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Aquatic Macroinvertebrates and Water Quality of Sandia Canyon, Los Alamos National Laboratory

December 1992–October 1993

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DISCLAIMER

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AQUATIC MACROINVERTEBRATES AND WATER QUALITY OF SANDIA CANYON, LOS ALAMOS NATIONAL LABORATORY DECEMBER 1992–OCTOBER 1993

by

Saul Cross

ABSTRACT

The Biological Resource Evaluation Team (BRET) of EM-8 at Los Alamos National Laboratory (LANL) has collected aquatic samples from the stream within Sandia Canyon since the summer of 1990. These field studies gather water quality measurements and collect macroinvertebrates from permanent sampling sites. An earlier report by Bennett (1994) discusses previous BRET aquatic studies in Sandia Canyon. This report updates and expands Bennett's initial findings.

During 1993, BRET collected water quality data and aquatic macroinvertebrates at five permanent stations within the canyon. The substrates of the upper three stations are largely sands and silts while the substrates of the two lower stations are largely rock and cobbles. The two upstream stations are located near outfalls that discharge industrial and sanitary waste effluent. The third station is within a natural cattail marsh, approximately 0.4 km (0.25 mi) downstream from Stations SC1 and SC2. Water quality parameters are slightly different at these first three stations from those expected of natural streams, suggesting slightly degraded water quality. Correspondingly, the macroinvertebrate communities at these stations are characterized by low diversities and poorly-developed community structures. The two downstream stations appear to be in a zone of recovery, where water quality parameters more closely resemble those found in natural streams of the area. Macroinvertebrate diversity increases and community structure becomes more complex at the two lower stations, which are further indications of improved water quality downstream.

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1 INTRODUCTION

In the summer of 1990, an accidental spill from the TA-3 Power Plant Environment Tank released more than 3,785 liters (1,000 gallons) of sulfuric acid into upper Sandia Canyon. The Biological Resource Evaluation Team (BRET) was asked to review the impacts of the spill and began regular monitoring of the Sandia wetlands at this time (Bennett 1994). The BRET initiated a study to assemble baseline information on the aquatic environment in Sandia Canyon and to determine if the environment was affected by industrial and sanitary waste discharges. In addition to monitoring chemical and physical conditions (temperature, dissolved oxygen, pH, and conductivity) of the stream monthly, the BRET collected aquatic invertebrates to gain a more complete understanding of the Sandia Canyon aquatic environment.

In a report for the Bureau of Reclamation (Battelle 1972), Battelle Columbus Laboratories outlined a comprehensive and interdisciplinary Environmental Evaluation System (EES). This EES uses physical, chemical, and biological parameters to assess possible environmental impacts of water resource projects. The current Sandia Canyon report refers to many of the environmental quality ratings developed by Battelle.

Water temperature directly influences aquatic organisms' physiological functions such as metabolism, growth, emergence, and reproduction (Anderson and Wallace 1984). Temperature is inversely related to oxygen solubility because water absorbs greater amounts of oxygen at lower temperatures. While aquatic organisms can tolerate wide fluctuations in pH and conductivity, a change in water temperature of a single degree Celsius can be significant (Lehmkuhl 1979).

Depressed oxygen environments often indicate the presence of organic wastes. The amount of dissolved oxygen (DO) in water has a direct and immediate effect on invertebrates using tracheal gills for respiration (as the larvae of dragonflies, mayflies, caddis flies, and stoneflies). Oxygen is present in air at levels greater than 200,000 ppm, but its maximum value at saturation in water is only 15 ppm (Eriksen *et al.* 1984). Although aquatic insects require more oxygen for metabolism at elevated temperatures, less is available due to decreased solubility (Gaufin *et al.* 1974). Certain stages in the life cycle of aquatic invertebrates, such as emergence, will not occur unless sufficient oxygen is present (Bell 1971). Cold-water mayflies and stoneflies cannot tolerate DO concentrations much below 5 mg/liter (Nebeker 1972).

Acid waters are characterized by low species diversity and low productivity. Acidity and basicity of waters is measured by pH. Low values pH indicate acidity, middle values (around 7.0) indicate neutrality, and high values indicate basicity. Some aquatic organisms, as mayflies, are sensitive to low pH, which can be caused by accidental acid spills or acid rain deposition. The normal pH of natural surface waters ranges from 6.5 to 9.0 (Canter and Hill 1979). In Los Alamos Canyon, the pH of natural surface waters ranges between 7.8 and 8.2 (LANL 1990), due in part to the alkaline substrates characteristic of the southwestern United States.

Conductivity measures the ability of water to carry an electrical current, and it reflects the concentrations of ionized substance in water. The conductivity of potable water in the United States ranges from 50 to 1,500 micro-mhos per centimeter (μmhos/cm), and the conductivity of industrial waste may be as high as 10,000 μmhos/cm. A rough approximation of the total dissolved solids (TDS) of freshwater can be obtained by multiplying the conductivity by 0.66. The upper limit of TDS that aquatic organisms can tolerate ranges from 5,000 to 10,000 mg/l (Battelle 1972).

Aquatic macroinvertebrates have been used extensively as water quality indicators. These organisms, especially the stream-dwelling insects, are well suited to this purpose due to their

- small size and total immersion in the water environment,
- abundance in virtually every stream,
- life cycles which are frequently of at least one year duration, allowing long-term detection of past disturbance, and
- relative ease of collection and identification to family or genus level.

In general, monitoring only the physical and chemical characteristics of waters provides little information of conditions prior to the sampling date. In contrast, changes in macroinvertebrate communities indicate water quality over a much longer period. Shifts in the numbers of individuals and community species composition indicate prior disturbances. These disturbances could result from infrequent discharges of waste that might remain undetected through a water quality monitoring program that did not incorporate biological data (Weber 1973).

Many early water quality investigations used aquatic invertebrates to compile extensive biological indicator species lists and attempted to measure species-specific tolerances to pollution. This method is prone to erroneous interpretations since species-level identification is difficult to ascertain, tolerances of some species vary greatly under different environmental conditions, and "intolerant" species may occur in polluted waters due to drift.

Recent studies have emphasized the importance of community structure in evaluating water quality (Gaufin and Tarzwell 1956; Hilsenhoff 1977; and Schwenneker and Hellenthal 1984). Examination of the macroinvertebrate habits (modes of existence) and functional feeding groups present provides an understanding of community complexity. Indices of species richness, evenness, and diversity have been developed to allow numerical comparisons of whole communities. Unpolluted environments have higher taxa diversity index values than polluted environments, which tend to be dominated by relatively few intolerant species.

2 ENVIRONMENTAL SETTING

2.1 General Setting

Sandia Canyon is located within the boundaries of Los Alamos National Laboratory (LANL). The Laboratory is located in north-central New Mexico on the Pajarito Plateau, approximately 120 kilometers (80 miles) north of Albuquerque and 40 km (25 mi) west of Santa Fe (Figure 1). The plateau is an apron of volcanic sedimentary rock stretching 33 to 40 km (20 to 25 mi) in a north-south direction and 8-16 km (5-10 mi) from east to west.

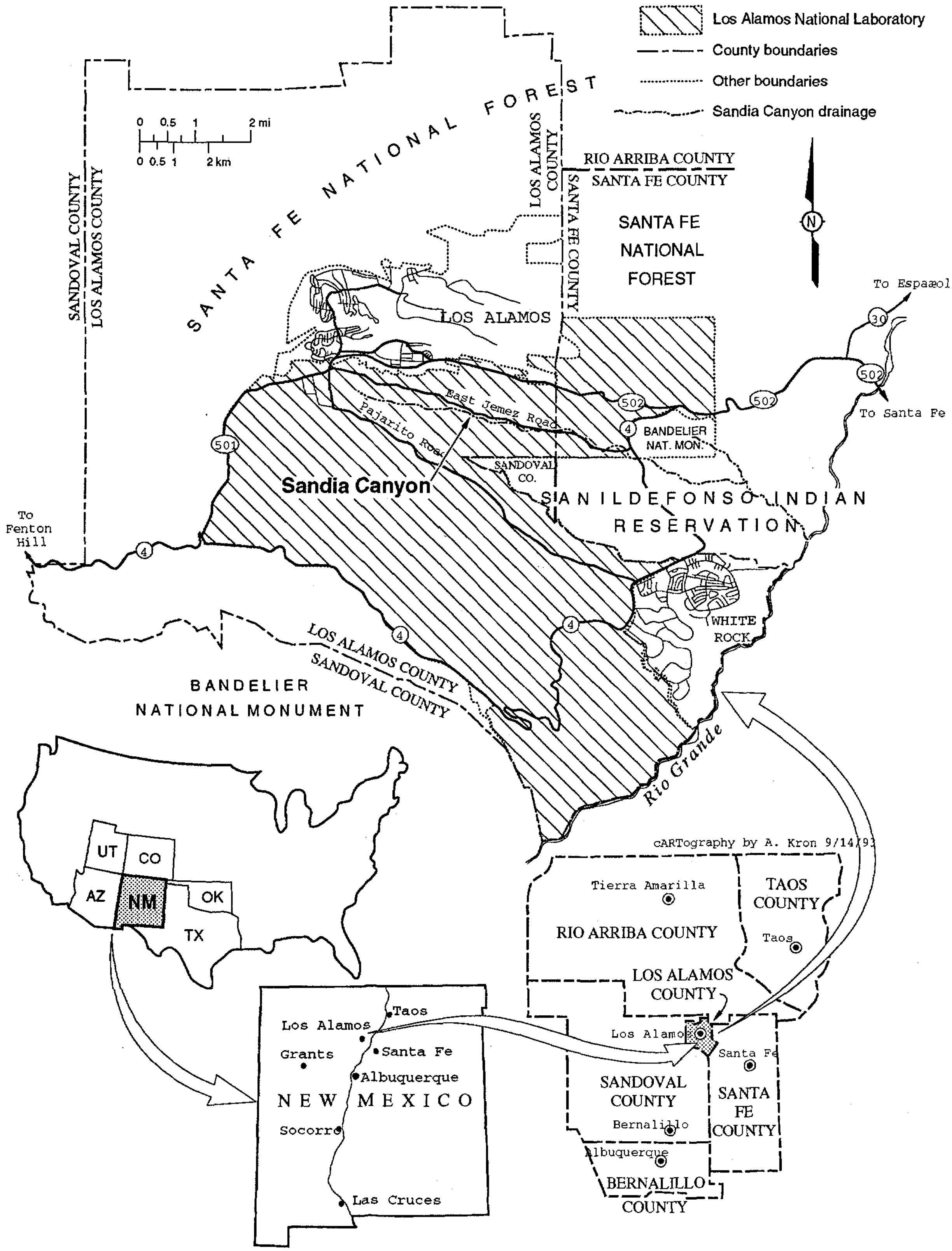


Fig. 1. Location of Los Alamos National Laboratory, New Mexico.

The average elevation of the plateau is 2,286 meters (7,500 feet). It slopes gently eastward from the edge of the Jemez Mountains, a complex pile of volcanic rock situated along the northwest margin of the Rio Grande rift. The plateau slope increases abruptly to sheer cliffs where the Rio Grande has cut through the volcanic rock and underlying sediments. From an elevation of approximately 1,890 meters (6,200 ft) at White Rock, the scarp drops to 1,646 meters (5,400 ft) at the Rio Grande. Intermittent streams flowing southeastward have dissected the plateau into a number of finger-like, narrow mesas separated by deep, narrow canyons. The bedrock of the plateau consists of Bandelier tuff erupted from the Jemez Mountains about 1.1 to 1.4 million years ago. The tuff overlaps other volcanics that, in turn, overlay the Puye Formation conglomerate (LANL 1988). This conglomerate intermixes with Chino Mesa basalts along the Rio Grande.

The LANL area is characterized by a semiarid, temperate, montane climate. In the summer months, temperatures typically range from a daily low of around 10°C (50°F) to a high of 27°C (80°F) (Bowen 1990). Winter temperatures generally range from near -10°C (15°F) to about 10°C (50°F) during a 24-hour period. Annual precipitation varies from 33 to 46 centimeters (13 to 18 in), most of it falling as rain in July and August.

