroup which does not show genetic relationship with any other CCCESU coho;
- Northern watersheds subgroup including the Noyo and the Pudding Rivers.

Many of these same general relationships were shown in the Bodega Marine Lab investigation which ran the same analysis using fewer resamplings and alleles for analysis (Hedgecock et. al 2002).

The consequences of this analytical information will continue to guide management and recovery into the future. These results led to the adult release of the Olema Creek fish reared as part of the Russian River Broodstock Program to Walker Creek. The watershed was selected because it is within the same oceanographic system and watershed as the Lagunitas/Olema population, despite concerns related to habitat condition and potential effects of mercury on the fish. This action was taken in accordance with similar recommendations described through the CDFG draft coho recovery plan (CDFG 2003).

4.0 ANALYSIS

Coho salmon

Olema Creek is one of the most intensely monitored watersheds for coho salmon within coastal Marin County. Through NPS monitoring efforts, the program has documented significant information about coho salmon behavior, distribution, and use of this small coastal watershed.

The NPS has evaluated salmonid habitat within Olema Creek, and has identified approximately 9 kilometers of year-round high quality habitat in the perennial reaches of the mainstem, beginning upstream from the town of Olema and extending just south of the five brooks area. Eastern tributaries draining from Bolinas Ridge are intermittent, but provide important habitat for winter spawning and overwintering juvenile coho. Access and use of many of these eastern tributaries are restricted by road crossings associated with State Route 1. An analysis commissioned by the County of Marin Department of Public Works identified the Giacomini Gulch and John West Fork culverts as the two highest priorities for restoration within the county (Taylor and Associates 2003). Tributaries draining Inverness Ridge from the west provide the perennial flow to the mainstem but the steep, narrow canyons do not provide any coho habitat.

Genetic evaluations suggest that coho salmon occurring in Olema Creek constitute part of the Lagunitas/Olema genetic subgroup that would likely encompass the entire Tomales Bay watershed. Our data show a strong correlation between adult spawner density and the summer juvenile density, suggesting that year class is the dominant factor associated with population observations in the watershed. Since 1999, all three coho year classes have shown a strong response to changed ocean productivity patterns described in association with the Pacific Decadal Oscillation (PDO) shifted the dominant productivity from the Alaska Current to the California Current in the late 1990s. This shift was likely triggered by the last major El Nino Southern Oscillation Event (ENSO) in 1997. We have observed that high winter spawner numbers have been consistent with increased juvenile densities the following summer, with peaks following Spawner Years 2000-2001 and SY 2001-2002 (Figure 4.1).

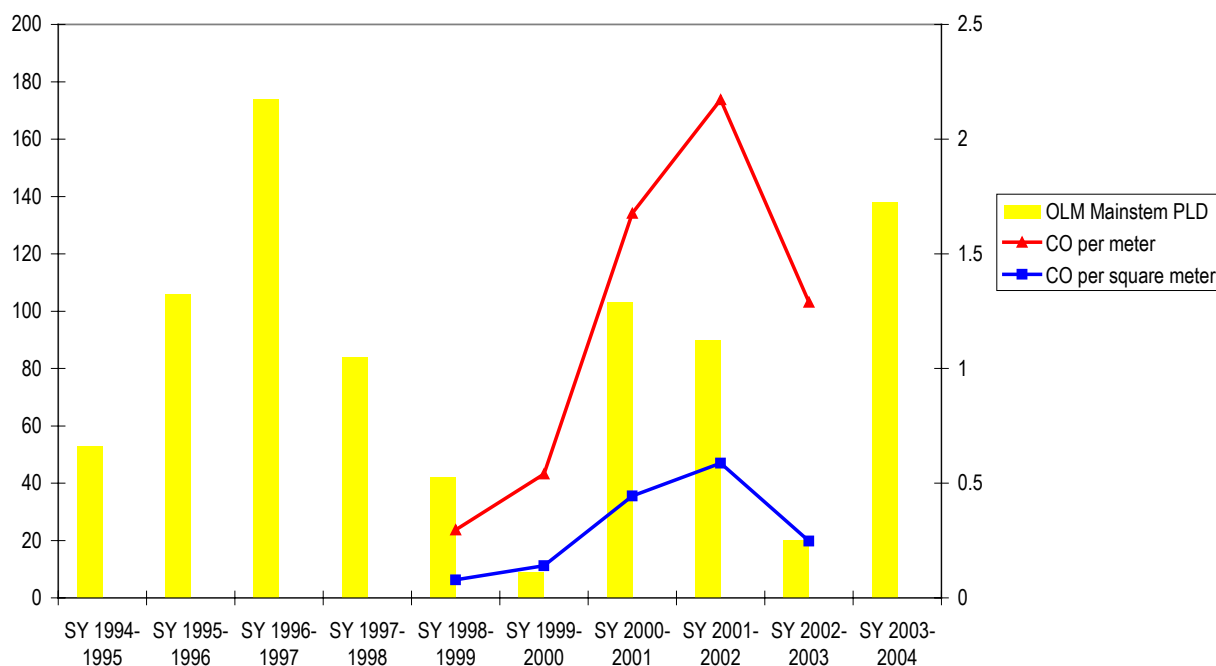


Figure 4.1. Adult coho escapement and subsequent juvenile coho salmon density observed at 8 index reaches within the Olema Creek Watershed. Spawner Year (SY) represents the winter of adult return, therefore SY 1998-1999 represents spawners from the winter 1998-99, and juveniles from the summer of 1999.

Through our monitoring efforts, we have been able to characterize overall watershed trends for coho salmon, including the initiation of basinwide snorkel estimates for a 7.6 kilometer reach of the watershed. Research is suggesting that the most important metric that should be used to characterize watershed condition and productivity is smolt trapping. Through the NPS monitoring program, we have instituted outmigrant smolt trapping in conjunction with the basinwide summer juvenile estimate. In spring 2004, we have implemented outmigrant smolt trapping on the lower Olema mainstem, to complement the summer juvenile estimate. This will allow us to characterize overwinter survival and watershed productivity within Olema Creek. It is likely that overwinter survival is a potential population bottleneck in these watersheds, as it has been observed in watersheds in the north coast (Walt Duffy 2004, personal communication). In Pine Gulch Creek, where we have conducted such monitoring since 2002, we have estimated overwinter survival at levels of juvenile coho at more than 40% when compared to summer juvenile basinwide estimates (Ketcham and Brown 2003). This survival is far greater than estimates of 2.5% to 25% more commonly found in literature (Nickelson and Lawson 1998; Oregon Department of Fish and Wildlife 2002).

John West Fork Observations

Intensive monitoring of the John West Fork, an intermittent tributary to Olema Creek, has documented juvenile rearing and survival within the intermittent reaches, with each pool representing highly localized but stressed conditions. We have observed habitat units to remain isolated for up to six months, while still supporting survival of salmonids. Surveys conducted in preparation for the Russian River Coho Broodstock Recovery Program in 2001 showed stratification within the isolated pools, with pockets of cooler water and higher dissolved oxygen near the bottom of the pools. High densities of coho salmon and steelhead survived in these intermittent pools, likely maintained by groundwater inflow.

