ECOLOGICAL SURVEY OF ABRAMS CREEK IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

RESEARCH/RESOURCES MANAGEMENT REPORT No. 28

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
SOUTHEAST REGION

UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS NATIONAL PARK
TWIN CREEKS AREA
GATLINBURG, TENNESSEE 37738

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Research/Resources Management Report No. 28

October 1978

Raymond C. Mathews, Jr.
U.S. Department of the Interior
National Park Service
Southeast Region
Uplands Field Research Laboratory
Great Smoky Mountains National Park
Twin Creeks Area
Gatlinburg, Tennessee 37738

Mathews, Raymond C., Jr. 1978. Ecological Survey of Abrams Creek in the Great Smoky Mountains National Park. U.S. Department of the Interior, National Park Service, NPS-SER Research/Resources Management Report No. 28. 195 pp.

ABSTRACT

Abrams Creek represents a unique resources management problem within Great Smoky Mountains National Park. Because of the management program in Cades Cove and past land practices, the quality of water in Abrams Creek has existed in a degraded state for many years. The National Park Service developed a land management program in 1967 designed to maintain the historic integrity of Cades Cove. The open aspect of the farm fields and meadows in Cades Cove were to be preserved as a background for interpreting the historic structures and features of the pioneer culture as it existed when the park was established. To maintain the fields in an efficient manner, the park allowed leasees to harvest hay and graze cattle under special use permits. This program is still used at the present time but is currently being reconsidered by park management due to the impacts of cattle and hay harvesting on the Abrams Creek drainage.

Cattle grazing in Cades Cove has increased streambank erosion, siltation, nutrient enrichment, temperature regimes, eutrophication, and productivity in Abrams Creek. This study investigated the water quality of Abrams Creek using chemical - physical parameters, benthic macroinvertebrate community structure analyses, fish population surveys, periphytic diatom indicators, and enteric

bacterial contamination analyses. These analyses showed that Abrams Creek improved ecologically since the reduction of the Cades Cove cattle herd from 1,200 to 500 head and a fencing program that excludes cattle from all but a few select watering and wading sites on Abrams Creek and its tributaries. A program to reduce streambank erosion by planting seedlings was not successful due to heavy deer browsing and hoof damage by cattle. Nevertheless, the water quality of Abrams Creek is probably better than it has been for many years. Yet, there is room for more improvement while still maintaining the historical features of the Cove.

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ACKNOWLEDGEMENTS

I wish to thank all those persons who assisted in this project. Several agencies and universities were involved in the program: Great Smoky Mountains National Park, U.S. Fish and Wildlife Service, Tennessee Wildlife Resources Agency, Tennessee Water Quality Control, Tennessee Valley Authority, Tennessee Technological University, and the University of Tennessee.

Special thanks are due to Jackie Klausmeyer, who assisted with field collections and laboratory analysis throughout the survey. Wayne Williams was instrumental in setting up a water quality laboratory and offering advice on chemical - physical procedures. Lynda Powell and David Rector spent many hours picking and sorting benthic organisms and assisted in field collections.

Allan Kelly and Pete Crittenden helped with field work, provided much-needed equipment, and offered helpful advice. David Etnier, Bruce Bauer, Bill Wolfe, and Noel Burkhead helped with identification of fish and benthic macroinvertebrates. Parley Winger offered helpful advice and lent equipment for field collections. Bill Winn, Eric Morgan, and Jim Jardosky provided assistance with computer application of the benthos program. Kathy Cheap, Dick Bryant, Maryanne Merritt, Eric Grigsley, Bill Dickenson, David Silsbee, Gary Larson, Polly Rooker, John Harris, Bruce Bauer, Douglas Peterson, Susan Bratton, and others helped with the fish electroshocking survey.

Raymond Herrmann and Susan Bratton provided logistical support and advice throughout the project. Susan Bratton identified the need for an intensive ecological survey of Abrams Creek. Ray Burge provided technical support to the satellite telemetry program under the direction of Raymond Herrmann.

Mike Meyers and Frank Claibo, who have been responsible for resource management in Cades Cove, helped relate to the many aspects of management of the Cove. Rex Caughron, who owns the cattle in Cades Cove, identified many aspects of cattle management there despite the effect this report might have on his livelihood.

Special thanks to the entire Uplands Laboratory staff, who reviewed the manuscript and gave many helpful suggestions.

Finally, I would like to express my appreciation to my wife, Theresa, who helped with initial field collections as well as picking and sorting benthic macroinvertebrates and gave support and encouragement throughout the survey.

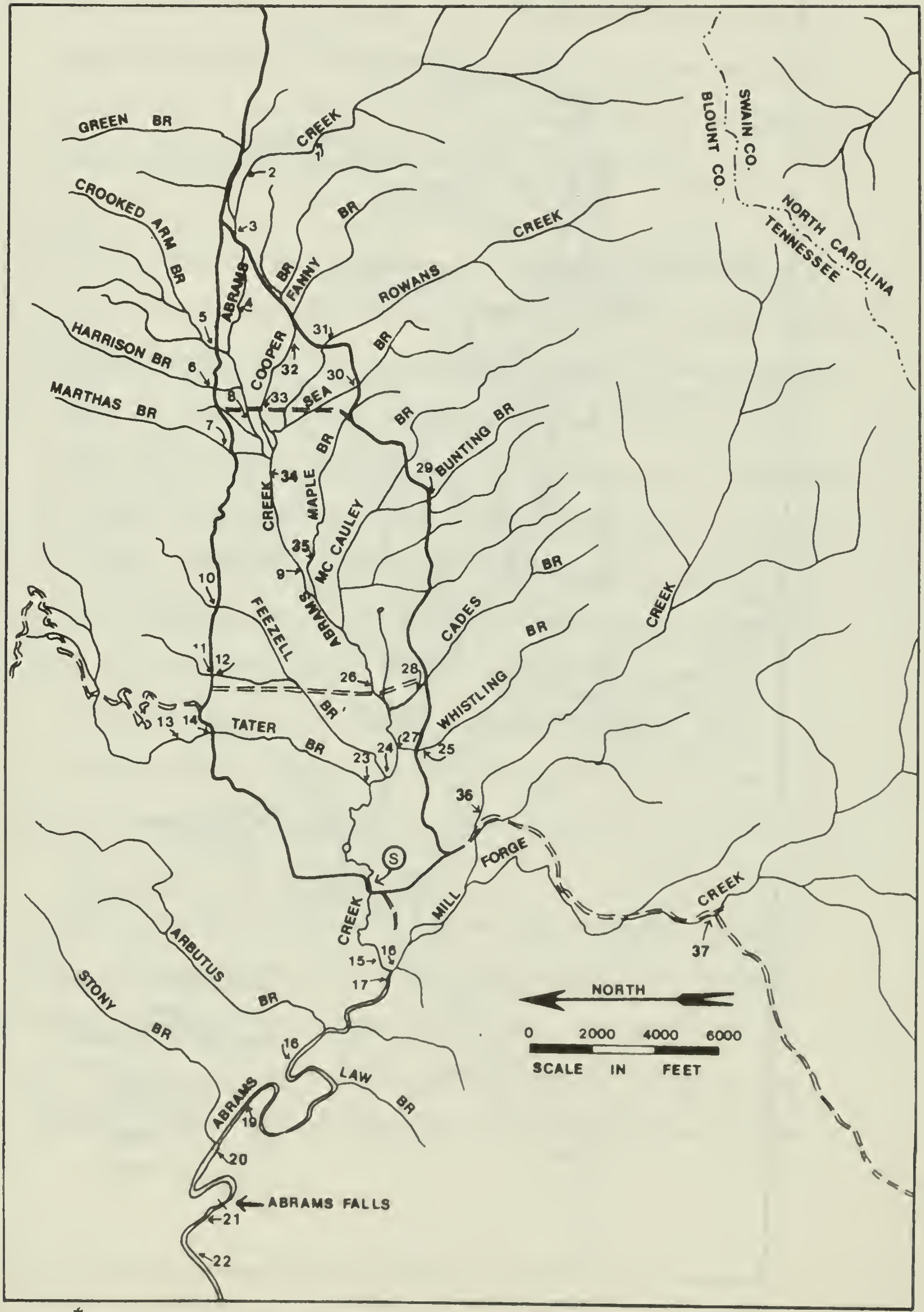
INTRODUCTION

Abrams Creek is located in the western portion of the Great Smoky Mountains National Park (Fig. 1). The creek flows in a westerly direction, passing through Cades Cove before draining into Chilhowee Lake on the border of the park (Fig. 2). The stream flows for about six miles in the Cove (Fig. 3), passing through pasture areas and dropping approximately 250 feet in elevation.

Cades Cove is a historical pastoral area of about 1,800 acres in the Great Smoky Mountains National Park. Before the Cove was opened to settlement, it was part of the Cherokee Indian Nation and remained undeveloped. Dense forest probably prevented or slowed the meandering rate of Abrams Creek through the Cove. The Cove was homesteaded in 1821 by pioneers attracted to the area because, unlike most of the land in the Smoky Mountains, it was flat and relatively fertile. The trees in the Cove were removed by burning and girdling and then replaced with crops and orchards. Cattle were kept at the Cove in winter, but they were grazed in summer on open fields (balds) on the tops of mountains adjacent to the Cove. The pioneer community which developed in the Cove had a peak population of 685 people in 1850. Extensive logging operations in Cades Cove were dominated by the Little River Lumber Company after the turn of the century (1908 - 1936). They logged up all major streams draining into

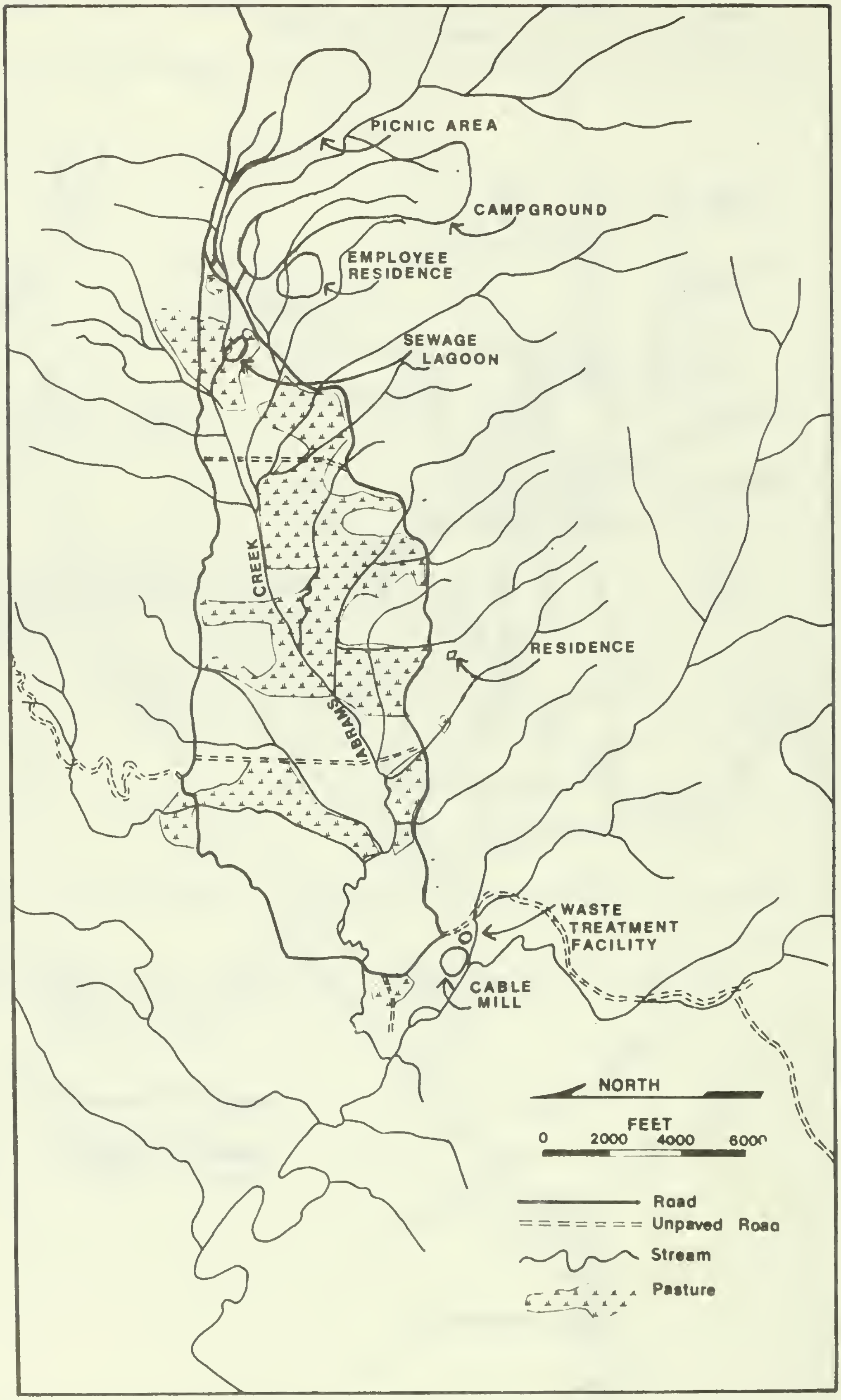
FIGURE 1. GREAT SMOKY MOUNTAINS NATIONAL PARK, SHOWING ABRAMS CREEK, CADES COVE AREA, AND ADJACENT RESERVOIRS

FIGURE 2 ABRAMS CREEK AND TRIBUTARIES, CADES COVE, G.S.M.N.P., SHOWING SAMPLE STATIONS*



*SATELLITE STATION INDICATED BY Ⓢ

FIGURE 3 CADES COVE AREA SHOWING CAMPGROUND, PICNIC AREA, RESIDENCES, SEWAGE LAGOON, CABLE MILL, WASTE TREATMENT FACILITY, PASTURES AND ROADS



the Cove, accelerating erosion and siltation in the watershed (Murless and Stallings, 1973). The pioneer community and all logging operations were abandoned when the Cove came under the jurisdiction of the National Park Service as part of the Great Smoky Mountains National Park in 1936 (Shields 1977).

Since the Park Service assumed managerial responsibilities for Cades Cove, Abrams Creek and its tributaries have been the subject of several management and management-oriented research programs (Table 1). In 1937, sheet and gully erosion in the Cove was attributed to heavy rainfall, improper farming, and overgrazing. To combat these problems, stream banks were sloped and mulched. But it was not until 1946 that a land management plan for the Cove was developed by the National Park Service in cooperation with the Soil Conservation Service. For about 20 years this program resulted in some stream channels cleared of trees and shrubs, while others were straightened. These actions did not entirely solve the erosion problems, however.

In 1967 a new park management program was developed for Cades Cove. The objective of the program was to maintain the open aspect of the fields in order to provide a background for interpretation of the historic structures and features of the pioneer culture that existed prior to the establishment of the park. In order to maintain the fields in an efficient manner, the park allowed leasees to grow hay and graze cattle under special use permits, using good range and farm management and soil conservation practices. This program is still in use. It includes periodic soil sampling, fertilization, seeding and renovation, control of cattle grazing, rotation control of winter feeding, and field moving.

Even with the constraints and controls of the 1967 management plan for the Cove, it was obvious in the early 1970's that the water quality of Abrams Creek was greatly reduced during its passage through the Cove. One of the most obvious changes in the water quality was turbidity. Kelly (1974) reported that the turbidity levels of the creek and some of its tributaries in the Cove were at levels considered detrimental to the native aquatic life occurring in the creek.

In 1975 a further stream and soil management program was developed for Cades Cove by the National Park Service. This program involved seeding and mulching of numerous eroded areas and the removal of numerous uprooted trees, brush, and debris from the creek, as well as minor stream alignment. The effect of this management program on the water quality of Abrams Creek was not investigated.

Even with the reduction in the number of cattle and restrictions on the number of points of entry to the creek by cattle, it was obvious that defecation and urination by the animals into the creek at the watering sites could reduce the water quality from inputs of nutrients and enteric bacteria. As part of the overall survey of backcountry water quality of the streams and springs in the park, Silsbee et al. (1976) estimated numbers of enteric bacteria (fecal coliform and fecal streptococcus) from water samples taken from Abrams Creek and some of its tributaries. The results of the study provided sufficient evidence that the enteric bacterial water quality of Abrams Creek in the Cove was not typical of such water quality of other streams in the park. The major source of these bacteria was attributed to the cattle, although deer, wild European boar, horses, and other mammals probably contributed to the contamination.

As a result of Kelly's (1974) and Silsbee's (1976) reports, the permittees, at the request of the National Park Service, erected fencing along the channel banks of the main creek and tributaries in the Cove in 1973 and reduced the number of cattle from 1,200 to 500 head in 1976. These efforts were directed at reducing the number of cattle wading and drinking in the creek and inducing cattle to enter the creek and tributaries at specific watering sites. Streambank erosion and enteric bacterial loads resulting from cattle activity were thereby greatly reduced.

Based upon the results of these reports and general observations that the water quality of Abrams Creek was still adversely impacted during its passage through the Cove, the present survey of the water quality of Abrams Creek and some of its tributaries was conducted in 1977. The objectives of this study of Abrams Creek and some of its tributaries were to:

(1) Monitor physical and chemical features,

(2) Determine the structure of the benthic macroinvertebrate community,

(3) Determine the bacteriological water quality and define problem areas,

(4) Correlate fish distributions and population structure (species) with water quality, and

(5) Monitor the algal periphyton (diatoms) community.

Table 1. Historical sketch of the management and management-oriented research programs in the Abrams Creek watershed

1937	Use of mulch and bank sloping in erosion control by National Park Service
1946	Land management plan developed by Soil Conservation Service
1959	Reclamation of lower Abrams Creek (i.e., Abrams Falls to Chilhowee Lake) sport fishery by use of toxicant (rotenone) administered by the U.S. Fish and Wildlife Service
1967	New park management program developed for Cades Cove
1968	Study on "Comparative ecology of streams in Cades Cove" by Maryville College
1972	Water quality survey of Abrams Creek and tributaries by the U.S. Fish and Wildlife Service
1973	Fencing program to exclude cattle from Abrams Creek and tributaries
1975	Stream and soil management program developed for Cades Cove
1976	Bacteriological water quality survey of Abrams Creek and tributaries by National Park Service, Uplands Field Research Laboratory. Cattle reduced from 1,200 to 500 head in Cades Cove.
1977	Water quality survey of Abrams Creek and tributaries by National Park Service, Uplands Field Research Laboratory (present study)

MATERIALS AND METHODS

Physical and Chemical

Physical and chemical features of Abrams Creek and selected tributaries were determined monthly from February to July 1977 at 37 sites by submerging plastic (polyethylene) or amberglass containers below the water surface at midstream. The samples were transported to the laboratory on ice and generally analyzed within 24 hours. The parameters monitored are listed in Table 2. Temperature, conductivity, and dissolved oxygen were analyzed in the field. Stream volume (cubic feet per second) was calculated from flow rates (feet per second) taken at 0.6 stream depth and stream width at particular sites. Acidity is a method of expressing the capacity of water to donate protons and gives an indication of the water's corrosiveness. Acidity is caused by carbon dioxide in the water, tannic acid, and hydrolyzing inorganic salts as ferrous and/or aluminum sulfate. The acidity of natural waters is normally very low (< 20 milligrams per liter). Alkalinity refers to the capacity of water to neutralize acids and is usually imparted by the bicarbonate, carbonate, and hydroxide components of natural or treated water supplies. Natural surface waters usually contain less alkalinity than sewage or wastewater samples. The hardness of water is defined as the amount of calcium and magnesium present. Although iron, aluminum, manganese, strontium, zinc, and hydrogen ions are capable of producing hardness, high concentrations of these ions are not commonly found in natural waters (American Public Health Association 1975) such as Abrams Creek. High levels of nitrate in water indicate biological wastes in the final stages of stabilization (American Public Health Association 1975). Nitrate-rich effluents discharged into receiving waters can degrade water quality by encouraging excessive algal growth. Biological oxygen demand (BOD) is an empirical measurement of the oxygen requirements of sewage. The test results are used to calculate the effect of waste discharges on the oxygen resources of the receiving waters.

The amount of settleable solids in streams gives an empirical estimate of another aspect of water quality. Settleable solids may cover bottom-dwelling organisms, trout, and other fish nests, as well as destroy habitat by filling spaces between rocks in riffles and pools. During flooding or high flow conditions, settleable solids may become entrained in the flow and substantially contribute to turbidity. Turbidity occurs in most surface waters as the result of suspended clay, silt, finely divided organic and inorganic matter, plankton, and other micro-organisms. Turbidity should not exceed 10 Jackson Turbidity Units (JTU) in cold water streams (Federal Water Pollution Control Administration 1968).

Table 2. Chemical - physical parameters and instrumentation or methods used for analysis.

Chemical - physical parameter	Analytical technique
Temperature (^{o}C)	LaMotte Chemical Co., Mercuric Thermometer, Model 1066
Total Acidity (as mg/l of $CaCO_3$)	Standard Methods (American Public Health Asso., 1975)
Total Alkalinity (as mg/l of $CaCO_3$)	Standard Methods (American Public Health Asso., 1975)
Total Hardness (as mg/l of $CaCO_3$)	Standard Methods (American Public Health Asso., 1975)
Suspended Solids (mg/l)	Laboratory Procedures (Vietti, 1971)
Conductivity (μhoms/cm)	YSI S-C-T Meter, Model 33
Turbidity (JTU)	Nephelometric Turbidimeter, H.F. Instrument Ltd., Model DRT-100
Settleable Solids (mg/l)	Imhoff Cone
Dissolved Oxygen (ppm)	YSI Dissolved Oxygen Meter, Model 54 A
pH	Hach pH Meter, Model 2075
Nitrate (NO_3)	Hach Kit, DR/2 Spectrophotometer, Model 2504-00
Ortho-phosphate (PO_4)	Hach Kit, Direct Reading Engineer's Laboratory, Model DR-EL/2
Biological Oxygen Demand (BOD_5)	Standard Methods (American Public Health Asso., 1975)
Stream Velocity (fps)	General Oceanics Digital Flowmeter, Model 2030

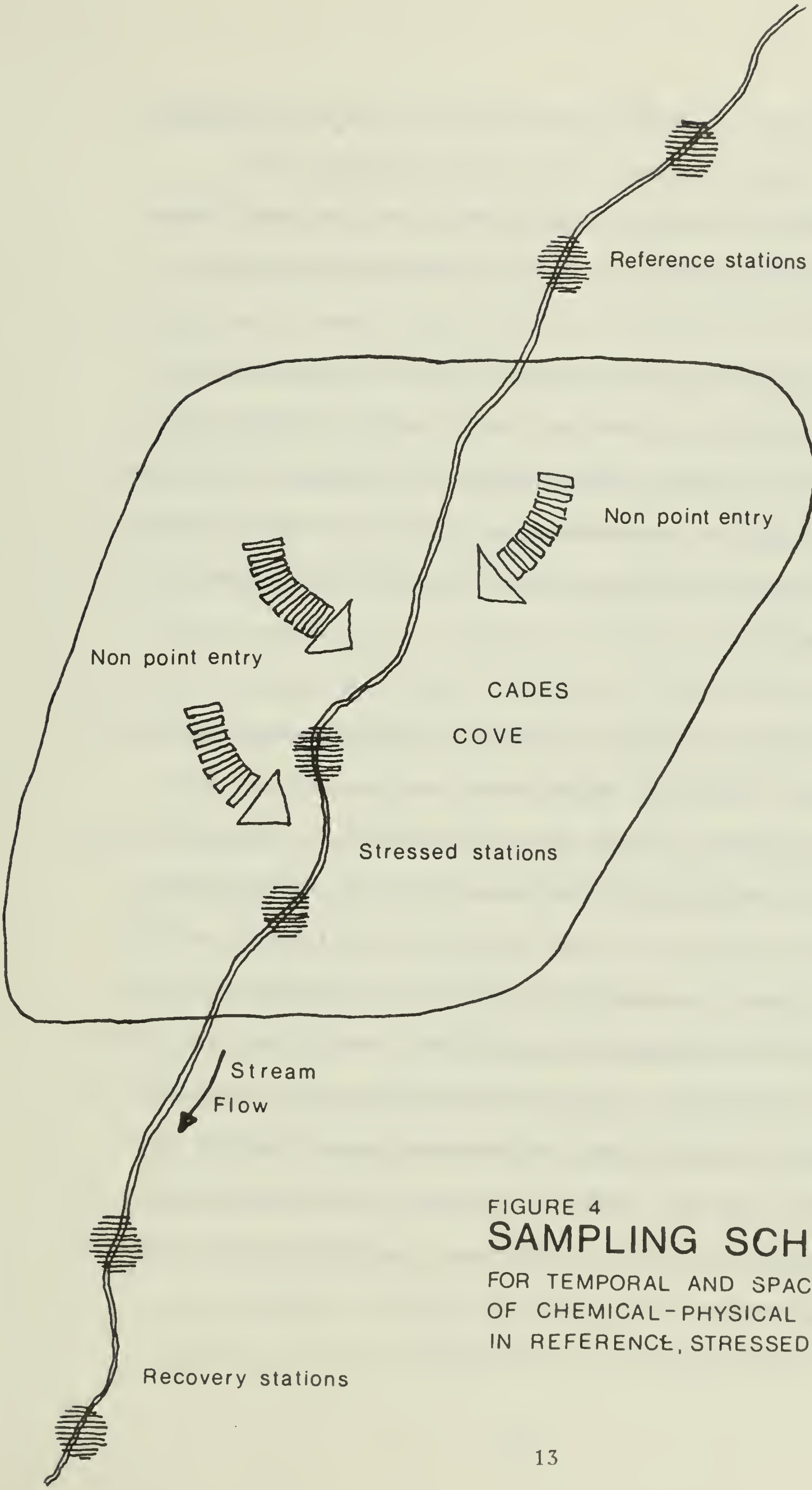


FIGURE 4
SAMPLING SCHEMATIC
FOR TEMPORAL AND SPACIAL COMPARISON OF CHEMICAL-PHYSICAL AND BIOTIC COMPONENTS IN REFERENCE, STRESSED, AND RECOVERY AREAS.

Conductivity is a numerical expression of the ability of water to conduct electric current. This number depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made.

Temperature levels and fluctuations affect the composition and distribution of fish, algae, and bottom fauna of streams and is influenced by turbidity, suspended solids, streamside vegetation, etc. The degree of streamside vegetation influences the amount of solar radiation reaching a stream and thus also influences the water temperature.

The basic sampling design was oriented towards temporal and spatial comparison of chemical - physical and biotic components in reference (stations 1 - 2), stressed (stations 3 - 15 and 23 - 37, and recovery (stations 17 - 22) areas (Fig. 4). Water samples could not be collected at some sample sites during all sampling periods, however, especially at the smallest tributaries during winter and summer, owing to insufficient stream flows. In addition, a control station (16) on Mill Creek was sampled for comparison to station 15 on Abrams Creek. Both streams were of similar size, substrate composition, and drainage area. Mill Creek, however, is not influenced by cattle activity and by groundwater flow through limestone strata.

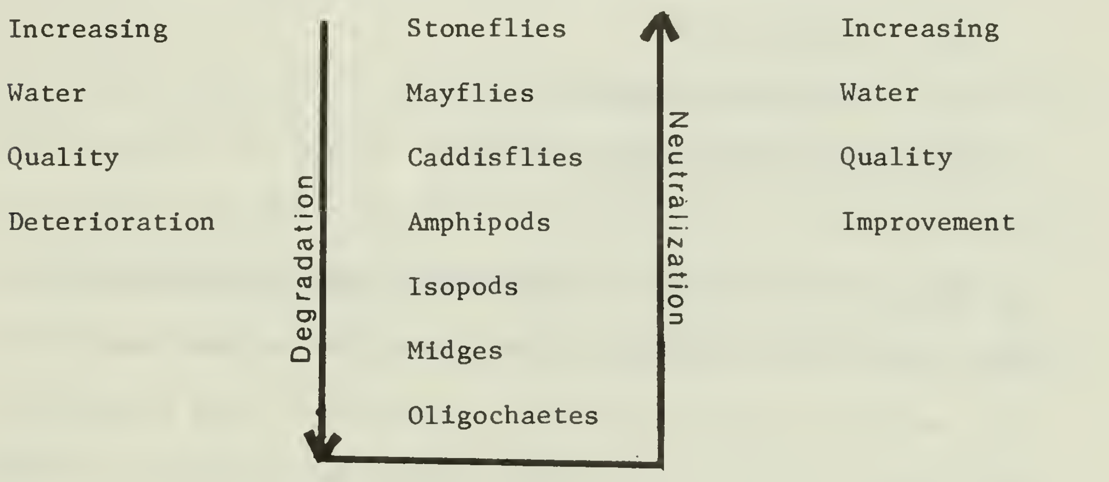
Biological

Quantitative and qualitative benthic macroinvertebrate samples were collected at 37 sites in February, March, May, and July 1977. Quantitative samples were taken in triplicate at each site using a square foot Surber sampler (0.093 square meter) with a 1,024 micron mesh net (Surber 1970). The organisms were collected by washing the largest rocks enclosed by the sampler, removing these rocks, and stirring the remaining bottom substrate by hand to a depth of 3 to 8 centimeters. Qualitative samples were taken during most of the sampling periods in an attempt to collect all species present at each sampling area. These samples were collected by kicking the bottom substrate for one minute and collecting the organisms in a Turtox long-handled bottom net (46 by 20 by 25.4 centimeters) with a pore size of 1,270 microns. All benthic macroinvertebrate samples were preserved in 10 percent formalin at the time of collection.

In the laboratory, each sample was washed in a series of U. S. Standard Sieves Nos. 30 (595 micron opening), 40 (420 micron opening), and 60 (250 micron opening), transferred to a white sorting tray; separated from the debris using the sugar floatation technique described by Anderson (1959); and then picked. The picked organisms were preserved in a solution containing 95 percent ethanol, 1 percent formalin, and 1 percent glycerine. Organisms were later identified to the lowest practical taxonomic level, using appropriate taxonomic literature, and enumerated. Wet weights of individual taxa were obtained by removing the organisms from the final preservative, placing them on paper towels for approximately two minutes, and then determining their weight to the nearest 0.1 milligram on an analytical balance (Torbal, Model EA - 1). Several taxonomic keys were used to identify the organisms; however, the most frequently used references were Parrish (1975), Usinger (1956), Pennak (1953), Ward and Whipple (1959), Ross (1944), and Needham et al. (1935). A checklist of benthic macroinvertebrate taxa was compiled for the study area. Qualitative samples were processed in a similar manner to the Surber samples except that the organisms were neither counted nor weighed.

Because of the general lack of mobility in benthic macroinvertebrates, these organisms are good indicators of the water quality of streams at different locations (EPA 1974). Generally, undisturbed waters support diverse benthic macroinvertebrate communities. Heavily polluted waters, however, will support only a few species since the pollutant(s) eliminate many intolerant species, leaving only the most tolerant species. The surviving species usually increase in density in response to organic enrichment as well as to reduced interspecific competition and predation pressures. The reduction of diversity and evenness (see below) in distribution of individuals among the species in a polluted system results in a simplified and unstable community

(Cairns and Dickson 1971). But as a pollutant is neutralized in a stream downstream from its source, benthic macroinvertebrate communities begin to recover and diversity increases. The usual order of disappearance and reappearance on a sensitivity scale of particular taxa of benthic macroinvertebrates in a clean water stream downstream from a pollution source is shown below (after Environmental Protection Agency 1974):



In this case, degradation was sufficient to eliminate all taxa except oligochaetes before neutralization processes improved the water quality and permitted pollution-intolerant species to inhabit the stream. In cases where water quality degradation was not as severe, the changes in taxa would not be expected to be as great as in the above example.

In order to assess benthic macroinvertebrate community structures in Abrams Creek along its course from Anthony Ridge to Abrams Falls, the following methods of analyses were used:

(1) Number and weight (wet weight of organisms per square meter)

(2) Number of taxa (S)

(3) Macroinvertebrate distribution

(4) Index of similarity (SI)

(5) Importance values (IV)

(6) Diversity ($\bar{H}$) and ($\bar{d}$)

(7) Evenness (J)

(8) Redundance (R)

(9) Equitability based on $\bar{d}$ (e)

(10) Equitability based on $\bar{H}$ (e')

The number and wet weight of organisms at each sample site per square meter were collected by multiplying values per square foot by a conversion factor of 10.764. The number of taxa present at each station and their distribution within the study area are based upon both quantitative and qualitative samples.

Similarities in taxa between benthic communities at particular sample stations and at multiple sample stations within two sections of the stream were evaluated on an annual basis using two indices of similarity (SI), calculated as follows:

$$SI = \frac{2C}{A + B}$$

where A = number of species occurring at sampling station X

B = number of species occurring at sampling station Y

C = number of species common to both sampling stations X and Y and

$$SI = \frac{N(C)}{A + B}$$

where A = number of species occurring at sampling station X (representing all stations in an ecological region)

B = number of species occurring at sampling station Y (representing all stations in an ecological region)

C = number of species common to both sampling sections X and Y

N = number of stations in sections X and Y

The values range from 0 to 1. The closer the value to 1, the greater the similarity of faunas. Although some bias may be introduced by the second SI formula due to the variable number of stations used in the computation, it provides a technique by which the various ecological regions (reference, stress, recovery, and control) can be compared.

Importance values (IV), modified from Cottam and Curtis (1956), were calculated for each taxon occurring in the quantitative samples each month. Importance values were calculated as follows:

$$IV = \%\ number + \%\ weight$$

where number = number of organisms in the "ith" species

weight = weight of organisms in the "ith" species

These importance values indicate the relative contribution, in number and weight, of each taxon to the community. The higher the importance value, the greater the contribution of that taxon to the community. The maximum obtainable importance value is 200.00.

Several diversity indices were calculated for the benthic populations. Margalef (1956) proposed analysis of mixed species populations by methods derived from information theory. The main objective of information theory is to try to measure the amount of order (or disorder) contained in a system (Margalef 1958). Four types of information might be collected regarding order in the community: (1) the number of species, (2) the number of individuals in each species, (3) the places occupied by individuals of each species, and (4) the places occupied by individuals as separate individuals (Krebs 1972). In most community work, only data of types (1) and (2) are obtained. All four were considered during this study, however, by using several types of indices which utilize two or more of these information sets in their formulation.

Diversity is a measure of the difficulty of predicting the species of an individual selected at random from the population. The more species present in the community and the more equal their abundance, the greater the uncertainty (i.e., difficulty of prediction) and the greater the diversity (Wilhm and Dorris 1968).

Diversity values were calculated (by computer, Tennessee Technological University) from pooled quantitative samples at each station (monthly). One of the indices used to describe the communities of benthic organisms, $\overline{H}$ (Brillouin 1962), was as follows:

$$\bar{H} = \frac{1}{N} \log \left(\frac{N!}{n\,!\; n\,!\ldots n\,!} \right)$$

where N = total number of individuals

n = number of individuals in the i'th species

$\bar{H}$ serves as a measure of diversity (or information) per individual. The $\bar{H}$ values obtained range from zero to $\log_2$ of the number of species. The minimum value of $\bar{H}$, zero, is obtained when all individuals belong to the same species. Conversely, the maximum of $\bar{H}$ is obtained when all individuals belong to different species.

The Shannon-Wiener diversity index, $\bar{d}$ (Hurlbert 1971) was also used. It was calculated as follows:

$$\bar{d} = \frac{C}{N} (N \log N - \sum n_i \log_{10} n_i)$$

where N = total number of individuals

n_i = number of individuals in the "i" species

c = 3.321938

The $\bar{d}$ index takes into account the richness of species as well as the distribution of individuals among the species. The range of values obtained varies from zero to $\log_2$ of the number of organisms. When all organisms belong to the same species, the value will equal zero, and when all individuals in the sample belong to different species, the maximum value is obtained. In other words, a greater number of species increases species diversity, and a more even or equatable distribution among species will also increase species diversity. In unpolluted waters, $\bar{d}$ generally ranges between 3 and 4 whereas, in polluted water, $\bar{d}$ is generally less than 1 (Wilhm 1970). Yet, $\bar{d}$ lacks the sensitivity to demonstrate differences in streams in the southeastern U.S., where degradation is slight to moderate (Weber 1973). $\bar{H}$ values are generally interpreted in the same manner as $\bar{d}$, but tend to have greater sensitivity to stream perturbation where small numbers of organisms are considered. Both indices were used in order to have a firm basis for interpreting water quality. $\bar{H}$ probably yields better insight into water quality in areas above Cades Cove, where there are small numbers of benthic organisms, and $\bar{d}$ in areas within and below the cove, where the number of benthic organisms is relatively large. Wilhm and Dorris (1968) found that diversity index values ($\bar{d}$ and $\bar{H}$) less than 1 have been obtained in areas of heavy pollution, values of 1 to 3 in areas of moderate pollution, and values exceeding 3 in clean water areas.

