# SURVEY OF SALMONID FISH AND THEIR HABITAT
# REDWOOD CREEK, MARIN COUNTY, CALIFORNIA


by

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# TABLE OF CONTENTS

## SUMMARY

Redwood Creek, Marin County, California is a moderately to heavily impacted stream that has been degraded by sedimentation, channel modifications, removal of organic material, seepage from septic systems, agricultural and domestic runoff, lagoon modification, and removal of water for commercial and domestic uses. While all these effects have impacted the stream's fishery resources, the most immediate threat is water withdrawal. Removal of water from the stream system directly affects the number of fish that can return as spawning adults in two ways. First, by reducing the stream flow so that water depths are too shallow to allow upstream migration and, second, by reducing the volume and quality of juvenile fish habitat. The area of the creek most affected by water removal at this time is the area below Muir Woods National Monument. This is the area that historically produced the largest number and size of salmonid smolts. During our survey approximately 1.25 miles of this critical rearing habitat was totally dry, and another 0.75 mile was seriously degraded, the direct results of water withdrawal. State and Federal agencies, local communities and landowners must work together to ensure adequate water remains in the creek during summer low flow periods for juvenile fish survival and growth. Persistent degradation of summer rearing habitat for juvenile salmonids, or maintaining the status quo, will result in the continued long-term decline of adult salmon and steelhead returns to Redwood Creek.

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## INTRODUCTION

On September 19, 1988, the Superintendent of Golden Gate National Recreation Area (GGNRA), requested the assistance of Redwood National Park staff in initiating a survey of the aquatic resources in GGNRA's Redwood Creek. Specifically requested were an evaluation of spawning and rearing habitat, a preliminary inventory of fish, and recommendations on methods of restoration of the Redwood Creek estuary.

During the first week of October 1988, ecologist Terry Hofstra, fishery biologist David Anderson, and biological technician Bob Coey, all of Redwood National Park, conducted a survey of Redwood Creek in GGNRA, Marin County, California. The creek flows through Muir Woods National Monument and Mt. Tamalpais State Park.

## BACKGROUND

The fishery resources of Redwood Creek, Marin County, California have been of particular interest for many years. In Muir Woods National Monument coho or silver salmon, *Oncorhynchus kisutch* and steelhead trout, *O. mykiss* (previously *Salmo gairdneri*)(Kendall 1988), are considered a special part of the park's resource (Hershey 1973). However, compared to historical accounts, the present day populations of these fish are severely reduced. The need to determine the cause(s) of the decline was identified by National Park Service managers over 20 years ago. In 1966, a Resource Study Proposal (attached) was prepared by Donald Reeser (then a park naturalist, now Superintendent of Haleakala National Park) that stated:

> The anadromous fish of Muir Woods are an integral part of the natural scene. Muir Woods is one of the very few natural areas near a large center of population that provides thousands of people an opportunity to observe the interesting spawning activities of the salmon and steelhead.... An adequate fish census has never been conducted on Redwood Creek, therefore we have limited knowledge of any long range population trends. The few superficial signs that we do have are indicative of a general decline in fish numbers.

As a result of Mr. Reeser's recommendations, a contract study was conducted by Sonoma State College for the National Park Service.

The study report was completed in 1971 (Arnold 1971). Since then, several surveys and memo reports have periodically been completed by the California Department of Fish and Game concerning Redwood Creek.

## GENERAL SETTING

For a description of the Redwood Creek watershed, climate, and hydrology, see Snider 1984.

## FISH LIFE HISTORIES

Both coho (silver) salmon and steelhead trout are found in Redwood Creek. They are members of the salmonid family, spending their adult life in the ocean and returning to their natal freshwater stream to spawn. Steelhead may spawn more that once but silver salmon all die after spawning. In Redwood Creek, adult coho generally return from the ocean in the fall following the winter's first rains. Upstream migration of adults to spawning areas may occur from late November through January. Steelhead generally enter the stream later, from late December through May. The eggs of both species are buried in nests called redds excavated by the adult fish in gravel stream bottoms. The eggs incubate in the stream for a variable period depending on water temperature, but averaging 30 to 60 days for coho and 60 to 90 days for steelhead. After hatching, the young fish are referred to as alevins or sac fry, as they have not yet completely absorbed the yolk sac of the egg. The young fish remain "buried" in the redd until the yolk sac is absorbed, whereupon they migrate up through the gravel and into the water column. After emergence from the gravels, the young fish, now referred to as fry, may remain close to the spawning area, in riffles along stream margins, in shallow pools, and in backwater areas.

As the fry grow in size, their habitat requirements become more restrictive. That is, they require deeper pools and areas of abundant food resources. It is in this "rearing" or "nursery" habitat where juvenile fish, now referred to as parr, find conditions favorable for increased growth. In a diverse stream system, rearing habitat is not spatially removed long distances from the spawning site. However, in many coastal streams where summer stream flows are low, fish move downstream to find the required deep water areas. Studies have shown that the smaller a fish is when it enters the ocean, the less its chances of surviving ocean residence and returning as an adult to spawn. Therefore, the rearing phase of a salmonid's life cycle is particularly important. Coho generally spend one full year as rearing juveniles and steelhead spend from one to four years. In Redwood Creek, it is likely that many steelhead fry leave as one-year-olds.

Following the rearing phase, anadromous salmonids, now called "smolts", undergo the physiological changes required to live in the ocean. This process is called smoltification and is primarily a function of size. Again, the larger the size of the smolt at migration to the ocean, the greater its chances of survival. Minimum size for successful parr-smolt transformation is approximately 100 mm for coho salmon (McMahon 1983). The greater the availability of rearing habitat, the greater the number of smolts produced and the greater the potential number of fish surviving ocean residence to return as adult spawners.

## METHODS

### Sampling Stations

Redwood Creek was surveyed by walking from upstream of the Muir Woods/Mt. Tamalpais State Park boundary near the confluence of Spike Buck and Redwood Creeks, to its mouth at Muir Beach, a distance of approximately 4.5 miles (7.2 km). The purpose of this initial survey was to make a preliminary evaluation of existing creek conditions and determine locations of sampling sites.

Arnold (1971) divided the stream into five areas (Areas I through V) for purposes of sampling (Figure 1). We located our stations within each of these areas to facilitate comparisons of data. However, we had only four stations because the stream section corresponding to Arnold's Area I, was totally dry during our sampling period. All stations were selected to be reasonably representative of the aquatic habitat available to salmonids. Figure 2 shows the locations of our sampling sites. Station 1, a 40 meter reach in Muir Woods is located 52.7 meters downstream from the second foot bridge (above the kiosk) and corresponds to Area IV of Arnold (1971). Station 2, a 31 meter reach, is located upstream of Muir Woods, inside Mt. Tamalpais State Park, just above the 200 foot contour and before the Eastwood/Bootjack trail intersection. It corresponds to Area V of Arnold (1971). Station 3, a 31.85 meter reach is located downstream of Muir Woods, at the 80 foot contour, in Mt. Tamalpais State Park. It corresponds to Area III of Arnold (1971). Station 4, a 29.9 meter reach, was located just upstream of the U.S. Highway 1 bridge below the 80 foot contour (approximately 60 feet). It corresponds to Area II of Arnold (1971). (See photographs).

On upper Redwood Creek, four additional locations were sampled to evaluate the presence and upstream distribution of fish species; Station A at the 280 foot contour, Station B at the 380 foot contour, and Stations C and D at the 600 foot contour. Stations A, B, C, and D were all located within Area V of Arnold (1971). While no other stations were established, Fern Creek and the pools adjacent to the Muir Beach parking lot were also electroshocked.