2.2 Description of Sandia Canyon

The head of Sandia Canyon is near the University House in Technical Area 3 (TA-3), and the canyon extends southeastward to the Rio Grande. The drainage basin is approximately 13.5 square kilometers (5.6 square miles). Industrial effluents from LANL activities maintain a year-round streamflow in Sandia Canyon.

The National Wetlands Inventory conducted by the U.S. Fish and Wildlife Service identified three types of wetlands or water systems in Sandia Canyon. BRET's research was conducted in the first stretch, a "persistent artificially flooded, palustrine wetland." This wetland occurs below TA-3 and receives effluent from the TA-3 steam plant, a sewage treatment plant, and an asphalt plant. Storm water runoff and snow melt also contribute to the stream seasonally. This portion of the stream has received effluent discharges since the early 1950s.

Farther downstream, the stream meets East Jemez Road. Here, the wetland area changes to a "temporarily flooded palustrine wetland" type. The stream's lower stretch is an "intermittent, temporarily flooded, riverine stream bed" (Cowardin 1979). The National Wetland Inventory map of Sandia Canyon is shown in Figure 2. LANL outfalls collectively discharge 1,639,000 liters per day (433,000 gallons per day) into Sandia Canyon.

2.3 Description of the Study Site

In 1990, three permanent sample stations were placed in the artificially flooded, palustrine wetland in Sandia Canyon. In order to better understand the aquatic environment, BRET began to monitor two additional stations in the winter of 1992 (Figure 3). The elevation of all five stations is approximately 2360 m (7200 ft) asl.

Station SC1 is below the rubble landfill and immediately beyond the effluent culvert. It receives effluent from the steam plant and the asphalt plant. The streamside vegetation in this section consists of redtop (*Agrostis alba*) and cattails (*Typha latifolia*). Debris including asphalt from the rubble landfill is carried down a side channel and washed into the stream. The stream bed is composed of silt and sand, and there is little or no emergent vegetation within the stream channel (Figure 4). The water flow is variable at this station due to erratic releases from the asphalt plant. When the plant discharges effluent, the greatly increased flow disturbs the stream bed substrate and redeposits portions downstream. Violent discharges sometimes result in the formation of a pool below the culvert. On the south, a nearby stand of young Douglas fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*) appears to be dying.

Station SC2 is approximately 14 m (45 ft) beyond the culvert. The streamside vegetation consists of redtop, Canada wildrye (*Elymus canadensis*), thistle (*Cirsium* sp.),

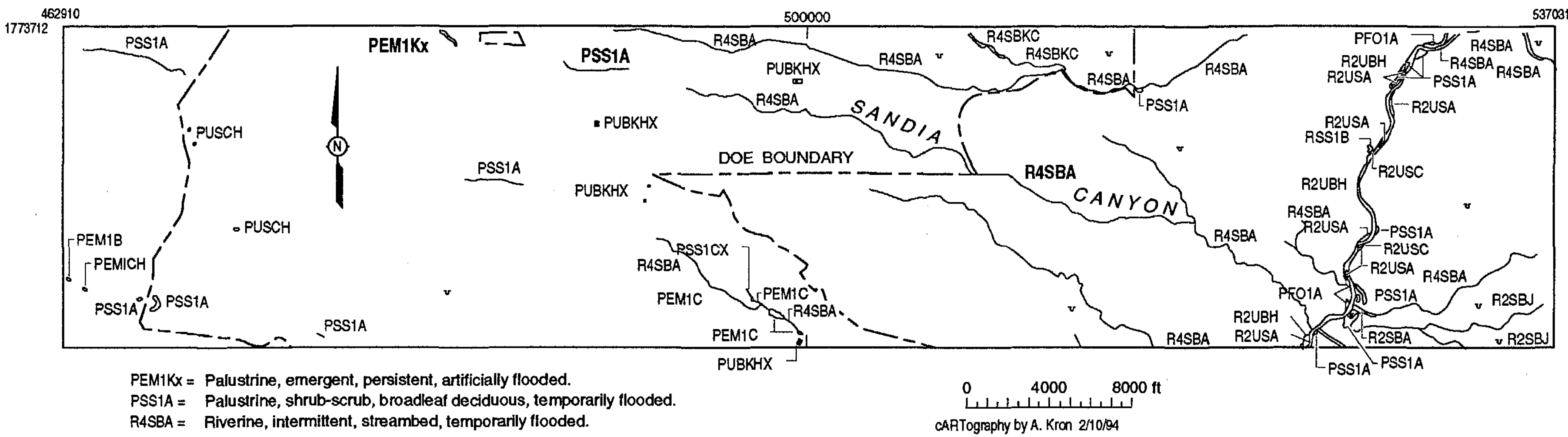


Fig. 2. National Wetland Inventory map for Sandia Canyon, Los Alamos County, New Mexico (developed by U.S. Fish and Wildlife Service).

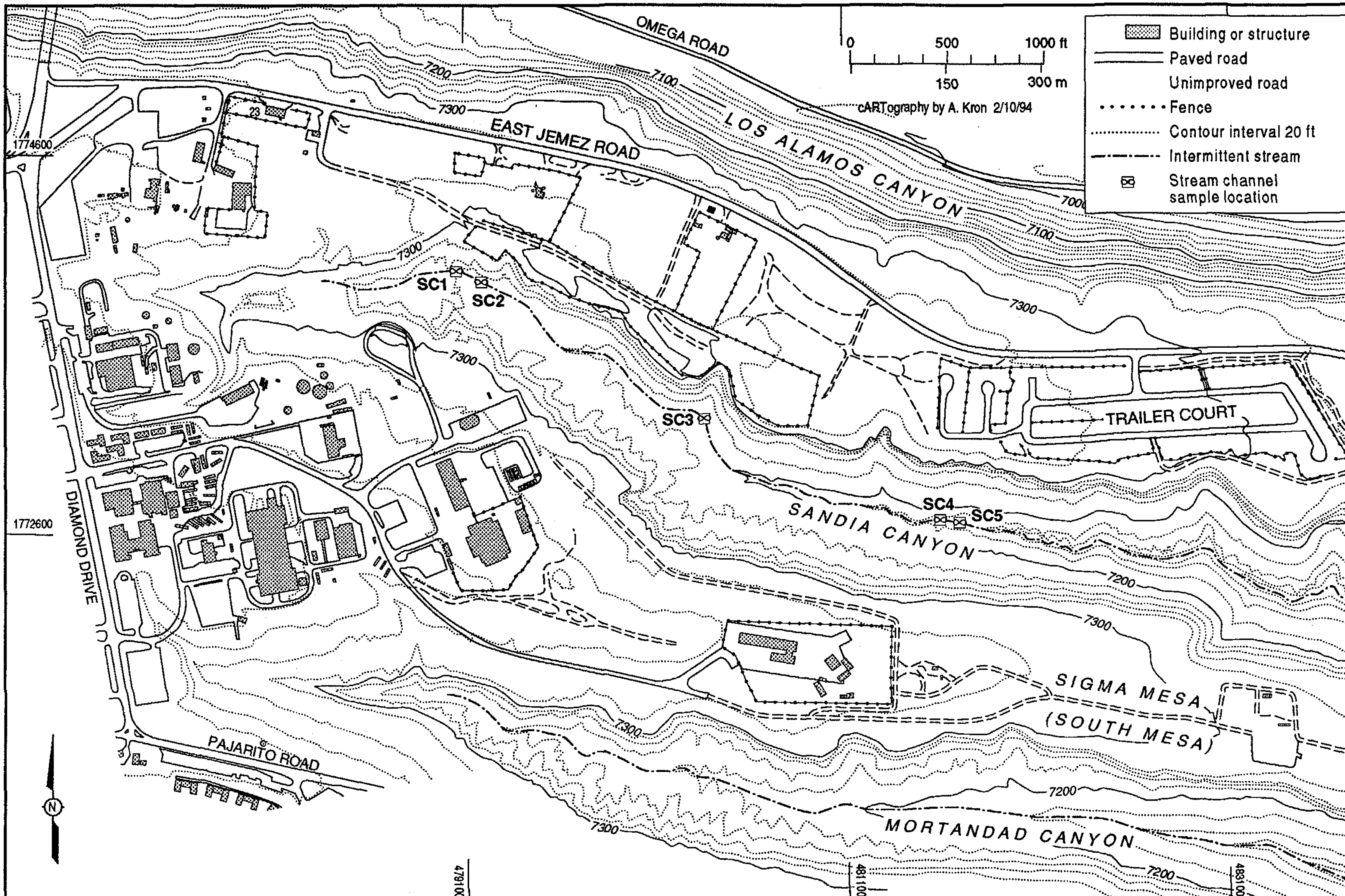


Fig. 3. Locations of sampling stations within Sandia Canyon.

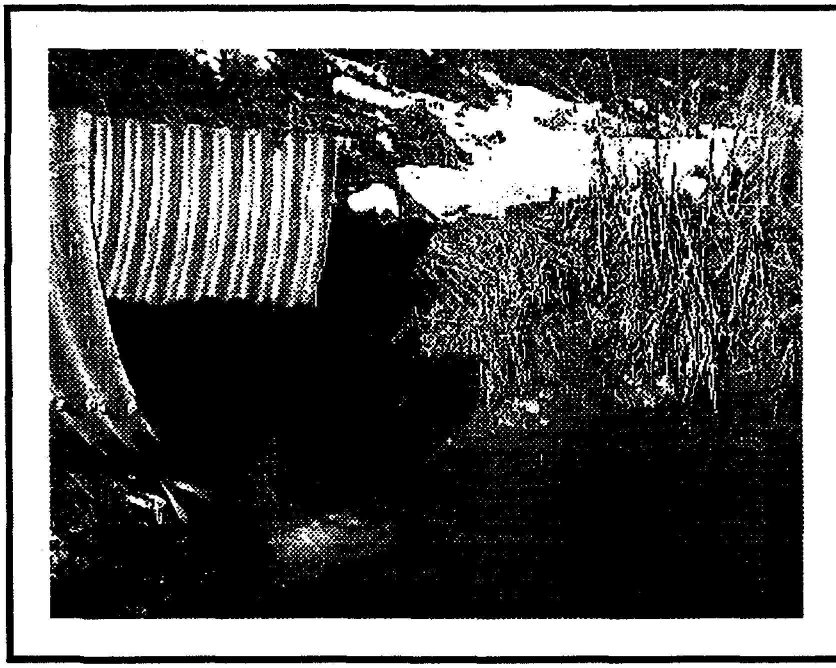


Fig. 4. Station SC1 in Sandia Canyon.

Fig. 5. Station SC3 in Sandia Canyon.

and cattails. This station is located immediately below the junction of the stream and discharge from the sewage treatment plant. The flow from this outfall varied greatly during 1993 and was frequently dry. The stream bed substrate consists of sands, silts, and gravel. At times, the smell of chlorine in the air is quite strong.

Station SC3 is approximately 0.4 km (0.25 mi) downstream from Station SC2. The vegetation in this area is characterized by redtop and wheatgrass (*Agropyron* sp.) on the south side of the stream channel and cattails on the north side. The stream bed substrate consists of silts and sands containing a large quantity of humus (Fig. 5). Water pools here, and the flow is much more stable than at SC1 and SC2.

Station SC4 is at a large pool below the cattail marsh, approximately 0.4 km (0.25 mi) downstream from Station SC3. Nearby limber pine (*Pinus flexilis*) and ponderosa pine (*Pinus ponderosa*) provide some shade. The vegetation is limited by exposed bedrock which surrounds the pool. Nearby vegetation includes June grass (*Koleria cristata*), Canada wildrye, and little bluestem (*Andropogon scoparius*). The stream substrate consists of sand and silt deposited on top of rock (Figure 6).