Because no fish counting stations are established to calculate adult escapement, the observer efficiency of redds and fish within the watershed is assumed to be on the order of 60-80% depending on the year. Within the two kilometer spawning habitat of the John West Fork tributary, the confidence level in our observations of both fish and redds is higher. Using rough calculations, we derived egg to smolt survival rates for 5 years of data from the John West Fork (table 4.1). Egg deposition is calculated at 2,500 eggs per female (Moring and Lantz 1975). Because we counted redds rather than individual females, and we know that females do not always lay all their eggs in a single redd, we used an estimate of 2,000 eggs per redd for our calculations.

Table 4.1. Multiple life stage observations of coho salmon within the John West Fork above the restored culvert since 1999. Note culvert fish passage enhancement (restoration) completed summer 1999.

	Spawner Year (SY)				
	1999-00	2000-01	2001-02	2002-03	2003-04
Maximum Live Coho count Male	5	21	6	12	
Maximum Live Coho count Female	3	29	7	6	
Redds	3	40	25	12	19
Estimated number of Eggs	6,000	80,000	50,000	24,000	38,000
Young of Year Coho passing through trap	13	6,520	5,399	1,561	Spring 2004
Summer index reach density [coho/meter]	0. 0 ^b	8.4 ^b	9.7 ^b	0. 6 ^b	Summer 2004
Juvenile survival estimate assuming 1,500 meters habitat	0	12,600	14,550	900	Summer 2004
Smolt outmigration (year old coho)	5	98	181	Spring 2004	Spring 2005
Egg to smolt survival	0.08%	0.13%	0.36%		

^b counts conducted in 3 pool units and two riffles above the culvert

Coho smolt production within John West Fork has increased dramatically over the past three survey seasons. We have assumed that juvenile fish are not able to move up through the culvert in the winter. The estimates presented in Table 4.1 are presented assuming this system is closed to juvenile access.

Regional observations

Habitat condition and coho response is controlled by the hydrologic regime within the watershed. With year class taken into account, our observations show that since 1999, we have seen an increasing trend in adult escapement and subsequent juvenile density and smolt conditions. The responses we have observed are not limited to Olema Creek, but are regional in nature. We analyzed the response of juvenile densities within the Lagunitas, San Geronimo/Devil's Gulch, Pine Gulch and Redwood Creek. For all watersheds we are able to compare coho density per meter. We are also able to compare densities of coho per square meter for all of the watersheds except for Redwood Creek. Results of these comparisons show that the same general trend in juvenile coho densities are occurring, with the highest observed densities in 2001 and 2002. In all watersheds we have seen a drop in coho juvenile density associated with the SY 2002-2003 year class. Figures 4.2 through 4.6 show coho density results from different watersheds through the last decade.

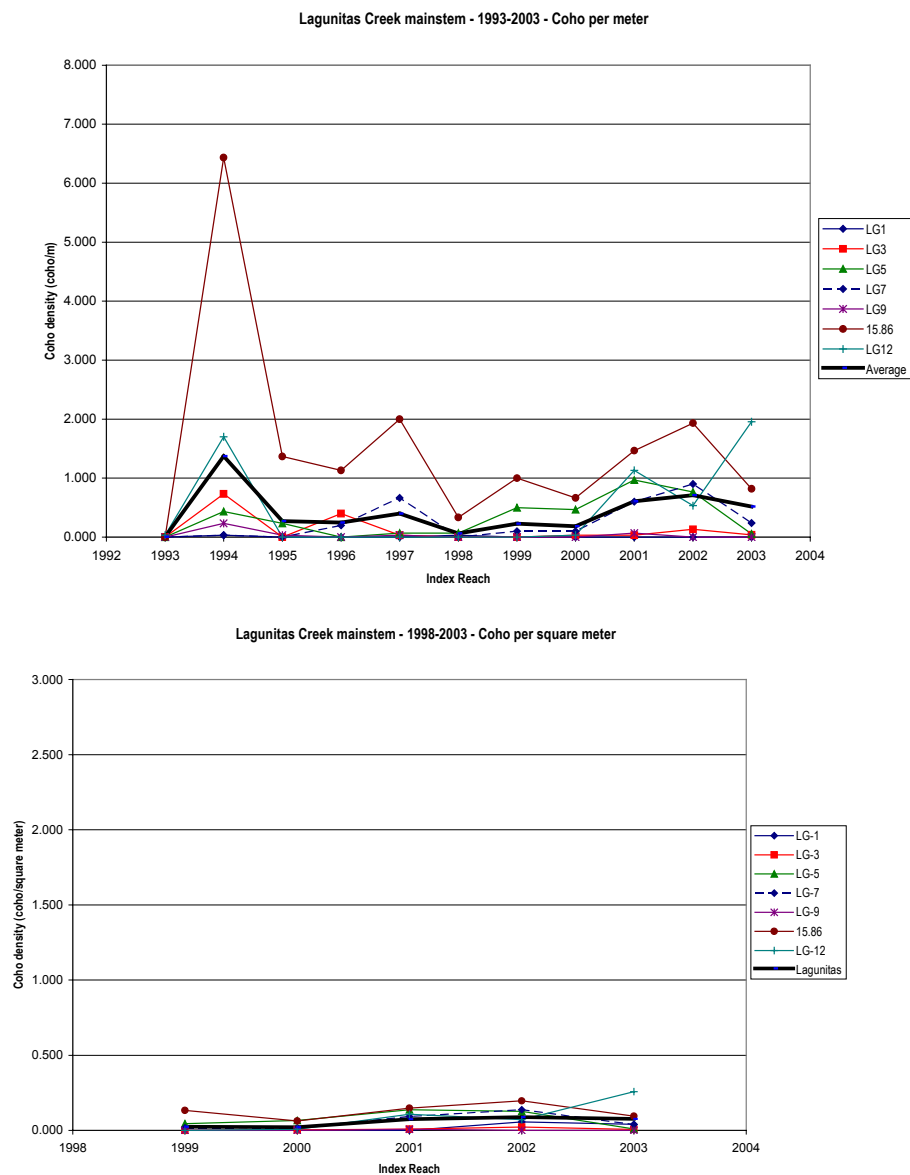


Figure 4.2

Juvenile coho salmon density per meter observed in seven index reach locations within the mainstem of Lagunitas Creek (above), four index reach locations in San Geronimo Creek (below), and two index reach locations in Devil's Gulch (below), Marin County, CA, 1993-2003 (MMWD data). Top: fish/m 1993-2003; Bottom: fish/m² 1999-2003.