The dominance diversity index, J, was used to estimate the evenness of distribution of individuals among the species in communities in Abrams Creek. Evenness (Pielou 1966) was calculated using the following formula:

$$J = \frac{\bar{d}}{\log_2 S}$$

where S = number of species

A value of J near zero indicated that the community was dominated by one or more species, whereas a value of 1 (maximum value) indicated a uniform distribution of individuals existed among the species.

Equitibility (Lloyd and Ghelardi 1964) is a comparison of $\bar{d}$ (which gives e) or $\bar{H}$ (which gives e') with a maximum based on the distribution obtained from the MacArthur (1957) broken stick model. The MacArthur model results in a distribution frequently observed in nature -- one with a few relatively abundant species and increasing numbers of species represented by only a few individuals (Weber 1973). Sample data are not expected to conform to the MacArthur model, since it is only a yardstick against which the distribution of abundances is being compared. The formulas for calculating equitibility (e and e') are as follows:

$$e = \frac{s'}{s}$$

where s = number of species in sample

$$s = 10^{(.339\ \bar{d})}$$

and

$$e' = \frac{s'}{s}$$

where s = number of species in sample

$$s' = 10^{(.339\ \bar{H})}$$

The value (s') refers to the number of species expected from a community that conforms to the MacArthur model. Equitibility as calculated may range from 0 to 1, except in unusual situations where the distribution in the sample is more equitable than the distribution resulting from the MacArthur model. Such an eventuality will result in values of (e) or (e') greater than 1, and this occasionally occurs in samples containing only a few specimens represented by several taxa (Weber 1973). Equitibility has been found to be very sensitive to even slight levels of degradation (Wilhm 1970). Equitibility values generally range between 0.6 and 0.8 in southeastern streams known to be unaffected by oxygen-demanding wastes. Even slight levels of degradation have been found to reduce equitibility below 0.5 and generally to a range of 0.0 to 0.3 (Weber 1973).

Redundancy (R) is an expression of the dominance of one or more species and is inversely proportional to the wealth (i.e., diversity) of species. It is calculated as follows (Brillouin 1962):

$$R = \frac{Hmax-\overline{H}}{Hmax-Hmin}$$

where $Hmin = \frac{1}{N} \left| \log_2 N! - \log_2 (N-S+1)! \right|$

$Hmax = \frac{1}{N} \left| \log N! \quad S\log \; K! - r\log \; (K+1) \right|$

K = greatest integer less than $\frac{N}{S}$

r = N - Ks

$\overline{H}$ = Brillouin diversity index

N = Total number of organisms (individuals)

S = Total number of species

Redundancy ranges between 0 and 1. The closer R is to zero, the less uniform (more diverse) the sample; whereas, the closer it is to 1, the more uniform (less diverse) the sample.

Each of the 10 parameters described above was tested for statistical significance between stations, seasons, and years on Abrams Creek, using a two-way ANOVA test (Barr et al. 1976). The level of significance was $P < .01$.

Since benthic macroinvertebrate populations exhibit a clumped or skewed distribution instead of the normal distribution required for many statistical analyses (Elliot 1971), the mean number and weight of organisms per square meter are transformed to normalize the distribution. This transformation was accomplished by $\log_e (X + 1)$, where X equals the mean number or mean wet weight of organisms per square meter.

Fish

An electroshocking survey of the fish in Abrams Creek was conducted during August - September 1977 by the Uplands Field Research Laboratory and the U.S. Fish and Wildlife Service (FWS) technical assistance group stationed at the Great Smoky Mountains National Park. Tiny Tiger backpack electroshockers (Model 5000-1, 350 watts, 110 WAC, 12 V6C) manufactured by D. W. Industries, Minneapolis, Minnesota, were used. All fish collected were identified, weighed, and measured (total length) and most were returned unharmed to the stream. Some fish were retained from each station for a reference collection.

The stream sections surveyed in the present work had been surveyed by the FWS in 1973-74. One section was located in the reference zone (station 1), two were in the stress zone (stations 9 and 26), and three were in the recovery zone (stations 17, 18, and 19). Using the same techniques and procedures as the FWS, each section of the stream surveyed for fish was one-tenth mile (528 feet) in length. Block nets, one-fourth inch square mesh, were used to prevent downstream escapement from each survey section. Riffles of sufficient width and height to retard upstream escapement were utilized at each survey station. Depending on stream size, two to six backpack electroshockers were used to remove fish. The stream sections were shocked until no fish were captured. Stream sections were measured in length, the width was taken every 50 feet, and the results were averaged.

The following formulas were used to estimate the number and weight of fish in each survey section:

$$\text{Number fish per acre} = \frac{\text{Number fish captured x escapement factor (27.71)}}{\text{Acres sampled}}$$

Weight (in lbs.) fish per acre = Average weight (in lbs.) x number of fish per acre

$$\text{where Acres} = \frac{\text{Average width (feet) x length (feet)}}{\text{43,000 feet per square acre}}$$

Escapement Factor (used by the FWS) = 27.71 percent (Anonymous 1970)

Results of these studies provided criteria for estimating the extent or type of pollution involved in each survey area as described by Parrish (1970). The distribution and abundance of sport, forage, or rough fishes relative to their ecological requirements was used to assess the general "health" of fish communities in Abrams Creek. The structure of the fish populations in the reference, stressed, and recovery areas in 1973-74 and 1977 were compared for changes in the numbers and biomass of sport, forage, and rough fish. Fish were superficially examined for disease and parasites, though most of the effort was directed towards trends in population structure.

Periphytic Diatoms

Heavy loads of suspended solids, alteration of thermal regimes resulting from removal of vegetation along the stream, and organic and inorganic enrichment from cattle and other animals could severely influence the composition and dynamics of the periphytic diatom communities in the Abrams Creek system. The periphytic diatom (i.e., occurring on, but not penetrating, the stream substrate or other submerged objects) communities are frequently a major source of primary production in small streams because turbulent, unidirectional flow restricts the establishment of planktonic algae populations.

Some diatom species have broad tolerance ranges to environmental conditions and therefore these species may be found in a wide variety of habitats. Other species, however, have very limited tolerance ranges and these species are usually restricted to specific habitat types and environmental conditions. Therefore, determining the predominant species composing the diatom community at different locations along a stream provides a useful means of assessing changes in habitat and water quality along the course of the stream. In view of the suspected changes in water quality along the course of Abrams Creek, periphytic communities were examined qualitatively by removing samples from the surface of rocks at different stream sections during May and June of 1977. The samples were preserved in 4 percent formalin and forwarded to Dr. Rex Lowe, Bowling Green State University, Bowling Green, Ohio, for identification and assessment of relative abundance. The ecological conditions under which the predominant species and the communities exist were assessed, following the criteria established by Lowe (1974) as well as conclusions drawn by Dr. Lowe's analysis of the samples.

Enteric Bacteria

Silsbee et al. (1976) determined fecal coliform numbers and fecal streptococcus bacteria in Abrams Creek as part of an overall survey of the backcountry quality of streams in the park. One recommendation from that survey called for long term monitoring of Abrams Creek and tributaries to determine the bacteriological effects of any changes in the locations and sizes of cattle herds. Thus, a bacteriological survey was incorporated into this program for comparison of the bacterial quality of Abrams Creek and tributaries between the two surveys.

The millipore membrane filtration method (Millipore Corporation 1973) employed by Silsbee et al. (1976) was used for comparative purposes for estimating the numbers of fecal coliform and fecal streptococcus bacteria in the creek. Estimates of the number of total coliform bacteria were also made. Bacteriological water samples were collected once each month from May through August at 37 stations on Abrams Creek and tributaries (Figs. 20 - 23). Some of the stations were located at strategic sites, such as near a campground, picnic area, sewage lagoon, residence, mill, and pastures.

Water samples were collected in sterile polyurethane bottles and kept on ice until processed -- less than six hours after samples were collected -- in the laboratory. Total coliform plates were cultured on Endo broth for 24 hours at 35°C. Fecal coliforms were cultured on MF-C broth for 24 hours at 44.5°C. Fecal streptococcus were cultured on KF streptococcus agar for 48 hours at 35°C. Thirty milliliters of stream water were filtered for total coliform plates and fecal coliform plates; 50 milliliters were filtered for fecal streptococcus plates. Following incubation, the colonies were counted under fluorescent illumination. Colonies were expressed as numbers per 100 milliliters of water.

The ratio of fecal coliform to fecal streptococcus was used to determine if the source of bacterial contamination was from humans or from other mammals (Fig. 5). Ratios less than or equal to 0.7 usually indicate pollution derived from livestock, wildlife, or poultry. Ratios greater than or equal to 4 indicate pollination derived from human wastes (i.e., defecation and urination). Ratios from 0.7 to 1.0 suggest a predominance of nonhuman animal wastes, and a ratio between 2 and 4 suggests a predominance of human wastes. Ratios between 1 and 2 are usually of "uncertain

Animal	Fecal Coliform [Million]	Fecal Streptococci [Million]	Ratio FC/FS
Man	13.0	3.0	4.4
Sheep	16.0	38.0	0.4
Cow	0.23	1.3	0.2
Turkey	0.29	2.8	0.1
Pig	3.3	84.0	0.04

FIGURE 5. Some typical FC/FS ratios. Average indicator density per gram of feces.*

*Data from Bureau of Water Hygiene, Environmental Protection Agency, Cincinnati, Ohio.

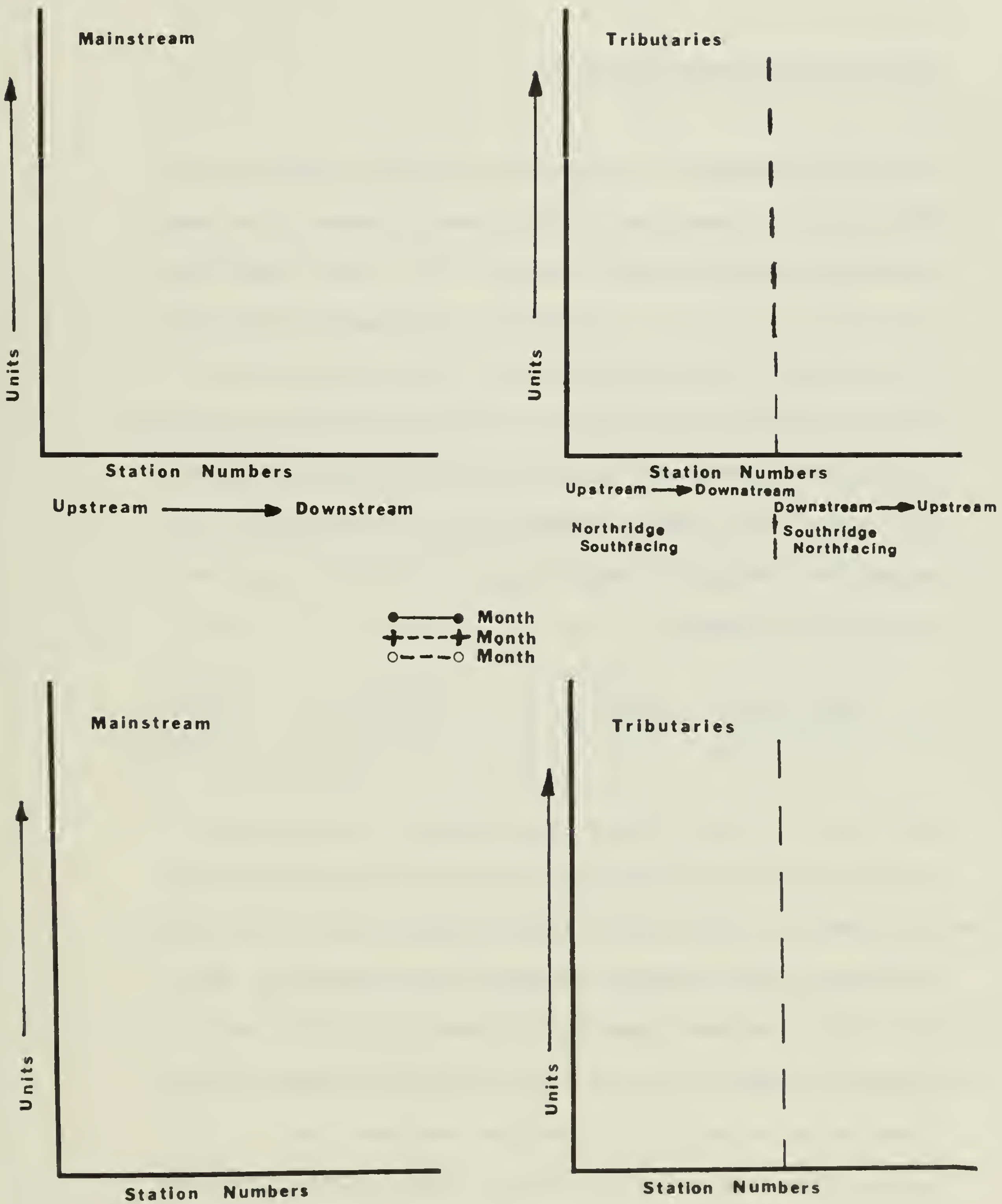
interpretation" (Geldreich 1969). Only samples in which the fecal streptococcus count was at least 100 were included in the analyses as suggested by Geldreich (1969).

Compilation of monthly physical - chemical characteristics (Tables 1 - 7) and benthic macroinvertebrate checklists (Tables 8 - 13) are contained in the Appendix. These data are summarized or graphically presented in the results section of the text. The graphics are designed so that mainstream (left side of page) and tributary (right side of page) station data are segregated for ease of examination (Figs. 6 - 17). Mainstream stations are oriented from upstream (left) to downstream (right) in the station data presentation for Abrams Creek, while Mill Creek (station 16) is separated to the right as a separate noncontiguous data point. The tributary stations are oriented left to right on the graphs from upstream-to-downstream north ridge tributaries (southfacing) and then downstream-to-upstream south ridge tributaries (north facing). After familiarization with station locations (Fig. 2), this technique is very helpful for gradient analysis. Suspended solids (Fig. 7) and volume flow (Fig. 17) were taken for mainstream stations only. The following illustration shows the graphics design for field data:

LEGEND FOR CHEMICAL - PHYSICAL FIGURES NOS. 6 THROUGH 16

FIGURE NUMBER

PARAMETER



RESULTS

Physical and Chemical Parameters

The water temperature was observed to fluctuate directly with the ambient air temperature within certain ranges as influenced by seasonal weather changes (Tables 1 - 7). These ranges were, in addition, observed to substantially increase in Cades Cove from reference through stressed areas. Below the confluence of Mill Creek and the influence of Cool Spring Seeps in the lower portion of the Cove, the range of water temperatures was lower than in the Cove, though the average was slightly higher. The ranges (and averages) of water temperature (^{o}C) in the ecological zones was as follows:

Reference	Stressed	Recovery	Control
1-18 (11.7)	0-25 (13.4)	0-20 (13.6)	1-19 (13.0)

The volume of flow of Abrams Creek increased during passage through Cades Cove from February to April. Reduced flow from tributaries to Abrams Creek and substantially lower water tables from late spring throughout the summer (Wayne Williams, GRSM sanitarian, personal communication) drastically alter the hydrologic regime in Abrams Creek in the Cove, however. The creek begins to enter the ground near stations 3 and 4. The subterranean water probably surfaces between station 26 and the satellite telemetry station (Fig. 2, Table 7). As a result of the subterranean flow, portions of Abrams Creek in the middle of the Cove are reduced in flow, often lacking any surface flow. Below the confluence of Mill Creek, Abrams Creek is near riverine in nature (i.e., fourth order stream). Several tributaries on the north side (southfacing) of the Cove were dry in July, including Crooked Arm Branch, Harrison Branch, Martha's Branch, Feezell Branch, and parts of Tater Branch.

The turbidity of Abrams Creek was not as great in 1977 as it was in 1972-73. Only during the month of June (1977 survey) did turbidity exceed 10 Jackson Turbidity Units (JTU) in the mainstream of Abrams Creek. The turbidity of the tributary streams during 1977 was similar to the main creek except for a few isolated tributary stations on Martha's, Feezell, and Tater Branches, where the turbidity was at times exceptionally high; e.g., stations 7, 10, 23, and 24.

The amount of suspended solids in Abrams Creek was generally greater at the downstream stations than at the upstream stations (Fig. 7). Furthermore, the amounts were generally greater in February, March, and April than in May, June, and July. Settleable solids did not contribute appreciably to the suspended solid loads in Abrams Creek or tributaries (Appendix, Tables 1 - 6). During each sampling period, the concentration of settleable solids at most stations was less than 0.1 milligram per liter. Only at stations 9, 10, 11, and 33 did concentrations of settleable solids exceed this level, ranging from 0.2 to 0.9 milligrams per liter.

Reference area stations were typically low in conductivity, never exceeding 20 μMHOS per cubic centimeter (cm^3). The conductivity of Abrams Creek and tributaries within Cades Cove was lowest at stations located at the east end (upstream section) of the Cove relative to the rest of the study area (Figs. 2 and 8). The conductivity of the creek typically increased sharply at the far west end (downstream section) of the Cove (stations 15, 17, and 24) before decreasing to intermediate levels downstream from the Cove (stations 18 to 22).

Total acidity of Abrams Creek varied considerably between sample periods (Fig. 9). The acidity was usually low (about 10 milligrams per liter) at stations 15 and 17, as compared to most of Abrams Creek. During July, the waters below the cove in Abrams Creek displayed no acidity at all. Tributary waters were fairly stable in acidity throughout the survey except for the months of February and July, when values were substantially less than the usual trend.

The total alkalinity of Abrams Creek and tributaries was high during April, May, June, and July relative to other months and other streams within the park. The highest levels were typically found at stations (e.g., 15 and 17) located at the east end of the Cove (Fig. 10) below spring seeps entering Abrams Creek and tributaries. During July, the alkalinity at most stations on Abrams Creek and tributaries was relatively high.

Total hardness was lowest at stations in the east end of the Cove and on Anthony Creek (Fig. 11). Hardness was highest on Abrams Creek at stations 15, 17, and 18, being at relatively moderate levels at most downstream stations. Tributary stations 10 and 24 tended to have a high hardness throughout the survey.

Concentrations of nitrate were greater from February to April than from May to July in the mainstream and the tributaries (Fig. 12). The concentrations were fairly consistent between stations at each sampling period. Nitrates were exceptionally high in concentration at stations 1, 8, 10, 20, and 30 in February, however.

Ortho-phosphate concentrations were generally less than 0.1 milligram per liter during all sampling periods (Fig. 13). Exceptionally high concentrations at mid-Cove sections of Abrams Creek (station 9) and just below the confluence of Abrams and

Mill Creeks (station 17) occurred during April and at tributary stations 13 and 30 during May. The station downstream from the sewage lagoon (no. 8) was very high in concentration in July while stations 2, 9, 13, and 17 were high in concentration in June. Bunting Creek (station 29) had consistently high concentrations as compared to the other tributary stations during February, March, April, and May.

The Biological Oxygen Demand (BOD_5) of Abrams Creek water was highest in February and March (Fig. 14); however, high demands occurred at stations 4 and 8 during other months. The influence of the sewage lagoon in Cades Cove, the location of cattle pastures adjacent to Abrams Creek, and seasonal changes in temperature probably affect the BOD_5 levels in Abrams Creek.

The pH of Abrams Creek was generally acidic (ranging from 6.0 to 6.9) from the upper portions of the study area to station 15 at the lower end of the Cove (Fig. 15 and Appendix, Table 7). Downstream from the Cove the pH ranged from 7.1 to 8.3 (Fig. 15). Tributary streams were usually slightly acidic except for the most downstream station on Feezell Branch (station 24), which was slightly alkaline during April, May, and July.

Dissolved oxygen (D.O.) was at or near 100 percent saturation at most stations on Abrams Creek and on Mill Creek in the winter and spring (Fig. 16). A severe D.O. depression (4.3 milligrams per liter) occurred during July at station 9 on Abrams Creek when flow through that area was reduced (Fig. 16). Many tributaries dried up in July. Several tributaries began showing reduced D.O. levels from April to July, especially station 5 (Crooked Arm Branch), station 6 (Harrison Branch), station 23 (Tater Branch), and station 24 (Feezell Branch).

Water quality data reconnaissance from satellite telemetry systems in Abrams Creek appeared statistically comparable to that retrieved by field instrumentation (Table 3). Significant differences did not exist below the 0.05 level between the two water analysis systems (i.e., satellite-associated telemetry instrumentation and ground truth water quality checks via portable field meters). Statistical analysis of data from the two systems indicates very highly significant differences ($P < 0.001$) for temporal changes in dissolved oxygen, temperature, and conductivity, and highly significant differences ($P < 0.01$) for such changes in pH data. The validity of data retrieved from satellite telemetry systems appeared sound and usable for interpretation of water quality in Abrams Creek.

Table 3. Analysis of Variance (F-Test) for Comparisons of Satellite-Associated Water Quality Data and Ground-Proof Checks for Abrams Creek

Dependent Variable	*Parameters	Sum of Squares	F Value	R-Square	Coefficient of Variance	**PR>F
Dissolved Oxygen (D.O.)	Time	31.53	407.10	0.99	1.14	0.0001
	System	0.01	0.23			0.6491
Temperature	Time	97.67	697.65	0.99	0.76	0.0001
	System	0.06	3.93			0.0756
Conductivity	Time	19,807.45	177.72	0.99	2.78	0.0001
	System	0.05	0.00			0.9503
pH	Time	3.15	6.59	0.87	2.69	0.0031
	System	0.04	0.77			0.4008

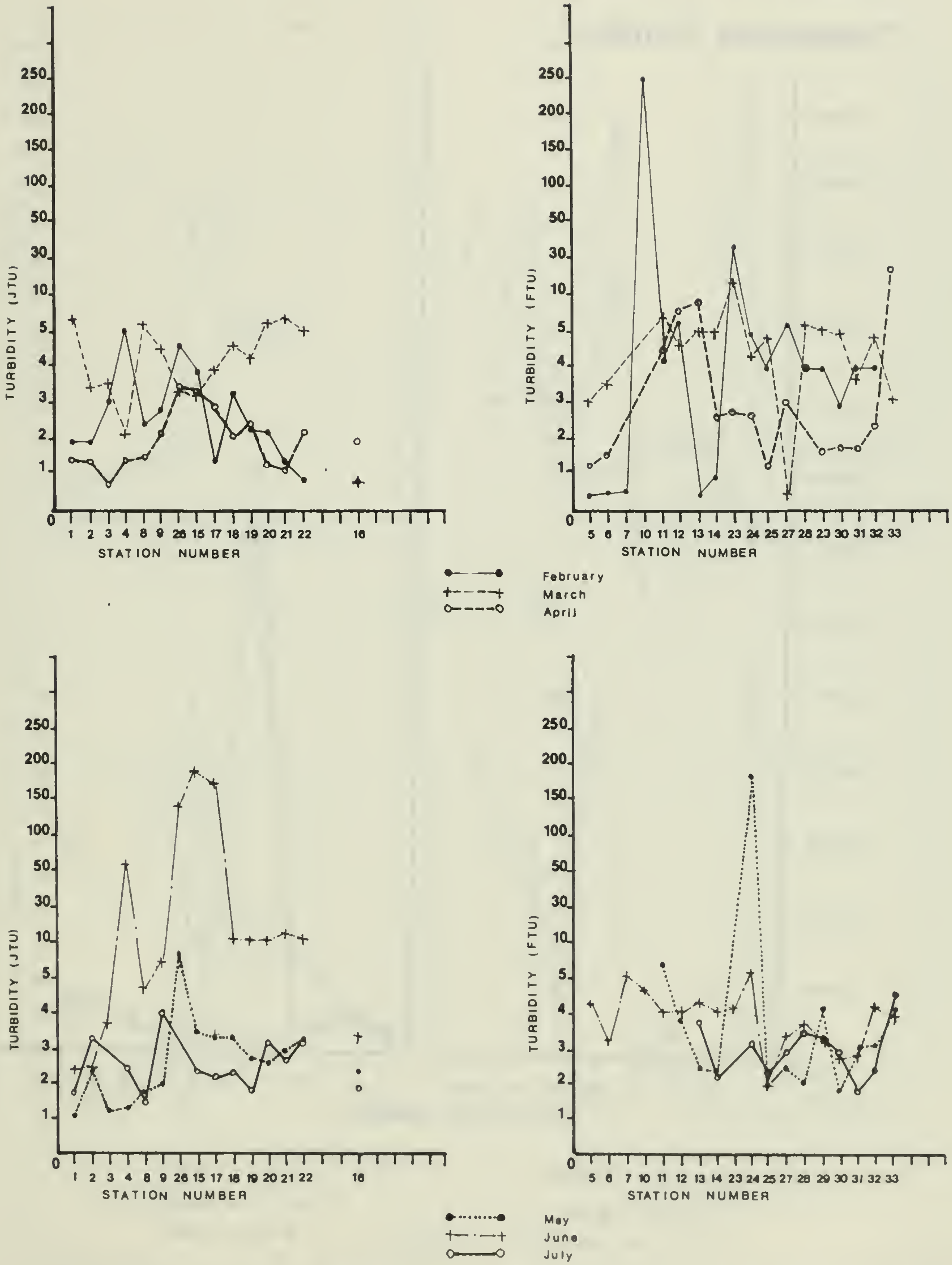
*Parameters: Time refers to comparisons of data taken at different dates. System refers to the apparatus used in taking data.

**PR>F: < 0.05 Significant difference

< 0.01 Highly significant difference

< 0.001 Very highly significant difference

FIGURE 6
TURBIDITY

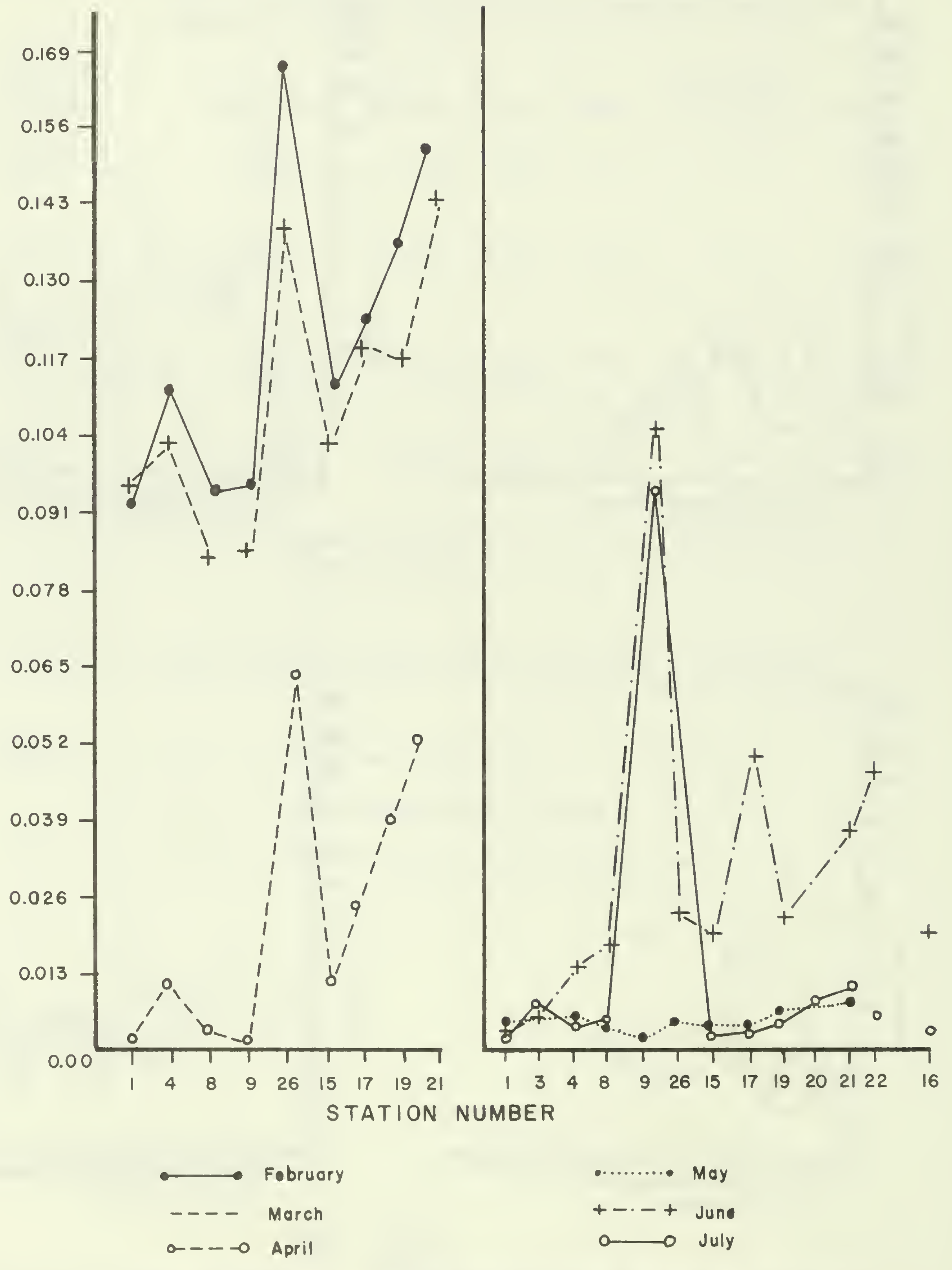


Turbidity Levels at Selected Stations on Abrams and Mill Creeks

Turbidity Levels at Selected Stations on Abrams Creek Tributaries

FIGURE 7

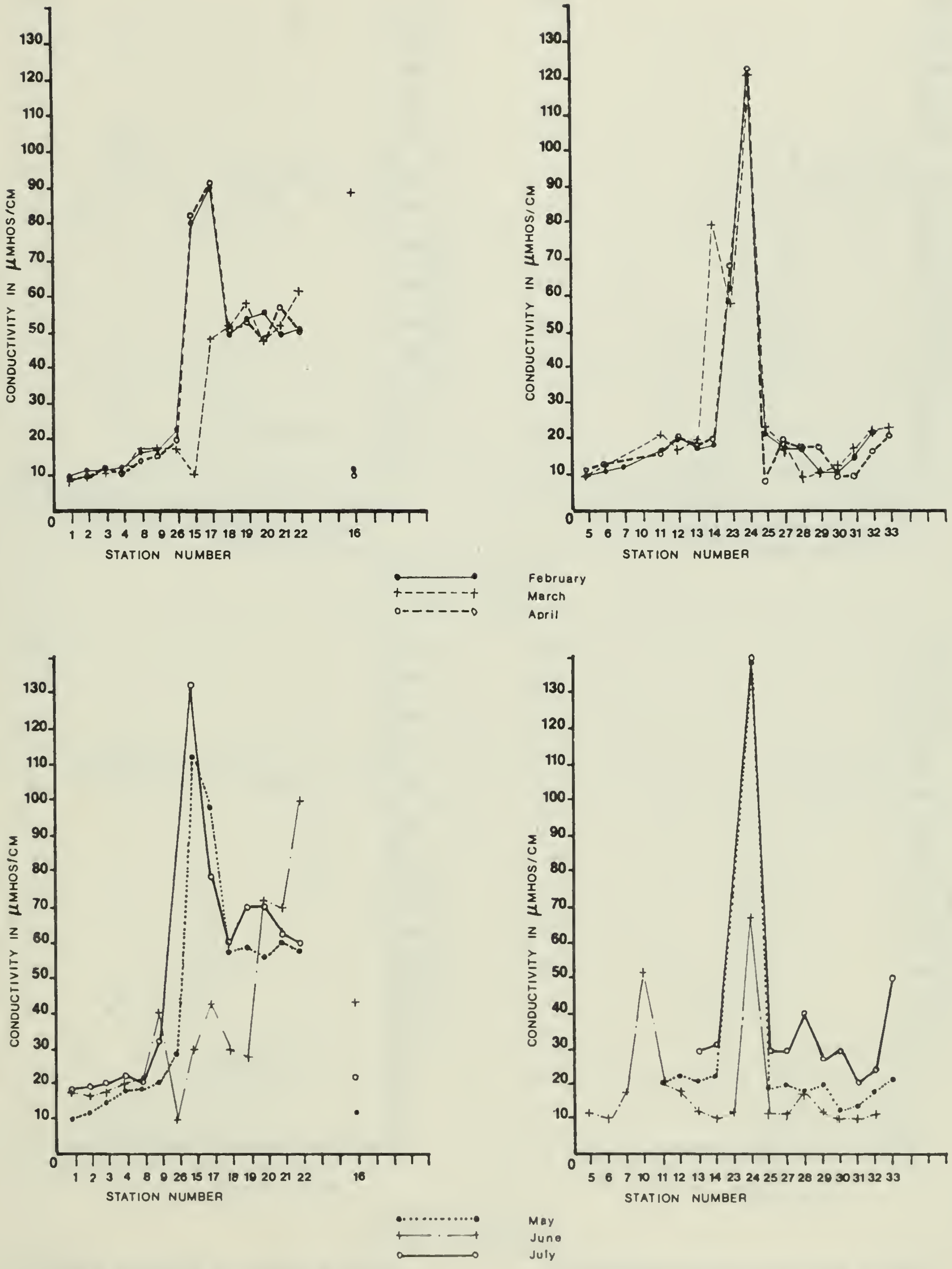
Suspended Solids



Suspended solids for Selected Stations on Abrams Creek (in mg/l)