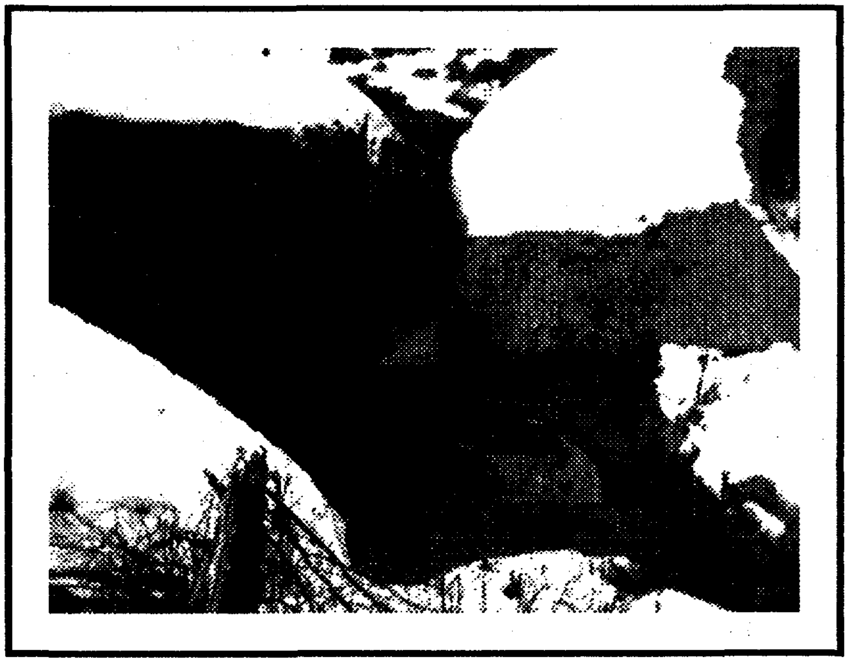


Fig. 6. The large pool at Station SC4 in Sandia Canyon.

Station SC5 is approximately 10 meters (33 ft) east of the pool at SC5. Streamside vegetation includes poison ivy (*Rhus radicans*), redtop, wolftail (*Lycurus* *phleboides*), and little bluestem. Nearby ponderosa pine and Rocky Mountain juniper (*Juniperus scopulorum*) provide some shade. The stream narrows here and forms riffles. The current is swift enough to remove most sand and silts, and the stream bed contains cobbles as large as 20 cm (8 in) in diameter.

3 HISTORICAL DISTURBANCES IN SANDIA CANYON

In addition to the impacts of routine effluent discharges, the hydrology of Sandia Canyon has been affected by the rubble landfill, Los Alamos County sanitary landfill, and accidental chemical spills.

3.1 Rubble Landfill

The rubble landfill was started in 1986 as an alternative disposal site for clean rubble. Presently, the landfill bridges the canyon and will be extended to the northeast. Large amounts of fill and sediments erode into the wetland during heavy storms and snow melt. Recent attempts have been made to stabilize the landfill and prevent eroding materials from entering the stream channel and wetland below. Dumping of asphalt over the side of the landfill aggravates the problem and many pieces of asphalt continue to enter the stream channel.

3.2 County Landfill

The county landfill is located to the north of Sandia Canyon and extends 1.2 km (0.75 mi) along the top of Los Alamos Mesa. The landfill receives Los Alamos County business and residential refuse as well as sanitary refuse from LANL. Fill material erodes off the landfill and into the wetland. In addition, paper trash and other debris fall or blow into the canyon. Consequently, the stream between SC2 and SC3 is littered with metal poles, sheets of plastic, and other trash.

3.3 Accidental Spills

During the summer of 1990, 3,785-5,300 liters (1,000-1,400 gallons) of sulfuric acid spilled from the TA-3 Power Plant Environmental Tank into the cattail-dominated wetland in Sandia Canyon. Three of BRET's five sampling stations were established at this time to assess the spill's impact. The stream channel was surveyed immediately after the spill for aquatic macroinvertebrates. Initially, no specimens were found at any of the sample locations, but communities began to re-establish within a month. Station SC4 was the first station where recovery was observed.

Another spill occurred during midsummer 1992, discharging chlorine from the sewage treatment plant into Sandia Canyon. Subsequent investigation revealed a significant decline in the number of stream macroinvertebrates. By the end of summer, the relative numbers of macroinvertebrates had nearly returned to normal.

4 METHODOLOGY

4.1 Water Quality Measurements

During 1993, five aquatic sampling stations were monitored in upper Sandia Canyon. An attempt was made to measure the temperature, pH, DO, and conductivity of stream water monthly. All measurements were taken with calibrated instruments in accordance with the manufacturer's specifications. All measurements were taken three times, and the average value was used in computations.

Temperature measurements were taken using the temperature probe of an Orion SA 250 pH meter or a YSI model 57 DO meter. All pH measurements were taken with an Orion SA 250 pH meter. DO was measured with a YSI model 57. The initial readings were multiplied by a factor of 0.78 to compensate for the elevation in upper Sandia Canyon. All conductivity measurements were taken with a VWR digital conductivity meter which displays the conductivity in units of μmhos/cm. Estimates of total dissolved solids were obtained by multiplying the conductivity readings by 0.66 (Battelle 1972).

4.2 Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrates were collected monthly at the same time that water quality measurements were taken. The substrate at each station was agitated, and various microhabitats at each site were included. Sampling employed a large, D-frame dip net with a diameter of 11.5 cm (4.5 in) at its widest point. The net was scraped against the stream bed for 60 seconds and then carefully removed from the water (Hilsenhoff 1977). All captured aquatic invertebrates were collected in scintillation vials containing 70% ethanol and taken to the BRET lab for identification.

Organisms were identified using a Bausch and Lomb "Stereozoom 7" binocular dissecting microscope. Identification of specimens was accomplished using taxonomic references for southwestern macroinvertebrates including Pennack 1978, Merritt and Cummins 1984, and McCafferty 1981. Organisms were identified to genus when possible, and stored in the permanent BRET invertebrate collection in vials containing 70% ethanol.

To better understand the community structure, collected data were analyzed by taxa, percentage of pollution-intolerant individuals, habit, and functional feeding group. The data from each station were pooled, and a diversity index was calculated using the equation discussed by Wilhm (1967):

$$D = (S-1) / \ln N,$$

where D = the taxa diversity index
S = the number of taxa
N = the number of individuals

5 RESULTS AND DISCUSSION

5.1 Water Quality Measurements

5.1.1 Temperature. Figure 7 shows the average monthly temperatures recorded at each sample station in degrees Celsius. Of the five sample stations, SC1 displayed the highest water temperature, averaging 17.4 °C (63.3 °F). SC1 receives effluent from the TA-3 steam plant that is normally discharged at a temperature higher than the natural stream temperature. SC4 and SC5, the farthest stations downstream from the site of effluent discharge, displayed the lowest temperatures.

5.1.2 pH. Figure 8 shows average monthly pH readings from the five sample stations. The highest pH was regularly measured at SC1, which had an average pH of 8.6. This is probably due to the influence of the steam plant effluent, which has a pH higher than the

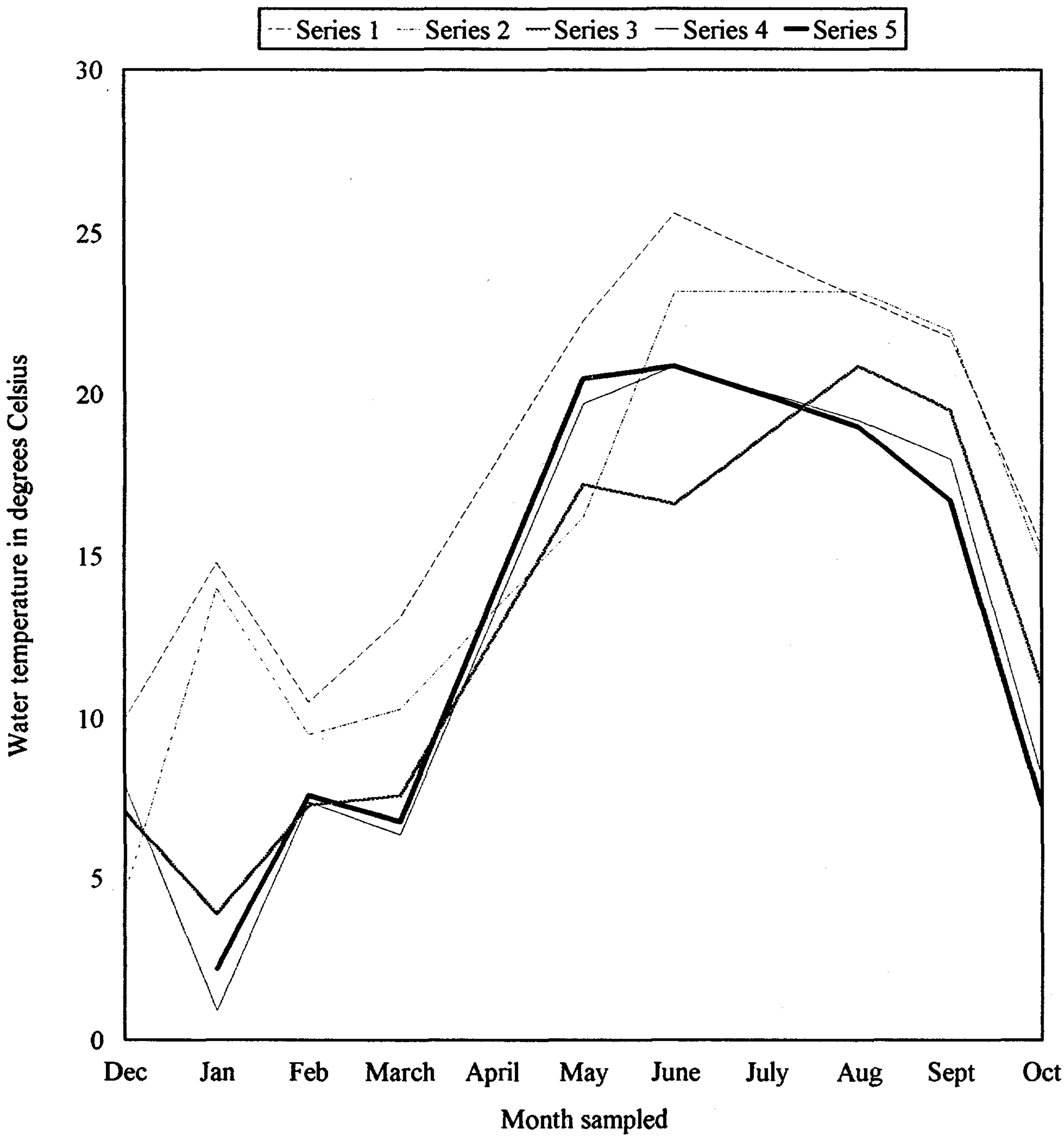


Fig. 7. Average water temperature for Sandia Canyon (December 1992 - October 1993).

