12-1976

Comparison of Fish and Benthic Faunal Compositions in Polluted and Pristine Forks of a Mountain River

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To the Graduate Council:

I am submitting herewith a thesis written by Lynn Betson Starnes entitled "Comparison of Fish and Benthic Faunal Compositions in Polluted and Pristine Forks of a Mountain River." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

David A. Etnier, Major Professor

We have read this thesis and recommend its acceptance:

Dewey Bunting, Clifford Amundsen

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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David A. Etnier

D. A. Etnier, Major Professor

We have read this thesis
and recommend its acceptance:

Clifford C. Amundsen

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COMPARISON OF FISH AND BENTHIC FAUNAL COMPOSITIONS IN POLLUTED AND PRISTINE FORKS OF A MOUNTAIN RIVER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Lynn Betson Starnes

December 1976

ACKNOWLEDGMENTS

The author wishes to express her gratitude to Dr. David A. Etnier, Department of Zoology, University of Tennessee for advice and guidance as major professor. Appreciation is also expressed to Dr. Dewey Bunting, Department of Zoology, and Dr. Clifford Amundsen, Department of Botany, for their cooperation and assistance as committee members.

Thanks are expressed to Don Owens, Division of Water Quality, Tennessee Public Health Department, for making available state information pertaining to Gatlinburg sewage treatment facilities.

Appreciation is expressed to Dr. Clyde Voigtlander and Dr. Donley Hill, Tennessee Valley Authority, for reviewing and editing the first draft. Thanks is also due Roger Betson, Hydrologic Research and Analysis Staff, Division of Water Control Planning, TVA, for assistance with hydrologic aspects of this study.

Special thanks are extended to Mrs. Roger Betson who typed the rough draft of this thesis.

Special thanks are also due Wayne C. Starnes for invaluable help in field collections as well as in editing the manuscript.

ABSTRACT

The Little Pigeon River in Sevier County, Tennessee presents a near ideal situation for the study of the effects of domestic sewage on species composition in a mountain river. The Little Pigeon system has two principal components, the West and Middle Prongs. The West Prong is polluted by municipal effluent from Gatlinburg and Pigeon Forge, while the Middle Prong remains relatively pristine. Physiographically, the two prongs are strikingly similar. The great similarity of natural physical and chemical water quality parameters presents an opportunity to use the pristine prong as a control for the study of changes, probably resulting from pollution, in the other.

Fish and aquatic invertebrates were sampled from riffle communities of both streams, and their composition was analyzed to gain insight into possible changes in the West Prong due to pollution. There were drastic differences in benthic invertebrates and observable differences in the fish faunal assemblages. These differences suggest that strong shifts in species composition as well as a sharp decline in population density of many invertebrates and some fish species had resulted in the West Prong due to pollution. It is speculated that these shifts were caused by organic solids.

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INTRODUCTION

Water pollution has many aspects but its most important impact is upon living organisms. Despite this biological relationship, most studies of water pollution depend primarily on physical and chemical measurements such as dissolved oxygen, BOD, suspended solids and other such parameters to determine the degree of pollution. Since chemical studies give information on physical-chemical conditions only at the instant of sampling, and pollution studies frequently cannot be made continuously during the period of the most critical conditions, there is a need for additional methods that can be used throughout the year for determining the extent and severity of brief critical or limiting environmental factors. This need is apparent for determining the extent and severity of brief critical or limiting environmental factors when the amount of pollution is not uniform throughout the year. The qualitative and quantitative composition of an aquatic population is determined by recurring critical conditions; though of short duration, as well as the more stable or long-term environmental factors. Therefore, the organisms which develop in a given area are, in turn, indicative of environmental conditions which have occurred during their development. They may be especially valuable because they can be used even during the seasons of winter and spring when flows are frequently large, dilution is at a maximum, dissolved oxygen is near saturation, and visual evidence of pollution is at a minimum.

CHAPTER I

LITERATURE SURVEY

I. BACKGROUND

Much of the initial impetus to the biological delineation of water pollution in the United States is attributable to the publications of Kolkwitz and Marsson (1908, 1909). Since Kolkwitz and Marsson published their classification of organisms associated with various zones of pollution in rivers receiving organic wastes, numerous studies have been conducted utilizing the concept of indicator species. Sladeck (1973) has the most comprehensive review of the literature on indicator species. Often overlooked is the fact that in these early evaluations of water quality, the main emphasis was placed not on the individual organisms, but on the total biological community. It is interesting to note that the use of the saprobic or indicator organisms system has been accepted and applied by the majority of hydrobiologists in continental Europe and the Soviet Union. It is only in Great Britain and North America that the indicator organism system has not received wide acceptance (Sladecek, 1973).

Surveys of the Illinois River by Forbes (1928) and Forbes and Richardson (1913, 1919) stimulated contemporary interest in the biological investigation of organic pollution. A publication by Ellis (1937) on the detection and measurement of stream pollution, the effects of various wastes on stream environment, and the toxicity of specific elements and compounds to fishes has served as a valuable reference handbook for many years.

When the application of biological principles to routine field investigations of water pollution in the United States was still relatively new, Brinley (1942) and Bartsch (1948) took cognizance of the biotic community and the effects of pollution on the ecological relationships of aquatic organisms. Patrick (1949) separated the biota into seven groups and demonstrated specific group responses to varying stream conditions.

After these pioneering researchers confirmed that aquatic communities are largely dependent upon nutrients delivered by the flowing water, whether these nutrients are natural or the result of human activity, more recent workers have diverged into the various facets of water pollution effects on aquatic organisms. The more important of these works will be discussed as they apply to the aspects of fish, aquatic invertebrates and water quality considered in this study.

II. FISH

Of all aquatic organisms, fish create the most human interest. They attract attention, especially when dead. While they are under closer scrutiny than other aquatic organisms, they may not be particularly good indicators of aquatic pollution. Being at the top of a pyramid of production, they are the last, and perhaps the least, affected (Maciolak, 1954).

Because fish are mobile, they may respond to changes by moving from the scene, returning when conditions are more auspicious. Having growth and survival rates that fluctuate widely, fish pose a difficult substrate of variability against which to measure minor change. Being flexible in their food habits and being associated with other species in a complex interaction on food organisms, they may persist by exploring alternatives (Larkin, 1954; Keast, 1965). For these reasons, fish have a reputation as poor "indicators" of pollution. In water quality samples the insoluble portions of sewage plant effluents are regarded as suspended solids, and are settleable. A substantial literature documents the lethal effects of such organic, nutrient-rich pollutants on fish. The effects are especially lethal when the pollutants are discharged accidentally in large quantities into streams (Hynes, 1960; Klein, 1962; Jones, 1964). Such pollutants can have direct toxic effects (Pruthi, 1927; Herbert, 1965), some of which are enhanced at reduced oxygen concentrations (Allan, et al., 1958). However, fish may be absent from the vicinity of the outfall even when oxygen concentrations are high because of these toxins (Katz and Gaufin, 1953; Rasmussen, 1955; Pentelow, 1938). Effects of low oxygen concentrations on embryonic development and hatching of fish are reviewed by Doudoroff and Warren (1965), Doudoroff and Shumway (1967), and Purdy (1937). Sedimentation and growths of sewage fungi may smother spawning areas (Rasmussen, 1955) as well as fish-food organisms (Katz and Gaufin, 1953).

Having considered some direct effects of pollutants on fish, the indirect effects concern the ecological consequences of addition of nutrients to streams. Indirect effects (Tsai, 1975) include turbidity, which screens sunlight and possibly reduces primary productivity, promotes oxygen depletion, and develops conditions "unnatural" to the stream. Suspended solids may blanket the stream bottom and cause a change in the substrate, thus causing a change in the food organisms available.

III. AQUATIC INVERTEBRATES

The impact of organic enrichment from domestic wastewater effluent on macroinvertebrate community structure and production has been discussed by several authors (Hynes, 1963; Nuttall and Purvus, 1974). These studies describe the classical ecological response of benthic communities to organic loading in North American and European freshwater systems. Certain trends are discussed but the manner by which organics cause these trends is not delineated. Whitton (1975) surmises that this lack of specific information on macroinvertebrates is caused by lack of the ability to simulate field conditions in the laboratory. He believes that in the bioassay approach the controls are inadequate and the conditions so unnatural that the use of the results for predictions about field situations is highly questionable. The result is that only the most general of population trends can be uncovered in the literature. In general, various biological, physical and chemical parameters associated with changes in species diversity, biomass, production, the predominance of certain tubificid and chironomid species in the biota, decreased dissolved oxygen (DO) concentrations, substrate modifications, nutrient enrichments, and/or reduced competition and predation are common results of organic pollution.

As with fish, the organic pollutants which researchers have found perhaps most detrimental to aquatic invertebrates are organic solids (Kemp, 1966; Patrick, 1953). Organic solids settle to the stream bottom as a blanket of debris that effectively covers the normal habitat of clean water bottom life. It could be an inexhaustible source of food but will sustain only those organisms that can qualify for life in that environment. They must be efficient in obtaining oxygen. They must be able to burrow or move so as to stay on top of the deepening layers. They must be resistent to the toxic action of hydrogen sulfide and other gases that may emanate from the bacterial action taking place in the accumulation of sludge layers. Bartsch (1948) concludes that sewage alters the normal conditions of food supply, dissolved oxygen, turbidity, substrate and chemical character of the stream and its bed.

The amount of research done on direct effects of sewage on aquatic invertebrates is infinitesimal when compared to the great amount done on the interpretation of stream conditions based on the biota present. Researchers have looked for organisms that would indicate the chemical and physical character of stream conditions. Kolkwitz and Marsson (1908, 1909) first proposed the use of aquatic organisms as indicators of the ecological conditions under which they exist. This system (the saprobic system) was modified and used by Richardson (1928); Gaufin (1956, 1958); Hynes (1962); Beck (1954, 1955). It depends on a taxonomic grouping of organisms in relation to whether they are found in clean water, polluted water, or both. This approach requires precise identification of organisms and is based on the differential tolerance of organisms to a single stress. Patrick (1949) and Wurtz (1955), using a system of histograms, have developed an elaborate system to report the results of stream surveys based on the differences in tolerances of various groups of aquatic organisms to pollution. Beck (1954) developed a biotic index as a method of evaluating the effects of pollution on bottom fauna organisms. Schiffman (1954) presented a useful method of cataloging stream bottom organisms with respect to their pollution tolerance. Other techniques based on tolerance of aquatic organisms to pollution have been reported by Beak (1964).

Despite the preponderance of research into the role of indicator organisms, the concept has certain problems and is not commonly accepted today. Dean (1963) points out that the lack of physiological data concerning tolerance limits has complicated many biological surveys of polluted areas. Needham (1938) observed that environmental conditions other than pollution may influence the distribution of organisms. The breakdown of an assemblage of organisms into pollution tolerant, intolerant, and faculative categories is somewhat subjective since tolerance for the same organism may vary under a different set of environmental conditions. Pollution tolerant organisms are also found in clean water areas (Hynes, 1960; Gaufin, 1952). Cairns (1974) believes analysis of community structure avoids the problems already mentioned in the use of indicator organisms and is the best means of assessing the biological impact of pollution.

