# 1994-1995 REDWOOD CREEK SPAWNER AND CARCASS SURVEY

## Introduction

Redwood, Olema, and Lagunitas Creeks are three coastal streams within the Golden Gate National Recreation Area (GGNRA) management area that currently support self-sustaining runs of both coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). Both species have been petitioned for listing as either threatened or endangered under the Endangered Species Act of 1973 (as amended). National Park Service's Natural Resource Management policies require the monitoring of natural resources under its stewardship "at regular intervals to detect or predict changes. The resulting information will be analyzed to detect changes that may require intervention and to provide reference points for comparison with other, more altered environments."

Because these anadromous fish spend parts of their lives in both freshwater and ocean, several factors such as ocean productivity and land-uses adjacent to streams may affect their abundance and distribution. The number of returning adults integrates factors that affect both ocean and freshwater survival.

Coho salmon in Redwood Creek were the focus of spawner and carcass surveys. Although both steelhead and coho are known to use Redwood Creek, the emphasis of the spawning survey program was on coho salmon because of their proposed listing as threatened and a life history pattern amenable for carcass counts. Unlike coho salmon, steelhead typically return to the ocean following spawning. Point Reyes National Seashore shares management of certain GGNRA streams including Olema and Lagunitas Creeks. A similar spawner survey was conducted on Olema Creek through the use of local volunteers.

The objectives of this spawning survey were:

1) To develop an index of annual escapement of coho salmon in Olema and Redwood Creeks for analysis of long-term trends.

2) To gather distributional information of spawning coho.

3) To determine population characteristics of returning coho adults including size, age (optional), and sex.

4) To measure certain hydrologic conditions related to salmon run.

**Past Work**:

Information regarding the number of coho salmon and steelhead returning to Muir Woods National Monument (MUWO) have been collected by Muir Woods staff since 1944. Much of the acquired information came from anecdotal accounts. In the winter of 1993, two spawning surveys by NPS staff were conducted from the confluence of Camino del Canyon and Redwood Creek to just above Bridge 4 near the Bootjack Trail. Only 7 redds, 13 live coho salmon (6 adults, 7 jacks), and 1 jack carcass were detected.

**Study Area Description**:

Redwood Creek. The Redwood Creek watershed is a coastal drainage
in southern Marin County, California (Figure 1). It covers 7.5 square miles (PWA *et al*. 1994). Before discharging into the ocean, Redwood Creek joins with its last tributary, Green Gulch, to form Big Lagoon at Muir Beach and associated backwater areas. Barring uncharacteristic hydrologic events, Big Lagoon is connected to the Pacific Ocean during winter and spring months and closed during the remainder of the year.

According to historic records, peak streamflows may range up to 1780 cfs at Frank Valley Road (PWA *et al*. 1994). Like most coastal northern California streams, peak flows occur during the winter and spring with flows closely mirroring recent precipitation patterns. More recently, winter flows at the tail of the drought (1992-1993) ranged from 0.005 cfs to 275 cfs at the Pacific Way Bridge (PWA *et al*. 1994).

The survey area lies entirely within lands owned by the National Park Service, as part of the Muir Woods National Monument and the Golden Gate National Recreation Area, and the Mt. Tamalpais State Park.

In addition, the Redwood Creek watershed harbors several sensitive aquatic species. California red-legged frog (*Rana aurora draytoni*), a federally proposed species, has been found in the wetlands and backwater areas associated with Big Lagoon. The foothill yellow-legged frog (*Rana boyli*) was historically found in Redwood Creek, around Muir Woods. However, recent survey efforts have not found any frogs (K. Freel, pers. comm., 1995; Ely 1993).

**Methods:**

Live and carcass counts have been chosen for use as an index of the number of returning adults. Sampling protocol developed for the Redwood Creek watershed in Humboldt County (Redwood National Park) by Dave Anderson and others were followed as closely as possible (Haux and Anderson, 1992).

Surveys would not have been completed without the assistance of several people including Rob Aramayo (Garcia and Assoc.), Shawn Gillette (NPS-GGNRA), Heather King (Intern-MUWO), Chris Mobley (NMFS), Steve Skartvedt (NPS-GGNRA), and Denise Vore (NPS-GGNRA). Technical assistance was provided by Mia Monroe (NPS-MUWO), Bill Cox (CDFG), and Dave Anderson (NPS-RNP).