## Fish Sampling

Fish sampling was conducted to provide a general evaluation of fish rearing habitat as the potential limiting factor to salmonid production. At each station, fish were captured with a 12 Volt DC battery backpack electroshocker. At sampling Stations 1 through 4, the upstream and downstream ends of each reach were blocked with nets and a multiple pass removal method was used to estimate fish numbers. Fish numbers were calculated using the maximum likelihood estimate formula (Van Deventer and Platts 1983) and MicroFish 2.2 software (Van Deventer and Platts 1985). Captured fish were anesthetized with MS-222 (tricaine methanesulfonate), identified to species, and length and weight measured to the nearest 1.0 mm and 0.1 g, respectively. Length measured for salmonids was fork length, and for sculpin, total length. Scale samples were collected from representative fish. The water surface area and volume of each station were estimated using cross section widths, depths, and reach length. Biomass of each section was determined from average fish weights multiplied by estimated fish numbers. Biomass or number of fish per standard unit (meter, meter$^2$, meter$^3$) was estimated by dividing biomass by standard unit.

Fish condition factor (K) was calculated as: $K = \frac{W \times 100,000}{L^3}$

where W = weight in grams and L = length in millimeters.

The backpack shocker was also used at Stations A, B, C, and D, Fern Creek, and the Muir Beach pools to evaluate the presence and/or limits of fish species distribution. At these locations, few measurements of individual fish were taken, and only a species' presence or absence was noted.

Differences in fish lengths and condition factors (K) among stations were tested using analysis of variance, Bartlett's test for homogeneity of variance, and Student-Newman-Keuls multiple range tests where appropriate. Data were log-transformed where non-homogeneous variances were encountered. The Kruskal-Wallis analysis of variance was used to determine differences in fish lengths among stations where data were nonparametric. Analysis of covariance was used to test the significance of differences in slopes of calculated regression equations among sites. All statistical tests were conducted using the Statistical Package for the Social Sciences (Norusis 1988).

Water Quality Sampling

Water quality data were collected at Stations 1 through 4 and at the Muir Beach pool. Parameters measured were water temperature (°C), conductivity (μhmos) , salinity (o/oo) , dissolved oxygen, and pH. Measurements were taken with portable instruments.

Sampling Dates

On October 4, the lower 4.5 miles (7.2 km) of Redwood Creek were surveyed by walking.

On October 5, Stations 1 and 2 were electroshocked to estimate fish populations. Water quality data were collected at Stations 1 and 2. Further upstream, Stations A, B, C, and D were electroshocked to determine extent of anadromous fish distribution.

On October 6, Stations 3 and 4 were electroshocked to estimate fish populations. Water quality data were collected at Stations 3 and 4. Fern Creek and the Muir Beach pools were electroshocked to determine extent of anadromous fish distribution.

On October 7, RNP personnel visited Muir Woods National Monument office to talk with employees about Redwood Creek and review park files for pertinent documents and data from previous studies.

## RESULTS

During the general survey conducted on October 4, a decrease in surface water flow was observed as we proceeded downstream on Redwood Creek until isolated stagnant pools were encountered. Isolated pools were first observed in the Monument adjacent to the lower parking lot. Marked flow reductions were apparent below the confluence of Kent Canyon Creek and Redwood Creek. Approximately 1.25 miles (2 km) of the lower creek was dry, from below the Muir Beach community pump station and heather farm to the horse pasture by the Muir Beach parking lot. No water was flowing into the ocean from Redwood Creek. Pools of stagnant water were found where historically a lagoon once existed. The lowermost pools were adjacent to the Muir Beach parking lot.

Fish found in the survey of Redwood Creek were coho salmon, Oncorhynchus kisutch, steelhead trout, O. mykiss, sculpin, threespine stickleback, and rockfish. Only coho, steelhead, and sculpin were found upstream. Sculpin, stickleback and the juvenile rockfish were shocked in the beach pools. No salmonids were found in this area. Crayfish and pacific giant salamander larvae were observed in upper Redwood Creek.

The distribution of species encountered during our study is presented in Table 1.

Fish length and weight data are presented in Table 2. Population statistics are found in Appendix A. Since the emphasis of our study was on salmonids, sculpin data are included for information only. No detailed analysis or interpretation of these data are included.

Generally, the mean length of fish increased at each downstream site. Only juvenile fish were electroshocked. One adult steelhead (fork length 55 cm) in poor condition was observed in a lower Redwood Creek pool. It was probably a stranded runback. Fish numbers, biomass per unit stream length, and fish condition factors are presented in Tables 3 and 4, respectively.

Steelhead length and age (from "reading" scales) data are presented in Table 5 and Figure 3.

Water quality parameters were measured for Stations 1 through 4, and at the Muir Beach pool (Table 6). Water temperatures ranged from 12.5 °C to 14 °C in areas with flowing water. A temperature of 17 °C was measured in the Muir Beach pools and 12 °C at Fern Creek. Dissolved oxygen was lowest in the two downstream stations where flow was less. In the stagnant lagoon pools, water clarity was very poor. These pools looked eutrophic.

## DISCUSSION

### Water Quality

Except for the Muir Beach pool, measured stream temperatures were within the preferred temperature range reported for rearing salmonids (Beschta et al. 1987). Those preferred ranges are 11.8 - 14.6 °C for coho salmon and 7.3 - 14.6 °C for steelhead. The upper lethal temperatures are 25.8 °C and 24.1 °C for rearing coho and steelhead, respectively. The temperature recorded at the Muir Beach pool was 17 °C. Arnold (1971) reported a lagoon temperature of 17 °C in 8/06/68. Temperature does not appear to be limiting the production of fish resources in Redwood Creek. For salmonids in freshwater, dissolved oxygen levels above 7.84 ppm are ideal (Davis 1975). At 6.00 ppm, the initial signs of distress occur, and at 4.16 ppm, a large proportion of the population is affected. Dissolved oxygen values measured at the upstream sites, Stations 1 and 2, were well above ideal levels. It was further downstream where conditions degraded, at Stations 3 and 4. The lack of oxygen at the lower stations was most likely due to poor aeration resulting from low surface water flow. Fish were present but in low numbers.

Values of pH were low at Stations 1, 3, and 4. It is difficult to explain the low pH values we measured. Low pH may be due to high biochemical oxygen demand (BOD) of the water, coupled with low reaeration capacity and reduced plant activity in the stream. In previous studies (Vollintine 1973), pH was within the normal range even though seepage from sewage treatment systems (high BOD) was entering the creek. Our low measurements may have been due to an equipment malfunction.

Fish

Table 1 presents fish distribution data. Those trout encountered at Stations A (above a log "stored sediment" jam), B, C, and D were believed to be resident rainbow/steelhead trout. Station D represents the upstream limit of our survey but not necessarily the upstream limit of trout distribution. Time limitations prevented us from surveying farther upstream. No coho were encountered at or upstream of Station A on Redwood Creek. This is probably due to what is believed to be a natural barrier to all upstream fish migration located approximately at the 280 foot contour of Redwood Creek. In Fern Creek, coho salmon and sculpin were shocked at the 220 foot contour, and at the 350 foot contour coho and a single steelhead were found. The previously reported upstream limit of coho utilization of Fern Creek was the 280 foot contour (Arnold 1971). Time limitations prevented our surveying farther upstream in Fern Creek, but a natural falls barrier apparently exists at approximately the 400 foot contour (Mia Monroe, personal communication). This barrier would represent the upstream limit to anadromous fish use of Fern Creek. Above this barrier, resident trout are likely to exist.