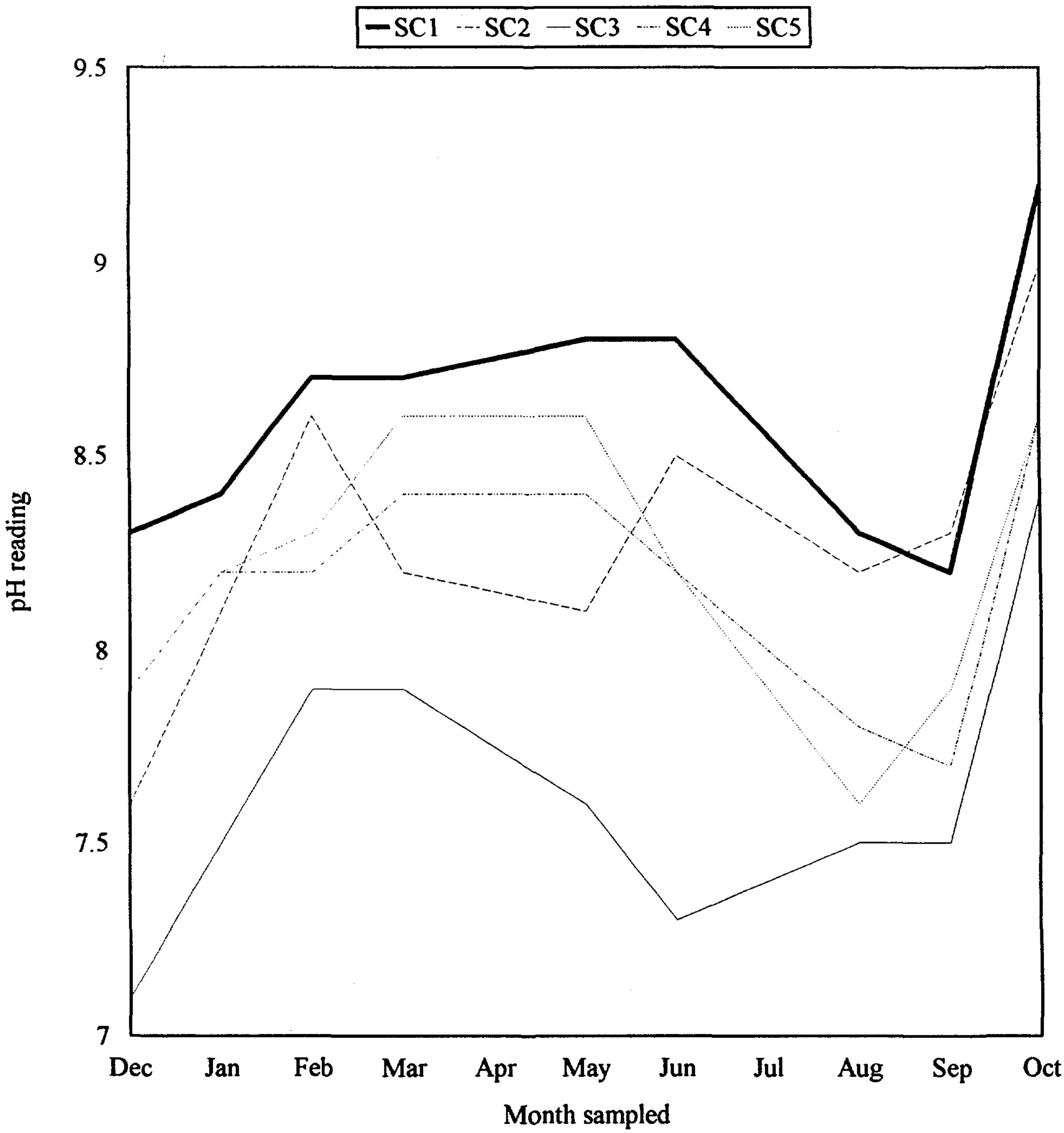


Fig. 8. Average pH for Sandia Canyon (December 1992 -- October 1993).

natural waters of the area. (The National Pollution Discharge Elimination System permit for this outfall allows a maximum pH of 9.0.)

The lowest average pH occurred at SC3, which had an average pH of 7.6. This is slightly below the range of natural waters in this area (7.8 - 8.2). In past sampling years, the low pH readings at SC3 were thought to be due to neutral (pH = 7) effluent discharges from the sewage treatment plant. In an effort to determine the causative factor, BRET included SC2 at the junction of this outfall in its 1993 monitoring program. The average pH at SC2 was 8.4, suggesting that another factor is responsible for the low pH of SC3.

The average pH of the sampling stations ranged from 7.6 to 8.6. All of these values fall within the "excellent" range of the Environmental Water Quality Index based on pH (Battelle 1972; Figure 9). A departure ±1 from the normal pH is considered insignificant to aquatic macroinvertebrates (Lehmkuhl 1979).

5.1.3 Dissolved Oxygen (DO). Due to mechanical problems with a YSI model 57 DO meter, DO measurements were only taken for four months. BRET has purchased a new DO meter to ensure the accuracy of future studies. The highest average DO readings (6.2 mg/l) occurred at SC4 and SC5, while the lowest (4.5 mg/l) occurred at SC3. Figure 10 shows the monthly DO concentrations (in mg/l) taken from the five sample stations.

Figure 11 shows the percent of DO saturation in water samples taken at the stations in Sandia Canyon during 1993. DO concentrations and percent saturation were usually highest at the two downstream stations: SC4 and SC5. A functional curve relating the percent of DO saturation to an Environmental Quality Index is shown in Figure 12 (Battelle 1972). Based on the average percent of DO saturation, SC4 and SC5 are within the "excellent" range while SC1, SC2, and SC3 are in the lower portion of the "good" range.

5.1.4 Conductivity and Total Dissolved Solids (TDS). Monthly conductivity readings in µmhos/cm are shown in Figure 13. The highest readings were recorded at SC1 in May (1872 µmhos/cm) and October (1683 µmhos/cm). This elevation in conductivity can

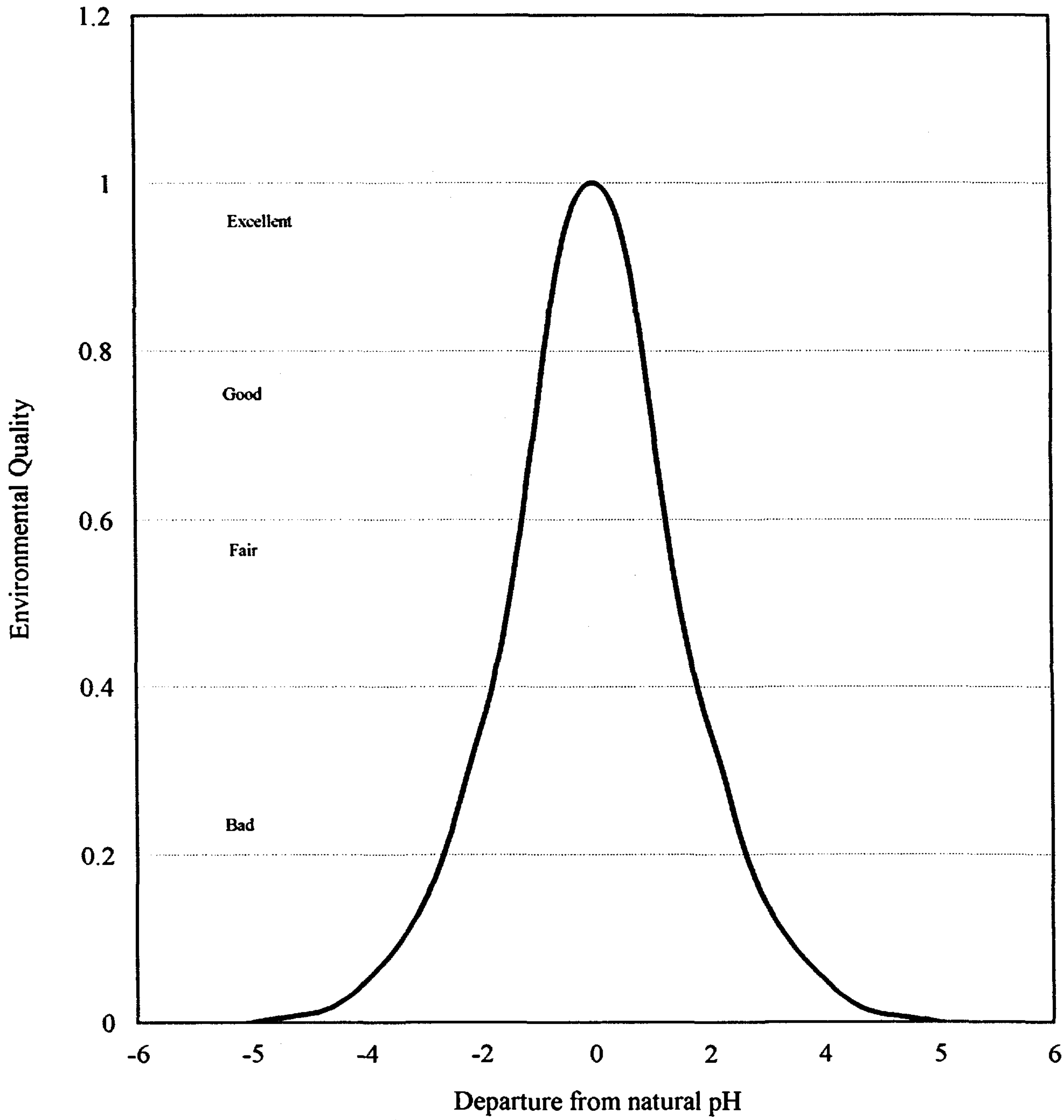
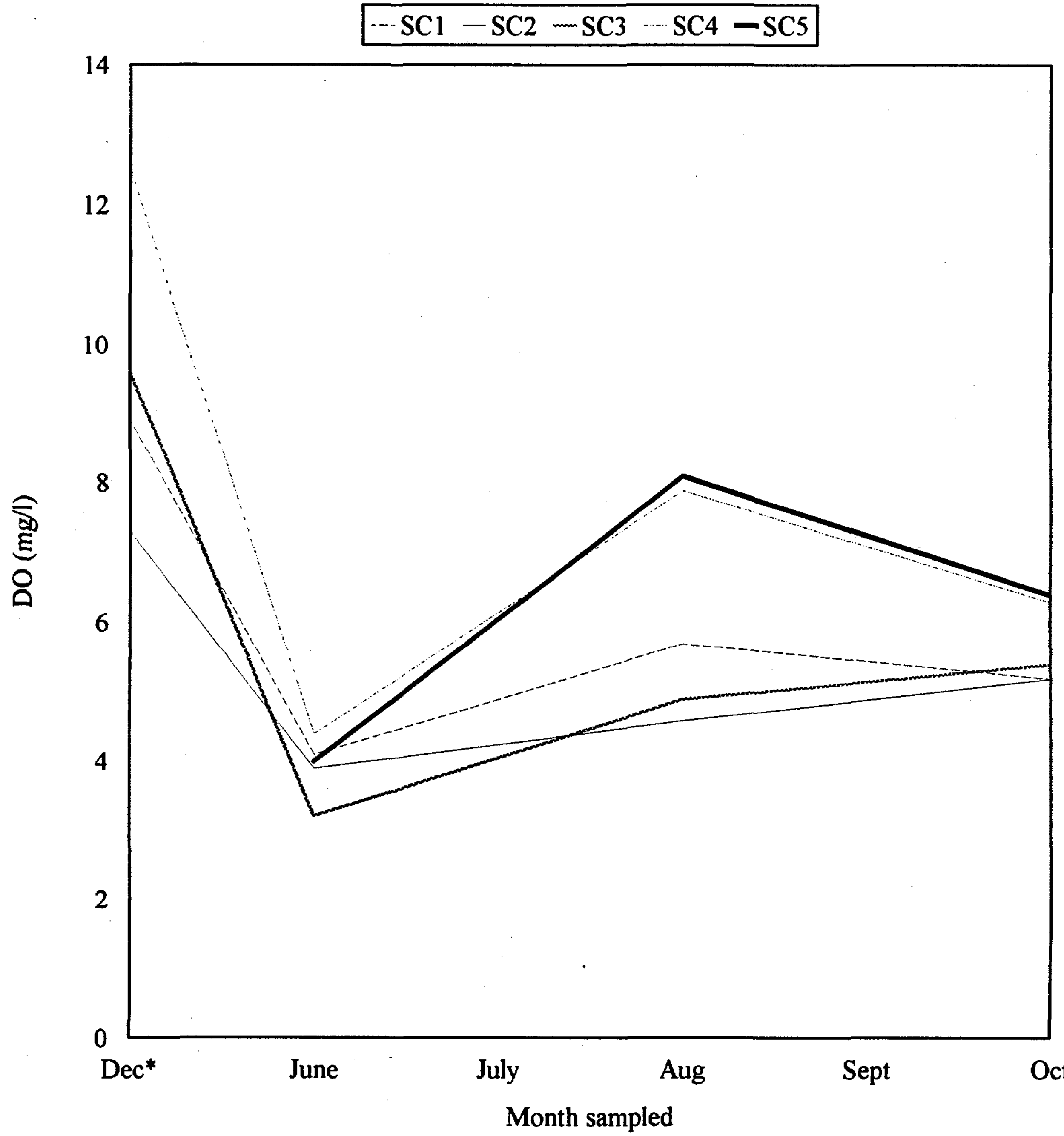
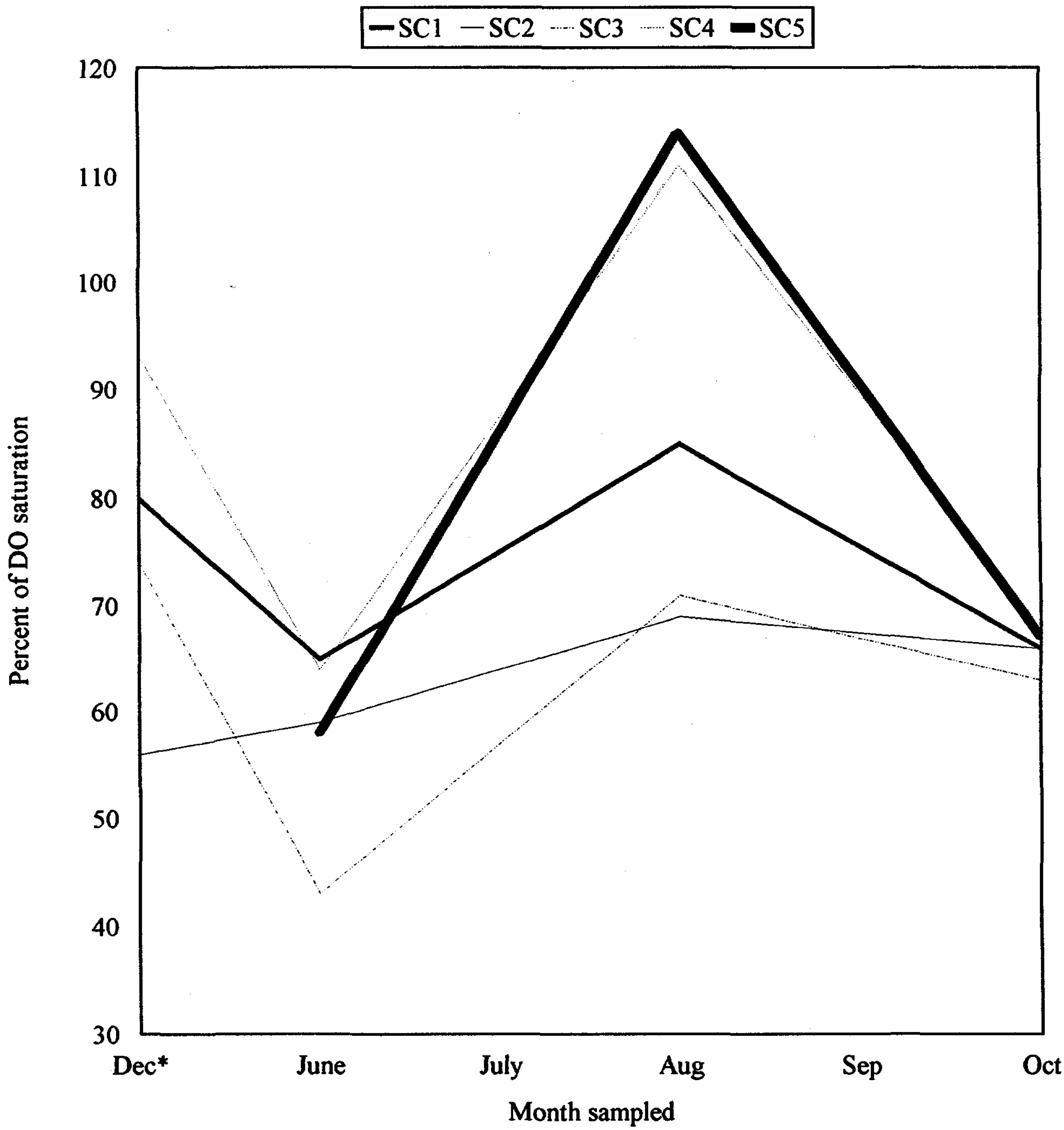


