REDWOOD CREEK
AQUATIC MONITORING REPORT

FEBRUARY MAY 1994

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by

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AQUATIC MONITORING PROGRAM

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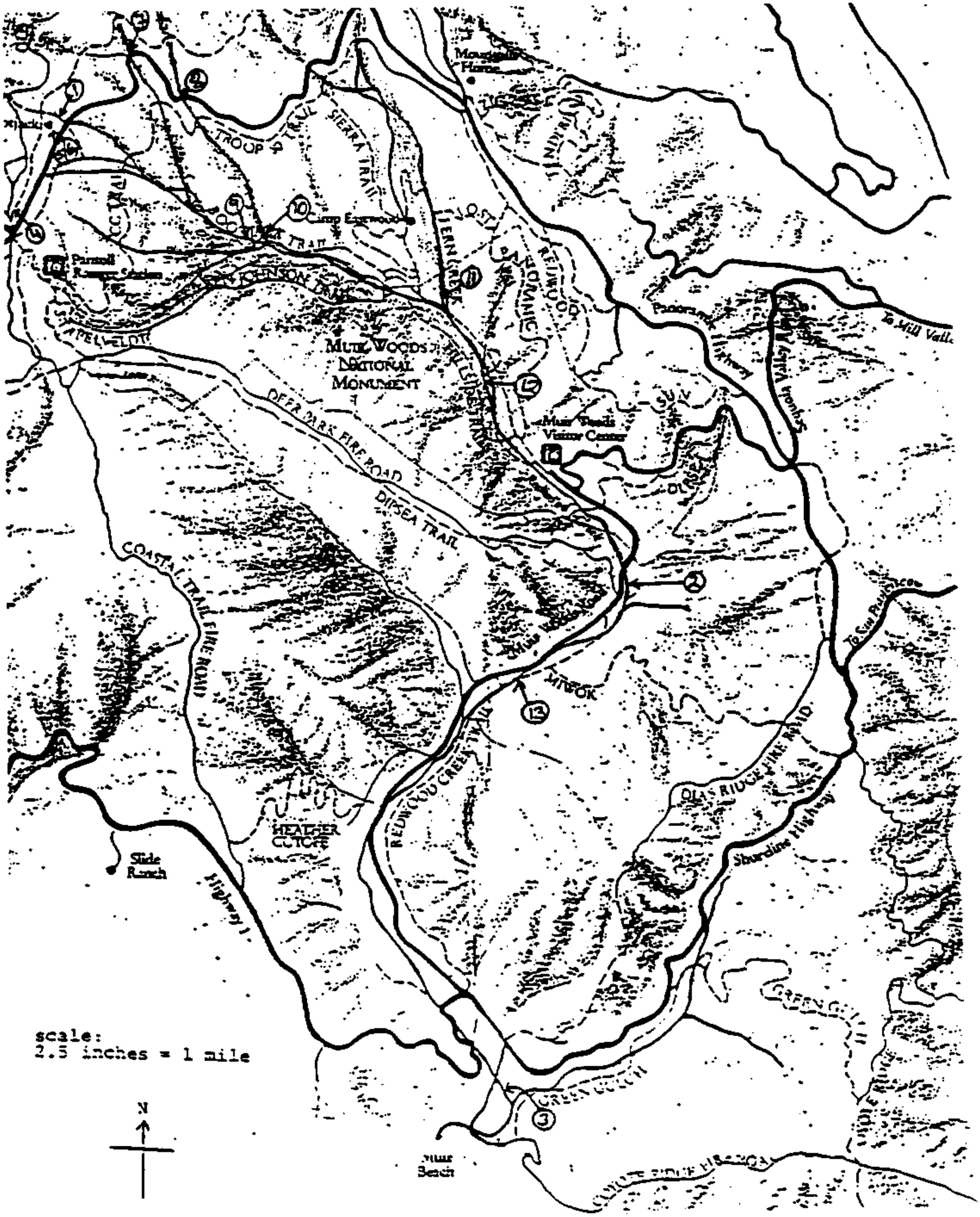
INTRODUCTION

Redwood Creek is a freshwater perennial stream protected in its entirety within State Park, National Park, and Water District lands in Marin County, California (NFS, 1992). The Redwood Creek watershed has been classified as one of seven "significant watersheds" within the Golden Gate National Recreation Area (GGNRA), a 75,000 acre expanse of land of which the Muir Woods National Monument comprises 550 acres. Redwood Creek and its surrounding environs have been recognized as a "special ecological area," which is defined as "...the most intact and diverse example of each ecological community" (NPS, 1993). As well as offering a scenic recreational area for approximately 1.6 million visitors a year (NPS, 1992), the Redwood Creek corridor also provides important habitat and feeding grounds for a diverse array of resident and migratory fauna.

Anadromous fish such as steelhead trout and silver salmon formerly spawned in Redwood Creek in large numbers. Although spawning still occurs, studies show that it has decreased greatly in recent years, primarily due to reduced stream flow resulting from water diversions and extractions (NPS, 1992). Other sensitive species that have suffered from nearby urban and agricultural development include the California Freshwater Shrimp and San Francisco Garter Snake (both federally listed as endangered species), and the Tree Lupin Moth (a federal endangered species candidate) (NPS, 1992).

The National Park Service has expressed its commitment to "work toward solving problems that have cumulatively resulted in the deterioration of the Redwood Creek ecosystem" (NPS, 1992). In an effort to assist NPS in reaching its goals, the Institute of Chemical Biology at the University of San Francisco (USF) directed a baseline study of the physical, chemical, and biological components of Redwood Creek. This report reflects the field and laboratory activities of the USF Environmental Monitoring class during the months of February through May 1994. The presented data include results of stream surveys, sediment compositions, water quality analyses, bacteria levels, chemical element scans, and population estimates of benthic macroinvertebrates and periphyton. Data collections and analyses were supervised by the authors of this report.



Map 1: Sampling stations in the Redwood Creek watershed, Marin County, CA.

1. MATERIALS AND METHODS

1.1. PHYSICAL CHARACTERISTICS

Maps of the Redwood Creek watershed were studied prior to project initiation, and the majority of the drainage was surveyed on foot. The following sampling stations were selected to conduct the study (Map 1):

Station:	Location:
1	Redwood Creek headwaters at Bootjack Camp (37°54'33"N/122^{0}36'10"W)
2	Redwood Creek downstream from Muir Woods National Monument parking lot, Muir Woods Road mile 1.96 (37^{0}53'18"N/122^{0}34'04"W)
3	Redwood Creek at Muir Beach parking lot (37°51'41"N /122°34'31" W)
4	Headwater rivulet feeding Redwood Creek, at culvert under Matt Davis Trail near Pan Toll ranger station (37°54'25"N/122°36'19"W)
5	Headwater rivulet feeding Redwood Creek, near Bootjack restrooms (37°54'33"N/122°36'14"W)
6	Headwater rivulet feeding Redwood Creek, near Bootjack restrooms 5 ft. to the north of station #5 (37°54'33"N/122°36^{1}14"W)
7	Headwater rivulet feeding Redwood Creek, Panoramic Highway mile 4.22 (37^{0}54'38"N/122^{0}35'40"W)
8	Headwater rivulet feeding Redwood Creek, Panoramic Highway mile 3.22 (37^{0}54'50"N/122°35'02"W)
9	Redwood Creek upstream from Buch Creek, on Bootjack Trail
10	Buch Creek at the mouth, on Bootjack Trail
11	Fern Creek at the mouth, in Muir Woods
12	Redwood Creek downstream from Cathedral Grove in Muir Woods
13	Redwood Creek between station 2 and station #3, Muir Woods Road mile 3.10 (37^{0}52'39"N/122°34'54"W)

Longitude and latitude references for the stations were determined at the nearest area of open canopy, using a handheld Magellan GPS Meridian™. Longitude and latitude coordinates for stations 9 through 12 are not available due to the dense redwood forest canopy in Muir Woods, which precludes line-of-site satellite access.