Table 2 presents length and weight data for fish captured at Stations 1 through 4. For both coho salmon and steelhead trout, average fork length and weight increased from upstream to downstream stations. A similar relationship has been noted in previous surveys (Arnold 1971, Dept. of Fish and Game 1976 and 1984). A multiple range comparison showed coho fork lengths were significantly (p = 0.05) larger at stations 3 and 4 than at stations 1 and 2. (Table 7). Steelhead were significantly (p = 0.057) larger at station 4 than at station 2 but no other statistically significant differences existed for steelhead among sites.

A straight line relationship exists between length and weight of fish captured in Redwood Creek (Table 8). There were no significant differences in the slopes of the straight line equations for coho or steelhead among different stations. It may be argued that the larger fish at downstream stations had emigrated to these locations as they grew in size and their habitat requirements became more restrictive. That is, they moved to areas of better habitat. However, one recent study (Dolloff 1987) indicates that most juvenile coho salmon do not preferentially move among different habitat types but tend to remain at the sites of their original, post-emergence distribution. Indeed, because of the intermittent nature of Redwood Creek, migration of juvenile coho salmon between different habitat areas would be impossible except early in the summer season. In either case, significantly larger fish were found at the downstream sampling stations. These data suggest the habitat that can produce, or is most suitable to larger size rearing salmonids, is found in the lower portions of Redwood Creek, from near our Station 3, downstream. Unfortunately, nearly half of the large fish habitat (that area downstream from the MBCSD pump station to the mouth of the creek) has been entirely eliminated by water withdrawals and lagoon modification.

Arnold also found that the larger fish occurred in the downstream portions of the creek with the largest found below the MBCSD pump station. This area was totally dry during our study. Other reports have noted the increasing frequency of large fish habitat occurring in downstream locations (Fish and Game 1976 and Snider 1984) .

Condition factor (K) may be used to compare the general condition, fatness, or well being of fish (Bagenal and Tesch 1978) and is based on the assumption that the heavier a fish is at a given length, the better its condition. Mean condition factors for fish captured in Redwood Creek are found in Table 4. There were no significant differences in condition factors for coho or steelhead among stations.

Fish population estimates (Appendix A) and average weights (Table 2) were used to calculate fish numbers and biomass per stream unit as found in Table 3. These calculations show decreasing numbers of coho per unit stream length in the downstream direction accompanied by an increase in biomass per unit stream length. This is somewhat different than the trends found by Arnold. He found the greatest numbers and largest fish in downstream areas near our Stations 3 and 4. From 11 seining sites within these areas, 577 coho and 290 steelhead juveniles were examined in October 1968. It is doubtful this many rearing juveniles existed in the entire stretch of stream below Muir Woods during our sampling period.

As illustrated by Table 5 and Figure 3, we sampled three age classes of steelhead, 0+, l+, and 2+. Scales analysis indicate that 99 mm was the cutoff size between 0+ and 1+ fish, and that 154 mm, was the cutoff between 1+ and 2+ fish. These data are similar to those found in 1979 (Fish and Game) of 97.5 mm for 0-f, and 150 mm for 1+ steelhead. The majority (90%) of steelhead captured were 0+ fish, young of the year.

## Stream Habitat Observations

Conspicuous in its absence from Redwood Creek is large woody debris. That is, the limbs, branches, and trees that fall into a stream from the adjacent forest. Organic debris such as this serves several functions. Catchments are created where inorganic and organic sediment are stored. Water quality and quantity are influenced. Organic material increases physical stream diversity by creating pools, gravel beds, and cover, all critical in the life histories of many vertebrate species, including amphibians, mammals, and fish.

Aquatic communities in the Pacific Northwest evolved in "debris-rich" environments associated with and characteristic of unmanaged coniferous forest streams. Species developed adaptations which enable them to maximize production in hydraulically complex channels where debris is abundant. Large woody debris biomass measured in unmanaged redwood forest streams of northwest coastal California shows an average loading of 16 to 134 $kg/m^2$ (Bisson et al. 1987). Organic loading depends upon average channel width, with wider channels having lower organic loading values. While we did not attempt to measure debris loading in Redwood Creek, it is extremely low and not what would be expected of an unmanaged old growth redwood forest stream system of the size of Redwood Creek. Debris removal has been an accepted management activity at Muir Woods National Monument

Monument since the 1930's and apparently is the cause of the low level of organic debris loading. Removal of organic debris from Redwood Creek has reduced the complexity and quality of the stream environment as habitat for aquatic organisms. Undoubtedly this has contributed to the decline in fishery resources that have occurred in Redwood Creek.

Stream bank stabilization structures were constructed along Redwood Creek in Muir Woods in the 1930's. These structures have severely reduced the natural processes of stream bank erosion and channel downcutting (Hagans and Weaver 1988). Stream bank erosion is one process whereby gravels, used for salmonid spawning, enter the stream. Therefore, the availability of spawning gravel has been reduced by stream stabilization structures. Future storm events could result in downstream transport of sediment which form gravel beds. Since the availability of gravel has been reduced, the long term result may be a reduction in quantity of salmonid spawning habitat. This possibility is increased by the absence of organic debris which can provide storage areas for gravels used for spawning.

Below Muir Woods, the stream suffers from what appears to be above normal levels of sediment in the channel. Perhaps this is the result of damage to the stream that accompanied logging which occurred in the 1960's (Snider 1984). It is also likely that the increased sediment load in the creek is the result of water withdrawals. Removing water from the stream reduces water velocities, volumes, and the ability of the stream to transport sediment. Therefore, sediment is deposited in these locations and will only be flushed away during higher than average flood flow events. Above normal levels of sediment coming into the creek have been reported as recently as 1986 (file memo), but no current information exists regarding degradation of water quality from other sources. Agricultural use of fertilizers and pesticides, seepage from septic systems have also been reported to degrade water quality in the lower part of the creek.

Our observations indicate a partitioning of the stream with respect to anadromous salmonid spawning and rearing habitat. Most of the coho salmon and steelhead spawning habitat occurs in upstream areas within the boundaries of Muir Woods National Monument while most of the large fish rearing habitat occurs downstream of the Monument. This relationship had been noticed in earlier surveys (California Department of Fish and Game 1976). Above the Monument boundaries, gravel abundance and quality probably limits the numbers of successful spawners to steelhead and very few salmon. Rearing habitat within the Monument has been greatly reduced by removal of organic debris although the "best" rearing habitat historically was probably found below the Monument. Some spawning gravels are also available below the Monument however these areas are impacted by increased levels of fine sediment.

Dewatering of Redwood Creek

The lower 1.25 miles of Redwood Creek was dry during our sampling period. The dry reach was below the pumps of the Muir Beach Community Services District (MBCSD) and the heather farm. The isolated pools and intermittent surface flow extending approximately 0.75 mile immediately above the pumps are also probably the result of water table draw-down around the pump sites, i.e. a cone of depression. (We also observed no flow entering the creek from Kent Canyon). A State Water Resources Control Board memo (Laudon 1988) states the pumped withdrawal is of stream origin. The result is the lowering of the water table below the stream gradient and loss of all aquatic habitat in the lower 1.25 miles of Redwood Creek. In a stream where 90% of the annual runoff occurs between November 1 and April 30 (Snider 1984), dewatering of the stream may be a frequent occurrence, especially in dry years.