FIGURE 8

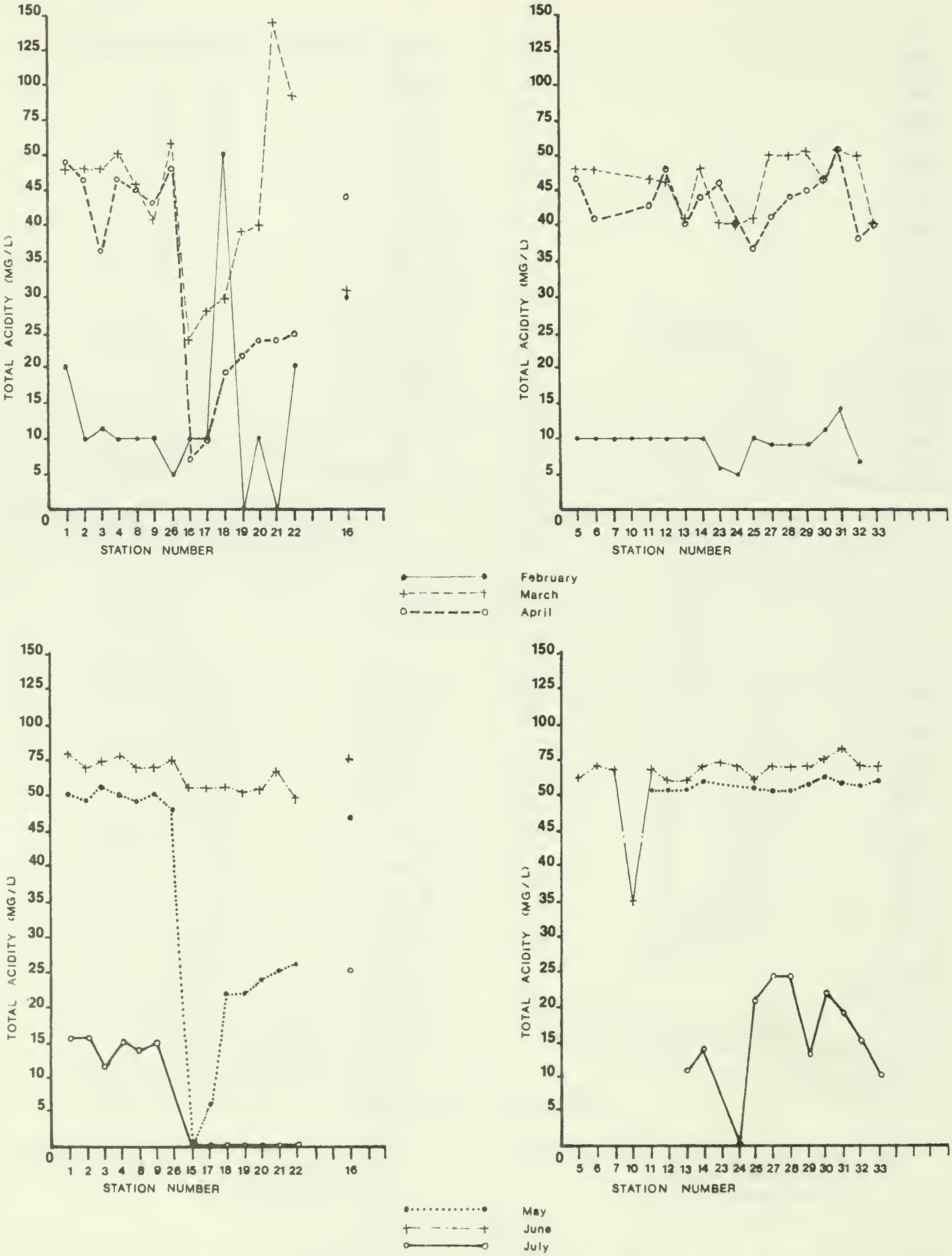
CONDUCTIVITY



Conductivity of Selected Stations on Abrams and Mill Creeks

Conductivity of Selected Stations on Abrams Creek Tributaries

FIGURE 9
TOTAL ACIDITY

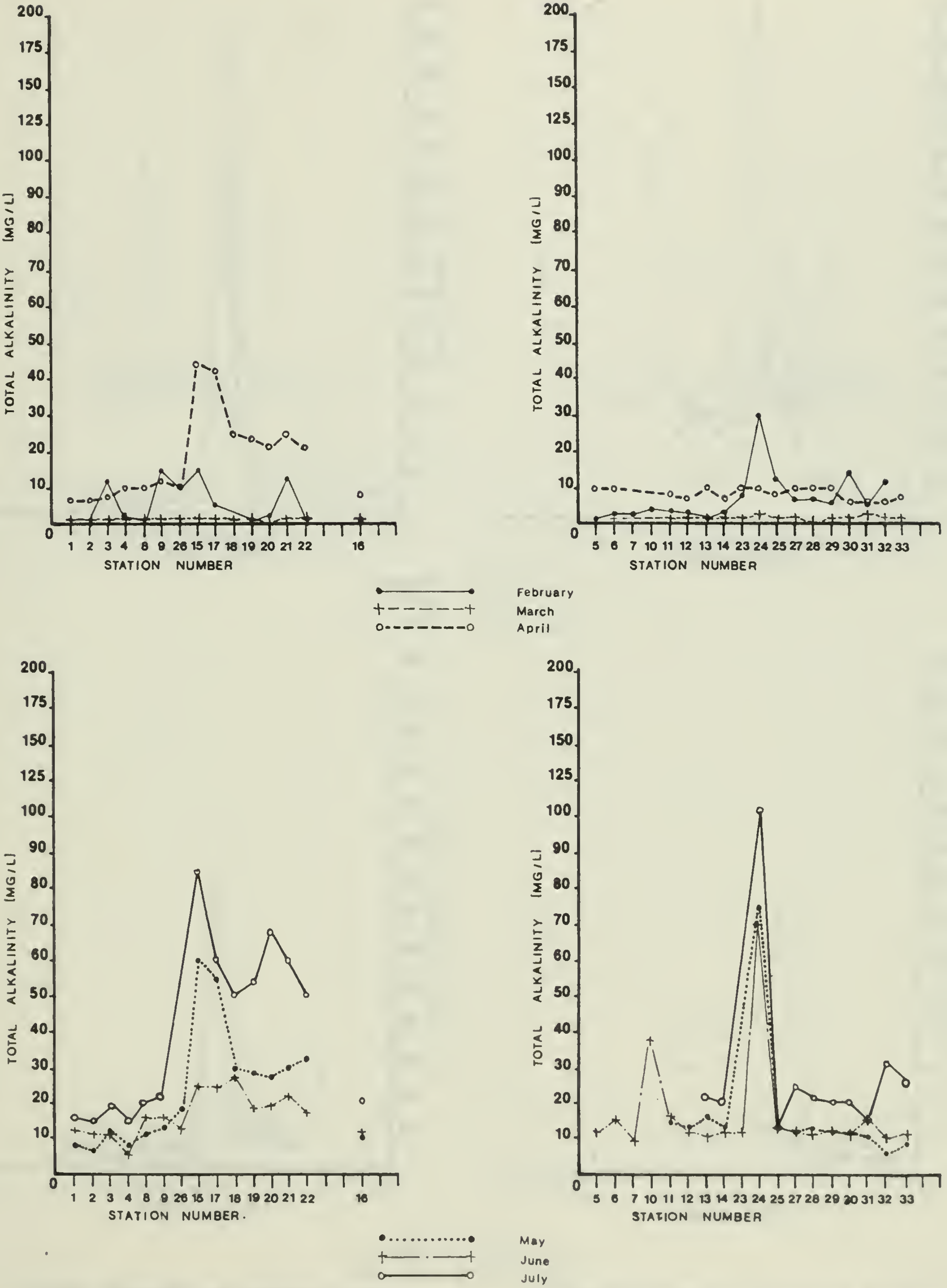


Total Acidity for Selected Stations on Abrams and Mill Creeks

Total Acidity for Selected Stations on Abrams Creek Tributaries

FIGURE 10

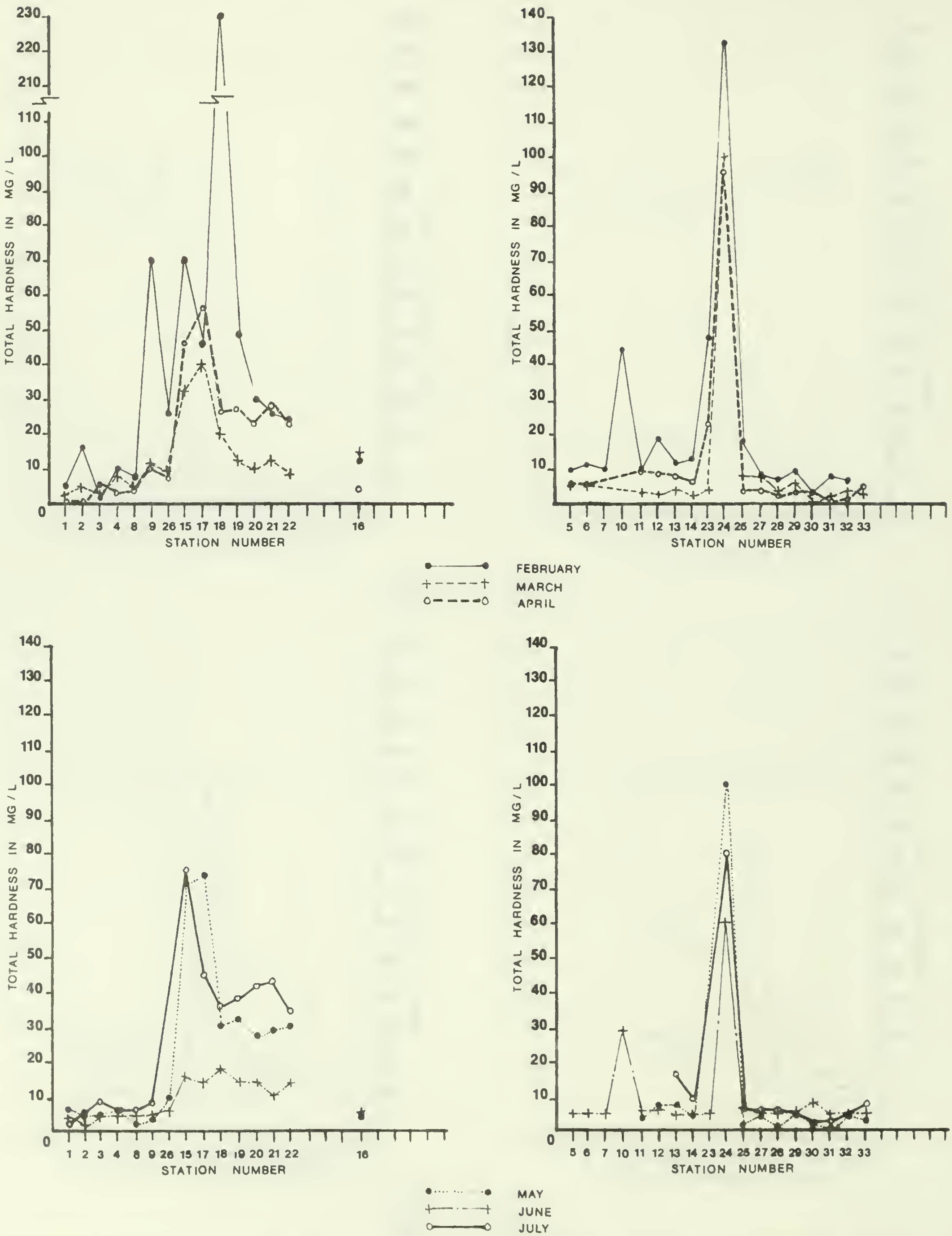
TOTAL ALKALINITY



Total Alkalinity for Selected Stations on Abrams and Mill Creeks

Total Alkalinity for Selected Stations on Abrams Creek Tributaries

FIGURE 11
Total Hardness

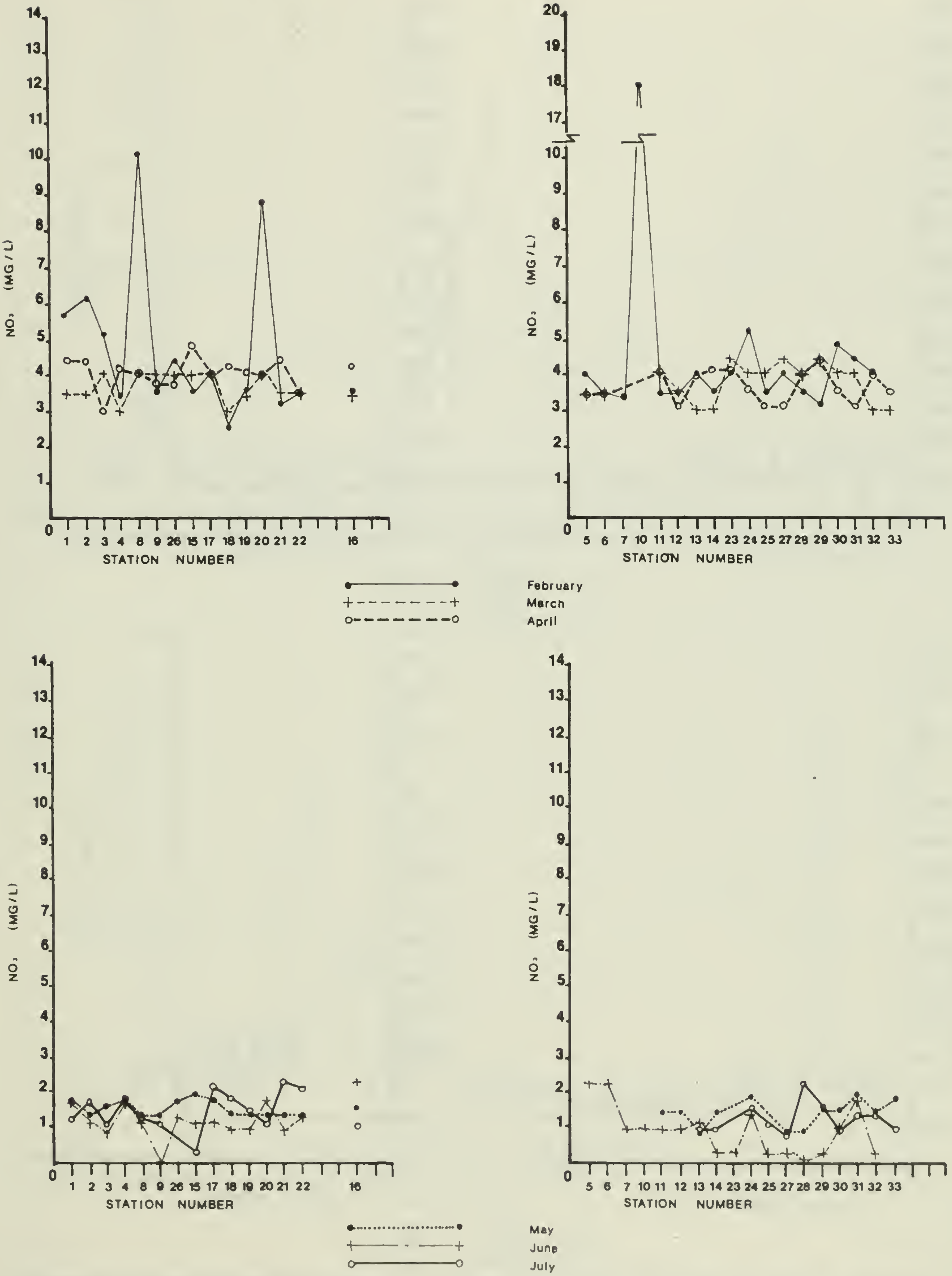


Total Hardness for Selected Stations on Abrams and Mill Creeks

Total Hardness for Selected Stations on Abrams Creek Tributaries

FIGURE 12

NITRATE (NO_3)

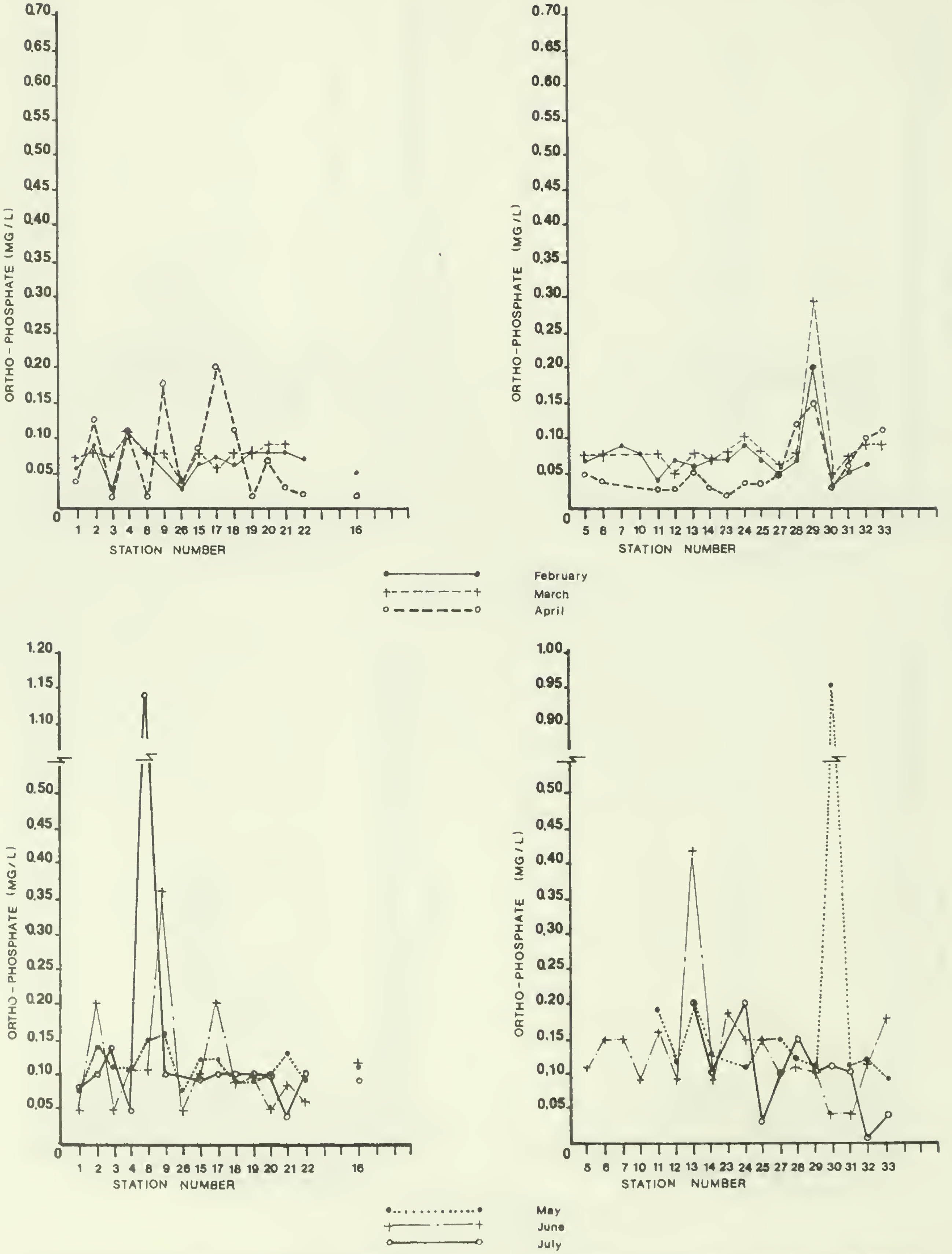


Nitrate Levels for Selected Stations on Abrams and Mill Creeks

Nitrate Levels for Selected Stations on Abrams Creek Tributaries

FIGURE 13

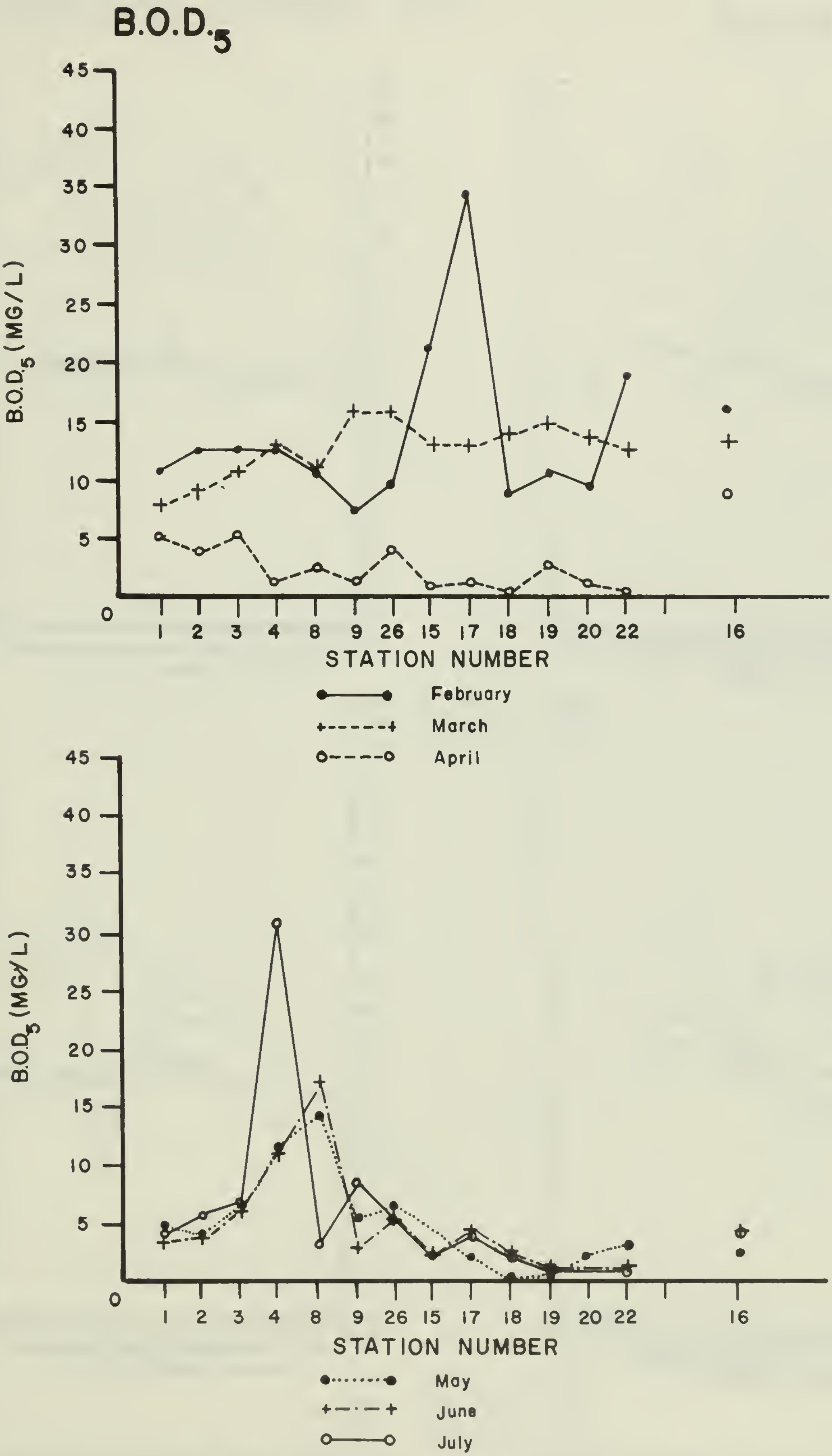
ORTHO-PHOSPHATE (PO_4)



Ortho-phosphate Levels for Selected Stations on Abrams and Mill Creeks

Ortho-phosphate Levels for Selected Stations on Abrams Creek Tributaries

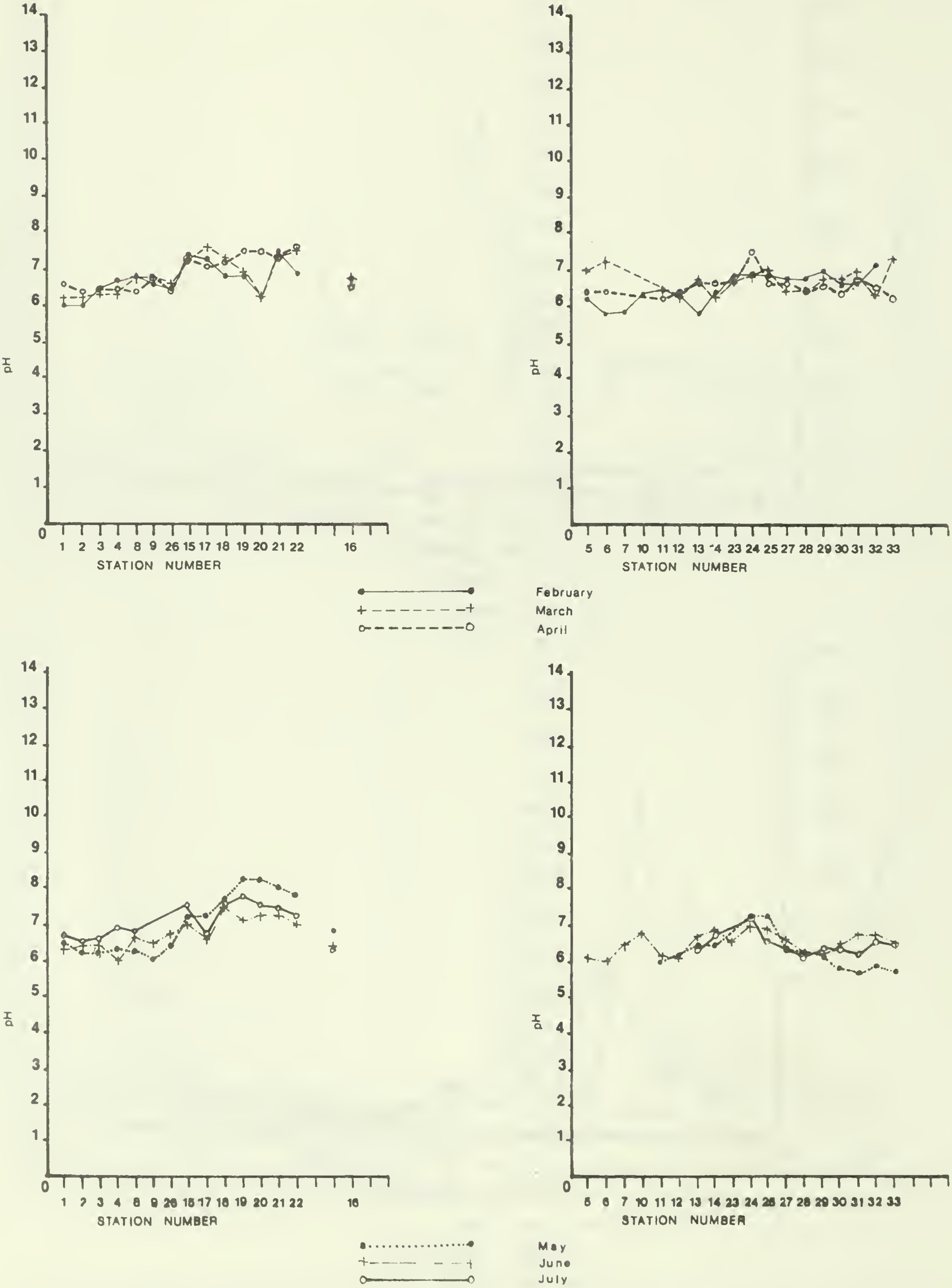
FIGURE 14



Biological Oxygen Demand for Selected Stations on Abrams and Mill Creeks

FIGURE 15

pH LEVELS

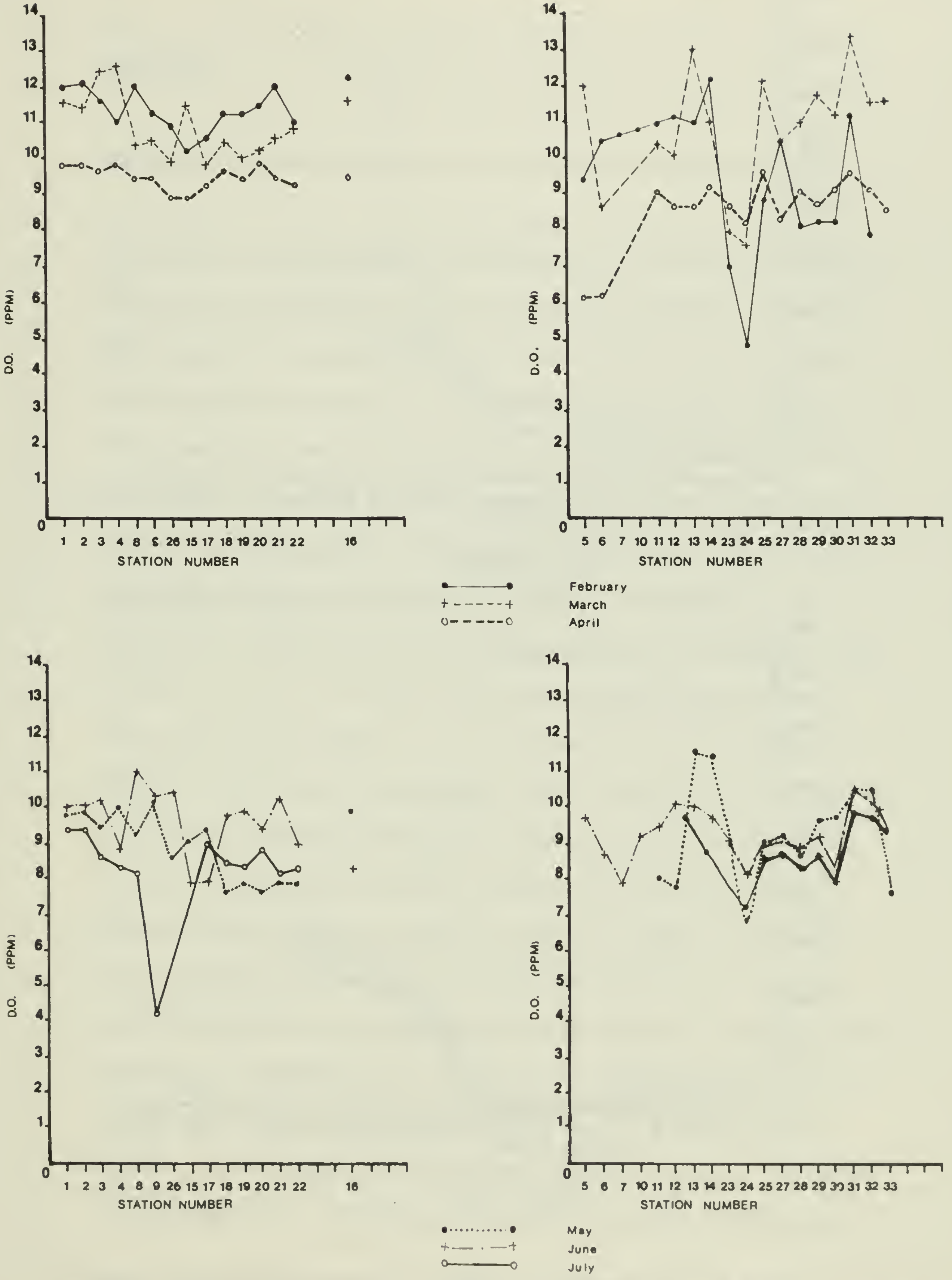


pH Levels for Selected Stations on Abrams and Mill Creeks

pH Levels for Selected Stations on Abrams Creek Tributaries

FIGURE 16

DISSOLVED OXYGEN (D.O.)

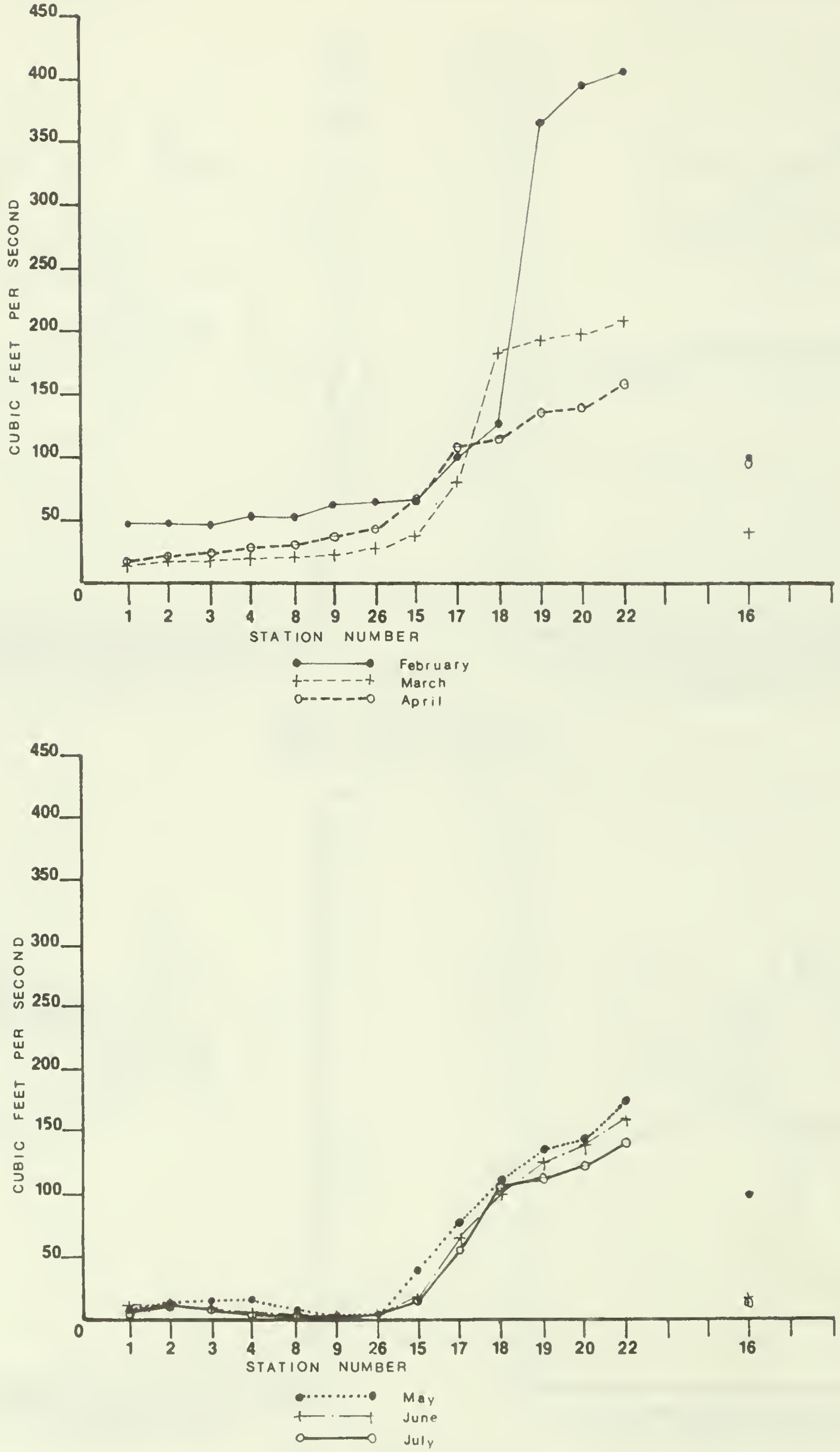


Dissolved O_2 at Selected Stations on Abrams and Mill Creeks

Dissolved O_2 at Selected Stations on Abrams Creek Tributaries

FIGURE 17

Volume Flow



Volume flow at Selected Stations of Abrams and Mill Creeks

Biological

Benthic Macroinvertebrate Distribution and Community Structure

The benthic macroinvertebrate population was represented by 95 taxa in Abrams and Mill Creeks during the combined sampling periods of 1974 and 1977: 54 taxa in 1974 and 91 in 1977. The macroinvertebrate community at reference zone stations during 1974 (station 1) and 1977 (stations 1 and 2) was characterized by an abundant fauna with a diverse assemblage of taxa representing the orders Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Collembola, Megaloptera, Odonata, Diptera, and Decapoda. In particular, pollution-sensitive Ephemeroptera and Plecoptera taxa (13 taxa in 1974, 21 taxa in 1977) were abundant and had high importance values (Tables 4 - 15, 20, and 21), with 11 taxa of mayflies and 10 taxa of stoneflies. But a reduction in the number of taxa representing these orders occurred at stations 9 and 26 in the stressed area (4 taxa in 1974; 16 taxa in 1977) which represent sites of Abrams Creek in Cades Cove where the greatest cattle activity and streambank erosion were observed. The importance (values) of pollution-tolerant Diptera at these stations increased by severalfold over that at the reference area stations during both years. The recovery stations, 17, 18, 19, and 20, however, showed marked increases over stressed areas in the number of taxa (Tables 4 - 9) and the importance of pollution-sensitive (organic) streambottom-dwelling organisms as represented by orders _Ephemeroptera_, _Plecoptera_, and _Trichoptera_ (Tables 10 - 15). The importance values of these pollution-sensitive orders tended to be greater in 1974 at stations 17 and 18, and in 1977 at station 19. Generally, the greatest standing crop (number and wet weight) of organisms and the number of taxa (S) was found in the recovery zone waters at stations 18 and 19 during both 1974 and 1977, with much higher values occurring for these parameters in 1977 than in 1974 (Tables 4 - 9 and 16).

Comparisons between station 15 and the control station (16) revealed fluctuating compositions in benthic community structure (Tables 4 - 15). There was a substantial increase in the standing crop for station 15 from 1974 to 1977, while station 16 showed only a slight increase in this regard.

The average values of the parameters used to examine the structure of the benthic macroinvertebrate community (Table 16) were relatively high in the reference area, indicating clean water conditions. In the stressed areas of Abrams Creek, the macrobenthic community was altered as indicated by depressed community structure values (especially number of taxa and diversity indices) (Table 16). In the recovery area, the community structure showed major increases in these values, reflecting the improved water quality. The most significant changes in benthic community structure and distribution from 1974 to 1977 were increases in the overall standing crop at most stations, relative abundance, and importance values of pollution-sensitive Plecoptera and moderately sensitive Trichoptera.