Fig. 9. Departure from natural pH versus an Environmental Quality Index (Battelle, 1972).



* No data available for January - May

Fig. 10. Average DO (mg/l) for Sandia Canyon (December 1992 - October 1993).



* Data unavailable for January 1992 - May 1993

Fig. 11. Percent of DO saturation for Sandia Canyon (December 1992 - October 1993).

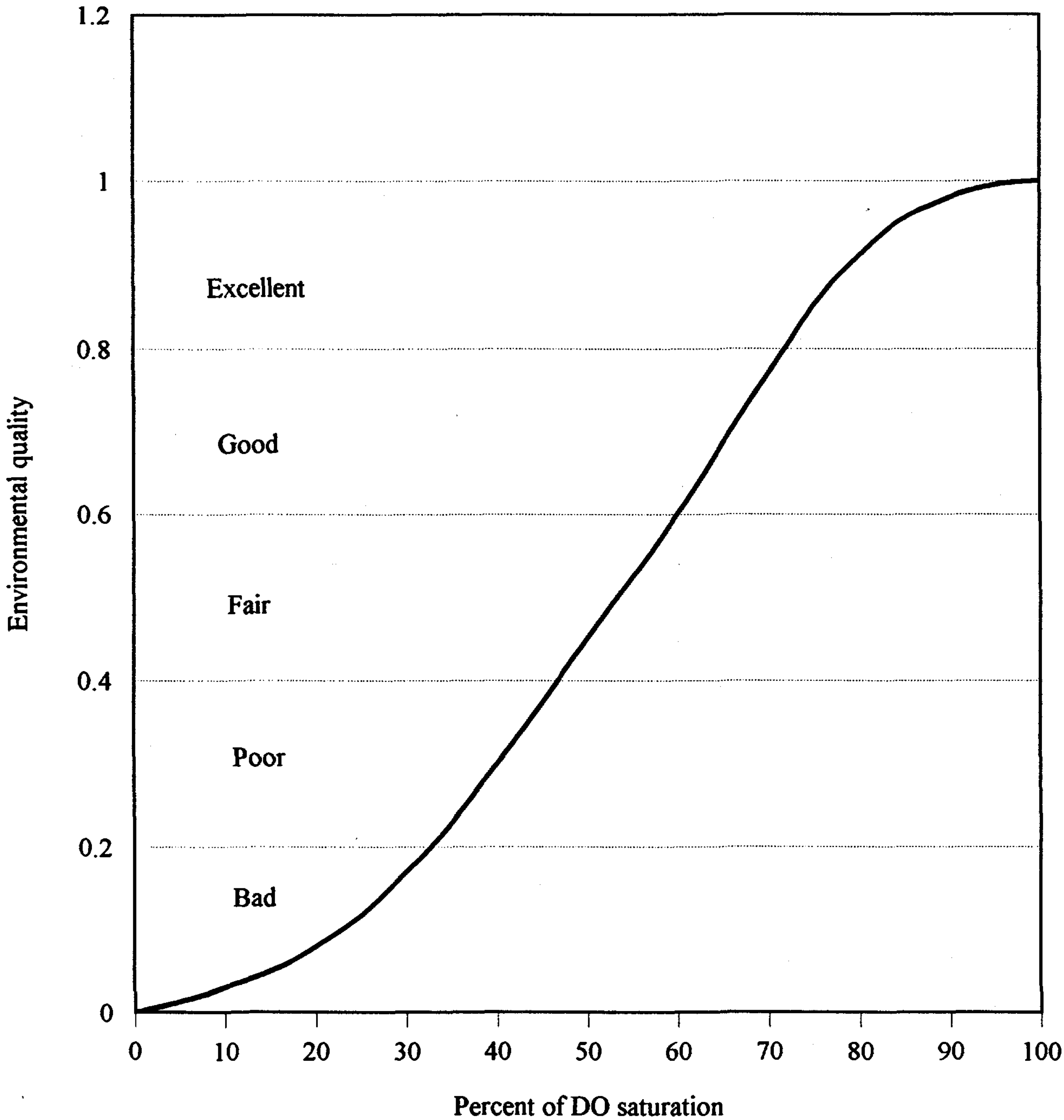


Fig. 12. Percent of DO saturation versus an Environmental Quality Index (Battelle, 1972).

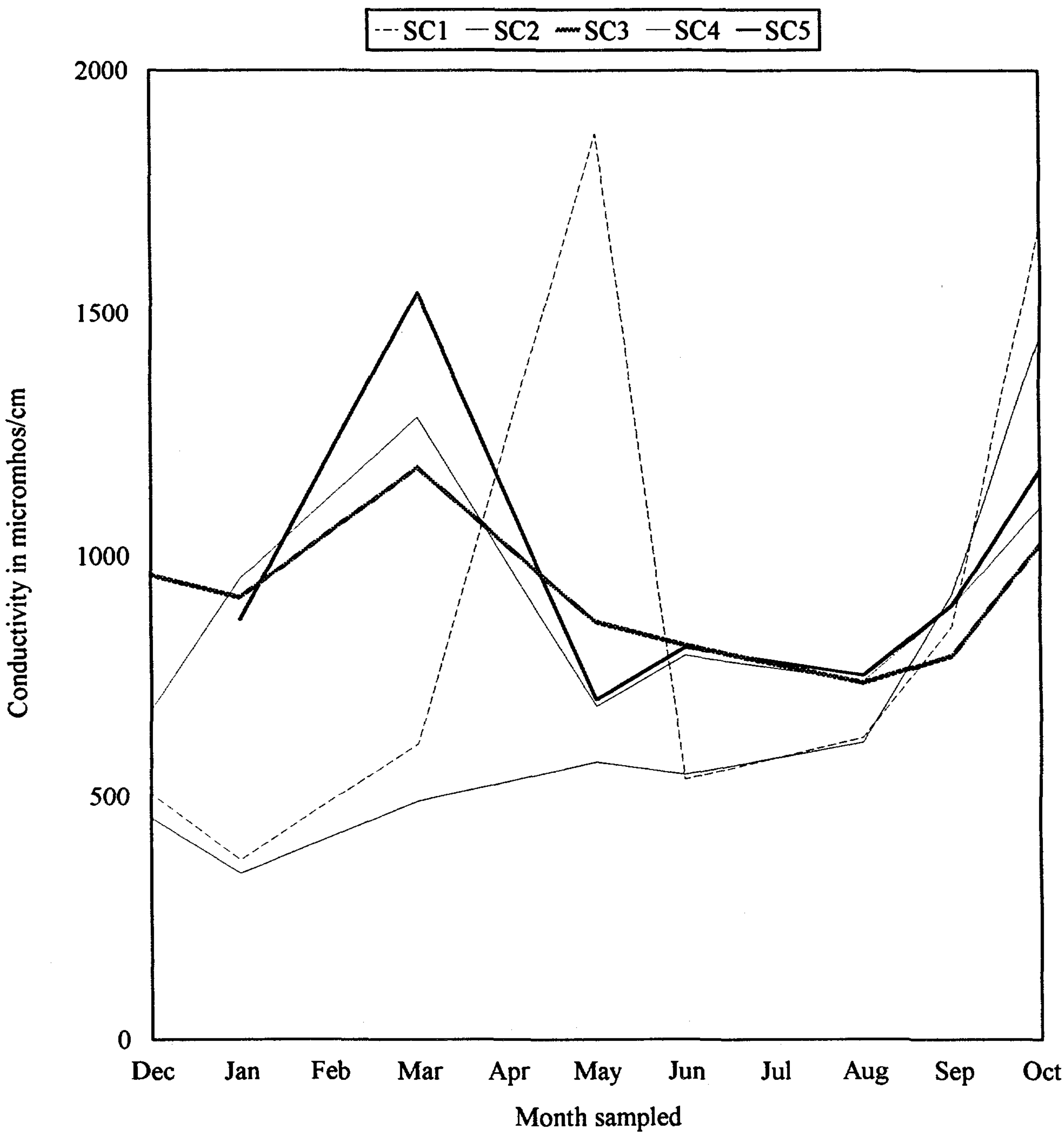


Fig. 13. Average conductivity for Sandia Canyon (December 1992 - November 1993).

probably be attributed to an influx of ions from parking lot runoff, following heavy rains. SC5 had the highest average conductivity (963 μmhos/cm) and SC2 had the lowest (704 μ mhos/cm).

A rough approximation of milligrams of TDS per liter of freshwater can be obtained by multiplying the conductivity by 0.66. Figure 14 illustrates estimated monthly TDS concentrations from the five stations. For each sample taken, the TDS concentrations of all stations fall within the "excellent" range of the Environmental Quality Index developed by Battelle (1972; Figure 15). The highest TDS concentration (1236 mg/l) occurred at SC1 in May. Aquatic organisms can generally tolerate TDS concentrations as high as 5000 mg/l, a concentration much higher than any found at the sampling stations.