Community structure of aquatic macroinvertebrate populations has been frequently used to evaluate conditions in streams. In addition to pollutants, several environmental factors may affect or limit the distribution of certain species (Gaufin, 1973). Chief among these are geographical location, erosion, floods, size of the stream, and the type of bottom. Even slight changes in environmental conditions, whether natural or man-induced, can lead to changes in community composition and diversity if the changes are persistent. Community composition is now recognized as being much more reliable than particular indicator organisms for evaluating environmental conditions (Gaufin, 1973).

IV. WATER QUALITY

Many aspects of water quality pertinent to this study have been discussed in relation to their effects on aquatic organisms. Chlorine has not been previously discussed. However, chlorine is used to disinfect municipal water supplies and sewage plant effluents. Due to its extreme toxicity, chlorine has the potential to cause considerable damage within natural aquatic systems. Brungs (1973) has produced a review of the biological effects of residual chlorine and estimated the maximum levels that would not damage aquatic life.

CHAPTER II

THE STUDY WATERSHEDS

I. LAND USE

The Little Pigeon River watershed is located in Sevier County in East Tennessee. The Great Smoky Mountains National Park contains the headwaters of the East, Middle, and West Prong of the Little Pigeon River. These prongs of the Little River are nearly pristine by water quality standards. Ground cover in the Park is nearly 100 percent forest. At the Park boundary, the West Prong of the Little Pigeon declines in gradient and enters the urban developments of Gatlinburg, Pigeon Forge, and Sevierville. As the Middle Prong (sometimes called simply Little Pigeon, see Figure 1) of the Little Pigeon leaves the Park, it continues to flow through largely forested areas having occasional houses and small farms. At Sevierville, the Middle and West Prong join to form the Little Pigeon which then joins the French Broad River.

From the time of the first settlers until the 1930's, economic conditions in this area of Sevier County were encumbered with numerous problems. Natural lines of communications and transportation were impeded by rugged terrain. Mountain streams were too small to allow industrial development. Frequent floods inhibited urban development. A lack of tillable land limited agricultural production and years of intensive logging exploited natural resources.

With the advent of the Great Smoky Mountain National Park, outsiders became aware of the natural beauty of the mountains. In 1971

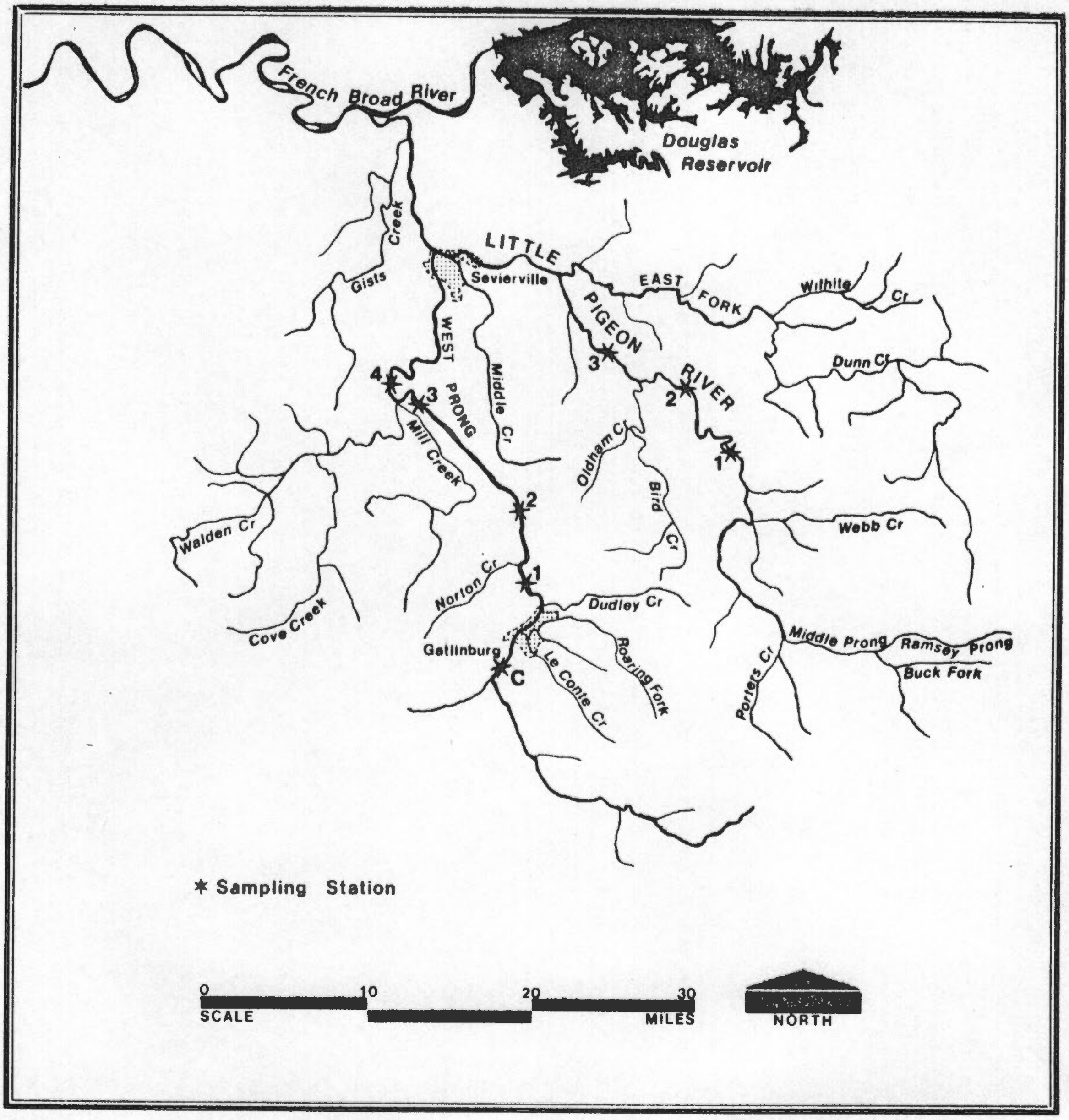

Figure 1. Location of stations on the Middle and West Prong of the Little Pigeon River.

more than seven million people frequented the Smokies and by 1990 that figure is expected to reach nearly twelve million (Pinkerton, 1973). Pinkerton (1973) found that the permanent population growth over the last decade was 16.5 percent in Sevier County as compared with 10 percent for the entire state.

Gatlinburg and Pigeon Forge are summer resort cities. Neither city possesses heavy industry. Both cities draw their visitors from the large numbers of people who come to visit the Great Smoky Mountains. Gatlinburg straddles the West Prong of the Little Pigeon and extends into the surrounding hills. Gatlinburg presently obtains its water supply from the West Prong above the park boundary. Owens (Pers. Comm.) stated that the present sewage treatment facilities were built in 1956 to handle 0.75 million gallons per day (mg/d), but the potential effluent discharge is 2.0 mg/d in dry weather and 3.5 mg/d in wet weather. Pigeon Forge built its plant with a capacity of 0.25 mg/d but has flows as high as 0.5 mg/d. The excess that cannot be treated is bypassed by both cities into the West Prong of the Little Pigeon.

II. GEOLOGY

An understanding of the geology of the watershed of the Little Pigeon River is critical before the two forks of the river can be compared. From examination of geologic maps (Hardeman, 1966), it is obvious that the Middle Prong and the West Prong drain similar bedrock formations through most of their courses. Three particular groups predominate: Walden Creek Group, Great Smoky Group and Snowbird Group. In the Middle Prong, these three groups comprise 87 percent of the watershed and similarly these same three groups make up 86 percent of the West Prong watershed. However, the percentage of the individual groups vary. In the Middle Prong 12 percent is the Walden Creek Group, 28 percent Great Smoky Group and 47 percent Snowbird Group. The West Prong was 31 percent Walden Group, 31 percent Great Smoky Group and Snowbird Group. The remaining 13 percent of the Middle and West Prong not accounted for in the three major groups is composed of small groups of formations present near the mouth of the Little Pigeon River. These formations are predominantly dolomite, with some shale, conglomerate, and sandstone more typical of the ridge and valley areas.

According to Hardeman (1966), the Walden Creek, Great Smoky, and Snowbird Groups are characterized by sedimentary rocks which are for the most part poorly sorted and coarse. The underlying rocks are siliceous in nature and thus not easily dissolved by ground water. Consequently, the total dissolved mineral solids content of the water is quite low. In general, these formations can be classified as sandstone and shale. The formations comprising these groups are limited to the region of the Great Smoky Mountains.

III. STATIONS

Sampling stations were chosen on the Middle and West Prongs to be as comparable as possible. Within the Great Smoky Mountain National Park the geology and land cover of the two watersheds are similar, hence, water quality should also be similar under pristine conditions. Any marked differences in the water quality of the two streams, therefore, should result from anthropogenic sources.

On the individual prongs, the specific stations were chosen so that stations were analogous. Only riffle ecosystems were selected as they possess perhaps the most diverse freshwater piscine and aquatic invertebrate fauna. The riffles used in the study were chosen because of similar substrate, gradient, width of stream, depth, bank vegetation and accessibility.

Because of complications that could be introduced by differing streamflow regimes, the stations were selected so that the contributing watershed drainage areas on the two prongs were similar. If the stations chosen for comparison had drainage areas that differed too greatly, factors such as stream gradient, scouring, or stream depth could have unexpected effects on fauna to be studied. Table 1 (TVA, Data Services Branch, Pers. Comm.) illustrates the drainage areas of the selected stations.

TABLE 1

RIVER MILES AND DRAINAGE AREAS OF STATIONS ON THE MIDDLE AND WEST PRONG OF THE LITTLE PIGEON RIVER

	West Prong		Middle Prong	
Station	River Km	Drainage Area (sq km)	River km	Drainage Area (sq km)
STA 1	25.7	153.3	32	195.84
STA 2	20.6	180.9	25.6	210.6
STA 3	14.0	195.0	18.5	266.2
STA 4	10.8	363.5		

Riffles selected as stations could not have exactly the same drainage areas due to physical characteristics of the stream. Some of the headwater, mountainous character is maintained as the river enters the valley; hence deep pools, narrow gorges, and areas of large boulders prevented selection of identical drainage areas. The depth of the water at all stations in summer flows ranged from .25 to 1 m. The substrate was generally one of cobble and small boulders 10 to 30 cm in diameter. The width of the Middle Prong and the West Prong at all stations was similar, averaging 20 to 30 m. Bank vegetation was mostly hardwood trees and alder shrubs.

CHAPTER III

METHODS

I. SAMPLE SITES

Five sample stations were chosen on the West Prong. A control station was established above Gatlinburg at the Park Boundary. The remaining stations (1-4) were located below the Gatlinburg sewage plant: station 1 was 1.6 km downstream from the plant; station 2 was above Pigeon Forge; station 3 was below the city of Pigeon Forge but above the Pigeon Forge sewage plant; and station 4 was 1.6 km below the Pigeon Forge outfall. See Figure 1 (p. 10) for station locations. The three stations on the Middle Prong were selected for their similarity to stations on the West Prong.