Similarities between benthic communities evaluated on an annual basis by use of the index of similarity (SI) revealed significant differences between the ecological areas sampled in 1974 and 1977 (Tables 17 and 18). Perhaps the best indicators are those comparing the cumulative indices for stations in the various areas. The SI between reference and stressed areas was only 0.14 in 1974, but increased to 0.38 in 1977; the SI between stressed and recovery areas was 0.11 in 1974 and 0.38 in 1977. The SI between stressed and control areas was 0.10 in 1974 and 0.43 in 1977. The SI between control and recovery areas was 0.19 in 1974 and 0.62 in 1977, which obviously indicates a much greater similarity of the areas during 1977. Also interesting to note is that the SI between stations 15 and 16 (control), the two stations comparatively analyzed as ecologically similar in regard to size and drainage area, increased from 0.59 in 1974 to 0.73 in 1977. Thus, substantial increases in the SI between all the ecological zones occurred from 1974 to 1977.

Statistical analyses of selected macroinvertebrate community parameters (Table 19) indicated that significant ($P < 0.05$) differences occurred between mean number of organisms per square meter for stations, seasons, and years; mean wet weight of organisms per square meter for stations and years; S for stations and seasons; $\bar{d}$ for stations and seasons; $\bar{H}$ for stations, seasons, and years; e' for seasons; and IV for stations and months. However, no significant differences ($P > 0.05$) existed between J or e for stations, seasons, or years.

Fish Distribution and Population Structure

Twelve species of fish were collected from Abrams Creek at stations 1, 8, 26, 17, 18, and 19 in 1977 (Table 22). They were categorized according to the economic classifications given by Lagler (1956) as to game, forage, or rough species. By assuming a density dependence between the trout and the other fish species, comparisons were made for abundances and biomasses between rainbow trout (the only game fish) and rough-forage fish, changes in the rainbow trout and rough-forage fish from upstream to downstream sampling stations, and changes between rainbow trout to changes in rough-forage fish populations between the surveys made at selected stations in 1973-74 and 1977 (Figs. 18 and 19; Tables 23 and 24). Since rainbow trout are sensitive to pollution, declines in their numbers and biomass were generally interpreted as being caused by declining water quality, although attention was also given to changes in fishing pressure. Removal of rainbow trout during periods of higher fishing pressure was not a factor of changes in water quality and thus was considered in intrepretations drawn from fish population surveys. Increases in the rough-forage fish populations were interpreted to indicate increased productivity through organic loading and thus decreased water quality. Silt and sediment, however, probably decreased their populations. Turbidity was generally higher in 1974 than 1977, coinciding with a reduction in cattle from 1,200 to 500 head. The level of silt and sediment may also have been much greater in 1974 than in 1977. This could have influenced the entire fish population in 1974, probably by decreasing numbers and biomass.

The entire fishery was increased in numbers (fish per acre) and biomass (pounds per acre) from 1973-74 to 1977 (Figs. 18A and 19A). The relative abundance and biomass of rainbow trout (Rt) compared to that of the combined composition of rough/forage fish (R/F) showed a decline in Rt from the upstream reference area (station 1) to stressed areas in the cove (stations 8 and 26), with subsequent increases in this relation in downstream recovery areas (stations 17, 18, and 19) below the Cove during both surveys (1973-74 and 1977) as shown in Figures 18A and 19A. The basic trend was relatively high numbers (fish per acre) and biomass (pounds per acre) of Rt in the reference area, declining in stressed areas to small population levels and again increasing in the recovery area to similar levels as at the reference area. No Rt were found at station 26 in the Cove (Figs. 18B and 19B).

The abundance of fishes between 1973-74 and 1977 changed in several ways: a drastic decrease in Rt and slight increase in the R/F composition from station 1 to 8; a total depletion of Rt and drastic increase in R/F at station 26; a reoccurrence of Rt at station 17 and decrease in R/F; a decline in both Rt and R/F at station 18; and an increase in Rt at station 19 with no substantial change in the R/F composition (Fig. 18C). Biomass composition changes (Fig. 19C) indicated somewhat different proportions, reflecting differences between number and weight in the fish population structure. In this regard, there was a decrease in Rt biomass from stations 1 to 8, although not as drastic as the decline in abundance, and the R/F biomass slightly increased. At station 26 there were no Rt and the R/F biomass moderately increased. Rainbow trout reoccurred at station 26. A small decrease in Rt and slight decrease in R/F biomass occurred at Station 18. However, at station 19, while the Rt biomass increased in roughly the same proportion as abundance, the biomass of R/F declined sharply.

Black spot (black grubs) cysts were prevalent on fish of all species at stations sampled in Cades Cove. No incidence of this

Table 4. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - APRIL 1974

		Mean		Diversity		Equitibility		Evenness	Redundancy	Dominant Taxa		
Sta. No.	Mean No. per m^2	Wet Wt. (mg/m^2)	No. of Taxa (S)	$\bar{d}$	$\bar{H}$	e	e'	$\bar{J}$	R	IR	Taxon	IV
2	635.08	2.69	20	2.96	2.50	0.79	0.54	0.68	0.60	1	*Epeorus*	48.27
										2	*Ephemerella*	41.09
										3	*Stenonema*	14.99
26	59.20	0.05	5	2.09	1.30	1.14	0.61	0.60	1.00	1	*Chironomidae*	57.07
										2	*Ephemerella*	49.49
										3	*Chrysmura*	41.41
15	150.70	1.61	28	3.13	2.22	1.22	0.60	0.68	0.76	1	*Tipula*	84.79
										2	*Agapetus*	16.22
										3	*Antiocha*	15.87
17	393.96	2.37	28	2.61	2.09	0.97	0.64	0.65	0.66	1	*Optioservus*	33.34
										2	*Acroneuria*	26.29
										3	*Pseudocloeon*	17.93
18	1,729.45	14.32	31	3.00	2.76	0.59	0.49	0.67	0.60	1	*Epeorus*	27.06
										2	*Cheumatopsyche*	26.68
										3	*Hydropsyche*	25.33
19	1,194.80	8.07	19	3.09	2.75	0.59	0.43	0.64	0.61	1	*Ephemerella*	52.91
										2	*Stenonema*	31.54
										3	*Cambarus*	29.63
16	661.99	3.77	22	3.26	2.80	0.81	0.56	0.71	0.55	1	*Chrysmura*	46.25
										2	*Epeorus*	32.16
										3	*Stenonema*	20.76

Table 5. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - JULY 1974

				Diversity		Equitibility		Evenness	Redundancy	Dominant Taxa		
Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	$\bar{d}$	$\bar{H}$	e	e'	J	R	IR	Taxon	IV
2	75.35	0.54	6	1.66	1.14	1.06	0.70	0.63	0.71	1	*Stenonema*	108.78
										2	*Ephemerella*	39.67
										3	*Leuctra*	18.28
26	21.53	0.22	2	1.00	0.50	1.10	0.74	0.50	1.00	1	Unid. Olig.	141.49
										2	*Caenis*	58.51
										3	--	--
15				- - - - - NO DATA - - - - -								
17	731.95	2.69	17	1.83	1.52	0.78	0.60	0.58	0.82	1	*Cheumatopsyche*	43.68
										2	*Isonychia*	43.28
										3	*Hydropsyche*	30.56
18	610.00	2.15	25	2.99	2.55	0.85	0.59	0.70	0.55	1	*Ephemerella*	39.91
										2	*Baetis*	37.64
										3	*Paragnetina*	18.76
19	1,158.96	6.14	27	2.96	2.64	0.74	0.56	0.68	0.57	1	*Isonychia*	46.69
										2	*Ephemerella*	45.45
										3	*Peltoperla*	33.16
16	258.34	0.75	16	2.72	2.15	0.98	0.61	0.68	0.58	1	*Ephemerella*	45.67
										2	*Pseudocloeon*	28.87
										3	*Glossosoma*	26.88

Table 6. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - FEBRUARY 1977

		Mean		Diversity		Equitibility		Even-ness	Redun-dancy	Dominant Taxa		
Sta. No.	Mean No. per m^2	Wet Wt. (mg/m^2)	No. of Taxa(S)	$\bar{d}$	$\bar{H}$	e	e'	J	R	IR	Taxon	IV
1	972.31	5.38	30	3.02	2.55	0.74	0.49	0.64	0.60	1	*Rhithrogena*	56.75
										2	*Pteronarcys*	49.12
										3	*Acroneuria*	15.57
2	800.09	7.86	28	3.34	2.88	0.88	0.59	0.72	0.51	1	*Iron*	49.40
										2	*Pteronarcys*	28.18
										3	*Ephemerella*	22.38
8	918.49	4.31	32	3.29	2.92	0.79	0.59	0.71	0.54	1	*Psephenus*	39.05
										2	*Eriocera*	18.84
										3	*Chironomidae*	15.06
9	2,012.87	6.78	21	2.54	2.34	0.56	0.47	0.62	0.65	1	*Simuliidae*	63.63
										2	*Tipula*	38.79
										3	*Allocapnia*	19.62
26	1,697.16	2.91	14	1.58	1.46	0.44	0.40	0.48	0.78	1	*Allocapnia*	82.82
										2	*Tipula*	49.22
										3	*Chironomidae*	31.30
15	1,571.54	21.21	29	3.10	2.85	0.54	0.60	0.71	0.57	1	*Cambarus*	44.57
										2	*Goniobasis*	30.39
										3	*Stenonema*	28.85
17	581.26	3.98	23	3.06	2.56	0.90	0.60	0.71	0.55	1	*Hydropsyche*	50.99
										2	*Stenonema*	49.37
										3	*Isoperla*	25.13

Table 6. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - FEBRUARY 1977 - Cont.

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
18	1,700.71	15.07	21	3.33	3.09	0.83	0.69	0.77	0.52	1	*Goniobasis*	76.52
										2	*Baetis*	20.85
										3	*Chironomidae*	18.29
19	1,585.86	14.75	32	3.25	2.91	0.79	0.59	0.72	0.54	1	*Cambarus*	50.91
										2	*Chironmidae*	29.91
										3	*Cheumatopsyche*	21.32
20	780.39	2.69	23	2.54	2.22	0.70	0.54	0.66	0.63	1	*Chironmidae*	39.89
										2	*Chauliodes*	30.61
										3	*Cheumatopsyche*	24.97
16	764.24	6.46	21	3.80	3.26	0.93	0.61	0.74	0.48	1	*Psephenus*	34.45
										2	*Chauliodes*	26.38
										3	*Chironomidae*	26.24

Table 7. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - MARCH 1977

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
1	427.01	4.63	25	3.15	2.61	0.91	0.59	0.71	0.55	1	*Pteronarcys*	51.47
										2	*Iron*	23.83
										3	*Simuliidae*	16.51
2	444.55	4.31	27	3.34	2.64	1.08	0.62	0.72	0.65	1	*Acroneuria*	33.12
										2	*Chironomidae*	21.94
										3	*Iron*	19.77
8	850.36	10.01	35	3.48	3.01	0.94	0.65	0.75	0.49	1	*Stenonema*	25.64
										2	*Tipula*	17.59
										3	*Longurio*	17.27
9	269.10	0.11	20	3.07	2.39	1.03	0.61	0.70	0.57	1	*Isogenus*	33.69
										2	*Tipola*	29.23
										3	*Stenonema*	29.15
26	71.80	0.32	9	1.93	1.27	1.07	0.64	0.61	0.84	1	*Stenonema*	63.02
										2	*Simuliidae*	35.32
										3	*Glossosoma*	24.59
15	925.70	22.93	21	2.59	2.32	0.78	0.64	0.69	0.60	1	*Cambarus*	40.32
										2	*Hydropysche*	28.89
										3	*Tipula*	20.55
17	1,054.86	24.00	36	3.62	3.14	0.86	0.57	0.72	0.50	1	*Cambarus*	54.96
										2	*Cheumatopsyche*	22.45
										3	*Hydropsyche*	19.53

Table 7. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - MARCH 1977 - Cont.

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
18	1,015.37	8.93	32	3.47	3.08	0.81	0.59	0.73	0.52	1	*Epeorus*	22.50
										2	*Orconectes*	20.56
										3	*Acroneuria*	18.86
19	3,878.59	14.32	35	2.67	2.23	0.80	0.52	0.63	0.62	1	*Cheumatopsyche*	74.92
										2	*Goniobasis*	36.49
										3	*Isoperla*	21.09
20				- - - - - NO DATA - - - - -								
16	301.39	5.06	20	2.82	2.28	0.94	0.62	0.70	0.57	1	*Pteronarcys*	59.90
										2	*Isoperla*	30.39
										3	*Glossosoma*	21.11

Table 8. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - MAY 1977

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	IR	Taxon	IV
1	39.50	1.08	10	1.64	0.94	1.17	0.66	0.55	1.00	1	Unid. Odonata	80.40
										2	*Tipula*	29.00
										3	*Cheumatopsyche*	19.03
2	624.31	7.00	21	3.33	2.83	0.87	0.58	0.71	0.53	1	*Stenonema*	56.72
										2	*Pycnopsyche*	29.77
										3	*Cambarus*	29.16
8	629.69	1.80	15	2.77	2.37	0.78	0.57	0.68	0.61	1	*Ephemerella*	52.65
										2	Unid. Olig.	29.00
										3	*Hydropsyche*	17.61
9	775.01	5.38	12	2.60	2.18	0.72	0.50	0.63	0.66	1	*Tipula*	76.17
										2	*Stenonema*	60.91
										3	*Chironomidae*	45.83
26	519.36	5.70	11	2.01	1.98	0.61	0.50	0.57	0.72	1	*Baetis*	93.75
										2	*Tipula*	90.94
										3	*Chironomidae*	42.83
15	950.78	88.26	14	3.07	2.73	0.80	0.61	0.71	0.55	1	*Cambarus*	82.23
										2	*Hydropsyche*	34.15
										3	*Stenonema*	15.11
17	1,135.60	27.45	30	3.22	2.93	0.75	0.57	0.71	0.56	1	*Cambarus*	72.89
										2	*Baetis*	19.79
										3	*Ephemerella*	18.77

Table 8. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - MAY 1977 - Cont.

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
18	1,399.32	29.33	20	2.78	2.50	0.66	0.53	0.65	0.64	1	*Tipulidae*	81.18
										2	*Goniobasis*	78.86
										3	*Ephemerella*	35.74
19	606.34	28.74	20	2.74	2.22	0.87	0.56	0.67	0.63	1	*Cambarus*	71.24
										2	*Ephemerella*	29.61
										3	*Arthripsodes*	24.81
20	775.01	3.98	19	2.02	1.78	0.49	0.41	0.53	0.74	1	*Cheumatopsyche*	59.57
										2	*Ephemerella*	38.78
										3	*Hydropsyche*	32.04
16	907.73	17.98	25	2.86	2.50	0.67	0.51	0.66	0.63	1	*Tipula*	67.96
										2	*Baetis*	42.15
										3	*Ephermerella*	23.71

Table 9. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - JULY 1977

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa (S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
1	247.57	7.05	13	2.30	1.79	0.98	0.66	0.67	0.66	1	*Cambarus*	98.99
										2	*Stenonema*	70.16
										3	*Polycentropus*	33.80
2	290.63	1.08	10	2.40	1.98	0.94	0.67	0.71	0.58	1	*Tipula*	76.46
										2	*Stenonema*	32.67
										3	*Allocapnia*	30.79
8	556.18	10.44	20	2.34	2.05	0.81	0.65	0.68	0.67	1	*Goniobasis*	86.00
										2	*Chironomidae*	29.37
										3	*Leuctra*	14.99
9	846.80	1.08	12	0.97	0.82	0.45	0.39	0.34	0.89	1	*Cambarus*	112.67
										2	Unid. Olig.	41.51
										3	*Tipula*	15.07
26				- - - - - NO DATA (DRY) - - - - -								
15	399.61	26.26	15	2.52	2.16	0.79	0.59	0.66	0.62	1	*Cambarus*	110.78
										2	*Orconectes*	74.64
										3	*Chironmidae*	55.66

Table 9. Summary of Benthic Macroinvertebrate Community Analyses for Collections at Each Sampling Station from Abrams and Mill Creeks - JULY 1977 - Cont.

Sta. No.	Mean No. per m^2	Mean Wet Wt. (mg/m^2)	No. of Taxa(S)	Diversity $\bar{d}$	Diversity $\bar{H}$	Equitibility e	Equitibility e'	Evenness J	Redundancy R	Dominant Taxa IR	Dominant Taxa Taxon	Dominant Taxa IV
17	703.21	53.07	26	3.29	2.85	0.87	0.62	0.72	0.52	1	*Cambarus*	97.79
										2	*Chironomidae*	27.74
										3	*Stenonema*	11.31
18	1,194.80	17.76	23	3.21	2.68	1.02	0.67	0.73	0.63	1	*Cabarus*	43.58
										2	*Goniobasis*	25.94
										3	*Baetis*	21.56
19	1,062.08	18.30	28	3.32	2.99	0.92	0.71	0.77	0.50	1	*Goniobasis*	51.20
										2	*Cambarus*	29.86
										3	*Hydropsyche*	27.97
20	430.56	200.96	22	3.12	2.56	1.03	0.66	0.73	0.51	1	*Cambarus*	90.49
										2	*Stenonema*	22.48
										3	*Ephemera*	13.15
16	309.47	0.59	11	3.12	2.36	1.15	0.64	0.72	0.51	1	*Acroneuria*	53.37
										2	*Cambarus*	29.27
										3	*Baetis*	21.31

Table 10. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
APRIL 1974

Taxon	Station Number						
	Abrams Creek						Mill Creek
	2	26	15	17	18	19	16
Annelida			3.91	0.61			
Coleoptera	1.06		3.82	9.83	2.92	5.12	25.20
Collembola							
Decapoda				24.36	9.21	4.77	
Diptera	29.95	89.39	107.02	20.51	22.18	1.11	2.58
Ephemeroptera	126.44	110.61	40.68	93.80	87.86	120.07	126.15
Lepidoptera				2.11		18.94	
Megaloptera			3.88				
Planaria							
Hemiptera							
Hirudinea							1.54
Gastropoda							
Odonata				27.41	20.97	8.96	18.27
Plecoptera	24.35						26.26
Trichoptera	18.20		40.69	21.37	56.86	41.03	

Table 11. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
JULY 1974

Taxon	Station Number						
	Abrams Creek						Mill Creek
	2	26	15	17	18	19	16
Annelida	15.25	141.49		2.13	3.21		
Coleoptera				1.38	4.91	5.67	11.27
Collembola							
Decapoda				3.53	13.52	6.30	
Diptera				7.61	4.17	5.14	15.76
Ephemeroptera	157.96	58.51		71.01	118.04	109.52	108.50
Lepidoptera							
Megaloptera				19.76		3.21	
Planaria							
Hemiptera							
Hirudinea							
Gastropoda				15.76	1.11	0.54	
Odonata							
Plecoptera	18.28			3.61	34.65	48.79	29.02
Trichoptera	8.51			75.21	20.39	20.82	35.40

Table 12. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
FEBRUARY 1977

Taxon	Station Number										
	Abrams Creek										Mill Creek
	1	2	8	9	26	15	17	18	19	20	16
Annelida	1.96		0.45	0.67	0.35	2.02	3.62	7.66	3.33	10.98	3.32
Coleoptera	8.84		39.42	1.71		1.82	8.85	2.51	5.94	4.34	36.31
Collembola			5.49								
Decapoda			5.92			3.28			50.93		
Diptera	28.18	42.68	46.76	116.26	108.49	23.06	26.67	25.40	44.79	50.97	28.14
Ephemeroptera	54.39	88.15	42.49	18.00	3.34	78.63	86.40	40.63	32.17	36.16	40.20
Lepidoptera											
Megaloptera						0.30			2.13	30.61	22.99
Planaria											
Hemiptera											
Hirudinea											
Gastropoda	0.50					48.74	3.80	76.39	4.53	5.02	1.27
Odonata			0.43								1.88
Plecoptera	98.78	59.52	42.05	41.23	83.93	3.51	32.40	11.07	12.92	17.09	48.11
Trichoptera	7.34	9.65	16.99	22.13	3.89	38.64	38.26	36.34	43.26	44.83	17.78

Table 13. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
MARCH 1977

Taxon	Station Number										
	Abrams Creek										Mill Creek
	1	2	8	9	26	15	17	18	19	20	16
Annelida	3.23	7.71	20.03	1.75	4.50	10.59	4.97	11.24	1.76		10.64
Coleoptera	0.89		14.67	1.98		0.46	7.31	3.76	9.01		4.82
Collembola						62.03	49.10	20.17			
Decapoda	2.13	2.82									
Diptera	32.23	45.10	40.44	63.57	35.48	40.28	19.83	25.32	24.67		27.94
Ephemeroptera	51.70	49.57	63.56	67.94	94.91	28.19	52.38	53.55	38.98		37.91
Lepidoptera											
Megaloptera			7.98	1.49			0.47	11.52			
Planaria											
Hemiptera											
Hirudinea						0.52	5.91	10.23	30.07		
Gastropoda				1.52							
Odonata							0.40				
Plecoptera	96.42	72.19	21.63	48.07	45.78	0.98	9.55	28.91	19.96	100.84	
Trichoptera	13.40	22.61	34.69	13.68	19.33	56.95	50.08	37.29	75.55	17.85	

Table 14. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
MAY 1977

Taxon	Station Number										
	Abrams Creek										Mill Creek
	1	2	8	9	26	15	17	18	19	20	16
Annelida	7.15	12.32	36.02	5.83		6.85	3.91	3.78		9.39	4.76
Coleoptera	3.06	1.41	14.69	1.71	0.96		6.94	8.89	1.38	2.60	10.17
Collembola						21.09					
Decapoda		38.06				71.36	77.51	4.51	71.26		
Diptera	37.68	80.99	16.61	111.56	123.60	22.22	22.64	79.72	10.21	7.29	1.31
Ephemeroptera	65.42	15.87	96.25	51.78	45.13	29.05	54.29	52.56	36.18	47.51	140.46
Lepidoptera											
Megaloptera						0.42	3.80	0.53			12.41
Planaria											
Hemiptera											
Hirudinea											
Gastropoda			6.02			1.58	4.67	19.82	16.20	6.71	1.08
Odonata	26.43				2.72						
Plecoptera	33.91	18.64	5.70	18.88	16.16	2.06	12.43	17.09	3.59	124.90	0.81
Trichoptera	26.35	34.71	24.71	10.24	11.43	45.37	13.81	23.10	61.18		29.00

Table 15. Importance Values for Major Taxa Collected at Each Station from Abrams and Mill Creeks.
JULY 1977

Taxon	Station Number										
	Abrams Creek										Mill Creek
	1	2	8	9	26	15	17	18	19	20	16
Annelida	4.62	0.98	41.51			5.53	5.28	4.58	6.99	7.54	3.04
Coleoptera	2.83	4.95	7.13				44.22	5.46	9.11	7.26	17.03
Collembola											
Decapoda	104.06	22.61				99.19	35.65	44.58	29.75	90.21	29.27
Diptera	30.17	77.04	27.98	130.38		22.70	12.57	5.15	10.45	11.40	6.30
Ephemeroptera	30.22	33.29	19.26	11.27		54.72	58.88	52.45	33.38	49.65	33.26
Lepidopyera											
Megaloptera		4.50		1.15		1.20	3.83	4.36	4.89	1.65	7.89
Planaria											
Hemiptera										1.64	
Hirudinea											
Gastropoda		96.80				1.20		22.94	50.98	2.93	
Odonata								0.49		1.76	
Plecoptera	15.22	41.22	19.03			6.05	5.32	22.20	20.78	16.77	90.70
Trichoptera	20.33	19.87	31.00	8.56		9.41	34.25	37.79	33.66	9.19	12.60

Table 16. Ranges (R) and averages ($\bar{x}$) of Benthic Macroinvertebrate Community Analysis for Collections of Ecological Zones from Abrams and Mill Creeks - 1974 and 1977

Ecological Zone	Year	Standing Crop: Mean No. per m^2	Standing Crop: Mean Wet Weight (mg/m^2)	No. of Taxa (S)	Diversity: $\bar{d}$	Diversity: $\bar{H}$	Equatability: e	Equatability: e'	Evenness: J	Redundancy: R
Reference (Stations 1, 2)										
R	'74	75.35-635.08	0.54-2.69	6-20	1.66-2.96	1.14-2.50	0.79-1.06	0.54-0.70	0.63-0.68	0.60-0.70
X		355.21	1.62	13	2.31	1.82	0.93	0.62	0.66	0.66
R	'77	39.50-972.31	1.08-7.86	10-30	1.64-3.34	0.94-2.88	0.74-1.17	0.49-0.67	0.55-0.72	0.51-1.00
X		480.75	4.80	21	2.82	2.28	0.95	0.61	0.68	0.64
R	Both	39.50-972.31	0.54-7.86	6-30	1.64-3.34	0.94-2.88	0.74-1.17	0.49-0.70	0.55-0.72	0.51-1.00
X		455.64	4.16	19	2.71	2.19	0.94	0.61	0.67	0.64
Stressed (Stations 8, 9, 26, 15)										
R	'74	21.53-150.70	0.05-1.61	2-28	1.00-3.13	0.50-2.22	1.10-1.22	0.74-1.61	0.50-0.68	0.76-1.00
X		77.14	0.63	12	2.07	1.34	1.15	0.98	0.59	0.92
R	'77	71.80-2,012.87	0.11-88.26	9-35	0.97-3.48	0.82-3.01	0.45-1.07	0.39-0.65	0.34-0.75	0.49-0.89
X		866.30	13.83	19	2.52	2.19	0.74	0.56	0.64	0.60
R	Both	21.53-2,012.87	0.05-8826	2-35	0.97-3.48	0.50-3.01	0.45-1.22	0.39-1.61	0.34-0.75	0.49-1.00
X		734.77	11.63	18	2.45	2.05	0.81	0.63	0.63	0.65

Table 16. Ranges (R) and averages ($\bar{x}$) of Benthic Macroinvertebrate Community Analysis for Collections of Ecological Zones from Abrams and Mill Creeks - 1974 and 1977 - Cont.

Ecological Zone	Year	Standing Crop: Mean No. per m	Standing Crop: Mean Wet Weight (mg/m)	No. of Taxa (S)	Diversity: $\bar{d}$	Diversity: $\bar{H}$	Equatability: e	Equatability: e'	Evenness: J	Redundancy: R
Recovery (Stations 17, 18, 19, 20)										
R	'74	393.96-1,729.45	2.15-14.32	17-31	1.83-3.09	1.52-2.76	0.59-0.97	0.43-0.64	0.58-0.70	0.55-0.82
X		969.86	5.96	25	2.75	2.39	0.75	0.55	0.65	0.64
R	'77	430.56-3,878.59	2.98-53.07	19-36	2.02-3.67	1.78-3.14	0.59-1.03	0.41-0.71	0.53.0.77	0.50-0.74
X		1,141.54	19.29	26	3.04	2.65	0.82	0.59	0.70	0.57
R	Both	393.96-3,878.59	2.15-53.07	17-36	1.83-3.67	1.52-3.14	0.59-1.03	0.41-0.71	0.53-0.77	0.50-0.82
X		1,129.67	15.48	26	2.96	2.57	0.80	0.58	0.68	0.59
Control (Station 16)										
R	'74	258.34-661.99	0.75-3.77	16.22	2.72-3.26	2.15-2.80	0.81-0.98	0.56-0.61	0.68-0.71	0.55-0.58
X		460.49	2.26	19	2.99	2.48	0.90	0.59	0.70	0.57
R	'77	301.39-907.73	0.59-17.98	11-25	2.82-3.89	2.28-3.26	0.67-1.15	0.51-0.64	0.66-0.74	0.48-0.63
X		570.71	7.52	19	3.15	2.60	0.92	0.60	0.71	0.55
R	Both	258.34-907.73	0.59-17.98	11-25	2.72-3.80	2.15-2.80	0.67-1.15	0.51-0.69	0.66-0.74	0.48-0.63
X		533.86	5.77	19		2.55	0.91	0.59	0.70	0.55

Table 17. Similarity Indices (SI) between Benthic Communities, Abrams Creek, April thru July, 1974.

Stations Compared	*Ecological Areas Compared	Similarity Index (SI)
2/26	R/S	0.66
2/15	R/S	0.35
2/17	R/S	0.64
2/16	R/C	0.53
26/15	S/S	0.31
15/16	S/C	0.59
16/17	C/S	0.53
17/18	S/R^1	0.91
18/19	R^1/R^1	0.95
2/26, 15, 17	R/S	0.14
2/18, 19	R/R^1	0.41
26, 15, 17/18, 19	S/R^1	0.11
26, 15, 17/16	S/C	0.10
18, 19/16	R^1/C	0.19

*R (Reference), S (Stressed), R^1 (Recovery), C (Control)

Table 18. Similarity Indices (SI) between Benthic Communities, Abrams Creek, February thru July, 1977

Stations Compared	Ecological Areas Compared*	Similarity Index (SI)
1/2	R/R	0.81
1/8	R/S	0.73
1/9	R/S	0.69
1/18	R/R^1	0.69
1/20	R/R^1	0.67
1/16	R/C	0.72
2/8	R/S	0.77
2/15	R/S	0.73
2/17	R/S	0.74
2/26	R/S	0.65
8/9	S/S	0.70
9/26	S/S	0.67
26/15	S/S	0.57
15/16	S/C	0.73
16/17	C/S	0.83
17/18	S/R	0.78
18/19	R^1/R^1	0.72
19/20	R^1/R^1	0.73
20/16	R^1/C	0.66
1, 2/8, 9, 26, 15, 17	R/S	0.38
1, 2/18, 19, 20	R/R^1	0.50
1, 2/16	R/C	0.60
8, 9, 26, 15, 17/18, 19, 20	S/R^1	0.38
8, 9, 26, 15, 17/16	S/C	0.43
18, 19, 20/16	R^1/C	0.62

*R (Reference), S (Stressed), R (Recovery), C (Control)

Table 19. Analysis of Variance (F-Test) for Comparisons of Macroinvertebrate Community Parameters for Abrams Creek.

Dependent variable	Parameters	Sum of squares	F Value	R-Square	Coefficient of variance	PR > F
Number of Organisms	Station	17.68	5.78	0.63	11.19	0.0004*
	Season	6.88	6.74			0.0038*
	Year	2.22	4.35			0.0456*
Wet weight	Station	21.64	7.48	0.71	33.66	0.0001*
	Season	3.05	3.16			0.0570
	Year	10.29	21.34			0.0001*
Number of Taxa (S)	Station	5.87	9.73	0.72	10.58	0.0001*
	Season	1.70	8.45			0.0012*
	Year	0.12	1.24			0.2746
$\bar{d}$	Station	0.68	8.73	0.69	8.63	0.0001*
	Season	0.15	5.82			0.0073*
	Year	0.04	3.07			0.0900
$\bar{H}$	Station	0.94	9.46	0.72	10.74	0.0001*
	Season	0.26	7.70			0.0020*
	Year	0.09	5.36			0.0277*
J	Station	0.05	2.34	0.38	11.39	0.0570
	Season	0.00	0.36			0.6997
	Year	0.01	3.53			0.0701
R	Station	0.12	11.90	0.75	8.56	0.0001*
	Season	0.01	3.91			0.0310*
	Year	0.02	11.12			0.0023*
e	Station	0.03	0.63	0.22	15.67	0.7072
	Season	0.04	2.36			0.1114
	Year	0.00	0.02			0.8940

(Continued on next page)

Table 19. Analysis of Variance (F-Test) for Comparisons of Macroinvertebrate Community Parameters for Abrams Creek - Cont.

Dependent variable	Parameters	Sum of squares	F Value	R-Square	Coefficient of variance	PR > F
e'	Station	0.01	0.49	0.30	9.03	0.8095
	Season	0.02	4.75			0.0161*
	Year	0.00	0.63			0.4319
IV	Station	7,980.71	3.38	0.64		0.0005*
	Month	8,673.68	9.18		37.71	0.0001*
	Year	322.90	1.37			0.2441

*Significant difference (<0.05)

Table 20. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek.