5.2 Aquatic Macroinvertebrate Sampling

Table I lists the 36 taxa of aquatic macroinvertebrates found in upper Sandia Canyon and the sampling stations where they occurred. A total of 3030 macroinvertebrates were collected, identified, and analyzed from December 1992 to October 1993. The number of taxa found at each station is shown in Figure 16.

The data shows a significant increase in taxa downstream. The upper three sampling stations (SC1, SC2, and SC3) had a combined average of 32% of all taxa collected. The lower two sampling stations (SC4 and SC5) had a combined average of 55% of all taxa collected. This trend is probably partially due to the effects of upstream effluent discharges, but the nature of the substrate is also important. The substrate of the three upper stations is primarily sand and silt which prohibit some species from colonizing these areas. The substrate of the two lower stations contains large stones and bedrock which favor diversity.

In general, larvae in the orders Plectoptera, Ephemeroptera, Trichoptera, and Odonata are intolerant of degraded waters, and their presence is an indication of good water quality (Gaufin and Tarzwell 1956; Weber 1973). These gilled macroinvertebrates

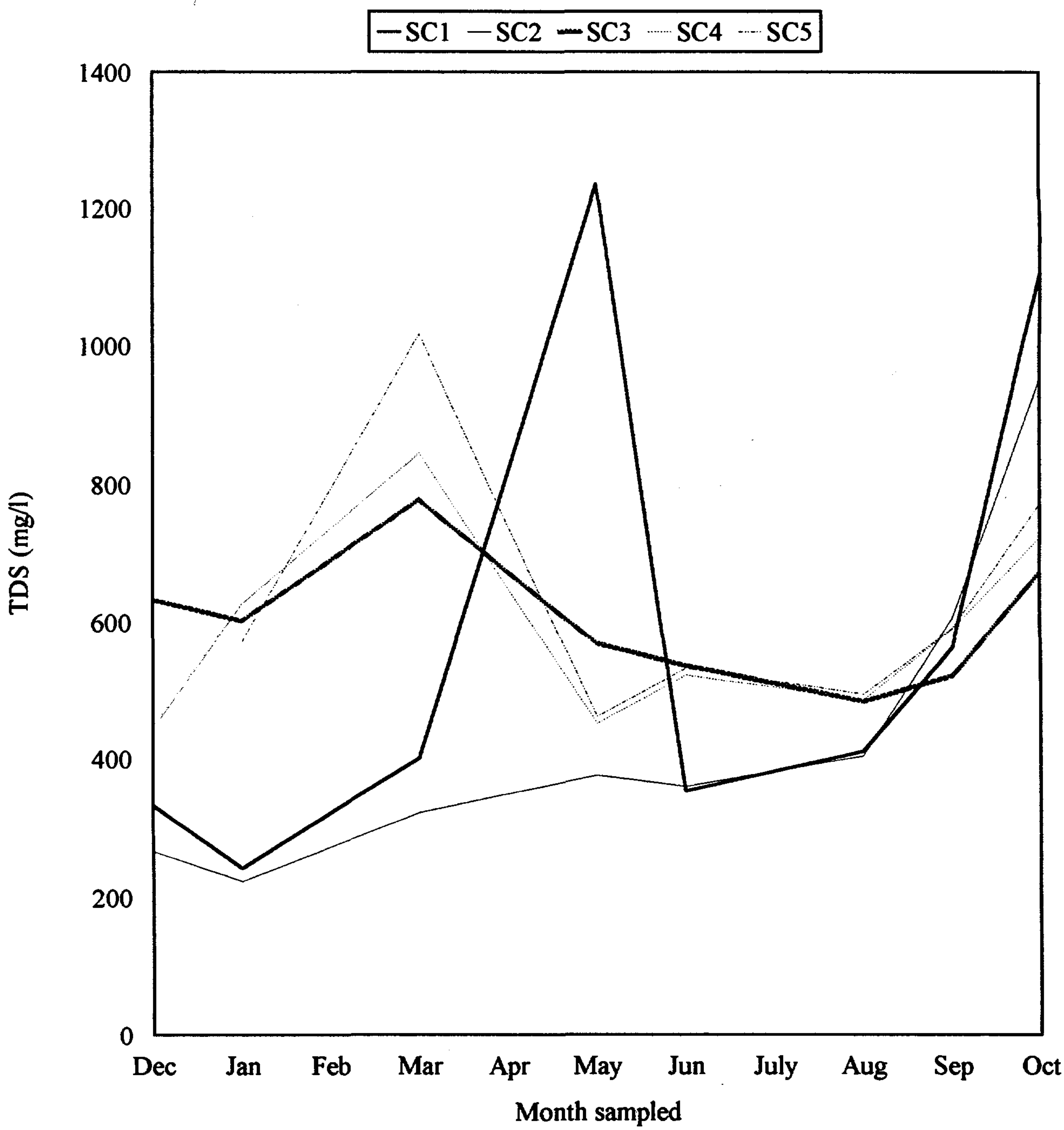


Fig. 14. Average TDS (mg/l) for Sandia Canyon (December 1992 - October 1993).

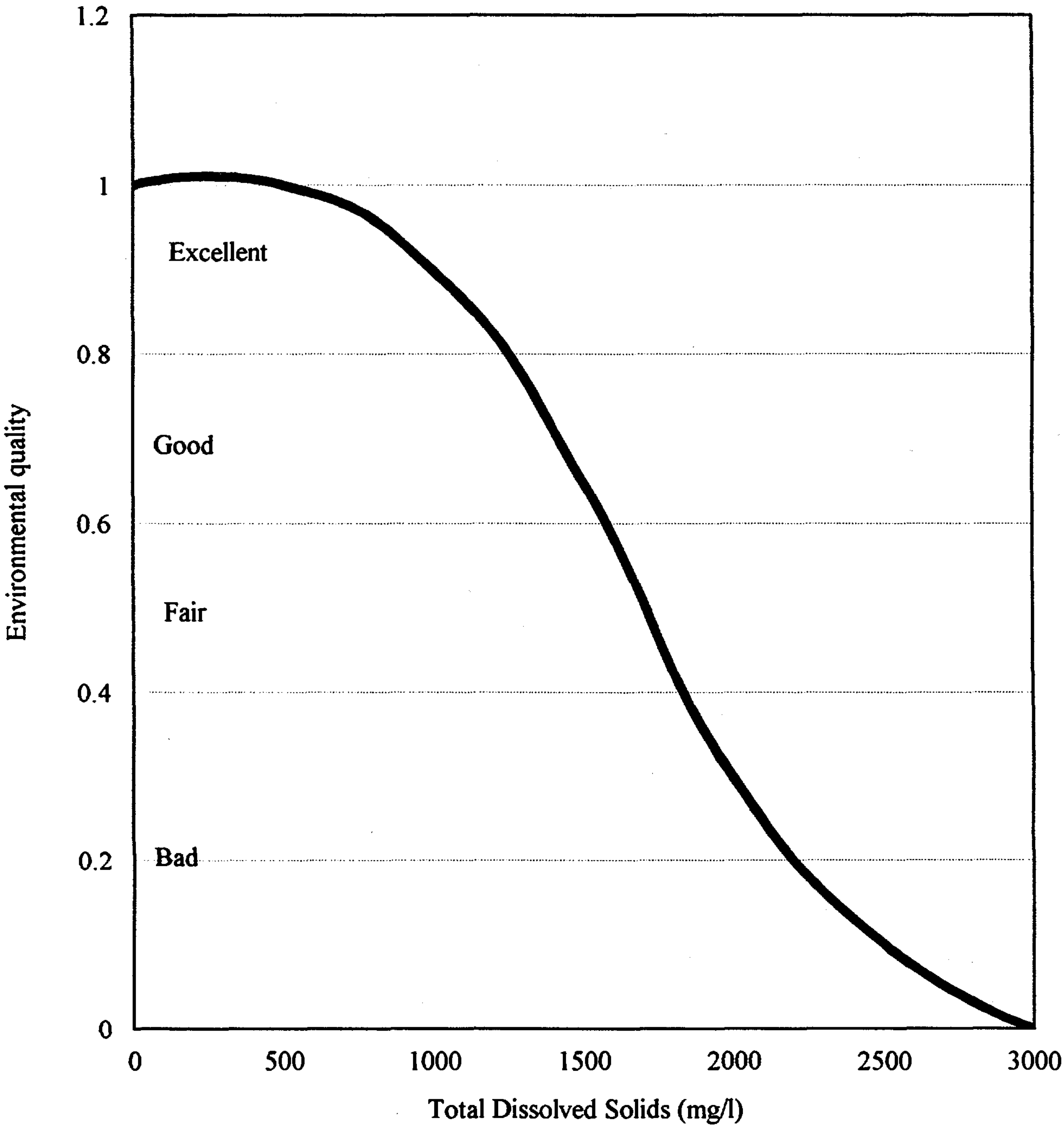


Fig. 15. TDS (mg/l) versus an Environmental Quality Index (Battelle, 1972).

Table I. Macroinvertebrate Taxa Found in Upper Sandia Canyon (December 1992 – October 1993)

Insects (all specimens are larvae unless otherwise noted):

Order	Family	Genus	Sampling Station
Plecoptera (stoneflies)	Perlodidae	Isoperla	5
Ephemeroptera (mayflies)	Baetidae	Baetis	1, 2, 3, 4, 5
	Baetidae	Callibaetis	3, 4, 5
	Siphlonuridae	Ameletus	3
	Tricorythidae	Tricorythodes (minutus)	3, 4, 5
Odonata (dragonflies and damselflies)	Aeshnidae	Anax	1
	Coenagriidae	Argia	5
	Gomphidae		5
	Lestidae	Lestes	2, 4
Hemiptera (true bugs)	Gerridae adult	Gerris	3, 4
Trichoptera (caddis flies)	Hydropsychidae	Hydropsyche	5
	Lepidostomatidae	Lepidostoma	4, 5
	Limnephilidae	Hesperophylax	4, 5
	Limnephilidae	Limnephilus	4
Coleoptera (beetles)	Curculionidae	Phytonomus	3
	Dryopidae adult	Helichus	5
	Dytiscidae	Dytiscus	4, 5
	Dytiscidae adult		2, 3, 4
	Elmidae		1, 5
	Haliplidae	Peltodytes	4
Diptera (flies)	Chironomidae	(bagworms)	3
	Chironomidae	(blackheads)	1, 3, 4, 5
	Chironomidae	(regulars)	1, 2, 3, 4, 5
	Chironomidae	(smallheads)	1, 3, 4
	Chironomidae	(striates)	1, 3, 4
	Simulidae		4
	Stratiomyidae		4
	Tipulidae	Tipula	3

Table I. (continued)

Non-insects:

Phylum	**Class**	**Order**	**Family**	**Sampling Station**
Nematoda				3
Annelida	Oligochaeta	regulars		3, 4, 5
	Oligochaeta	coil worms		1, 2, 3, 5
Arthropoda	Crustacea	Copepoda		4
	Crustacea	Ostracoda	Candoniidae	2, 3, 4, 5
	Crustacea	Ostracoda	Cyprididae	1, 2, 3, 4, 5
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	4, 5

are sensitive to depressed oxygen environments and environmental pollutants. Figure 17 illustrates the percentage of individuals from these orders found at each station. Much higher percentages of intolerant species occur downstream. SC1 has the lowest percentage (6.6) and SC5 has the highest (51.2).

A natural aquatic ecosystem has a balanced community occupying all available microhabitats and utilizing a variety of food resources. Table II lists the habit, or mode of existence, for most of the aquatic insects collected in this study (taxonomic difficulties prohibited a more thorough breakdown of the dipteran family Chironomidae). All stations contained representative swimmers and burrowers. In contrast, very few clingers, sprawlers, or climbers were found at the upper stations in comparison with the lower stations. Once again, this lack of diversity may be a result of the silty and sandy substrate upstream.

Aquatic insects base their selection of food particles more on particle size than origin. Thus, the familiar trophic (feeding) categories of herbivore, carnivore, and omnivore have little application to aquatic macroinvertebrates. To more accurately describe the trophic relations of aquatic insects, a series of functional feeding groups or trophic categories has been developed (Merritt and Cummins 1984). These categories (Table III) are determined by feeding mechanism more than food origin.