Spawning surveys were initiated on December 8, 1994 following the breaching of the sandbar in late-November. Surveys were conducted at approximately two-week intervals and generally required two consecutive days to complete. Ideally, surveys should be completed within one day to prevent double counting of fish. However, counts completed within two days were considered acceptable because most coho and steelhead only move upstream during daylight hours (Sandercock 1991; Shapovalov and Taft 1954).

**Study Area**.

Three survey reaches were established on Redwood Creek totaling 6.7 km (Table 1). Surveys on Redwood Creek started approximately 140 meters below the Pacific Way Bridge crossing above the Muir Beach parking lot (Station 1) to 0.5 km above bridge four in Muir Woods (Station 19, Figure 3). On Fern Creek, surveys were conducted from the confluence with Redwood Creek to the Lost Trail stream crossing for a total of 1 km.

General.

Surveys were conducted using two observers walking upstream carefully inspecting banks, pools and instream woody debris for live salmonids or carcasses. Water clarity, gage heights, air and water temperatures were recorded during the surveys.

Water Temperature

Three remote temperature loggers (Onset Instruments, Stowaway WTS6-2K) were installed at three locations along Redwood Creek in January 1995: pedestrian foot bridge at Big Lagoon, downstream of Muir Beach Community Center, and downstream of a main channel debris pool near MP 2.25.

Global Positioning System (GPS)

The first two surveys were conducted using a hand held global position system (Trimble Navigation Pathfinder). The GPS unit was used to map the creek morphology, mark the locations of redds and fish, and note the location of significant features. Due to the narrow canyon and dense overstory vegetation, no satellite signals were detected within the Muir Woods National Monument reach of Redwood and Fern Creeks.

Fish Measurements

When live fish or carcasses were encountered, the approximate locations were marked on a map using known landmarks. For observations of live fish, the species, sex, and fork length were recorded. For most live fish, lengths were estimated by framing fish with nearby objects in the stream and then measuring distances between objects. In addition, we recorded activity patterns of fish as either "dead," "spawning," or "other."

For carcasses, scale samples, recapture status, species identification, fork length, and sex were recorded. We obtained fork lengths using a measuring rod (nearest cm). For freshly dead fish, we periodically checked sex identification by looking for milt or eggs. Upon completion of measurements, fish were marked by removal of dorsal and/or tail fins and returned to their original locations.

Redds

Redds were difficult to determine in the field. However, known redd sites below Muir Woods National Monument were counted and marked on maps.

**Results**

General

A total of 20 coho carcasses were recovered during the 1994-1995 surveys. No steelhead carcasses were found. Many of the fresh carcasses were lodged within woody debris, often in pools. Several skeletons (uncounted) were found out of water on gravel bars or banks. One of the twenty marked carcasses was recovered at a later date. Scale samples were taken from 13 carcasses. No estimate of the adult spawning population size was attempted.

Male coho carcasses ranged in fork length from 40 to 73 cm. Female lengths ranged from 58 to 67 cm. Figure 4 shows the

length-frequency distribution of recovered coho carcasses.

Peak numbers of live coho salmon were observed in late-December and early January surveys (Figure 5). No coho were observed in the February survey. However, because of storm events that occurred after February, it is possible that a few coho may have entered Redwood Creek after the surveys ceased in early February. Shapovalov and Taft (1954) found adult coho entering Waddell Creek as late as March.

Observations of live coho salmon were not uniformly distributed throughout the study reaches. No coho or redds were observed in the approximately 140 m of creek below the Pacific Way bridge, an area within the scope of the Big Lagoon restoration project. The middle reach (Stations 7-14) typically had the highest proportion of fish (Table 2). In addition, the 0.76 km between Stations 9 and 10 had the highest frequency and density of observed fish categorized as "other" and "spawning" (83 and 11 observations/km, respectively). Two large holding pools were present between Stations 9 and 10. One pool behind a debris jam had, on two occasions, 15 and 14 fish. This pool has since been reduced in depth and extent by sediments and loss of woody debris.

The downstream-most redds were located between Stations 3 and 4 (Highway 1 road crossing to Muir Beach Community Center pedestrian bridge) (Figure 6).