II. AQUATIC INVERTEBRATES

Aquatic invertebrate sampling was done monthly except for quarterly sampling at the West Prong control from May 1975 to May 1976 with April 1976 omitted. Water conditions permitting, fish sampling was conducted concurrently with benthic sampling. An unmodified Surber square-foot sampler was used to take the samples. The sampler was equipped with a fine mesh bag (96 threads per inch). The gravel and rubble substrate of the chosen riffles were ideally suited to Surber sampling as the average stream depth rarely exceeded the height of the sampler. To enable comparisons of samples to be made, the individual selection of sample sites was biased to always be in cobble substrate. Three samples were taken per station. The samples were put in jars, preserved with 60 percent isopropyl alcohol, and returned to the laboratory for sorting and identification. Identifications were made to species where literature, consultants, and personal expertise made it practical. Due to the paucity of keys, the difficulty of identification, and the large numbers of individuals collected, the identification of chironomids was to family level. Keys used in identification were: Plecoptera (Frison, 1935; Hitchcock, 1974), Trichoptera (Ross, 1944), and Ephemeroptera (Burks, 1953; Lewis, 1974), and Diptera (Johanson, 1973; Usinger, 1956).

III. FISH COLLECTIONS

Fish samples were taken with sodium cyanide (Lewis, 1960) using a 6 m. block net at the lower end of the sample area to collect affected fish. The cyanide was added at a point 15 m. above the net. Samples were made only over riffles. This facilitated pick-up of fish, as affected fish were washed into the block net. Obviously then, pool-living fish have been mostly excluded from the study by intentional sample bias. Sampling was not performed from December to April due to cold water temperatures and frequent high flows. Seining was attempted but proved impractical owing to high water levels, frequency of cobbles and small boulders, growths of algae, and the cold air temperatures. Also, seining effort could not be quantified in comparisons with cyanide samples. With the exception of the first and last sampling month all fish were field sorted, identified, counted and returned, apparently alive, to the river.

Sodium cyanide was used as a non-lethal immobilizing agent for fish. This was done to lessen the effects of monthly sampling on the riffles and thus not decimate the study populations. Recovery rates for the fish released after cyanide collection appeared high: 80 - 95 percent for cyprinids and 95 - 100 percent for other fish collected. The first collection, the last collection and any fish of questionable identification are being kept in a voucher collection for additional work. Fish kept were returned to the University laboratory in 10 percent formalin.

Nomenclature of common and scientific names used in this study follow Bailey (1970).

An analysis of variance (ANOVA) was performed on the transformed total numbers of fish collected at each station. The raw data were transformed using $\sqrt{x+1}$. The ANOVA was performed to see if any differences existed between the two prongs and between the stations.

IV. WATER QUALITY

Water quality samples collected in 1968 were analyzed by the Tennessee Valley Authority, Chattanooga. The 1975 sample was analyzed at the City of Knoxville Water Plant. Data from samples in 1968 as well as 1975 have been used mainly for comparative purposes. The 1968 data have been used to show natural mineral quality in both the West and Middle Prong of the Little Pigeon. Additional 1975 data have been used to determine metals and trace metals. As dates of water quality collection do not coincide with the dates of this study, the data were not relied on heavily but were used to support inferences made during the study.

Additional water quality information has been generated from the use of a model by Betson and McMaster (1975) which predicts mineral water quality. By considering the underlying geology of the Little Pigeon watershed and the degree of forest cover, predictions can be made as to what natural water quality should be.

CHAPTER IV

RESULTS

I. AQUATIC INVERTEBRATES

The raw data from samples collected in the West Prong and the Middle Prong of the Little Pigeon are presented in Tables A-1 through A-8. The results show firstly a lower total number of taxa per sample date (Figure 2) in the West Prong below Gatlinburg than in the Middle Prong. The West Prong control station above Gatlinburg had a higher total number of taxa than the West Prong below Gatlinburg and more closely approximated trends in the Middle Prong than the West Prong below Gatlinburg. Secondly, the mean number of organisms per sample date (Figure 3), with few exceptions, was lower in the West Prong below Gatlinburg than in the Middle Prong. Again, the West Prong control above Gatlinburg had, in general, a higher number per sample date than the West Prong below Gatlinburg. Lastly, the composition of organisms (Figure 4) for the sample year was different in the two prongs with Ephemeroptera and Plecoptera making up a larger percentage of the population in the Middle Prong than on the West Prong.

The West Prong control (above Gatlinburg) and the station on the Middle Prong had a higher total number of taxa per sample date (Figure 2) than the stations on the West Prong below Gatlinburg over the study year. In the Middle Prong over all stations the lowest total taxa number was 17 while the highest total taxa number was 36. In the West Prong below Gatlinburg over the sample year the lowest number of taxa collected was 3 and the highest number of taxa was 15. There was no overlap of the

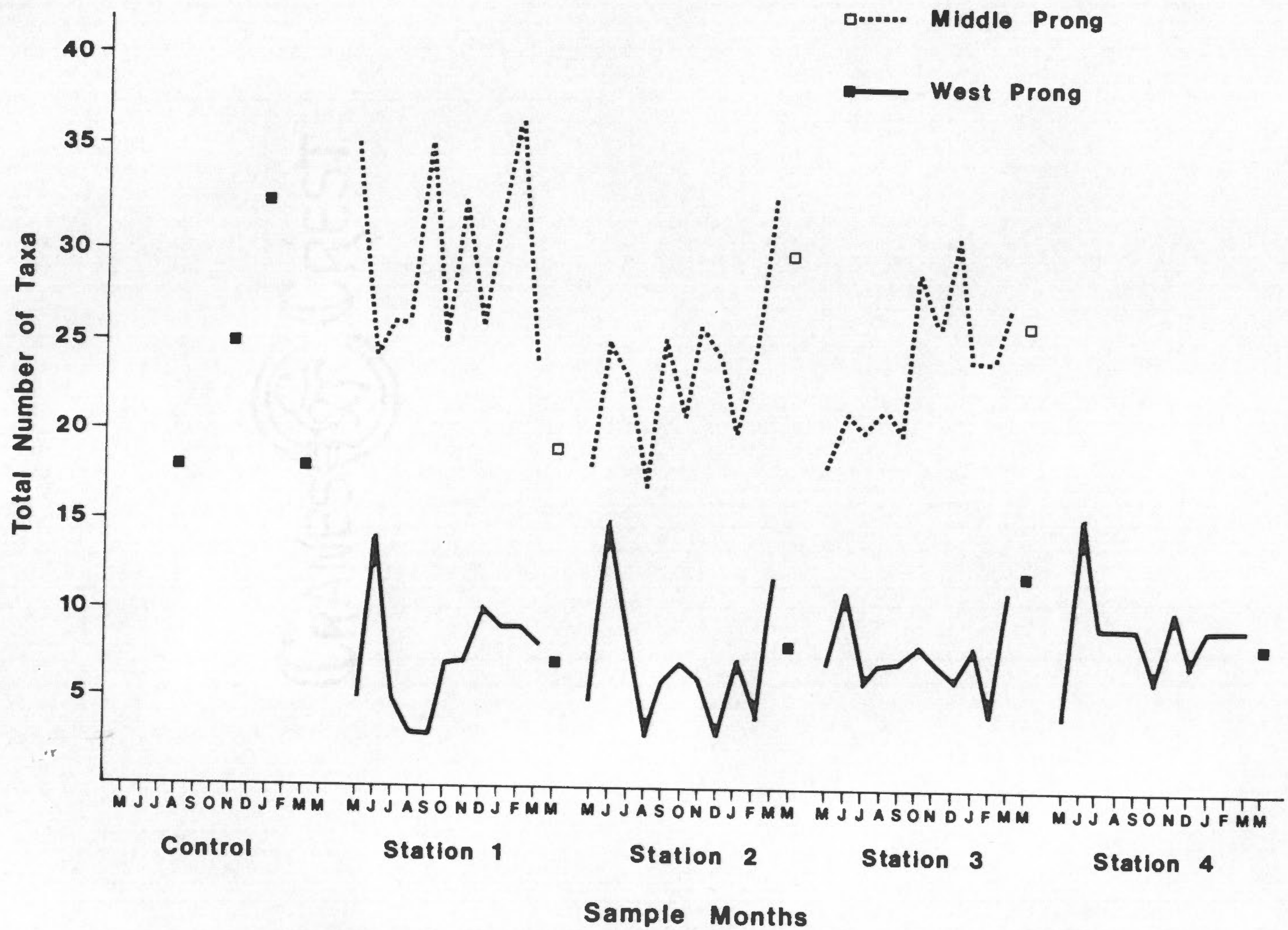

Figure 2. Comparison of total numbers of taxa obtained on the Middle and West Prong of the Little Pigeon River. Comparisons are made between stations of the Middle and West Prongs on each sampled date.

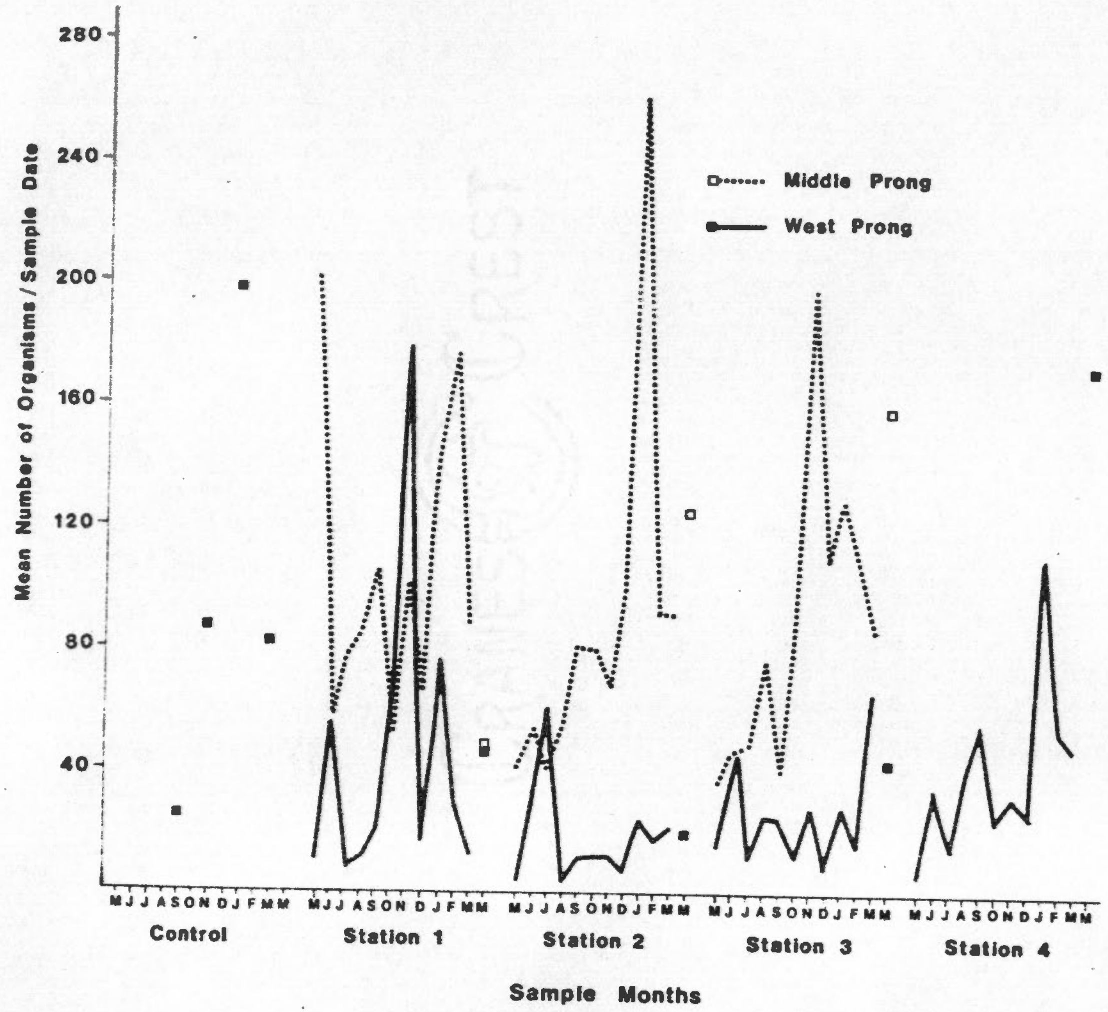

Figure 3. Comparison of the mean number of aquatic invertebrates in the Middle and West Prong of the Little Pigeon River. Comparisons are made between stations of the Middle and West Prong on each sampled date.

