

LOBOS CREEK
MONITORING REPORT
JUNE 1995 - NOVEMBER 1995
FINAL REPORT

INSTITUTE OF CHEMICAL BIOLOGY

UNIVERSITY OF SAN FRANCISCO

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INTRODUCTION

Lobos Creek was first mentioned in the diaries of Colonel Juan Bautista de Anza and Father Pedro Font (1776). On March 27, 1776, Anza discovered an outlet to a lake (Mountain Lake) which flowed with enough water to operate a mill. The outlet was named Arroyo del Puerto and is presently known as Lobos Creek.

Historically, Lobos Creek has served as a municipal water source for the city of San Francisco. Until 1895, the Spring Valley Water Works Company diverted between one and two million gallons of water per day from Lobos Creek. By the middle of 1895, the amount of water obtained from the watershed was fractional compared to the amount required by the city; therefore, it was no longer feasible to continue pumping water from the creek for the City of San Francisco. Water from Lobos Creek was again used by the San Francisco Water Works Company in 1901 to supply water to the Richmond district after several dry seasons. Reports of high levels of bacteria and foul taste, however, forced the company to abandon the supply a second time.

Although no longer a municipal water source, Lobos Creek is home to a variety of flora and fauna. Numerous studies have been conducted to determine the overall condition of the watershed area, the hydraulic connections between the creek and nearby Mountain Lake, and the presence of rare or endangered species.

The creek and the surrounding land serve as a recreational area for the residents and tourists of San Francisco. The purpose of this investigation was to document the hydrologic and biologic components of Lobos Creek. Historic literature was also studied to compare present conditions with past physical characteristics. This report first presents an annotated historical bibliography and then presents data collected between June 1995 and November 1995. Figure 1 shows the location of the creek and the sampling stations.

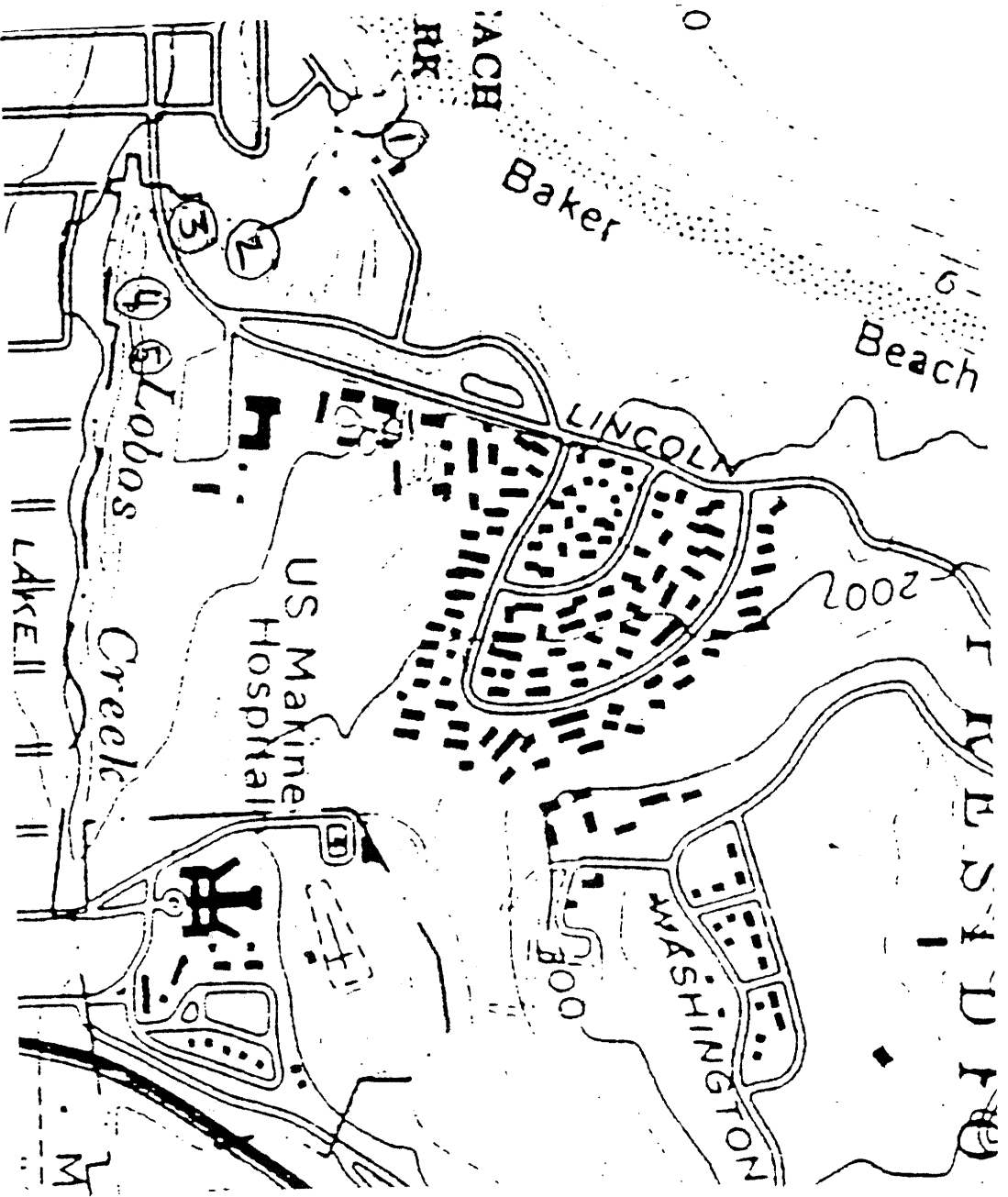


Figure 1: Sampling stations in the Lobos Creek watershed, San Francisco, CA.

ANNOTATED BIBLIOGRAPHY

[Bancroft, Hubert Howe]. History of California. Vol. I (1542-1800). In The Works of Hubert Howe Bancroft. Vol. XVIII. Wallace Heberd Publisher, Santa Barbara.

Page 280 depicts a 1776 map depicting Lobos Creek. An interpretation of the original Spanish written description of Lobos Creek is found on page 282. On March 27th, Anza discovered a lake (Mountain Lake) and an outlet which flowed with enough water to operate a mill. The outlet was called Arroyo del Puerto and is presently known as Lobos Creek.

[Byington, Lewis Francis]. 1931. The History of San Francisco. S. J. Clarke Publishing Co., Chicago.

The work discusses the past uses of Lobos Creek as a municipal water source for the city of San Francisco (pages 276 and 468). References are made to the Mountain Lake Water Company and the Spring Valley Company as responsible for the diversion of water from Lobos Creek, beginning in 1854.

Dames and Moore. 1994. Watershed Sanitary Survey, Lobos Creek Watershed, Presidio of San Francisco.

The document discusses the physical, chemical, and biological characters of the Lobos Creek Watershed. Of particular interest are potential contaminant sources of the watershed (p. 3-51 through 3-62) and contaminants of concern (p. 5-1 through 5-45). Potential contaminants sources include, but are not limited to, wastewater collection systems and treatment facilities, urban runoff, industrial and commercial facilities, recreational use, undeveloped land, solid/hazardous waste disposal facilities, and wildlife. Contaminants of concern identified by Dames and Moore include benzene and carbon tetrachloride exceeding state MCL's in 1992, dichlorodithiomethane surpassing state MCL's in 1990 and 1992, coliform bacteria, manganese, and iron. Other contaminants with more than one high level include nitrates, fluoride, tetrachloroethylene (PCE), 1,2 dichloroethane, barium, xylene, silver, arsenic, and turbidity.

Geohydrology, Water Quality, and Estimation of Ground-Water Recharge in San Francisco, California, 1987-1992. 1992. U.S. Geological Survey, Water Resources Investigations, San Francisco, California. Report no. 93-4019.

Page 14 discusses levels of possible contaminants at Lobos Creek, i.e. boron, methylene blue active substance, and nitrogen species.

Geo/Resource Consultants, Inc. 1991. Groundwater Assessment and Drought Response for the Presidio, San Francisco, California. Job No. 1602-009-00.

The hydraulic connection between Mountain Lake and Lobos Creek is discussed on page ES-4. The work completed by Geo/Resource Consultants, Inc. confirms that the two watersheds are connected. The report also states that Mountain Lake water is diluted before reaching Lobos Creek and that the majority of recharge to Lobos Creek is from the southern basin.

Gilliam, Harold. 1960. The Face of San Francisco. Doubleday and Co., Inc. Garden City, New York.

The work discusses various areas and sites of San Francisco. Page 189 briefly mentions Lobos Creek as flowing out of Mountain Lake and entering the ocean at Baker Beach. In the Spanish-Mexican period, the creek supplied water to sailing vessels anchored off the shore.

Gilliam, Harold. 1960. Natural World of San Francisco. Doubleday and Co., Inc. Garden City, New York.

Page 37 mentions Lobos Creek as an excellent area for watching seasonal changes along the shore. The work also mentions that the coast live oak (*Quercus agrifolia*) can be found at Lobos Creek (page 98).

Holloran, Pete. 1994. Building Community on Shifting Sands. Natural Resources Bulletin.

The article discusses the past and present states of the Lobos Creek watershed, especially the shifting sand dunes. The Xerces blue butterfly (*Glaucopsyche xerces*), last seen at the dunes adjacent to Lobos Creek, was presumed extinct in the 1940's. Numerous species of plants, wildlife, and insects

endemic to these dunes are no longer present. The article states that these taxa have been replaced by non-natives, but efforts to restore the area are underway.

Hill, J. R. 1993. Water Rights Evaluation: Presidio of San Francisco. Prepared for National Park Service, Western Region.

This report discusses the water rights associated with the Presidio. Also mentioned is the possible hydrologic connection between Mountain Lake and Lobos Creek (pages 4-5). Suggested management options include the possible reduction of the amount of diversions from Lobos Creek, thereby improving water parameters. The past and present physical and chemical characteristics of the creek are also discussed throughout the report.

Iverson, Eve. Lobos Creek: Witness to History.

The article discusses the physical and hydrological characteristics of the watershed. Also mentioned is the Army's use of the creek's water and the function of the water diversion structure (located west of Lincoln Boulevard). Descriptions of flora and fauna presently found at the watershed are also discussed.

Manson, Marsden. 1907. Outline of History of the Water Supply of the City of San Francisco. In Reports on the Water Supply of San Francisco, California: 1900 to 1908, Inclusive. Britton and Rey, San Francisco, pp. 3-13.

The work reports the historical significance of Mountain Lake with respect to municipal water supplies. On June 1, 1851, the Mountain Lake Water Company made a contract with San Francisco to supply the city with water from Mountain Lake and Lobos Creek. In 1857 the San Francisco Water Works was organized to divert water from Lobos Creek to San Francisco. Shortly thereafter, the Mountain Lake Water Company was confronted with numerous lawsuits and subsequently folded in 1862. A small company, the Spring Valley Water Works, was also emerging at this time. The company grew to be substantially stronger than the San Francisco Water Works, and in 1865 the former bought out the latter, inheriting all rights to Mountain Lake and Lobos Creek. Lobos Creek continued to supply between one and two million gallons of water per day until it was abandoned in 1895. Water from Lobos Creek and Mountain Lake was again used in 1901 to supply water to the Richmond district after several dry seasons. Foul water, however, forced the company to abandon the supply a second time.

McCarten, N. F. 1989. A Botanical Study of Lobos Creek, San Francisco, California. Department of Integrative Biology, University of California, Berkeley, California, 19 p.

The document discusses the botanical resources of Lobos Creek by characterizing plant communities and discussing native, non-native, and sensitive plant species. Recommendations for improving conditions for native plant habitats are mentioned on pages 9-11.

Purdy, Helen Throop. 1912. San Francisco: As It Was, As It Is, and How to See It. Paul Elder and Company, San Francisco, 221 p.

On pages 42-43, Purdy reports that in 1858, a flume was constructed to divert water from Lobos Creek and Mountain Lake to town.

San Francisco- The Financial, Commercial, and Industrial Metropolis of the Pacific Coast. 1915. Compiled under the direction of the San Francisco Chamber of Commerce. H. S. Crocker Co., San Francisco.

Page 123 discusses the history of Lobos Creek as a water source for the city of San Francisco. According to the document, in 1858 the San Francisco Water Works Co. began the diversion of water from Lobos Creek to two reservoirs via a series of pipes and tunnels. The company continued diverting water from Lobos Creek until 1865, when it consolidated with the Spring Valley Water Works.

Thompson, Erwin N. and Sally B. Woodbridge. 1992. Special History Study of the Presidio of San Francisco: An Outline of its Evolution as a U. S. Army Post, 1847- 1900. United States Department of the Interior, 250 p.

Page 62 contains a 1907 map of Major Hart's proposal for the development of the Presidio. Lobos Creek is also depicted on the map. Page 180 discusses the historical significance of Lobos Creek as a municipal water source. In 1853, Mountain Lake Water Company was formed with the intent to obtain water from Mountain Lake. The company subsequently failed and was taken over by the San Francisco Water Works. In 1897, the Army installed a new pumping system at Mountain Lake to divert water for domestic use. Between 1910 and 1912, the pumping plant was sold off and a new plant was constructed at the mouth of Lobos Creek along with a new six-million gallon reservoir on Presidio Hill (page 182).

U. S. Geological Society. 1992. Geohydrology, Water Quality, and Water Budgets of Golden Gate Park and the Lake Merced Area in the Western Part of San Francisco, California. U. S. Geological Survey, Water Resources Investigation Report 90-4080.

Pages 14 through 16 discuss certain water quality measurements at various well sites on Lobos Creek. Parameters studied include boron, methylene, nitrogen-ammonia, nitrogen-nitrate, and nitrogen- $\text{NO}_2 + \text{NO}_3$.

DISCUSSION

The historical record suggests that the surface flow of Lobos Creek has, over the years, declined significantly. Studies have shown that the watershed provides potential habitat for certain species of rare or endangered insects and plants. To date, however, these sensitive species have not been found at the creek to date.

The historical documents cited above may be useful to the NPS in the restoration efforts at Lobos Creek. The recent landslide and subsequent collapse of a residential building into the creek has significantly altered the watershed. The water course has been diverted, and clean-up efforts may have further disturbed the area. Future studies should be conducted to determine the overall consequences of this incident.

WATER QUALITY

Measurements of basic water quality characteristics (air and water temperatures, conductivity, dissolved oxygen, flow, turbidity, and pH) were made in the field every two weeks from June 1995 through November 1995.

Chemical water quality analysis was performed at the University of San Francisco every two weeks from June through November on samples collected in mid-stream and at mid-depth. Levels of ammonia, chloride, sulfate, nitrate, alkalinity, and orthophosphate, total suspended solids (TSS), carbonate, and bicarbonate were measured. Water samples were collected using standard methods and analysis was performed within 24 hours. A complete description of the analytical methods can be found in the Water Analysis Handbook (HACH Company) and the Standard Methods for the Examination of Water and Wastewater (American Public Health Association): 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).