The result of dewatering is the loss of important aquatic habitat, especially coho salmon rearing habitat. The Department of Fish and Game (Snider 1984) estimated preferred summertime rearing flows for coho salmon and steelhead trout in Redwood Creek to be approximately 8 cubic feet per second. Whether these volumes of flow were ever typical of summertime Redwood Creek conditions is unknown. Flow measured in Redwood Creek at the lower Frank Valley bridge on September 4, 1988, one month before our study, was 0.064 ft/sec (Vicki Ozaki, personal communication). Summer flows measured in lower Redwood Creek by Lehre in August and September 1974 were 0.56 $ft^3$/sec and 0.31 $ft^3$/sec respectively. The differences in flows measured in 1988 and those measured in 1974 may be due to increased withdrawal of water for domestic and commercial use. Withdrawal of water can also affect the upstream migration of spawning adults by reducing the depth of water over riffles that fish must negotiate and therefore making it more difficult to swim upstream (Snider 1984). Also, withdrawal could reduce the duration of migrational flows needed by returning salmon and steelhead, as well as the downstream passage of adult steelhead after spawning.

Reduced water flows impact not only the quantity of habitat but also influence water quality. Reduced flows limit aeration and directly reduce levels of dissolved oxygen. In areas where septic seepage and agricultural runoff of fertilizers and pesticides occurs, these problems are compounded.

Lagoon

Recent studies of small west coast streams have demonstrated the importance of estuaries, or lagoons, as rearing habitat for juvenile salmonids. In northern California, Redwood National Park studies of the Redwood Creek estuary {Hofstra 1983) have shown large numbers of steelhead trout and Chinook salmon utilize the estuary during the summer as juvenile rearing habitat. By providing an area where increased growth may occur, the summertime lagoon that forms at the mouth of the creek provides critical habitat in the life history of Redwood Creek salmonids. Even when the creek mouth remains open during the summer, fish voluntarily remain and utilize the estuary. Historic accounts indicate the lagoon used to provide summer habitat for coho salmon as well. However, since the construction of flood control levees and channelization the needed backwater areas that would have been used by coho have mostly been eliminated. Steelhead also utilize small coastal estuaries, or lagoons, for summertime rearing (Hofstra unpublished data, Zedonis and Barnhart 1988). Other small coastal streams studied in San Mateo County to the south (San Gregorio Creek) have shown summer steelhead utilization and increased growth in the lagoons. Generally, the larger the smolt, the greater its chances of survival in the ocean and therefore the greater the chance of it returning as an adult to spawn.

It is the lower reaches of small coastal streams that provide most of the habitat necessary for a productive anadromous fish resource (Snider 1985) and it is this portion of Redwood Creek that has been most impacted. It is likely the lagoon and associated lower stream reaches that historically existed at the mouth of Redwood Creek provided excellent rearing habitat for coho salmon and steelhead trout. Even when extremely low summer flows or drought conditions existed, rearing habitat for juvenile salmonids was probably available in the lagoon. The lagoon therefore provided an area that was always available to fish. However, the functioning of this area as a viable part of the overall watershed has been lost by elimination of summer stream flows through water withdrawal for commercial and domestic uses, alteration of circulation patterns, dredging, construction of levees, dikes, and a parking lot, and degradation of water quality through agricultural and domestic development and runoff.

## CONCLUSIONS

Redwood Creek is a moderately to heavily impacted stream. Upstream of Muir Woods, logging and sedimentation have impacted the creek. Within the Monument, removal of organic material from the stream and bank stabilization have reduced available habitat. Farther downstream, logging, sedimentation, agricultural activities, water withdrawals, use of fertilizers and pesticides, and lagoon modification have impacted the quality, quantity and diversity of aquatic habitat.

The results of our limited study, and those of previous investigations, indicate that the most critical factor presently limiting salmonid production in Redwood Creek is rearing habitat for larger juvenile fish. Habitat alterations in Redwood Creek have resulted in a spatial separation of spawning and rearing habitat that probably did not exist historically as it does today. Most anadromous fish spawning probably occurs within the boundaries of Muir Woods National Monument, while most large fish rearing habitat occurs downstream. Low summer stream flows appear to prevent movement of fish to these higher quality rearing areas. Nevertheless, over half of the large fish habitat in Redwood Creek has been totally eliminated by water withdrawals.

In spite of these abuses, anadromous fishery resources still exist. Continued habitat degradation, domestic and agricultural water withdrawal, and poor land use practices, however, may someday eliminate coho salmon and steelhead from Redwood Creek entirely.

## RECOMMENDATIONS

1. The major threat facing the aquatic resources of Redwood Creek is withdrawal of water for domestic and commercial uses. Efforts should be directed toward eliminating all illegal water withdrawals presently occurring. Total volume of withdrawal presently occurring (legal and illegal) should be estimated, and the possibility of extending municipal water supplies to all landowners in the valley should be investigated. Any further decreases in stream flows will have serious negative effects to aquatic resources, therefore, GGNRA should contest all new applications for water rights on Redwood Creek and request that an Instream Flow Incremental Methodology (IFIM) study be conducted to quantify the fishery impacts that would result from additional water withdrawals.

2. The aquatic habitat of Redwood Creek has been degraded by removal of large organic material. Physical features and habitat components that were present in the old growth forest are no longer present. These physical features should be restored. The practice of routinely removing organic material from the stream

should be discontinued.  Consideration should be given to restoring stream features and diversity by adding large organic material back to the active stream channel where feasible.

3. A cooperative management plan or agreement with the State Department of Parks and Recreation and Department of Fish and Game should be developed for Redwood Creek.  Such an integrated and cooperative approach to management would facilitate restoration and protection of the creek.

4. A long-term resource monitoring plan to collect data that can be used in identification of problems and resource trends should be developed and implemented.  Such a plan would specify resources to be monitored, permanent monitoring locations, schedules, responsibilities, etc.  The techniques used should be standardized and repeatable from year to year.  They could include juvenile fish population estimates and growth monitoring in established sites, spawning-carcass-redd surveys in stream index reaches, yearly low flow stream surveys and water quality monitoring.  These regularly collected basic resources inventory data would be invaluable in identifying impacts and assessing long-term trends in resource quality.

5. A plan for restoration of the lower creek and lagoon should be developed.  Restoring the lagoon will once again make available important fish rearing habitat and will restore a unique component of the overall watershed with its attendant biotic community.

6. Stream flow gauges should be installed at several locations within Redwood Creek.  Specific locations should be determined after hydrologic consultation and in cooperation with the Department of Parks and Recreation and Department of Fish and Game.

7. Total areas of stream habitat should be quantified by conducting a basinwide habitat inventory following the procedures of Hankin and Reeves (1988).  This is a relatively inexpensive procedure and would provide a basinwide perspective of habitat types and locations.  It would also provide a quantified basis for future monitoring and evaluating restoration efforts.

8. An historical investigation of Redwood Creek should be conducted.  This could include interviews with long time residents, copying of their old photos as they relate to the creek and historic land use, and a review and analysis of all available literature and documents that pertain to Redwood Creek. This kind of information would help define restoration goals.

# REFERENCES


Arnold, J. R. 1971. A study of the silver salmon *Oncorhynchus kisutch* (Walbaum) and steelhead trout *Salmo gairdneri gairdneri* (Richardson) in Redwood Creek, Marin County, California. U.S.D.I., National Park Service, Contract 14-10-9-990-33. 44 pp.

Bagenal, T.B. and F. W. Tesch 1978. Age and growth In: Methods for assessment of fish production in fresh waters. Third Edition. Pages 101-136. T. Bagenal (ed). Blackwell Scientific Publications: Oxford. 365 pp.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat. Chapter 6 *In* Streamside Management: fisheries and forestry interactions. University of Washington Institute of Forest Resources Contribution 57:191-232.

Bisson, P. A., K. Sullivan, and J. L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Trans. Amer. Fish. Soc. 117:262-273.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific northwest: past, present, and future. University of Washington Institute of Forest Resources Contribution 57:143-190.