Stream Survey

Stream surveys were conducted at stations 1 through 3 on February 2 according to methods outlined by the U.S. Forest Service (Platts et al., 1983). A transect was set up perpendicular to the stream flow at each of the primary stations. Parameters measured at the transects included width, depth, channel substrate, and embeddedness. Stream channel stability, stream bank soil alteration, and watershed soil stability were assessed visually and subjective scores were recorded for each condition.

Stream Flow

Water flow was calculated by measuring stream cross-sectional areas at the transects and measuring water velocity with a Swoffer pygmy current meter (see Tables 1, 5, and 6 for stations and dates). Flows are reported to the nearest 0.01 cubic feet per second (cfs).

Stream Sediments

Substrate stream sediment samples were collected at stations 1 through 3 on March 16, and characterized to substrate size compositions. Samples were collected using a modified McNeil sampler with an inside tube diameter of 6 inches. The apparatus was worked into the substrate to a depth of approximately 6 inches. Sand, gravel, and cobble were extracted from the tube by hand and a cylindrical plastic plunger with an "O" ring base was used to collect the water portion of the sample, including any suspended sediments. The rock portion of the sample was then transferred to labeled plastic bags. The water was poured into labeled 1/2 gallon plastic bottles. This procedure was repeated for 3 replicate samples at stations 2 and 3, and for 2 replicate samples at station 1, where the narrow nature of the headwater portion of Redwood Creek renders additional replicates unnecessary.

The sediment samples were then taken to the laboratory, transferred into stainless steel pans, and oven-dried. The distribution of particle sizes for each sample was determined by sieve analysis. Sediments were sifted through a series of fifteen sieves with decreasing mesh sizes (Table A). The weight of the material retained on each sieve was recorded and a percentage of the total weight calculated.

Table A
Sieve and mesh sizes used for sediment analysis

Sieve size	mesh diameter	Sieve size	mesh diameter
	(mm)	(mm)	
3 in	76.200	No. 16	1.191
1 1/2 in	38.100	No. 20	0.841
3/4 in	19.050	No. 30	0.595
1/2 in	12.700	No. 50	0.297
3/8 in	9.525	No. 100	0.150
No. 4	4.750	No. 150T	0.104
No. 5T	3.962	No. 200	0.074
No. 8	2.380		

1.2. WATER QUALITY

Measurements of air and water temperatures (°C), conductivity (µmhos), dissolved oxygen (mg/L), dissolved oxygen saturation (%), turbidity (nephlometric turbidity units, NTU), and hydrogen ion concentration (pH) were collected in the field on March 7 at stations 1 through 3, and on April 25 at stations 1 through 12. A list of the instruments used is provided in the appendix . On the same days, water samples from all stations (except station 13) were collected in 500 ml plastic bottles, stored on ice, and analyzed at the USF laboratory within 24 hours. The methods for testing for the following chemical elements are described in the Water Analysis Handbook (HACH Company, 1989) and the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1985): alkalinity (HACH, 81-85), ammonia (APHA, 384-386), chloride (HACH, 145-148), nitrate (HACH, 392-395), phosphate (APHA, 446-448), and sulfate (HACH, 567-571).

1.3. COLIFORM ANALYSIS

One hundred ml water samples were collected at stations 1 through 3 on March 16 and analyzed for total coliform and fecal coliform bacteria levels using multiple tube fermentation techniques (APHA, 1985). Analyses were performed by Babcock & Sons Laboratory in Riverside, CA. Results are reported as the most probable number (MPN) of bacteria per 100 ml sample.

1.4. CHEMICAL ELEMENT SCAN

Sets of two 60 ml filtered (0.45 urn pore size) water samples were collected at stations 1 through 3 on March 7 and analyzed for levels of various common chemical elements. One bottle from each set, preserved with 3 drops of concentrated nitric acid (HNO_3), was used for a 26 chemical element scan by inductively coupled plasma (ICP) emission spectroscopy; the other bottle, preserved with 3 ml HNO_3 and 0.03 g potassium dichromate ($K_2Cr_2O_7$), was tested for mercury using cold vapor atomic absorption (AA) spectrometry. Analyses were performed by UCLA Laboratory of Biomedical & Environmental Sciences in Los Angeles, CA. Results are reported in mg/L.

1.5. BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates (BMIs) were collected for identification and population estimate calculations at station 2 on April 6 and at station 13 on April 18. At each site a 0.25 m^2 quadrant was sampled in a representative riffle section of the stream. A hand-held kick screen was placed at the downstream side of the quadrant with the net flush against the stream bottom. Using a small brush, large rocks were scrubbed to remove all attached BMI's. Smaller rocks and sediments within the sampling area were thoroughly churned up manually to an approximate depth of 8 cm. All dislodged materials were directed downstream into the kick screen and transferred into a 500 ml plastic container. The contents were then preserved in approximately 80% ethyl alcohol.

In the laboratory, the samples were cleaned of vegetative materials and sediments, and the BMIs were sorted and identified to family using McCafferty's Aquatic Entomology key (1981).

1.6. PERIPHYTON

Relative periphyton abundance was established using a representative grab sample from station 2 on February 9. One square meter characteristic of the stream at this location was selected for sample collection. Rocks from this area were selected at random and all attached materials were scraped into a plastic test tube using a knife. Filamentous green algae were collected in a separate test tube. Both tubes were filled with stream water.

Upon return to the laboratory, preliminary identifications of the fresh algal samples were made using a standard microscope with 4X, 10X, and 40X magnifications. The samples were then preserved with Lugol's solution and, at a later date, identified to genera using the USEPA Algae and Water Pollution key (Palmer, 1977). Where size was used as an identifying characteristic, ocular micrometers were utilized.

In order to make a statistically valid estimate of the relative abundances of the various genera, a minimum of 300 cells per sample were counted. Relative genus abundance is expressed as a percentage of the total.

2. RESULTS AND DISCUSSION

2.1. PHYSICAL CHARACTERISTICS

Stream Survey

Stream surveys provide an important overview of the general physical conditions of a stream. Measurements of stream habitat conditions, such as depth, flow, and embeddedness can be incorporated into models designed to indicate fish standing crops and to assist in evaluating impacts from land management activities (Platts *et al,* 1983).

Stream surveys revealed stable conditions at all three sampling stations (1 through 3). Embeddedness at station 3 was high (70-80%), but such a reading is to be expected during the height of the run-off season, and with the characteristically low flow at the wide lower section of the creek where transported sediments typically settle out. Stream channels were stable to fairly stable and stream bank soil alteration was very low. Gravel was the predominant stream substrate at all sites, but sizes decreased from the headwaters down to the mouth at Muir Beach. Complete data are summarized in Table 1.

Stream Flow

Stream flows on February 2 ranged from a low of 0.12 cubic feet per second (cfs) at station 1, to a high of 2.85 cfs at station 3. On March 7, the range was from 0.15 cfs at station 1, to 5.60 cfs at station 3. During the month of March, flows were considerably higher, a condition attributable to an increase in precipitational runoff. Qualitative evaluations of flow readings cannot be made at this point due to a lack of available data. Flow readings are listed in Tables 1 and 5.

Stream Sediments

Stream sediments are an important indication of the general condition of the stream substrate. Sediments may alter water chemistry, thereby reducing food production and decreasing habitat quality for aquatic organisms such as fish and benthic macroinvertebrates (Brown *et al.,* 1993). Organic-rich sediments may increase the biochemical oxygen demand (Edwards, 1962) and consequently reduce dissolved oxygen availability. The amount of fines (particles passing through the 0.84 mm mesh diameter sieve) are of particular concern because of their potential adverse effect on sensitive components of the aquatic environment. Thus, a high percentage of fines is usually indicative of a stressed stream condition.

The amount of fines expressed as a percentage of the total was low at all three sampling stations (1 through 3). The highest value (9.34%) was observed at station 3. Station 2 had the lowest amount of fines (2.38%). The low levels of fines at station 2 suggest the stream at this location has a high potential of serving as a spawning site for salmonids. Complete stream sediment data are summarized in Tables 2 through 4.