On June 29, 1995, and October 30, 1995, two water samples were collected at each station in 60 ml plastic bottles and sent to UCLA Biomedical laboratory for chemical element analysis. One sample, preserved with 3 drops HNO_3 , was used for a 24 element scan using inductively coupled plasma (ICP) emission spectroscopy. The other sample was preserved with 3 ml HNO_3 and 0.03g $\text{K}_2\text{Cr}_2\text{O}_7$ and tested for mercury by atomic absorption (AA) spectrometry. Water samples of 100 ml each were also collected on July 20, 1995, and October 30, 1995, and analyzed by E.S. Babcock and Sons Laboratories in Riverside, California for coliform bacteria.

Tables 1 through 16 list the results of all water quality analyses and Figures 2 through 4 present high, low and average values for selected water quality parameters measured during the sample period. The following paragraphs discuss water and air temperatures, conductivity, dissolved oxygen, total suspended solids (TSS), turbidity, alkalinity, hardness, hydrogen ion, and ammonia, chloride, orthophosphate, nitrate, and sulfate levels for each station. The highest and lowest values are reported in the following discussion and are listed in Table 16.

WATER AND AIR TEMPERATURES

Water and air temperatures were measured in the field using an Omega model PHH-71 meter and probe and were recorded to the nearest 0.1 degree Celsius.

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

Water temperatures ranged from a low of 23.0 degrees C at Station 2 on August 17 to a high of 34.5 degrees C at Station 1 on October 30.

CONDUCTIVITY

Specific conductance (electrical conductivity) was measured using a YSI transistorized meter equipped with a platinized nickel electrode. Values were recorded to the nearest 5 $\mu\text{mhos/cm}$.

Specific conductance refers to the water's capacity to conduct an electric current and is a quick method of measuring ion concentration. Conductivity is also an indicator of total dissolved matter and alkalinity in the water. 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 apart from any other toxic or corrosive effects they may exhibit (Eckblad, 1978).

Conductivity values were fairly constant along the entirety of Lobos Creek, ranging from a high of 550 $\mu\text{mhos/cm}$ at stations 1 and 3 on September 1 and 15, respectively, to a low of 450 $\mu\text{mhos/cm}$ at Station 4 on October 30. Measurements recorded at all stations throughout the sampling period fell within 100 $\mu\text{mhos/cm}$ or less of one another, indicating stable conditions for aquatic life along the length of the stream.

DISSOLVED OXYGEN

Dissolved oxygen was measured in the field using an Omega model PHH-71 meter and probe and recorded to the nearest 0.1 mg/l.

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 rather specific to the concentration required. The USEPA (1986) recognizes a lower limit of 4.0 mg/l, although such a limited amount of dissolved oxygen could have a deleterious effect on aquatic organisms in a stream system such as Lobos Creek.

During the sampling period, dissolved oxygen readings ranged from a low of 7.2 mg/l at stations 2 and 4 on July 6 to a high of 16.2 mg/l at Station 1 on September 1. In general, dissolved oxygen measurements were lower at stations 4 and 5 (sampling period station averages are 9.4 mg/l and 9.8 mg/l, respectively) and higher at stations 1, 2, and 3 (sampling period station averages are 13.3 mg/l, 12.1 mg/l, and 12.1 mg/l, respectively). All measurements recorded indicate that Lobos Creek contains sufficient amounts of dissolved oxygen to support aquatic organisms.

TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids were measured using standard filtration and weighing methods (1000 ml sample aliquots). Drying was accomplished at 103-105°C, and a 1.0 mg/l minimum limit of accurate measurement was accepted.

The amount of suspended solids is one measure of watershed erosion. In addition to erosional silt, periphyton, zooplankton and organic detritus are typical components of suspended solids found in natural waters (McMillan, 1985). High concentrations of suspended solids can kill adult fish, smother eggs and fry, reduce primary productivity and alter temperature regimes. Over a period of time, amounts of inert solids in excess of 90 mg/l can be lethal to individual fish in a population, and 270 mg/l may kill 50% of some fish populations when exposure is extended for 2 to 12 weeks (McKee and Wolf, 1963).

TSS levels measured in Lobos Creek ranged from a high of 18.1 mg/l at Station 2 on November 10 to a low of <1.0 mg/l at several stations during the sampling period. Measured TSS levels, being well below suggested excessive values, never posed a threat to aquatic life. However, no TSS measurements were made during times of heavy rainfall and runoff when TSS levels would be expected to increase and perhaps stress populations of aquatic organisms.

TURBIDITY

Turbidity of water samples was determined in the field using a HACH 2100P turbidimeter, which is accurate to 0.01 nephelometric turbidity units (NTU).

Turbidity is a measure of the optical property of water (Thurston *et al.*, 1979) and is attributable to suspended and colloidal organic and inorganic matter which affect the penetration of light. For stream water designated for

domestic use, the upper limit of 250 NTU has been recommended by McKee and Wolf (1963), who also 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.

Recorded turbidity values ranged from a high of 16.80 NTU at Station 3 on November 10 to a low of 0.54 at Station 2 on August 3. All turbidity values recorded in the sampling period were well below the upper limits suggested by McKee and Wolf. As with TSS, turbidity values may be expected to increase during periods of rainfall and heavy runoff.

OIL AND GREASE

The water's surface was visually inspected for any signs of trace amounts of oil or grease. Chemicals collectively referred to as oils and greases are hazardous to aquatic life in even trace amounts.

During water quality sampling, no traces of oil and grease contamination within Lobos Creek were observed.

ALKALINITY

Total alkalinity was determined by potentiometric titration (APHA, 1985) and reported in mg/l (as calcium carbonate equivalents).

Alkalinity refers to the total amount of alkalinities in water capable of neutralizing acids (*i. e.*, buffering capacity). Alkalinity levels above 600 mg/l may be harmful to irrigated crops, and those above approximately 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 values had a narrow range throughout the watercourse during the sampling period, suggesting a stable environment for aquatic life. The highest level (183 mg/l) was recorded at Station 3 on November 10; the lowest value (151 mg/l) was recorded at Station 1 also on November 10.

HARDNESS

Total hardness was computed by multiplying the concentrations in mg/l of each cation contributing to hardness (Ca, Mg, Sr, Fe, Al, Zn, Mn) by the appropriate constant to obtain equivalent calcium carbonate concentrations and then summing the equivalents (Standard Methods, 1971). Calculated values are expressed in mg/l calcium carbonate.

In general, chloride values were highest at Station 1 (sampling period mean was 50.5 mg/l) and lowest at Station 2 (sampling period mean was 45.0 mg/l).

HYDROGEN ION CONCENTRATION

A Nester pH pen was used to measure pH in the field. Measured values were recorded to the nearest 0.1 pH unit.

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 as well as 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 pH units. The pH for the protection of freshwater aquatic life is set at 6.5 to 9.0 pH units.

Measured pH levels ranged from a high (most basic) reading of 8.1 at several stations during the sampling period to a low (least basic) reading of 7.2 at Station 4 on July 6. This fairly narrow pH range is beneficial to aquatic life since it provides stable conditions along the length of the stream.

DISCUSSION

Measured levels of nitrogen and orthophosphate encountered during the study suggest possible subsurface contamination from domestic sewage runoff.

COLIFORM BACTERIA

The coliform bacteria comprise all of the aerobic and facultative anaerobic, gram-negative, non-endospore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C (APHA, 1985). Because these organisms are commonly found in human (and other mammalian) feces, they are used in water quality analysis as indicative of fecal waste pollution. Because some coliform bacteria are not enteric (found in the digestive system) but are found in plant and soil samples, fecal coliform counts are often made to distinguish between the two.

Total coliform and fecal coliform bacteria were measured using multiple tube fermentation techniques as described in Standard Methods (APHA, 1985) and reported as the most probable number (MPN) of bacteria per 100 ml of water sample. Treated or chlorinated drinking water should contain no coliform bacteria per 100 ml of sample (APHA, 1985); coliform bacteria in untreated water samples are to be expected. Contact recreation water should contain a level of total coliform less than 240 MPN per 100 ml and a fecal coliform level less than 200 MPN (log mean) per 100 ml sample (SFBRR, 1986).

Coliform bacteria results are listed in Tables 2, 9 and 11 through 15. Table 16 lists high and low values of coliform recorded during the sample period.

TOTAL COLIFORM

Total coliform levels during the sampling period ranged from a low of 900 MPN at Stations 1 and 5 on July 20, and Station 4 on October 30, to a high of >1600 MPN at Stations 1, 2, 3 and 5 on October 30. Total coliform levels exceeded the APHA criterion for drinking water and the SFBRR criterion for recreation water on each date at all stations.

FECAL COLIFORM

Fecal coliform levels during the sample period ranged from a low of 13 MPN at Station 5 on July 20, to a high of 240 MPN at Station 5 on October 30. Fecal coliform levels exceeded the SFBRR criterion for contact recreation water at Station 5 on October 30.

DISCUSSION

The high levels of total and fecal coliform suggest that Lobos Creek may be subject to periodic, if not constant, introductions of sewage or runoff from nearby urban areas. Elevated levels, however, may also be due, at least in

part, to the introduction of fecal matter into the water by resident wildlife populations or domestic animals. Therefore, use of untreated stream water for domestic purposes or use of the stream for contact recreation is not advised.

Table 1.
Lobos Creek Water Quality, July 6, 1995.

Station	1	2	3	4	5	MEAN
Date	6/7	6/7	6/7	6/7	6/7	
Time	0920	1000	0945	1246	1307	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	29.5	24.7	29.3	26.2	27.8	27.5
Water Temp (C)	25.7	24.6	24.8	24.7	25.4	25.0
Conduct (umhos/cm)	500	500	490	510	500	500
DO (mg/l)	13.0	7.2	7.4	7.2	7.4	8.4
DO Sat (%)	92	53	54	55	55	62
Flow (cfs)	2.5	3.4	2.3	4.3	3.7	3.2
TSS (mg/l)	<1.0	<1.0	<1.0	<1.0	8.0	1.6
Turbidity (NTU)	1.10	3.27	0.67	1.55	1.12	1.54
Alkalinity (mg/l)	155	164	167	159	158	161
Chloride (mg/l)	50.3	35.2	46.0	42.8	45.2	43.9
Hardness (mg/l)	188	219	219	220	221	213
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.80	8.61	8.60	7.60	7.00	8.12
Sulfate (mg/l)	65	68	69	69	68	68
Orthophosphate (mg/l)	0.043	0.091	0.067	0.054	0.033	0.058
pH (pH units)	7.9	7.7	7.6	7.2	7.4	7.6

Note: Hardness values are calculated from element samples taken 6/29/95.

Table 2.
Lobos Creek Water Quality, July 20, 1995.

Station	1	2	3	4	5	MEAN
Date	20/7	20/7	20/7	20/7	20/7	
Time	1000	1030	1045	0900	0915	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	23.9	22.0	24.5	26.0	26.3	24.5
Water Temp (C)	23.4	24.3	25.2	27.8	26.8	25.5
Conduct (umhos/cm)	500	490	500	510	500	500
DO (mg/l)	12.8	12.0	10.8	7.6	7.9	10.2
DO Sat (%)	95	88	75	54	56	74
Flow (cfs)	3.1	2.9	3.8	2.2	2.4	2.9
TSS (mg/l)	1.6	4.8	5.8	3.1	1.4	3.3
Turbidity (NTU)	1.17	0.75	0.97	0.82	0.92	0.93
Alkalinity (mg/l)	172	173	176	171	179	174
Chloride (mg/l)	48.0	44.4	38.4	46.4	42.0	43.8
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.20	9.02	8.40	8.20	7.80	8.12
Sulfate (mg/l)	51	55	58	57	60	56
Orthophosphate (mg/l)	0.037	0.023	0.019	0.017	0.018	0.023
pH (pH units)	8.0	7.8	7.7	7.5	7.5	7.7
Total Coliform (MPN)	900	1600	1600	1600	900	1320
Fecal Coliform (MPN)	80	80	50	130	13	71

Note: Station 4 coliform sample taken 3 Aug. 1995.

Table 3.
Lobos Creek Water Quality, August 3, 1995.

Station	1	2	3	4	5	MEAN
Date	3/8	3/8	3/8	3/8	3/8	
Time	1005	1030	1043	0900	0920	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	20.6	21.4	21.2	26.1	24.1	22.7
Water Temp (C)	26.7	26.5	26.8	28.8	28.0	27.4
Conduct (umhos/cm)	500	500	500	500	500	500
DO (mg/l)	13.0	11.5	11.7	7.9	8.0	10.4
DO Sat (%)	88	78	80	55	55	71
Flow (cfs)	3.5	3.8	3.1	2.8	3.9	3.4
TSS (mg/l)	<1.0	<1.0	1.0	1.7	<1.0	1.4
Turbidity (NTU)	1.92	0.54	1.50	0.99	1.45	1.28
Alkalinity (mg/l)	161	172	174	178	178	173
Chloride (mg/l)	50.4	46.0	49.6	48.8	46.8	48.3
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.60	8.20	8.00	7.60	7.20	7.92
Sulfate (mg/l)	48	53	54	58	52	53
Orthophosphate (mg/l)	0.035	0.019	0.021	0.023	0.021	0.024
pH (pH units)	8.0	7.8	7.7	7.6	7.6	7.7

Table 4.
Lobos Creek Water Quality, August 17,1995.

Station	1	2	3	4	5	MEAN
Date	17/8	17/8	17/8	17/8	17/8	
Time	1005	1025	1035	0915	0935	
Weather	clear	clear	clear	clear	clear	
Air Temp (C)	27.0	23.4	23.3	25.9	27.2	25.4
Water Temp (C)	26.9	23.0	26.1	28.5	27.9	26.5
Conduct (umhos/cm)	500	500	500	510	500	502
DO (mg/l)	12.7	12.2	12.5	7.6	7.3	10.5
DO Sat (%)	95	88	85	52	50	74
Flow (cfs)	1.7	2.8	3.1	2.2	2.5	2.5
TSS (mg/l)	<1.0	1.2	1.6	1.1	2.9	1.7
Turbidity (NTU)	0.8	2.3	1.8	5.7	0.7	2.3
Alkalinity (mg/l)	155	166	176	168	178	169
Chloride (mg/l)	59.2	49.2	45.2	44.4	46.4	48.9
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	10.08	8.19	7.77	7.14	7.14	8.06
Sulfate (mg/l)	53	58	54	59	58	56
Orthophosphate (mg/l)	0.127	0.077	0.071	0.086	0.077	0.088
pH (pH units)	8.1	7.8	7.8	7.5	7.5	7.7

Table 5.
Lobos Creek Water Quality, September 1,1995.