Steelhead

Steelhead were not observed until the January 19-20th survey. The maximum number of steelhead observed during a single survey was 3. While steelhead may start to enter at the same time as coho salmon, steelhead entries in other streams can extend until mid-May, a much longer period than for coho salmon (Shapovalov and Taft 1954). In addition, Shapovalov and Taft (1954) noted that peak entry of steelhead occurred in early March. Our survey ended prior to the completion of the steelhead spawning season.

Coho Jacks

Two different year classes returned to Redwood Creek for spawning. The majority of returning adults spend one year in freshwater and two years in the ocean. A fraction of the returning adults spend only one year in both freshwater and the ocean. These precocious males (also called jacks) represent salmon that have spent one, rather than two, seasons in the ocean. Based on scale readings and length measurements of returning adults to a Santa Cruz County stream, Waddell

Creek, Shapovalov and Taft (1954) found that returning coho less than 49 cm (fork length) were almost always jacks. Only 1.1% of the returning coho less than 49 cm spent two years in the ocean (Shapovalov and Taft 1954).

Using a cutoff length of 50 cm for jacks, a total of 3 jacks in Redwood Creek were identified from coho carcasses. This represents 16 percent of the recovered coho carcasses. The actual percentage of jacks in the spawning run may be higher. Boydstun (1994) noted that these marked smaller, fish were less likely to be recaptured than the larger, older adults.

**Discussion**

Fish aging through scales or other means will be required to confirm whether most fish less than 50 cm spend only one year in the ocean. Aging of coho carcasses will also help determine the percentage of coho that spent less than one year in freshwater.

The percentage of returning spawners comprised of jacks can be quite variable. The proportion of jacks returning to Waddell Creek ranged between 1.4 to 43.7% with an average of 16% (Shapovalov and Taft 1954). On the South Fork of the Eel River, 16 to 37% of the returning coho from 1938 to 1950 were classified as jacks, using their criteria of fish less than 24 inches (Murphy 1952). Additional years of data from Redwood Creek and other streams within GGNRA will help determine the proportion of jacks.

It is thought that the number of returning jacks may be related to the size of outmigrating smolts. Releases of hatchery reared coho in a British Columbia stream suggested that coho that emigrate earlier and at a larger size than average, resulted in a high rate of jack returns (Bilton *et al*. 1984).

It is difficult to estimate the total number of adult coho salmon that returned to Redwood Creek to spawn. As was mentioned before, weir counts remain the most accurate means of determining the total number of returning fish. Our index method which uses the total number of carcasses for the season has its share of problems. This assumes that factors (such as sampling frequency, rate of scavenging, visibility, observer variability, and stream conditions) remain constant.

Various factors can contribute to the number of observed fish including: current stream conditions (e.g., turbidity), observer experience, habitat type (e.g., pools vs. riffles), and observation method. In an evaluation of various measures

of counting returning adult salmon, counts made from walking along the banks observed, on average, 20% of the fish present (Shardlow *et al*. 1987). Bank counts in their study detected fewer fish than other methods (rafting- 43%, swimming- 63%, aircraft- 85%, and helicopter- 100%). However, it should be noted that their study stream averaged 20 m in width with flows ranging from 2.1-12.3 cubic meters per second. Streams within GGNRA rarely exceed 6-7 m in width and pools rarely exceed 2 m in depth. Therefore, our walking surveys probably approximates the actual numbers of carcasses and live fish more closely than the walking surveys in Shardlow *et al*. (1987) studies. Nevertheless, calibration of our walking counts should be conducted. Calibration using more "accurate" measures such as rafting, aircraft, and helicopter counts would be impractical on our streams due to their small size and dense riparian vegetation. However, walking survey counts should be supplemented by swimming counts to determine the proportion of unseen fish, particularly in areas with a high percentage of pools.

Shardlow recommended several improvements to survey techniques including the use of counts along fixed lengths at standardized locations rather than counts conducted along the length of the creek. By reducing the sampling area, the same level of effort could be used to sample fewer sites more frequently. This recommendation would be most appropriate for Olema Creek, which has suitable spawning areas along a much greater length than Redwood Creek.

Recommended survey frequencies for carcass counts range from 3-4 days (W. Evans pers. comm., 1995) to 1 week (J. Glase pers. comm., 1995). Widely spaced surveys (e.g. two weeks), such as ours, may increase the likelihood of scavengers, etc. removing carcasses.

Future efforts to improve our spawner surveys will involve the estimation of observer bias as well as an attempt to determine the average residence time between entry of adult salmon and death.