2.2. WATER QUALITY

The following water quality characteristics were measured during the monitoring period. A brief discussion of the importance of each parameter, and its established or proposed limit (i.e., EPA criteria), is followed by a description of the minimum and maximum concentrations, and other significant values recorded during the study period. The water quality data for all individual stations is summarized in Tables 5 and 6.

Water and Air Temperatures

Water temperatures naturally fluctuate according to the season and the time of day. High temperatures reduce the solubility of oxygen, accelerate the metabolism of aquatic organisms, increase the toxicity of heavy metals and can alter the species composition within a community (McKee and Wolf, 1963).

Water temperatures ranged from a low of 9.0 °C at station 1 on April 25, to a high of 12.8 °C at station 3 on March 7. The highest recorded air temperature was 19.8 °C at station 1 on March 7; the lowest was 8.0 °C at station 1 on April 25.

Conductivity

Specific conductance refers to the water's capacity to conduct an electric current. Measuring conductivity is a quick method of determining the ion concentration of a body of water, and indicating total dissolved matter and alkalinity. All substances in solution collectively exert osmotic pressure on aquatic organisms. When the osmotic pressure is sufficiently high, water drawn over respiratory membranes and other delicate external organs can cause considerable cell damage. High concentrations of many kinds of pollutants present this danger along with any other toxic or corrosive effects they may exhibit (Eckblad, 1978).

The highest conductivity readings, 210 µmhos, were observed at station 1 and station 3 on March 7 and April 25, respectively. The lowest value, 120 µmhos, was obtained from station 11 on April 25.

Dissolved oxygen

Dissolved oxygen concentrations vary considerably with water depth, temperature, time of day, flow rate and other natural factors (Eckblad, 1978). Aquatic organisms require dissolved oxygen, and many fish species are somewhat specific to the concentration required. In 1976, the USEPA set a lower limit of 5.0 mg/L. This limit was revised in 1986 by the USEPA and is currently set at 4.0 mg/L.

Oxygen readings ranged from a high of 12.1 mg/L (91% saturation) at station 1 on April 25, to a low of 9.5 mg/L (75% saturation) at station 3 on the same day. All obtained values suggest that Redwood Creek as a whole carries sufficient amounts of dissolved oxygen for fish and other aquatic organisms.

Turbidity

Turbidity is a measure of an optical property of water (Thurston *et al,* 1979) and is attributable to suspended and colloidal organic and inorganic matters which affect the penetration of light. McKee and Wolf (1963) have recommended an upper limit of 250 NTU for stream water designated for domestic use. They further indicated that turbidity levels over 400 NTU may be harmful to some fish life stages. High turbidity can kill adult fish, smother eggs and fry, reduce primary productivity, and alter temperature regimes.

Station 4 contained the highest turbidity level of 69.4 NTU on April 25. All other values were less than 10 NTU. Considering that these readings were taken during the winter run-off season, levels were very low and suggest that erosion is not extensive along the course of Redwood Creek.

Hydrogen ion concentration

The logarithm of the reciprocal of the hydrogen ion concentration is known as pH; consequently, a change of one pH unit represents a tenfold increase in hydrogen ion concentration. The solubility of metals in sediments and suspended material, and the toxicity of many compounds are affected by pH. The USEPA (1976) recognizes a criterion for domestic water (prior to treatment) of 5.0 to 9.0. The pH range for the protection of freshwater aquatic life is set at 6.5 to 9.0.

The highest (most basic) pH reading of 8.1 was observed at station 1 on March 7; the lowest (most acidic) value of 6.8 was obtained from station 5 on April 25. Such a narrow pH range is beneficial to aquatic organisms because it provides stable conditions along the length of the stream.

Alkalinity

Alkalinity refers to the total amount of alkalinities in water capable of neutralizing acids (i.e., buffering capacity). Alkalinity above 600 mg/L may be harmful to irrigated crops, and those above 400 mg/L may be a problem to human health (USEPA, 1976). Alkalinity is important to aquatic life because it buffers pH changes and reduces the toxicity of some heavy metals (McMillan, 1985). There is no maximum criterion for aquatic life, but the USEPA (1976) has established a minimum level of 20 mg/L.

Alkalinity levels ranged from a high of 140.0 mg/L at station 5 on April 25, to a low of 57.0 mg/L at station 10 on the same day.

Ammonia

Ammonia concentrations in water samples naturally occur as a product of organic decomposition. The USEPA (1976) criterion for protection of aquatic life is an upper limit of 0.02 mg/L of ammonia (NHa).

Ammonia readings at stations 1 through 3 were all below the detection limit of 0.02 mg/L. Ammonia levels form other stations are not available.

Nitrate

Nitrates that occur in water are often normal decomposition products of organic materials. Nitrate is also the common form in which nitrogen is added as fertilizer to agricultural crops and re vegetation projects. The maximum nitrate criterion for domestic water is 10.2 mg N/L; tested fish species have proved tolerant of much higher levels.

Nitrate levels at all stations were all below 1.0 mg/L and did not pose any threats to the health of the stream.

Sulfate

Sulfates appear in natural streams in a wide range of concentrations, often because of leaching of minerals and oxidation of sulfurous material associated with mining operations. The USEPA (1976) has set an upper limit of 250 mg/L for sul-fates in drinking water.

The highest sulfate level, 26.0 mg/L, was observed at station 4 on April 25. Station 5 contained the lowest concentration of 1.0 mg/L on the same day.

Orthophosphates

Orthophosphate is a general indicator of water quality and is an essential nutrient for aquatic life. Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm run-off (APHA 1992). Excessive amounts of orthophosphate can stimulate nuisance growths (blooms) of aquatic algae and perhaps higher plants. Although no criteria have been established for freshwater, it is recommended (USEPA, 1976) that orthophosphate concentrations should not exceed 0.05 mg/L for protection of aquatic life.

Orthophosphate concentrations were relatively low, ranging from a high of 0.098 mg/L at station 9 on April 25, to a low of 0.002 mg/L at stations 1, 4, and 6 on April 25.

Chloride

Chloride is present in nearly all water supplies, usually as a metallic salt. In drinking water, chloride concentrations in excess of 250 mg/L give a salty taste. Chlorides in drinking water are not usually harmful until high concentrations are reached. Large amounts may act corrosively on metal pipes and be harmful to plant life. The USEPA (1976) has set an upper limit of 500 mg/L for chlorides in drinking water.

Chloride concentrations ranged from a high of 20.5 mg/L at station 3 on April 25, to a low of 7.5 mg/L at station 8 on the same day. Chloride levels at station 3 might be elevated due to tidal actions adding saline ocean water to the mouth portion of Redwood Creek.

2.3. COLIFORM ANALYSIS

Since coliform bacteria are commonly found in human (and other mammalian) feces, they are used in water quality analysis as indicative of fecal waste pollution (Brown *et al.,* 1993). Due to the fact that some coliform bacteria are not enteric (present in the digestive system) but are found in plant and soil samples, a distinction is often made between total and fecal coliform counts. Treated or chlorinated drinking water should contain no coliform bacteria per 100 ml of sample (APHA, 1985), but coliform bacteria in untreated waters are to be expected.

Coliform levels were lowest at the headwaters station 1 and highest at Muir Beach station 3. Increasing coliform levels along the length of a creek are to be expected due to the accumulation of run-off and animal droppings. Fecal coliform counts ^t station 3 measured 30 MPN - a natural level which does not indicate any fecal water contamination. Complete data are summarized in Table 7.

2.4. CHEMICAL ELEMENT SCAN

The 16 chemical elements considered to be most important to this study are described below. Element concentrations for stations 1 through 3 are listed after each description and the complete element scan data are summarized in Table 8.