Station	1	2	3	4	5	MEAN
Date	1/9	1/9	1/9	1/9	1/9	
Time	0933	0945	1000	0900	0915	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	19.7	24.2	26.3	27.7	28.1	25.2
Water Temp (C)	26.0	26.4	29.6	30.9	29.8	28.5
Conduct (umhos/cm)	550	500	500	500	500	510
DO (mg/l)	16.2	14.3	14.6	9.7	9.7	12.9
DO Sat (%)	108	97	97	65	62	86
Flow (cfs)	3.4	2.8	1.7	2.2	NA	2.5
TSS (mg/l)	<1.0	11.3	<1.0	<1.0	2.9	7.1
Turbidity (NTU)	0.96	2.09	1.25	1.25	1.42	1.39
Alkalinity (mg/l)	165	178	168	169	181	172
Chloride (mg/l)	40.8	45.2	47.2	40.0	46.0	43.8
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.35	5.46	6.3	5.46	6.93	6.30
Sulfate (mg/l)	51	55	56	57	55	55
Orthophosphate (mg/l)	0.023	0.017	0.015	0.014	0.016	0.017
pH (pH units)	8.0	7.8	7.7	7.6	7.6	7.7

Table 6.
Lobos Creek Water Quality, September 15, 1995.

Station	1	2	3	4	5	MEAN
Date	15/9	15/9	15/9	15/9	15/9	
Time	0925	0935	0945	0900	0910	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	25.8	27.3	25.4	29.7	29.4	27.5
Water Temp (C)	25.5	26.0	24.6	30.9	29.8	27.4
Conduct (umhos/cm)	500	500	550	500	500	510
DO (mg/l)	11.4	13.7	12.2	12.3	12.7	12.5
DO Sat (%)	94	129	101	92	86	100
Flow (cfs)	3.7	3.6	1.9	2.0	NA	2.8
TSS (mg/l)	1.3	2.9	<1.0	<1.0	<1.0	2.1
Turbidity (NTU)	0.94	6.06	3.44	2.63	1.07	2.83
Alkalinity (mg/l)	164	176	177	173	176	173
Chloride (mg/l)	44.0	46.0	47.2	46.8	43.2	45.4
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.35	7.35	7.35	7.14	6.51	7.14
Sulfate (mg/l)	48	44	48	60	59	52
Orthophosphate (mg/l)	0.061	0.031	0.066	0.04	0.038	0.047
pH (pH units)	8.0	7.9	7.8	7.9	7.6	7.8

Table 7.
Lobos Creek Water Quality, September 29, 1995.

Station	1	2	3	4	5	MEAN
Date	29/9	29/9	29/9	29/9	29/9	
Time	0930	0950	1000	0900	0910	
Weather	clear	clear	clear	clear	clear	
Air Temp (C)	32.3	30.6	31.5	26.8	26.5	29.5
Water Temp (C)	24.2	23.6	25.3	26.8	26.0	25.2
Conduct (umhos/cm)	500	500	500	490	500	498
DO (mg/l)	13.7	13.0	13.5	9.5	9.7	11.9
DO Sat (%)	93	87	88	64	64	79
Flow (cfs)	3.3	2.5	2.0	2.0	2.6	2.5
TSS (mg/l)	<1.0	3.9	<1.0	1.4	3.0	2.8
Turbidity (NTU)	0.64	0.87	4.88	1.55	2.24	2.04
Alkalinity (mg/l)	168	176	167	168	174	171
Chloride (mg/l)	44.8	45.6	44.0	46.0	47.2	45.5
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.19	7.56	8.61	7.77	7.98	8.02
Sulfate (mg/l)	48	52	51	55	49	51
Orthophosphate (mg/l)	0.027	0.02	0.02	0.022	0.019	0.022
pH (pH units)	8.1	7.9	7.7	7.7	7.8	7.8

** Note: The channel at the mouth of the stream has changed course since the last sampling date, and the stream now flows northwest into the ocean rather than southwest as it did previously.

Table 8.
Lobos Creek Water Quality, October 13, 1995.

Station	1	2	3	4	5	MEAN
Date	13/10	13/10	13/10	13/10	13/10	
Time	0935	0950	0955	0910	0920	
Weather	clear	clear	clear	clear	clear	
Air Temp (C)	27.0	26.8	29.9	28.7	27.1	27.9
Water Temp (C)	27.0	26.2	25.5	30.5	28.1	27.5
Conduct (umhos/cm)	500	500	500	475	500	495
DO (mg/l)	11.5	10.5	10.6	10.6	10.9	10.8
DO Sat (%)	74	69	69	70	72	71
Flow (cfs)	2.6	3.4	2.0	1.9	NA	2.5
TSS (mg/l)	9.5	4.0	<1.0	2.7	4.4	5.1
Turbidity (NTU)	4.81	2.25	1.99	1.80	2.82	2.73
Alkalinity (mg/l)	160	175	175	178	166	171
Chloride (mg/l)	52.8	40.0	41.6	46.8	45.2	45.3
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.8	6.6	6.8	6.4	5.9	6.70
Sulfate (mg/l)	53	48	54	56	59	54
Orthophosphate (mg/l)	0.013	0.007	0.006	0.005	0.007	0.008
pH (pH units)	8.1	8.0	7.8	7.7	7.7	7.9

Note: No flow reading taken at Station 5 because of thick instream growth of vascular plants.

Table 9.
Lobos Creek Water Quality, October 30,1995.

Station	1	2	3	4	5	MEAN
Date	30/10	30/10	30/10	30/10	30/10	
Time	1010	1035	1110	0915	0930	
Weather	overcast	overcast	overcast	overcast	overcast	
Air Temp (C)	30.5	31.5	31.8	28.6	30.4	30.6
Water Temp (C)	34.5	34.0	34.3	32.8	32.6	33.6
Conduct (umhos/cm)	500	500	500	450	500	490
DO (mg/l)	14.2	13.3	13.5	10.5	11.5	12.6
DO Sat (%)	95	86	88	69	75	83
Flow (cfs)	3.2	4.4	1.9	2.8	NA	3.1
TSS (mg/l)	<1	2.4	2.2	5.8	5.3	3.9
Turbidity (NTU)	1.38	2.50	2.66	4.47	4.09	3.02
Alkalinity (mg/l)	154	167	164	168	177	166
Chloride (mg/l)	56.8	48.0	47.6	48.0	53.2	50.7
Hardness (mg/l)	236	238	241	241	242	240
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.6	6.3	6.5	6.1	6.3	6.6
Sulfate (mg/l)	53	54	57	58	53	55
Orthophosphate (mg/l)	0.013	0.01	0.009	0.009	0.009	0.010
pH (pH units)	8.1	8.1	7.9	8.1	7.8	8.0
Total Coliform (MPN)	>1600	>1600	>1600	900	>1600	>1600
Fecal Coliform (MPN)	130	80	130	30	240	122

Table 10.
Lobos Creek Water Quality, November 10,1995.

Station	1	2	3	4	5	MEAN
Date	10/11	10/11	10/11	10/11	10/11	
Time	1005	1015	1025	0920	0935	
Weather	prt cldy	prt cldy	prt cldy	clear	prt cldy	
Air Temp (C)	31.3	32.2	32.2	30.1	30.7	31.3
Water Temp (C)	32.9	33.7	33.6	33.3	33.3	33.4
Conduct (umhos/cm)	460	455	500	500	500	483
DO (mg/l)	14.3	13.7	13.9	11.5	12.6	13.2
DO Sat (%)	94	89	89	76	82	86
Flow (cfs)	3.3	4.0	2.4	2.3	NA	3.0
TSS (mg/l)	1.4	18.1	2.0	5.2	10.7	7.5
Turbidity (NTU)	1.83	3.80	16.80	4.18	4.80	6.28
Alkalinity (mg/l)	151	162	183	166	166	166
Chloride (mg/l)	58.0	50.8	46.0	48.0	47.6	50.1
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.1	7.9	6.3	6.5	6.6	6.9
Sulfate (mg/l)	54	58	57	56	54	56
Orthophosphate (mg/l)	0.018	0.021	0.016	0.011	0.096	0.032
pH (pH units)	8.1	8.0	7.9	8.0	7.8	8.0

Note: No flow reading taken at Station 5 because of thick instream growth of vascular plants.

Table 11.
Lobos Creek Station 1 Water Quality, Summer-Fall,1995.

Date	6/7	20/7	3/8	17/8	9/1	15/9	29/9	13/10	30/10	10/11	MEAN
Time	0920	1000	1005	1005	0933	0925	0930	0935	1010	1005	
Weather	overcast	overcast	overcast	clear	overcast	overcast	clear	clear	overcast	prt cldy	
Air Temp (C)	29.5	23.9	20.6	27.0	19.7	25.8	32.3	27.0	30.5	31.3	26.8
Water Temp (C)	25.7	23.4	26.7	26.9	26.0	25.5	24.2	27.0	34.5	32.9	27.3
Conduct (umhos/cm)	500	500	500	500	550	500	500	500	500	460	501
DO (mg/l)	13.0	12.8	13.0	12.7	16.2	11.4	13.7	11.5	14.2	14.3	13.3
DO Sat (%)	92	95	88	95	108	94	93	74	95	94	93
Flow (cfs)	2.5	3.1	3.5	<u>1.7</u>	3.4	3.7	3.3	2.6	3.2	<u>3.3</u>	3.0
TSS (mg/l)	<1.0	1.6	<1.0	<1.0	<1.0	1.3	<1.0	9.45	<1.0	1.44	3.4
Turbidity (NTU)	1.10	1.17	1.92	0.82	0.96	0.94	0.64	4.81	1.38	1.83	1.56
Alkalinity (mg/l)	155	172	161	155	165	164	168	160	154	151	161
Chloride (mg/l)	50.3	48.0	50.4	59.2	40.8	44.0	44.8	52.8	56.8	58.0	50.5
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.80	7.20	8.60	10.08	7.35	7.35	8.19	7.8	7.6	7.1	8.01
Sulfate (mg/l)	65	51	48	53	51	48	48	53	53	54	52
Orthophosphate (mg/l)	0.043	0.037	0.035	0.127	0.023	0.061	0.027	0.013	0.013	0.018	0.040
pH (pH units)	7.9	8.0	8.0	8.1	8.0	8.0	8.1	8.1	8.1	8.1	8.0
Total Coliform	---	900	---	---	---	---	---	---	>1600	---	1250
Fecal Coliform	---	80	---	---	---	---	---	---	130	---	105
Hardness (mg/l)	188	---	---	---	---	---	---	---	236	---	212

Table 12.

Lobos Creek Station 2 Water Quality, Summer-Fall, 1995.

Date	6/7	20/7	3/8	17/8	1/9	15/9	29/9	13/10	30/10	10/11	MEAN
Time	1000	1030	1030	1025	0945	0935	0950	0950	1035	1015	
Weather	overcast	overcast	overcast	clear	overcast	overcast	clear	clear	overcast	prt cldy	
Air Temp (C)	24.7	22.0	21.4	23.4	24.2	27.3	30.6	26.8	31.5	32.2	26.4
Water Temp (C)	24.6	24.3	26.5	23.0	26.4	26.0	23.6	26.2	34.0	33.7	26.8
Conduct (umhos/cm)	500	490	500	500	500	500	500	500	500	455	495
DO (mg/l)	7.2	12.0	11.5	12.2	14.3	13.7	13.0	10.5	13.3	13.7	12.1
DO Sat (%)	53	88	78	88	97	129	87	69	86	89	86
Flow (cfs)	3.4	2.9	3.8	2.8	2.8	3.6	2.5	3.4	4.4	4.0	3.4
TSS (mg/l)	<1.0	4.8	<1.0	1.2	11.3	2.9	3.9	4.0	2.4	18.1	6.1
Turbidity (NTU)	3.27	0.75	0.54	2.27	2.09	6.06	0.87	2.25	2.50	3.80	2.44
Alkalinity (mg/l)	164	173	172	166	178	176	176	175	167	162	171
Chloride (mg/l)	35.2	44.4	46.0	49.2	45.2	46.0	45.6	40.0	48.0	50.8	45.0
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.61	9.02	8.20	8.19	5.46	7.35	7.56	6.6	6.3	7.9	7.52
Sulfate (mg/l)	68	55	53	58	55	44	52	48	54	58	55
Orthophosphate (mg/l)	0.091	0.023	0.019	0.077	0.017	0.031	0.02	0.007	0.01	0.021	0.032
pH (pH units)	7.7	7.8	7.8	7.8	7.8	7.9	7.9	8.0	8.1	8.0	7.9
Total Coliform	---	1600	---	---	---	---	---	---	>1600	---	1600
Fecal Coliform	---	80	---	---	---	---	---	---	80	---	80
Hardness (mg/l)	219	---	---	---	---	---	---	---	238	---	229

Table 13.
Lobos Creek Station 3 Water Quality, Summer-Fall ,1995.

Date	6/7	20/7	3/8	17/8	1/9	15/9	29/9	13/10	30/10	10/11	MEAN
Time	0945	1045	1043	1035	1000	0945	1000	0955	1110	1025	
Weather	overcast	overcast	overcast	clear	overcast	overcast	clear	clear	overcast	prt cldy	
Air Temp (C)	29.3	24.5	21.2	23.3	26.3	25.4	31.5	29.9	31.8	32.2	27.5
Water Temp (C)	24.8	25.2	26.8	26.1	29.6	24.6	25.3	25.5	34.3	33.6	27.6
Conduct (umhos/cm)	490	500	500	500	500	550	500	500	500	500	504
DO (mg/l)	7.4	10.8	11.7	12.5	14.6	12.2	13.5	10.6	13.5	13.9	12.1
DO Sat (%)	54	75	80	85	97	101	88	69	88	89	83
Flow (cfs)	2.3	3.8	3.1	3.1	1.7	1.9	2.0	2.0	1.9	2.4	2.4
TSS (mg/l)	<1.0	5.8	1.0	1.6	<1.0	<1.0	<1.0	<1.0	2.2	2.0	2.5
Turbidity (NTU)	0.67	0.97	1.50	1.78	1.25	3.44	4.88	1.99	2.66	16.80	3.59
Alkalinity (mg/l)	167	176	174	176	168	177	167	175	164	183	173
Chloride (mg/l)	46.0	38.4	49.6	45.2	47.2	47.2	44.0	41.6	47.6	46.0	45.3
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	8.60	8.40	8.00	7.77	6.30	7.35	8.61	6.8	6.5	6.3	7.46
Sulfate (mg/l)	69	58	54	54	56	48	51	54	57	57	56
Orthophosphate (mg/l)	0.067	0.019	0.021	0.071	0.015	0.066	0.02	0.006	0.009	0.016	0.031
pH (pH units)	7.6	7.7	7.7	7.8	7.7	7.8	7.7	7.8	7.9	7.9	7.8
Total Coliform	---	1600	---	---	---	---	---	---	>1600	---	1600
Fecal Coliform	---	50	---	---	---	---	---	---	130	---	90
Hardness (mg/l)	219	---	---	---	---	---	---	---	241	---	230

Table 14.
Lobos Creek Station 4 Water Quality, Summer-Fall,1995.