**Factors Affecting Spawning Success**

There has not been an assessment of factors contributing to the spawning success of coho salmon and steelhead (attractant flows, instream velocity, unnatural barriers to upstream migration, holding areas, spawning gravel quality, and general water quality parameters). Generally, sufficient freshwater flows (temperature and quantity) and an open bar are needed to facilitate movement from the ocean to Redwood Creek. Because of the absence of instream impoundments on Redwood Creek,

attractant flows for salmon are generally not impaired by human actions. All crossings over Redwood Creek are bridge structures. Bridges with hardened bottoms are not downcut on the downstream side. There was concern expressed that spawning areas in MUWO occur in channelized reaches with narrow cross-sections may have excessively high velocities that would impair egg deposition (W. Evans, pers. comm. 1995)

Within Redwood Creek, sufficient holding areas must be present within the creek. It is unclear how long Redwood Creek coho hold within the stream prior to spawning. Estimates from studies on other streams range from weeks to even months (Sandercock 1991). Typical holding areas where non-spawning coho adults have been observed include flatwater with undercut banks, deep pools, and deep water with woody debris (Fong pers. obs., 1995). Most of the holding areas are located downstream of MUWO; however, high winter flows in 1995 dramatically filled the two main holding pools with the greatest number of adults. Within the MUWO section of Redwood Creek, few deep pools exist and areas with undercut banks are limited to areas that have not been protected with rock revetment.

Late-winter water temperatures from mid-January to mid-March 1995 ranged from 7.5$^{o}$C to nearly 13.5$^{o}$C, with daily water temperatures varying by as much as 2$^{o}$C (Figure 7). These water temperatures are within range of the reported temperatures for coho upstream migrations (Sandercock 1991).

Water and sediment quality are likely sufficient for spawning and egg development. Winter water temperatures and dissolved oxygen are probably satisfactory for egg development. Sufficient gravel appears to be present throughout Redwood Creek. However, a quantitative assessment has not been conducted. At two sampling sites accessible by salmon for spawning, the percentage of gravel (3/8 to 3 inch diameter) ranged from 55 to 90 percent with a relatively low percentage of fines (Podlech *et al.* 1994). Because of the "flashy" nature of small coastal streams such as Redwood Creek, redds, particularly those located in incised channels, may be susceptible to scour and fill by flood events. Information regarding channel morphology was collected over the summer of 1995. However, this information has not been analyzed yet.

**Literature Cited**:

Bilton, H.T., R.B. Morley, A.S. Coburn, and J. Van Tine. 1984. The influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity: results of releases from Quisam river Hatchery,

B.C. in 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1306:1-98.

Boydstun, L.B. 1994. Analysis of two mark-recapture methods to estimate the fall chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. Calif. Fish and Game. 80(1):1-13.

Haux, S. and D. Anderson. December 1992. Redwood Creek basin spawning and carcass survey protocol (draft). Redwood National Park, Fish and Wildlife Branch, Research and Resource Management Division. np.

Hofstra, T.D. and D.G. Anderson. 1989. Survey of salmonid fish and their habitat. Redwood Creek, Marin County, California. Unpublished report prepared for National Park Service-GGNRA. 18 pp.

Murphy, G.I. 1952. An analysis of silver salmon counts at Benbow Dam, South Fork of Eel River. Calif. Fish Game 38:105-112.

Philip Williams and Associates (PWA), Moss Landing Marine Laboratory, Jerry Smith, John Northmore Roberts and Associates, and Nancy Hornor. 1994. Preliminary Environmental Assessment of Wetland Restoration Alternatives for Big Lagoon at Muir Beach, Marin County. Prepared for California Department of Transportation, District IV.

Podlech, M., R.J. Brown, and D. Karentz. September 1994. Redwood Creek aquatic monitoring report-February-May 1994. University of San Francisco. 22 pp.

Sandercock, F.K. 1991. Life history of coho salmon. Pages 397-445. In: C. Groot and L. Margolis (eds), Pacific salmon life histories, UBC Press, Vancouver, BC.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dept. Fish and Game Fish. Bull. 98:375 p.

Shardlow, T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for Pacific salmon (*Oncorhynchus* spp.). Can J. Fish. Aquat. Sci. 44:1031-1037.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. Status review of coho salmon from Washington, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memorandum NMFS-NWFSC-24, 258 pp.