Calcium (Ca)

Calcium is an essential macronutrient for both plants and animals. It is the fifth most common element and is considered to be non-toxic. Calcium is present in most natural water at concentrations from zero to several hundred milligrams (APHA, 1985). Calcium is customarily added to water as it passes through or over calcium-rich geologic formations. Calcium contributes substantially to the hardness of water. There are no established water quality standards for this element.

Calcium concentrations for stations 1, 2, and 3 were 13.467 mg/L, 11.807 mg/L, and 12.826 mg/L, respectively.

Aluminum (Al)

Aluminum is the third most abundant metallic element in the earth's crust. The element is not known to have a nutritional function in organisms and may be toxic to life in high concentrations and acidic environments (Lepp, 1981). McKee and Wolf (1963) suggest an upper limit of 0.07 mg/L for the protection of fish and their ova.

Aluminum concentrations for stations 1, 2, and 3 were 0.054 mg/L, 0.052 mg/L, and 0.042 mg/L, respectively.

Iron (Fe)

Iron is an essential macronutrient for both plants and animals. This element occurs universally in natural waters, commonly in minor amounts. Iron can enter watercourses by leaching of natural deposits, from iron-bearing industrial wastes or emissions, or from acidic mine wastes (HACH, 1983). Iron precipitates can be detrimental to aquatic life (McMillan, 1985). A maximum level of 1 mg/L has been set by the USEPA (1976) for the protection of aquatic life, and on the basis of taste and aesthetics an upper limit of 0.300 mg/L has been recommended for domestic water supplies.

Iron concentrations for stations 1, 2, and 3 were 0.013 mg/L, 0.009 mg/L, and 0.022 mg/L, respectively.

Magnesium (Mg)

Magnesium is an essential macronutrient for plants and animals and is the eighth most abundant earth element. It is a common constituent of water and contributes significantly to hardness properties. Natural concentrations in surface water may range from zero to several hundred milligrams per liter. Concentrations in excess of 125 mg/L can have a cathartic and diuretic effect on humans (APHA, 1985).

Magnesium concentrations for stations 1, 2, and 3 were 21.701 mg/L, 12.709 mg/L, and 13.037 mg/L, respectively.

Manganese (Mn)

Manganese is a necessary micronutrient for living organisms and is normally present in surface waters in various oxidation states as soluble complexes or as suspended particles. In natural waters manganese rarely exceeds 1 mg/L, but levels of 0.1 mg/L are sufficient to cause taste and staining problems for domestic users. The maximum allowable manganese level (USEPA, 1976) in public water supplies is 0.05 mg/L, with a total iron plus manganese content not to exceed 0.3 mg/L. McKee and Wolf (1963) recommend a maximum level of 1 mg/L for the protection of freshwater aquatic life.

Manganese concentrations for stations 1,2, and 3 were 0.002 mg/L, 0.002 mg/L, and 0.008 mg/L, respectively.

Zinc (Zn)

Zinc is an element essential for human growth and for many aquatic organisms. The mean zinc concentration in US drinking waters is 1.33 mg/L; when in concentrations greater than 5 mg/L it affects taste. Acute toxicity of aquatic organisms has been demonstrated in concentrations as low as 0.090 mg/L. The USEPA (1980) has suggested 24-hour criteria of 0.047 mg/L for the protection of freshwater organisms.

Zinc concentrations for stations 1, 2, and 3 were 0.016 mg/L, 0.013 mg/L, and 0.009 mg/L, respectively.

Lead (Pb)

Lead is a toxic element that bioaccumulates in animals. Natural waters seldom contain more than 0.02 mg/L of lead (APHA, 1985). Lead toxicity in the aquatic environment is influenced by pH, alkalinity and hardness. McKee and Wolf (1963) have reported lead poisoning in humans to be caused by drinking water with as low as 0.042 mg/L lead. A criterion of 0.050 mg/1 for lead in domestic water supplies has been established (USEPA, 1976). The USEPA (1980) criterion for the protection of freshwater organisms is set at 0.0032 mg/L. This level was surpassed at station 1.

Lead concentrations for stations 1, 2, and 3 were 0.005 mg/L, <0.001 mg/L, and <0.001 mg/L, respectively.

Chromium (Cr)

Chromium is a toxic metal and a suspected carcinogen. Hexavalent chromium is more toxic to humans and aquatic life than is the trivalent form. Chromium may occur in natural water in both forms, but is usually found in the hexavalent state. The drinking water standard for chromium is 0.05 mg/L (USEPA, 1976). For the protection of freshwater aquatic life, 24-hour average concentrations of hexavalent chromium should not exceed 0.029 mg/L (USEPA, 1980).

Chromium concentrations for stations 1, 2, and 3 were 0.008 mg/L, 0.001 mg/L, and 0.002 mg/L, respectively.

Copper (Cu)

Copper is an essential micronutrient for both plants and animals. Copper salts, in quantities exceeding physiological demands, are also used to control algal growths in water supplies. The recommended USEPA (1980) criterion for protection of freshwater aquatic life is 5.6 |ig/L (=0.0056 mg/L) for a 24-hour average exposure. Since water hardness influences copper toxicity, criteria for instantaneous exposure may be calculated by taking water hardness into account. The USEPA drinking water standard is 1.0 mg/L based on taste effects.

Copper concentrations for stations 1,2, and 3 were 0.008 mg/L, 0.001 mg/L, and 0.001 mg/L, respectively.

Boron (B)

Boron is commonly associated with natural geothermal waters. Although small amounts of boron are essential for plant growth, concentrations in irrigation water in excess of 0.5 mg/L may harm sensitive species; yet, 0.75 mg/L is safe for most plants (Marshack, 1985). Boron is generally not considered a health hazard to man or other animals (Nolte, 1985). Drinking water concentrations of less than 0.1 mg/L are generally considered innocuous (APHA, 1985).

Boron concentrations for stations 1, 2, and 3 were 0.214 mg/L, 0.020 mg/L, and 0.079 mg/L, respectively.

Cadmium (Cd)

Cadmium is highly toxic to humans and other animals. A concentration of 0.002 mg/L has been found to be lethal to certain fish, and minute quantities of cadmium are suspected of causing certain cancers and adverse changes in human arteries and kidneys (APHA, 1985). Drinking waters in the US have a mean of about 0.008 mg/L cadmium. USEPA (1980) human health criterion for the ingestion of water containing cadmium is 0.010 mg/L. The criteria for the protection of aquatic organisms are dependent on hardness. For example, at a water hardness of 100 mg/L calcium carbonate, the amount of total recoverable cadmium should not exceed 3.0 ug/L (=0.003 mg/L) at any time, and at a hardness of 200 mg/L, cadmium should not exceed 6.3 ug/L (=0.0063 mg/L).

Cadmium concentrations for stations 1, 2, and 3 were 0.001 mg/L, <0.001 mg/L, and <0.001 mg/L, respectively.

Sodium (Na)

Sodium is the earth's sixth most abundant element and is present in nearly all natural surface waters. Although sodium has low toxitity, the ratio of sodium to total cations has important implications for agriculture and can affect many physiological processes in humans and other animals.

Sodium concentrations for stations 1, 2, and 3 were 8.420 mg/L, 10.785 mg/L, and 13.487 mg/L, respectively.

Silicon (Si)

Silicon is the world's second most abundant element and is naturally present in most surface waters and is essential for the growth of diatoms. It appears as the oxide (in quartz and sand) and in the form of complex silicate minerals. Silicon has no known toxic effects in the aquatic environment, and there are no water quality standards for this element (Brown *et* a/., 1993).

Silicon concentrations for stations 1,2, and 3 were 12.125 mg/L, 9.698 mg/L, and 8.683 mg/L, respectively.

Selenium (Se)

Excessive selenium may present a health hazard to humans. Selenium has been reported to affect normal embryo development in domestic animals (USEPA, 1980), and it may similarly affect fish and wildlife (Davis *et* a/., 1988). Tissue concentrations of selenium in excess of 2 mg/L may cause toxic effects in sensitive species of fish. However, small quantities of selenium are beneficial. It is assumed to be an essential micronutrient for humans and other animals. For selenium the USEPA has established a drinking water standard of 10 ug/L (=0.010

mg/L) for the protection of public health. However, the analytical methods employed did not distinguish elemental selenium from the more toxic selenite form of selenium. The freshwater aquatic life criteria for exposure to selenite is 0.035 mg/L, measured as an 24-hour average.