Date	6/7	20/7	3/8	17/8	1/9	15/9	29/9	13/10	30/10	10/11	MEAN
Time	1246	0900	0900	0915	0900	0900	0900	0910	0915	0920	
Weather	overcast	overcast	overcast	clear	overcast	overcast	clear	clear	overcast	clear	
Air Temp (C)	26.2	26.0	26.1	25.9	27.7	29.7	26.8	28.7	28.6	30.1	27.6
Water Temp (C)	24.7	27.8	28.8	28.5	30.9	30.9	26.8	30.5	32.8	33.3	29.5
Conduct (umhos/cm)	510	510	500	510	500	500	490	475	450	500	495
DO (mg/l)	7.2	7.6	7.9	7.6	9.7	12.3	9.5	10.6	10.5	11.5	9.4
DO Sat (%)	55	54	55	52	65	92	64	70	69	76	65
Flow (cfs)	4.3	2.2	2.8	2.2	2.2	2.0	2.0	1.9	2.8	2.3	2.5
TSS (mg/l)	<1.0	3.1	1.7	1.1	<1.0	<1.0	1.4	2.7	5.8	5.2	3.0
Turbidity (NTU)	1.55	0.82	0.99	5.73	1.25	2.63	1.55	1.80	4.47	4.18	2.50
Alkalinity (mg/l)	159	171	178	168	169	173	168	178	168	166	170
Chloride (mg/l)	42.8	46.4	48.8	44.4	40.0	46.8	46.0	46.8	48.0	48.0	45.8
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.60	8.20	7.60	7.14	5.46	7.14	7.77	6.4	6.1	6.5	6.99
Sulfate (mg/l)	69	57	58	59	57	60	55	56	58	56	59
Orthophosphate (mg/l)	0.054	0.017	0.023	0.086	0.014	0.040	0.022	0.005	0.009	0.011	0.028
pH (pH units)	7.2	7.5	7.6	7.5	7.6	7.9	7.7	7.7	8.1	8.0	7.7
Total Coliform	---	1600	---	---	---	---	---	---	900	---	1250
Fecal Coliform	---	130	---	---	---	---	---	---	30	---	80
Hardness (mg/l)	220	---	---	---	---	---	---	---	241	---	231

Table 15.
Lobos Creek Station 5 Water Quality, Summer-Fall,1995.

Date	6/7	20/7	3/8	17/8	1/9	15/9	29/9	13/10	30/10	10/11	MEAN
Time	1307	0915	0920	0935	0915	0910	0910	0920	0930	0935	
Weather	overcast	overcast	overcast	clear	overcast	overcast	clear	clear	overcast	prt cldy	
Air Temp (C)	27.8	26.3	24.1	27.2	28.1	29.4	26.5	27.1	30.4	30.7	27.8
Water Temp (C)	25.4	26.8	28.0	27.9	29.8	29.8	26.0	28.1	32.6	33.3	28.8
Conduct (umhos/cm)	500	500	500	500	500	500	500	500	500	500	500
DO (mg/l)	7.4	7.9	8.0	7.3	9.7	12.7	9.7	10.9	11.5	12.6	9.8
DO Sat (%)	55	56	55	50	62	86	64	72	75	82	66
Flow (cfs)	3.7	2.4	3.9	2.5	NA	NA	2.6	NA	NA	NA	3.0
TSS (mg/l)	8.0	1.4	<1.0	2.9	2.9	<1.0	3.0	4.4	5.3	10.7	4.8
Turbidity (NTU)	1.12	0.92	1.45	0.69	1.42	1.07	2.24	2.82	4.09	4.80	2.06
Alkalinity (mg/l)	158	179	178	178	181	176	174	166	177	166	173
Chloride (mg/l)	45.2	42.0	46.8	46.4	46.0	43.2	47.2	45.2	53.2	47.6	46.3
Ammonia (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (mg N/l)	7.00	7.80	7.20	7.14	6.93	6.51	7.98	5.9	6.3	6.6	6.94
Sulfate (mg/l)	68	60	52	58	55	59	49	59	53	54	57
Orthophosphate (mg/l)	0.033	0.018	0.021	0.077	0.016	0.038	0.019	0.007	0.009	0.096	0.033
pH (pH units)	7.4	7.5	7.6	7.5	7.6	7.6	7.8	7.7	7.8	7.8	7.6
Total Coliform	---	900	---	---	---	---	---	---	>1600	---	1250
Fecal Coliform	---	13	---	---	---	---	---	---	240	---	127
Hardness (mg/l)	221	---	---	---	---	---	---	---	242	---	232

Table 16.

Lobos Creek June-November 1995, Water quality and element analysis, parameter highs and lows.

	HIGH	LOW
Air Temp (C)	32.3	19.7
Water Temp (C)	34.5	23.0
Conduct (umhos/cm)	550	450
DO (mg/l)	16.2	7.2
DO Sat (%)	129	50
Flow (cfs)	4.4	1.7
TSS (mg/l)	18.1	<1.0
Turbidity (NTU)	16.80	0.54
Oil & Grease (mg/l)	none	none
Alkalinity (mg/l)	183	151
Hardness (mg/l)	242	188
Ammonia (mg/l)	<0.02	<0.02
Nitrate (mg N/l)	10.08	5.46
Sulfate (mg/l)	69	44
Othophosphate (mg/l)	0.127	0.005
pH (pH units)	8.1	7.2
Total Coliform (MPN)	>1600	900
Fecal Coliform (MPN)	240	13
Ca (mg/l)	29.9	27.1
Al (mg/l)	0.121	0.040
Fe (mg/l)	0.012	<0.001
Mg (mg/l)	40.6	29.1
Ti (mg/l)	0.002	0.001
Mn (mg/l)	0.048	0.005
Ba (mg/l)	0.027	0.010
Zn (mg/l)	0.015	<0.001
Sr (mg/l)	0.178	0.159
V (mg/l)	0.002	0.001
Pb (mg/l)	0.008	<0.001
Mo (mg/l)	0.014	0.003
Cr (mg/l)	0.007	<0.001
Cu (mg/l)	0.003	<0.001
Ni (mg/l)	0.002	<0.001
B (mg/l)	0.183	0.048
Co (mg/l)	0.004	<0.001
Ag (mg/l)	0.001	<0.001
Cd (mg/l)	0.002	0.001
Na (mg/l)	35.7	32.5
Si (mg/l)	17.9	13.0
As (mg/l)	0.01	<0.01
Hg (mg/l)	<0.0001	<0.0001
Se (mg/l)	0.004	<0.001
K (mg/l)	1.90	1.20

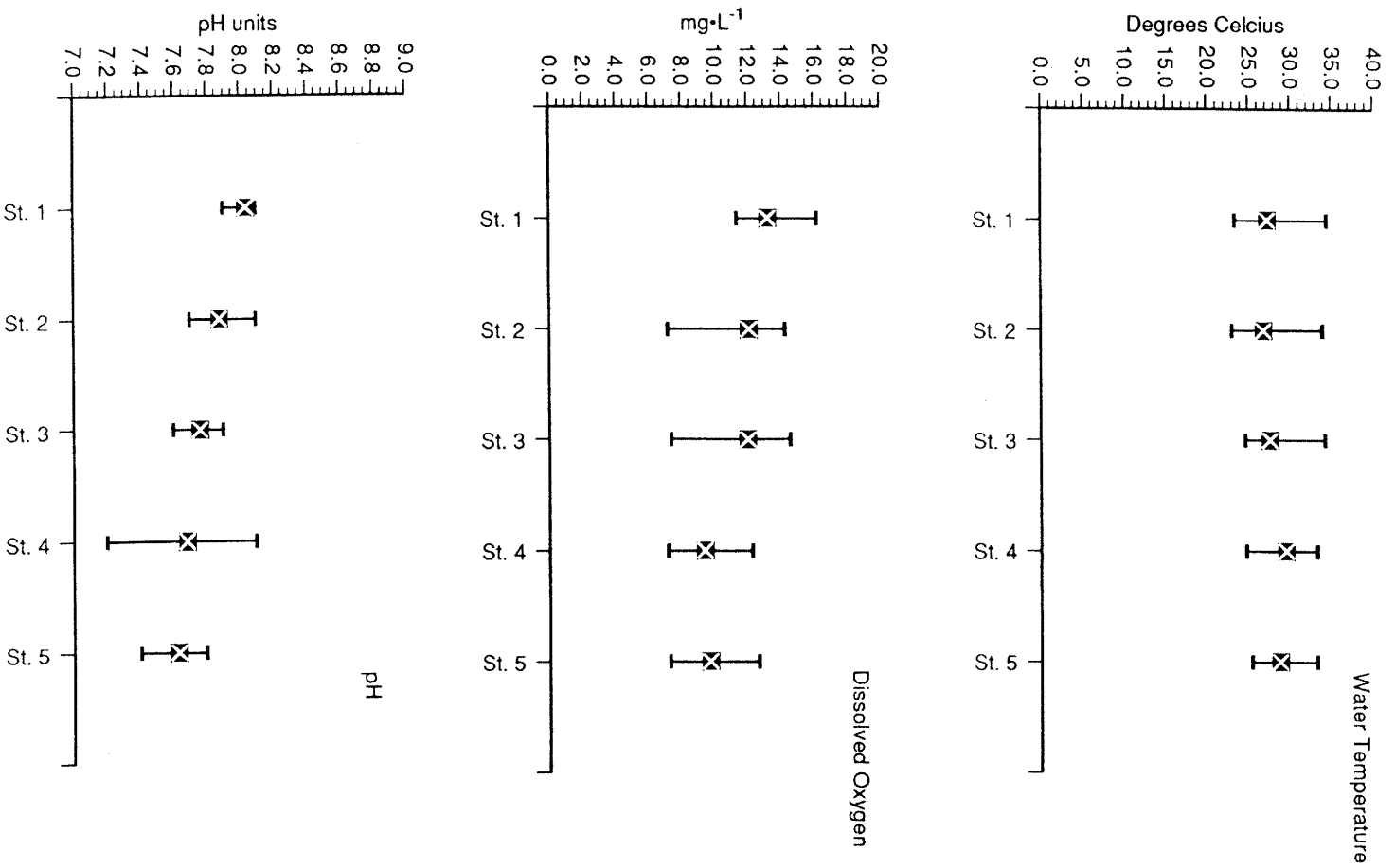


Figure 2: Water Quality Parameters. The figure indicates mean water temperature, pH, and dissolved oxygen for all stations. Bars indicate high and low values recorded. Sampling dates ranged from July 6 through November 10, 1995.

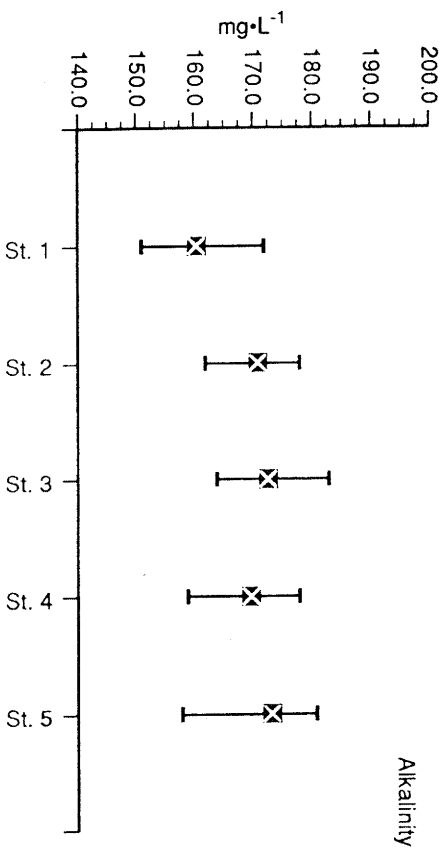
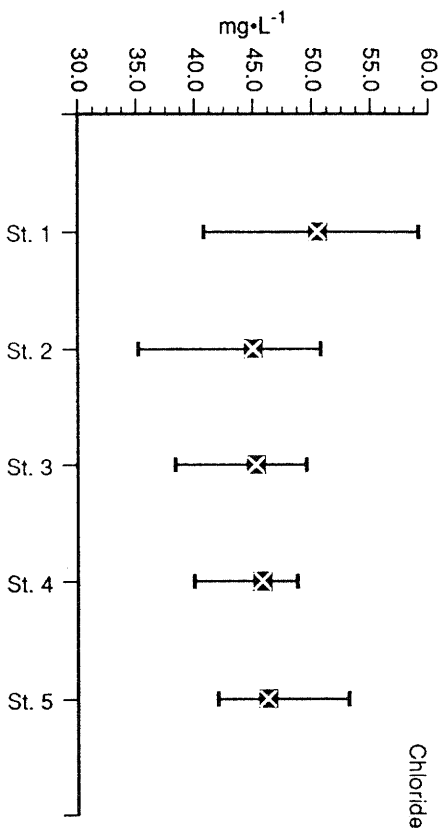
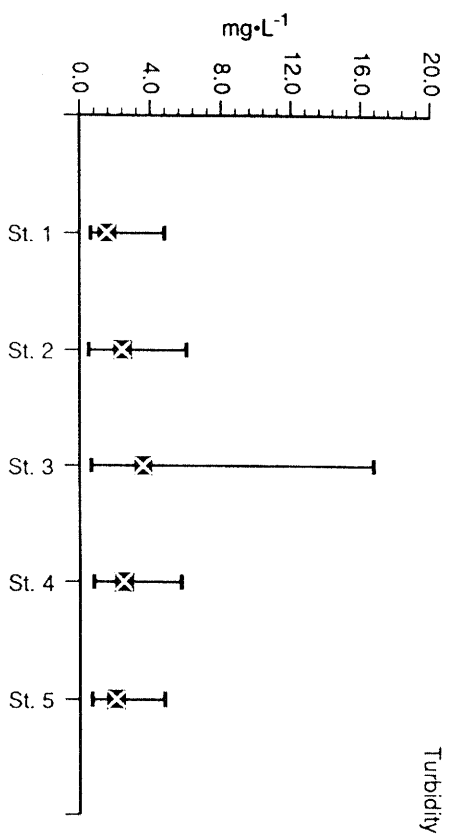


Figure 3: Water Quality Parameters. The figure indicates mean turbidity, chloride, and alkalinity measurements for all stations. Bars indicate high and low values recorded. Sampling dates ranged from July 6 through November 10, 1995.