All Months - April through July 1974*

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Nematamorpha											
Annelida											
Oligochaeta		X			X		X	X	X		X
Arthropoda											
Insecta											
Diptera											
Chironomidae		X			X	X	X	X	X		X
Tipulidae											
Antocha	X				X	X	X	X	X		
Dicranota											
Eriocera	X					X					
Hexatoma											
Longurio											
Pedicia											
Tipola					X		X	X			
Simuliidae								X	X		
Prosimulium											
Rhagionidae							X	X			
Atheris variegata							X		X		
Blepharoceridae		X						X			
Blepharocera									X		
Tanyderidae						X		X			
Protoplasa											
Tahanidae											
Tahanus											
Empididae											
Coleoptera											
Elmidae											
Helichus											
Hexacylloepus											
Latiusculus											
Limnius		X				X			X		
Optioservus						X		X	X		
Oulimnius											
Promoresia					X	X		X	X		
Psephenidae											
Ectoparia							X				
Psephenus						X	X	X	X		

*From Alan Kelly's collections, U.S. Fish and Wildlife Service, GRSM

Table 20. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: April through July 1974*

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella											
Leptophlebiidae		X			X	X	X	X	X		X
Habrophlebia											
Paraleptophlebia											
Caeninae											
Caenis											X
Heptageniidae											
Anthroplea											
Cinygmula		X			X	X	X	X	X		X
Heptagenia											
Iron		X			X	X	X	X	X		
Rithrogena						X					
Stenonema		X			X	X	X	X	X		
Siphlonuridae											
Ameletus											
Siphlonurus											
Baetidae											
Baetis		X					X	X	X		
Baetisca											
Centroptilum							X		X		
Isonychia							X	X	X		
Leptophlebia		X									
Pseudocloeon		X			X	X	X	X	X		X
Ephemeridae											
Ephemera								X			
Hexagenia											
Megaloptera											
Corydalidae											
Chauliodes							X		X		
Sialidae											
Nigronia											
Hemiptera											
Gerridae											
Odonata											
Zygoptera											
Agrionidae											
Agrion							X				

Table 20. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: April through July 1974

Taxon	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Anisoptera											
Gomphidae											
Gomphus											
Lanthus											
Hagenius						X					
Plecoptera											
Perlodidae											
Diploperla											
Isogenus		X					X	X	X		
Isoperla		X				X	X	X			
Pternarcidae											
Pteronarcys		X									
Perlidae											
Acroneuria		X				X	X	X	X		
Paragnetina								X	X		
Peltoperlidae											
Peltoperla								X	X		
Leuctridae											
Leuctra		X					X	X	X		
Capniidae											
Allocapnia											
Taeniopterygidae											
Brachyptera											
Chloroperlidae											
Alloperla		X						X	X		
Hastaperla											
Nemouridae											
Namoura							X	X			
Taeniopteryx											
Trichoptera											
Rhyacophiladae											
Rhyacophila						X		X	X		
Hydropsychidae											
Arctopsyche								X			
Cheumatopsyche					X	X	X	X	X		
Diplectrona		X					X		X		
Hydropsyche		X			X	X	X	X	X		
Glossomatidae											
Agapetus					X		X				
Glossosoma					X	X	X				

Table 20. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: April through July 1974

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Psychomyiidae											
Psychomyia							X		X		
Polycentropus						X		X			
Goeridae											
Goera					X	X	X	X	X		
Hydroptilidae											
Neotrichia											
Ochrotrichia											
Limnephilidae											
Neophylax											
Phryganeidae											
Ptilostomis											
Lepidostomatidae											
Lepidostoma											
Leptoceridae											
Arthripsodes											
Leptocella											
Leptocerus											
Philopotamidae											
Chimarra											
Tretonius		X					X	X	X		
Brachycentridae											
Micrasema							X	X			
Crustacea											
Decapoda							X	X	X		
Astacidae											
Cambarus											
Orconectes											
Mollusca											
Gastropoda							X	X	X		
Prosobranchia											
Megogastropoda											
Pleuroceridae											
Goniobasis											
Pulmonata											
Basommatophera											
Ancylidae											
Ferrissia											

Table 21. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek

All Months: February through July 1977

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Nematomorpha				X							
Annelida											
Oligochaeta	X	X	X	X	X	X	X	X	X	X	X
Anthropoda											
Insecta											
Diptera											
Chironmodidae	X	X	X	X	X	X	X	X	X	X	X
Tipulidae											
Antocha	X	X	X	X	X	X	X	X	X	X	X
Dicranota								X			
Eriocera	X	X	X				X	X		X	
Hexatoma		X	X	X			X	X	X		
Longurio				X							
Pedicia							X				
Tipola	X	X	X	X	X	X	X	X	X	X	X
Simuliidae											
Prosimulium	X	X	X	X	X	X	X	X	X	X	X
Rhagionidae											
Atherix variegata	X	X	X	X		X	X	X	X	X	
Blepharoceridae											
Blepharocera	X	X									
Tanyderidae											
Protoplasa							X				
Tahanidae											
Tahanus									X		
Empididae		X									
Collembola			X		X		X	X			
Coleoptera											
Elmidae	X		X	X		X		X			
Helichus								X			
Hexacylloepus									X		
Latiusculus											
Limnius					X				X		
Optioservus	X	X	X		X	X	X	X	X	X	
Oulimnius										X	
Promoresia	X	X	X	X	X	X	X	X	X	X	
Psephenidae									X		
Ectoparia	X						X				
Psephenus	X		X	X		X	X	X	X	X	X
Limnichidae											
Limnichus				X							

Table 21. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: February through July 1977

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella	X	X	X	X	X	X	X	X	X	X	X
Leptophlebiidae											
Habrophlebia											
Paraleptophlebia	X	X	X	X		X	X	X			X
Caeninae											
Caenis											
Heptageniidae											
Arthroplea										X	
Cinygmula			X								
Heptagenia		X	X		X	X	X				
Iron	X	X	X	X	X	X	X	X	X	X	X
Rithrogena	X	X				X	X				
Stenonema	X	X	X	X	X	X	X	X	X	X	X
Siphlonuridae											
Ameletus	X	X		X	X	X	X	X	X	X	X
Siphlonurus									X		
Baetidae											
Baetis	X	X	X	X	X	X	X	X	X	X	X
Baetisca			X						X		
Centroptilum											
Isonychia		X	X	X	X	X	X	X	X	X	X
Leptophlebia							X				
Pseudocloeon					X			X			
Ephemeridae											
Ephemera		X	X	X	X	X	X	X	X	X	
Hexagenia			X								
Megaloptera											
Corydalidae						X					
Chavliodes	X		X	X	X	X	X	X	X	X	
Sialidae											
Nigronia			X			X	X	X			
Hemiptera											
Gerridae									X		
Odonata											
Zygoptera											
Agrionidae											
Agrion			X								X
Anisoptera											
Gomphidae											
Gomphus	X							X		X	
Lanthus											
Hagenius						X	X				

able 21. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: February through July 1977

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Plecoptera											
Perlodidae											
Diploperla									X		
Isogenus	X	X	X	X	X	X	X		X		
Isoperla	X	X	X	X	X	X	X	X	X	X	X
Pteronarciolae											
Pteronarcys	X	X	X	X		X	X	X			
Perlidae											
Acroneuria	X	X	X		X	X	X	X	X	X	
Paraqnetina			X		X		X				
Peltoperlidae											
Peltoperla	X	X	X		X	X	X	X	X	X	
Leuctridae											
Leuctra	X	X	X	X	X	X	X	X	X	X	X
Capniidae											
Allocapnia	X	X	X	X	X	X	X	X	X	X	X
Taeniopterygidae											
Brachyptera				X		X		X			
Chloroperlidae											
Alloperla		X	X				X				X
Hastaperla		X			X	X	X	X			
Nemouridae											
Nemoura			X	X		X	X	X		X	
Taeniopteryx	X	X									
Trichoptera											
Rhyacophilidae		X	X		X	X	X	X	X	X	X
Rhyacophila											
Hydropsychidae											
Arctopsyche							X	X	X	X	
Cheumatopsyche	X	X	X	X	X	X	X	X	X	X	X
Diplectrona			X							X	
Hydropsyche	X	X	X	X	X	X	X	X	X	X	
Parapsyche						X					
Glossosomatidae											
Agapetus											
Glossosoma	X	X	X	X	X	X	X	X	X	X	X
Psychomyiidae											
Psychomyia								X			
Polycentropus	X	X	X	X	X	X	X	X	X	X	X

Table 21. Checklist of the Benthic Macroinvertebrates Collected from Abrams Creek - Cont.

All Months: February through July 1977

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Goeridae											
Goera			X		X	X	X				
Hydroptilidae							X				
Neotrichia		X									
Ochrotrichia					X						
Limnephilidae											
Neophylax		X									
Pycnopsyche	X	X	X		X		X				
Phryganeidae											
Ptilostomis							X				X
Lepidostomatidae											
Lepidostoma						X					
Leptoceridae											
Athripsodes	X	X	X		X						
Leptocella	X	X	X	X					X		
Leptocerus	X										
Philopotamidae											
Chimarra	X	X	X	X					X		
Trentonius											
Brachycentridae											
Micrasema											
Crustacea											
Decapoda											
Astacidae											
Cambarus	X	X	X		X	X	X	X	X		
Orconectes	X	X			X			X			
Mollusca											
Gastropoda											
Prosobranchia											
Mesoqastropoda											
Pleuroceridae											
Goniobasis			X		X		X	X	X	X	
Pulmonata											
Basommatophera											
Ancylidae											
Ferrissia				X	X	X	X	X	X		

Table 22. Species List of Fish Captured from Abrams Creek - August through September 1977

Common Name	Scientific Name	*Ecological Type
Rainbow trout	*Salmo gairdneri*	Game
Tennessee darter	*Etheostoma simoterum*	Forage
Blacknose dace	*Rhinichthys atratulus*	Forage
Rosyside dace	*Clinostomus foxdoloides*	Forage
Longnose dace	*Rhinichthys cataractae*	Forage
River chub	*Nocomis micropogon*	Rough
Creek chub	*Semotilus atromaculatus*	Rough
Northern hogsucker	*Hypentelium nigricans*	Rough
White sucker	*Catastomus cummersoni*	Rough
Warpaint shiner	*Notropis coccogenis*	Forage
Stoneroller	*Compostoma anomalum*	Rough
Tennessee shiner	*Notropis leuciodus*	Forage

*From Lagler (1956)

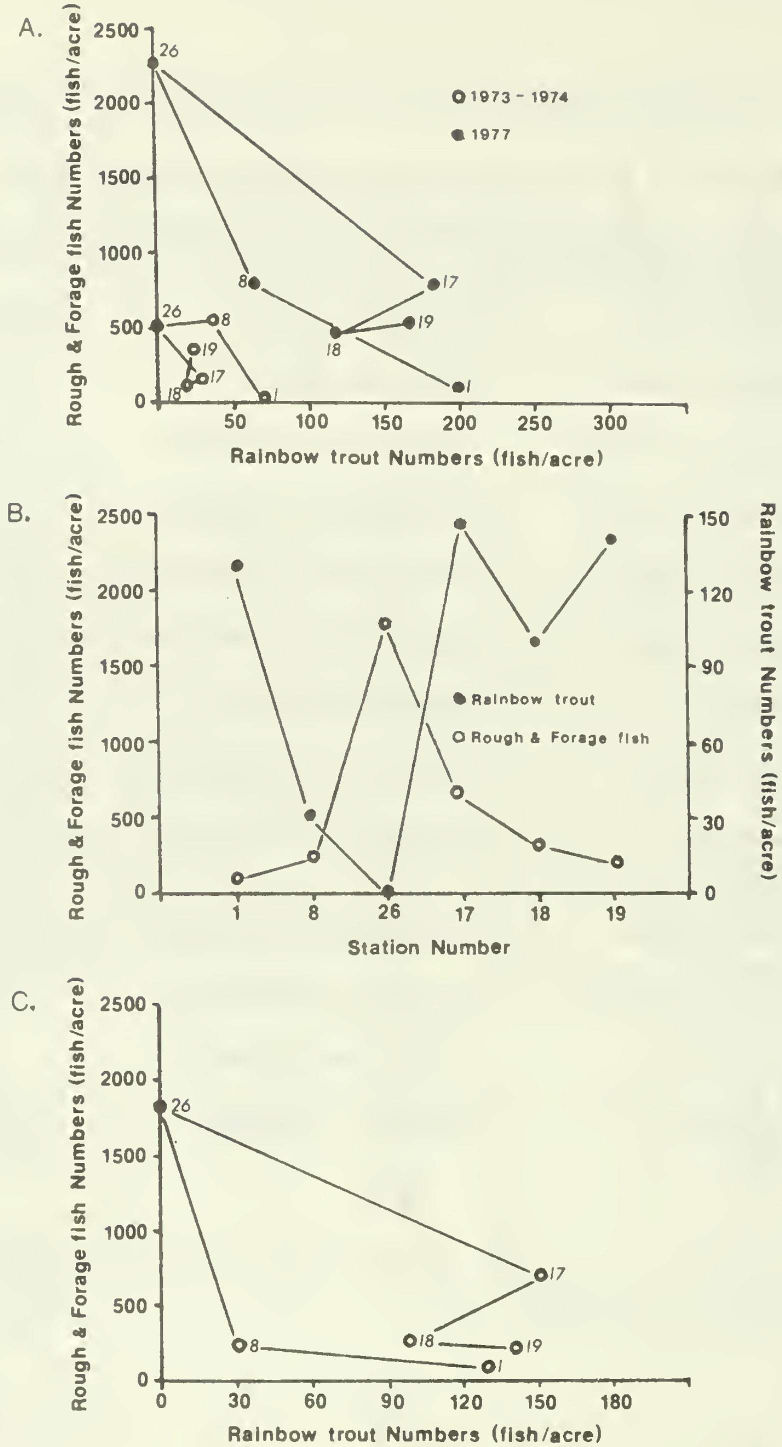


FIGURE 18.

FISHERY DYNAMICS (POPULATION) FOR SELECTED STATIONS ON ABRAMS CREEK

A. Comparison of Rainbow trout (Rt) to Rough and Forage fish (R/F) populations (fish/acre) for 1973-4 and 1977

B. Change in Rt and R/F fish populations between the years 1973-4 and 1977 for selected stations

C. Comparison of change in Rt to change in R/F populations between the years 1973-4 and 1977 for selected stations

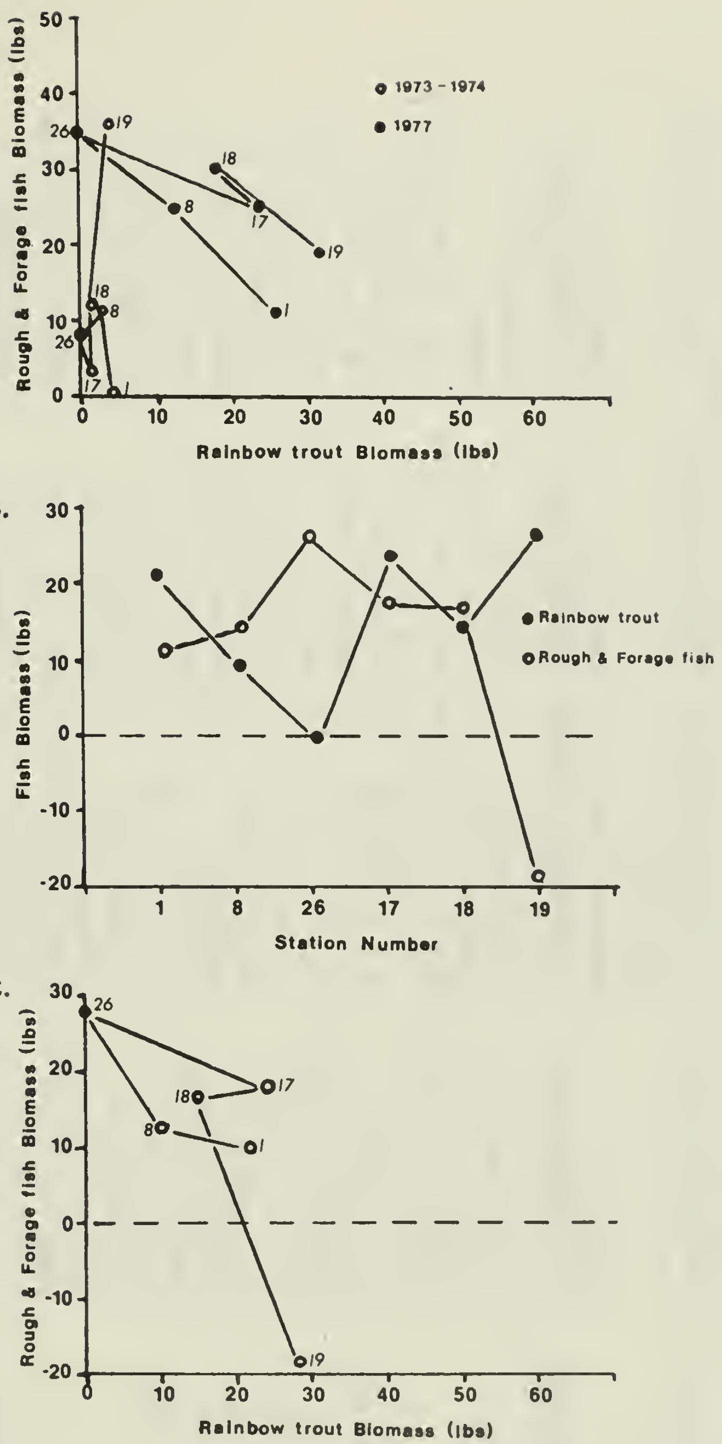


FIGURE 19.

FISHERY DYNAMICS (BIOMASS) FOR SELECTED STATIONS ON ABRAMS CREEK

A. Comparison of Rainbow trout (Rt) to Rough and Forage fish (R/F) biomass (lbs/acre) for 1973-4 and 1977

B. Change in Rt and R/F biomass between the years 1973-4 and 1977 for selected stations

C. Comparison of change in Rt to change in R/F biomass between the years 1973-4 and 1977

Table 23. Fishery Survey of Abrams Creek - July 1972 through August 1974.

Station Number and Location	Total Fish No.-Weight/Acre	Game Fish (Rainbow Trout) No.-Weight/Acre	Forage Fish No.-Weight/Acre	Rough Fish No.-Weight/Acre
1 - Anthony Creek above horse camp	92 fish/acre 4.6 lbs. fish/ acre	68 fish/acre 4.37 lbs. fish/ acre	24 fish/acre .24 lbs. fish/ acre	No rough fish caught
8 - Abrams Creek at Sparks Lane	641 fish/acre 14.45 lbs. fish/ acre	33.3 fish/acre 3.5 lbs. fish/ acre	463 fish/acre 6.27 lbs. fish/ acre	144 fish/acre 4.6 lbs. fish/ acre
26- Abrams Creek at Hyatt Lane	518 fish/acre 7.49 lbs. fish/ acre	No game fish collected	455 fish/acre 2.75 lbs. fish/ acre	73 fish/acre 5.11 lbs. fish/ acre
17- Abrams Creek at confluence with Mill Creek	188 fish/acre 5.5 lbs. fish/ acre	27 fish/acre 1.9 lbs. fish/ acre	122 fish/acre 1.97 lbs. fish/ acre	40 fish/acre 1.6 lbs. fish/ acre
18- Abrams Creek above Shoe	158 fish/acre 15.5 lbs. fish/ acre	18 fish/acre lbs. fish/ acre	No forage fish collected	140 fish/acre 13.1 lbs. fish/ acre
19- Abrams Creek below Shoe	374 fish/acre 42 lbs. fish/ acre	23 fish/acre 4.4 lbs. fish/ acre	39 fish/acre 0.50 lbs. fish/ acre	310 fish/acre 36.3 lbs. fish/ acre

Table 24. Fishery Survey or Abrams Creek - August through September, 1977.

Station Number and Location	Total Fish No.-Weight/Acre	(Rainbow Trout) No.-Weight/Acre	Forage Fish No.-Weight/Acre	Rough Fish No.-Weight/Acre
1 - Anthony Creek above horse camp	314 fish/acre 37.33 lbs. fish/acre	196 fish/acre 26.02 lbs. fish/acre	108 fish/acre 5.4 lbs. fish/acre	10 fish/acre 5.89 lbs. fish/acre
8 - Abrams Creek at Sparks Lane	885 fish/acre 38.76 lbs. fish/acre	64 fish/acre 13.31 lbs. fish/acre	493 fish/acre 10.94 lbs. fish/acre	328 fish/acre 14.59 lbs. fish/acre
26- Abrams Creek at Hyatt Lane	2317 fish/acre 35.57 lbs. fish/acre	None collected	1277 fish/acre 13.68 lbs. fish/acre	1040 fish/acre 21.89 lbs. fish/acre
17- Abrams Creek at confluence with Mill Creek	1017 fish/acre 49.08 lbs. fish/acre	176 fish/acre 25.98 lbs. fish/acre	264 fish/acre 3.74 lbs. fish/acre	577 fish/acre 19.33 lbs. fish/acre
18- Abrams Creek above Shoe	582 fish/acre 47.70 lbs. fish/acre	116 fish/acre 17.28 lbs. fish/acre	173 fish/acre 1.31 lbs. fish/acre	293 fish/acre 29.11 lbs. fish/acre
19- Abrams Creek below Shoe	740 fish/acre 51.83 lbs. fish/acre	166 fish/acre 32.72 lbs. fish/acre	163 fish/acre 2.39 lbs. fish/acre	412 fish/acre 16.76 lbs. fish/acre

parasite was found at the other sample stations. Exposed portions of epithelium behind the opercle flap were evident in some rainbow trout taken at the upper Cove, station 8. Mucous accumulations from epithelial tissue were also quite high in these exposed areas behind the opercle flap, indicating irritation, probably by silt and sediments.

Bacteriological Dynamics

The numbers of total coliform, fecal coliform, and fecal streptococcus bacteria were variable along the main stream from the most upstream station (1) to the base station (22) (Figs. 20 and 21; Tables 25 - 27). This variability also occurred between sample periods.

The numbers of total coliforms increased (Fig. 21; Table 27), in general, once the stream entered the Cove (station 3). With the exceptions of the high counts at stations 4 and 15 in June, the highest counts in the Cove typically were found at stations 34, 9, and 26 (except when the creek was dry at station 26). In May and August the numbers of these bacteria at stations downstream from the Cove were reduced, frequently to levels comparable to those of the uppermost stations (1 and 2). But in June and July, numbers either increased or remained at levels comparable to the highest numbers found in the Cove.

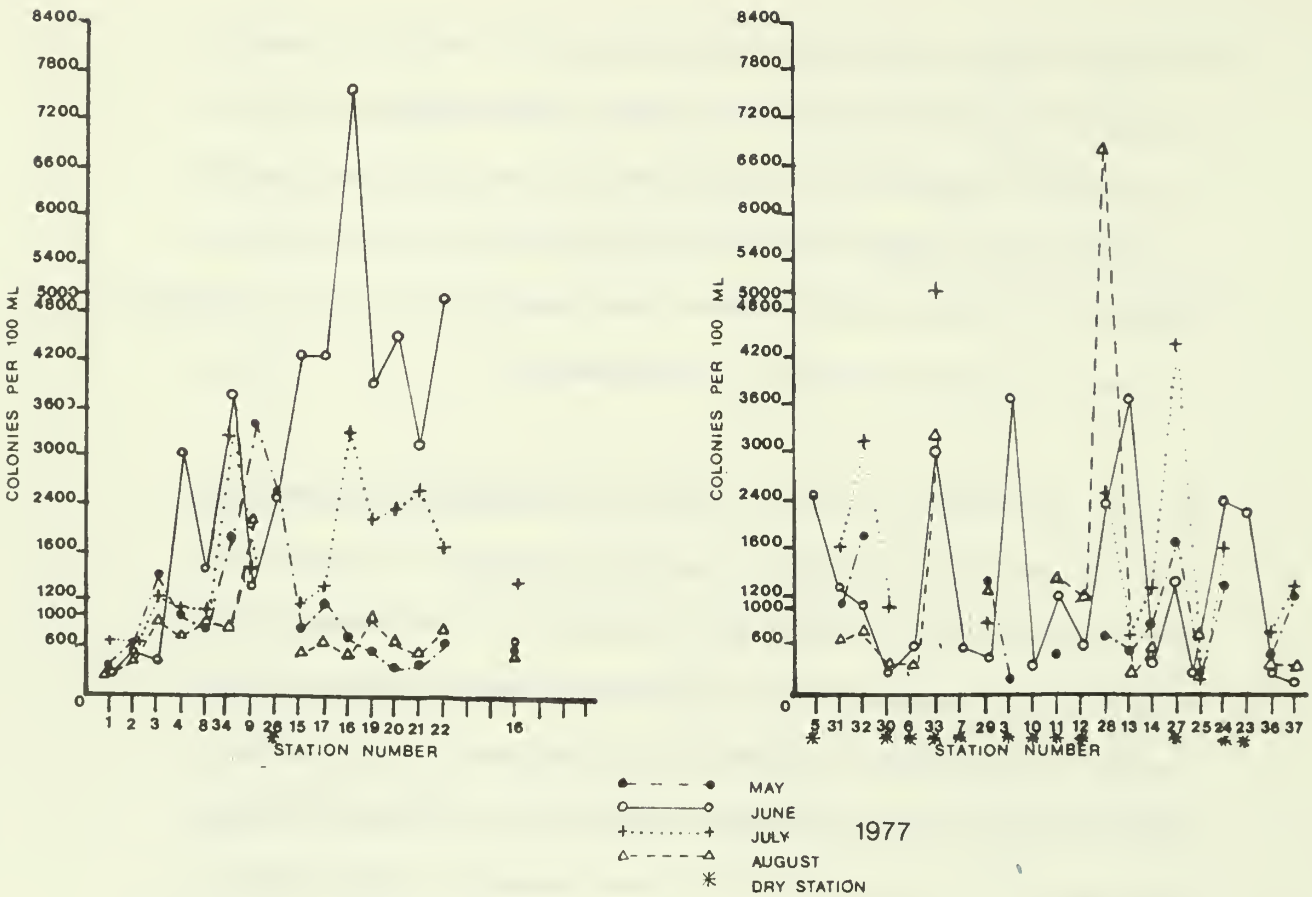
The lowest numbers of fecal coliform (Fig. 21; Table 26) were generally found at stations 1 to 8 and from stations 15 to 22. The greatest numbers of this bacteria were found at stations 34, 9, and 26. The highest counts occurred in May. In June, the numbers of bacteria were elevated from stations 15 to 22 as compared to counts at these stations in other months.

In May, the numbers of fecal streptococcus (Table 25) were less than 200 per 100 milliliters from the headwaters to station 22, except for a count of about 625 at station 9. The counts in June were typically greater than those found in May, particularly in the Cove and stations downstream from the Cove. In July, the counts generally decreased from station 1 to station 9 (Abrams Creek was dry at station 26) and then decreased again at the downstream stations. In August, the counts were similar to those found in May, except the highest count, about 600, occurred at station 18. The ratio of fecal coliforms to fecal streptococcus for all sample periods (Figs. 22 and 23) was conspicuously above 3 at stations 34, 9, and 26, except for station 26 when it was dry. At other stations the index was less than 1.5.

The numbers of total coliforms, fecal coliforms, and fecal streptococcus bacteria in the tributaries varied greatly, often without apparent explanation (Figs. 20 and 21; Tables 25 - 27). Nonetheless, tributaries along the south side of Abrams Creek

FIGURE 20

TOTAL COLIFORM

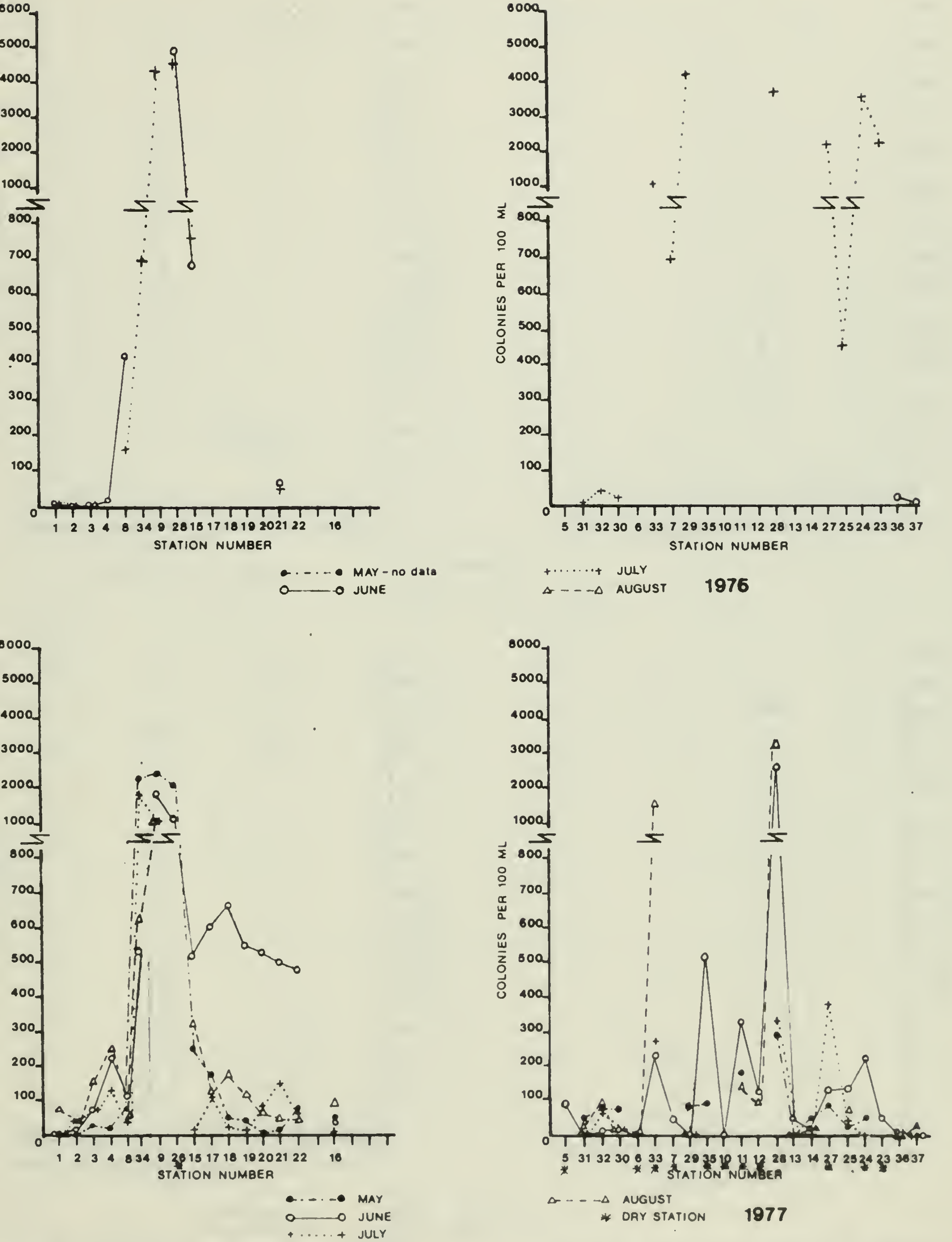


Total Coliform for Selected Stations on Abrams and Mill Creeks

Total Coliform for Selected Stations on Abrams Creek Tributaries

No Total Coliform information available for these Stations in 1976

FIGURE 21
Fecal Coliform

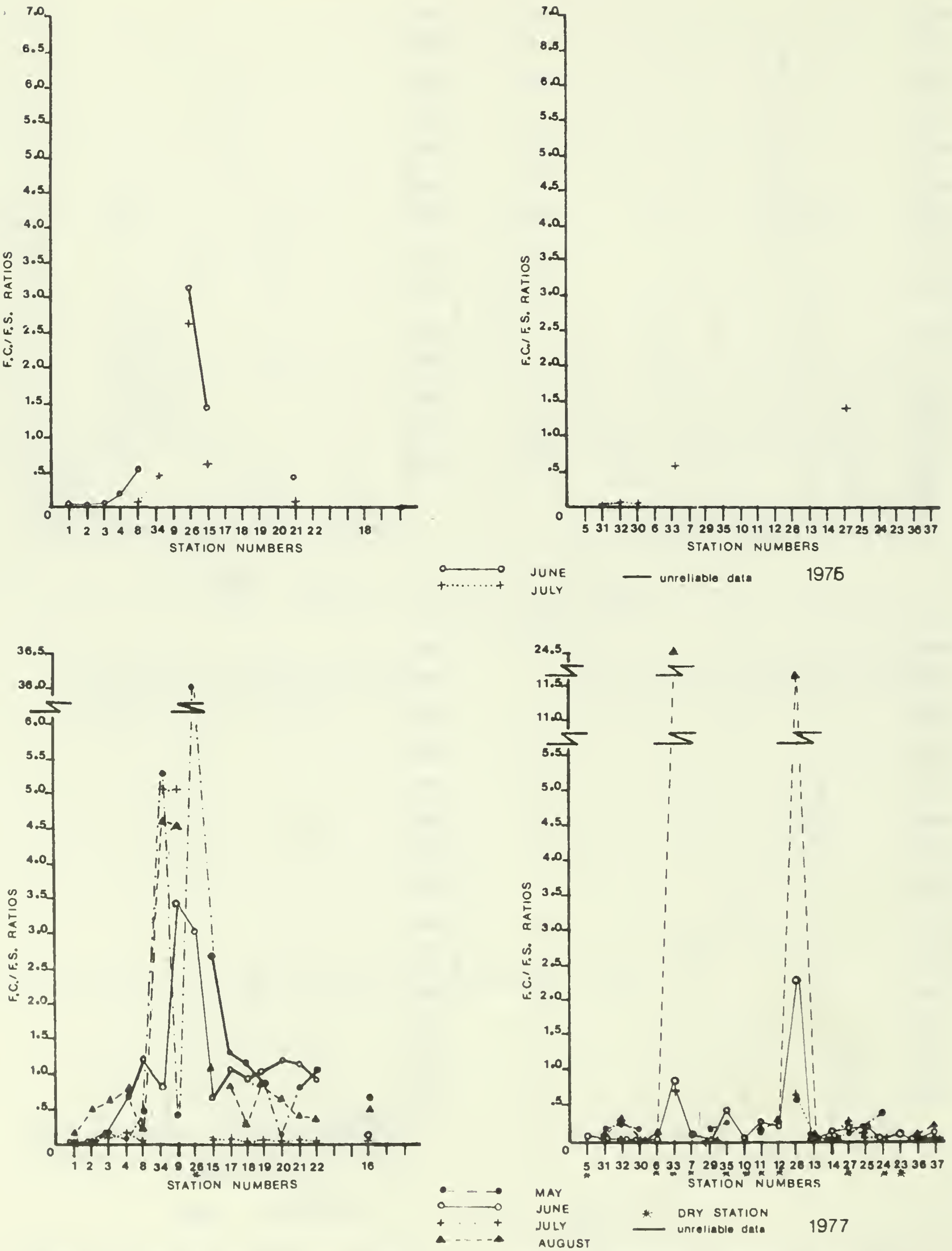


Total Fecal Coliform for Selected Stations on Abrams and Mill Creeks

Total Fecal Coliform for Selected Stations on Abrams Creek Tributaries

FIGURE 22

F.C. / F.S. RATIOS

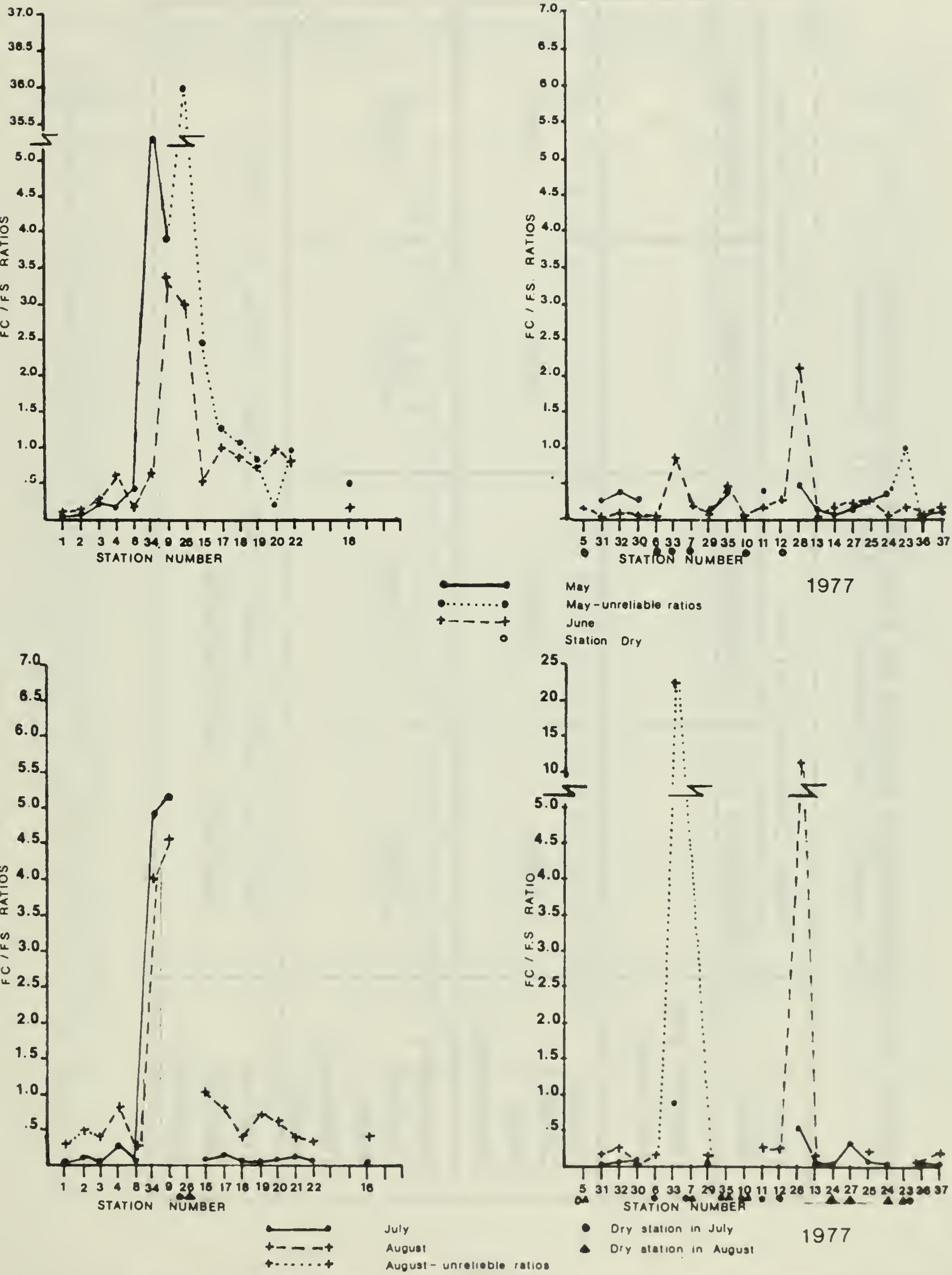


F.C./F.S. Ratios for Selected Stations on Abrams and Mill Creeks

F.C./F.S. Ratios for Selected Stations on Abrams Creek Tributaries

FIGURE 23

F.C. / F.S. RATIOS



F.C. / F.S. Ratio for Selected Stations on Abrams and Mill Creeks

F.C. / F.S. Ratio for Selected Stations on Abrams Creek Tributaries

FIGURE 24. Recommended Limits of Total and Fecal Coliform (also specific requirements of State of Tennessee).*

Type of Water	Total Coliform/ 100 ml		Fecal Coliform/ 100 ml	
	Desirable	Permissible	Desirable	Permissible
Potable and well water	0	1	0	0
Primary Contact Water (Swimming)	$<$1000	$<$2400	$<$200	$<$1000
Secondary Contact Water (Boating, fishing)	$<$5000	$<$10,000	$<$1000	$<$5000
Treated Sewage Effluent	Coliform levels should not exceed those of water receiving the discharge			

*ACCORDING TO U.S. ENVIRONMENTAL PROTECTION AGENCY (1975) AND TENNESSEE DEPARTMENT OF PUBLIC HEALTH (1973).