Selenium concentrations for stations 1, 2, and 3 were 0.013 mg/L, <0.001 mg/L, and <0.001 mg/L, respectively.

Potassium (K)

Potassium is an essential macronutrient for both plants and animals. Potassium ranks seventh among the elements in order of abundance, yet its concentration in most drinking waters seldom reaches 20 mg/L. Brines may contain more than 100 mg/L (HACH, 1983).

Potassium concentrations for stations 1, 2, and 3 were 0.060 mg/L, 0.522 mg/L, and 0.582 mg/L, respectively.

Arsenic (As)

Arsenic seldom occurs in drinking water above 0.010 mg/L (APHA, 1985). Arsenic is a known carcinogen and a poison. Poisoning in humans may occur from arsenic accumulation in the body at low intake levels. Although water hardness does not affect arsenic toxicity, higher temperatures may increase toxicity. The USEPA (1980) criterion for protection of freshwater aquatic life is 0.040 mg/L.

Arsenic concentrations for stations 1, 2, and 3 were 0.016 mg/L, <0.001 mg/L, and <0.001 mg/L, respectively.

Mercury (Hg)

Organic and inorganic mercury salts are very toxic (APHA, 1985). For mercury criteria, however, various sources cite different limits. The EPA ambient water quality criteria for the protection of freshwater aquatic life, as listed by the California Regional Water Quality Control Board, is 0.002 mg/L for an average 24-hour exposure with a maximum exposure level of 0.00041 mg/L (Marshack, 1985). The USEPA (1986) lists the following limits for freshwater: 0.0024 mg/L for acute toxicity and 0.00012 mg/L for chronic toxicity. CSDOH (1977) states that 0.002 mg/L mercury is the maximum contaminant level for water used continually for drinking or culinary purpose.

Mercury concentrations for stations 1,2, and 3 were all <0.001 mg/L.

Summary of Element Scan

A noteworthy trend among the element levels is the relatively high concentrations of several heavy metals (e.g. magnesium, nickel, cobalt, lead, chromium, etc.) and other elements at station 1. These elevated levels are probably a result of the serpentine rock and soil found on Mt. Tamalpais where the headwaters of Redwood Creek are located. Concentrations of these elements decrease downstream. Since the high levels are a natural phenomenon, any considerations as to management are unwarranted. This portion of Redwood Creek does, however, provide an appropriate site for further studies on heavy metals.

2.5. BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates (BMIs) are those invertebrate animals that can be observed with the unaided eye and can be retained by a US Standard No. 30 sieve (0.595 mm mesh) (Eckblad, 1978). BMIs are particularly useful in environmental monitoring of freshwater streams since throughout their life cycles they occupy a relatively stable position in the benthos. BMI compositions can provide valuable information on water quality shifts that occur insidiously over the long term due to their extended exposure to substances in the water column and substrate. Various groups of BMIs have very specific environmental requirements and are intolerant of adverse conditions. Thus, their presence or absence is a strong indication of the overall health of a stream.

A wide variety of taxa comprise the designation of benthic macroinvertebrate, but the most common ones are the Insecta, Mollusca, Oligochaeta, Platyhelminthes, Crustacea, and Nematoda (Brown et al, 1993). The two BMI sampling sites on Redwood Creek contained members of the following classes: Insecta, Annelida, Nematoda, Plathyhelmenthes, and Arachnida. Only the Insecta were keyed to family and the following discussion focuses on this group. The complete BMI data is summarized in Tables 9 and 10, and Figure 1.

Station 2

The most abundant order at this station was the Diptera, the true flies, a very diverse group which is found in a large variety of freshwater environments. Dipterans are an important source of food for fish. Most of the dipterans at station 2 belong to the family Chironomidae, the nonbiting midges. Immatures are primarily burrowers who inhabit sandy, silty stream substrates. Chironomidae feed on detritus and periphyton. The family Simuliidae, the next most abundant of the Dipterans, are the black flies whose immatures are found typically in swifter moving water. They have special cephalic fans that are used to strain detritus and planktonic algae from the stream, and therefore are adversely affected by high total suspended solids (TSS) levels. The Tipulidae, Ceratopogonidae, and Empididae families are all predators that feed on other insect larvae or algae (McMillan, 1985). Members of the suborders Nematocera and Brachycera were also present.

Ephemeroptera (mayflies) was the second most abundant order at station 2. This large taxonomic group is generally intolerant of adverse environmental conditions, though some species do very well in eutrophic waters. Ephemeroptera feed on detritus and periphyton. The order is composed of defenseless organisms that are consequently preyed upon heavily by most other aquatic organisms. Ephemerellidae was the most abundant family of this order in the sample. Ephemerellidae are among the most common of the ephemeropterans, and are not representative of any particular aquatic environment, successfully inhabiting a wide range of ecosystems (McMillan, 1985). Other families present included Heptageniidae, Baetidae, Siphlonuridae, Trichorythidae, and Leptophlebiidae.

Trichoptera (caddisflies), a large order of aquatic insects which feed on planktonic detritus, algae, and larger prey using nets and cases constructed from rocks and wood, comprised the third most abundant order at station 2. Because of their reliance on nets they tend to inhabit stream systems with low levels of suspended solids which can clog and break their nets. Thus, Trichopterans are good indicators of undisturbed streams (McMillan, 1985). The most common family was the predaceous Polycentropodidae. Also present were Hydropsychidae, Philopotamidae, Psychomyiidae, Rhyacophilidae, and Hydroptilidae.

Plecoptera (stoneflies) is probably the most indicative order of aquatic insects with respect to stream quality. There are only 9 families found in north America, many of which are intolerant of adverse stream conditions. Most species are restricted to dean and cool lotic waters (though there are some which survive in eutrophic conditions as well as in ephemeral streams). Plecopterans feed mostly on ephemeropteran nymphs and dipteran larvae (McMillan, 1985). This order was the fourth most abundant of the six orders found at RCM. The families Perlidae, Nemouridae, Chloroperlidae, and Perlodidae were present in similar amounts.

The fifth most abundant taxonomic group in the sample was Coleoptera (beetles), which is the largest order of insects and can be found in almost every terrestrial and aquatic habitat. Nevertheless, certain families of the aquatic coleopterans are useful as indicators of stream conditions. The most abundant family observed was Elmidae, which tends to inhabit streams with low sediment loads and high dissolved oxygen levels. They feed on detritus, scrape algae from the substrate, and in some cases are highly aggressive predators of insects, tadpoles, and even small fish (McMillan, 1985). Hydroscaphidae and Psephenidae were also present, though in low numbers.

The least abundant order at station 2 were the Hemiptera (true bugs), which are associated with a variety of aquatic habitats, including hot springs (McMillan, 1985). Two families, Belostomatidae and Veliidae, were present in small numbers.

The overall benthic macroinvertebrate composition at this section of Redwood Creek suggests that the water and habitat quality of the stream is relatively high. The presence of a variety of orders and families that are sensitive to high sediment loads and low oxygen levels contributes to that assumption.

Station 13

Numbers of individuals of the orders Ephemeroptera, Plecoptera, Trichoptera, and Hemiptera at station 13 were very similar to those at station 2. Also, the families within the orders did not vary substantially. The major differences in BMI abundances at station 13 were observed among the Dipterans and Coleopterans. The former was only the fifth most abundant order at this station, the latter the most abundant (Figure 1).

The benthic macroinvertebrate composition and relative diversity at this station provide further indication of the health of Redwood Creek.