California Department of Fish and Game 1976. Stream survey report. On file at Muir Woods National Monument. 7 pp.

California Department of Fish and Game 1979. File memorandum. On file at Muir Woods National Monument. 4 pp.

California Department of Fish and Game 1984. File memorandum. On file at Muir Woods National Monument. 3 pp.

Davis, J. C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. Jour. Fish. Res. Bd. Can. 32(12):2295-2332.

Dolloff, C. A. 1987. Seasonal population characteristics and habitat use by juvenile coho salmon in a small southeast Alaska stream. Trans. Amer. Fish. Soc. 116(6):829-838.

Hagans, D. K. and W. E. Weaver 1988. Geologic site analysis for the proposed Dip-sea Trail foot bridge, Muir Woods National Monument. Unpublished report, Redwood National Park, Arcata, California 14 pp.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. Jour, of Fish, and Ag. Sci. 45:834-844.

Hershey, M. C. 1973. The silver salmon of Muir Woods. Muir Woods Natural History Association. 14 pp.

Hofstra, T. D. 1983. Management alternatives for the Redwood Creek estuary. Redwood National Park, California. 50 pp.

Kendall, R. L. 1988. Taxonomic changes in North American trout names. Trans. Amer. Fish. Soc. 117(4):321.

Lehre, A. K. 1974. The climate and hydrology of the Golden Gate National Recreation Area. In: The terrestrial environment of the Golden Gate National Recreation Area with proposals for resources management and research. Unpublished manuscript. On file. Golden Gate National Recreation Area.

Laudon, J. 1988. Redwood Creek underflow, Marin County. Memorandum of August 5, 1988. Division of Water Rights, State Water Resources Control Board. 8 pp.

McMahon, T. E. 1983. Habitat suitability index models: 'coho salmon. U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-82/10.49. 29 pp.

Norusis, M. J. 1988. SPSS/PC+ V3.0 Manual. SPSS, Chicago, 111.

Snider, W. M. 1984. An assessment of coho salmon and steelhead resource requirements in Redwood Creek, Marin County. California Department of Fish and Game, Environmental Services Branch. Administrative Report No. 84-1. 19 pp.

Snider, W. M. 1985. Instream flow requirements of anadromous salmonids, Brush Creek, Mendocino County, California. Department of Fish and Game Stream Evaluation Report no. 85-1. Environmental Services Branch, Sacramento, California. 33 pp.

Van Deventer, J. S., and W. S. Platts. 1983. Sampling and estimating fish populations from streams. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 48:349-354.

Van Deventer, J. S., and W. S. Platts. 1985. A computer software system for entering, managing, and analyzing fish capture data from streams. USDA Forest Service Research Note INT-352. Intermountain Research Station, Ogden, Utah. 12 pp.

Vollintine, L. 1973. Land use in Redwood Creek watershed, Marin County. U.C. Berkeley class report. 135 pp.

Zedonis, P. A. 1988. Biological parameters and salmonid populations, (emphasis on steelhead), Mattole River lagoon, California, July to October 1988. Summary report to Bureau of Land Management, Agreement No. CA-950-CA6-018. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California. 42 pp.

# FIGURES

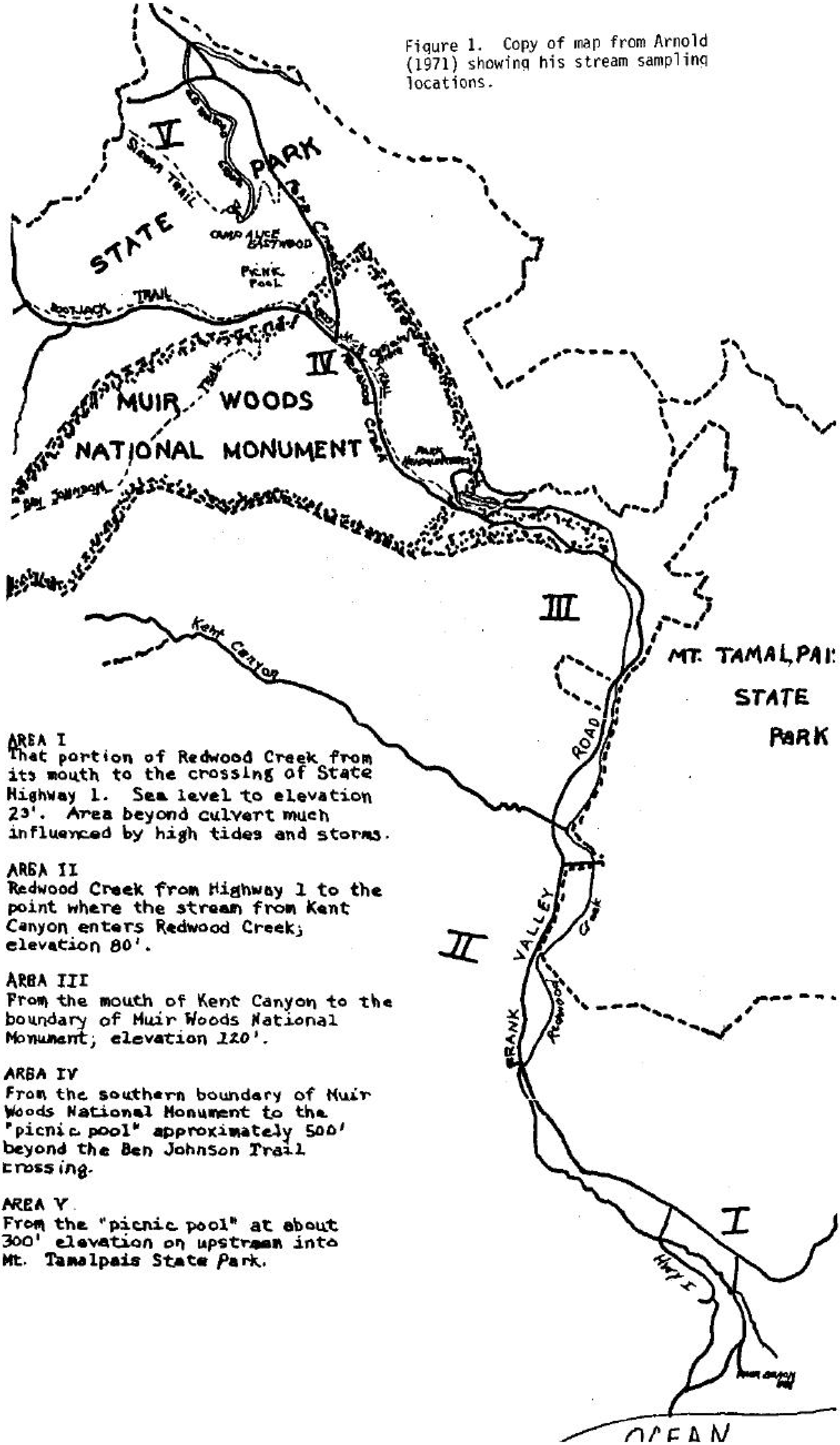


Figure 1. Copy of map from Arnold (1971) showing his stream sampling locations.