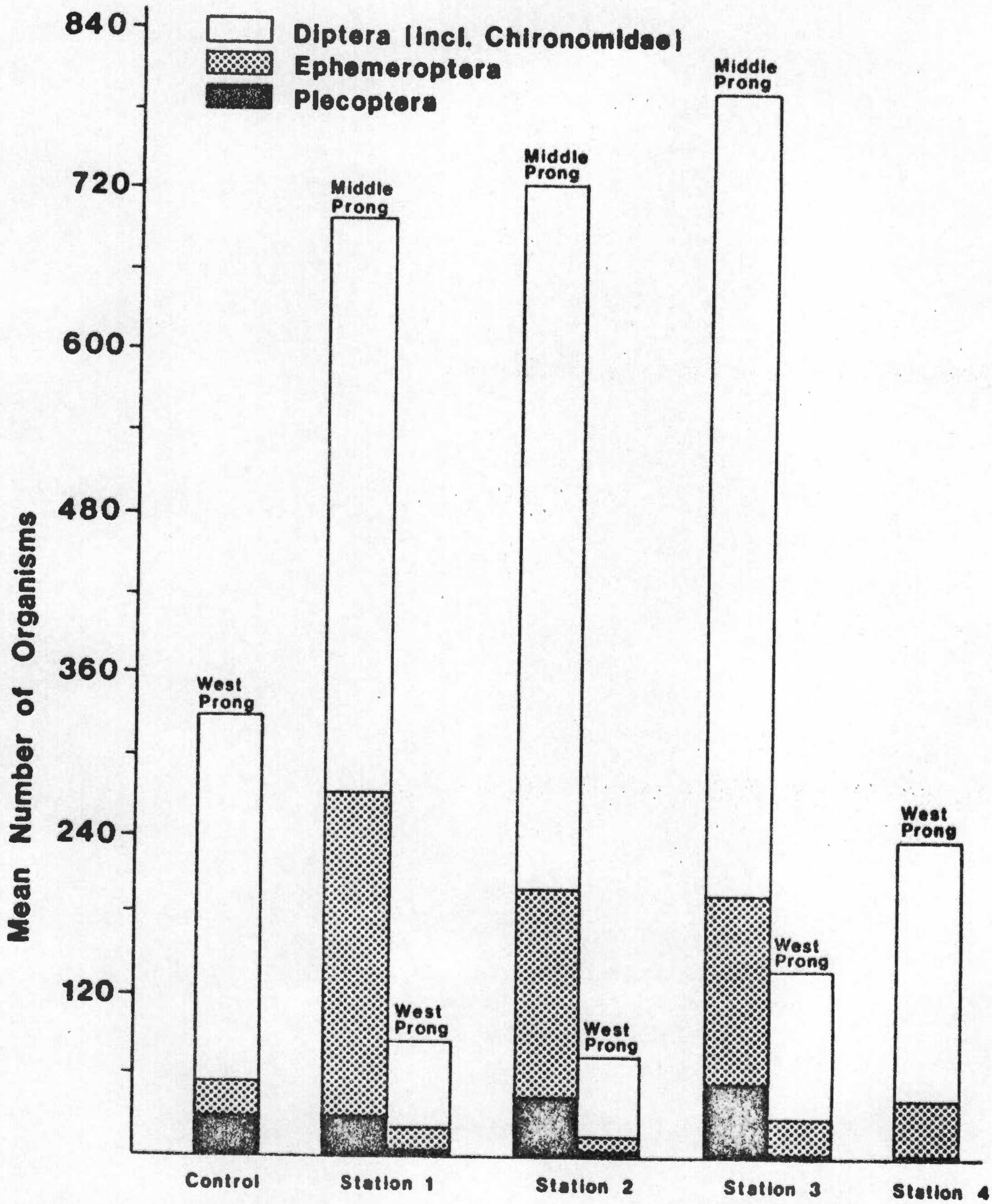

Figure 4. The composition of the yearly mean number of aquatic invertebrates in the Middle and West Prong of the Little Pigeon River. Comparisons of the composition of three orders of aquatic invertebrates are made between stations of the Middle and West Prong.

highest value on the West Prong (15) and the lowest on the Middle Prong (17). The control station above Gatlinburg on the West Prong more closely resembled the Middle Prong than the West Prong below Gatlinburg with a range of 18 to 33 total taxa. In the Middle Prong the range of values for total number of taxa was fairly consistent with station 1, 19 to 36; station 2, 17 to 33, and station 3, 18 to 31. The West Prong stations below Gatlinburg had, in general, a lower range of values for total numbers of taxa per sample date, with station 1, 3 to 14, station 2, 3 to 15; station 3, 4 to 12; and station 4, 4 to 15. The number of taxa collected per sample date showed the Middle Prong to have greater totals per collection date than the West Prong below Gatlinburg.

The Middle Prong had, with a few exceptions, a higher mean number of organisms per sample date when comparing it to the West Prong, station by station (Figure 3). While Figure 3 shows that the mean numbers of organisms were higher in the Middle Prong than in the West Prong below Gatlinburg there were exceptions which could be accounted for by the effects of seasonal abundance and emergence periods, individual bias in selection of individual Surber sites, and environmental effects including scouring from high flows. The mean number of organisms collected per sample date at West Prong control above Gatlinburg ranged from 24.6 to 198. The summer quarter sample was low, but the other three quarterly samples most closely resembled the mean numbers on the Middle Prong than the West Prong. The mean numbers on the Middle Prong varied, with station 1 having a range of 46.0 to 196.0, station 2 a range of 41.3 to 262.6, and station 3 a range of 36.6 to 166.3. The West Prong range of mean numbers was slightly lower: station 1, 8.3 to 179.6; station 2, 4.3 to

62.0; station 3, 8.3 to 65.3; and station 4, 6.3 to 177.6. While some exceptions existed, the Middle Prong had a higher mean number of organisms per sample date than the West Prong below Gatlinburg.

Figure 4 demonstrates how some of the changes in total taxa and in mean numbers of organisms affects the percentages of certain families in the study areas. In all stations, Diptera made up the largest percentage of the number of organisms. Inspection of the raw data in Tables A-1 - A-8 reveals that Chironomidae made up the majority of the numbers of Diptera present in the samples. In some cases, Chironomidae comprised the majority of all individuals. While Chironomidae were not keyed to genera in the study, some selected samples were sorted to see if there was a predominance of *Chironomus* (blood worm) present in the summer in the West Prong compared to the Middle Prong. In those samples checked *Chironomus* occurred infrequently and then only in station 1 on the West Prong.

The greatest difference that Figure 4 points out is in the mean numbers of Plecoptera and Ephemeroptera in the Middle and West Prong. The mean number of Plecoptera in the West Prong at station 1 was 2 while station 2 had 2; station 3 had 3 and station 4 had 1. These values can be compared with those obtained in the Middle Prong: station 1, 30; station 2, 47; and station 3, 58. The control above Gatlinburg had an average of 29 Plecoptera. The difference between the Middle and West Prong in this family was greater than 10 fold. Like Plecoptera, Ephemeroptera showed a greater number of organisms present in the Middle Prong. The mean number of Ephemeroptera at West Prong station 1 was 13 while the Middle Prong station 1 had 248. The West Prong station 2 had an average of 3 while the Middle Prong had 166. Lastly, the West Prong control had an average of 29 Ephemeroptera per station.

II. FISH

Table B-1 lists the common and scientific names of fish sampled in the Little Pigeon River. Data obtained during sampling of the West Prong are listed in Table B-2. Table B-3 summarizes the data collected on the Middle Prong. The data indicate that while the total numbers of fish were similar in the Middle and West Prong, species represented in the Middle Prong were slightly different from species present in the West Prong.

The 3-way analysis of variance presents results which indicate that the total numbers of fish on the Middle Prong was different than the West Prong. At the 5 percent level no significant differences could be determined between areas and stations but significant differences were detected between species and species interactive with areas and stations (Table 2). These statistical results will be elaborated on using concrete examples from the raw data.

From Table B-2 and Table B-3 it is possible to determine the number of species and the numbers of individuals present during the sampling. Over the seven sample months West Prong station 1 had 40 species representing 636 individuals. This can be contrasted with Middle Prong station 1, where there were 56 species and 717 individuals over seven months. At station 2 in the West Prong a total of 50 species and 430 individuals were represented in seven months of sampling. Station 2 on the Middle Prong had a total of 52 species with 445

TABLE 2

ANALYSIS OF VARIANCE SUMMARIES FOR FISH COLLECTED IN THE MIDDLE AND WEST PRONG OF THE LITTLE PIGEON

Test	DF	SS	MS	F	Sig.
Prongs	1	2.278735	2.278733	8.54	N.S.
Stations x Prongs	4	2.572956	.643239	1	N.S.
Species	30	640.352073	21.345069	32.88	S
Species x Prong	30	104.352073	3.494065	5.38	S
Species x Station	120	463.435945	3.862966	5.95	S
Error	1085	704.313473	.649137		
Total	1270	1917.775121			

individuals for the study. At station 3 on the West Prong 48 species were collected in the study with 226 individuals while station 3 on the Middle Prong had a total of 52 species with 354 individuals for the study. Station 4 on the West Prong yielded a total of 45 species with 654 individuals.

Table B-1 lists the common and scientific names of 37 species collected one or more times during the cyanide collections on the Little Pigeon. It is important to note that this is not a complete species list of the Little Pigeon. Collections were made on the same seven riffles month after month to determine population changes within these particular riffles. As such, many species of fish regarded as pool species were never collected or may have been collected only a few times in the study area. An example of this are the red horses (*Moxostoma*) which were collected on the West Prong at the station 4 riffle in the spring spawning run in both 1975 and 1976; otherwise *Moxostoma* were not collected in riffles.

One group of fish particularly important in this study are the Percidae. This family includes the darters, most commonly associated with gravel riffles. A comparison of the percid populations shows station 1 on the West Prong with 58 total individuals and three species represented for the seven month study while the Middle Prong had 275 individuals and seven species represented. At station 2, the West Prong had 79 total individuals of four species while the Middle Prong had 353 total individuals of eight species represented. West Prong station 3 had 89 total individuals of six different species while the Middle Prong station 3 had 226 individuals of eight species. Lastly, station 4 on the West Prong had 481 individuals of five species.