Table 25. Fecal Streptococcus Colonies per 100 Milliliters of Water Sampled at Stations on Abrams Creek and Tributaries, 1977

STATION	MAY	JUNE	JULY	AUGUST
1	128	276	1,000	263
2	138	314	702	80
3	140	400	970	223
4	198	322	606	303
5	DRY	582	DRY	DRY
6	DRY	312	DRY	117
7	DRY	486	DRY	DRY
8	198	822	864	213
9	642	554	206	227
10	DRY	168	DRY	DRY
11	1,264	1,040	DRY	613
12	DRY	420	DRY	263
13	134	1,554	1,298	123
14	972	230	1,128	277
15	98	790	538	323
16	74	262	1,460	190
17	136	588	1,104	157
18	50	742	1,200	557
19	52	550	1,092	133
20	62	454	1,980	107
21	32	452	1,712	137
22	74	522	1,704	140
23	DRY	354	DRY	DRY
24	130	2,664	450	DRY
25	143	602	1,348	377
26	60	336	DRY	DRY
27	636	676	1,164	DRY
28	540	1,130	590	277
29	484	286	160	103
30	294	672	560	313
31	218	1,296	1,320	260
32	248	230	2,132	323
33	DRY	272	374	67
34	416	766	360	157
35	250	1,112	DRY	DRY
36	174	864	738	233
37	134	112	1,600	180

Table 26. Fecal Coliform Colonies per 100 Milliliters of Water Sampled at Stations on Abrams Creek and Tributaries, 1977

STATION	MAY	JUNE	JULY	AUGUST
1	7	3	0	70
2	7	17	40	40
3	33	80	87	147
4	23	223	137	247
5	DRY	93	DRY	DRY
6	DRY	7	DRY	13
7	DRY	53	DRY	DRY
8	87	107	43	60
9	2,553	1,900	1,057	1,037
10	DRY	13	DRY	DRY
11	177	340	DRY	150
12	DRY	133	DRY	97
13	13	50	10	13
14	63	33	7	20
15	263	520	20	330
16	53	40	10	93
17	183	600	110	123
18	57	670	30	180
19	43	550	23	113
20	10	530	87	73
21	23	493	153	57
22	77	480	70	53
23	DRY	67	DRY	DRY
24	56	223	10	DRY
25	31	140	43	70
26	2,160	1,010	DRY	DRY
27	90	133	387	DRY
28	293	2,613	340	3,270
29	83	13	0	10
30	70	17	20	20
31	50	10	10	37
32	77	17	60	93
33	DRY	233	280	1,647
34	2,227	533	1,817	637
35	93	517	DRY	DRY
36	3	33	28	13
37	5	13	0	37

Table 27. Total Coliform Colonies per 100 milliliters of Water Sampled at Stations on Abrams Creek and Tributaries, 1977

STATION	MAY	JUNE	JULY	AUGUST
1	463	363	667	303
2	660	547	667	480
3	1,500	473	1,213	973
4	1,046	3,013	1,110	770
5	DRY	2,567	DRY	DRY
6	DRY	620	DRY	410
7	DRY	623	DRY	DRY
8	827	1,530	1,140	903
9	3,400	1,387	1,573	2,200
10	DRY	440	DRY	DRY
11	540	1,237	DRY	1,533
12	DRY	657	DRY	1,253
13	597	3,767	807	317
14	953	423	1,307	640
15	806	4,267	1,113	567
16	547	767	1,453	500
17	1,140	4,217	1,320	617
18	740	7,673	3,300	553
19	570	3,923	2,233	1,040
20	423	4,480	2,367	610
21	410	3,180	2,567	573
22	643	4,940	1,833	700
23	DRY	2,320		DRY
24	1,486	2,420	1,833	DRY
25	352	333	267	870
26	2,500	2,450	DRY	DRY
27	1,983	1,470	4,400	DRY
28	720	2,400	2,567	6,933
29	1,426	567	877	1,290
30	2,206	367	1,107	480
31	1,200	1,333	1,867	737
32	1,186	1,133	3,200	847
33	DRY	3.113	5,133	3,467
34	2,016	3,833	3,300	930
35	260	3,733	DRY	DRY
36	543	387	803	463
37	1,276	283	1,333	383

typically had greater numbers of these bacteria than north side streams, this being particularly true for total coliforms and fecal coliforms.

The fecal coliform to fecal streptococcus ratios were nearly always less than 1 in the tributaries (Figs. 22 and 23). Stations 28 and 33 had a ratio greater than 5 in August, however.

Periphytic Diatom Community Structure

Twelve species of periphytic diatoms were collected from the seven sampling stations on Abrams Creek in May and June 1977 (Tables 28 and 29). Eleven of these species were present every month. *Fragilaria vaucheria* occurred in relatively high abundance at stations 9 and 26 during May but was not represented at any station during June.

Eunotia rhomboidea and *Navicula contenta* f. *biceps* were the predominant species at station 1, the reference area for this survey. *Gomphonema parvulum* and *Synedra ulna* were the most abundant species at station 3. This station was above the area of cattle influence and the sewage lagoon but was located directly below a picnic area adjacent to the stream (Figs. 2 and 3). Station 4 was adjacent to the sewage lagoon, and *Achnanthes* sp. and

Synedra ulna were the most abundant species. At station 9, directly below the sewage lagoon and in the area of cattle watering, Fragilaria vaucheria and Meridion circulare were the most representative species. Fragilaria vaurcheria and Meridion were the most abundant species at station 26 (located at the lower cove below cattle pasture but not a watering site). Station 15, located just before Abrams Creek exits the Cove, was most represented by Meridion circulare and Synedra ulna. Together, stations 9, 26, and 15 made up the stressed area relative to cattle activity. Station 18 was the recovery station located below the confluence of Mill Creek; Diatoma hiemale var. mesodon was in greatest abundance there. Therefore, determining the predominant species composing the diatom community at different locations along Abrams Creek provided a useful means of assessing changes in habitat and water quality along the course of the stream.

Table 28. Abrams Creek Diatom Data - May 1977. Those with a relative abundance of five percent or greater are listed for each collection.

Station Number	Taxon
1	**Eunotia rhomboidea* *Diatoma hiemale* var. *mesodon* *Meridion circulare* *Navicula contenta* f. *biceps*
3	**Gomphonema parvulum* *Synedra ulna* *Diatoma hiemale* var. *mesodon* *Achnanthes* sp.
4	**Achnanthes* sp. *Gomphonema parvulum* *Synedra ulna*
9	**Fragilaria vaucheria* *Gomphonema parvulum* *Synedra ulna*
26	**Fragilaria vaucheria* *Synedra ulna* *Melosira varians*
15	**Meridion circulare* *Gomphonema parvulum* *Diatoma hiemale* var. *mesodon*
18	**Diatoma hiemale* var. *mesodon* *Synedra ulna*

*Taxon with greatest relative abundance

Table 29. Abrams Creek Diatom Data - June 1977. Those with a relative abundance of five percent or greater are listed for each collection.

Station Number	Taxon
1	**Navicula contenta* f. *biceps*
	Diatoma hiemale var. *mesodon*
	Meridion circulare
	Achnanthes sp.
	Eunotia rhomboidea
3	**Synedra ulna*
	Meridion circulare
	Gomphonema parvulum
	Achnanthes sp.
4	**Synedra ulna*
	Navicula mutica var. *stigma*
	Pinnularia sp.
	Gomphonema parvulum
9	**Meridion circulare*
	Diatoma hiemale var. *mesodon*
	Gomphonema parculum
	Synedra ulna
	Eunotia sp.
26	**Meridion circulare*
15	**Synedra ulna*
	Gomphonema parculum
18	**Melosira varians*
	Synedra ulna

*Taxon with greatest relative abundance

Table 30. Ecological Profile of Diatoms Collected from Abrams Creek - May through June, 1977

	ECOLOGICAL PARAMETERS	*Meridion circulare*	*Navicala contenta f. biceps*	*Gomphonema parvulum*	*Synedra ulna*	*Achnanthes sp.*	*Fragilaria vaucheriae*	*Meloseria varidas*	*Navicula mutica var. stigma*
pH	Acidobiontic								
	Acidophilous								
	Indifferent			X	X				
	Alkaliphilous	X	X				X	X	
	Alkalibiontic								
Nutrient	Eutrophic	X			X		X	X	
	Mesotrophic								
	Oligotrophic								
	Dystrophic								
Halobion	Polyhalobous								
	Euhalobous								
	Mesohalobous								
	alpha range								
	beta range								
	Oligohalobous								
	halophilous								
	indifferent	X	X	X	X		X	X	
	halophobous								
	Euryhalobous								
Saprobien	Polysaprobic								
	Mesosaprobic			X					
	alpha range								
	beta range				X		X	X	
	Oligosaprobic	X			X				
	Saprophilic								
	Saproxenous								
	Saprophobic								
Current	Limnobiontic								
	Limnophilous								
	Indifferent				X		X	X	
	Rheophilous	X		X			X		
	Rheobiontic	X							

Table 30. Ecological Profile of Diatoms Collected from Abrams Creek - May through June 1977 - Cont.

	ECOLOGICAL PARAMETERS	*Meridion circulare*	*Navicala contenta f. biceps*	*Gomphonema parvulum*	*Synedra ulna*	*Achanthes* sp.	*Fragilaria vaucheriae*	*Meloseria varidas*	*Navicula mutica* var. *stigma*
General Habitat	Marine								
	Estuary								
	Lake	X						X	
	Pond	X						X	
	River	X							
	Spring and Stream	X					X	X	
	Aerophilous		X						
	Other							X	
Specific Habitat	Euplanktonic				X				
	Tychoplanktonic	X							
	Periphytic	X		X			X	X	
	epipelic								
	epilithic								
	epidendric								
	epizooic								
	epiphytic								
	attached								
	unattached								
Seasonal Dist.	Winter								
	Spring	X			X				
	Summer				X			X	
	Fall				X				
Temperature	Euthermal	X							
	Mesothermal	X		X	X			X	X
	Oligothermal	X			X	X	X	X	
	Stenothermal			X					
	Metathermal								
	Eurythermal				X			X	
	Undesignated								

Table 30. Ecological Profile of Diatoms Collected from Abrams Creek - May through June, 1977 - Cont.

Geographical distribution and additional comments:

a = *Meridion circulare:*
Cosmppolitan; seldom in the tropics; calciphilous; an indicator of high oxygen concentration.

b = *Navicula contenta* f. *biceps:*
Cosmopolitan; polyoxybiontic

c = *Gomphonema parvulum:*
Cosmopolitan; a facultative nitrogen hetereograph and may be a pollution indicator; the great adaptability of this species accounts for its variability; calcium and iron indifferent.

d = *Synedra ulna:*
Cosmopolitan; great ecological span; prefers dirty water; calcium indifferent; it is unsuitable as an ecological indicator.

e = *Acanthes* species:
Requires high oxygen concentration; cosmopolitan; euryphotic; does not seem to appear in large numbers under conditions of heavy organic enrichment.

f = *Fragilaria vaucheriae:*
Cosmopolitan; may prefer flowing, well-aerated water.

g = *Melosira viridans:*
Cosmopolitan; euryoxybiontic; indifferent to iron concentration; probably an obligate nitrogen heterotroph; has an extraordinary large ecological span which on one hand has massive growths in eutrophic waters in summer and on the other hand, large growths in katharobic water in January and February.

h = *Diatoma hiemale:*
Cosmopolitan; alkaliphilous to alkalibiontic; oligohalobous; saproxenous; oligothermal and stenothermal.

DISCUSSION

Cades Cove is an important and controversial management problem in the Great Smoky Mountains National Park. From one point of view, the cattle maintained in the Cove help fulfill, in part, the preservation of pioneer culture, as well as National Park Service policy to maintain certain areas as historic settings. As stated in the Resources Management Plan for the Great Smoky Mountains National Park, III-D-1 (National Park Service 1969) the primary purpose of managing the cattle in Cades Cove is to preserve the characteristic feature of pioneer culture as nearly as possible in the condition that existed when the park was established. The open landscape of meadow and field is thus maintained against the natural succession of forest and thicket. The overall objective of the plan is to maintain the open aspect rather than an authentic forest stage composition. The environmental impacts which develop as a result of this plan are interrelated with the natural phenomena which affect Abrams Creek.

Before developing an understanding of the present physical and chemical features of Abrams Creek, some information about the physical conditions of the creek in the Cove needs to be addressed. The gradient of the creek is similar to other major creeks in the park except for that portion of its passage through Cades Cove. Here the gradient is very low and, even with a forested landscape which existed before the settlers arrived, it could be expected that the low gradient would favor meandering. Such meandering and the limestone bedrock would be expected to alter the water quality of the creek. The clearing of the land by the settlers increased the exposure of the creek to solar radiation by removing shade and, when combined with farming, cattle grazing and watering, the water quality of the creek was undoubtedly further altered. Evidence for such changes in water quality were still evident in this study.

It should be emphasized that the treatment effect of cattle in Cades Cove is difficult to sort out from present data, since the water quality of Abrams Creek would be expected to change during the passage through the Cove since (1) the stream morphology and geology changes in the Cove; (2) the water quality of Abrams Creek without the effects of cattle is not known; and (3) the impact of other free-ranging mammals on the system is not known. The magnitude of improvements of water quality between Kelly's (1974) survey in 1972 - 1974 and this study (1977), however, strongly suggests that removal of 700 cattle in 1976 and fencing in 1973 improved the water quality of Abrams Creek.

Geologically, Cades Cove was formed by erosion of rocks of the pre-Cambrian Ocoee series, principally composed of quartz, feldspar, and slate (King et al. 1968), which overlie Ordovician limestones and shales in reversed position caused by the development of the "Great Smoky Overthrust" (Keith 1927).

Erosion succeeded in breeching the overthrust sheet in the Cove area, thereby creating a "window" through which overridden Ordovician rock is now exposed (King and Stupka 1950). Limestone is soluable and poorly resistant to erosion under the climatic conditions of the region and therefore has apparently provided for subterranean flow in the Cove.

The physical and chemical characteristics of Abrams Creek in the Cove are substantially altered by subterranean flow. In Abrams Creek at the upper end of the Cove, variable amounts of the flow is diverted underground. During very dry periods in the summer, portions of Abrams Creek have no surface flow, leaving only standing pools and dry stream beds. The diverted ground water flows through an underground limestone strata, where it is buffered. Since Abrams Creek is slightly acidic above the Cove, probably resulting from organic acids (especially tannic acid) derived from the heavily forested drainage and because the composition of the Cove soils and streambed substrate is mainly derived from the alluvial depositions of the surrounding Cades Sandstone of the Ocoee Series (Stewart Myhr, Tenn. Dept. of Conservation, Div. of Geology, Knoxville, TN, pers. communication), which are typically acidic (Cain 1931), the physical - chemical changes incurred by the diverted water are substantial. The water re-emerges into Abrams Creek via springs and seeps at the lower end of the Cove. Changes in the character of the surface flow below this area also result in changes in the faunal composition in Abrams Creek. Thus, other alterations (natural or manmade) to the watershed must be interpreted in relation to these circumstances.

One of the obvious alterations of water quality of Abrams Creek in Cades Cove is turbidity. This change in the creek alters its aesthetic appeal, but it also causes changes in the water temperature and erosional capacity of the creek. Water temperature increases because the particulates in a stream absorb and transfer solar heat to the stream (Cordone and Kelly 1960; Aitken 1936). Due to this action, increased turbidity and siltation loads in Abrams Creek are probably responsible in part for the increased temperature of the creek in the Cove. The exposure to solar radiation also influences the temperature of the creek in the Cove.

Turbidity and suspended solid levels were especially high during June and coincided with moderate stream flow and large numbers of cattle watering and wading in stream sections for long periods of time in response to hot temperatures and insect pests observed on the cattle. Suspended solids generally remained high during the entire study at stations (especially 9 and 26) where cattle had severely eroded streambanks as observed during watering and/or wading periods.

Very low levels of suspended solids and turbidity occur in Abrams Creek upstream from the Cove except in winter and early spring, when anchor ice probably causes shearing of stream substrate, and the flow is high. Suspended solids were highest in concentration for all of Abrams Creek during this period, which may also have resulted from shearing anchor ice. Loosened soil which fell into the creek from the freezing - thawing process on the numerous vegetatively denuded streamsides along Abrams Creek in the Cove is an additional source of sediment in winter. The natural meandering characteristics of the creek in the Cove is probably the major reason for bank erosion since the stream was straightened and sloped in the Cove in 1946. Bank erosion has probably been accelerated from these physical modifications of the creek. Fences erected along Abrams Creek in the Cove in 1976 are already in jeopardy of collapsing into the creek due to such channel displacement.

Additional sediment sources arose when hoof damage to streambanks occurred were cattle entered and exited watering and wading sites. There are eight such sites on the mainstream of Abrams Creek, representing about 20 percent of the streambanks within Cades Cove. Other sites occur on tributaries to Abrams Creek in the Cove. Roots of trees and shrubs were cut and grass was trampled by cattle, leaving little or no vegetation to stabilize the channel. Furthermore, the dense deer population in Cades Cove, estimated to be at least 160 head by the Tennessee Wildlife Resources Agency in 1975, resulted in heavy browsing and loss of vegetative growth on stream banks. Trees planted along Abrams Creek to help reduce erosion failed because of almost complete loss of these trees by deer browsing. Ground hogs were also observed living in burrows dug in or near streambanks, thus reducing soil stability and probably adding to the sedimentation - siltation problem.

Erosion of Cades Sandstone formation from ridges around the western portion of Cades Cove deposited by alluvial processes in the Cove break down into fine sediments and silt in Abrams Creek, according to Stewart Myhr (Tenn. Dept. of Conservation, Div. of Geology, Knoxville, TN, pers. communication). High loads of silt and sediment (Fig. 7) were observed in Abrams Creek and tributaries, often seen inundating riffles, filling pools, and accumulating behind debris traps. The impact of these materials on the creek and the organisms living in the creek are not well understood. Nevertheless, sediment and silt can limit the supply of dissolved oxygen in the stream through the destruction of photosynthetic organisms (Cordone and Kelly 1960) and through its effect of decreasing benthic decomposition (Dunham 1958, Phelps 1944). Cairns (1967) noted that heavy or irritating concentrations of silt can interfere with gill movements in fish, thus affecting the circulation in capillaries. Cairns (1967) stated that high concentrations of silt can cause fish to produce large quantities of mucous which might be torn away, exposing large portions of epithelium to the invasion of parasites. Such exposed layers of epithelial tissue and large amounts of mucous around the gills were evident on the rainbow trout taken in the upper cove section of Abrams Creek (station 8). No trout were captured in the lower Cove section of Abrams Creek (station 26). These conditions may have been influenced by siltation in this area of Abrams Creek.

Furthermore, in a small stream such as Abrams Creek in the Cove, where most fish reside in the pools, any processes which add sufficient sediment to a stream to reduce riffle and pool areas or volumes will probably reduce the carrying capacity of the stream for fish. As a general rule, the density of fish will decline in direct proportion as the area or volume of a riffle or pool declines (assuming productivity is not increased (Bjornn 1974). Riffle areas in Abrams Creek downstream of Cades Cove are also supporting growths of pasture grasses which were probably dislodged and transported downstream from the Cove. These grasses hold the collected silt and sediment, which further adds to habitat loss for fish. Pasture grasses growing in riffle areas will probably be a persistent problem in Abrams Creek.

Sediment or silt in sufficient amounts to fill the interstitial spaces between larger substrate materials will reduce the winter capacity of streams for fish. Small amounts of sediment or silt added to limited areas of mountain streams in Idaho during short periods, however, caused only limited temporary impacts on aquatic life in a study conducted by Bjornn (1974). Bjornn (1969) also indicated, however, that when fine sediments comprise more than 20 to 30 percent of the riffle material, as may be the case in Abrams Creek and tributaries, they become detrimental to the survival of trout.

Among the indirect effects of stream turbidity upon fish are injury or destruction of fish eggs, spawning sites, food supply, and young fish. Hobbs (1937), in a study of reproduction in rainbow trout, found that the majority of losses in different streams and in different redds of the same stream were attributed to sediment. He noted that where the redds were clean, losses were slight, and where the redds were dirty (i.e., silt and sediment laden), losses were heavy. Spawning habitat for trout in Abrams Creek through the Cove is probably nonexistent due to silt coverage on suitable substrate. Rainbow trout redds were found above and below the Cove, but not within the perimeter of the Cove, although drifting trout eggs were found in lower Cove sections of Abrams Creek. The eggs appeared to be dead or infertile. In areas of Abrams Creek which typically go dry during the summer (e.g., stations 9 and 26), no trout were captured or observed but rough and forage fish were abundant during normal flow periods.

McCrimmon (1954), using fingerling trout, studied the effects of sediment upon fish habitats and populations. He found that the extent of bottom sedimentation determined the amount of suitable shelter available to trout and thus influenced the extent of predation. As the sediment destroyed the shelter, the mortality of the young fry by predation increased. Sediment may be the factor limiting the number of catchable-size trout in many small streams, for even though abundant fingerlings are produced and riffle areas are kept clean by current velocity, sediment deposited in pools and runs fill in the spaces between boulders and rubble, reducing shelter for trout. This action can significantly increase predation pressure on the trout, since they are rendered more vulnerable to capture (Cordone and Kelly 1960). An established standard for sediment levels carried by or deposited in a stream has not been determined for all streams in general. Sediment levels carried in the water of Abrams Creek did not appear high during normal flow, although deposits on the streambed may have been substantial. If so, transport downstream during high flow resulting from storm activity may have caused a significant impact on fish habitats and populations as described above.

Temperature, dissolved oxygen, flow, and pH may also have affected the distribution of trout in Abrams Creek. Rainbow trout (Salmo gairdneri) tolerate water temperatures from about $0^{o}C$. to over $26^{o}C$. However, they prefer temperatures below $21^{o}C$. (Calhoun 1966), which compares favorably with Abrams Creek and tributaries, which ranged between $0^{o}C$. and $25^{o}C$. (Tables 1 - 6). Rainbow prefer well-oxygenated water but can survive at very low oxygen levels (Calhoun 1966). The dissolved oxygen levels of Abrams Creek were generally well-oxygenated (except during summer) though widely varied between 4.3 and 12.0 milligrams per liter. Low concentrations of dissolved oxygen in the summer may have affected the capability of trout to utilize Cove portions of Abrams Creek and tributaries (Fig. 16). Low flow periods during the summer with associated diverted ground flow of portions of Abrams Creek within the Cove probably created an unfavorable habitat for trout. Some sections of Abrams Creek within the Cove during very dry periods of the summer completely dried up, leaving no habitat for fish. Rainbow do well in waters of varying pH, reportedly found in waters ranging from 5.8 to 9.5 (Calhoun 1966). The pH of Abrams Creek was variable, ranging between 5.8 and 8.3 (Fig. 15), but this also would not be considered limiting to trout tolerance.

The fish community in Abrams Creek generally increased in abundance and biomass between 1973-74 and 1977. Much of this improvement probably resulted from reduced siltation, turbidity, and summer water temperatures, but a lessening of fishing pressure also contributed to the improvement. Since 1974, fishing pressure has decreased by about half because the creel limit was reduced from 5 to 4 and the size limits were increased. The size limit of rainbow trout in Abrams Creek upstream from the Cove (this section more often referred to as Anthony Creek) increased from 7 to 9 inches. Downstream from the Cove (generally referred to as Big Abrams Creek) and in the Cove itself, the size limit was increased from 7 to 12 inches. These fishing regulations were placed in effect in April of 1975. Previous to that date the regulations had not been changed for at least 15 years (Allan Kelly, U.S. Fish and Wildlife Service, personal communication).

In a stream, the basic food supply for higher organisms is bacteria, algae, fungi, and insects. After introduction of silt, as much as a 90 percent reduction in these aquatic organisms has been observed (Zierbell and Knox 1957; Cordone and Pennoyer 1960). The reduction of bottom-dwelling invertebrates obviously has a severe effect upon trout populations as well as other fish species which feed on aquatic invertebrates. Rainbow trout eat a wide variety of foods, depending primarily on availability, which in turn depends on such factors as water quality, season, and size of fish. A compilation of the findings of studies indicates that immature and adult aquatic insects (principally caddisflies, mayflies, and dipterans), zooplankton, terrestrial insects, and fish are usually the most significant foods, though their relative importance varies greatly between waters and seasons. Oligochaetes, mollusks, fish eggs, amphipods, and algae head the list of foods eaten less extensively (Bundick and Cooper 1956, Hazzard 1935, Idyll 1942, Metzelaar 1929, Needham 1935, and Rawson and Elsey 1950). These food items were generally more prevalent in Cove sections of Abrams Creek, whereas preferred food items such as mayflies and caddisflies predominated in areas outside the Cove.

The density of aquatic insects (drift and benthos) is smaller in riffles of natural streams with large amounts of sediment. In addition, species diversity indices of benthic insects usually decline immediately following sedimentation, but with short term loads, the indices usually show recovery within a few weeks (Bjornn 1974). Diversity indices of benthic macroinvertebrates declined in the Cove, probably resulting from the multiple stresses applied from siltation, sedimentation, nutrification, organic loading, and altered temperature regimes. Diversity changes were perhaps not as drastic as expected in transition through the ecological zones, considering the considerable differences in the chemical - physical nature of the water in the various zones resulting from natural (especially stream channel meandering) and man-altered (especially cattle grazing and sewage treatment system) changes in the stream.

The erosion of sandstone sediments into Abrams Creek and tributaries derived from erosion off surrounding mountains composed of Cades Sandstone (King et al. 1968) was reflected in conductivity levels. Increases in conductivity occurred in Abrams Creek and tributaries within Cades Cove. The addition of these sandstone constituents, principally feldspar, quartz, and slate (King et al. 1968), to the water increases the osmotic pressure of the water. Also, the influence of emerging ground flow via spring seeps into Abrams Creek (e. g., station 26) at the lower end of Cades Cove was considerable, averaging 74 µhmos per cm^3 and ranging from 10 - 132 µhmos per cm^3. Most park waters, as well as the section of Abrams Creek upstream from the Cove, rarely exceed 20 µhmos per cubic centimeter (cm^3). Thus the osmotic stress imposed upon the system may be substantial based on conditions outside of this area (i.e., low conductivity and thus low osmotic pressure) which the aquatic organisms in other stream areas of Abrams Creek are adapted to (McKee and Wolf 1963; Hart et al. 1945). Movement of aquatic organisms through this area may be somewhat limited by these sudden changes in water quality. Coinciding with increased conductivity in the area of ground water seepage into Abrams Creek, the alkalinity and hardness also increased. The alkalinity undoubtedly increased as a result of the carbonate input from the limestone during groundflow, which also caused the acidity to decrease. Increased hardness was undoubtedly related to the input of calcium and magnesium from the limestone groundflow. Increased hardness in Cove sections of Abrams Creek above the influence of the spring seeps was probably derived from the erosion of Cades Sandstone, especially the mineral feldspar constitutent, into Abrams Creek.

Natural streams undergo continual change with time through the forces of solution, erosion, and deposition, with associated changes in fish fauna that follow from a newly formed cutting, tumbling stream through to the old-age stage, characterized by sluggishness and meandering near base level. Man has altered the natural pattern of the Abrams Creek drainage, for example, through land clearing, farming, channelization, sewage treatment outfalls, and cattle grazing. These practices have undoubtedly changed the natural conditions in the creek. Increased temperature regimes, nutrient enrichment, and changes in the benthic macroinvertebrate composition (i.e., food items) are some of the alterations resulting in Abrams Creek within the Cove. It is not known, however, to what extent these changes influenced the fish species composition in Abrams Creek in the Cove because the creek meandered before it was straightened and was often dry during summers in some areas. In the Cove, the creek may not have been much of a trout stream once the land was cleared of timber.

The prevalence of black spot (parasitic digenetic trematodes) in the Cove fishery may be more closely correlated to the open nature of the Cove than to organic loading and nutrification because such terrain provides good access for foraging on infected fish by hosts of the parasites; e.g., birds and mammals (Don Estes, U.S. Fish and Wildlife Service, Coop. Fishery Research Unit, Tennessee Tech. Univ., Cookeville, TN, personal communication). Black spots are cysts containing the resting metacercariae of worms, which for the most part belong to the strigeids. The life cycles of these parasites vary considerably in the different species but tend to follow the same general pattern. The infected fish are devoured by fish-eating birds and mammals, most likely Kingfishers and raccoons in the Cove. The parasites are then liberated in the intestine, where they mature and produce the eggs which eventually pass out in the feces of the host. In water, these eggs hatch into miracidia, which must find and penetrate certain species of snails, such as Ferrissia, which were common in the Cove. After multiplying in the snail for several generations, they emerge as cercariae, which penetrate underneath the scales or into the muscles of fish (Davis 1953). Black spot is not considered to be a serious threat to fish unless present in very large numbers, which was not the case in the Abrams Creek fishery. The pigmented cysts, however, degrade the appearance of fish, resulting in an aesthetic impact, particularly for trout fishermen.

The reference area section of Abrams Creek is a nutrient-limited system, as are most park waters, which results in a low level of productivity. Since increased productivity generally results in greater abundance of organisms, a factor incorporated into the diversity formulas, these indices tended to be increased in the Cove stressed areas and lessened in the reference areas of Abrams Creek. The number of different species, however, also incorporated into the diversity index formulation, declined substantially in the stressed areas as expected due to their intolerance of many of the impacts imposed upon the system. The number of species was greater in the reference area because of the clean water quality and complexity of the undisturbed substrate (boulder, rock, and sand substrate). This tended to increase the value of the diversity indices in the reference area and decrease it in the stressed area.

Diversity indices and standing crop values in recovery areas exceeded those found in reference areas. This was probably due to the riverine nature of recovery area waters as a complex substrate and more abundant habitat was provided there, as well as nutrient influx from the cove. So the aspect of both number of individual organisms and species was enhanced in the recovery area.

Cattle defecation in Cades Cove undoubtedly provides nutrient loading to Abrams Creek. This was not, however, reflected in the concentrations of nitrate and ortho-phosphate, which were at levels relatively consistent in concentration throughout Abrams Creek. The reason for this occurrence is attributed to these nutrients being assimilated by the increased abundance and biomass (i.e., standing crop) of some types of aquatic organisms in Cove sections of Abrams Creek through various pathways in the food chain. Periphytic diatoms were observed to be more prevalent in the Cove and just below the confluence of Mill Creek than in other sections of Abrams Creek. The standing crop of benthic macroinvertebrates and fish increased sharply from the upstream reference areas through the Cove stressed areas. The aquatic faunal composition changes were less dramatic in transition from the Cove through downstream recovery areas, though increased diversity and standing crop did occur in the benthic community. The standing crop (number and biomass) of fish in the recovery area, however, was less than in the Cove. The concentrations of nutrients showed peaks well above the trend at certain stations in Abrams Creek. These appear correlated to possible waste water leaching from the Cove sewage lagoon to Abrams Creek and to the septic outfall from the residence in the Cove (Cades Branch) not connected into the sewage treatment facility. Other sources, generally less profound, were related to human activity during seasonal use (May 15 - October 15) of the picnic ground above the Cove, to untypically large numbers of cattle watering and wading in a small tributary to Abrams Creek (Feezel Branch), and to heavy year-around hog activity observed in and around Tater Branch as indicated by rooting disturbance. Some instances of relatively high nutrient concentrations, such as on Stony Branch entering Abrams Creek below the Cove, are not understood. It is generally accepted that animal wastes are major contributors of nitrogen and phosphorous in agriculatural land runoff (Holt et al. 1970; Holt 1971; and Robbins et al. 1971). Grazing cattle reportedly produce about 17.60 kilograms per year per animal of total phosphorous and 57.47 kilograms per year per animal of total nitrogen (Omernik 1977). In this aspect, cattle nutrient production far exceeds that of other common farm animals (hogs, sheep, and poultry) according to Omernik (1977). An estimate of the total nutrient production available for export can, therefore, be determined for the overall cattle densities (i.e., animal units per acre). The cattle herd (1,200 head) in Cades Cove during 1974 thus produced about 21,120 kilograms of total phosphorous and 68,988 kilograms of total nitrogen, while during this study (1977) the herd (500 head) produced about 8,800 kilograms of total phosphorous and 28,745 kilograms of total nitrogen. A considerable difference in nutrient enrichment and eutrophication therefore existed between the two study periods. Of course, the exact amount of nutrient export to Abrams Creek drainage would be difficult to determine. Omernik (1977) showed that total phosphorous export is about 2.9 times greater for predominantly agricultural land than for predominantly forest lands, and total nitrogen is 2.8 times greater. Regarding the inorganic forms, orthophosphorous export from agricultural watersheds is 2.3 times greater than from forested watersheds, whereas the difference in inorganic nitrogen export is over 13 times greater. Inorganic nitrogen concentrations are, on the average, reported to be 39 times greater in streams draining agricultural watersheds than they are in streams draining forest areas (Omernik 1977).

Differences in wildlife nutrient exports in forested systems, compared to cattle exports in agricultural lands, varies considerably on the basis of land uses (i.e., agricultural vs. forested watersheds) according to Omernik (1977). For this reason, the reduction of cattle from 1,200 to 500 head in Cades Cove (i.e., change in land use category) would be expected to result in substantial changes in the aquatic faunal composition. As expected, benthic macroinvertebrate and fish communities in Cove and downstream recovery sections of Abrams Creek showed significant improvement between the surveys conducted in 1973-74 and 1977. This is most easily evaluated in terms of the Similarity Indices (SI) between the different (four) ecological areas of the two survey years. These indices clearly showed that less abrupt changes between reference, stressed, recovery, and control areas existed in 1977 than in 1974. Obviously, the more closely the stressed area approaches similar species composition with other ecological areas, the more improvement is assumed in the water quality. Because of natural differences in the ecological areas, SI would be different even without pollution; however, the trends are very meaningful in the interpretation of water quality changes. Community structure analyses on the benthic community reflect a pristine reference area, disturbed Cove area, a zone of recovery from stressed conditions in the Cove, and a relatively undisturbed control area. The composition of the benthic taxonomic assemblages showed similar results as more sensitive species became less represented in abundance and importance value (IV) from undisturbed upstream sections through the Cove, and then improved downstream from the Cove.

At the confluence of Abrams and Mill Creeks (station 17), the BOD_5 during February was 34.0 milligrams per liter, which exceeds the daily average effluent concentration limit of 30.0 milligrams per liter for discharges to surface water courses in the State of Tennessee (Tennessee Department of Public Health, 1973). The BOD_5 concentrations were building up to this level on a steady trend from station 9 in the middle of the Cove on downstream to station 17 just below the confluence, apparently reflecting increasing accumulation of organic waste throughout the Cove drainage. Below the confluence, the BOD_5 dropped off sharply as organic loading declined, dilution entered from Mill Creek, and stream processes presumably assimilated the organic carbon. This area was, however, characterized by luxuriant growths of filamentous slime algae similar to aquatic ecosystems affected by municipal sewage effluents described by Keup (1966). During the summer, high BOD_5 concentrations at stations 8 and 9 were possibly due to a combination of organics derived from the sewage lagoon leachate, horses (about 40 head) maintained and rented at the Cove horseback-riding concession, and cattle located between these stations. The high bacterial counts which were typical of this area of the Cove supported derivation from these sources.

Assuming seepage from the sewage lagoon does exist, it would be expected to have a greater influence during the summer than at other times, as the water table drops, low flow conditions prevail, and septic loading is increased by the large number of visitors to the area. The trend for BOD_5 concentrations declining from winter through summer is thought to be a factor of the change from dormant inactive states in the spring and summer Active organisms assimilate increased amounts of organics due to increased metabolic processes. As a consequence, the high levels of BOD_5 observed in the winter were not seen in the spring and summer, since much of the organics were tied up by aquatic organisms during the warmer seasons. Also, high flow conditions in the winter and spring would tend to carry more foreign sediment, including organic material, than low flow during the summer.

Algal communities in the reference area (station 1) indicated an undisturbed environment of high oxygen concentration and low organic enrichment. The character of the algal communities changed somewhat, even below the picnic ground (station 3), where Abrams Creek first enters the Cove. Pollution-tolerant species were more dominant in the community structure, including indicators of eutrophic conditions. This structure apparently resulted from the activities of heavy visitor usage on the stream, especially in the area of the picnic ground upstream. Conditions, however, did not indicate heavy organic enrichment, although facultative nitrogen heterotrophs and general pollution indicator species were present.