2.6. PERIPHYTON

Primary producers such as algae form the basis of every food chain. Through photosynthesis they also provide oxygen necessary for respiration and other metabolic processes of consumer organisms. Additionally, some algae are capable of nitrogen fixation, providing an essential nutrient to the surrounding flora. Algae are excellent indicators of water quality conditions in a stream. Some types inhabit only undisturbed streams, whereas others typically thrive in polluted waters. A determination of the presence or absence of genera, and their relative abundance, can give a good indication of the overall health of a water course.

The most abundant algal genera observed at station 2 were *Navicula, Cocconeis, Audouinella,* and *Synedra.* According to Palmer (1977), *Navicula, Cocconeis,* and *Audouinella* are algae associated with dean water. *Synedra,* however, is classified as an alga that can adversely affect the taste and odor of a stream if it becomes very abundant (Palmer, 1977). Although only a limited amount of algal data was collected during the study period, it nevertheless suggests that the presence of adverse water quality conditions is unlikely. Furthermore, algal productivity suggests an abundant food base that could provide sufficient resources for fish and other aquatic organisms. Complete algal data are summarized in Table 11 and Figure 2.

CONCLUDING REMARKS

This study was performed as a class exercise for upper division Environmental Science students at the University of San Francisco. A wide variety of physical, chemical, and biological data was collected in order to set up a data base for a continuing monitoring program of Redwood Creek.

From the available data, Redwood Creek appears to be a relatively "healthy", stream with a diverse array of aquatic fauna and flora. The only unusual measurements were obtained from element scans of station 1, the Redwood Creek headwaters. The occurrence of high levels of heavy metals in water samples from station 1 are most likely a natural result of the serpentine rock and soil in the area. Further studies with regard to these elements would greatly supplement existing water quality information.

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Table 1: Data from stream surveys performed on stations 1 through 3 on Redwood Creek on February 2, 1994.

Station:	1	2	3
Stream width:	1.6 ft.	11.7 ft.	17.9 ft.
Stream depth (ave.):	0.1 ft.	1.2 ft.	1.3 ft.
Flow:	0.12 cfs	1.42 cfs	2.85 cfs
Stream substrate [1]:	gravel	gravel	gravel
Embeddedness (ave.):	30%	20-30 %	70-80 %
Stream channel stability:	stable	fairly stable	stable
Stream bank soil alteration[2]:	1-25%	1-25%	1-25%
Watershed soil stability:	stable	fairly stable	stable

1: stream substrate ratings:
> 609.0 mm - large boulder
305.0-609.0 mm - small boulder
76.1-304.0 mm-rubble
4.81-76.0 mm-gravel
< 4.80 mm - fine sediment

2: soil alteration ratings:
0% - streambanks are stable
1-25% - light alteration
16 – 50% - moderate alteration
51-75% major alteration
76-100% - severe alteration

Table 2: Sediment samples collected March 16,1994 at station 1. Two replicate samples (1,2) and the calculated means are reported in grams by sieve size. Subtotal B accounts for fine sediments (particles passing through 0.84 mm diameter sieve mesh size) which can have adverse effects on fish at levels above 12%. Note: Subtotal percentages may not add up to 100% due to rounding error.

Sieve Size	Replicate 1	Replicate 2	Meanl	Mean % Wt.
3 Inch	0.0	204.8	102.4	3.02%
1.5 "	859.3	947.1	903.2	26.61%
3/4 "	1085.9	645.2	865.6	25.50%
1/2 "	240.5	339.4	290.0	8.54%
3/8 "	249.3	337.8	293.6	8.65%
# 4	192.5	336.1	264.3	7.79%
# 5T	49.3	97.6	73.5	2.16%
# 8	139.5	276.2	207.9	6.12%
#16	141.9	252.0	197.0	5.80%
#20	51.5	81.1	66.3	1 .95%
Subtotal A	3009.7	3517.3	3263.5	96.14%
#30	38.5	50.9	44.7	1 .32%
#50	47.6	60.8	54.2	1 .60%
#100	19.2	21.4	20.3	0.60%
#150T	5.1	5.2	5.2	0.15%
#200T	2.7	2.7	2.7	0.08%
Pan	3.5	4.8	4.2	0.12%
Subtotal B	116.6	145.8	131.2	3.86%

Table 3: Sediment samples collected March 16,1994 at station 2. Three replicate samples (1-3) and the calculated means are reported in grams by sieve size. Subtotal B accounts for fine sediments (particles passing through 0.84 mm diameter sieve mesh size) which can have adverse effects on fish at levels above 12%. Note: Subtotal percentages may not add up to 100% due to *rounding error.*

Sieve Size	Replicate 1	Replicate 2	Replicate 3	Mean	Mean % Wt.
3 Inch	0.0	0.0	0.0	0.0	0.00%
1.5 "	1465.7	1214.9	2358.6	1679.7	42.65%
3/4 "	1026.8	1357.7	819.4	1068.0	27.12%
1/2 "	361.5	639.7	335.4	445.5	11.31%
3/8 "	237.2	387.2	371.1	331.8	8.43%
# 4	132.9	120.1	234.9	162.6	4.13%
# 5T	17.7	15.1	52.6	28.5	0.72%
# 8	56.3	37.4	110.5	68.1	1 .73%
#16	32.8	38.7	51.3	40.9	1 .04%
#20	13.9	29.3	14.8	19.3	0.49%
Subtotal A	3344.8	3840.1	4348.6	3844.5	97.62%
#30	15.7	44.7	13.2	24.5	0.62%
#50	28.3	83.6	20.1	44.0	1.12%
#100	10.5	28.2	7.3	15.3	0.39%
#150T	2.3	7.1	2.2	3.9	0.10%
#200T	1.2	3.7	1.7	2.2	0.06%
Pan	1.8	6.4	3.0	3.7	0.09%
Subtotal B	59.8	173.7	47.5	93.7	2.38%

Table 4: Sediment samples collected March 16,1994 at station 3. Three replicate samples (1-3) and the calculated means are reported in grams by sieve size. Subtotal B accounts for fine sediments (particles passing through 0.84 mm diameter sieve mesh size) which can have adverse effects on fish at levels above 12%. Note: Subtotal percentages may not add up to 100% due to rounding error.

Sieve Size	Replicate 1	Replicate 2	Replicate 3	Mean	Mean % Wt.
3 Inch	0.0	0.0	0.0	0.0	0.00%
1.5 "	0.0	577.5	196.1	257.9	5.12%
3/4 "	551.1	1382.1	1469.0	1134.1	22.50%
1/2 "	677.5	760.0	990.0	809.2	16.05%
3/8 "	689.8	606.3	781.0	692.4	13.73%
# 4	593.2	497.4	588.0	559.5	11.10%
# 5T	107.1	117.3	126.6	117.0	2.32%
# 8	542.5	354.3	506.9	467.9	9.28%
#16	363.8	328.4	497.1	396.4	7.86%
#20	107.9	113.9	185.6	135.8	2.69%
Subtotal A	3632.9	4737.2	5340.3	4570.1	90.66%
#30	93.2	87.0	208.6	129.6	2.57%
#50	144.0	158.4	413.6	238.7	4.73%
#100	45.5	69.9	109.2	74.9	1 .49%
#150T	6.4	13.9	17.4	12.6	0.25%
#200T	3.5	6.9	8.4	6.3	0.12%
Pan	4.5	11.1	11.4	9.0	0.18%
Subtotal B	297.1	347.2	768.6	471.0	9.34%

Table 5: Water Quality Data for stations 1 through 3 on Redwood Creek on March 7,1994 and April 25, 1994.