A sharp contrast was present in both total numbers and numbers of species of percids between the Middle and West Prong. For example, *Etheostoma rufilineatum* was the dominant darter in total numbers in all stations on the Middle Prong but did not occur in West Prong station 1 and only a single individual was collected at station 2; it is not until station 4 that it appeared in large numbers. *Percina evides* is another darter not collected until station 3 and 4 on the West Prong but it appeared in the Middle Prong more consistently, with a single occurence at station 1 and nearly monthly occurence at station 2.

The populations of the subgenus *Catonotus* have undergone changes in the West Prong. Table B-4 shows that Carl Hubbs collected *Etheostoma kennicotti* from below the Pigeon Forge Bridge (roughly station 3). Also,

D. A. Etnier collected *Etheostoma kennicotti* from the same locality in 1968 (Table B-6). In 1969, D. A. Etnier collected *Etheostoma flabellare* from the mouth of Norton Creek (Table B-6). Early collection records indicated that *Catonotus* were present in the West Prong below Gatlinburg but no individuals were collected during the study. However, *Etheostoma flabellare* (Table B-5) were collected in the qualitative collection at the West Prong control station above Gatlinburg. Apparently a population of *Catonotus* exists above Gatlinburg but not below Gatlinburg.

One additional darter which was absent in collections from the West Prong was *Percina aurantica*. Though peripheral to the riffle community, *Percina aurantica* was occasionally taken in the Middle Prong cyanide samples and was observed to occur in abundance in flowing pool areas. Hubbs (1937) documented the occurrence of *Percina aurantica* in the West Prong. Twenty-eight cyanide samples in this study and an additional 12-15 recent collections by other workers have failed to demonstrate its continued existence.

Other fish in addition to the *Catonotus* and *Percina aurantica* have disappeared or decreased in numbers in the West Prong below Gatlinburg. Hubbs in 1937 collected *Percina macrocephala*. This fish has not been recollected in recent years. Dr. D. A. Etnier made several collections as presented in Table B-6, and an abundance of species was evident. In 1968 at a site equivalent to station 3 in this study, Etnier collected *Etheostoma kennicotti*, *Etheostoma zonale* and other species not present in Table B-2 of this study. Also, when compared with fish collected in this study the numbers collected were higher. For example, D. A. Etnier

(Table B-6) collected 109 *Etheostoma chlorobranchium* and 46 *Etheostoma swannanoa* near station 1. During seven cyanide samples at station 1 of this study, only 17 *Etheostoma chlorobranchium* and 38 *Etheostoma swannanoa* were collected (Table B-2). This indicates that changes in fish populations in the West Prong have occurred since the 1968-1969 collections.

One particular game fish of interest in these two prongs is *Salmo gairdneri*. Stocking of this fish was discontinued in 1975 on the West Prong but continues in the Middle Prong. *Salmo gairdneri* were not collected on the West Prong during this study but were netted for examination as they floated downstream in distress at station 3 and 4 on the West Prong on the July 4, 1975, week-end. On the other hand, they were collected on three separate occasions in the Middle Prong even though sampling was not being done in typical trout habitat. In addition to these confirmed collections, there were several other occasions where trout entered the block net but recovered and escaped before the net was taken ashore.

Perhaps the most conspicuous fish on the West Prong was *Campostoma anomalum*. While schools of these fish could be seen in both prongs grazing algae off the rocks, the populations were noticeably larger on the West Prong. Station 1 on the West Prong had a total of 522 *Campostoma* per sample while the Middle Prong station 1 had 427 but this probably does not reflect the actual *Campostoma* populations. One possible reason is that the sample areas had to be walked through due to overgrown banks to place the cyanide at the head of the riffle. This scared large numbers of *Campostoma* upstream away from the sample area. Visually, numbers of *Campostoma* appeared much higher on the West Prong at station 1 and 2 than at any Middle Prong station.

The hogsucker, *Hypentelium nigricans* like *Campostoma*, had a larger population in the West Prong than in the Middle Prong. Station 1 on the Middle Prong had a single collection of 4 individuals while at the West Prong station 1 *Hypentelium nigricans* were taken in every collection with a total of 60 individuals. In the West Prong stations 1-3, 132 total individuals were collected while the Middle Prong stations 1-3 yielded 12 total individuals.

Other fish collected during the study included *Phenacobius* *Notropis* and *Hybopsis*. *Phenacobius*, a riffle inhabitant, was picked up in station 2 and further downstream in both prongs. *Hybopsis insignis*, another riffle fish, was collected at every station of the Middle Prong but only station 3 and 4 of the West Prong. *Hybopsis amblops* and *Notropis*, typical pool species, showed very little differences in either diversity or abundance between the Middle and West Prong.

III. WATER QUALITY

Table C-1 summarizes and compares selected 1968 water quality parameters for 3 stations: one above Gatlinburg and one below Gatlinburg at station 1 of this study on the West Prong and one on the Middle Prong at station 3 of this study.

Using information on geologic formations in the study area, predictions can be made on what mineral water quality should be in the Middle and West Prong using a nonpoint source mineral water quality model presented by Betson and McMaster (1975). With information on land cover (fraction of area forested) plus underlying geologic formations this model can be used to predict the natural water quality. Table C-1 shows the predicted values for the Little Pigeon watershed at station 1 of both prongs and also how closely these values for parameters like pH, sodium, silica, calcium, magnesium, chloride and iron resemble the actual values recorded over the months sampled in the three selected stations. This model demonstrates that those aspects of water quality are largely a function of the underlying geology. Since the geology and land cover of both watersheds is similar, it follows that the water leaving the park on the Middle and West Prong should have very similar chemistry and therefore any differences noted should not be due to natural water chemistry differences.

Several parameters measured in Table C-1 can indicate anthropogenic influences: fecal coliform, dissolved oxygen (DO), 5-day BOD, and total phosphates. Fecal coliform counts varied between the Middle and West Prong, with the West Prong being extremely high in the summer months when compared to the low values in the Middle Prong. Above Gatlinburg fecal coliform was barely detectable, more like the Middle Prong then the West Prong below Gatlinburg. Middle Prong station 3 did have one high fecal coliform reading in June 1968 when stream flow was also high. The highest fecal coliform readings were at station 1 below Gatlinburg. An additional parameter considered is dissolved oxygen. Lowered DO might indicate decay is taking place. However, DO in stations on both the Middle and West Prong was high and indicates a well-aerated stream. The 5-day BOD was also similar in the three stations with an almost imperceptible rise in the West Prong below Gatlinburg. Total phosphate in the West Prong below Gatlinburg was tenfold higher than the low and very similar results from the Middle Prong and above Gatlinburg.

Even with the contributions from the Gatlinburg sewage plant, the West Prong water quality shows minor change. Fecal coliform frequently exceeds EPA (1972) recreation water quality criteria indicating that untreated sewage probably enters the water. But the data in Table C-1 along with other data taken at these sites but not included indicate that in general water chemistry changed very little below the sewage plant outfall. Trace metals or toxic chemicals that might impact fauna would not be expected from this non-industrial resort community (Table C-2). A single sample in which trace constituents were analyzed was taken in October 1975 at these three stations and showed low or undetectable levels of each constituent. Therefore, other than an elevation in the loadings of fecal coliform and total phosphates, the impact of Gatlinburg upon the quality of water in the West Prong has been almost undetectable at least as quantified by a conventional monthly sampling program with the samples collected on week-days and with those samples analyzed for conventional water quality parameters.

CHAPTER V

DISCUSSION

In order to utilize fish and macroinvertebrates as "indicators" of environmental conditions in streams, it is essential to have a knowledge of the species composition and abundance of the various organisms living in riffles and which prevail in clean and organically enriched waters. By looking at conditions in the Middle Prong of the Little Pigeon, which is known to be a relatively pristine stream, it is possible to see how changes in the West Prong, as indicated by the results herein, have come about.

Of the biotic, physical and chemical parameters that integrate to form the environmental milieu to which macroinvertebrates respond, producing observed patterns of distribution and levels of abundance, certain parameters appear to be more direct in their mode of control. Excluding various degrees of human perturbation, under natural conditions the availability of food, nature of sediments and current flow generally constitute the parameters of primary significance in determining microdistribution patterns.

Geographical distribution of stream species may be determined by physical-chemical factors as it is understood that no animal can occur naturally in a region to which, for some historical reason, it has not gained access, even though suitable habitat occurs there (Whitton, 1975). Attempts to link microdistribution and abundance of faunal elements with specific parameters have been inconclusive. In the Little Pigeon within similar sampling locations, species would be expected to be similar if not identical. The underlying geologic formations are remarkably similar causing stream water chemistries to be nearly identical and the prongs join before any natural barrier could be found which would prevent an exchange of faunas. Therefore, any detected differences in species of abundance of benthos or fish should be due to natural or anthropogenic microhabitat differences.

In the riffle habitat, as chosen in this study, current becomes an important parameter as any organisms living in the riffle must be specialized to swim against or avoid the current. Instead of using large amounts of energy to swim in the current, many organisms adapt to life in fast flowing water by taking advantage of the boundary layer phenomenon in current flow. The rate of flow decreases rapidly towards the bottom until at the boundary layer it declines very rapidly to zero. When the substrate is irregular, the flow is turbulent and the boundary layer is thicker than it would be if the flow were laminar. In order to maintain themselves in fast flowing water, benthic animals must be prepared to live in the boundary layer with suitable anatomical adaptations.

Hynes (1972) has researched the evolution of unique adaptations of macroinvertebrates to the particular microhabitat associated with the boundary layer as found in shallow riffle streams. Examples of this erosional riffle fauna (Hynes, 1972) have been taken from the Little Pigeon and include such forms as the dorso-ventrally flattened setipalpian stoneflies (Plecoptera) and the mayflies (Ephemeroptera) in the family Heptageniidae. Some of the latter (for example, *Rhithrogena*), have gills modified to form a sucker-like disc. In beetle larvae (Coleoptera) such as the water penny, (*Psephenus*) peripheral bristles on the expanded thoracic and abdominal tergites act to form a similar seal with the substrate. While some organisms flatten and live under the stones so as to avoid current, change of body shape allows some organisms to live on the surface of the rock and remain within the boundary layer. Blackflies (Simuliidae) spin a layer of silk in which the circlet of hooks on the flattened posterior prolegs are imbedded to maintain their position on exposed surfaces of rocks. Blackflies, along with net-spinning caddisflies (Trichoptera, i.e., Hydropsychidae) have evolved filtering devices for obtaining particulate food from flowing water. Free-living Trichoptera and the larvae of Corydalidae have developed clawed posterior prolegs to grip the roughness of the substrate. Stationary or portable cases constructed of heavy materials are common adaptions for maintaining position in rapid waters as seen in certain caddisflies and midges. *Goera* uses the weight of an added ballast stone which it adjusts according to current to maintain position.

Since these organisms are highly specialized to living in fast flowing water, any change in habitat is likely to affect composition of the riffle community. In addition, aquatic insects are not able to migrate large distances as fish do. If at any time during development, environmental conditions become lethal for a given insect or macroinvertebrate, that organism will be eliminated even though the conditions may be present for only a short time. Therefore, species diversity and total numbers of the aquatic insects have been looked at carefully for any differences between the Middle and West Prong that might indicate a change has taken place. The results indicate a sharp decrease in the abundance of the population in aquatic insects in the West Prong below Gatlinburg when compared between the West Prong above Gatlinburg and the Middle Prong. The results also indicate that certain families and genera have been affected more strongly than others. In general, the families most affected are those just discussed for their adaptations to life in the boundary layer of the shallow riffle habitat.