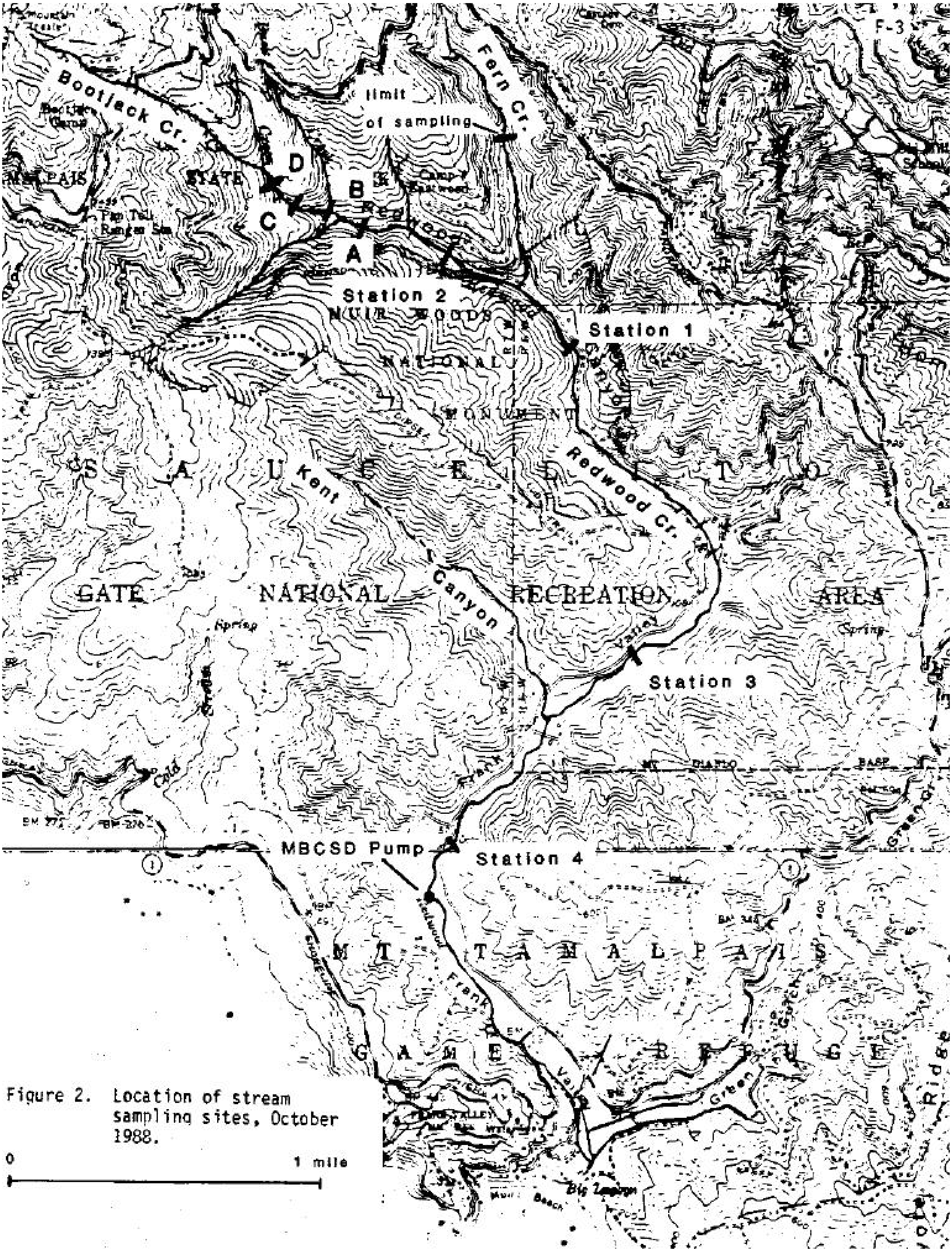


Figure 2. Location of stream sampling sites, October 1988.

## STEELHEAD TROUT

**Redwood Creek, Marin County**

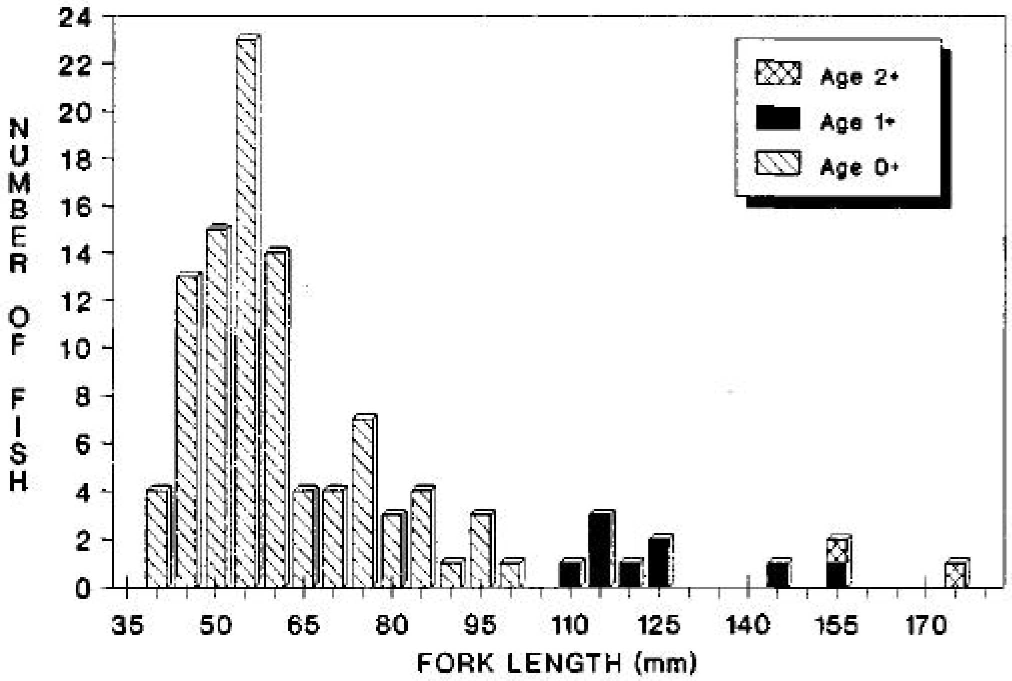


Figure 3. Length-frequency histogram and age of juvenile steelhead trout determined from aged scales, Redwood Creek, Marin County, October 1988.

# TABLES

TABLE 1. Distribution and percentages of species present for electrofished sections of Redwood Creek, Marin County, California, October 1988.

| Location | COHO | Fish<br>STEELHEAD TROUT | SCULPIN |
|---|---|---|---|
| Redwood Creek | | | |
| Station D (600 ft contour) | | X | |
| Station C (600 ft contour) | | X | |
| Station B (380 ft contour) | | X | |
| Station A (280 ft contour) | | X | |
| Station 2 (200 ft contour) | X (7%) | X(56%) | X (38%) |
| Station 1 (150 ft contour) | X (21%) | X (9%) | X (71%) |
| Station 3 (80 ft contour) | X (16%) | X(36%) | X (48%) |
| Station 4 (60 ft contour) | X (5%) | X(77%) | X (18%) |
| Fern Creek | | | |
| 350 foot contour | X | X | |
| 220 foot contour | X | X | X |
| Beach Pools | | | X |
| (a few stickleback and juvenile rockfish were also found) | | | |

TABLE 2. Mean lengths (mm) and weights (g), their standard deviations (S.D.) and ranges, and median lengths (mm) of fish electroshocked at study sites in Redwood Creek, Marin County, California, October 5-6, 1988.