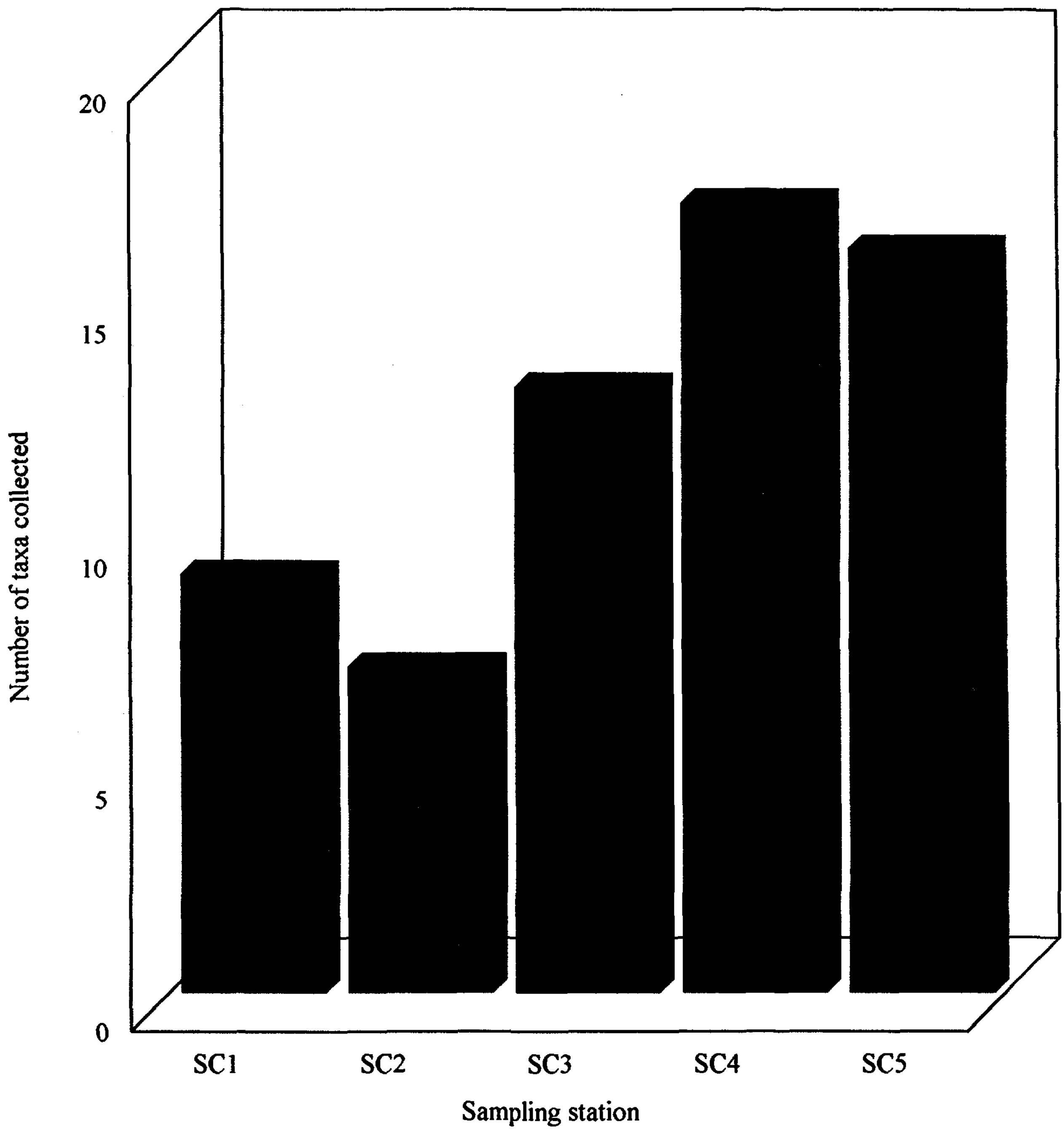


Fig. 16. Number of taxa collected in Sandia Canyon (December 1992 - October 1993).

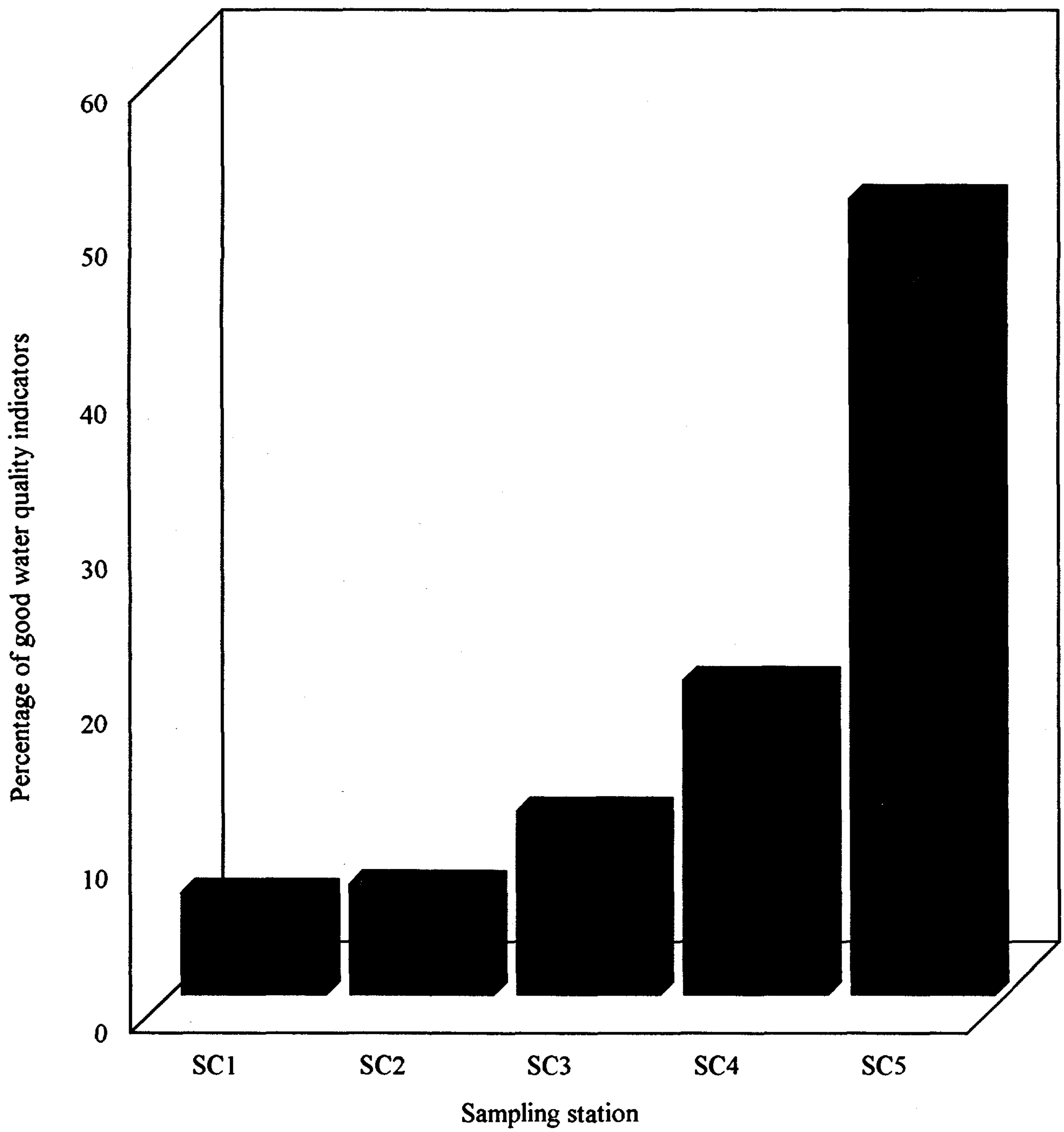


Fig. 17. Percentage of good water quality indicators in Sandia Canyon (December 1992 - October 1993).

Table II. Mode of Existence of Collected Sandia Canyon Aquatic Insects
(adapted from *An Introduction to the Aquatic Insects*, Merritt and Cummins, 1984)

Order	Family	Genus	Mode of Existence
Plecoptera (stoneflies)	Perlodidae	Isoperla	cg-sp
Ephemeroptera (mayflies)	Baetidae	Baetis	sw, cb, cg
	Baetidae	Callibaetis	sw, cb
	Siphlonuridae	Ameletus	sw, cb
	Tricorythidae	Tricorythodes	sp, cg
Odonata (dragonflies and damselflies)	Aeshnidae	Anax	cb
	Coenagriidae	Argia	cg, cb-sp
	Gomphidae		bu
	Lestidae	Lestes	cb, sw
Hemiptera (true bugs)	Gerridae adult	Gerris	sk
Trichoptera (caddis flies)	Hydropsychidae	Hydropsyche	cg
	Lepidostomatidae	Lepidostoma	cb-sp-cg
	Limnephilidae	Hesperophylax	sp
	Limnephilidae	Limnephilus	cb, sp, cg
Coleoptera (beetles)	Dryopidae	Helichus adult	cg, cb
	Dytiscidae	Dytiscus	sw
	Dytiscidae adult		cb, sw
	Elmidae		cg
	Haliplidae	Peltodytes	cb, cg
Diptera (flies)	Chironomidae	(blackheads)	bu?
	Chironomidae	(regulars)	bu?
	Chironomidae	(smallheads)	bu?
	Chironomidae	(striates)	bu?
	Simulidae		cg
	Stratiomyidae		cb, sp
	Tipulidae	Tipula	bu

Abbreviations used in table:

cb = climber — cg = clinger
bu = burrower — sk = skater
sp = sprawler — sw = swimmer

Table III. Chief Functional Feeding Groups of Aquatic Insects

Functional Group	Dominant Food
Collectors	Fine particulate organic matter
Shredders	Coarse particulate organic matter
Scrapers	Attached algae and associated material
Predators	Engulfers or piercers feeding on living animal tissue

A natural ecosystem usually contains varied representatives of the primary functional feeding groups. Table IV lists the functional feeding group for most of the insects collected during this study. Upper Sandia Canyon does not support a large algal population, and scrapers were therefore not abundant at any sampling station. Collectors were found at all stations, but the other functional feeding groups were poorly represented at the upstream sampling sites (SC1, SC2, and SC3). These sites yielded no shredders, while three shredder species were collected at each of the lower stations (SC4 and SC5). Large numbers of predators were not found at any station, but the lower sites contained the most species and the largest numbers of predators.

Wilhm's biodiversity indices (1967) were calculated from the total numbers of individuals and taxa collected at each of the sample stations from December 1992 to October 1993 (Figure 18). The upper three stations had an average taxa diversity index of 0.99 (1.06 if the unusually large October sample for SC3 is discarded). The lower two stations had an average taxa diversity index of 2.04. Small high-elevation streams tend to have low taxa diversity overall (Hilsenhoff 1977), and the differences recorded between stations appear to be significant.