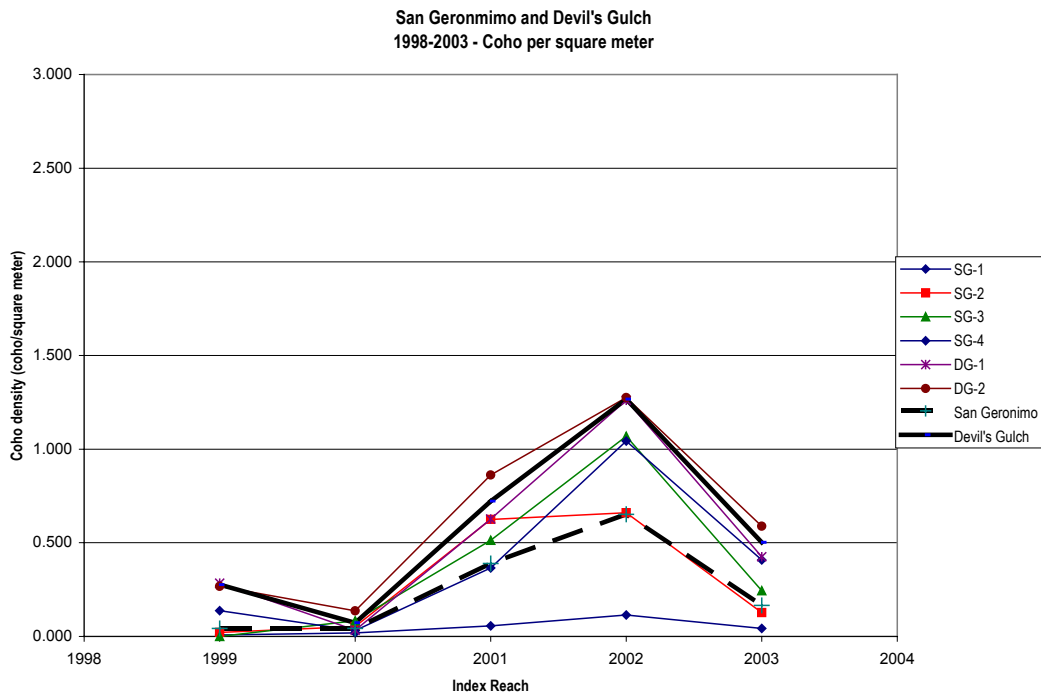
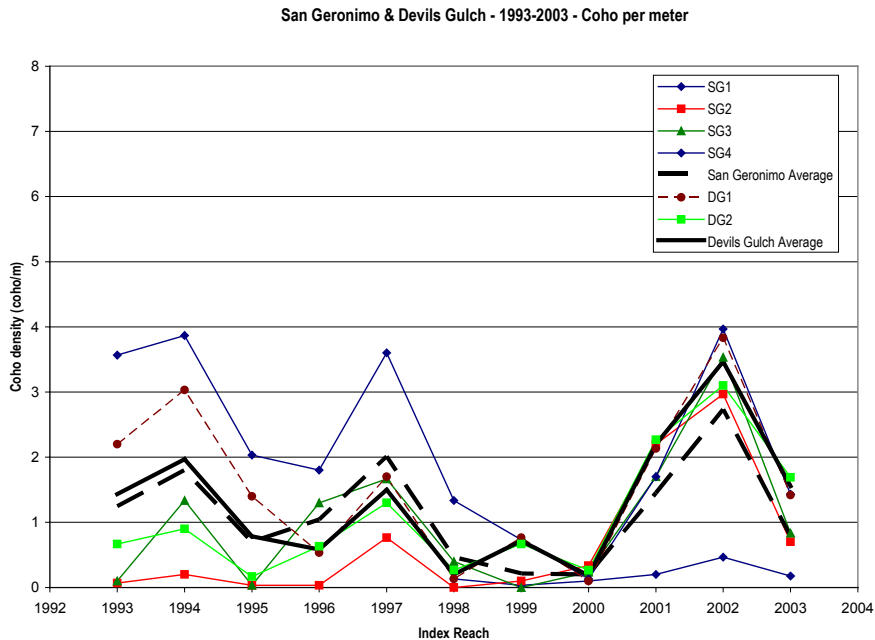


Figure 4.3

Juvenile coho salmon density per meter observed in four index reach locations in San Geronimo Creek (below), and two index reach locations in Devil's Gulch (below), Marin County, CA, 1993-2003 (MMWD data). Top: fish/m 1993-2003; Bottom: fish/m² 1999-2003.

San Geronimo Creek and Devil's Gulch are the major tributaries of Lagunitas Creek upstream of the estuarine waters. MMWD (Ettlinger 2004 personal communication) has shown a correlation between spawning density in the San Geronimo Creek watershed and increased juvenile density in the mainstem of Lagunitas Creek. Watershed average densities range from 0.1 to 1.3 coho per meter in the mainstem, while tributary ranges are from 0.2 to more than 3 coho per meter

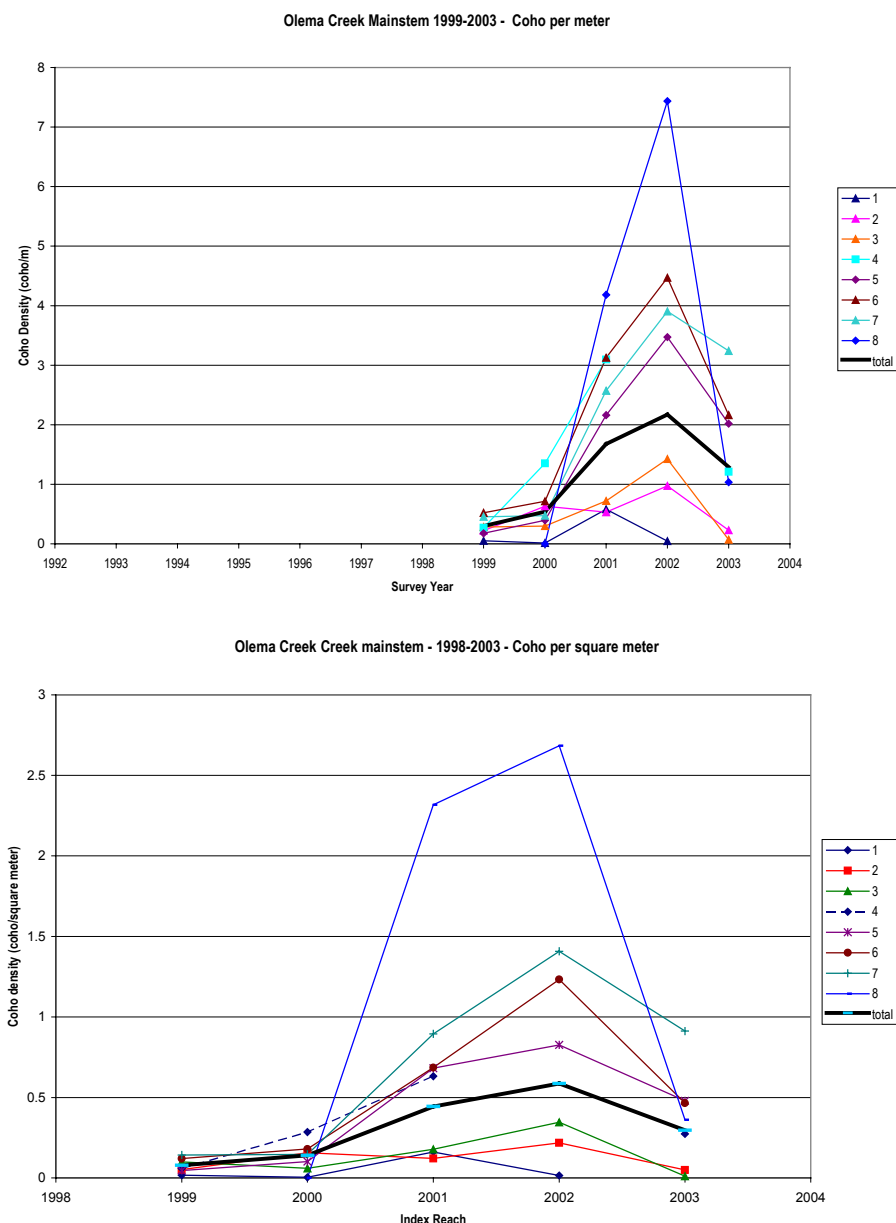


Figure 4.4 Juvenile coho salmon density per meter observed in eight index reach locations within the mainstem of Olema Creek Marin County, CA, 1999-2003 (NPS data). Top: fish/m; Bottom: fish/m².