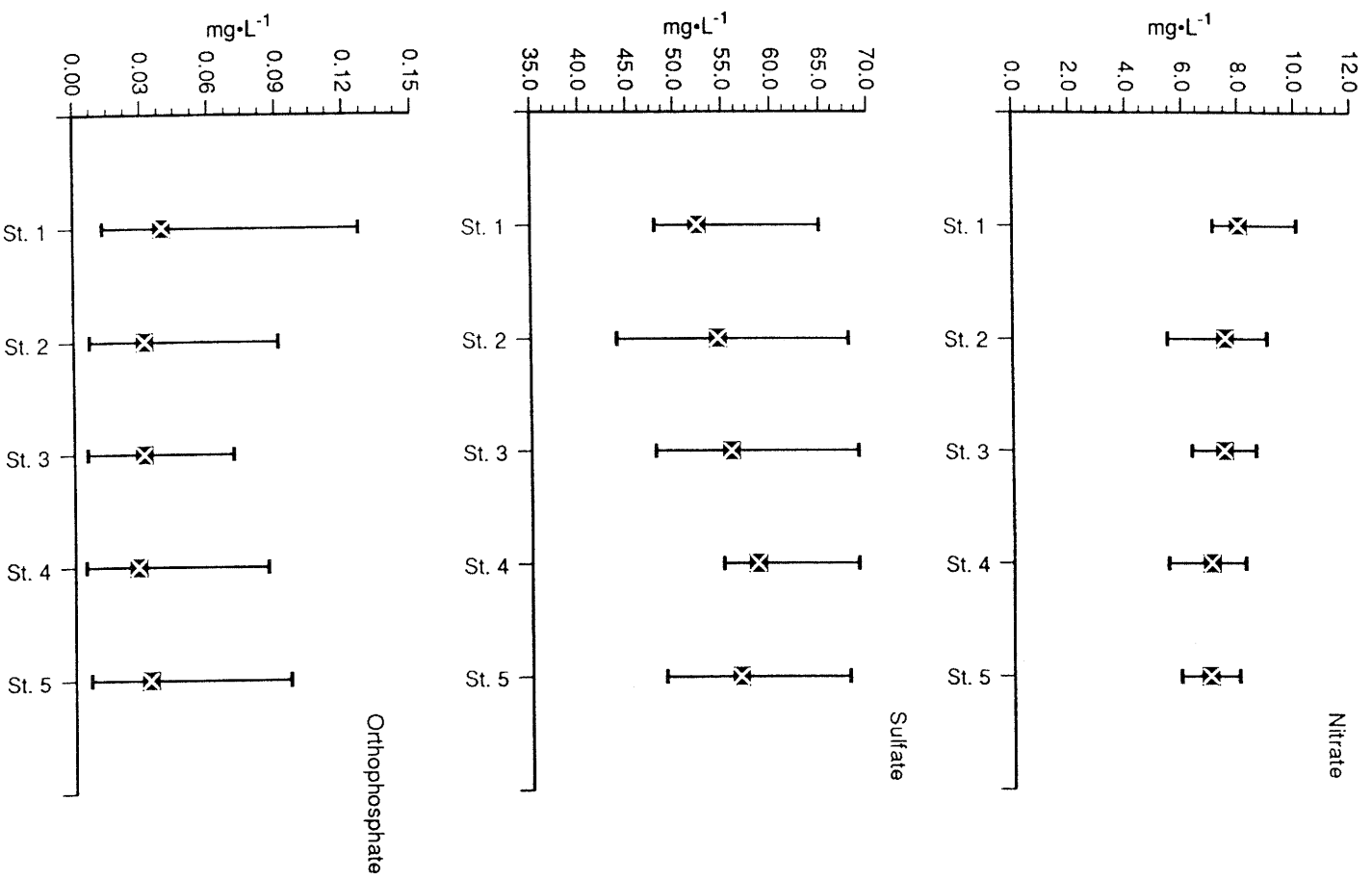


Figure 4: Water Quality Parameters. The figure indicates mean nitrate, sulfate, and orthophosphate measurements for all stations. Bars indicate high and low values recorded. Sampling dates ranged from July 6 through November 10, 1995.

ELEMENT ANALYSIS

The levels of 24 chemical elements dissolved in the collected water samples were analyzed using inductively coupled plasma (ICP) emission spectroscopy, except for mercury which was measured by atomic absorption (AA) spectrometry. Samples were filtered (0.45 μm pore size), preserved with ultra-pure nitric acid and stored in acid-washed containers prior to analysis. Results are reported in milligrams per liter (mg/l) unless otherwise stated. Tables 17 and 18 present element levels measured at each station on June 29, and October 30, 1995, respectively.

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 ranged from 27.1 mg/l at Stations 1 and 3 on June 29, to 29.9 mg/l at several stations on October 30. In general, calcium levels were rather during the sampling period.

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 but are probably not of concern in the basic waters of Lobos Creek.

During the sample year, the highest aluminum value (0.121 mg/l) was recorded at Station 2 on June 29. The lowest aluminum value (0.040 mg/l) was recorded at Station 2 on October 30. Aluminum concentrations exceeded the suggested upper limit for the protection of fish and their ova at every station on October 30.

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 through leaching of natural deposits, from iron-bearing industrial wastes or emissions and 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 (1986) 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 levels ranged from a minimum of <0.001 mg/l at several stations on both sampling dates to a maximum of 0.012 mg/l at Station 4 on June 29. Iron concentrations were well below the USEPA upper limit established for the protection of aquatic life.

MAGNESIUM (Mg)

Magnesium is an essential macronutrient for plants and animals and is the eighth most abundant 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, 1992).

Magnesium values ranged from low of 29.1 mg/l at Station 1 on June 29, to a high of 40.6 mg/l at Station 5 on October 30, during the sampling period. Recorded values never exceeded the APHA recommended criterion of 125 mg/l on any sampling day.

TITANIUM (Ti)

Titanium is normally present in small amounts in surface waters. There are no recommended or established criteria for this biologically non-essential element.

During the sampling year, titanium values were low at all stations on each sampling date, never exceeding 0.002 mg/l.

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 (HACH, 1983). The maximum allowable manganese level (USEPA (USEPA, 1986) in domestic water supplies is 0.05 mg/l, with a total (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 levels during the sampling period ranged from a low of 0.005 mg/l at Station 4 on June 29, to a high of 0.048 mg/l at Station 5 on October 30. Manganese levels never exceeded McKee and Wolf's recommended limit for the protection of aquatic life on any sampling date.

BARIUM (Ba)

Barium is a relatively abundant element (16th most common) in nature, but only trace amounts are usually found in surface waters. Barium concentrations in US drinking water range from 0.0007 mg/l to 0.9 mg/l, with a mean of 0.049 mg/l (Standard Methods, 1985). Water is not suitable for drinking if it contains more than 1 mg/l of barium. Concentrations in excess of 1 mg/l indicate pollution by industrial wastes (HACH, 1983).

The lowest barium value was 0.010 mg/l, recorded at Stations 2 and 3 on October 30; the highest value (0.027 mg/l) was recorded at Station 1 on June 29. Barium concentrations recorded during the sample period are not indicative of industrial pollution.

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 odor and taste. Acute toxicity of aquatic organisms has been demonstrated in concentrations as low as 0.090 mg/l, and a 24-hour criterion of 0.047 mg/l has been suggested for the protection of freshwater organisms (USEPA, 1986). The USEPA (1986) instantaneous zinc criterion is dependent on hardness. For example, zinc concentrations should not exceed 0.320 mg/l at a hardness of 100 mg/l calcium carbonate, and 0.570 mg/l at a hardness of 200 mg/l.

The minimum zinc value recorded during the sampling period was <0.001 mg/l at Station 2 on October 30, and the maximum recorded value was 0.015 mg/l at Station 1 on June 29. During the sampling period, recorded zinc concentrations did not exceed any of the USEPA criteria for the protection of aquatic life.

STRONTIUM (Sr)

Strontium is an alkaline-earth element which resembles calcium and accumulates in bone. The USEPA estimated permissible ambient goal (based on human health) is 0.027 mg/l (Marshack, 1985).

The highest strontium level (0.178 mg/l) was recorded at Station 1 on October 30, and the lowest (0.159 mg/l) was recorded at four stations on June 29. All recorded strontium values exceeded the USEPA permissible ambient goal of 0.027 mg/l.

VANADIUM (Va)

Vanadium is a common element in soils, and some of its compounds may benefit humans by reducing dental caries and blood cholesterol levels (McMillian, 1985). In the US, drinking water supplies have a mean concentration of 0.006 mg/l. Fish may be adversely affected by as little as 4.8 mg/l in soft water and 30 mg/l in hard water (McKee and Wolf, 1963). The USEPA estimated permissible ambient goal, based on human health, is 0.007 mg/l of vanadium.

During the sample period, vanadium concentrations ranged from a minimum of 0.001 mg/l to a maximum of 0.002 mg/l at several stations on both sampling dates. Recorded vanadium concentrations did not exceed the USEPA ambient goal on either sampling date.

LEAD (Pb)

Lead is a toxic element that accumulates in animals. Natural waters seldom have more than 0.02 mg/l (APHA, 1985). Lead tends to be precipitated by numerous substances, effectively reducing levels found in flowing water. 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 containing levels as low as 0.042 mg/l. The lead criteria for protection of freshwater life as proposed by the USEPA (1986) are dependent on water hardness and duration of exposure. For example, at a hardness of 100 mg/l calcium carbonate, the concentration of lead should not exceed 0.082 mg/l on a one-hour average, and 0.0032 mg/l on a four-day average, more than once every three years. At a hardness of 200 mg/l, the criteria increase to 0.200 mg/l and 0.0077 mg/l, respectively. A criterion of 0.050 mg/l for lead in domestic water supplies has been established (USEPA, 1986).

Lead levels ranged from a low of <0.001 mg/l at Station 1 on June 29, to a high of 0.008 mg/l at Station 2 on June 29. Overall, lead levels on each sampling date were quite low and do not appear to pose a threat to the health of aquatic organisms.

MOLYBDENUM (Mo)

Molybdenum is an essential micronutrient that has received limited attention but in high concentrations can be detrimental to the health of animals.

An estimated permissible ambient goal of 0.070 mg/l has been suggested by the USEPA for molybdenum, based on health effects (Marshack, 1985).

During the sampling period, molybdenum levels in Lobos Creek were lowest (0.003 mg/l) at Station 2 on October 30, and highest (0.014 mg/l) at Station 2 on June 29. The USEPA estimated permissible ambient goal based on health effects was never exceeded.

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. According to Marshack (1985) criteria for hexavalent chromium should be used when valence is not known. The drinking water standard for chromium is 0.05 mg/l (USEPA, 1976). For the protection of freshwater life, the concentration of hexavalent chromium should not exceed 0.016 mg/l on a one-hour average, and 0.011 mg/l on a four-day average, more than once every three years (USEPA, 1986).

During the sample period, chromium levels ranged from a low of <0.001 mg/l at Station 4 on June 29, to a high of 0.007 mg/l on June 29. Assuming that all chromium was in the hexavalent form, the criterion for the protection of aquatic life was not exceeded at any station on either sampling date.

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 (1986) criteria for the protection of freshwater aquatic life are dependent on water hardness and duration of exposure. For example, the one-hour average concentration of copper should not exceed 0.018 mg/l at a hardness of 100 mg/l calcium carbonate and 0.034 mg/l at a hardness of 200 mg/l; the four-day average concentration of copper should not exceed 0.012 mg/l at a hardness of 100 mg/l calcium carbonate and 0.021 mg/l at a hardness of 200 mg/l. The USEPA (1986) drinking water standard is 1.0 mg/l, based on taste and odor.

The highest copper concentration recorded during the sampling period was 0.003 mg/l at Stations 2 and 5 on June 29. Concentrations did not exceed any of the of the USEPA criteria established for the protection of aquatic life or drinking water supplies.

NICKEL (Ni)

Nickel is seldom found in natural waters (HACH, 1983), though it may be added to surface waters via leaching of nickel-bearing geological formations. Serpentine rock and serpentine-derived soils are often high in nickel. The USEPA (1986) criterion to protect aquatic organisms may be derived through calculations which take into account water hardness. For example, over a 24-hour period nickel should not exceed $96 \mu\text{g/l}$ ($=0.096 \text{ mg/l}$) if hardness is 100 mg/l calcium carbonate and $160 \mu\text{g/l}$ (0.160 mg/l) if hardness is 200 mg/l . The recommended criterion for the protection of human health is 0.632 mg/l .

During the sampling period, nickel levels were relatively low, never exceeding 0.002 mg/l at any station on either sampling date. Nickel levels recorded during the sample period did not exceed USEPA criteria for the protection of aquatic life.

BORON (B)

Boron is most 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 not generally considered to be a health hazard to humans or other animals except in extremely high doses (Nolte, 1985). Drinking water concentrations of less than 0.1 mg/l are generally considered innocuous (APHA, 1985).

During the sample period, boron levels ranged from a minimum of 0.048 mg/l at Station 1 on June 29, to a maximum of 0.183 mg/l at Station 2 on October 30. Boron levels recorded during the two sampling dates indicate that concentrations of this element in the waters of Lobos Creek are not high enough to harm sensitive plant species.

COBALT (Co)

Cobalt is commonly found in natural surface waters only in minute amounts. The importance of cobalt as an essential element has been established for animals and some plants. In high concentrations the element is relatively non-toxic to man and other animals. In plants, cobalt deficiencies are often of greater concern than are harmful concentrations (Lepp, 1981). There are no established criteria for this element.

During the sampling period, cobalt levels ranged from a low of $<0.001 \text{ mg/l}$ at Stations 1 and 4 on June 29, to a high of 0.004 mg/l at Stations 5 and 4 on June 29 and October 30, respectively.

SILVER (Ag)

According to Lepp (1981), freshwater averages 0.002 mg/l of silver. Drinking waters have been reported to have a mean of 0.13 $\mu\text{g/l}$ ($=0.00013 \text{ mg/l}$) of silver (Standard Methods, 1985). Silver is considered to be one of the most toxic heavy metal ions, particularly to micro-organisms and fish; however, because the monovalent silver ion is very easily reduced, it is not readily accessible to living organisms in the natural environment (Lepp, 1981). Toxic effects on fish have been observed at concentrations as low as 0.00012 mg/l. The toxicity of silver to aquatic life is in part dependent on the hardness of water. For instance, the USEPA (1986) criterion is 0.0041 mg/l at a hardness of 100 mg/l calcium carbonate and 0.013 mg/l at a hardness of 200 mg/l.

The highest level of silver recorded was 0.001 mg/l at several stations on both sampling dates. All other samplings had silver present in quantities too small to be detected with the analytical methods employed. Silver concentrations in Lobos Creek are not great enough to harm aquatic life.