Station	1		2		3	
Date	3/7/94	4/25/94	3/7/94	4/25/94	3/7/94	4/25/94
Time	14:00	-	15:25	18:10	15:45	19:05
Weather	clear	rain	clear	rain	foggy	overcast
Field Data						
Air Temp (C)	19.8	8.0	14.7	9.4	13.8	9.8
Water Temp (C)	12.3	9.0	11.3	10.2	12.8	11.1
Conductivity (umhos)	210	160	160	160	185	210
Flow (cfs)	0.15	-	4.30	~	5.60	—
DO (mg/l)	10.4	12.1	10.7	10.7	10.7	9.5
DO Sat (%)	91	91	92	86	92	75
Turbidity (NTU)	1.51	4.30	1.71	3.17	1.87	3.15
Laboratory Data						
Alkalinity (mg/l)	118.0	110.0	74.5	90.0	75.5	87.0
Ammonia (mg/l)	<0.02	--	<0.02	-	<0.02	—
Nitrate (mg N/l)	0.14	0.22	0.10	0.13	0.31	0.24
Sulfate (mg/l)	2.0	2.0	10.0	12.0	13.0	16.0
Orthophosphate (mg/l)	0.012	0.002	0.023	0.010	0.025	0.034
Chloride (mg/l)	10.5	10.0	11.6	11.5	17.4	20.5
pH (pH units)	8.1	7.9	7.1	7.1	7.2	7.1

Note: -- indicates unavailable data

Table 6: Water quality data for stations 4 through 12 on Redwood Creek and some tributaries on April 25, 1994.

Station	4	5	6	7	8	9	10	11	12
Time	--	--	--	--	--	1715	1720	1705	1655
Weather	rain	rain	rain	rain	rain	rain	rain	rain	rain
Field Data									
Air Temp (C)	7.6	7.2	7.8	7.3	8.2	9.6	9.4	9.4	9.5
Water Temp (C)	10.7	12.1	9.1	9.2	9.5	10.1	10.3	10.0	10.1
Conduct (umhos/cm)	133	135	187	140	135	196	160	120	160
Flow (cfs)	0.02	0.02	0.02	--	-	0.74	0.04	0.45	0.03
DO (mg/l)	11.8	10.8	10.1	11.5	11.5	11.8	11.5	11.6	11.3
DO Sat {%)	95	85	76	88	89	92	89	90	89
Turbidity (NTU)	69.4	5.9	4.6	9.7	7.8	1.74	3.81	1.90	1.33
Laboratory Data									
Alkalinity (mg/l)	100.0	140.0	123.0	62.0	65.0	127.0	57.0	64.0	99.0
Ammonia (mg/l)	--	--	--	--	--	--	--	--	--
Nitrate (mg N/l)	0.06	0.14	0.12	0.04	0.05	0.13	0.10	0.06	0.11
Sulfate (mg/l)	26.0	1.0	2.0	3.0	13.0	6.0	2.0	11.0	8.0
Orthophosphate (mg/l)	0.002	0.003	0.002	0.028	0.014	0.098	0.074	0.090	0.007
Chloride (mg/l)	15.4	9.2	9.4	8.0	7.5	11.8	10.3	9.5	11.6
pH (pH units)	7.5	6.8	6.9	7.2	7.3	7.4	7.3	7.1	7.3

Note: -- indicates unavailable data

Table 7: Coliform levels at stations 1 through 3 on Redwood Creek on March 16, 1994. All values are reported in Most Probable Number per 100 ml (MPN).

Station	Total Coliform	Fecal Coliform
#1	2.0	< 2.0
#2	27.0	7.0
#3	50.0	30.0

Table 8: Redwood Creek Element Scan for stations 1 through 3 on Redwood Creek; performed by UCLA using the Inductively Coupled Plasma-emission spectroscopy method (ICP) for all elements except mercury, for which a Cold Vapor method was used. All measurements are in mg/L

Collection Data: 3-7-94 Analysis Date: 4-7-94

	Station		
	1	**2**	**3**
Ca	13.467	11.807	12.826
Al	0.054	0.052	0.042
Fe	0.013	0.009	0.022
Mg	21.701	12.709	13.037
Ti	0.001	0.001	0.001
Mn	0.002	0.002	0.008
Ba	0.006	0.017	0.025
Zn	0.016	0.013	0.009
Sr	0.065	0.111	0.133
V	0.003	<0.001	<0.001
Pb	0.005	<0.001	<0.001
Mo	0.017	0.010	0.012
Cr	0.008	0.001	0.002
Cu	0.008	0.001	0.001
Ni	0.012	0.005	0.004
B	0.214	0.020	0.079
Co	0.006	<0.001	<0.001
Ag	0.003	0.003	0.003
Cd	0.001	<0.001	<0.001
Ma	8.420	10.785	13.487
S	12.125	9.698	8.683
Se	0.013	<0.001	<0.001
As	0.016	<0.001	<0.001
K	0.060	0.522	0.582
Hg	<0.001	<0.001	<0.001

Table 9: Distribution of benthic macroinvertebrates (Insecta) per 0.25 square meter at station 2 on April 4, 1994. Note: * indicates pupae of suborders not identified to family.

Order	Family	# of individuals
Coleoptera	*Elmidae*	21
	Hydroscaphidae	1
	Psephenidae	1
	total:	23
Diptera	*Brachycera**	1
	Ceratopogonidae	1
	Chironomidae	497
	Empididae	2
	*Nematocera**	15
	Simuliidae	45
	Tipulidae	2
	Unknown	18
	total:	581
Plecoptera	*Chloroperlidae*	8
	Nemouridae	11
	Perlidae	10
	Perlodidae	13
	total:	42

Order	Family	# of individuals
Hemiptera	*Belostomatidae*	1
	Veliidae	2
	total:	3
Trichoptera	*Hydropsychidae*	8
	Hydroptilidae	4
	Philopotamidae	2
	Polycentropodidae	59
	Psychomyiidae	8
	Rhyacophilidae	2
	Unknown	5
	total:	88
Ephemeroptera	*Baetidae*	22
	Ephemerellidae	63
	Heptageniidae	49
	Leptophlebiidae	1
	Sipholonuridae	16
	Trichorythidae	14
	Unknown	7
	total:	172

Table 10: Distribution of benthic macroinvertebrates (Insecta) per 0.25 square meter at station 13 on April 18, 1994. Note: * indicates pupae of suborders not identified to family.

Order	Family	# of individuals	Order	Family	# of individuals
Coleoptera	*Elmidae*	256	Hemiptera	*Veliidae*	3
	Hydroscaphidae	7		**total:**	3
	Psephenidae	1			
	total:	264	Trichoptera	*Glossosomatidae*	5
				Hydroptilidae	6
Diptera	*Chironomidae*	27		*Phryganeidae*	1
	*Nematocera**	1		*Polycentropodidae*	29
	Simuliidae	6		*Psychomyiidae*	7
	total:	34		*Rhyacophilidae*	35
				total:	83
Plecoptera	*Chloroperlidae*	49			
	Nemouridae	18	Ephemeroptera	*Baetidae*	57
	Peltoperlidae	17	.	*Ephemerellidae*	10
	Perlodidae	10		*Heptageniidae*	8
	total:	94		*Leptophlebiidae*	7
				Sipholonuridae	21
				Trichorythidae	41
				Unknown #1	8
				Unknown #2	20
				total:	172