The results of the macroinvertebrate data indicates a sharp drop in both numbers of species and total numbers of individual Plecoptera and Ephemeroptera in the West Prong below Gatlinburg when compared to the West Prong above Gatlinburg or to the Middle Prong. Plecoptera, for example, are represented by a 78 percent increase in numbers of species and a 97 percent increase in the number of total individuals in the Middle Prong station 1 when compared to the West Prong station 1. Even the West Prong control station above Gatlinburg which was only sampled four times instead of 12 yielded a 66 percent increase in the number of species and a 94 percent increase in the number of individuals compared to West Prong station 1, and, yielded species not found at downstream stations. In the Plecoptera neither total numbers nor numbers of species noticeably increased downstream from station 1 on the West Prong, while numbers of species and total numbers remained high going downstream in the Middle Prong. In general, the population of Plecoptera in the West Prong below Gatlinburg is very low when compared to the Middle Prong. Ephemeroptera, though having higher number of species and total numbers, exhibited trends similar to those with Plecoptera. Middle Prong station 1 had a 52 percent increase in the number of species and a 92 percent increase in the total number of individuals compared with West Prong station 1. Populations changed very little downstream in the two prongs as the West Prong populations remained low while the Middle Prong populations remained high in both Ephemeroptera and Plecoptera.

The reduction in population numbers and number of species is an important result as is the realization of which families have been most affected. The dorso-ventrally flattened setipalpian Plecoptera and also the Heptageniidae (Ephemeroptera) had extremely reduced populations. *Rhithrogena* was never collected at West Prong station 1 but was collected in the Middle Prong. *Psephenus* existed in large numbers in the Middle Prong as would be expected from Surber samples in cobble substrate, but collection of *Psephenus* in the West Prong was a rare event, usually only once or twice for the 12-month study at each of the 4 stations. These observations indicate that the organisms normally associated with current swept gravel have been reduced in population below Gatlinburg and its sewage plant when compared to a station above Gatlinburg or to the Middle Prong.

In running water not only macroinvertebrates but also fish have adapted to use current in the riffle habitat. Fish such as *Salmo* occurring in and relying on their ability to swim in fast water are more terete and streamlined than fish in lakes or rivers with little or no current. However, not all fish living in rapid waters are powerful swimmers. Many Little Pigeon residents such as *Cottus*, *Etheostoma*, *Hypentelium* and *Percina evides* maintain themselves close to the bottom or in shelter under or behind stones. These fish have adapted themselves to being in or near the boundary layer, and have anatomical adaptations (Hynes, 1972; Whitton, 1975) which seem to be associated with this benthic habitat. These fishes are usually dorso-ventrally flattened or have an arched dorsal profile. The eyes tend to be dorsal, and the gill openings tend to be placed laterally rather then latero-ventrally. There also appear to be modifications in the mouth which has moved more or less ventrad so that when it is opened it does not disrupt the arched dorsal profile. Lastly, an internal modification noted in bottom dwelling fishes is the reduction in size or complete absence of the swim bladder.

Nearly all species of fish have fairly well defined breeding habits and requirements which are more restrictive than requirements necessary for other facets of life history, and those determine to a large extent the suitability of particular rivers and streams for various species. Many species select or prepare definite nest sites on stony or gravel substrate. Certain species of *Etheostoma*, *Campostoma*, and *Nocomis* which construct nests are restricted not only by the size of material of the substratum, which they must be able to move, but by the need to be free of silt. A great many species such as *Moxostoma* and *Hypentelium* (Jenkins, 1970; Hynes, 1972) breed on gravel or stones but construct no nest. Nearly all fish that spawn this way move on to clean gravel to do so, often moving upstream into shallower and swifter water than is their normal habitat. The eggs of these species either adhere to stones until they hatch, or drift and roll into interstices and small pockets of dead water.

Having looked at the adaptions of certain species of fish to be unique habitat of the riffles, the results of the study must be considered with these adaptions in mind. The discussion of fish adaptions thus far should be applicable to either the West Prong or the Middle

Prong in that they are pertinent to any fast water stream. The results of the study indicate that a shift has taken place in fish species below Gatlinburg when compared to the Middle Prong. For example, both a reduction in total numbers and the number of species of Percidae has taken place in the West Prong below Gatlinburg when compared to the Middle Prong. For a specialized species to change in abundance or disappear must indicate for fish, as well as macroinvertebrates, a change in the riffle or in the conditions in the riffle habitat.

At the same time that the Percidae are decreasing in numbers below Gatlinburg, *Campostoma* and *Hypentelium* both show increases in numbers in the West Prong below Gatlinburg. *Campostoma* feeds by grazing algae from the surfaces of stones. Hence, any nutrients added to the West Prong which would enhance the growth of algae would increase food available to these fish and ostensibly the carrying capacity. The hogsucker, *Hypentelium nigrigans*, similarly rolls stones over and sucks up ooze from beneath them (Raney and Lachner, 1946), so added organics and suspended solids might increase available food. These two rather opportunistic species increased in numbers while the sight-feeding Percidae (Hynes, 1972) decreased in numbers.

While all species of fish have requirements necessary for each facet of their life history, breeding habits and requirements are generally more restrictive than those to merely maintain life. So while adult fish can survive pollution, it is possible that reproduction can be curtailed. Certain species of *Etheostoma*, *Campostoma*, and *Nocomis* construct nests while *Moxostoma*, *Hypentelium* and *Percina* spawn on current swept gravel with no nest. Whitton (1975) noted that there must be a flow of water through the interstices to maintain the required high level of dissolved oxygen for egg development in all these species. If organic solids fill the interstices then either the eggs suffocate or are excluded altogether, drifting downstream out of the riffle or being eaten by predatory species. Further, species which are particular in spawning site selection may be seriously curtailed or fail to spawn altogether.

The results have indicated that a change has taken place in both the fish and macroinvertebrate faunas of the riffle communities in the West Prong below Gatlinburg when compared to the West Prong above Gatlinburg or to the Middle Prong. Water quality comparisons indicate that natural mineral water quality parameters in the two prongs is similar if not identical, supporting the premise that the two prongs are comparable study sites. Treated and at times untreated sewage enter the West Prong from the Gatlinburg sewage treatment plant, while the Middle Prong suffers no known major anthropogenic influence. Elevated levels of fecal coliform and total phosphates in the West Prong indicate the addition of organics.

Residential sewage is a complex of organic compounds in solution and suspension. These organics and solids are in evidence at West Prong station 1 where offensive odor and milky color have been observed. Suspended solids are present as a powder of sediment lying in pools, behind rocks and in the spaces between stones. These sediments were collected in samples taken during the summer and appear to coat legs and gills of aquatic insects. Additionally, during fish collections taken in the summer months, the block seine was covered with partially digested lettuce leaves, chicken, and other indistinguishable gelatinous masses. This was particularly true on the July 1975 sample when these suspended solids were also noticeable at West Prong station 2. If suspended solids become heavy enough to cover up and fill the spaces or interstices, the animals which inhabit these spaces either die or move to an area that is not affected. Movement renders the organisms more susceptable to predation, and the populations of these types of organisms that inhabit the interstices are likely to decrease. Another organism more equipped to live in the habitat covered with the suspended solids might take over the new area if present.

If this study were done in a lake or a pond instead of a stream, the explanation of the effects of suspended solids on biota could be well documented (Kemp, 1966; Hynes, 1960). Without current, the incoming nutrients and solids would accumulate in layers covering available habitat. Decay within these layers would reduce D.O. and also produce gases such as hydrogen sulfide which would be injurious to faunal population as gases accumulated. In general, the only benthos persisting would be those that can live in the accumulating muck. The only fish present would be those which could utilize these organisms and which could tolerate lower D.O. concentrations.

Since the city of Gatlinburg treats its sewage with chlorine, the potentially toxic effects of chlorine must be considered. The toxicity of chlorine to aquatic life will depend not so much on the amount of chlorine added but on the concentrations of residual chlorine remaining and on the relative amounts of free chlorine and chloramines. Available water quality data for the West Prong of the Little Pigeon does not include information for free chlorine, residual chlorine or any chloramines. However, the state of Tennessee monitors the level of residual chlorine at the point slightly below where the chlorine is added. For the study year, the residual chlorine level never exceeded 0.5 mg/d (D. Owens, Pers Comm). The 0.5 mg/l level occurs in the summer months and any untreated sewage (1 to 2 times the treated amount) is added to the chlorinated sewage after the residual chlorine measurement. So before the effluent (treated and untreated) reach the West Prong, the residual chlorine is considerably lower (but unmeasured) than 0.5. In spite of the potentially toxic effects of chlorine and its by-products, the West Prong still has relatively large numbers of aquatic invertebrates and fish. Only certain highly specialized species have disappeared. Chlorine effects cannot be discounted without further tests but it does not seem likely that the levels of chlorine added to the Gatlinburg and Pigeon Forge effluents could affect selectively almost 15 km of the West Prong.

Because of the numbers and types of species which have decreased or disappeared from the West Prong below Gatlinburg it appears that some factor such as suspended solids could be affecting the interstices and boundary layer of the riffle. The sewage input into the West Prong is highest in the summer when natural flows are low. Spates even in the mountainous area are infrequent and occur when temperatures are highest for the year. The soluble organics entering the system would be diluted but due to low flow suspended solids would either remain in suspension and wash out of the system or eventually settle out. Most of the suspended solids would settle out near the plant with smaller particles being carried downstream with the current. If sufficient solids accumulate to partially or completely fill in interstices, then macroinvertebrates and the organisms that depend on them for food are affected. Apparently no research has been done in a stream environment on the subceptibility of insects to this type of pollution. Considerable time may be needed to affect a particular species. In a dry summer these organic solids may cover the substrate for two or three months, while in a wet summer the organic solids may be present for only several days. They are present in large quantities in the summer and their effects are not entirely known, but they would affect the boundary layer and dead spaces in the river. The species shown by this study to be declining in numbers are all inhabitants of that layer.

An interesting factor that might also point to the importance of organic solids is that in most pollution studies when clean water species disappear, certain species of Diptera or other sewage related species usually take their place and take advantage of the new food supply. This is reflected in a decrease in numbers of species but an increase in numbers of individuals. In this study, there is a decrease in numbers of species in the West Prong but the abundance of pollution tolerant species does not increase when compared to the Middle Prong. Perhaps because the excessive pollution only lasts three or four months, the increased organics are not present long enough for species to take advantage of them before they are flushed by heavy winter flows.

If the faunal changes are effected by organic solids there are several reasons why water quality parameters differed little in the two streams. First, most samples are taken from the surface, and except at the outfall the majority of the suspended solids visible appeared to be at or near the bottom. Secondly, there is a dilution factor. Very clean water flows from the mountains through Gatlinburg. Even in low flows, dilution would make soluble portions of the sewage "dilute" quickly as the sewage passed downstream. In high flows, the spate-like conditions would flush or scour any accumulated materials from the system. Thirdly, Gatlinburg experiences heavy tourist trade all summer but week-ends are especially busy as local residents join tourists in the resort city. This allows some peak outputs from the city to go unnoticed as water quality sampling regimes are based on week-day samples. Lastly, the sewage plant is really only overtaxed seriously during the summer influx of tourists. Winter rains would flush the effects of the summer overload from the plant and might even allow for a partial recovery of the stream until the summer input returns again. So seasonal variability affects results the sampling program will yield, and only the summer could be expected to show the effects of heavy loads of untreated sewage.