Results from Olema Creek show a watershed wide response by coho during survey years 2001 and 2002. Average watershed densities within the index reaches have ranged from 0.4 to 2.2 coho per meter. The reduced density in 2003 corresponded with the weakest spawning year class and a 7.5 kilometer mainstem juvenile snorkel based estimate of $11,926 \pm 3,244$ coho.

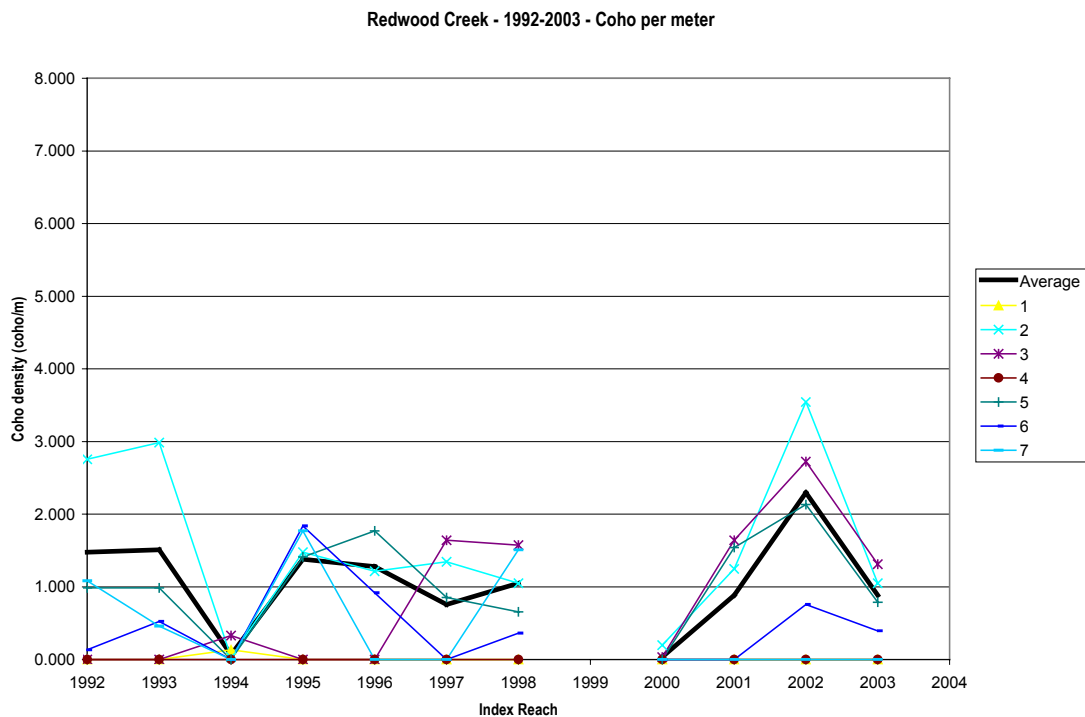


Figure 4.5 Juvenile coho salmon density per meter observed in seven index reach locations within the mainstem of Redwood Creek Marin County, CA, 1992-2003 (J. Smith-SJSU data).

The index reach locations within Redwood Creek are responsive to spatial distribution to spawning habitat, and densities are also effected by summer water use patterns. Densities have fluctuated from very near 0 to greater than 2.1, with a recent resurgence of juvenile densities corresponding to density increases along the Marin County coast.

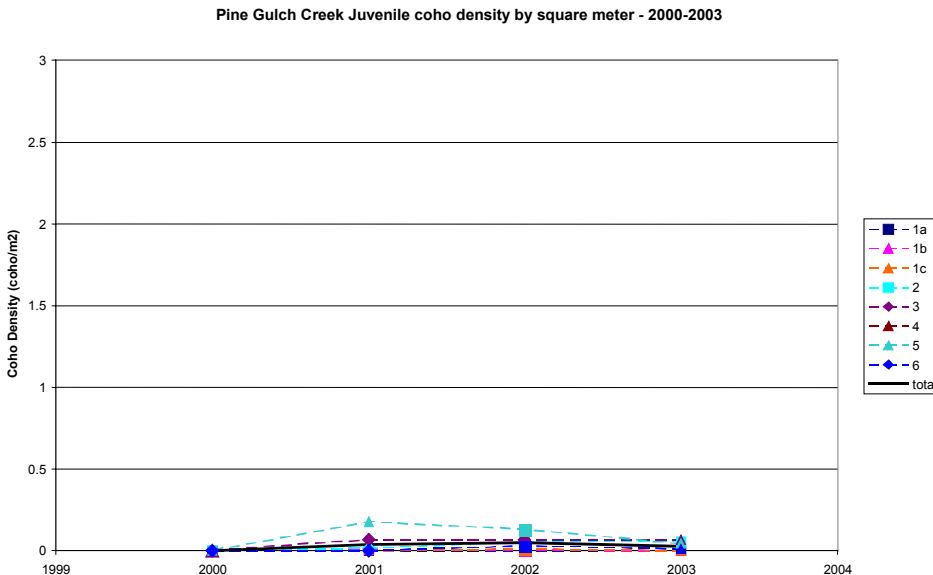
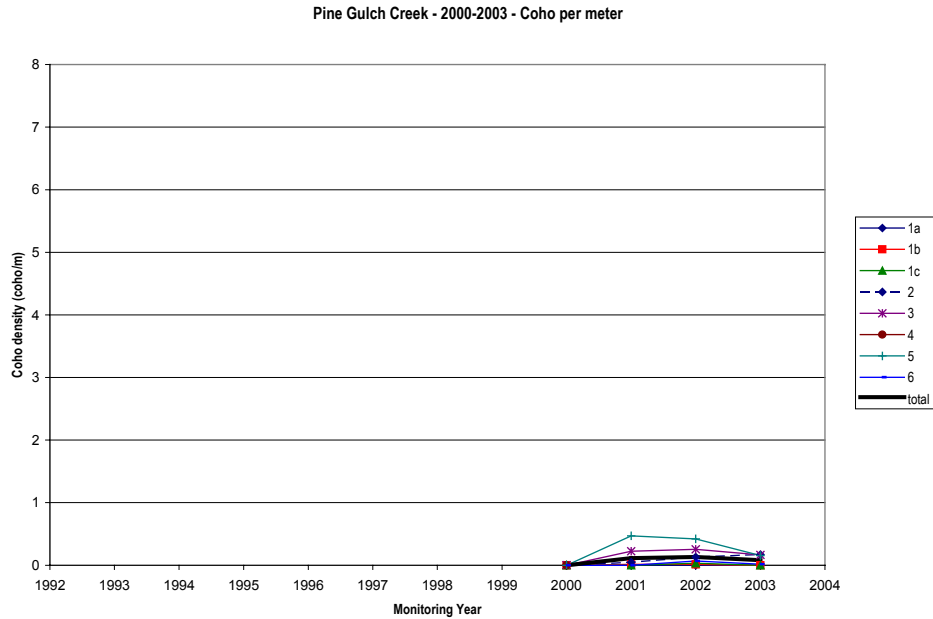


Figure 4.6 Juvenile coho salmon density per meter observed in seven index reach locations within the mainstem of Pine Gulch Creek, Marin County, CA, 2000-2003 (NPS data). Top: fish/m; Bottom: fish/m².