At station 4, adjacent to the sewage lagoon, the situation changed to one favoring diatoms which are tolerant of varying stream flow regimes as well as moderate pollution and eutrophication, although organic enrichment was not characterized by ecological parameters represented by diatom species present at station 4. Highly variable stream flow regimes resulting from ground flow divergence of surface waters from Abrams Creek at and above this station resulted in the reophilus (i.e., characteristic of running water but found in standing water) species present. The eutrophic nature of the water at the station may also be influenced by the sewage lagoon and the horse pasturage upstream from the sewage lagoon.

In and around station 9, where cattle enter the stream for watering and wading, the diatom community indicates a zone where oxidation of organic matter is proceeding; the concentration of inorganic nutrients is high; and the water is generally turbid, eutrophic, and characterized by periods of both flowing and standing water regimes. During July the water in this area at times exists in stagnating pools until rainfall increases the volume of flow and flushes the system. Station 26 is also often characterized by stagnant pools or completely dry conditions during parts of the summer. As a consequence of this variable flow regime, some of the diatom species in the area of the stations (9 and 26) are among those usually found in pond and lake environments. The diatom community is characterized by eurythermal (i.e., occurring over a temperature range of 15° C. or greater) tolerance. It depicts an environment which is highly eutrophic, oxidizing heavy organic loads, and nitrogen enriched in the form of ammonia compounds.

As Abrams Creek leaves the Cove (station 15), another environmental component highly modifies the water, with abrupt changes in the productivity and community assemblage of diatoms. The ground water flow surfaces in areas upstream of this station, mainly by spring seeps entering the drainage. Waters which flowed through the underground limestone strata were buffered as detected from elevated pH levels in the resurfacing waters. Changes in pH during June and July ranged from an average of 6.5 where surface flow was directed underground to an average of 8.4 at the resurfacing zone (as indicated by the satellite telemetry station downstream from station 26). The diatom community in this area was dominated by species alkaliphilous (i.e., occurring at a pH around 7, with best development over 7). It also indicated a eutrophic environment where oxidation of biodegradable compounds was complete and the concentration of inorganic nutrients was high. Massive algal blooms were observed at this station (15) and downstream to an area just below the confluence of Mill Creek and Abrams Creek (station 17). This is thought to be a result of increased pH and temperature. Higher pH levels support more algae production, since carbon becomes more available in the form of carbonates and free carbon dioxide (Rex Lowe, Bowling Green State University, pers. communication). Carbonates were also undoubtedly abundant in this area (i.e., stations 15 and 17) from the input of the limestone during ground flow. As a general rule, alkaline waters support greater production of algae than acidic ones, such as characterized by most of Abrams Creek. The overall diatom community in the Cove was indicative of a eutrophic-nutrient enriched stream (Rex Lowe, Bowling Green State University, pers. communication). The diatom composition at station 18 in the recovery zone indicated improved water quality, similar to that indicated by the benthic and fish communities at higher trophic levels. The diatom community at this station was dominated by species which were less tolerant of alterations of thermal regimes and more cosmopolitan in distribution, thus indicating moderate improvement.

The purpose of the bacterial investigation was to estimate the numbers of three types of bacteria in Abrams Creek and tributaries. Water samples were collected monthly from May to August 1977 at 36 stations. The numbers of bacteria were variable between samples and sampling periods.

One of the major contributions to the variation in bacterial counts undoubtedly originated from intermittent nonpoint sources of contamination by cattle and free-ranging mammals in the Cove and the Abrams Creek watershed. The difficulty of interpreting such introductions is that they occurred inconsistently. Such introductions resulted in high counts on some sampling dates but not on others at particular stations.

Much of the enteric bacteria contamination along certain portions of Abrams Creek probably originated from the large numbers of visitors. It is highly possible that the high ratios of fecal coliforms to fecal streptococcus bacteria (Figs. 22 and 23) at station 34, 9, and 26 originated from underground seepage from the sewage lagoon and contamination from numerous visitors observed along the road just upstream from station 34. Subterranean drainage from the lagoon is a possibility, since overflow from the lagoon occurred infrequently; this overflow is chlorinated and contains no live enteric bacteria (W. Williams, Park Sanitarian, National Park Service, personal communication). Subterranean drainage from the lagoon probably surfaces at springs located just upstream from station 34.

Another factor influencing the bacterial counts in the streams in Cades Cove was precipitation. Heavy rainfall could have increased the distribution of enteric bacteria. This could be so even after the flow of the streams declined after the rainfall. The mechanisms by which this spread of bacteria occurred is not fully understood, however.

Tributary streams along the south side of Cades Cove generally had higher bacteria counts than did north side streams. This was probably influenced by the greater contact of these streams with pastures than the north side streams. Furthermore, the low ratios of fecal coliforms to fecal streptococcus bacteria at nearly all stations on the tributaries suggests that the main source of these bacteria originated from nonhuman sources. The abundance of cattle, deer, wild European hogs, skunks, squirrels, and ground hogs could be the primary sources of the enteric bacteria. In the previous investigation, most of the ratios from Cades Cove fell into the animal range (80 percent) and none were clearly human according to Silsbee et al. (1976).

The number of total coliform bacteria in Abrams Creek were often above levels recommended by the U.S. Environmental Protection Agency and Tennessee State standards for primary contact recreational waters (Fig. 24), a result similar to that found by Silsbee et al. in 1976. These bacteria appear to originate from several sources, including humans and other animals.

An important question that evolved from this study was whether the reduction in the number of cattle at the Cove during 1976 had any effects on the numbers of enteric bacteria in Abrams Creek in 1977. This question was examined by comparing counts of fecal coliform bacteria made in July 1976 (Silsbee et al.) and in July 1977 at nearly identical main stream sample stations (11) on Abrams Creek under very similar climatic conditions. Based upon these data, the numbers of bacteria were significantly higher in 1976 than in 1977 (unpaired t-test, $P < .05$). These results occurred even though the number of visitors at the Cove in July 1977 was about four times higher than the number in July 1976. Based upon these results and circumstances, it appeared that the reduction in the numbers of fecal coliforms was related to the decline of cattle in Abrams Creek in Cades Cove in July 1977.

From a management standpoint, in determining actions to improve the water quality of Abrams Creek, the basic problem stems from a conflict of interest in park "natural" and "historical" area policy. Unaltered ecosystems are an essential part of our national parks. The purpose of the National Park Service, established as the administrative agency of the National Park system by the Act of August 25, 1916, is "to conserve the scenery and the natural and historical objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (39 Stat. 535). Only through sound management strategies can the natural resources of our national parks be preserved and maintained for future generations. From a conservation viewpoint, the preservation of these fragile resources is crucial, since the wilderness of our parks will serve as a baseline to which human manipulation of the environment (an unnatural process) can be measured. The National Park Service has established procedures for treatment of archaeological, historical, and other cultural properties in conformity with the Historic Preservation Act of 1966, Executive Order 11593, and guidelines of the Advisory Council on Historic Preservation. The procedures adopted by the National Park Service require determination of the adverse effects only upon National Register property and not on the ecosystems of peripheral areas. In the future, a policy could be developed to deal with the effects of management practices in historical sections of national parks on adjacent natural areas before impacts develop.

SUMMARY AND CONCLUSIONS

(1) Abrams Creek within Cades Cove represents a unique resources management problem within Great Smoky Mountains National Park. Erosion of the streambank was recognized by the National Park Service as a problem as early as 1937 and was attributed to heavy rainfall, improper farming, and overgrazing. A management program developed in cooperation with the Soil Conservation Service in 1946 resulted in some stream channels being cleared of trees and shrubs, while others were straightened. These actions did not solve the erosion problem.

(2) The National Park Service developed its own management program in 1967. The objective of this program was to maintain the open aspect of the farm fields and meadows which provide a background for interpreting the historic structures and features of the pioneer culture as it existed when the park was established. To maintain these fields in an efficient manner, the park has allowed leasees to grow hay and graze cattle under special use permits. This program is still used at the present time, but is being reconsidered by park management due to the impact of cattle on the Abrams Creek drainage.

(3) A fencing program developed by the park in 1973 resulted in cattle being excluded from major portions of Abrams Creek and tributaries, with only specific sites left open for cattle to water and wade. This caused extensive streambank erosion in these areas and probably has not reduced all of the impact of cattle on Abrams Creek. In addition, some of these fence rows are falling into Abrams Creek as it meanders and cuts into banks. Nonetheless, vegetation is returning to many streambanks now protected from the cattle because of the fencing. In these areas, erosion appears to be reduced from previous levels.

(4) The number of cattle grazing in Cades Cove was reduced from 1,200 to 500 head in 1976 by order of the National Park Service in an effort to curtail the impact to Abrams Creek while still maintaining the land management program. The magnitude of improvements of water quality between Kelly's (1974) survey and this study (1977) strongly indicate that the cattle reduction improved the water quality. However, due to the complex interrelationship of factors affecting the Abrams Creek drainage, the treatment effect of cattle on water quality was difficult to sort out since (a) Abrams Creek has, since man's settlement of the area, meandered and caused bank erosion anyway -- especially since the channel was straightened; (b) the water quality of Abrams Creek without the effect of cattle is not known; and (c) the impact of

other free-ranging mammals on the system has not been investigated.

(5) The primary effect of cattle grazing in Cades Cove was to increase streambank erosion and siltation. Other inputs to the creek from the cattle include nutrients and enteric bacteria.

(6) During different stages of cultural development in Cades Cove, Abrams Creek undoubtedly experienced considerable changes from Anthony Ridge to Chilhowee Lake. Before the Cove was opened to settlement, it was part of the Cherokee Indian Nation and remained undeveloped. The dense forest in Cades Cove probably prevented or slowed the meandering rate in Abrams Creek. When settlers moved into the area around 1821, they gradually cleared the entire Cove by burning or girdling trees and planting crops and orchards. Cattle were grazed in the Cove during the winter and on the grassy balds high above the Cove during the summer. This action probably accelerated the meandering character of Abrams Creek. Since the Cove is still maintained in this open aspect, it is expected to continue its accelerated meandering until it is allowed to return to forest. Extensive logging operations in Cades Cove were dominated by the Little River Lumber Company after the turn of the century (1908 - 1936). They logged up all major streams draining into the Cove. Accelerated erosion, siltation,

and high turbidity loads resulted from these operations and probably caused extensive impacts to the Abrams Creek drainage. Trees are still being selectively cut in Cades Cove in order to maintain the open aspect, which allows more solar radiation to be received by Abrams Creek and results in less resistance to streambank erosion.

(7) The physical and chemical characteristics of Abrams Creek in Cades Cove are substantially altered by subterranean flow. In Abrams Creek at the upper end of the Cove, variable amounts of flow are diverted underground. During very dry periods in the summer, portions of Abrams Creek have no surface flow, leaving standing pools and dry streambeds. The diverted ground water flows through an underground limestone strata, where it is buffered. Since the composition of the area soils and streambed is mainly derived from the alluvial depositions of the surrounding Cades sandstone of the Ocoee Series, which is typically acidic, the physical - chemical changes incurred by the diverted water are substantial. The water re-emerges into Abrams Creek via springs and seeps at the lower end of the Cove. Changes in the character of the surface flow below this area also result in changes in the faunal composition in Abrams Creek.

(8) The sewage treatment lagoons in Cades Cove, which serve the picnic, campground, maintenance area, and ranger residences above the Cove, could be contributing impacts to Abrams Creek. High bacterial counts with fecal coliform/fecal streptococcus ratios indicative of derivation from human sources, BOD_5 concentrations, and nutrient concentrations in the area of the sewage treatment lagoon system support the possible origin from the lagoon. Leachates from the lagoon system could easily enter Abrams Creek through the porous substrate in the Cove, where the extensive ground flow regime could transport to the surface flow. Assuming seepage from the sewage lagoon does exist, it would be expected to have its greatest impact during the summer when the water table drops, low flow conditions prevail, and septic loading is increased by the large number of visitors to the area.

(9) Turbidity and suspended solids were high in Abrams Creek and its tributaries where large numbers of cattle typically water and wade for long periods of time, especially during the summer in response to hot temperatures and insect pests observed on the cattle. Very low levels of suspended solids and turbidity occur in Abrams Creek upstream from the Cove except in winter and early spring when anchor ice probably causes shearing of the stream substrate and the flow is high. Loosened soil which falls into the creek from the freezing - thawing

process on numerous vegetatively denuded streamsides is an additional source of sediment in winter.

(10) Additional sediment sources arose from hoof damage to streambanks on Abrams Creek, which occurred where cattle entered and exited watering and wading sites. There are eight such sites on the mainstream of Abrams Creek, representing about 20 percent of the streambank within Cades Cove. Other sites occur on the tributaries to Abrams Creek in the Cove. Roots of trees and shrubs were cut and grass trampled by cattle, leaving little or no vegetation to stabilize the channel. Furthermore, the dense deer population in Cades Cove, estimated to be at least 160 head in 1975, resulted in heavy browsing and loss of vegetative growth on streambanks. Trees planted along Abrams Creek to help reduce erosion failed because of almost complete loss of these trees by deer browsing. Ground hogs were also observed living in burrows dug in or near streambanks, probably reducing soil stability and adding to the sedimentation - siltation problem.

(11) The natural meandering characteristics of Abrams Creek in the Cove is probably the major reason for bank erosion since the stream was straightened and sloped in the Cove in 1946. Bank erosion has probably been accelerated from these physical modifications of the creek. Fences erected along Abrams Creek

in the Cove in 1976 are already in jeopardy of collapsing in many places into the creek due to such channel displacement.

(12) In general, benthic macroinvertebrate communities in stressed regions were characterized by reductions from reference and recovery areas in the following parameters: number of taxa; importance (IV) of intolerant *Ephemeroptera*, *Plecoptera*, and *Trichoptera*; and diversity ($\bar{d}$ and $\bar{H}$).

(13) The benthic macroinvertebrate communities in Abrams Creek in Cades Cove were altered as compared to upstream reference and control area; however, substantial recovery occurred downstream. Recovery also occurred between 1973-74 and 1977 as a result of improved water quality in the stressed area.

(14) Fish populations in stressed regions of Abrams Creek were characterized by reductions in the standing crop of rainbow trout, increased standing crops of rough and forage fish, exposed epithelial tissue behind opercle flaps in rainbow trout, and prevalence of black spot cyst on all species.

(15) The rainbow trout population in Abrams Creek increased from 1973-74 to 1977 as a result of improved water quality,

strict fishing regulations, and reduced fishing pressure. Low flow periods during the summer with associated diverted ground flow of portions of Abrams Creek within the Cove probably created an unfavorable habitat for trout. Some sections of Abrams Creek within the Cove, during very dry periods of summer, typically dry up, leaving no habitat for any fish. No trout were observed or captured in these sections during normal flow conditions.

(16) Periphytic diatoms from Abrams Creek in the Cove indicated a eutrophic-nutrient-enriched stream system. Luxuriant growths of filamentous slime algae in Abrams Creek just below the Cove resulted from organic loading, nutrient enrichment, altered light regimes, and the effect of buffered subterranean flow.

(17) Enteric bacterial contamination along portions of Abrams Creek and tributaries was heavy and at times at levels considered unacceptable to secondary contact (fishing) users of the stream.

(18) The primary source of bacterial contamination was probably due largely to the abundance of cattle; however, probable subterranean drainage from the Cove sewage lagoon was also suspected to contribute heavily. Deer, wild European hogs, ground hogs, and other mammals were additional sources.

(19) Man has altered the natural ecosystem of the Abrams Creek drainage through land clearing, farming, channelization, sewage treatment outfalls, and cattle grazing. These practices have undoubtedly changed the natural conditions in the creek. Increased temperature regimes, nutrient enrichment, organic loading, accelerated streambank erosion, bacterial contamination, as well as alterations in the composition of diatoms, benthic macroinvertebrates, and fish are some of the changes man has caused to Abrams Creek within Cades Cove. Through programs to limit cattle access to a few select watering and wading sites on Abrams Creek and its tributaries and a reduction of the Cades Cove cattle herd from 1,200 to 500 head, much improvement has been made to the drainage. A program to reduce streambank erosion by planting seedlings has not been successful due to heavy deer browsing and hoof damage by cattle. Nevertheless, the water quality of Abrams Creek is probably better than it has been for many years. There is room for more improvement while still maintaining the historical features of the Cove. It is hoped that the improvements seen in Abrams Creek between 1974 and 1977 will serve as a baseline for formulating additional management programs in Cades Cove in order to further improve the system as deemed necessary.

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APPENDIX

TABLES 1 - 6

Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Months: February - July

ABBREVIATIONS

Sta.	=	Station
Turb.	=	Turbidity
Temp.	=	Temperature
D. O.	=	Dissolved Oxygen
Acid.	=	Acidity
Alk.	=	Alkalinity
BOD_5	=	Biological Oxygen Demand (5 days)
Susp.	=	Suspended
Cond.	=	Conductivity
Phos.	=	Phosphate

TABLE 1. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Month: February

Sta. No.	Turb. (JTU)	Air Temp (°C)	Water Temp (°C)	D. O. (ppm)	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hard-ness (mg/l)	BOD_5 (mg/l)	Settle-able Solids (mg/l)	Susp. Solids (mg/l)	Conduct. µmhos/cm³	Ortho-phos. (mg/l)	pH
1	1.9	4	1	12.0	5.90	20	1	5	11.0	< .1	0.092	10	0.06	6.0
2	1.9	0	1	12.1	6.10	10	1	17	12.5	< .1		11	0.09	6.0
3	3.0	13	3	11.6	5.30	12	12	1	12.5	< .1		11	0.03	6.5
4	5.0	-1	0	11.0	3.50	10	2	10	12.5	< .1	0.111	12	0.11	6.7
5	0.5	19	5	9.4	4.00	10	1	10		< .1		10	0.07	6.2
6	0.6	19	4	10.5	3.50	10	2	11		< .1		11	0.08	5.7
7	0.7	19	4	10.7	3.40	10	2	10		< .1		13	0.09	5.8
8	2.3	2	0	12.0	10.40	10	1	8	10.5	< .1	0.094	16	0.08	6.8
9	2.8	2	1	11.2	3.60	10	15	70	7.5	< .1	0.098	17		6.6
10		2	4	10.8	18.00	10	4	45		0.2			0.08	6.4
11	4.2	18	4	11.0	3.50	10	3	10		< .1		16	0.04	6.5
12	5.8	19	4	11.2	3.50	10	2	19		< .1		20	0.07	6.3
13	0.5	18	4	11.0	4.00	10	1	12		< .1		18	0.06	5.8
14	1.0	18	4	12.2	3.50	10	2	13		< .1		19	0.07	6.4
15	3.8	10	9	10.2	3.60	10	15	70	21.0	< .1	0.112	80	0.06	7.4
16	0.8	4	1	12.2	3.60	30	1	13	17.0	< .1		12	0.05	6.8
17	1.3	19	8	10.5	4.00	10	5	46	34.0	< .1	0.123	90	0.07	7.3
18	3.2	8	7	11.2	2.60	50	1	230	9.0	< .1		50	0.06	6.8

TABLE 2. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams.

Month: February

Sta. No.	Turb. (JTU)	Air Temp (°C)	Water Temp (°C)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hard-ness (mg/1)	BOD_5 (mg/1)	Settle-able Solids (mg/1)	Susp. Solids (mg/1)	Conduct. (µmhos/cm³)	Ortho-phos. (mg/1)	pH
19	2.2	2	1	11.2	3.60	0	2	48	10.5	<.1	0.139	54	.08	6.8
20	2.1	2	0	11.4	8.80	10	13	30	10.0	<.1		56	0.08	6.2
21	1.4	2	0	12.0	3.20	0	1	26		<.1	0.153	50	0.08	7.5
22	0.8	2	0	11.0	3.50	20	1	25	19.0	<.1		51	0.07	6.9
23	42.0	9	9	7.0	4.00	6	8	48	19.0	<.1		62	0.07	6.9
24	5.0	11	0	4.8	5.30	5	30	133	20.0	<.1		121	0.09	6.9
25	4.0	13	6	8.8	3.50	10	13	19		<.1		21	0.07	6.9
26	4.6	10	1	10.8	4.40	5	9	20	10.0	<.1	0.164	22	0.03	6.5
27	6.0	10	1	10.5	4.00	9	7	9		<.1		18	0.05	6.8
28	4.0	12	5	8.1	3.50	9	7	8		<.1		18	0.07	6.8
29	4.0	14	4	8.3	3.10	9	6	10		<.1		11	0.20	7.0
30	3.0	12	4	8.3	4.80	11	14	4		<.1		11	0.03	6.7
31	4.0	13	3	11.2	4.40	14	5	9		<.1		16	0.05	6.7
32	4.0	13	4	7.7	4.00	7	12	7		<.1		22	0.06	7.2

TABLE 2. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: March

Sta. No.	Turb. (JTU)	Air Temp (°C)	Water Temp (°C)	D. O. (ppm)	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hardness (mg/l)	BOD_5 (mg/l)	Settleable Solids (mg/l)	Susp. Solids (mg/l)	Conduct. μmhos/cm³	Orthophos. (mg/l)	pH
1	6.4	22	8	11.6	3.52	48	1	3	8.0	< .1	0.093	9	0.07	6.2
2	3.4	25	9	11.4	3.52	48	1	4	9.0	< .1		10	0.08	6.2
3	3.5	15	8	12.4	3.96	48	1	2	11.0	< .1		11	0.07	6.3
4	2.1	15	8	12.6	3.01	50	1	8	13.0	< .1	0.103	13	0.11	6.3
5	3.1	15	9	12.0	3.52	48	1	5		< .1		10	0.08	7.0
6	3.6	25	11	8.7	3.52	48	1	5		< .1		12	0.08	7.2
7	Dry											14		
8	5.9	25	10	10.4	3.96	46	1	4	11.0	< .1	0.083	15	0.08	6.8
9	4.5	27	11	10.5	3.96	41	1	11	16.0	< .1	0.084	17	0.08	6.8
10	Dry											15		6.7
11	7.1	15	9	10.4	3.96	47	1	4		< .1		21	0.08	6.5
12	4.8	15	10	10.1	3.52	46	1	3		< .1		17	0.05	6.3
13	5.2	15	8	13.0	3.08	41	1	4		< .1		20	0.08	6.8
14	5.1	15	9	11.0	3.08	48	1	3		< .1		79	0.07	6.3
15	3.1	13	11	11.4	3.96	24	1	34	13.0	< .1	0.102	10	0.08	7.3
16	0.8	24	10	11.6	3.52	31	1	14	13.0	< .1		89		6.8
17	3.8	13	11	9.8	3.96	28	1	40	13.0	< .1	0.113	48	0.06	7.6
18	4.6	15	8	10.4	3.08	30	1	20	13.5	< .1		52	0.08	7.3

TABLE 2. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: March

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp. (°C)	D. O. (ppm)	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hardness (mg/l)	BOD_5 (mg/l)	Settleable Solids (mg/l)	Susp. Solids (mg/l)	Conduct. (μmhos/cm³)	Orthophos. (mg/l)	pH
19	4.2	25	12	10.0	3.52	39	1	12	14.5	<.1	0.117	57	0.08	6.9
20	6.0	25	12	10.2	3.96	40	1	10	14.0	<.1		48	0.09	6.2
21	6.2	25	12	10.6	3.52	141	0	12		0.1	0.144	52	0.09	7.4
22	5.0	25	12	10.8	3.52	90	1	9	13.0	<.1		62		7.5
23	13.0	24	19	7.9	4.40	40	1	4	13.0	<.1		58	0.08	6.8
24	4.4	24	16	7.6	3.96	40	2	100	15.0	<.1		121	0.10	6.9
25	4.9	15	8	12.2	3.96	41	1	8		<.1		23	0.08	7.0
26	3.2	14	13	9.9	3.96	63	1	9	15.5	<.1	0.139	17	0.04	6.6
27	0.5	25	14	10.4	4.40	50	1	8		<.1		18	0.06	6.5
28	5.8	15	9	11.0	3.96	50	0	4		<.1		10	0.08	6.5
29	5.5	15	8	11.8	4.40	51	1	6		<.1		11	0.29	6.8
30	5.1	15	9	11.2	3.96	47	1	0		<.1		12	0.05	6.8
31	3.8	15	8	13.4	3.96	55	2	3		<.1		17	0.07	7.0
32	4.9	15	9	11.6	3.08	50	1	4		<.1		22	0.09	6.3
33	3.2	15	8	11.6	3.08	40	1	3		<.1		23	0.09	7.3

TABLE 3. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Month: April

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp. (°C)	D. O. (ppm	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hard- ness (mg/l)	BOD_5 (mg/l)	Settle- able Solids (mg/l)	Susp. Solids (mg/l)	Conduct. (μmhos/cm³	Ortho- phos. (mg/l)	pH
1	1.4	22	12	9.8	4.40	49	6	0	5.5	<.1	0.002	10	0.04	6.6
2	1.3	21	12	9.8	4.40	47	6	0	4.0	<.1		10	0.13	6.4
3	0.7	27	14	9.6	3.08	37	7	5	5.5	<.1		12	0.02	6.5
4	1.3	22	12	9.8	4.18	47	10	3	1.5	<.1	0.011	12	0.11	6.5
5	1.3	22	14	6.2	3.52	47	10	5		<.1		11	0.05	6.4
6	1.6	18	14	6.3	3.52	41	10	5		<.1		12	0.04	6.4
7	Dry											13		
8	1.5	25	15	9.4	3.96	45	10	4	2.5	<.1	0.004	15	0.02	6.4
9	2.1	23	14	9.4	3.74	43	12	10	1.5	<.1	0.002	16	0.18	6.8
10	Dry													6.2
11	4.5	20	13	9.1	3.96	43	9	10		<.1		17	0.03	6.2
12	7.8	20	15	8.7	3.08	48	7	9		<.1		21	0.03	6.4
13	9.5	20	13	8.7	3.96	40	10	8		<.1		19	0.05	6.7
14	2.6	20	15	9.2	4.18	44	7	6		<.1		20	0.03	6.7
15	3.2	21	15	8.8	4.84	7	44	47	1.0	<.1	0.011	82	0.08	7.4
16	1.9	22	14	9.4	4.18	44	8	5	8.5	<.1		10	0.02	6.6
17	2.9	21	15	9.2	3.96	10	43	56	1.0	<.1	0.023	91	0.20	7.1
18	2.0	22	14	9.7	4.18	19	25	26	0.5	<.1		51	0.11	7.3

TABLE 3. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: April

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp. (°C)	D. O. (ppm)	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hard-ness (mg/l)	BOD_5 (mg/l)	Settle-able Solids (mg/l)	Susp. Solids (mg/l)	Conduct. (µmhos/cm³)	Ortho-phos. (mg/l)	pH
19	2.3	21	14	9.4	3.96	22	24	27	3.0	<.1	0.039	53	0.02	7.5
20	1.2	21	14	9.8	3.96	24	21	23	1.5	<.1		49	0.07	7.5
21	1.1	20	14	9.4	4.40	24	25	29		<.1	0.053	57	0.03	7.4
22	2.1	22	14	9.2	3.52	25	21	24	0.5	<.1		51	0.02	7.6
23	2.7	24	21	8.7	4.18	46	10	24	0.5	<.1		69	0.02	6.8
24	2.6	21	18	8.1	3.52	40	10	96	4.0	<.1		123	0.04	7.5
25	1.3	25	15	9.6	3.08	37	9	4		<.1		9	0.04	6.7
26	3.4	27	15	8.7	3.74	48	10	7	4.0	<.1	0.064	20	0.04	6.5
27	3.1	20	16	8.2	3.08	41	10	4				20	0.05	6.7
28	4.0	26	16	9.1	3.96	44	10	3		<.1		19	0.12	6.5
29	1.7	20	14	8.6	4.40	45	10	4		<.1		19	0.15	6.1
30	1.8	21	14	9.1	3.52	47	6	4		<.1		10	0.03	6.4
31	1.8	20	13	9.6	3.08	55	6	0		<.1		10	0.06	6.7
32	2.4	22	13	9.1	3.96	38	6	1		<.1		17	0.10	6.5
33	27.0	21	15	8.6	3.52	40	8	5		0.7		21	0.11	6.3

TABLE 4. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Month: May

Sta. No.	Turb. (JTU)	Air Temp. (oC)	Water Temp. (oC)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hard-ness (mg/1)	BOD_5 (mg/1)	Settle-able Solids (mg/1)	Susp. Solids (mg/1)	Conduct. (µmhos/cm³)	Ortho-phos. (mg/1)	pH
1	1.1	20	15	9.7	1.76	51	8	7	5.0	<.1	0.004	10	0.08	6.5
2	2.4	22	15	9.8	1.32	49	7	5	4.0	<.1		12	0.14	6.2
3	1.2	30	18	9.4	1.54	53	12	5	7.0	<.1		15	0.11	6.2
4	1.3	18	15	10.0	1.76	50	8	6	12.0	<.1	0.006	18	0.11	6.3
5	Dry													
6	Dry													
7	Dry													
8	1.8	25	16	9.3	1.32	49	11	2	14.5	<.1	0.003	18	0.15	6.2
9	2.0	25	19	10.1	1.32	50	12	3	5.5	<.1	0.002	20	0.16	6.0
10	Dry													
11	7.5	25	15	8.1	1.32	53	14	4		<.1		20	0.19	6.0
12	3.9	25	17	7.7	1.32	51	13	8		<.1		22	0.12	6.2
13	2.6	25	15	10.6	0.88	53	17	8		<.1		21	0.20	6.5
14	2.5	25	16	10.4	1.32	60	13	5		<.1		22	0.13	6.5
15	2.6	20	15	9.1	1.98	0	60	72		<.1	0.004	112	0.12	7.2
16	2.3	20	16	9.8	1.54	47	10	4	2.5	<.1		12	0.11	6.8
17	2.4	19	15	9.4	1.76	6	55	74	1.0	<.1	0.004	98	0.12	7.2

TABLE 4. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: May

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp. (°C)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hard-ness (mg/1)	BOD_5 (mg/1)	Settle-able Solids (mg/1)	Susp. Solids (mg/1)	Conduct. (μmhos/cm³)	Ortho-phos. (mg/1)	pH
18	2.4	28	20	7.6	1.32	27	30	31	1.0	< .1		58	0.09	7.7
19	1.8	29	18	7.8	1.32	27	29	33	2.5	< .1	0.006	59	0.09	8.3
20	1.7	29	18	7.6	1.32	29	28	29	2.0	< .1		56	0.10	8.2
21	2.0	29	18	7.8	1.32	30	30	30	3.0	< .1	0.007	60	0.13	8.0
22	2.3	22	18	7.8	1.32	31	32	31	4.5	< .1				
23	Dry													
24	185.0	23	18	7.2	1.76	0	75	100		< .1		139	0.11	7.3
25	2.0	29	19	9.1	0.00	55	13	1		< .1		19	0.15	7.3
26	8.6	31	23	8.7	1.76	48	18	10	6.5	< .1	0.005	29	0.08	6.4
27	2.6	30	22	9.3	0.88	53	11	4		< .1		20	0.15	6.4
28	2.1	31	22	8.1	0.88	52	12	1		< .1		19	0.12	6.3
29	4.2	30	15	9.6	1.32	57	11	5		< .1		20	0.11	6.1
30	1.8	24	15	9.7	1.32	64	11	1		< .1		12	0.95	5.8
31	3.2	24	15	10.5	1.98	59	10	0		< .1		14	0.11	5.7
32	3.4	22	15	10.5	1.32	56	6	4		< .1		19	0.12	5.9
33	4.2	22	20	7.6	1.76	60	8	3		0.9		23	0.09	5.7

TABLE 5. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Month: June

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp. (°C)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hard-ness (mg/1)	BOD_5 (mg/1)	Settle-able Solids (mg/1)	Susp. Solids (mg/1)	Conduct. (μmhos/cm³)	Ortho-phos. (mg/1)	pH
1	2.5	21	15	9.9	1.76	80	12	4	3.5	<.1	0.005	17	0.05	6.3
2	2.6	20	16	10.0	1.10	70	11	2	4.0	<.1		16	0.20	6.4
3	3.7	22	16	10.2	0.88	75	11	5	6.5	<.1	0.006	17	0.05	6.4
4	60.0	22	15	8.9	1.76	76	6	5	11.5	<.1	0.014	20	0.11	6.0
5	4.3	21	16	9.6	2.20	62	11	5		<.1		11	0.11	6.1
6	3.3	21	16	8.7	2.20	70	15	5		<.1		10	0.15	6.0
7	5.7	25	16	7.9	0.88	65	9	5		<.1		18	0.15	6.5
8	4.7	21	16	11.0	1.10	70	16	5	17.0	<.1	0.017	21	0.11	6.7
9	7.6	24	18	10.3	0.00	70	16	5	3.0	0.1	0.106	40	0.37	6.5
10	4.8	24	15	9.2	0.88	35	38	30		<.1		52	0.08	6.8
11	4.1	27	19	9.5	0.88	68	16	6		<.1		22	0.16	6.2
12	4.1	27	21	10.1	0.88	60	11	6		<.1		18	0.09	6.1
13	4.4	27	20	10.0	1.01	60	10	5		<.1		12	0.42	6.7
14	4.1	27	18	9.6	0.44	70	11	5		<.1		10	0.09	6.9
15	190.0	23	17	7.8	1.10	54	24	16	2.5	0.1	0.019	30	0.10	7.0
16	3.4	23	18	8.3	2.20	75	11	5	4.0	<.1	0.019	43	0.11	6.4
17	180.0	25	18	7.9	1.10	55	24	15	4.5	0.1	0.050	43	0.20	6.6

TABLE 5. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: June

Sta. No.	Turb. (JTU)	Air Temp. (oC)	Water Temp. (oC)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hard-ness (mg/1)	BOD_5 (mg/1)	Settle-able Solids (mg/1)	Susp. Solids (mg/1)	Conduct. (μmhos/cm³)	Ortho-phos. (mg/1)	pH
18	14.0	22	14	9.7	0.88	54	27	18	2.5	<.1		30	0.08	7.5
19	12.0	20	15	9.8	0.88	52	18	15	1.0	<.1	0.029	28	0.09	7.1
20	13.0	23	15	9.4	1.76	53	19	15		<.1		72	0.05	7.2
21	16.0	20	16	10.2	0.88	67	21	11		<.1	0.037	70	0.08	7.2
22	15.0	21	17	9.0	1.32	49	17	15	1.5	<.1	0.048	100	0.06	7.0
23	4.2	27	24	9.1	0.44	73	11	5	2.0	<.1		12	0.19	6.6
24	6.0	27	21	7.3	1.32	10	70	60	3.5	<.1		68	0.15	7.0
25	2.0	26	20	8.6	0.44	60	13	6		<.1		11	0.15	6.9
26	140.0	25	19	10.4	1.32	75	13	6	5.5	0.2	0.029	10	0.05	6.8
27	3.4	27	21	8.7	0.44	70	12	5		<.1		11	0.10	6.6
28	3.8	27	22	8.4	0.20	70	11	5		<.1		18	0.11	6.3
29	3.3	28	20	8.7	0.44	70	12	6		<.1		12	0.10	6.3
30	2.8	29	21	7.9	0.88	75	11	8		<.1		10	0.04	6.5
31	2.9	28	18	9.8	1.76	82	15	5		<.1		10	0.04	6.8
32	4.2	28	18	9.6	0.44	70	10	5		<.1		11	0.11	6.8
33	4.0	28	19	8.8	1.32	71	11	5		<.1			0.18	6.5

TABLE 6. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams

Month: July

Sta. No.	Turb. (JTU)	Air Temp. (oC)	Water Temp. (oC)	D. O. (ppm)	NO_3 (mg/l)	Total Acid. (mg/l)	Total Alk. (mg/l)	Total Hard-ness (mg/l)	BOD_5 (mg/l)	Settle-able Solids (mg/l)	Susp. Solids (mg/l)	Conduct. (μmhos/cm³)	Ortho-phos. (mg/l)	pH
1	1.8	21	18	9.4	1.32	16	15	2	4.0	<.1	0.001	18	0.08	6.6
2	3.3	23	18	9.4	1.76	16	13	5	6.0	<.1		19	0.10	6.6
3	3.8	23	19	8.6	1.14	12	18	9	7.0	<.1	0.007	20	0.14	6.6
4	2.5	24	20	8.3	1.76	15	12	5	31.0	<.1	0.003	22	0.05	6.9
5	Dry													
6	Dry													
7	Dry													
8	1.6	27	22	8.2	1.14	14	18	6	3.0	<.1	0.003	21	1.14	6.8
9	4.0	29	25	4.3	1.10	15	20	8	8.5	<.1	0.087	32	0.10	
10	Dry													
11	Dry													
12	Dry													
13	3.8	30	22	9.4	0.88	11	22	17		<.1		30	0.20	6.4
14	2.2	31	25	8.8	0.88	14	20	10		<.1		32	0.10	6.9
15	2.4	29	16	7.6	0.44	0	85	75	2.5	<.1	0.002	132	0.10	7.5
16	1.9	30	19	8.0	1.06	25	20	6	4.0	<.1	0.002	21	0.09	6.3
17	2.3	20	14	9.0	2.11	0	60	45	4.0	<.1	0.003	78	0.10	6.7
18	2.4	21	17	8.5	1.76	0	50	36	2.0	<.1		60	0.10	7.5

TABLE 6. Chemical - Physical Parameters from Selected Stations of Abrams and Mill Creeks and Tributary Streams - Cont.