CHAPTER VI

CONCLUSION

The results of this study show conclusively that substantial habitat perturbation has occurred in the riffle communities in the West Prong Little Pigeon River where fish and aquatic invertebrates are concerned. A general recapitulation of results and speculations on the causative aspects of the pollution will shed some light in this regard.

Available water quality data from 1968 and one 1975 sample along with model predictions indicate that the natural mineral water quality of the Middle Prong and West Prong is similar. Therefore, any large faunal changes taking place between the two prongs should be due to the known addition of organics to the West Prong at Gatlinburg and Pigeon Forge instead of any inherent differences in water quality. Water quality data indicate a mild organic loading as shown by an increase in fecal coliform and total phosphates in the West Prong below Gatlinburg. Suspended solids were not tested for in the 1968 water quality study but in the 1975-1976 faunal collections, organics were in evidence as color, smell, and a covering of solids on the substrate during the May to September samples. The effects of increased organics in a stream would be on microhabitats which would cause a change in the fauna adapted to these microhabitats.

Both fish and aquatic invertebrates have been described in several riffle communities of the Little Pigeon River system. The results show an overall decrease in numbers of species and abundance in the West Prong below Gatlinburg when compared to the West Prong above Gatlinburg or to the Middle Prong. More important than the mere decline in numbers of species or numbers, however, are the findings that certain groups of organisms were affected more strongly than others by the input of domestic sewage. Most strongly affected are those specialized organisms that utilize the riffle boundary layer and interstitial spaces for food, living space, or spawning grounds.

Gatlinburg and Pigeon Forge, as resort cities, present some interesting implications to the results of this study. As summer resorts, the vast majority of the tourist industry occurs from June through August and even more important is the fact that the heaviest tourist traffic occurs on week-ends and holidays. A conventional week-day water quality sampling regime under these circumstances will be incapable of detecting the heaviest discharge of organic effluents due to the rapid stream flushing; as data in this study indicates. Hence, such a stream will appear to have clean water at times and yet factors such as organics and solids may still be present in restricted areas in sufficient quantities to affect the aquatic invertebrates. Therefore, for water quality parameters to be useful in detecting the effects of resorts on the aquatic environment, the sampling strategy must be set up such that samples are taken when the pollution occurs. Because of the personnel problems involved with week-end and/or holiday sampling, another means of continuous monitoring is necessary. In cases of organic pollution, aquatic invertebrates may be more sensitive and accurate means of assessing the impact of the pollution than are water quality parameters.

The input of civilizations' industrial and domestic waste products on the aquatic environment changes that environment and leads to changes in the distribution and abundance of individual species and therefore to alterations in the community. In evaluating the reliability of aquatic organisms to reflect environmental conditions which have prevailed during the life history of the organisms comprising the population, the organisms must be considered not as separate species but as biological associations. The mere occurrence or absence of a single species in a locality is an unreliable indicator of polluted conditions. Conversely many aquatic organisms that are intolerant of persistent organic pollution can live for a short period of time in a polluted area when pollution effects are at a minimum. The organisms should be considered in groups or communities according to their morphological adaptions and physiological requirements.

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APPENDICES

APPENDIX A

TABLE A-1. Mean Values (Rounded the the Nearest Whole Number) of Three Surber Samples Taken Quarterly, West Prong, Little Pigeon River, Control Station (Above Gatlinburg), River km 31.3

	Summer 8/17/75	Fall 11/15/75	Winter 1/17/76	Spring 3/13/76
Platyhelminthes				
Turbellaria				
Planaria sp.		*1		
Nemertea				
Prostoma rubrum				*1
Nematomorpha		*1	*1	*1
Annelida				
Oligochaeta	*1	5	8	7
Arthropoda				
Crustacea				
Decapoda				
Cyclops sp			*1	
Arachnoidea				
Hydracarina		*1	*1	
Insecta				
Ephemeroptera				
Heptageniidae				
Epeorus sp.	2	*2	2	2
Stenonema sp.[2]	*1	1	6	
Stenonema sp. cf. *rubrum*	*1	*1	4	4
Rhithrogena sp.		*1		
Baetidae				
Baetis sp.[2]	*1		2	
Ephemerella sp. cf. *invaria*		*1	2	
Paraleptophlebia sp.		*1		
Megaloptera				
Nigronia serricornis			*1	
Plecoptera				
Pteronarcidae				
Pteronarcys sp. cf. *dorsata*		*1	*1	
Taeniopterygidae				
Brachyptera fasciata				*1
Leuctridae				
Leuctra ferruginea	1			
Perlidae				
Acroneuria ruralis				*1
Paragentina immarginata			*1	
Perlodidae				
Isoperla bilineata	2	7	6	
Isoperla richardsoni				*1
Isogenus decisus				*1
Chloroperlidae				

Table A-1 (continued)

	Summer 8/17/75	Fall 11/15/75	Winter 1/17/76	Spring 3/13/76
Alloperla sp.		1		
Chloroperla sp. cf. *cydippe*	2	*1	4	3
Trichoptera				
Hydropsychidae				
Cheumatopsyche sp.	3	3	36	5
Hydropsyche bronta			*1	*1
Hydropsyche slossonae			*1	*1
Hydropsyche sparna	1	*1	2	*1
Rhyacophilidae				
Rhyacophilia fuscula		*1	*1	
Glossosoma nigrior L	*1	1		
Psychomyiidae				
Polycentropus sp. cf. *cinereus*		*1	2	1
Philopotamidae				
Sortosa distinctus			*1	
Limnephilidae				
Pycnopsyche guttifer		*1		
Brachycentridae				
Microsema sp.	*1		*1	
Coleoptera				
Psephenidae				
Psephenus sp.	1		1	
Elmidae				
Stenelmis sp.	*1	*1	*1	
Optioservus sp.				2
Diptera				
Chironomidae A				2
P			*1	3
L	8	62	102	49
Tipulidae				
Antocha sp.	*1	*1	3	4
Eriocera sp.		*1	*1	
Pedicia sp.			*1	*1
Rhagionidae				
Atherix variegata		*1	1	1
Empididae			*1	
Heleidae				
Palpomyia sp.			1	*1
Mollusca				
Gastropoda				
Ancylidae				
Ferrissia sp.			2	

TABLE A-1 (continued)

	Summer 8/17/75	Fall 11/15/75	Winter 1/17/76	Spring 3/13/76
Total number of insects	74	262	594	250
Mean number per sample date	24.6	87.3	198.0	83.3
Total taxa per sample date	18	25	33	18

[2]Early instars.

*1 = mean values are less than 1.

TABLE A-2. Mean Values (Rounded to Nearest Whole Number) of Three Surber Samples Taken Monthly May 1975 to May 1976, West Prong, Little Pigeon River, Station, 1, River km 32

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes												
Turbellaria												
Planaria sp.											*1	
Nemertea												
Prostoma rubrum										*1		
Nematomorpha												
Gordioidea												
Gordius sp.										*1		*1
Annelida												
Oligochaeta	8	13	7	6	10	46	174	7	64	11	2	19
Arthropoda												
Insecta												
Plecoptera												
Leuctridae										*1		
Leuctra ferruginea[1]												
Chloroperlidae												
Chloroperla sp. cf. *cydippe*											*1	
Ephemeroptera												
Heptageniidae												
Epeorus so,		*1							*1			
Stenonema sp.[2]								*1				
Stenonema sp. cf. *rubrum*	*1	*1				*1		*1				
Stenonema sp.		*1		*1								
Heptagenia sp. cf. *maculipennis*		*2										
Baetidae												
Paraleptophlebia sp.		*1										
Ephemerella sp.									*1	*1		
Ephemerella sp. cf. *invaria*	*1											
Ephemerella sp. cf. *deficiens*									*1			
Isonychia sp.								*1				

TABLE A-2 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Caenis sp. cf. *simulans*			9										
Baetis sp. cf. *intercalcaris*			1										
Hemiptera													
Gyrinidae													
Dineutus sp.												*1	
Trichoptera													
Hydropsychidae													
Cheumatopsyche sp.			*1	*1			*1	*1	1	1		*1	*1
Hydropsyche morosa				*1									
Hydropsyche sparna									*1				
Lepidostomatidae													
Lepidostoma sp.											*1		
Coleoptera													
Psephenidae													
Psephenus sp.			*1										
Elmidae													
Promoresia sp.								*1					
Dubiraphia sp.									*1				
Heleidae													
Dashylea sp.	P										*1		
	L									*1			
Dryopidae													
Helichus sp.	A									*1			
Diptera													
Chironomidae	A		2			*1				*1			
	P		8			2		*1			2		*1
	L	2	17	*1	4	8	*1	*1	*1	7	12	12	25
Tanydaridae													
Protoplasa fitchii									2				
Tipulidae													

TABLE A-2 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Antocha sp.	L	*1	3						*1				
Antocha sp. cf. *saxicola*	P												*1
Psychodidae													
Psychoda sp.	P						5						
	L						14	3					
Simulidae													
Simulium sp.							*1			*1			*1
Mollusca													
Gastropoda													
Ferrissia sp.								*1		3		1	*1
Physa sp.				*1		*1	2	*1	5			*1	
Total number per sample date		34	183	25	32	63	201	539	53	226	85	41	139
Mean number per sample date		11	61	8	11	21	70	180	18	76	28	14	46
Total taxa per sample date		5	14	5	3	3	7	7	10	9	9	8	7

[1] Known from adults and mature larvae or nymphs.

[2] Early instars.

[3] Mature nymphs sharing some characters of *Stenonema rubrum* and *S. nepotellum*.

*1 = mean values less than 1.

TABLE A-3. Mean Values (Rounded to the Nearest Whole Number) of Three Surbers Taken Monthly from May 1975 to May 1976, West Prong, Little Pigeon River, Station 2, Riber km 20.5

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes												
Turbellaria												
Planaria sp.									*1		*1	
Nematomorpha												
Gordioidea												
Gordius sp.							2					*1
Annelida												
Oligochaeta	1	4	4	4	1	4	3	3	13	7	1	5
Arthropoda												
Insecta												
Plectoptera												
Peltoperlidae											*1	
Leuctridae												
Leuctra sp.		*1	*1									
Perlidae												
Acroneuria ruralis					*1							
Neophasganophora capitata		*1										
Ephemeroptera												
Heptageniidae												
Stenonema sp.[2]		3	21	*1		*1						
Stenonema sp. cf. *rubrum*			15						*1			*1
Stenonema sp. cf. *pudicum*			*1									
Stenonema sp.[3]			5								*1	
Stenonema sp.[4]			2									
Heptagenia sp.	*1											
Baetidae												
Ephemerella sp.[2]									*1			
Isonychia sp.												*1
Caenis sp. cf. *simulans*		1										
Baetis sp.												*1

TABLE A-3 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Hemiptera													
Gyrinidae													
Dineutus sp.												*1	
Megaloptera													
Corydalidae													
Nigronia serricornis			*1										
Trichoptera													
Rhyacophilidae													
Glossosoma nigrior	P											*1	
Hydropsychidae													
Cheumatopsyche sp.		*1	5	7	*1	1	4	3	3	5	4	4	2
Hydropsyche morosa			1										
Hydropsyche slossonae										*1			
Hydropsyche sparna		1	*1	2							*1	*1	
Coleoptera													
Psephenidae													
Psephenus sp.						*2		*1	*1				
Elmidae													
Stenelmis sp.	A		*1				*1						
	L					*1	*1						*1
Heleidae													
Diptera													
Chironomidae	P		1			*1		*1				2	
	L		6	*1		11	*1	4		4	5	13	10
Pentaneura sp.		*1											
Tanydaridae													
Protoplasa fitchii												*1	
Tipulidae													
Antocha sp.	L		5										
Antocha sp. cf. *saxicola*	P		1										

TABLE A-3 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Empididae			1										
Psychodidae													
Psychoda sp.	P						*1						
	L						2						
Tabanidae													
Chrysops sp.	P												
	L		1										
Mollusca													
Gastropoda													
Ferrissia sp.							*1						
Physa sp.								*1				*1	
Total number per sample date		13	98	186	14	36	36	36	19	74	53	65	57
Mean number per sample date		4	33	62	5	12	12	12	6	24	18	22	19
Total taxa per sample date		5	15	9	3	6	7	6	3	7	4	12	8

[1] Known from adults and mature larvae and nymphs.