The index reach locations within the Pine Gulch mainstem are representative of overall watershed conditions, even at very low coho densities. These data are included to show a potential signal corresponding to a natural return of coho to a small coastal watershed. While density was very low, we found a rather broad distribution of coho throughout the watershed. It should be noted that no juvenile coho were observed in the watershed prior to 2001, despite implementation of the index reach monitoring program in 2000. Juvenile density estimates using the Hankin-Reeves snorkel survey protocol in 2002 were twice that observed in 2001 and 2003. The reported index reach densities were not all that much different.

Steelhead

While monitoring of coho salmon shows strong adult escapement, juvenile, density, and smolt density correlation between year class, steelhead do not track in the same manner. While observations of steelhead adults encountered during coho spawner surveys are recorded, the behavior and potential impacts of targeted steelhead surveys have been determined to be incompatible with our monitoring goals. Steelhead are elusive, making adult counts difficult, and when we have encountered them on redds, they seem more subject to flush great distances, whereas coho generally move to cover in the same pool. With that said, steelhead are ubiquitous in the Olema Creek watershed. Observations throughout the perennial and intermittent sections of Olema Creek and its tributaries reveal steelhead. They are present up nearly all tributaries, and their reproductive and life cycle flexibility make them far more persistent in these watersheds than coho. Our data do not show distinct year class distinctions in steelhead, which is consistent with their flexible life-cycle. This is likely because juvenile steelhead density is likely based on a combination of ocean-run and resident reproduction.

As part of summer index reach monitoring, we have encountered steelhead in every sample location and nearly every habitat feature sampled. Monitoring results from these surveys do show a steady decline in observed steelhead juvenile density during the five years of index reach monitoring. Our program has not attempted to conduct basinwide estimates for steelhead for the same reasons enumerated for the adult steelhead. They are very skittish fish, and their behavior is not conducive to accurate snorkel counts. Staff does, however, document their presence or absence in conjunction with other surveys.

One issue that is commonly raised, with respect to the interaction of coho and steelhead, are the effects coho reintroduction might have on steelhead populations. In the Olema watershed, the declines we have observed could have some relationship to the large increase in coho over the past few years, but there are other environmental factors that could be affecting the success of steelhead in the watersheds. Most important of these is the presence or lack of spring rainfall. There have been some years where the measured rain from March into the summer is not adequate to raise spring flows to accommodate adult steelhead upstream migration, and in some cases, could effect emergence of juveniles from redds.

For steelhead, spawning occurs later in the winter and early spring. While we have not observed limitations on the ability of ocean-run steelhead to access the watershed in late January – March, we have observed some very dry spring conditions that likely limited the emergence success from steelhead redds. This is most acute in the John West Fork tributary, where steelhead young of year numbers observed to be moving downstream through the smolt trap have ranged from 47 to 6,603 (Table 3.9). It is likely that this response is limited to the intermittent tributaries, but it is a sign of how steelhead respond in these drier springs.

Despite all of our winter monitoring efforts, and observation of coho and ocean-run steelhead spawning in the stream, we have not actually observed spawning by resident rainbow trout, though it is very likely to occur. When we have observed female steelhead on a redd, a large male has often been seen in accompaniment. When a smaller male has been observed, we could not determine whether this was a resident, or a “half-pounder” that may have returned early.

5.0 RECOMMENDATIONS

5.1 *Adult Escapement*

Our program now includes 10 years of spawner surveys within the watershed. Adult escapement is an important measure, and is conducive to involving many volunteers for spawner counts. We plan to continue these efforts, making a point to increase frequency (see methods below) so that we can employ additional statistical evaluation to determine actual escapement.

Methods

Adult spawner surveys have been conducted based on environmental conditions. Staff should work to increase survey frequency to improve our ability to conduct Area Under the Curve (AUC) estimates. The current surveys are adequate, and provide good AUC estimates in some years. This really will involve conducting a few more surveys under suboptimal conditions to estimate watershed escapement.

Coordination of volunteers is essential to the conducting watershed based surveys, but we have not been able to determine the efficiency of these volunteers in the identification of fish and redds. While fish are constantly moving and recounts would not readily improve results, redd identification and measurement is being investigated as a better measure of coho productivity within a watershed. Investigations by the CDFG in northern California indicate that measuring the surface area of redds can be a good measure of female effort and reproduction within a watershed (Gallagher 2003 personal communication). Staff should follow up watershed scale surveys with redd based surveys to collect more detailed redd dimension information, as well as to confirm redd identification and/or missed redds as part of the survey. A better count of redds, and an understanding of female redd effort could be used as a measure to determine total eggs distributed in any given year.

Analysis

Staff should document date of entry for coho salmon and maintain datasets previously established and extended through this analysis. The analysis of spawner survey data should be reported annually with the results of the other coastal Marin County watersheds. Our data are shared with the MMWD and reported as part of the Lagunitas Creek watershed, but the only real compatible measure is redd counts. The NPS and MMWD should strive to analyze some basic escapement data in the same manner for ready comparison. Our suggestion is that the MMWD apply AUC estimates to their existing data to see how well the results compare. They survey weekly under more variable conditions, and have a high likelihood of recounting fish. The AUC method would account for much of this possibility and could complement the analytical methods they currently use.

As noted above, additional effort related to redd investigations will add a valuable component (egg estimates) to the data already collected through this program. Many programs report egg to smolt survival as a measure of watershed success. The work we do between these life stages would simply complement the effort and provide more reasonable breakdown of potential population bottlenecks.

5.2 *Smolt trap operations*

In 2004, staff installed a smolt trap on lower Olema Creek to complement the basinwide estimate conducted in summer 2003. We are in our third year of similar complementary sampling on the Pine Gulch Creek watershed. It is our plan to evaluate these results to determine watershed overwinter survival as well as smolt density. Smolt density has been used in many watersheds to predict adult escapement.

Methods

Operations of the smolt traps have been modified through the years to increase efficiency and reduce handling stress to the fish. In the past, all 1+ fish were anesthetized, weighed, and measured. With installation of trap locations in lower Olema Creek and Pine Gulch Creek, our trapping expectations are much higher. In addition, trap efficiency should be tested. The NPS will operate these traps and conduct efficiency testing using the following methods:

Randomly select 10 smolts/presmolts (or 20% - whichever is greater) of each species. These fish should be weighed, measured, marked, and released upstream to test trap efficiency. Fish recaptured in the trap will be

documented and released downstream. The mark may be a fin clip (caudal) that may also be used for genetic analysis, or a dye mark administered with a pan-jet needless injector. This will insure that sampling numbers are adequate for detailed biotic analysis, as well as insure that enough fish are marked to estimate trap efficiency.