COHO SALMON

| Location | No. | Mean FRKL[a] | S.D. | Median | Range | Mean WT (g) | S.D. | Range |
|---|---|---|---|---|---|---|---|---|
| Station 2 | 3 | 60.3 | 3.1 | 61 | 57- 63 | 2.6 | 0.5 | 2.1 - 3.1 |
| Station 1 | 26 | 63.6 | 6.1 | 62.5 | 54- 78 | 3.3 | 1.0 | 1.7 - 6.0 |
| Station 3 | 11 | 79.4 | 6.6 | 80 | 68- 90 | 6.5 | 1.6 | 3.7 - 9.1 |
| Station 4 | 1 | 83 | - | 83 | --- | 5.1 | - | — |

STEELHEAD TROUT

| Location | No. | Mean FRKL[a] | S.D. | Median | Range | Mean WT (g) | S.D. | Range |
|---|---|---|---|---|---|---|---|---|
| Station 2 | 25 | 58.1 | 16.0 | 61 | 41-114 | 3.2 | 3.0 | 0.9 -15.3 |
| Station 1 | 11 | 64.5 | 26.5 | 56 | 38-114 | 4.3 | 4.4 | 0.8 -13.6 |
| Station 3 | 25 | 61.4 | 17.2 | 57 | 43-120 | 3.5 | 3.6 | 0.4 -18.0 |
| Station 4 | 16 | 78.1 | 33.0 | 72 | 49-154 | 7.9 | 10.2 | 1.5 -32.7 |

SCULPIN

| Location | No. | Mean TL[b] | S.D. | Range | No. | Mean WT (g) | S.D. | Range |
|---|---|---|---|---|---|---|---|---|
| Station 2 | 16 | 56.1 | 16.7 | 30-85 | 17 | 3.5 | 1.9 | 1.1 - 8.4 |
| Station 1 | 83 | 55.0 | 14.6 | 25-125 | 41 | 2.7 | 3.7 | 0.3 -23.9 |
| Station 3 | 33 | 77.4 | 34.6 | 40-157 | 33 | 11.0 | 15.7 | 0.8 -56.5 |
| Station 4 | 4 | 75.8 | 37.5 | 40-112 | 4 | 8.3 | 8.3 | 0.8 -17.1 |

a. FRKL = Fork length (mm)
b. TL = Total length (mm)

TABLE 3. Fish numbers and biomass (g) per stream length (m), water surface area ($m^2$), and water volume ($m^3$) for study sites on Redwood Creek, Marin County, California, October 5-6, 1988.

| Location | No./m | No./$m^2$ | No./$m^3$ | g/m | g/$m^2$ | g/$m^3$ |
|---|---|---|---|---|---|---|
| COHO | | | | | | |
| Station 2 | 0.10 | 0.03 | 0.43 | 0.25 | 0.08 | 1.14 |
| Station 1 | 0.65 | 0.16 | 1.08 | 2.15 | 0.52 | 3.58 |
| Station 3 | 0.35 | 0.12 | 0.60 | 2.26 | 0.84 | 3.95 |
| Station 4 | 0.03 | 0.01 | 0.07 | 0.17 | 0.08 | 0.38 |
| STEELHED | | | | | | |
| Station 2 | 0.81 | 0.25 | 3.61 | 2.54 | 0.80 | 11.40 |
| Station 1 | 0.30 | 0.07 | 0.50 | 1.30 | 0.29 | 2.17 |
| Station 3 | 0.78 | 0.29 | 1.37 | 2.74 | 1.02 | 4.79 |
| Station 4 | 0.80 | 0.35 | 1.80 | 6.32 | 2.79 | 14.13 |
| SCULPIN | | | | | | |
| Station 2 | 0.77 | 0.24 | 3.47 | 2.04 | 0.64 | 9.13 |
| Station 1 | 2.23 | 0.54 | 3.71 | 5.93 | 1.44 | 9.88 |
| Station 3 | 1.26 | 0.47 | 2.20 | 13.83 | 5.12 | 24.17 |
| Station 4 | 0.13 | 0.06 | 0.30 | 1.11 | 0.49 | 2.48 |

TABLE 4. Mean condition factors (K) and standard deviation (S.D) of fish collected in Redwood Creek, Marin County, California, October 5-6, 1988.

| Location | COHO | STEELHEAD | SCULPIN |
|---|---|---|---|
| Station 2 | 1.21 (0.27) | 1.43 (0.41) | 2.0 (0.96) |
| Station 1 | 1.26 (0.21) | 1.24 (0.37) | 1.1 (0.23) |
| Station 3 | 1.28 (0.08) | 1.23 (0.25) | 1.4 (0.24) |
| Station 4 | 0.89 — | 1.22 (0.22) | 1.3 (0.16) |

TABLE 5. Age and fork length data derived from scales of steelhead trout electrofished from Redwood Creek, Marin County, California, October 1988.

| Fork length (mm) | Age | Fork length (mm) | Age |
|---|---|---|---|
| 79 | 0+ | 109 | 1+ |
| 81 | 0+ | 114 | 1+ |
| 83 | 0+ | 114 | 1+ |
| 83 | 0+ | 120 | 1+ |
| 85 | 0+ | 123 | 1+ |
| 85 | 0+ | 143 | 1+ |
| 88 | 0+ | 153 | 2+ |
| 99 | 0+ | 154 | 1+ |
| | | 174 | 2+ |

TABLE 6. Water quality parameters measured at Redwood Creek, Marin County, California on October 6, 1988. Parameters were water temperature (°C), dissolved oxygen (ppm), salinity ($^{Q}/_{OQ}$), specific conductance (µmhos at 25°C), and pH.

| Location | Time | Temp-erature (°C) | Dissolved Oxygen (ppm) | Salinity (0/00) | Sp. Conductance (µmhos @ 25 °C) | pH |
|---|---|---|---|---|---|---|
| Station 2 | 0929 | 13.0 | 10.1 | 0.0 | — | 7.2 |
| Station 1 | 0840 | 13.0 | 10.2 | 0.0 | 235 | 6.3 |
| Station 3 | 1440 | 13.5 | 5.9 | 0.0 | 225 | 6.0 |
| Station 4 | 1710 | 13.0 | 0.9 -2.8 | 0.0 | 255 | 6.1 |
| Beach pool | 1830 | 17.0 | —- | 0.0 | 535 | -- |

TABLE 7. Site differences (p=0.05) in coho salmon fork length (mm).

| | Station 2 | Station 1 |
|---|---|---|
| Station 2 | | |
| Station 1 | | |
| Station 3 | X | X |
| Station 4 | X | X |

TABLE 8. Length - Weight relationships of juvenile salmonids electroshocked in Redwood Creek, Marin County, California, October 5-6, 1988. The equation is $W = a L^b$, and when expressed as $\log W = \log a + b \log L$, gave a straight line relationship. (X = log length and Y = log weight).

| Location | Length – Weight Relationship | $r^2_{adj}$ | df |
|---|---|---|---|
| COHO | | | |
| Station 2 | Y= -0.65 + 0.60 X | 0 | 2 |
| Station 1 | Y= -4.32 + 2.68 X | 66.9 | 25 |
| Station 3 | Y= -4.97 + 3.04 X | 93.6 | 10 |
| Station 4 | one fish captured | | |
| STEELHEAD | | | |
| Station 2 | Y= -4.07 + 2.55 X | 83.5 | 24 |
| Station 1 | Y= -4.29 + 2.64 X | 92.9 | 10 |
| Station 3 | Y= -5.04 + 3.06 X | 87.7 | 24 |
| Station 4 | Y= -4.20 + 2.61 X | 98.5 | 15 |
| SCULPIN | | | |
| Station 2 | Y= -2.74 + 1.85 X | 96.0 | 15 |
| Station 1 | Y= –4.47 + 2.72 X | 91.5 | 38 |
| Station 3 | Y= -4.72 + 2.93 X | 98.3 | 32 |
| Station 4 | Y= -4.66 + 2.88 X | 99.4 | 3 |

# APPENDIX
(Fish Population Estimate Statistics)

Stream: REDWOOD CREEK STATION 1 (MUWO)
Species: COHO

Removal Pattern: 21 5
Total Catch = 26
Population Estimate = 26

Chi Square = 0.673
Pop Est Standard Err 1.154
Lower Conf Interval = 26.000
Upper Conf Interval = 28.377

Capture Probability =0.839
Capt Prob Standard Err =0.093
Lower Conf Interval =0.648
Upper Conf Interval =1.030
The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 23.623.