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 to cause certain cancers and adverse changes in human arteries and kidneys (APHA, 1985). Drinking waters in the US have a mean of approximately 0.008 mg/l cadmium. The USEPA (1986) 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, on the average over a period of one hour, cadmium should not exceed 0.0039 mg/l if the hardness is 100 mg/l calcium carbonate and 0.0086 mg/l if the hardness is 200 mg/l more than once every three years. Over a four-day period, these concentrations decrease to 0.0011 and 0.0020 mg/l for hardnesses of 100 mg/l and 200 mg/l, respectively.

During the sampling period, the highest cadmium level (0.002 mg/l) was recorded at Station 4 on October 30. All other stations during both sampling times exhibited a cadmium value of 0.001 mg/l. Criteria for the protection of aquatic organisms were not exceeded on either sampling date.

SODIUM (Na)

Sodium is the earth's sixth most abundant element and is present in nearly all natural surface waters. Although sodium has low toxicity, 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 in Lobos Creek ranged from a low of 32.5 mg/l at Stations 2 and 3 on June 29, to a high of 35.7 mg/l at Station 5 on October 30. Sodium levels in Lobos Creek were low and very constant sampling periods.

SILICON (Si)

Silicon is the world's second most abundant element and is naturally present in most surface waters. 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. However, the oxide form (silica) in water is undesirable for a number of industrial uses because it forms scale on equipment.

Silicon levels ranged from a low of 13.0 mg/l at Stations 4 and 5 on June 29, and Station 4 on October 30, to a high of 17.9 mg/l at Station 1 on June 29.

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 al.*, 1986). 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, and its role as an essential micronutrient is assumed for humans and other animals. For selenium the USEPA (1986) has established a drinking water standard of 10 µg/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 aquatic life criterion for exposure to selenite is 35 µg/l (=0.035 mg/l) as a 24-hour average (USEPA, 1986).

During the sampling period, the highest value of selenium recorded was 0.004 mg/l at Station 4 on June 29. At most of the other stations, selenium was present in amounts too small to be detected by the analytical methods employed. Assuming the selenium present was in the selenite form, the USEPA criterion for the protection of aquatic life was not exceeded at any station on either sampling date.

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.

Potassium concentrations ranged from a low of 1.20 mg/l at Station 1 on June 29, to a high of 1.90 mg/l at Station 5 on October 30. Thus, potassium levels appear to be modest in Lobos Creek.

ARSENIC (As)

Arsenic seldom occurs in drinking water in concentrations above 0.010 mg/l (APHA, 1985). Arsenic is a known carcinogen and 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. According to USEPA (1986) aquatic life may be adversely affected if the arsenic (III) concentration exceeds 0.360 mg/l on a one-hour average and 0.190 mg/l on a four-day average, more than once every three years. The analytical method used does not distinguish between the different forms of arsenic, therefore detected levels are assumed to be the most toxic form, arsenic (III). CSDOH (1977) states a maximum contaminant level for arsenic of 0.050 mg/l in drinking water.

Arsenic concentrations recorded during the sampling period ranged from a low of <0.01 mg/l at most stations on both sampling dates to a high of 0.01 mg/l at Stations 3 and 5 on June 29, and Station 5 on October 30. Recorded arsenic concentrations were well below those recommended for the protection of aquatic life.

MERCURY (Hg)

Organic and inorganic mercury salts are very toxic (APHA, 1985). The USEPA (1986) criteria for the protection of freshwater organisms are dependent on duration of exposure. For example, the concentration of mercury (II) should not exceed 0.0024 mg/l on a one-hour average and 0.0012 mg/l on a four-day average, more than once over a three-year period. The analytical method used does not distinguish between the different forms of mercury, therefore detected levels are assumed to be the most toxic form, mercury (II). The CSDOH (1977) recognizes 0.002 mg/l of mercury as the maximum contaminant level for water used continually for drinking or culinary purpose.

Mercury concentrations recorded at Lobos Creek on each sampling date did not exceed <0.0001 mg/l and do not appear to pose a threat to aquatic life.

DISCUSSION

Of the 24 elements tested, only aluminum and strontium exceeded suggested limits for the protection of aquatic life and human health (McKee and Wolf, 1963; Marshack, 1985). Since human contact with Lobos Creek is possible, the levels of aluminum and strontium should continue to be monitored.

Table 17. Lobos Creek Element Analysis, June 29, 1995.

Station	1	2	3	4	5	MEAN
Ca (mg/l)	27.1	27.2	27.1	27.2	27.2	27.2
Al (mg/l)	0.112	0.121	0.120	0.091	0.107	0.110
Fe (mg/l)	0.006	0.001	<0.001	0.012	<0.001	0.004
Mg (mg/l)	29.1	36.5	36.5	36.8	36.9	35.2
Ti (mg/l)	0.001	0.001	0.001	0.001	0.001	0.001
Mn (mg/l)	0.007	0.007	0.008	0.005	0.006	0.007
Ba (mg/l)	0.027	0.012	0.012	0.011	0.011	0.015
Zn (mg/l)	0.015	0.012	0.012	0.010	0.010	0.012
Sr (mg/l)	0.165	0.159	0.159	0.159	0.159	0.160
V (mg/l)	0.001	0.002	0.002	0.001	0.002	0.002
Pb (mg/l)	<0.001	0.008	0.005	0.001	0.007	0.004
Mo (mg/l)	0.013	0.014	0.012	0.013	0.007	0.012
Cr (mg/l)	0.007	0.001	0.001	<0.001	0.001	0.002
Cu (mg/l)	<0.001	0.003	0.002	0.001	0.003	0.002
Ni (mg/l)	0.001	0.001	0.001	0.001	0.002	0.001
B (mg/l)	0.048	0.098	0.100	0.093	0.096	0.087
Co (mg/l)	<0.001	0.002	0.003	<0.001	0.004	0.002
Ag (mg/l)	<0.001	<0.001	0.001	<0.001	0.001	<0.001
Cd (mg/l)	0.001	0.001	0.001	0.001	0.001	0.001
Na (mg/l)	33.3	32.5	32.5	32.8	33.1	32.8
Si (mg/l)	17.9	13.2	13.2	13.0	13.0	14.1
As (mg/l)	<0.01	<0.01	0.01	<0.01	0.01	<0.01
Hg (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Se (mg/l)	<0.001	0.002	<0.001	0.004	<0.001	0.001
K (mg/l)	1.20	1.37	1.41	1.67	1.31	1.39

Table 18. Lobos Creek Element Analysis, October 30, 1995.

Station	1	2	3	4	5	MEAN
Ca (mg/l)	29.9	29.6	29.9	29.8	29.9	29.8
Al (mg/l)	0.066	0.04	0.058	0.064	0.061	0.058
Fe (mg/l)	0.011	<0.001	0.001	0.003	0.001	0.003
Mg (mg/l)	39.0	39.8	40.2	40.3	40.6	40.0
Ti (mg/l)	0.001	0.002	0.001	0.002	0.001	0.001
Mn (mg/l)	0.010	0.018	0.025	0.046	0.048	0.029
Ba (mg/l)	0.015	0.010	0.010	0.011	0.011	0.011
Zn (mg/l)	0.001	<0.001	0.001	0.003	0.007	0.002
Sr (mg/l)	0.178	0.172	0.174	0.172	0.173	0.174
V (mg/l)	0.001	0.001	0.001	0.002	0.001	0.001
Pb (mg/l)	0.002	0.004	0.004	0.006	0.004	0.004
Mo (mg/l)	0.008	0.003	0.006	0.005	0.004	0.005
Cr (mg/l)	0.002	0.001	0.001	0.001	0.001	0.001
Cu (mg/l)	0.001	0.002	0.001	0.002	0.002	0.002
Ni (mg/l)	0.001	0.002	0.002	<0.001	0.001	0.001
B (mg/l)	0.139	0.183	0.180	0.166	0.168	0.167
Co (mg/l)	0.001	0.002	0.002	0.004	0.003	0.002
Ag (mg/l)	<0.001	0.001	<0.001	0.001	<0.001	<0.001
Cd (mg/l)	0.001	0.001	0.001	0.002	0.001	0.001
Na (mg/l)	35.4	35.2	35.5	35.6	35.7	35.5
Si (mg/l)	14.9	13.1	13.2	13.0	13.1	13.5
As (mg/l)	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Hg (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Se (mg/l)	<0.001	<0.001	0.001	0.003	<0.001	0.001
K (mg/l)	1.44	1.77	1.81	1.78	1.90	1.74

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are those invertebrate animals that can be seen by the unaided eye and can be retained by a US Standard No. 30 sieve (0.595 mm mesh) (Eckblad, 1978). A wide variety of taxa comprise the benthic macroinvertebrates, but chiefly they include the Insecta, Arachnida, Mollusca, Oligochaeta, Platyhelminthes, Crustacea (most notably Amphipoda, Isopoda, Decapoda) and usually the Nematoda (Brown *et al.*, 1993). Benthic macroinvertebrates are particularly useful in environmental monitoring of freshwater streams since throughout their life cycles they occupy a relatively stable position in the benthos. Benthic macroinvertebrate compositions can provide valuable information on water quality shifts that occur insidiously over the long term because of their extended exposure to substances in the water column and substrate. Various groups of benthic macroinvertebrates have very specific environmental requirements and are intolerant of adverse conditions. Thus, the presence or absence of certain groups is a strong indication of the overall chemical and physical conditions and general productivity of a freshwater lotic ecosystem such as Lobos Creek.

METHODS

Benthic macroinvertebrates (BMIs) were collected for identification and population estimate calculations at all stations on June 29, and October 30, 1995. At each station, 4 sub-samples were collected from a 12" x 12" quadrant, using a Surber sampler with appropriate mesh size. The Surber sampler was placed flush against the stream bottom with the net portion of the sampler directed downstream. Using a small brush, larger rocks were scrubbed to remove all attached benthic macroinvertebrates. 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 sampler screen and transferred into a 500 ml plastic container. The contents were then preserved in 80% ethyl alcohol.

In the laboratory, samples were cleaned of vegetative materials and sediments. Most benthic macroinvertebrates were sorted and identified to family using McCafferty (1981). Non-insect benthic macroinvertebrates were identified to phylum and/or class.

In this study, both quantitative and qualitative measures were used in presenting and assessing the macroinvertebrates collected throughout benthic strata.

QUANTITATIVE MEASURES

Community abundance - Community abundance is expressed as the total number of organisms found within a square meter of substrate. According to the productivity assessment used in the KGRA-ARM report (1983) streams classified as *rich* contain more than 2,152 organisms per square meter; a designation of *moderate* indicates between 1,076 and 2,152 organisms per square meter; and *low* indicates a community abundance of less than 1,076 organisms per square meter.

Diversity - While community abundance is one measure of the biomass in a given area, the number of families is an indication of the diversity of organisms found within the study area. The identification of individual organisms to the species level is an extremely difficult and time-consuming process. Frequently, individual organisms are not readily identifiable to their specific names. Instead the lowest practical taxonomic category used in this study is the family.

Distribution - In addition to diversity, expressed as the total number of families present, the percent distribution of the dominant orders is used as an indication of the equal or unequal distribution of the major taxa at a given station.

QUALITATIVE MEASURES

Indicator Taxa - An examination of the ecological requirements of the individual families is often more useful in assessing the overall conditions of the stream, especially when coupled with an evaluation of community abundance (Knight, 1985). Certain benthic macroinvertebrates (most notably the family Chironomidae) are tolerant of a range of environmental conditions, but others have narrower tolerances and are more sensitive to such disturbances as siltation, low flow and low oxygen content. Among the taxa sampled, stoneflies (order Plecoptera) are suggested as excellent indicators of water quality because they are always associated with clean and cool flowing water; therefore, they are considered most intolerant of pollution (Hynes, 1976). Other orders generally intolerant of pollution or other disturbances and having specific ecological requirements include the Trichoptera and Ephemeroptera (McCafferty, 1981).

RESULTS AND DISCUSSION

Benthic macroinvertebrates were absent from the samples taken on both dates at Station 1 near the mouth of the stream. The absence of these invertebrates may be partially explained by the presence of sandy and more saline substrate at this site which is not suitable for these organisms and by the increased marine influence in this reach of freshwater stream. However,

stations 2, 3, 4, and 5 contained members of the following major classes of benthic macroinvertebrates: Insecta, Crustacea, Arachnida, Nematoda, Mollusca, and Annelida. Complete benthic macroinvertebrate data are summarized in Tables 19 through 21 and relative abundances at each station are presented in Figure 5.

Station 2

Community abundance values at Station 2 on June 29 was 1793, a value indicating *moderate* productivity; however, the community abundance value decreased on October 30 to 465, indicating a drop to *low* productivity at this station (Table 21). The most abundant family of organisms at this station on both dates was the dipteran family Chironomidae, which numbered 722 and 117 individuals on June 29 and October 30, respectively. The Chironomidae are among the most widely adapted of all aquatic insects and are tolerant of ecological disturbances. On June 29, the second most abundant family, numbering 20 individuals, was the Lepidostomatidae of the order Trichoptera. In contrast to the Chironomidae, the Lepidostomatidae are among those BMIs most intolerant of adverse ecological conditions (McCafferty, 1981). The class Gastropoda was the next most abundant (11 individuals) at this Station in June after the Lepidostomatidae.

On October 30, as mentioned previously, the most abundant family at Station 2 was the Chironomidae; this family was followed in order of abundance by the classes Oligochaeta and Tubellaria, with 27 and 15 individuals identified in each, respectively. These two classes of organisms are also tolerant of a wide range of ecological disturbances that occur within lotic habitats.

Station 3

Community abundance values recorded for BMIs at Station 3 on June 29 and October 30, were 743 (*low* productivity) and 1834 (*moderate* productivity), respectively (Table 21). In the June sample, the most abundant organisms, numbering 74 individuals, were members of the dipteran family Chironomidae. The second most numerous organisms in the sample belonged to the class Oligochaeta (72 individuals). The third and fourth most abundant organisms identified were of the order Amphipoda (59 individuals) and the family Lepidostomatidae (46 individuals). Of all abundant invertebrates present in the sample, only the Lepidostomatidae have specific ecological requirements and are generally intolerant of disturbance.

The October 30 sample from Station 3 exhibited a very different assemblage of BMIs than the June 29 sample. The class Tubellaria was present in the greatest number (160 individuals) in this sample; the tubellarians are adapted to a wide range of habitat conditions and are considered very tolerant of disturbance (Platts, *et al.*, 1983; McCafferty, 1981). Other tolerant classes of

organisms present in large numbers in this sample included the Oligochaeta and the Gastropoda, numbering 101 and 93 individuals, respectively. Although the majority of BMIs identified in this sample were of tolerant classes of organisms, the trichopteran family Lepidostomatidae was the second most abundant group of organisms in the sample, with 124 individuals.