Future reporting should also include temperature and flow data measured at or near the trap site to determine how these environmental factors effect outmigration. At the John West Fork site, the NPS has anecdotal observations of increased movement of fish under cooler, cloudier conditions. Deployment of water and air temperature loggers near the trap should be implemented.

Analysis

The recommended processing and efficiency testing methods will reduce the potential number of fish that are handled and marked through this program. Random selection of the fish will facilitate effective statistical evaluation of the data for reporting purposes.

Reporting of the seven day moving average of the daily maximum temperature (7DMADMT) should be calculated and reported for the trap sites. Within the Olema Creek watershed, the same should be done with temperature data collected at the Bear Valley Road Bridge site, upstream of the Olema Flat area.

5.3 Index Reach Monitoring

Index reach monitoring may not be representative temporally because juvenile fish are not evenly distributed within a watershed (Duffy 2004 personal communication). This is true where no other information is collected. Based on evaluation of our data within Olema Creek, we feel that the index reaches in the mainstem, and the fisheries results are representative of watershed conditions through both wet and dry water years.

Methods

The NPS will consider modification of index reach monitoring to the tributary monitoring efforts. Rather than sampling discreet reaches within the tributaries, the NPS will test monitoring efforts on randomly selected units within a longer reach. This would be conducted on Quarry Gulch and John West Fork within the Olema Creek watershed, and will be implemented in other watersheds where monitoring efforts are currently being established.

Based on location, size, and ability to conduct effective electrofishing activities, the NPS recommends discontinuing monitoring efforts on Olema mainstem Index Reach 4 (Truttman). This area represents very stable and well developed habitat, but the pool units are very large, and requires two backpack units to electrofish. Monitoring of this area is not essential to the overall understanding of watershed condition and productivity.

In order to minimize handling of fish and increase efficiency, the index reach monitoring protocol will reduce the number of fish weighed and measured. A total of 10 randomly selected fish per species, per age class should be weighed and measured for each electrofishing pass within a habitat unit. Through the five years of conducting index reach monitoring, the NPS has sampled an average of 23.6 pool, 7.6 riffle and 5.0 flatwater units between the eight index reaches on the Olema mainstem. Typically pool and flatwater units are sampled with two passes to collect depletion information, and riffles are sampled with a single pass due to logistics and the potential to injure fish in the shallow waters. By this calculation, up to 67 electrofishing passes may be conducted, allowing for weights and measures of up to 670 species and age class biometric measurements to be collected. The raw catch information presented in Table 3.12, total catch of coho and steelhead YOY has exceeded this number in many of the monitoring seasons. This assumes that in every pass, more than 10 fish of each species and age class will be collected, which is not the case through our program. It is our estimation that through this method, approximately 300 fish of each species and age class will be weighed and measured, which is a significant reduction from previous years. Remaining fish will be identified, counted, and weighed collectively for eventual use in biomass productivity estimates. This method should reduce the number of fish that are subjected to the stress of anesthesia and handling.

INDEX REACH – JOHN WEST FORK

Three index reaches on the John West Fork have been monitored since 2000. As opposed to our findings on the mainstem, that index reach monitoring is representative of watershed response, the John West Fork index reach

locations and results are highly linked to very localized observations specifically related to the culvert restoration. We have seen coho juvenile densities in excess of 9 fish per meter, which is linked to high redd densities observed the previous winter. Based on our findings we are recommending that index reach surveys be modified to cover a more representative part of the watershed, while still retaining elements related to the culvert restoration.

A full habitat survey of the two kilometer spawn survey reach should be conducted identifying pool, riffle, and flatwater habitat. Three reaches, including the 200 meters below the culvert, intermittent section in the 400 meters below the cattle crossing, and intermittent or perennial reaches in the 1400 meters upstream of the cattle crossing would be evaluated as separate reaches. Staff would randomly select three pool units to sample within each spatial reach area. These reaches would be sampled in June, once intermittent flow has established and movement between units is limited. This will provide more representative data that can be used to describe the juvenile densities and use within the watershed.

INDEX REACH – QUARRY GULCH

Three index reaches on the John West Fork have been monitored since 2000. These are confined to the lower areas west of State Route 1 and, while representative of a proposed habitat restoration area, are not developed to represent conditions (other than presence/absence of coho) in the tributary. Based on our findings we are recommending that index reach surveys be modified to cover a more representative part of the watershed, while still retaining elements related to the proposed restoration.

A full habitat survey of the lower 1.5 kilometers of the stream channel should be conducted identifying pool, riffle, and flatwater habitat. Two reaches, including the intermittent to perennial sections of the 800 meters below the State Route 1 culvert, and the intermittent or perennial reaches in the 700 meters upstream of the State Route 1 culvert would be evaluated as separate reaches. Staff would randomly select three pool units to sample within each spatial reach area. These reaches would be sampled in June, once intermittent flow has established and movement between units is limited. This will provide more representative data that can be used to describe the juvenile densities and use within the watershed.

Analysis

All data should be analyzed to a confidence level of 95%

5.4 Basinwide population estimate

Methods

The level of monitoring effort to conduct basinwide population estimates is very high. In order to operate more efficiently, and accommodate continued implementation of the index reach monitoring program, the NPS has used the index reach pool units as the snorkel survey calibration units. Because the snorkel survey methods are based on random sampling and calibration, this may introduce bias since the index reach habitat units are not randomly selected. Four index reaches including approximately 14 pools are monitored within the basinwide snorkel survey area. In order to prevent bias, the NPS will randomly select a subset of these index reach pools that will be used for the calibration. In addition, five randomly selected pools from the snorkel survey will be electrofished for use in the snorkel survey calibration.

Analysis

The analysis of field collected data has proven very effective at providing the NPS with a high level of confidence in its data.

5.5 Population extrapolation

Methods

The NPS has extrapolated population estimates based on densities collected through the index reach monitoring efforts, and applied to habitat surveys conducted in the same monitoring season. These extrapolations are conducted to compare with the basinwide population estimates conducted using a more statistically rigorous method. These

extrapolations are not statistically acceptable, but will continue to be presented as information collected through this program.

Analysis

The NPS should continue to report this information with the appropriate caveat that the data is not statistically valid, and that the extrapolation assumes equal density throughout the watershed and does not account for spatial variability. The program should also specify whether the extrapolation is conducted using a habitat survey from the same season, or if it is one conducted in previous years. While at the watershed scale, it is likely that stream length and surface area do not change significantly, localized changes may have significant bearing on overall habitat quality and condition.

5.6 Genetic Analysis

The NPS will continue to collect genetic samples for analysis through the NOAA-Fisheries Genetics Lab.

5.7 Other Monitoring Efforts

A number of other monitoring efforts have been conducted through the years in association with this program. These include watershed habitat and condition assessment, woody debris analysis, and temperature monitoring. Streamflow data are reported in conjunction with water quality monitoring and have been incorporated where appropriate to this document.