Month: July

Sta. No.	Turb. (JTU)	Air Temp. (°C)	Water Temp (°C)	D. O. (ppm)	NO_3 (mg/1)	Total Acid. (mg/1)	Total Alk. (mg/1)	Total Hardness (mg/1)	BOD_5 (mg/1)	Settleable Solids (mg/1)	Susp. Solids (mg/1)	Conduct. μmhos/cm³	Orthophos. (mg/1)	pH
19	1.8	21	17	8.4	1.50	0	54	38	1.0	<.1	0.004	70	0.10	7.8
20	3.3	22	17	8.8	1.14	0	68	41		<.1	0.006	70	0.10	7.5
21	2.8	22	17	8.2	2.20	0	60	42		<.1	0.010	63	0.04	7.4
22	3.2	22	17	8.3	1.98	0	50	35	1.0	<.1	0.012	60	0.10	7.2
23	Dry													
24	3.3	29	18	6.9	1.50	0	110	80	3.0	<.1		140	0.20	7.2
25	2.4	30	25	7.9	1.01	21	13	6		<.1		30	0.03	6.6
26	Dry													
27	3.0	30	27	8.1	0.66	24	25	7		<.1		30	0.10	6.4
29	3.5	28	19	7.9	1.06	13	20	5		<.1		28	0.10	6.4
30	3.0	29	21	8.1	0.88	22	20	2		<.1		30	0.11	6.4
31	1.7	29	18	7.2	1.32	19	15	3		<.1		20	0.10	6.3
32	2.5	29	20	9.0	1.32	15	30	5		<.1		25	0.01	6.6
33	4.6	32	25	9.1	0.88	10	27	8		<.1		50	0.09	6.5

TABLE 7. Satellite-Associated Water Quality Data Collected from Abrams Creek.

Date	Temperature (^{o}C)			Dissolved Oxygen (mg/1)			Specific Conductance (MicroMHOS/cm^3 @ 25° C)			pH Units			Oxidation-Reduction Potential (millivolts)		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
6-24	19.4	18.5	18.	7.9	7.1	7.6	98	35	79	7.8	7.1	7.7	371.0	344.0	356.0
6-25	19.6	16.5	17.8	8.4	7.8	8.2	51	27	40	7.7	7.0	7.3	430.0	391.0	406.0
6-26	18.6	16.5	17.1	8.3	8.0	8.1	43	27	36	7.4	7.1	7.3	438.0	426.0	432.0
6-27	19.6	16.3	17.5	8.1	7.5	7.8	63	47	55	7.6	7.4	7.5	434.0	418.0	425.0
6-28	19.8	16.5	17.8	7.8	6.8	7.5	82	56	74	7.7	7.4	7.6	422.0	402.0	408.0
6-29	19.0	16.5	17.5	7.7	7.0	7.4	94	78	88	7.9	7.7	7.8	406.0	395.0	400.0
6-30	19.1	16.1	17.5	7.6	6.9	7.3	105	94	101	7.9	7.8	7.9	406.0	395.0	401.0
7-1	19.8	16.6	17.8	7.5	6.9	7.2	109	56	97	8.0	7.4	7.8	422.0	391.0	402.0
7-2	19.0	16.5	17.6	7.5	7.0	7.3	105	78	95	7.9	7.5	7.8	426.0	410.0	417.0
7-3	18.0	15.3	16.6	7.7	7.0	7.4	117	102	108	8.0	7.9	7.9	410.0	395.0	404.0
7-4	17.8	15.5	16.8	7.7	6.8	7.3	125	113	120	8.1	7.9	8.0	410.0	391.0	400.0
7-5	17.3	15.9	16.5	7.7	6.9	7.3	129	121	125	8.1	7.9	8.0	402.0	391.0	397.0
7-6	17.8	16.9	16.8	N.D.	N.D.	N.D.	129	129	129	8.1	7.9	8.0	402.0	333.0	395.0
7-7	17.5	16.1	16.8	N.D.	N.D.	N.D.	129	117	123	8.1	8.0	8.1	398.0	383.0	393.0
7-8	17.3	15.5	16.3	N.D	N.D.	N.D.	145	117	132	8.1	8.0	8.1	398.0	383.0	392.0
7-9	17.1	15.5	16.1	N.D.	N.D.	N.D.	148	145	147	8.2	8.1	8.1	398.0	383.0	394.0
7-10	15.5	15.5	15.5	N.D.	N.D.	N.D.	145	145	145	8.0	8.0	8.0	398.0	398.0	398.0

TABLE 7. Satellite-Associated Water Quality Data Collected from Abrams Creek.- Cont.

Date	Temperature (^{O}C)			Dissolved Oxygen (mg/1)			Specific Conductance (MicroMHOS/cm^3 @ 25° C)			pH Units			Oxidation-Reduction Potential (millivolts)		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
7-11	16.8	16.5	16.8	N.D.	N.D.	N.D.	137	137	137	8.1	8.0	8.0	405.0	398.0	402.0
7-12	17.8	15.5	16.3	N.D.	N.D.	N.D.	135	109	135	8.1	7.8	8.0	414.0	385.0	405.0
7-13	17.5	15.7	16.5	N.D.	N.D.	N.D.	141	113	129	8.1	7.9	8.0	414.0	395.0	405.0
7-14	16.8	15.3	16.0	N.D.	N.D.	N.D.	152	145	147	8.1	8.0	8.1	410.0	391.0	401.0
7-15	16.8	14.9	15.7	N.D.	N.D.	N.D.	156	148	153	8.1	8.1	8.1	406.0	391.0	400.0
7-16	15.9	14.5	15.1	N.D.	N.D.	N.D.	164	156	162	8.2	8.1	8.1	405.0	391.0	400.0
7-17	15.9	14.3	16.0	N.D.	N.D.	N.D.	164	160	162	8.2	8.1	8.1	406.0	391.0	400.0
7-18	15.9	14.3	15.0	N.D.	N.D.	N.D.	164	150	154	8.2	8.1	8.1	410.0	391.0	403.0
7-19	15.9	14.3	15.0	N.D.	N.D.	N.D.	168	150	155	8.2	8.1	8.1	410.0	395.0	404.0
7-20	16.5	14.3	15.2	N.D.	N.D.	N.D.	168	152	161	9.1	8.1	8.4	410.0	344.0	387.0
7-21	16.5	14.5	15.3	N.D	N.D.	N.D.	164	152	159	8.7	8.5	8.6	391.0	391.0	382.0
7-22	15.1	14.5	14.8	N.D.	N.D.	N.D.	156	157	148	8.5	8.5	8.6	395.0	387.0	392.0
7-23	16.1	14.7	15.2	N.D.	N.D.	N.D.	133	121	127	8.6	8.4	8.5	402.0	379.0	392.0
7-24	15.7	14.5	15.0	N.D.	N.D.	N.D.	172	129	138	8.7	8.6	8.6	391.0	379.0	388.0
7-25	16.1	14.5	15.5	N.D.	N.D.	N.D.	168	90	145	8.6	8.2	8.5	414.0	387.0	396.0
7-26	16.8	15.1	16.1	N.D.	N.D.	N.D.	148	102	131	8.6	8.3	8.5	414.0	391.0	402.0
7-27	15.7	14.1	14.9	N.D.	N.D.	N.D.	148	148	148	8.6	8.5	8.6	405.0	391.0	399.0
7-28	15.7	14.3	15.0	N.D.	N.D.	N.D.	152	145	148	8.7	8.6	8.7	398.0	333.0	362.0

TABLE 7. Satellite-Associated Water Quality Data Collected from Abrams Creek - Cont.

Date	Temperature (°C)			Dissolved Oxygen (mg/l)			Specific Conductance (MicroMHOS/cm^3 @ 25° C)			pH Units			Oxidation-Reduction Potential (millivolts)		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
7-29	14.7	14.3	14.5	N.D.	N.D.	N.D.	148	137	143	8.6	8.5	8.6	402.0	395.0	398.0
7-30	15.5	14.3	14.8	N.D.	N.D.	N.D.	137	129	133	8.5	8.5	8.5	402.0	387.0	396.0
7-31	15.9	14.1	14.9	N.D.	N.D.	N.D.	129	125	129	8.7	8.5	8.6	406.0	379.0	394.0
8-1	15.5	14.3	14.9	N.D.	N.D.	N.D.	128	125	126	8.7	8.5	8.6	402.0	387.0	395.0
8-2	15.9	14.3	15.0	N.D.	N.D.	N.D.	125	121	123	8.7	8.6	8.7	402.0	379.0	390.0
8-3	15.3	14.3	14.8	N.D.	N.D.	N.D.	129	121	124	8.7	8.6	8.7	398.0	387.0	392.0
8-4	15.5	14.1	14.8	N.D.	N.D.	N.D.	125	121	124	8.7	8.6	8.7	402.0	383.0	393.0
8-5	15.9	14.5	15.2	N.D.	N.D.	N.D.	129	121	124	8.8	8.6	8.7	395.0	375.0	386.0
8-6	15.5	14.5	15.0	N.D.	N.D.	N.D.	184	117	144	8.8	7.9	8.4	N.D.	N.D.	N.D.
8-7	15.1	13.9	14.5	8.4	8.0	8.2	176	145	163	7.9	7.8	7.9	N.D.	N.D.	N.D.
8-8	15.1	13.9	14.5	8.4	8.0	8.2	145	109	124	8.1	7.8	7.9	N.D.	N.D.	N.D.
8-9	19.0	14.1	15.6	8.1	7.5	7.9	109	59	82	8.0	7.2	7.7	N.D.	N.D.	N.D.

TABLE 8. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

APRIL 1974*

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Nematamorpha											
Annelida											
Oligochaeta					X		X		X		
Arthropoda											
Insecta											
Diptera											
Chironomidae		X			X	X	X	X	X		X
Tipulidae											
Antocha	X				X		X	X	X		
Dicranota											
Eriocera	X										
Hexatoma											
Longurio											
Pedicia											
Tipola					X		X	X			
Simuliidae											
Prosimulium											
Rhagionidae							X	X			
Atheris variegata											
Blepharoceridae		X						X			
Blepharocera											
Tanyderidae						X		X			
Protoplasa											
Tahanidae											
Tahanus											
Empididae											
Coleoptera											
Elmidae											
Helichus											
Hexacylloepus											
Latiusculus											
Limnius		X				X			X		
Optioservus						X		X	X		
Oulimnius											
Promoresia					X	X		X	X		
Psephenidae											
Ectoparia							X				
Psephenus						X	X	X	X		

*From Alan Kelly's collections, U. S. Fish and Wildlife Service, GRSM

TABLE 8. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

APRIL 1974

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella											
Leptophlebiidae		X			X	X	X	X	X		X
Habrophlebia											
Paraleptophlebia							X				
Caeninae											
Caenis											
Heptageniidae											
Arthroplea											
Cinygmula		X			X	X	X	X	X		X
Heptagenia											
Iron		X			X	X	X	X	X		
Rithrogena						X					
Stenonema		X			X	X	X	X	X		
Siphlonuridae											
Ameletus											
Siphlonurus											
Baetidae											
Baetis		X					X		X		
Baetisca											
Centroptilum							X		X		
Isonychia							X	X	X		
Leptophlebia		X									
Pseudocloeon		X			X	X	X	X	X		X
Ephemeridae											
Ephemera								X			
Hexagenia											
Megaloptera											
Corydalidae											
Chauliodes							X		X		
Sialidae											
Nigronia											
Hemiptera											
Gerridae											
Odonata											
Zygoptera											
Agrionidae											
Agrion											

TABLE 8. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

APRIL 1974

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20	26
Anisoptera											
Gomphidae											
Gomphus											
Lanthus						X					
Hagenius											
Plecoptera											
Perlodidae											
Diploperla											
Isogenus		X					X	X	X		
Isoperla		X				X	X	X			
Pternarcidae											
Pteronarcys		X				X		X			
Perlidae											
Acroneuria		X				X	X	X	X		
Paragnetina								X	X		
Peltoperlidae											
Peltoperla											
Leuctridae											
Leuctra								X			
Capniidae											
Allocapnia											
Taeniopterygidae											
Brachyptera											
Chloroperlidae											
Alloperla		X						X	X		
Hastaperla											
Nemouridae											
Nemoura							X	X			
Taeniopteryx											
Trichoptera											
Rhyacophilidae											
Rhyacophila						X		X	X		
Hydropsychidae											
Arctopsyche								X			
Cheumatopsyche					X	X	X	X	X		
Diplectrona		X					X				
Hydropsyche		X			X	X		X	X		
Glossosomatidae											
Agapetus					X		X				
Glossosoma					X		X				

TABLE 8. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

APRIL 1974

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20	26
Psychomyiidae											
Psychomyia							X				
Polycentropus						X		X			
Goeridae											
Goera					X	X	X	X	X		
Hydroptilidae											
Neotrichia											
Ochrotrichia											
Limnephilidae											
Neophylax											
Phryganeidae											
Ptilostomis											
Lepidostomatidae											
Lepidostoma											
Leptoceridae											
Arthripsodes											
Leptocella											
Leptocerus											
Philopotamidae											
Chimarra											
Tretonius		X					X		X		
Brachycentridae											
Micrasema							X				
Crustacea											
Decapoda							X	X	X		
Astacidae											
Cambarus											
Orconectes											
Mollusca											
Gastropoda											
Prosobranchia											
Mesogastropoda											
Pleuroceridae											
Goniobasis											
Pulmonata											
Basommatophera											
Ancylidae											
Ferrissia											

TABLE 9. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

JULY 1974*

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Nematamorpha											
Annelida		X					X				
Oligochaeta		X						X			X
Arthropoda											
Insecta											
Diptera											
Chironomidae						X	X	X	X		X
Tipulidae											
Antocha						X	X	X	X		
Dicranota											
Eriocera						X					
Hexatoma											
Longurio											
Pedicia											
Tipola								X			
Simuliidae								X			
Prosimulium									X		
Rhagionidae											
Atherix variegata							X		X		
Blepharoceridae											
Blepharocera									X		
Tanyderidae											
Protoplasa											
Tahanidae											
Tahanus											
Empididae											
Coleoptera											
Elmidae											
Helicus											
Hexacylloepus											
Latiusculus											
Limnius											
Optioservus						X		X			
Oulimnius											
Promoresia								X	X		
Psephenidae											
Ectoparia							X				
Psephenus						X		X	X		

*From Alan Kelly's collections, U.S. Fish and Wildlife Service, GRSM

TABLE 9. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

JULY 1974

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Anisoptera											
Gomphidae											
Gomphus											
Lanthus											
Hagenius											
Perlodidae											
Diploperla											
Isogenus											
Isoperla								X	X		
Pteronarcidae											
Pternarcys						X			X		
Perlidae											
Acroneuria						X	X	X	X		
Paragnetina								X			
Peltoperlidae											
Peltoperla								X	X		
Leuctridae											
Leuctra		X					X		X		
Capniidae											
Allocapnia											
Taeniopterygidae											
Brachyptera											
Chloroperlidae											
Alloperla											
Hastaperla											
Nemouridae											
Nemoura											
Taeniopteryx											
Trichoptera											
Rhyacophilidae											
Rhyacophila								X	X		
Hydropsychidae											
Arctopsyche											
Cheumatopsyche						X	X	X	X		
Diplectrona									X		
Hydropsyche	X					X	X	X	X		
Glossosomatidae											
Agapetus											
Glossosoma						X					

TABLE 9. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

JULY 1974

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella		X				X	X	X	X		
Leptophlebiidae											
Habrophlebia											
Paraleptophlebia											
Caeninae											
Caenis											X
Heptageniidae											
Arthroplen											
Cinygmula											
Heptagenia											
Iron						X	X	X	X		
Rithrogena						X					
Stenonema		X				X	X	X	X		
Siphlonuridae											
Ameletus											
Siphlonurus											
Baetidae											
Baetis		X					X	X	X		
Baetisca											
Centroptilum											
Isonychia							X	X	X		
Leptophlebia											
Pseudoclocon						X		X	X		
Ephemeridae											
Ephemera											
Hexagenia											
Megaloptera											
Corydalidae											
Chauliodes							X		X		
Sialidae											
Nigronia											
Hemiptera											
Gerridae											
Odonata											
Zygoptera											
Agrionidae											
Agrion							X				

TABLE 9. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

JULY 1974

	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Psychomyiidae											
Psychomyia											
Polycentropus									X		
Goeridae											
Goera						X					
Hydroptilidae											
Neotrichia											
Ochrotrichia											
Limnephilidae											
Neophylax											
Phryganeidae											
Ptilostomis											
Lepidostomatidae											
Lepidostoma											
Leptoceridae											
Athripsodes											
Leptocella											
Leptocerus											
Philopotamidae											
Chimarra											
Trentonius								X	X		
Brachycentridae											
Micrasema								X			
Crustacea											
Decapoda							X	X	X		
Astacidae											
Cambarus											
Orconectes											
Mollusca											
Gastropoda							X	X	X		
Prosobranchia											
Mesogastropoda											
Pleuroceridae											
Pulmonata											
Bassomatophera											
Ancylidae											
Ferrissia											

TABLE 10. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

FEBRUARY 1977

Taxon	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Nematamorpha											
Annelida											
Oligochaeta	X		X	X	X	X	X	X	X	X	X
Arthropoda											
Insecta											
Diptera											
Chironomidae	X	X	X	X	X	X	X	X	X	X	X
Tipulidae											
Antocha	X	X	X	X	X	X	X	X	X	X	X
Dicranota											
Eriocera	X		X				X				
Hexatoma											
Longurio				X							
Pedicia											
Tipola	X			X		X					X
Simuliidae		X	X	X	X	X		X	X	X	X
Prosimulium	X		X								
Rhagionidae											
Atherix variegata	X	X	X			X			X	X	
Blepharoceridae											
Blepharocera		X									
Tanyderidae											
Protoplasa											
Tahanidae											
Tahanus											
Collembola			X								
Coleoptera											
Elmidae	X		X								
Helichus											
Hexacylloepus											
Latiusculus											
Limnius					X						
Optioservus					X	X		X	X	X	
Oulimnius											
Promoresia					X		X	X	X		
Psephenidae											
Ectoparia						X			X		
Psephenus			X	X		X	X		X	X	

TABLE 10. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

FEBRUARY 1977

Taxon	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella	X	X	X	X	X	X	X	X	X	X	X
Leptophlebiidae											
Habrophlebia											
Paraleptophlebia	X	X	X	X		X	X	X			X
Caeninae											
Caenis											
Heptageniidae											
Arthroplea										X	
Cinygmula			X								
Heptagenia					X						
Iron	X	X	X	X	X	X		X	X	X	
Rithrogena	X	X				X					
Stenonema		X	X	X	X	X	X	X	X		
Siphlonuridae											
Ameletus	X				X						
Siphlonurus											
Baetidae											
Baetis		X	X	X	X	X	X	X	X	X	X
Baetisca			X								
Centroptilum											
Isonychia		X	X	X	X	X	X			X	X
Leptophlebia											
Pseudocloeon					X						
Ephemeridae											
Ephemera						X			X	X	
Hexagenia											
Megaloptera											
Corydalidae						X					
Chauliodes					X	X			X	X	
Sialidae											
Nigronia						X					
Hemiptera											
Gerridae											
Odonata											
Zygoptera											
Agrionidae											
Agrion			X								

TABLE 10. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

FEBRUARY 1977

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Anisoptera											
Gromphidae											
Gomphus											
Lanthus											
Hagenius						X					
Plecoptera											
Perlodidae											
Diploperla											
Isogenus	X	X	X	X	X	X	X	X	X	X	X
Isoperla											
Pteronarcidae											
Pteronarcys	X	X									
Perlidae											
Acroneuria	X	X				X		X	X	X	
Paragnetina			X								
Peltoperlidae											
Peltoperla	X	X			X	X	X	X	X	X	X
Leuctridae											
Leuctra	X	X	X						X		X
Capniidae											
Allocapnia		X	X	X	X	X	X				X
Taeniopterygidae											
Brachyptera				X		X					
Chloroperlidae											
Alloperla			X								
Hastaperla											
Nemouridae											
Nemoura				X		X			X	X	
Taeniopteryx	X	X									
Trichoptera											
Rhyacophilidae											
Rhyacophila	X	X	X		X			X	X	X	
Hydropsychidae											
Arctopsyche											
Cheumatopsyche	X	X	X		X	X	X	X	X	X	X
Diplectrona											
Hydropsyche	X	X	X	X	X	X	X	X	X	X	X
Glossosomatidae											
Agapetus											
Glossosoma		X	X	X	X	X	X	X	X	X	X

TABLE 10. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

FEBRUARY 1977

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Psychomyiidae											
Psychomyia			X								
Polycentropus				X		X		X	X		
Goeridae											
Goera			X			X	X				
Hydroptilidae							X				
Neotrichia		X									
Ochrotrichia											
Limnephilidae											
Neophylax		X									
Phryganeidae											
Philostomis											
Lepidostomatidae											
Lepidostoma											
Leptoceridae											
Athripsodes	X	X	X								
Leptocella									X		
Leptocerus											
Philopotamidae											
Chimmara			X						X		
Trentonius											
Brachycentridae											
Micrasema											
Crustacea											
Decapoda											
Astacidae											
Cambarus			X		X				X		
Orconectes											
Mollusca											
Gastropoda											
Prosobranchia											
Mesogastropoda											
Pleuroceridae											
Goniobasis					X			X	X	X	
Pulmonata											
Basommatophera											
Ancylidae											
Ferrissia						X					

TABLE 11. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

MARCH 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	26
Nematamorpha										
Annelida										
Oligochaeta	X	X	X	X	X	X	X	X	X	X
Arthropoda										
Insecta										
Diptera										
Chironomidae	X	X	X	X	X	X	X	X	X	
Tipulidae										
Antocha		X	X	X	X	X	X	X	X	
Dicranota										
Eriocera		X	X				X			
Hexatoma	X	X	X							
Longurio										
Pedicia										
Tipula	X	X	X	X	X		X		X	
Simuliidae										
Prosimulium	X	X	X	X	X	X		X	X	X
Rhagionidae										
Atherix variegata							X	X	X	
Blepharoceridae										
Blepharocera	X									
Tanyderidae										
Protoplasa							X			
Tahanidae										
Tahanus									X	
Empididae										
Collembola					X		X	X		
Coleoptera										
Elmidae			X							
Helichus										
Hexacylloepus									X	
Latiusculus										
Limnius									X	
Optioservus					X	X	X	X	X	
Oulimnius									X	
Promoresia								X	X	
Psephenidae										
Ectoparia							X			
Psephenus	X		X			X	X	X	X	
Limnichidae										
Lirinchus				X						

TABLE 11. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MARCH 1977

Taxon	1	2	8	9	15	16	17	18	19	26
	Station No.									
Ephemeroptera										
Ephemerellidae										
Ephemerella	X	X	X		X	X	X	X	X	X
Leptophlebiidae										
Habrophlebia										
Paraleptophlebia	X	X	X			X				
Caeninae										
Caenis										
Heptageniidae										
Arthroplea										
Cinygmula										
Heptagenia			X			X				
Iron	X	X	X	X	X	X	X	X	X	X
Rithrogena		X								
Stenonema	X	X	X	X	X	X	X		X	X
Siphlonuridae										
Ameletus				X					X	X
Siphlonurus									X	
Baetidae										
Baetis	X		X	X			X	X	X	
Baetisca									X	
Centroptilum										
Isonychia		X	X		X		X	X		
Leptophlebia										
Pseudocloeon					X			X		
Ephemeridae										
Ephemera				X			X	X		
Hexagenia			X							
Megaloptra										
Corydalidae										
Chauliodes					X		X			
Sialidae										
Nigronia			X				X	X		
Hemiptera										
Gerridae										
Odonata										
Zygoptera										
Agrionidae										
Agrion										

TABLE 11. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MARCH 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	26
Anistoptera										
Gomphidae										
Gomphus										
Lanthus							X			
Hagenius										
Plecoptera										
Perlodidae										
Diploperla									X	
Isogenus		X	X	X			X		X	
Isoperla	X	X	X	X	X	X	X	X	X	X
Pteronarcidae										
Pteronarcys	X	X	X			X	X			
Perlidae										
Acroneuria	X	X				X		X		
Paragnetina							X			
Peltoperla	X	X	X				X		X	
Peltoperla										
Leuctridae										
Leuctra								X		
Capniidae										
Allocapnia	X	X	X	X						
Taeniopterygidae										
Brachyptera								X		
Chloroperlidae										
Alloperla										
Hastaperla						X	X	X		
Nemouridae										
Nemoura			X			X				
Taeniopteryx										
Trichoptera										
Rhyacophilidae										
Rhyacophila		X	X				X	X	X	
Hydropsychidae								X		
Arctopsyche										
Cheumatopsyche	X	X	X	X	X	X	X	X	X	
Diplectrona			X							
Hydropsyche	X	X	X	X	X	X	X	X	X	
Glossomomatidae										
Agapetus										
Glossomoma		X	X		X	X	X	X	X	

TABLE 11. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MARCH 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	26
Psychomyiidae										
Psychomyia								X		
Polycentropus										
Goeridae										
Goera					X					
Hydroptilidae							X			
Neotrichia										
Ochrotichia										
Limnephilidae										
Neophylax										
Pycnopsyche	X		X				X			
Phryganeidae										
Philostomis							X			
Lepidostomatidae										
Lepidostoma										
Leptoceridae										
Athripsodes	X	X								
Laptocella	X									
Leptocerus	X									
Philopotamidae										
Chimarra	X	X	X	X						
Trentonius										
Brachycentridae										
Micrasema										
Crustacea										
Decapoda										
Astacidae										
Cambarus					X		X			
Orconectes	X	X			X			X		
Mollusca										
Gastropoda										
Prosobranchia										
Mesogastropoda										
Pleuroceridae										
Goniobasis							X		X	
Pulmonata										
Basommatophera										
Ancylidae										
Ferrissia				X	X		X	X	X	

TABLE 12. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

MAY 1977

Taxon	Station No. 1	2	8	9	15	16	17	18	19	20	26
Nematamorpha											
Annelida											
Oligochaeta		X	X	X	X	X	X	X		X	
Arthropod											
Insecta											
Diptera											
Chironomidae		X	X	X	X	X	X	X	X	X	
Tipulidae											
Antocha	X	X	X		X		X	X	X	X	
Dicranota								X			
Eriocera		X	X								
Hexatoma		X	X				X	X			
Longurio											
Pedicia							X				
Tipola	X	X	X	X		X		X			X
Simuliidae											
Prosimulium					X		X	X	X		X
Rhagionidae											
Atherix variegata			X						X		
Blepharoceridae											
Blepharocera											
Tanyderidae											
Protoplasa											
Tahanidae											
Tahanus											
Empididae		X									
Collembola					X						
Coleoptera											
Elmidae				X							
Helicus											
Hexacylloepus											
Latiusculus											
Limnius											
Optioservus	X	X				X	X		X		
Oulimnius											
Promoresia		X	X								
Psephenidae								X			
Ectoparia							X				
Psephenus			X	X		X	X	X	X	X	X

TABLE 12. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MAY 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20	26
Ephemeroptera											
Ephemerellidae											
Ephemerella		X	X	X	X	X	X	X	X	X	X
Leptophlebiidae											
Habrophlebia											
Paraleptophlebia		X	X	X		X	X			X	
Caeninae											
Caenis											
Heptageniidae											
Arthroplea											
Cinygmula											
Heptagenia		X					X				
Iron			X		X	X	X	X		X	
Rithrogena						X		X			
Stenonema		X	X	X	X	X	X	X	X	X	
Siphlonuridae											
Ameletus		X			X	X	X			X	
Siphlonurus											
Baetidae											
Baetis		X	X	X	X	X	X	X	X	X	X
Baetisca											
Centroptilum											
Isonychia					X	X			X	X	
Leptophlebia											X
Pseudocloeon											
Ephemeridae											
Ephemera		X	X						X	X	
Hexagenia											
Megaloptera											
Corydalidae											
Chauliodes					X	X	X	X			
Sialidae											
Nigronia											
Hemiptera											
Gerridae											
Odonata											
Zygoptera											
Agrionidae											
Agrion											X

TABLE 12. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MAY 1977

Taxon	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Anisoptera											
Gomphidae											
Gomphus		X									
Lanthus											
Hagenius											
Plecoptera											
Perlodidae											
Diploperla											
Isogenus											
Isoperla	X	X	X	X		X	X	X	X	X	X
Pteronarcidae											
Pteronarcys				X			X	X			
Perlidae											
Acroneuria	X	X	X		X		X	X	X		
Paragnetina											
Peltoperlidae											
Peltoperla	X							X			
Leuctridae											
Leuctra		X	X	X	X	X	X	X	X		X
Capniidae											
Allocapnia	X	X		X				X			
Taeniopterygidae											
Brachyptera											
Chloroperlidae											
Alloperla		X					X				X
Hastaperla		X			X						
Nemouridae											
Nemoura							X	X			
Taeniopteryx											
Trichoptera											
Rhyacophilidae											
Rhyacophila		X			X	X				X	X
Hydropsychidae											
Arctopsyche								X	X	X	
Cheumatopsyche	X	X	X	X		X	X	X	X	X	X
Diplectrona										X	
Hydropsyche	X		X	X	X	X	X	X	X	X	
Parasyche						X					
Glossosomatidae											
Agapetus											
Glossosoma		X	X	X	X	X	X	X	X		

TABLE 12. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

MAY 1977

Taxon	Station No.										
	1	2	8	9	15	16	17	18	19	20	26
Psychomyiidae											
Psychomyia											
Polycentropus		X	X	X	X	X	X	X		X	X
Goeridae											
Goera											
Hydroptilidae											
Neotrichia											
Ochrotrichia					X						
Limnephilidae											
Neophylax											
Pycnopsyche		X					X				
Phryganeidae											X
Ptilostomis											
Lepidostomatidae											
Lepidostoma						X					
Leptoceridae											
Athripsodes					X						
Leptocella		X			X						
Leptocerus											
Philopotamidae											
Chimarra											
Trentonius											
Brachycentridae											
Micrasema											
Crustacea											
Decapoda											
Astacidae											
Cambarus		X			X		X	X	X		
Orconectes											
Mollusca											
Gastropoda											
Prosobranchia											
Mesogastropoda											
Pleuroceridae											
Goniobasis			X		X		X	X	X	X	
Pulmonata											
Basommatophera											
Ancylidae											
Ferrissia						X					

TABLE 12. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks.

JULY 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20
Nematamorpha				X						
Annelida										
Oligochaeta	X	X	X	X	X	X	X	X	X	X
Arthropoda										
Insecta										
Diptera										
Chironomidae	X	X	X	X	X	X	X	X	X	X
Tipulidae										
Antocha	X	X	X		X		X	X	X	X
Dicranota										
Eriocera								X		X
Hexatoma									X	
Longurio										
Pedicia										
Tipola		X		X					X	
Simuliidae										
Prosimulium		X		X		X	X	X	X	
Rhagionidae										
Atherix variegata	X		X	X					X	
Blepharoceridae										
Blepharocera										
Tanyderidae										
Protoplasa										
Tahanidae										
Tahanus										
Empididae										X
Coleoptera			X			X		X		
Elmidae										
Helichus										
Hexacylloepus										
Latiusculus										
Limnius										
Optioservus	X		X						X	
Oulimnius										
Promoresia	X			X		X	X	X	X	X
Psephenidae										
Ectoparia	X									
Psephenus	X		X	X		X	X	X	X	X

TABLE 13. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks- Cont.

JULY 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20
Ephemeroptera										
Ephemerellidae										
Ephemerella	X		X	X	X		X	X	X	X
Leptophlebiidae										
Habrophlebia										
Paraleptophlebia										
Caeninae										
Caenis										
Heptageniidae										
Arthroplea										
Cinygmula										
Heptagenia										
Iron			X				X	X	X	
Rithrogena										
Stenonema	X	X	X	X	X	X	X	X	X	X
Siphlonuridae										
Ameletus							X	X	X	X
Siphlonurus										
Baetidae										
Baetis	X	X	X	X	X	X	X	X	X	X
Baetisca										
Centroptilum										
Isonychia		X						X	X	X
Leptophlebia							X			
Pseudoclocon										
Ephemeridae										
Ephemera					X		X	X	X	X
Hexagenia										
Megaloptera										
Corydalidae										
Chauliodes	X		X	X	X	X	X	X	X	X
Síalidae										
Nigronia										
Hemiptera										
Gerridae										X
Odonata										
Zygoptera										
Agrionidae										
Agrion										

TABLE 13. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

JULY 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20
Anisoptera										
Gomphidae										
Gomphus	X							X		X
Lanthus										
Hagenius										
Plecoptera										
Perlodidae										
Diploperla										
Isogenus					X					
Isoperla						X	X			
Pteronarcidae										
Pteronarcys										
Perlidae										
Acroneuria	X	X	X		X	X	X	X	X	X
Paragnetina										
Peltoperlidae										
Peltoperla								X		
Leuctridae										
Leuctra	X		X		X	X	X		X	X
Capniidae										
Allocapnia	X	X	X		X	X	X	X	X	X
Taeniopterygidae										
Brachyptera										
Chloroperlidae										
Alloperla										
Hastaperla										
Nemouridae										
Nemoura										
Taeniopteryx										
Trichoptera										
Rhyacophilidae										
Ryacophila						X		X	X	
Hydropsychidae										
Arctopsyche							X			
Cheumatopsyche	X					X	X	X	X	X
Diplectrona										
Hydropsyche			X	X	X		X	X	X	X
Glossosomatidae										
Agapetus										
Glossosoma	X		X			X		X	X	

TABLE 13. Checklist of the Benthic Macroinvertebrates Collected from Abrams and Mill Creeks - Cont.

JULY 1977

Taxon	Station No.									
	1	2	8	9	15	16	17	18	19	20
Psychomyiidae										
Psychomyia										
Polycentropus	X				X			X	X	
Goeridae										
Goera										
Hydroptilidae										
Neotrichia										
Ochrotrichia										
Limnephilidae										
Neophylax										
Pycnopsyche	X		X		X					
Phryganeidae										
Ptilostomis										
Lepidostomatidae										
Lepidostoma										
Leptoceridae										
Athripsodes										
Leptocella			X							
Leptocerus										
Philopotamidae										
Chimarra										
Trentonius										
Brachycentridae										
Micrasema										
Crustacea										
Decapoda										
Astacidae										
Cambarus	X				X	X	X	X	X	X
Orconectes					X					
Mollusca										
Gastropoda										
Prosobranchia										
Mesogastropoda										
Pleuroceridae										
Goniobasis			X		X		X	X	X	X
Pulmonata										
Basommatophera										
Ancylidae										
Ferrissia					X		X			

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.