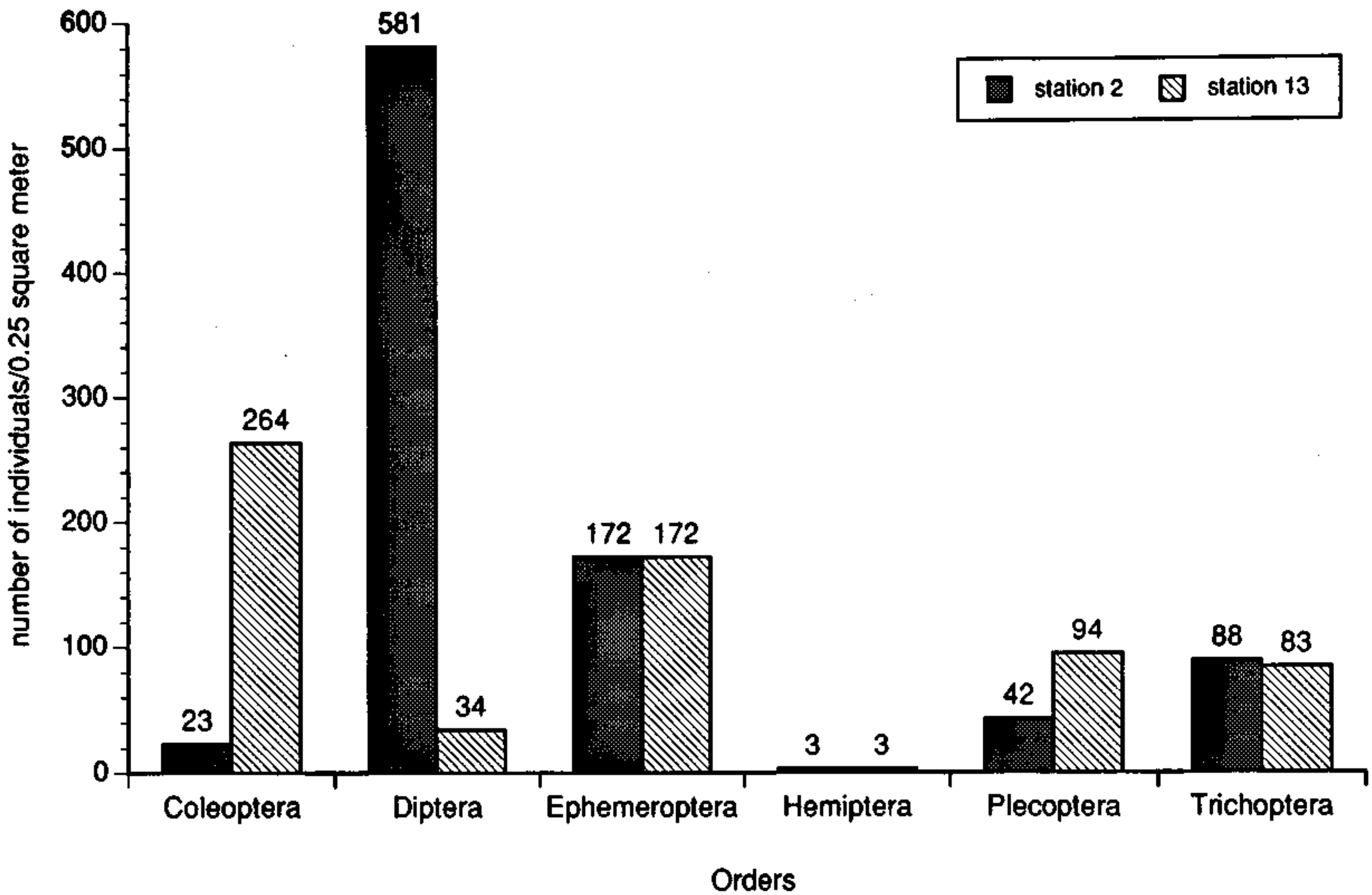

Figure 1: Distribution of benthic macroinvertebrate orders at station 2 (4/4/94) and station 13 (4/18/94).

Table 11: Relative abundance of periphyton genera at station 2 on February 9, 1994.

Group	Genus	Number counted	Relative Abundance(%)
Red algae	*Audouinella*	35	11.44
Green algae	*Cladophora*	2	0.65
	Closterium	1	0.33
Diatoms	*Cocconeis*	73	23.86
	Cymbella	9	2.94
	Fragilaria	15	4.90
	Gomphonema	26	8.50
	Mebsira	15	4.90
	Navicula	80	26.14
	Synedra	31	10.13
	Tabellaria	17	5.56
	unknown #1	2	0.65
	Total:	306	100.00

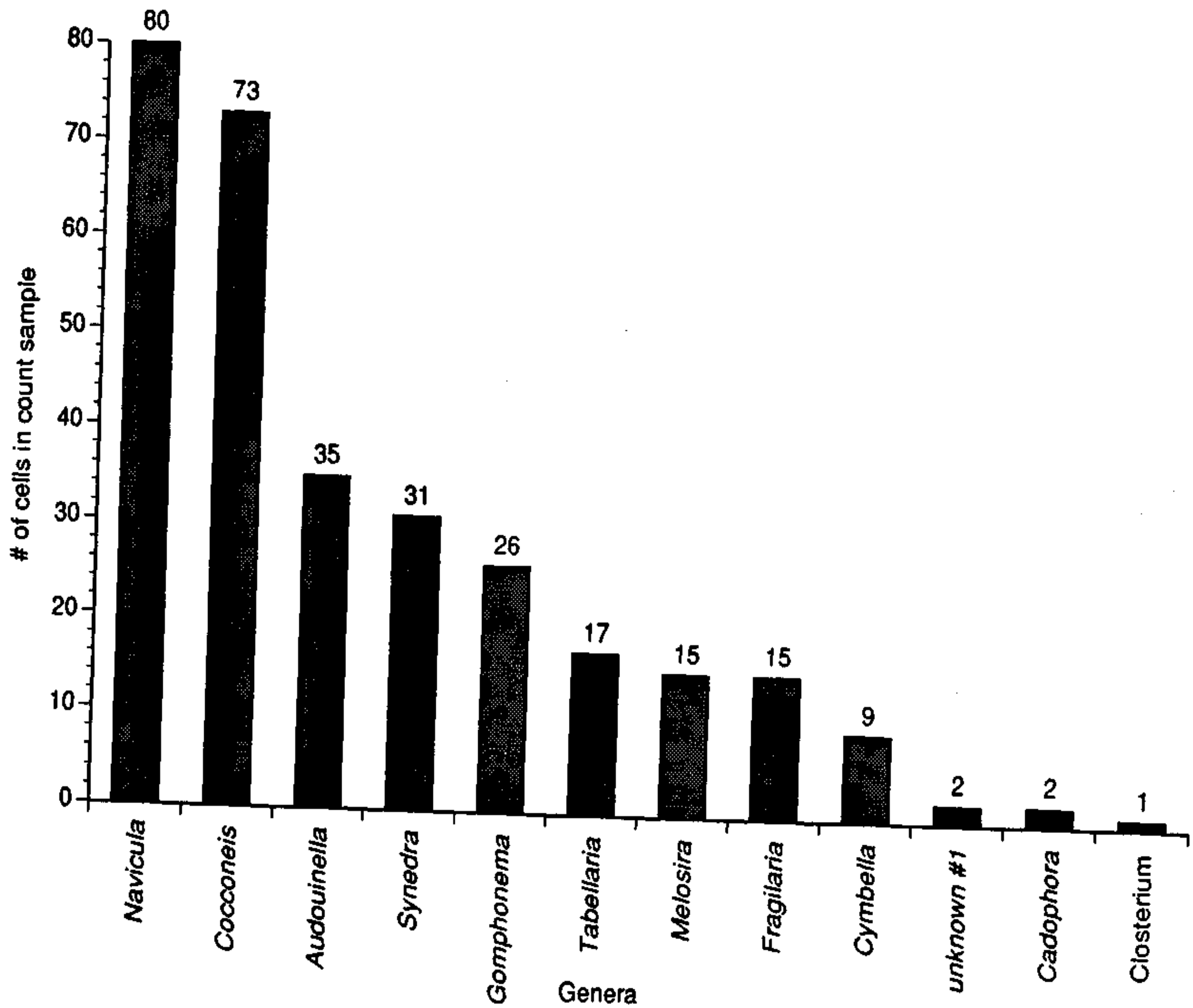

Figure 2: Distribution of periphyton genera at station 2 on February 9, 1994. A total of 306 cells were counted.

APPENDIX

The following instruments were used for field measurements:

Air Temperature:	Omega electric thermistor digital thermometer
Water Temperature:	Omega electric thermistor digital thermometer
Conductivity:	YSI transistorized meter with platinized nickel electrode
Dissolved Oxygen:	Omega model PHH-71 meter and probe
Turbidity:	Hach 21 OOP turbidimeter
pH:	Nestler pH pen
Flow:	Swoffer pygmy current meter