Habitat assessment

In the initial stages of this program, extensive watershed monitoring was conducted to assess condition and habitat quality. Much of this information was evaluated as part of a Masters Project document (Beamish 2000). Repetition of such habitat surveys would be valuable to evaluate change over time. More recently, two reaches of Olema Creek were analyzed as part of dissertation research related to the role of woody debris in forming habitat within hardwood dominated riparian zones (Opperman 2003). This work found that in Olema Creek, many of the wood-associated, habitat forming features were living trees that would not normally be counted as part of a woody debris survey. Detailed surveys of woody debris features could be repeated to evaluate this work in a temporal context.

Temperature

The NPS has deployed temperature loggers at multiple locations within the watershed since 1997. Evaluation of these data should be conducted and reported in the next year. Stream temperature is a concern with respect to salmonid habitat, and evaluation of existing long-term monitoring data would be important to understanding watershed condition and performance.



Water Quality

Extensive water quality monitoring is conducted within the watershed and will be reported separately. Evaluation of data in 2001 showed that Giacomini Gulch and Quarry Gulch were significant sources of sediment and pathogens to the mainstem of Olema Creek. Further evaluation on these subwatersheds identified potential sources and solutions. Continued water quality monitoring has occurred and results will be reported in detail in the next year.

6.0 REFERENCES

- Anderson, R.O. and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283-300. *In*: L.A. Nielsen and D.L. Johnson (eds.) Fisheries techniques. American Fisheries Society, Bethesda, MD.
- Anderson, D. and H. McGuire. 1994. Redwood Creek basin 1991-1992 spawning and carcass survey, annual report. Unpublished report. National Park Service, Redwood National Park. Arcata, CA.
- Beidler, W. M. and T. E. Nickelson. 1980. An evaluation of the Oregon Department of Fish and Wildlife standard spawning fish survey system for coho salmon. Oregon Department of Fish and Wildlife Information Report Series, Fisheries Number 80-9.
- Bohlin, T., S. Hamrin, T.G. Heggberget, G. Rasmussen, and S.J. Saltveit. 1989. Electrofishing: theory and practice with special emphasis on salmonids. *Hydrobiologia* 173: 9-43.
- Bratovich, P.M. and D.W. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California. Vol I. Migration, spawning, embryo incubation and emergence, juvenile rearing, emigration. Prepared for the Marin Municipal Water District. 187 p.
- Brown, L. R., and P. B. Moyle. 1991. Status of coho salmon in California. Report to the National Marine Fisheries Service, 114 p. (Available from Environmental and Technical Services Division, U.S. Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)
- Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. *N. Am. J. Fish. Manage.* 14:237-261.
- Brown, G.G. and B. J. Ketcham. 2002. Documentation of Coho Salmon in Pine Gulch Creek, Marin County, CA. Coho Salmon and Steelhead Trout Restoration Project. PORE-NRWR-02/02. 12 pp. plus appendices.
- California Department of Fish and Game (CDFG). 1968. Field notes from Bruce Thompson and Jim Michaels – July 1968.
- California Department of Fish and Game (CDFG). 2002. Status review of California coho salmon north of San Francisco. Report to the California Fish and game Commission. 231pp.
- California Department of Fish and Game (CDFG). 2003. Public Review draft Recovery Strategy for California Coho Salmon (*Oncorhynchus kisutch*). Species Recovery Plan Report 2003-1.
- California Regional Water Quality Control Board (CRWQCB). 2001. Controlling pathogens in Tomales Bay, California. Total maximum daily load: Sources and loadings. Progress report, June 30, 2001. CRWQCB, San Francisco Bay Region. San Francisco, CA. 78 pp.
- Cederholm, C.J. and W.J. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981, p. 98-110. *In* E.L.Brannon and E.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, WA.
- Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. *Transactions of the American Fisheries Society*. 94:40-52.
- Collins, Barry W. (editor). 2003. Interim restoration effectiveness and validation monitoring protocols, California Coastal Salmonid Restoration Monitoring and Evaluation Program. March 2003, p. 320. California Department of Fish and Game. http://www.dfg.ca.gov/nafwfb/2003/200303_Interim_Protocol_Manual.pdf

- Dietrich W. E. 1997. Analysis of the Olema Creek avulsion. Performed as part of field work for graduate geomorphology class, Spring 1996. UC Berkeley.
- Dollof, C.A., D.G. Hankin, and G.H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. Gen. Tech. Rept. SE-83. USDA Forest Service Southeastern Forest Experiment Station, Asheville, NC. 25 pp.
- Downie, S. and G. Petersen. undated. Spawning Inventory. California Department of Fish and Game unpublished instructions for conducting spawner surveys.
- Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. WH. Freeman and Co., New York. 818 p.
- Federal Register. 1996. Final Rule. Endangered and threatened species: Threatened status for Central California Coast coho salmon evolutionarily significant unit (ESU), October 31, 1996. 61 (212): 56138-56149
- Federal Register. 1997. Final Rule. Endangered and threatened species: Listing of several evolutionary significant units (ESU's) of west coast steelhead, August 18, 1997. 62(159): 43937-43954
- Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R. and Collins, B. 1998. California salmonid stream habitat restoration manual. 1998. 3rd ed. California Department of Fish and Game. 495 p.
<http://www.dfg.ca.gov/nafwb/pubs/manual3.pdf>
- Garza, C. and Gilbert-Horvath. 2003. Report on the genetics of coho salmon (*Oncorhynchus kisutch*) held at the Warm Springs (Don Clausen) Hatchery for recovery efforts in the Russian River. NOAA Southwest Fisheries Science Center. Santa Cruz Laboratory. 15pp.
- Gilbert, G.K. 1908. Characteristics of the rift and Earth movement on the fault, Tomales Bay to Bolinas Lagoon. in Report of the State Earthquake Investigation Commission: Carnegie Institution of Washington Publication 87. v.1. p 30-35, 66-87.
- Hassler, Thomas. J., 1987. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- Coho. U.S. Fish and Wildlife Service Biol. Rep. 82 (11.70). U.S. Army Corps of Engineers, TR EL-82-4. 19 pp.
- Hedgecock, D., Banks, M., Bucklin, K., et al. 2002. Documenting biodiversity of coastal salmon (*Oncorhynchus* spp.) in northern California. Bodega Marine Laboratory. University California at Davis. 47 pp. plus appendices.
- Irvine, J. R., R. C. Bocking, and K. K. English, and M. Labelle. 1992. Estimating coho salmon (*Oncorhynchus kisutch*) escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Canadian Journal of Fisheries and Aquatic Sciences 49: 1972-1981.
- Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1987. Instream indexing of coho salmon (*Oncorhynchus kisutch*) escapement in French Creek, British Columbia. Canadian Technical Report of Fisheries and Aquatic, No. 1573.
- Ketcham B.J., and G.G. Brown. 2003. Coho salmon (*Oncorhynchus kisutch*) in Pine Gulch Creek, Marin County, CA. 2002 Monitoring Report. Coho Salmon and Steelhead Trout Restoration Program. PORE-NR-WR-03/01. 20pp. Plus appendices.
- Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--coho salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp.