6 CONCLUSIONS

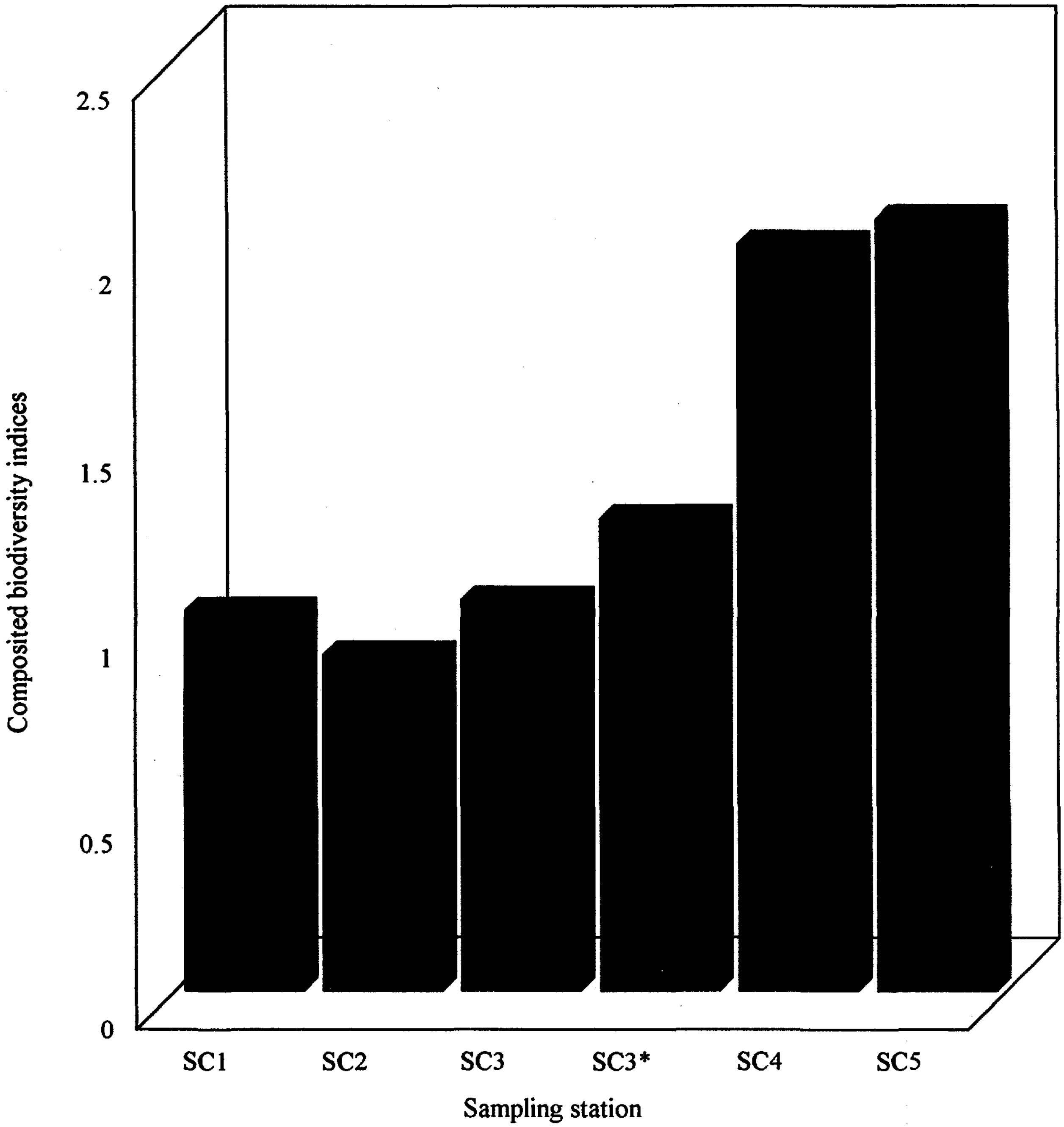
Averaged water quality measurements of temperature, pH, percent of DO saturation, and TDS are within acceptable ranges for all stations. However, the upstream stations have greater monthly variances than the downstream stations. These fluctuations

Table IV. Functional Feeding Groups of Collected Sandia Canyon Aquatic Insects
(adapted from *An Introduction to the Aquatic Insects*, Merritt and Cummins, 1984)

Order	**Family**	**Genus**	**Functional Feeding Group**
Plecoptera (stoneflies)	Perlodidae	Isoperla	pr
Ephemeroptera (mayflies)	Baetidae	Baetis	cg, sc
	Baetidae	Callibaetis	cg
	Siphlonuridae	Ameletus	sc, pr
	Tricorythidae	Tricorythodes	cg
Odonata (dragonflies and damselflies)	Aeshnidae	Anax	pr
	Coenagriidae	Argia	pr
	Gomphidae		pr
	Lestidae	Lestes	pr
Hemiptera (true bugs)	Gerridae adult	Gerris	pr
Trichoptera (caddis flies)	Hydropsychidae	Hydropsyche	cf
	Lepidostomatidae	Lepidostoma	sh
	Limnephilidae	Hesperophylax	sh
	Limnephilidae	Limnephilus	sh
Coleoptera (beetles)	Dryopidae	adult	pr
	Dytiscidae	Dytiscus	pr
	Dytiscidae adult		pr
	Elmidae		cg, sc
	Haliplidae	Peltodytes	pi, sh
Diptera (flies)	Chironomidae	(blackheads)	probably cg
	Chironomidae	(regulars)	probably cg
	Chironomidae	(smallheads)	probably cg
	Chironomidae	(striates)	probably cg
	Simulidae		cf
	Stratiomyidae		cg
	Tipulidae	Tipula	sh, cg

Abbreviations used in table:

cf = collector filterers
cg = collector gatherers
pi = piercers
pr = predators
sc = scrapers
sh = shredders



* Calculated excluding October sample

Fig. 18. Biodiversity indices for Sandia Canyon sampling stations (December 1992 - October 1993).

may partially explain observed differences in the aquatic macroinvertebrate communities.

In comparison with the two downstream stations (SC4 and SC5), the three upstream stations have a reduced number of macroinvertebrate taxa, lower percentage of good water quality indicators, and lower biodiversity. The upstream communities are also less complex when analyzed by resident organism habits and functional feeding groups.

Station SC1 receives effluents directly from several industrial waste water outfalls, which exert a strong influence on stream conditions, especially following accidental spills. The fact that pH and temperature at SC1 are slightly higher than expected in natural waters of the area is also attributable to the effluents from these outfalls. The aquatic community here is affected greatly by fluctuations in water flow, which periodically scours the substrate. Aquatic macroinvertebrate recolonization is limited due to the lack of a natural upstream area. In addition, SC1 has a substrate of sand and silt which discourages clinging and climbing macroinvertebrate colonization. In terms of insect taxa, this station has the lowest percentage of good water quality indicators (6.6). Four of its six aquatic insects taxa are in the Chironomidae, a pollution-resistant dipteran family which can tolerate low oxygen levels.

Station SC2 receives a large input of effluents from the sewage treatment plant, which is probably responsible for this station's low DO levels. Although SC2 is only 14 meters (45 ft) downstream, the pH and temperature readings there are closer to those of natural streams than those at SC1. The substrate at SC2 is more varied than at SC1; it contains gravel as well as sand and silt. This station contains the lowest number of taxa of any sampling station and the macroinvertebrate community is not very complex.

Station SC3 is intermediate in TDS between the two upstream stations receiving effluent and the two downstream stations in a more natural setting. The cattail marsh above SC3 apparently exerts a moderating influence, and the biological community is more complex than at the upstream sites. Although the substrate is largely sand and silt, the greatest number of individual macroinvertebrates was collected here, and 43% of all macroinvertebrate taxa collected were found at SC3. Perhaps due to upstream vegetative decomposition and settling which occur in the pond at SC3, the average pH (7.6) and average percent of DO saturation (63%) were very low.

Station SC4 had the lowest average water temperature (12.1°C) and the highest oxygen saturation (84%). Here, and at SC5, the rocky substrate permits the establishment of clinging and climbing taxa. SC4 contained the highest number of macroinvertebrate taxa (17). The macroinvertebrate community here is diverse, with many habits and functional feeding groups represented.

Station SC5 was similar to SC4 in all water quality measurements. The percentage of good water quality species (51.2) here was more than twice as great as at the next highest station (SC4 with 20.2%). In terms of macroinvertebrate habits, SC5 had the most complex aquatic insect community, with two swimming, two burrowing, five clinging, two climbing, and one sprawling taxa.

This continuing study has greatly broadened our knowledge of the physical and chemical conditions present in upper Sandia Canyon and their impact on the aquatic communities there. The three upstream sampling stations have depauperate communities due to a combination of pollutant discharges, widely fluctuating water and temperature levels, restricted colonization, and a substrate of scoured sand and silt. In contrast, the downstream two sampling stations have increased biodiversity and more complex community structure. These downstream communities and taxa closely resemble those of natural streams in the area, suggesting that any impacts due to upstream effluent discharges are mitigated by the intervening cattail marsh.

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REFERENCES

Anderson, N. H., and Wallace, J. B., "Habitat, Life History, and Behavioral Adaptations of Aquatic Insects, " pp. 38-58 in *An Introduction to the Aquatic Insects of North America*, second edition, edited by R. W. Merritt and K. W. Cummins, Kendall/Hunt Publishing Company, Dubuque, Iowa (1984).

Battelle, Columbus Laboratories, "Environmental Evaluation System for Water Resources Planning" Bureau of Reclamation, U.S. Department of Interior, Contract Number 14-06-D-1782, Columbus Ohio (1972).

Bell, Henry, "Effect of Low pH on the Survival and Emergence of Aquatic Insects" in *Water Research*, Vol. 5, pp. 313-319, Pergamon Press (1971).

Bennett, Kathryn, "Aquatic Macroinvertebrates and Water Quality Monitoring of Sandia Canyon," Los Alamos National Laboratory report, LA-12738 (1994).

Bowen, B.M., "Los Alamos Climatology," Los Alamos National Laboratory report, LA-11735-MS (1990).

Canter, L.W., and Hill, L.G., *Handbook of Variables for Environmental Impact Assessment*, Ann Arbor Science Publishers, Inc., Michigan (1979).

Cowardin, L.M., Carter, V., Glet, F.C., and E.T. LaRoe, *Classification of Wetlands and Deep Water Habitats of the United States*, U.S. Fish and Wildlife Service, Washington, D.C., Publication No. FWS/OBS-79/31 (1979).

Cummins, Kenneth W. and Merritt, Richard W., "Ecology and Distribution of Aquatic Insects," pp. 59-65 in *An Introduction to the Aquatic Insects of North America*, second edition, edited by R. W. Merritt and K. W. Cummins, Kendall/Hunt Publishing Company, Dubuque, Iowa (1984).

Eriksen, Clyde, Vincent H. Resh, Steven S. Bailing, and Gary A. Lamberti, "Aquatic Insect Respiration," pp. 27-37 in *An Introduction to the Aquatic Insects of North*

America, second edition, edited by R. W. Merritt and K. W. Cummins, Kendall/Hunt Publishing Company, Dubuque, Iowa (1984).

Gaufin, A.R., Clubb, Robert, and Newell, Robert, "Studies on the Tolerance of Aquatic Insects to Low Oxygen Concentrations," *Great Basin Naturalist*, Vol. 34, No. 1, pp. 45-59 (1974).

Gaufin, A.R. and Tarzwell, C.M., "Aquatic Macro-Invertebrate Communities as Indicators of Organic Pollution in Lytle Creek," *Sewage and Industrial Waste*, Vol. 28, No. 7, pp. 906-924 (1956).

Hilsenhoff, William, "The Use of Arthropods to Evaluate Water Quality of Streams," Technical Bulletin No. 100, Department of Natural Resources, Madison, Wisconsin 53707 (1977).

LANL, *Environmental Surveillance at Los Alamos During 1988*, Los Alamos National Laboratory report, LA-11628-MS (1988).

LANL, *Environmental Surveillance at Los Alamos During 1989*, Los Alamos National Laboratory report, LA-12000-ENV (1990).

Lehmkuhl, D. M., "Environmental Disturbance and Life Histories: Principles and Examples," *Journal of the Fisheries Research Board of Canada*, Vol. 36, pp. 329-334 (1979).

McCafferty, W. Patrick, *Aquatic Entomology*, Jones and Bartlett Puslishers, Inc., Boston, Mass. (1981).

Merritt, R. W. and Cummins, K. W., Eds., *An Introduction to the Aquatic Insects of North America*, second edition, Kendall/Hunt Publishing Company, Dubuque, Iowa (1984).

Nebeker, A.V., "Effect of Low Oxygen Concentration on Survival and Emergence of Aquatic Insects." *Trans. Amer. Fish Soc.*, No. 4, pp. 675-679 (1972).

Pennak, R.W., *Fresh-Water Invertebrates of the United States*, second ed., John Wiley & Sons, New York, New York (1978).

Schwenneker, Bruce W. and Ronald A. Hellenthal, "Sampling Considerations in Using Stream Insects for Monitoring Water Quality," *Environmental Entomology*, Vol. 13, No. 3 (1984).

Weber, C.I., "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents," National Environmental Research Center, Cincinnati, Ohio, PB-227-183, pp. 70-109 (1973).

Wilhm, J.L., "Comparison of Some Diversity Indices Applied to Populations of Benthic Macroinvertebrate in a Stream Receiving Organic Waste," *Journal WPCF* Vol. 39, No. 10, Part 1, pp. 1673-1683 (1967).