Stream: REDWOOD CREEK STATION 1 (MUWO)
Species: STEELHEAD TROUT

Removal Pattern: 7 4
Total Catch = 11
Population Estimate = 12

Chi Square = 0.677
Pop Est Standard Err = 2.732
Lower Conf Interval = 11.000
Upper Conf Interval =18.033

Capture Probability = 0.647
Capt Prob Standard Err = 0.248
Lower Conf Interval = 0.099
Upper Conf Interval = 1.195

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 5.962.

Stream: REDWOOD CREEK STATION 1 (MUWO)
Species: SCULPIN

Removal Pattern::: 66 18
Total Catch = 84
Population Estimate = 89

Chi Square = 0.115
Pop Est Standard Err = 4.060
Lower Conf Interval = 84.000
Upper Conf Interval = 97.067

Capture Probability = 0.750
Capt Prob Standard Err = 0.068
Lower Conf Interval = 0.614
Upper Conf Interval = 0.886

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 80.933.

Stream: REDWOOD CREEK STATION 2 (MUWO)
Species: COHO

Removal Pattern: 2 1
Total Catch = 3
Population Estimate = 3

Chi Square = 0.381
Pop Est Standard Err = 0.745
Lower Conf Interval = 3.000
Upper Conf Interval = 6.207

Capture Probability = 0.750
Capt Prob Standard Err = 0.373
Lower Conf Interval = -.854
Upper Conf Interval = 2.354

The population estimate lower confidence interval was set equal to the total catch. Actualcalculated lower CI was -0.207.

Stream: REDWOOD CREEK STATION 2 (MUWO)
Species: STEELHEAD TROUT

Removal Pattern: 20 5
Total catch - 25
Population Estimate = 25

Chi Square = 0.725
Pop Est Standard Err = 1.133
Lower Conf Interval = 25.000
Upper Ccnf Interval = 27.442

Capture Probability = 0.833
Capt Prob Standard Err = 0.097
Lower Conf Interval = 0.634
Upper Conf Interval = 1.033

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 22.558.

Stream: REDWOOD CREEK STATION 2 (MUWO)
Species: SCULPIN

Removal Pattern 10 7
Total Catch = 17
Population Estimate = 24

Chi Square = 0.249
Pop Est Standard Err = 11.274
Lower Conf Interval = 17.000
Upper Conf Interval = 47.326

Capture Probability = 0.447
Capt Prob Standard Err = 0.283
Lower Conf Interval = -.138
Upper Conf Interval = 1.032

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 0 674.

Stream: REDWOOD CREEK STATION 3 (MUWO)
Species: COHO

Removal Pattern: 9 2
Total Catch = 11
Population Estimate = 11

Chi Square = 0.242
Pop Est Standard Err = 0.704
Lower Conf Interval = 11.000
Upper Conf Interval = 12.569

Capture Probability = 0.846
Capt Prob Standard Err = 0.138
Lower Conf Interval = 0.538
Upper Conf Interval = 1.154

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 9.431.

Stream- REDWOOD CREEK STATION 3 (MUWO)
Species: STEELHEAD TROUT

Removal Pattern: 22 3
Total Catch = 25
Population Estimate = 25

Chi Square = 0.163
Pop Est Standard Err = 0.668
Lower Conf Interval = 25.000
Upper Conf Interval = 26.379

Capture Probability = 0.893
Capt Prob Standard Err = 0.073
Lower Conf Interval = 0.742
Upper Conf Interval = 1.043

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI. was 23.621.

Stream: REDWOOD CREEK STATION 3 (MUWO)
Species: SCULPIN

Removal Pattern: 22 11
Total Catch = 33
Population Estimate = 40

Chi Square = 0.175
Pop Est Standard Err = 7.599
Lower Conf Interval = 33.000
Upper Conf Interval = 55.372

Capture Probability = 0.569
Capt Prob Standard Err = 0.165
Lower Conf Interval = 0.236
Upper Conf Interval = 0.902

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 24.628.

A-5

Stream: REDWOOD CREEK STATION 4 (MUWO)
Species: STEELHEAD TROUT

Removal Pattern: 10 7

| | | |
|---|---|---|
| Total Catch | = | 17 |
| Population Estimate | = | 24 |
| Chi Square | = | 0.249 |
| Pop Est Standard Err | = | 11.274 |
| Lower Conf Interval | = | 17.000 |
| Upper Conf Interval | = | 47.326 |
| Capture Probability | = | 0.447 |
| Capt Prob Standard Err | = | 0.283 |
| Lower Conf Interval | = | -.138 |
| Upper Conf Interval | = | 1.032 |

The population estimate lower confidence interval was set equal to the total catch. Actual calculated lower CI was 0.674.

PHOTOGRAPHS

STATION 1
Downstream view from top of Station 1.

Note absence of organic debris in the channel.

October 5, 1988

STATION 1
Downstream view from near top of Station 1.

October 5, 1988

STATION 1
Upstream view from near bottom of Station 1.

October 5, 1988

NOTE: There are no photographs of Station 2.

STATION 3
Downstream view from top of Station 3. Note bedload in channel and slack water conditions.

October 6, 1988

STATION 3
Downstream view from near top of Station 3. Note bedload in channel and slack water conditions.

October 6, 1988

STATION 3
Upstream view from near bottom of Station 3.

October 6, 1988

STATION 4
Upstream view from bottom of Station 4. Note bedload conditions.

October 6, 1988

STATION 4
Undercut bank near middle of Station 4

October 6, 1988

STATION 4
Downstream view from near top of Station4. Note bedload conditions and slack water conditions.

October 6, 1988

Juvenile steelhead trout (top) and juvenile coho salmon (bottom) captured at Station 3.

October 6, 1988

Stranded runback steelhead trout found just above Station 3.

October 6, 1988

One of the few pools found on the creek, just upstream of Station 3. This is where we found the runback steelhead trout.

October 6, 1988.

# United States Department of the Interior

NATIONAL PARK SERVICE
GOLDEN GATE NATIONAL RECREATION AREA
FORT MASON, SAN FRANCISCO, CALIFORNIA 94123

IN REPLY REFER TO:

N1423 (WR-GOGA)

SEP 19 1988



Memorandum

To: Superintendent, Redwood N.P.

From: Superintendent, Golden Gate N.R.A.

Subject: Survey of Redwood Creek

We request the assistance of your staff in initiating a survey of the aquatic resources in GGNRA's Redwood Creek. The two years of drought have brought the opportunity to measure low flow limiting factors that are critical to the evaluation of the Coho salmon habitat in the stream. The anadromous fish that use the stream have not been inventoried nor has the habitat been evaluated at the level needed for making management decisions.

Terry Hofstra and a small crew could cover the needed area in approximately four days. The creek is approximately 10 miles long and has good access through its length. Within the four days we anticipate an evaluation of spawning and rearing habitat as well as a preliminary inventory of the fish. We also hope to be advised on some methods for restoring the Redwood Creek Estuary and how such a restoration would enhance natural diversity.

Your group at Redwood N.P. has been invaluable to us this year. Your staff deserves the highest commendation for its thorough work, helpful attitude and continued professionalism. Thank you very much for all of your assistance!