- Livingston, D. 1991. History of Ranching in the Olema Valley. National Park Service. Point Reyes National Seashore.
- Manning, D.J., and Roelofs, T.D. 1996. Coho Carrying Capacity and Limiting Habitats Analysis – 1996 Smolt Trapping Protocol. Department of Fisheries, Humboldt State University.
- Manning, D.J. 1999. Coho and Steelhead Restoration Project Annual Coho Salmon Spawner Survey Report: 1997-98. Coho and Steelhead Restoration Project. PORE-NR-WR-99/01. 45 pp. plus appendices.
- Manning, D.J. 2001. Carrying capacity and limiting habitat analysis for coho salmon (*Oncorhynchus kisutch*) in streams of northwestern California. Humboldt State University: Masters Thesis. 119 p.
- Marin Municipal Water District (MMWD). 2003. Juvenile salmonid population monitoring report, Lagunitas Creek, Marin County, California, fall 2002. Marin Municipal Water District, Corte Madera, CA.
- Moring, J. R., and R. L. Lantz. 1975. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I- Biological studies. Oreg. Dep. Fish Wildl., Fish. Res. Rep. 9, 66 p.
- Moyle, P. B. 1976. Inland fishes of California. Univ. California Press, Berkeley, 405 p.
- Moyle, P.B., Marchetti, M.P., Balrige, J., and Taylor, T.L. 1998. Fish Health and Diversity: Justifying Flows for a California Stream. American Fisheries Society: Fisheries Vol. 23, No. 7. Pp. 6-16.
- National Marine Fisheries Service (NMFS). 2001. Status review and update for coho salmon (*Oncorhynchus kisutch*) from the central California coast and the California portion of the southern Oregon/northern California coasts Evolutionary Significant Units. Prepared by the Southwest Fisheries Science Center, Santa Cruz Laboratory, Santa Cruz, CA. 40pp.
- National Park Service (NPS). 2001a. Point Reyes National Seashore Water Quality Monitoring Report May 1999-May 2001. U.S. Department of Interior, National Park Service
- National Park Service (NPS). 2001b. Coho and Steelhead Restoration Project Annual Section 10 Permit Data Report: July 1, 1999 – June 30, 2000. Coho and Steelhead Restoration Project. PORE-NR-WR-01/01. 8 pp. plus appendices
- National Park Service (NPS). 2002a. Coho and Steelhead Restoration Project Annual Section 10 Permit Report: July 1, 2000 – June 30, 2001. Coho and Steelhead Restoration Project. PORENR-WR-02/03. 9 pp. plus appendices.
- National Park Service (NPS). 2002b. Coho and Steelhead Restoration Project Annual Section 10 Permit Report: July 1 – December 31, 2001. Coho and Steelhead Restoration Project. PORENR- WR-02/04. 9 pp. plus appendices.
- National Park Service (NPS). 2003a. Coho and Steelhead Restoration Project Annual Section 10 Permit Report: January 1 – December 31, 2002. Coho and Steelhead Restoration Project. PORENR- WR-03/02. 14 pp. plus appendices.
- National Park Service (NPS). 2003b. Draft stream aquatic resource monitoring protocol. San Francisco Area Network Inventory and Monitoring Program. 200 pp.
- National Park Service (NPS). 2004. Draft San Francisco Area Network water quality planning meetings summary. San Francisco Area Network water quality monitoring program. 31 pp. Plus appendices.
- Neimi T.M. and Hall, N.T. 1996. Historical changes in the tidal marsh of Tomales Bay and Olema Creek,

- Marin County, California. *Journal of Coastal Research*, 12(1), 90-102. Fort Lauderdale, FL.
- Niemi, T.M. 1992. Late holocene Slip Rate, Prehistoric Earthquakes, and Quaternary Neotectonics of the Northern San Andreas Fault, Marin County, California. Stanford University, PhD Dissertation.
- Nickelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, R. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. *Oreg. Dep. Fish. Wildl., Res. Develop. Sect. and Ocean Salmon Manage.*, 83 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)
- Nickelson, T.E., and P.W. Lawson. 1998. Population viability of coho salmon, *Oncorhynchus kisutch*, in Oregon coastal basins: application of a habitat-based life cycle model. *Journal of Fisheries and Aquatic Science* 55:2383-2392.
- Opperman 2003. Large Woody Debris and Anadromous Fish Habitat in California's Mediterranean-climate Watersheds. Master's Thesis. University of California, Berkeley; Department of Environmental Science, Policy and Management April 7, 2003.
- Robison, E.G.; A. Mirati; and M. Allen. 1999. Oregon road/stream crossing restoration guide: spring 1999. Advanced Fish Passage Training Version. 75 p.
- Roni, P., T.J.Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollack, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *N. Am. J. Fish. Man.* 22 (1): 1-20.
- Sandercock, F.K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). Pages 395-446. In: C. Groot and L. Margolis, eds. *Pacific salmon life histories*. UBC Press, Vancouver, British Columbia.
- Scarlett, W.J. and C.J. Cederholm. 1984. Juvenile coho salmon fall-winter utilization of two small tributaries of the Clearwater River, Jefferson County, Washington, p. 227-242. In J.M. Walton and D.B. Houston, editors. *Proceedings of the Olympic Wild Fish Conference*, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.
- Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with specific reference to Waddell Creek, California, and recommendations regarding their management. *California Department of Fish and Game Fish Bulletin* 98.
- Skeesick, D.B. 1970. The fall immigration of juvenile coho salmon into a small tributary. *Res. Rep. Fish Comm. Oregon* 2: 90-95.
- Smith, J.J. 2001. Distribution and abundance of coho and steelhead in Redwood Creek in Fall 2001. Report to Golden Gate National Recreation Area, National Park Service. 10 pp.
- Taylor, R.N. and M. Love. 2003. Fish passage evaluation at road crossings. Section 10 of the California Salmonid Stream Habitat Restoration Manual, CDFG Agreement #P9985035.
- Taylor and Associates. 2003. Marin County Stream Crossing Inventory and Fish Passage Evaluation: Final Report. Prepared for the County of Marin – Department of Public Works, June 2003. 70 pp.
- Tripp, D. and P. McCart. 1983. Effects of different coho stocking strategies on coho and cutthroat trout production in isolated headwater streams. *Can. Tech. Rep. Fish. Aquat. Sci.* 40: 452-461.
- Tschaplinski, P. J., and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. *Can. J. Fish. Aquat. Sci.* 40:452-461.

- VanDeventer, J.S. and W.S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data: users guide for Microfish 3.0. Gen. Tech. Rept. INT-254. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 29 p.
- Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status Review of Coho Salmon from Washington, Oregon, and California. US Department of Commerce. NOAA Technical Memo NMFS-NWFSC-24, 258 p.

Personal Communications

- Duffy, Walt, PhD. Leader, California Cooperative Fishery Research Unit. Humboldt State University, Arcata, CA.
- Ettlinger, Eric. Aquatic Ecologist. Marin Municipal Water District, Corte Madera, CA.
- Gallagher, Sean. Fisheries Biologist. Anadromous Fisheries Resource Assessment and Monitoring Program. California Department of Fish and Game, Fort Bragg, CA.
- Niemi, Tina, PhD. Department of GeoSciences. University of Missouri, Kansas City, MO.
- Plant, Richard. Trout Unlimited/Tomales Bay Advisory Committee.

APPENDICES

Appendix A – Annual Adult Escapement Summary Report 1997-98 through 2003-04

Appendix B – Annual Outmigrant Smolt Trap Summary Report 1998-2003

Appendix C – Annual Summer Index Reach Monitoring Program Summary Report 1999-2003.