Station 4

Community abundances for Station 4 on June 29, and October 30 were 130 and 381, respectively. Both of these abundance values were indicative of *low* overall productivity at this station. In the June sample, the most abundant group of organisms belonged to the family Chironomidae, which numbered 26 individuals. The second most abundant group was the class Gastropoda, totaling 17 individuals. Both of these groups are tolerant of disturbances and wide ranges of habitat conditions.

Gastropoda, with 148 individuals, was the most abundant group of organisms in the October 30 sample, followed by the class Pelecypoda, with 11 individuals.

Station 5

Community abundance values at Station 5 on June 29, and October 30 were 862 (low productivity) and 1027 (low productivity), respectively. On June 29, the Chironomidae (165 individuals) were the most common organisms identified at this station; the second most abundant family was the Lepidostomatidae (125 individuals). Amphipoda, a class of crustaceans, and the dipteran family, Simuliidae, were the third most abundant groups of organisms in this sample, each totaling 16 individuals.

In the October 30 sample, the most abundant group of organisms, numbering 188 individuals, belonged to the class Gastropoda. Amphipoda, with 116 individuals, was the second most abundant group of organisms, and was followed by the third most abundant group, Coenagrionidae with 43 individuals. The Coenagrionidae (of the insect order Odonata), in contrast to most of the other BMIs found within Lobos Creek which are detritovores/herbivores, are predatory organisms. The Chironomidae, with 41 total individuals, were the fourth most abundant group of organisms collected at this station in October.

SUMMARY AND CONCLUSIONS

The overall benthic macroinvertebrate community compositions were similar at all stations on both sampling dates. The majority of the organisms identified in each sample are among the benthic macroinvertebrates most tolerant of a wide range of habitat conditions which have the capacity to with-

stand severe disturbances of freshwater lotic ecosystems. The abundance of these tolerant organisms in each sample indicates that Lobos Creek contains an assemblage of BMIs that is to be expected in similar urban stream systems which have been significantly altered and degraded by invasive human activities. Community abundance values calculated for benthic macroinvertebrate samples were all indicative of *low* to *moderate* community productivity. Such values reinforce the conclusion that Lobos Creek is a disturbed urban stream.

Although the high populations of tolerant BMIs collected indicate the generally disturbed character of Lobos Creek, the presence of the caddisfly (order Trichoptera) family Lepidostomatidae in relatively high numbers at stations 2, 3, and 5 suggests that the stream is also capable of supporting populations of BMIs which are intolerant of high levels of pollution and disturbances (Figure 5). The Lepidostomatidae generally require clean, cool waters and have narrow ranges of tolerance. However, the Lepidostomatidae also prefer erosional and depositional areas within streams, a characteristic of this family which tends to support the conclusion that Lobos Creek is a physically altered and disturbed habitat (Merritt and Cummins, 1984).

In order to determine if benthic macroinvertebrate community compositions in Lobos Creek are altered by seasonal or ecological changes, such as increased erosion and flow from rainfall and runoff, additional sampling would have to be carried out over a longer period than was feasible for this initial study.

Table 19. Benthic macroinvertebrates collected on June 29, 1995, at Lobos Creek: Stations 2, 3, 4, 5.

Organism	Station	2	3	4	5
<i>Turbellaria</i>					
Planariidae		1	8	1	
<i>Oligochaeta</i>		9	72		7
<i>Gastropoda</i>		11	40	17	8
<i>Pelecypoda</i>		1			
<i>Nematoda</i>		4		1	
<i>Arachnida</i>					
Hydracarina			1		
Oribatei				1	
<i>Crustacea</i>					
Amphipoda			59	4	16
<i>Insecta</i>					
Odonata (Dragon/Damselflies)					
Coenagrionidae				1	
~~Libellulidae~~ <i>Argia</i> sp.					11
Plecoptera (Stoneflies)					
Nemouridae			7		1
Unidentifiable					4
Hemiptera (Water Bugs)					
Mesoveliidae				2	
Velidae					
Unidentifiable					1
Coleoptera (Water Beetles)					
Dysticidae					2
Trichoptera (Caddisflies)					
Pupae			8		
Hydropsychidae					1
Lepidostomatidae		20	46		125
Unidentifiable					3
Station		2	3	4	5
Lepidoptera (Aquatic Caterpillars)					
Unidentifiable		1		1	
Diptera (True Flies)					
Nematocera pupae		1	4		7
Simuliidae pupae					3
Other pupae				1	1
Chironomidae		722	74	26	165
Dixidae				1	
Simuliidae		2	1		16
Total Individuals:		772	320	56	371

Table 20. Benthic macroinvertebrates collected on October 30, 1995, at Lobos Creek: Stations 2, 3, 4, 5.

Organism	Station	2	3	4	5
<i>Turbellaria</i>					
Planariidae		15	160	1	19
<i>Oligochaeta</i>		27	101		
<i>Hirudinea</i>		2			
<i>Gastropoda</i>		6	93	148	188
<i>Pelecypoda</i>			1	11	4
<i>Nematoda</i>		6		1	3
<i>Arachnida</i>					
Oribatei			1		
<i>Crustacea</i>					
Amphipoda		1	69	1	116
<i>Insecta</i>					
Odonata (Dragon/Damselflies)					
Coenagrionidae		5	1		43
Plecoptera (Stoneflies)					
Nemouridae		1	3		1
Hemiptera (Water Bugs)					
Veliidae		2			
Trichoptera (Caddisflies)					
Pupae			6		
Hydropsychidae			1		
Lepidostomatidae		11	124		15
Lepidoptera (Aquatic Caterpillars)					
Unidentifiable		1			
Station	2	3	4	5	
Diptera (True Flies)					
Brachycera pupae		2			
Nematocera pupae	3	4		1	
Simuliidae pupae	2				
Chironomidae	117	28		41	
Ephydriidae	1	2	2	8	
Muscidae-Anthomyiidae				1	
Simuliidae				2	
Total Individuals:	200	596	164	442	

Table 21: A summary of benthic macroinvertebrate community structure at stations 2, 3, 4 and 5 for organisms collected on June 29, and October 30, 1995.

Stn.	Date	Community Abundance (No./sq. meter)	Taxa (No.)
2	6/29/95	1793	10
	10/30/95	465	15
3	6/29/95	743	11
	10/30/95	1384	15
4	6/29/95	130	11
	10/30/95	381	6
5	6/29/95	862	16
	10/30/95	1027	13

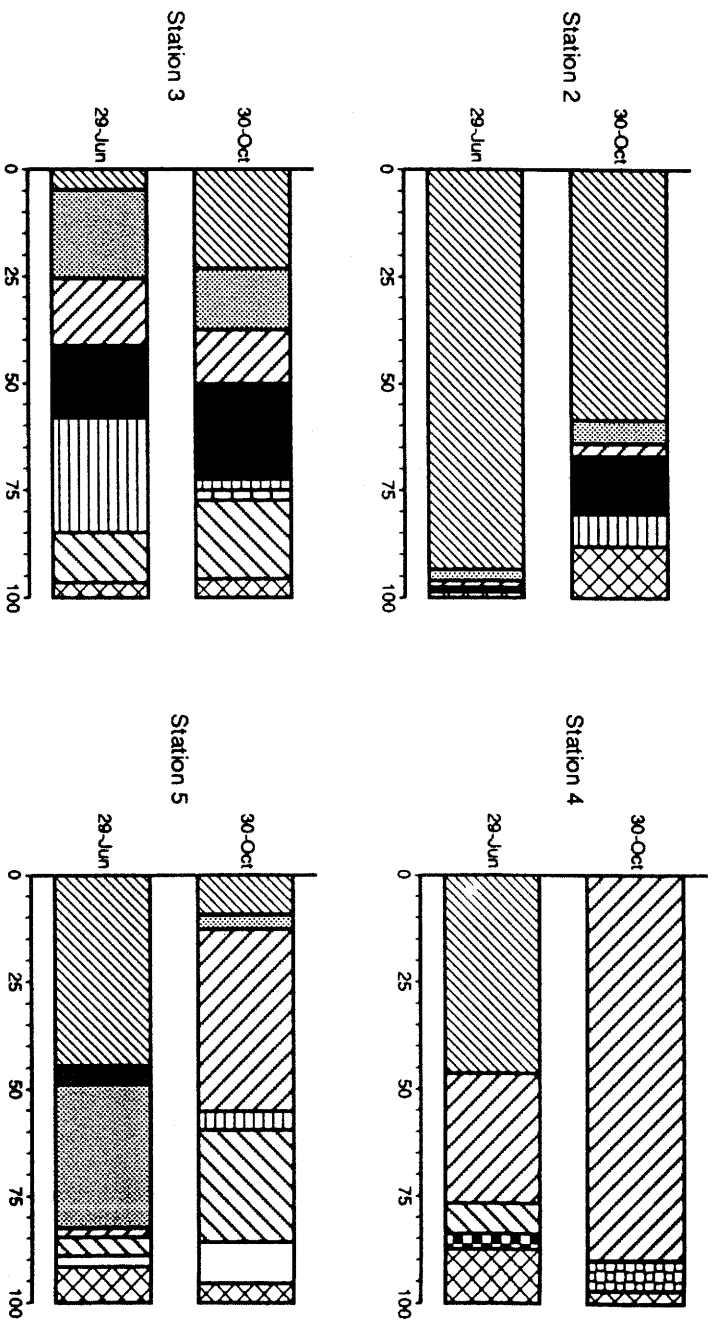


Figure 5: BENTHIC MACROINVERTEBRATE POPULATIONS. The figures show relative abundances of benthic macroinvertebrate taxa for each station and all sampling dates.

PERIPHYTON

METHODS

Sampling. Five sampling stations were established at the creek (Figure 1). Periphyton samples including biomass, species abundance and chlorophyll were collected every other week from June 21, 1995 through August 17, 1995.

Eight glass construction bricks (20cm x 20cm) were placed at each station in Lobos Creek on June 21, 1995. All bricks were placed at similar depth and exposed to comparable light intensities. Two bricks from each station were sampled following 14, 28, 42, and 56 day exposure. Biomass was determined following drying for 36 hours at 105°C (dry weights) and combustion of the samples at 500°C for 4 hours (organic contents) (Standard Methods 1992).

In the determination of species abundance and chlorophyll, glass slides (25mm x 75mm) were fixed to a standard construction brick and submerged horizontally at constant depth. Four slides were removed from each station following 14, 28, 42, and 56 day exposure.

Samples for taxonomic determination and cell densities were mounted with a 30% Karo syrup mixture. Cell identifications were performed at 400X magnification using a Zeiss standard microscope. Cells were identified to species wherever possible according to Patrick and Reimer (1966 and 1975), Prescott (1970), and Smith (1950). Cell counts were determined at 400X magnification using a Whipple disk. Each cell in multicellular, filamentous, and colonial taxa was counted independently only if they fell within the boundary of the grid; fragmented cells were not included. Three replicate counts were performed for each sample, and expressed numbers are the average.

Chlorophyll samples were prepared by filtering 50-100 ml of water through a 0.45µ Whatman glass microfiber filter. Samples were stored at -80°C and later analyzed using an acetone extraction method (Wetzel and Likens, 1991).

Data analysis. The amounts of chlorophylls a, b, and c1 and c2 were determined by the following equations:

$$\text{Chl } a \text{ } (\mu\text{g/l}) = (C_a) (v) / (V),$$

$$\text{Chl } b \text{ } (\mu\text{g/l}) = (C_b) (v) / (V), \text{ and}$$

$$\text{Chl } c_1 + c_2 \text{ } (\mu\text{g/l}) = (C_c) (v) / (V),$$

where v is the volume of the extract in ml, V is the volume of water filtered in L, and C_a , C_b , and C_c are

$$C_a = 11.85 A_{664} - 1.54 A_{647} - 0.08 A_{630},$$

$$C_b = 21.03 A_{647} - 5.43 A_{664} - 2.66 A_{630}, \text{ and}$$

$$C_c = 24.52 A_{630} - 1.67 A_{664} - 7.60 A_{647},$$

where A is the absorbance value at the corresponding wavelength. Phaeopigments were calculated by

$$P = \frac{(26.7) [1.7 (A_{665}) - A_{665}] (V)}{V}$$

Diversity indices were determined for every sampling date according to the formulas listed by Shannon-Weiner (Wilhm and Dorris, 1968) and calculated as

$$H' = - \sum_{i=1}^s (n_i/n) \log (n_i/n)$$

where n is the total number of cells in all taxa, n_i is the number of individuals in the i th taxon, and s is the total number of taxa.

RESULTS

A total of twenty three species were identified from the glass slides. Four species comprised at least 90% of the biomass: *Achnanthes lanceolata*, *Cladophora glomerata*, *Cocconeis placentula*, and *Navicula minuscula* (Figure 6). Less abundant algae included diatoms (Chrysophyta), green algae (Chlorophyta), and some blue-greens (Cyanobacteria). Taxa found on the glass slides were also observed on natural substrata; however, many species found to be natural flora of the creek were not colonizers of the artificial substrata. Tables 22 and 23 list all species identified on both artificial and natural substrates.

The lowest density recorded occurred at Station 4 following a 14 day exposure (66 cells/mm²), and the greatest density was recorded after a 56 day exposure (6833 cells/mm²) at station 5. The accumulation of dry weights varied from station to station. Elevated measurements were most likely due to the large numbers of benthic macroinvertebrates, including the classes Gastropoda and Oligochaeta observed on the bricks following 14 days (station 4), 28 days (station 3), and 42 days (station 5). Results also indicate an increase in organic weight from 14 to 28 day exposure, but show a leveling off for the rest of the study. Mean organic weights were 0.71 mg/m² after 14 days, 1.18 mg/m² after

28 days, 1.07 mg/m² after 42 days, and 1.26 mg/m² after 56 days. Chlorophyll a values tended to increase from 14 to 28 day exposure, but showed little or no increase for the remainder of the study. Mean chlorophyll a values were 1.60 µg/cm² after 14 days, 1.98 µg/cm² after 28 days, 2.11 µg/cm² after 42 days, and 2.88 µg/cm² after 56 days. Species diversities generally decreased with increasing exposure time. A summary of all data is presented in Table 24.

Figure 7 depicts the ratio of chlorophyll a to ash-free dry weight (mg/g). Large variations between stations may be the result of observed insect larvae such as families Simuliidae and Chironomidae, members of the class Gastropoda, and/or inorganic matter on the slides.

DISCUSSION

Changes in diversity and abundance of diatom assemblages are frequently used to monitor water quality. Diversity and abundance can be affected by a variety of factors including water temperature, light, current, substrate type, grazing, current velocity, nutrient concentrations, amount of drifting particles in the water, and water pollution (Eloranta and Kunas, 1979; Stevenson, 1984). Material accumulated on submerged substrata can hinder attachment and colonization of some algae.

Position of the samplers may also affect colonization rates. Munteanu and Maly (1981) showed that slides oriented parallel and perpendicular to the current will show differences in colonization rates and species composition. In this study, slides were positioned parallel to the current, and large numbers of *Cocconeis placentula* were observed to be settled at the edges of the slides. These results are consistent with those presented by Munteanu and Maly (1981). This settling can be explained by distinct patterns of current flow around the slides, and also by certain physical adaptations of *Cocconeis* (Munteanu and Maly, 1981). *Cocconeis* secures itself to a smooth substrate by secreting a gelatinous film, thereby enhancing adhesion. Furthermore, cells of *Cocconeis* are able to adhere by remaining flat on the slide in order to avoid the shearing stress of flowing water.

Smooth substrate surfaces, however, may also interfere with or inhibit colonization by certain taxa. Cells of *Achnanthes* attach by means of a gelatinous stalk and possess irregularly shaped frustules, and, therefore, are not as well suited for adhering to a smooth substrate as *Cocconeis* (Munteanu and Maly, 1981). Stevenson (1983) suggested that immigration rates are highest on rough or previously colonized substrates at the outer edges of streams. Substrates exposed to the main current are subject to shearing stress which not only washes away nutrient poor waters and waste products from cells, but also detaches cells, thereby decreasing density.

Substrate composition also may have caused of the minimal occurrence of the filamentous algae on the samplers. *Cladophora glomerata* grew abundantly at all stations, indicated by large visible tufts of filamentous algae. *Cladophora glomerata* did appear on the submerged glass slides, however, species abundance did not increase with longer exposure. The *C. glomerata* on the slides at the conclusion of the study was indicative of only young, immature filaments. In freshwater, *C. glomerata* attaches primarily to rocks, stones, and rough surfaced substrates sheltered from the main current (Dodds, 1992). The cracks and crevices on the stones allow the basal cells to escape the shearing stress of the water, and remain fixed to the substrate. It was apparent that some cells had affixed themselves to the slides, but no abundant growth of the filament was evident.

Water quality often can be assessed by the types of algae present. For example, an abundance of *C. glomerata* is often associated with nutrient enrichment of the water. *Cladophora glomerata* responds to eutrophication by reaching optimum growth, indicated by the presence of diatom epiphytes on large tufts of the alga. Although diatom epiphytes were present on the algal tufts and large amounts of the alga were present in the creek, water quality measurements suggest that eutrophication was not a significant factor in the abundant growth. Other taxa present are not necessarily associated with eutrophicated or polluted waters.

SUMMARY

The relative abundance and species composition at each site varied with exposure time. Dominant taxa were *Cocconeis placentula*, *Navicula minuscula*, and *Achnanthes lanceolata*. Diversities decreased with exposure time. Early succession species such as *C. placentula* colonized the substrate, secreting mucilage required for other taxa to colonize. *Cocconeis placentula* was by far the most abundant species, and its large numbers were responsible for the decreased diversities.

Artificial substrata are often used to measure periphyton community structure and rates of periphytic accumulation. As shown by this and other studies, sampling with artificial substrata will yield different assemblages than those found on natural substrata. Substrate suitability varies between species, and parameters affecting colonization include substrate type, current, light intensity, and water temperature. Species identified on glass substrata were present on stones sampled from the creek. All species identified on the stones, however, were not found on the artificial substrata.

TABLE 22: SPECIES PRESENT ON NATURAL SUBSTRATA. The table lists species identified from natural stone substrata. The source of identification is also listed.

Species	Station	Identification
Cyanophyta		
Anabaena limnetica	1	Smith, 1950
Chroococcus sp.	1,2,3,4,5	Prescott, 1964
Nodularia spumigena	1,5	Smith, 1950
Oscillatoria acutissima	1,2,4,5	Smith, 1950
Oscillatoria agardhii	2,4,5	Smith, 1950
Plectonema sp.	3	Smith, 1950
Spirulina sp.	3	Smith, 1950
Synechocystis sp.	3,4	Smith, 1950
Chrysophyta		
Achnanthes clevei	2	Patrick and Reimer, 1966
Acnathes lanceolata	2,3	Patrick and Reimer, 1966
Amphora sp.	1,5	Patrick and Reimer, 1966
Cocconeis fluviatilis	3,4	
Cocconeis pediculus	2,4	Patrick and Reimer, 1966
Cocconeis placentula	1,3,4	Patrick and Reimer, 1966
Cymatopleura solea	3,5	Smith, 1950
Cymbella sp. 1	1,2,3,4,5	Patrick and Reimer, 1966
Diatoma vulgare	3	Patrick and Reimer, 1966
Fragillaria capucina	1,2,3,4,5	Patrick and Reimer, 1966
Gomphonema acuminatum	2,3,4	Patrick and Reimer, 1975
Gomphonema parvulum	4	Patrick and Reimer, 1975
Gyrosigma nodiferum	1,3,5	Patrick and Reimer, 1966
Hannaea arcus	3,4	Patrick and Reimer, 1966
Meridion circulare	3	Patrick and Reimer, 1966
Navicula circumtexta	1,3,4,5	Patrick and Reimer, 1966
Navicula lanceolata	2,4	Patrick and Reimer, 1966
Navicula minima	1,5	Patrick and Reimer, 1966
Navicula miriscula	3,4	Patrick and Reimer, 1966
Navicula seminulum	1,5	Patrick and Reimer, 1966
Nitzschia acicularis	1,3,5	Smith, 1950
Rhicosphenia curvata	2,3,4	Patrick and Reimer, 1966
Synedra miriscula	1,3,5	Patrick and Reimer, 1966
Synedra ulna	2,3,4	Patrick and Reimer, 1966
Chlorophyta		
Cladophora glomerata	3, 4	Smith, 1950
Closterium sp.	3	Smith, 1950
Rhodophyta		
Batrachospermum vagum	3	Smith, 1950

TABLE 23: SPECIES PRESENT ON GLASS. The table shows all species identified from glass bricks. The identification source is also shown.

Species	Identification
Cyanophyta	
Chroococcus sp.	Prescott, 1964
Synechocystis sp.	Smith, 1950
Chrysophyta	
Achnanthes clevei	Patrick and Reimer, 1966
Acananthes lanceolata	Patrick and Reimer, 1966
Amphora sp.	Patrick and Reimer, 1966
Cocconeis fluviatilis	
Cocconeis placentula	Patrick and Reimer, 1966
Cymatopleura solea	Smith, 1950
Cymbella sp. 1	Patrick and Reimer, 1966
Fragillaria capucina	Patrick and Reimer, 1966
Gomphonema acuminatum	Patrick and Reimer, 1975
Gomphonema parvulum	Patrick and Reimer, 1975
Gyrosigma nodiferum	Patrick and Reimer, 1966
Hannaea arcus	Patrick and Reimer, 1966
Meridion circulare	Patrick and Reimer, 1966
Navicula circumtexta	Patrick and Reimer, 1966
Navicula minima	Patrick and Reimer, 1966
Navicula miniscula	Patrick and Reimer, 1966
Nitzschia acicularis	Smith, 1950
Rhicosphenia curvata	Patrick and Reimer, 1966
Synedra miniscula	Patrick and Reimer, 1966
Synedra una	Patrick and Reimer, 1966
Chlorophyta	
Cladophora glomerata	Smith, 1950

TABLE 24: SUMMARY OF ALL DATA. The table summarizes data for all stations. Included measurement organic weight, total chlorophyll, chlorophyll a, phaeopigments, and species diversities.

	Stations				
	Days of Colonization				
	2	3	4	5	
Dry Weight (mg•m-2)					
14	3.09	4.51	69.37	9.97	
28	6.74	53.72	4.17	5.44	
42	5.17	2.94	3.31	22.04	
56	5.30	3.99	5.80	6.97	
Organic Weight (mg•m-2)					
14	0.55	0.30	1.52	0.45	
28	1.43	2.00	0.22	1.06	
42	1.13	1.06	0.68	1.40	
56	1.33	1.15	1.28	1.26	
Total Chlorophyll (µg•cm-2)					
14	5.46	5.06	2.92	3.61	
28	5.20	4.32	4.76	5.32	
42	7.36	3.85	3.55	4.72	
56	5.16	***	***	5.76	
Total Chlorophyll a (µg•cm-2)					
14	1.93	2.05	0.86	1.57	
28	2.62	2.13	1.58	1.60	
42	3.56	1.71	1.38	1.79	
56	2.85	***	***	2.91	
Phaeopigments (µg•cm-2)					
14	2.04	2.17	0.47	2.27	
28	3.40	2.76	2.30	1.41	
42	3.78	2.19	1.14	1.77	
56	3.73	***	***	3.74	
Number of species per sample					
14	15	20	12	11	
28	12	20	7	12	
42	8	19	9	5	
56	9	***	***	4	
Cell Density (X10 ¹² cells • mm-2)					
14	0.32	20.65	0.66	9.00	
28	65.60	31.90	35.04	7.99	
42	56.03	47.37	44.30	45.56	
56	59.06	***	***	68.33	

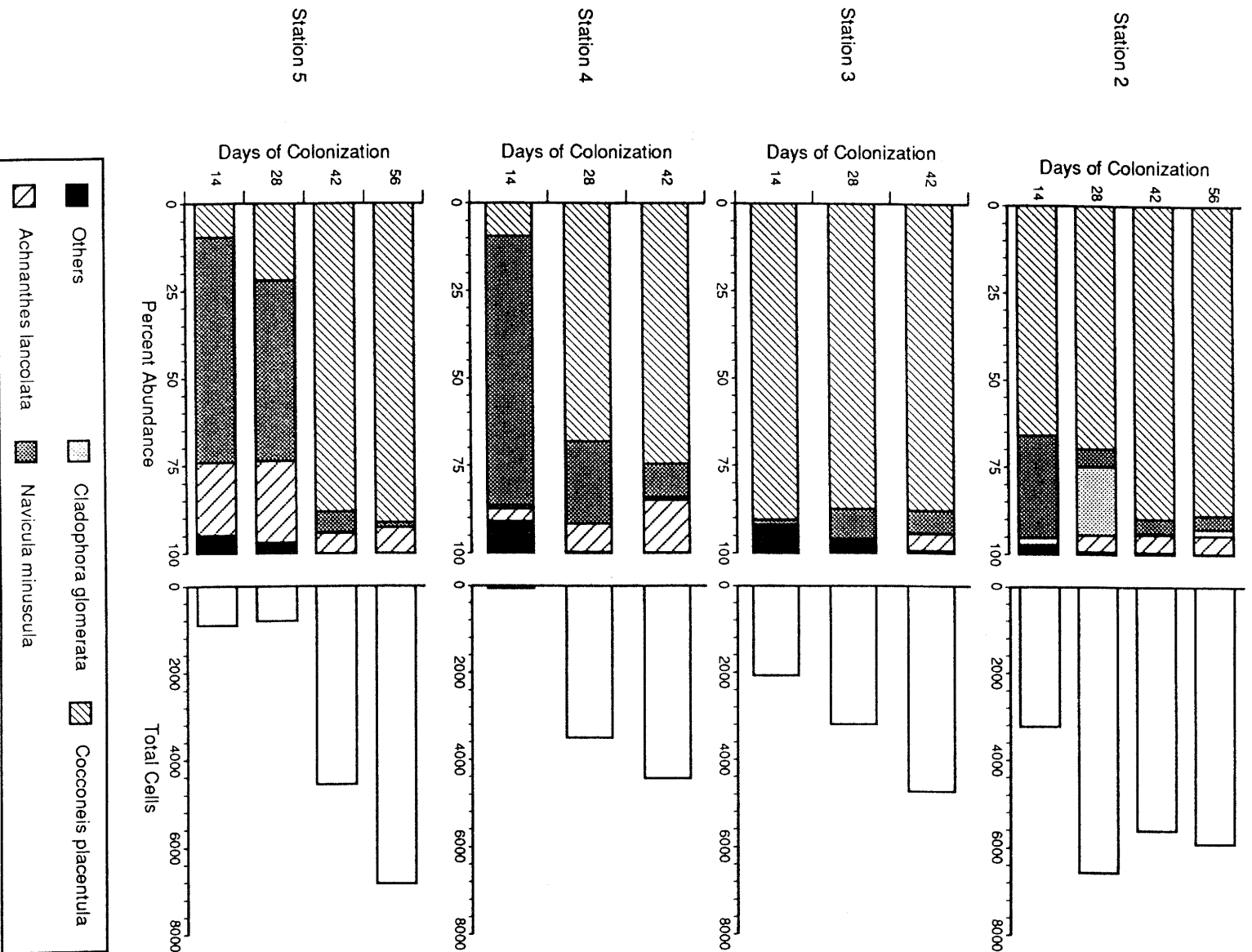


Figure 6: Species Composition. The figures show species composition of the four most abundant species. Total cells are shown to the right and are expressed as cells per square millimeter. Due to vandalism, data for 56 days of colonization is not available.

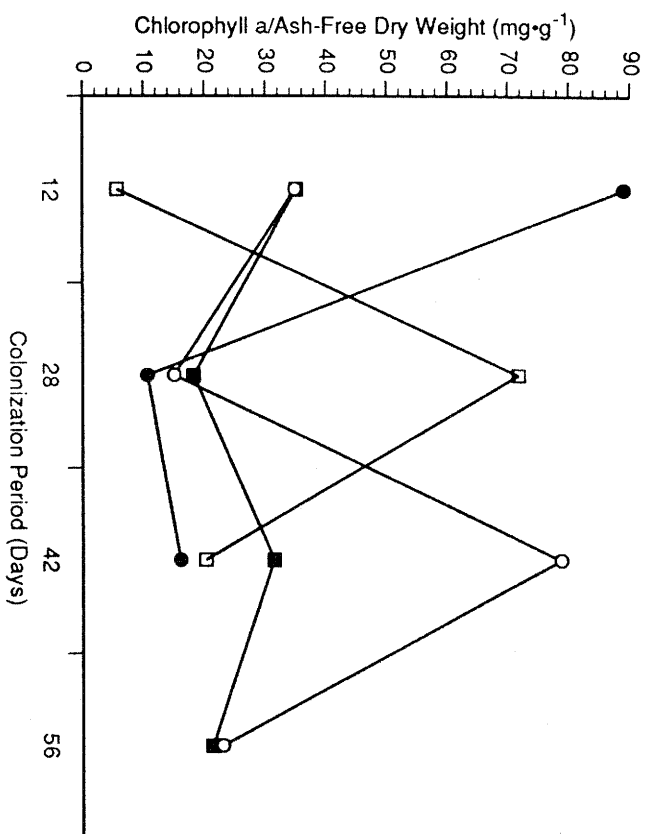


FIGURE 7: CHLOROPHYLL A / ASH-FREE DRY WEIGHT. The figure shows the ratio of chlorophyll a to ash-free dry weight for all sampling stations.

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