[2] Early instars.

[3] Mature nymphs sharing some characters of *Stenonema rubrum* and *S. nepotellum*.

[4] Mature nymphs sharing some characters of *Stenonema pudicum* and *S. carolina*.

*1 = mean values less than 1.

TABLE A-4. Mean Values (Rounded to the Nearest Whole Number) of Three Surbers Taken Monthly from May 1975 to May 1976, West Prong, Little Pigeon River, Station 3, River km 15.3

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes													
Turbellaria													
Planaria sp.										*1		*1	
Nematomorpha													
Gordioidea													
Gordius sp.						*1	1	*1				*1	
Annelida													
Oligochaeta		2	2	1	3	1	3	5	1	3		1	1
Arthropoda													
Insecta													
Plecoptera													
Perlidae													*1
Ephemeroptera													
Heptageniidae													
Stenonema sp.[2]		*1	3	4	*1	*1		2	*1				
Stenonema sp. cf. *rubrum*			*1					1		1		*1	*1
Stenonema sp.[3]		*1	4		*1	*1	*1						
Heptagenia sp.[2]													*1
Baetidae													
Ephemerella sp. cf. *invaria*		2											
Ephemerella sp. cf. *tuberculata*												*1	
Caenis sp. cf. *simulans*			2	*1									
Baetis sp.[2]			3			*1							*1
Trichoptera													
Rhyacophilidae													
Glossosoma nigrior	P										1		*1
	L								*1	*1	*1	2	*1
Hydropsychidae													
Cheumatopsyche sp.	P	*1			2								*1
	L	*1	18	2	15	13	3	14	5	2	3	2	3
Hydropsyche morosa			2	2	*1								

TABLE A-4 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Hydropsyche slossonae	P											*1	
	L									*1			*1
Hydropsyche sparna			3	*1				*1					
Philopotamidae													
Chimarra aterrima										*1			
Psychomyiidae													
Polycentropus sp. cf. *cinereus*							*1						
Coleoptera													
Psephenidae													
Psephenus sp.			*1						*1				
Elmidae													
Stenelmis sp.							*1					*1	
Diptera													
Chironomidae	A					*1		*1					
	P								*1	*1			1
	L	6	7		4	4	3	3	*1	20	9	56	29
Tipulidae													
Antocha sp.	L	2	2										
Antocha sp. cf. *saxicola*		*1	1										
Psychodidae													
Psychoda sp.	P												
	L							*1					
Simuliidae					*1							*1	4
Dixidae													
Paradixa sp.	A												*1
Mollusca													
Gastropoda													
Ferrissia sp.									*1				*1

TABLE A-4 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Total numbers per sample date	49	139	32	91	60	34	85	25	83	47	131	129
Mean numbers per sample date	16	46	8	30	20	12	28	8	28	16	63	43
Total taxa per sample date	7	11	6	7	7	8	7	6	8	4	11	12

[1]Known from adults and mature larvae or nymphs.

[2]Early instars.

[3]Mature nymphs sharing some characters of *Stenonema rubrum* and *S. nepotellum*.

*1 = mean values less than 1.

TABLE A-5. Mean Values (Rounded to the Nearest Whole Number) of Three Surber Samples Taken Monthly from May 1975 to May 1976, West Prong, Little Pigeon, Station 4, River km 11.5

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Nemertea												
Prostoma rubrum							*1					
Nematomorpha												
Gordioidea												
Gordius sp.					*1		1					
Annelida												
Oligochaeta	4	3	3	1	6	*1	13	17	63	13	2	38
Arthropoda												
Crustacea												
Isopoda												
Lirceus sp. cf. *brachyurus*[2]						*1						*1
Insecta												
Plecoptera												
Taeniopterygidae												
Brachyptera fasciata									*1			
Leuctridae												
Leuctra ferruginea[1]		*1										
Ephemeroptera												
Heptageniidae												
Stenonema sp.[2]			1		2	*1			2	1	2	
Stenonema sp. cf. *rubrum*		2					3	1	*1	3	4	5
Stenonema sp. cf. *pudicum*							*1					
Stenonema sp.[3]		2	3	*1	2	*1				*1	2	
Stenonema sp.[4]					*1							
Baetidae												
Ephemerella sp. cf. *invaria*	*1											
Ephemerella sp. cf. *temporalis*											*1	
Isonychia sp.				*1								
Caenis sp. cf. *simulans*		1	2									

TABLE A-5 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Odonata													
Coenagrionidae													
Argia sp.						*1							
Enallagna divagans										*1			
Megaloptera													
Corydalidae													
Corydalus cornutus					*1								
Trichoptera													
Rhyacophilidae													
Glossosoma nigrior												*1	
Hydropsychidae													
Cheumatopsyche sp.	P			*1	1					*1	*1		
	L		10	4	18	26	16	10	2	13	9	24	
Hydropsyche morosa			1	*1	*1								
Hydropsyche sparna	P			*1							*1		
Coleoptera	L		2	*1	1	1							
Psephenidae													
Psephenus sp.											*1		
Ectoparia sp.					*1								
Elmidae													
Dubiraphia sp.								*1					
Stenelmis sp.			*1				*1		*1				*1
Diptera													
Chironomidae	A			*1				*1		*1			
	P		*1		3	1			*1	*1	2		4
	L	2	7	*1	13	12	6	2	2	27	19	25	94
Tipulidae													
Antocha sp.		*1	2	*1									
Empididae													
Hemerodromia sp.	P		*1										
	L		*1										

TABLE A-5 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Simulidae	L		*1					*1	*1				9
Simulium sp.	P												*1
Tabanidae													
Chrysops sp.			*2										
Dixidae													
Paradixa sp.													*1
Mollusca													
Gastropoda													
Ferrissia sp.						1		1	2	2	4	*1	*1
Physa sp.								*1					
Pleurocera sp.											1		
Pelecypoda													
Sphaeriidae													
Psidium sp.			*1	*1								*1	
Cyreniidae													
Corbicula sp.												*1	
Total number per sample date		18	103	47	121	165	71	97	75	329	161	141	533
Mean number per sample date		6	34	16	40	55	23	32	25	109.6	54	47	178
Total taxa per sample date		4	15	9	9	9	6	10	7	9	9	9	8

[1] Known from adults and mature larvae or nymphs.

[2] Early instars.

[3] Mature nymphs sharing some characters of *Stenonema rubrum* and *S. nepotellum*.

[4] Mature nymphs sharing some characters of *Stenonema pudicum* and *S. carolina*.

*1 = mean values less than 1.

TABLE A-6. Mean Values (Rounded to the Nearest Whole Number) of Three Surber Samples Taken Monthly from May 1975 to May 1976, Middle Prong, Little Pigeon River, Station 1, River km 32

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes												
Turbellaria												
Planaria sp.				*1			*1		*1	*1		
Nemertea												
Prostoma rubrum							*1				*1	
Nematomorpha												
Gordius sp.					*1				1		*1	
Annelida												
Oligochaeta					2	2	1	*1	*1		*1	
Arthropoda												
Arachnoidea												
Hydrocarina				1	*1	*1					*1	
Insecta												
Plecoptera												
Leuctridae												
Leuctra ferruginea[1]	*1	*1	2	3			2	*1	*1	*1		*1
Perlidae												
Neophasganophora capitata		*1	*1	*1	*1	*1		*1				*1
Acroneuria sp.[2]		2										
Acroneuria abnormis	*1			*1	1	2			2	*1	*1	
Acroneuria internata						*1						
Acroneuria ruralis			*1					*1				
Paragentina immarginata	3				*1			2	*1	1		
Perlesta placida	4	4	1									
Perlodidae												
Isoperla sp.												*1
Isoperla bilineata								2	6	4	2	
Isogenus decisus										*1		
Isogenus hansoni							*1	*1	2	*1		
Chloroperlidae												

TABLE A-6 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Chloroperla sp.[2]	*1				*1	1						
Chloroperla sp. cf. *cydippe*				*1	*1		1			*1		1
Ephemeroptera												
Ephemeridae												
Ephemera simulans												
Potomanthus sp.												
Baetidae												
Baetis sp.[2]	2	4		*1		*1	*1		*1			1
Baetis sp. cf. *intercalaris*	*1			1	5	*1			1	2		
Isonychia sp.	1	2	*1	*1	2	2	2	*1	*1	3		*1
Ephemerella sp.[2]								*1	*1		*1	
Ephemerella sp. cf. *cornutus*	4	*1										
Ephemerella sp. cf. *deficiens*	*1								2			
Ephemerella sp. cf. *dorothea*	2	2	*1	*1	*1	*1		*1			*1	
Ephemerella sp. cf. *simplex*									2	2		
Caenis sp.		2		2	1		*1					
Leptophlebia sp.			2									
Paraleptophlebia sp.[2]							*1	*1	*1			
Paraleptophlebia sp. cf. *praepedita*					*1			*1		*1		
Pseudocleon sp.							*1					
Heptageniidae												
Rhithrogena sp.[2]	2	2						1	2			
Rhithrogena sp. cf. *pellucida*												4
Heptagenia sp.[2]												1
Heptagenia sp. cf. *maculipennis*		5	12	13	2	*1	*1		2			*1
Heptagenia sp. cf. *flavescens*					*1							
Epeorus sp.	1	1	1			*1	1	2	5	5	1	
Stenonema sp.[2]			8						*1		5	
Stenonema sp. cf. *rubrum*	*1	3	24	9	1	6	7	4	1	1		3
Stenonema sp. cf. *pudicum*	*1		3		2	1		3	1	3	*1	*1

TABLE A-6 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Stenonema sp.[1,3]		*1		8						2	*1	4	
Stenonema sp.[2,4]					*1	2				3		4	
Hemiptera						*1							
Gyrinidae[2]													
Megaloptera													
Corydalidae													
Corydalus cornutus		*1				*1		*1			*1		
Nigronia serricornis				*1	*1	*1		*1			*1		
Trichoptera													
Rhyacophilidae													
Rhyacophila fuscula									*1		*1		
Rhyacophila glaberrima		*1									*1		
Glossosoma nigrior	P								*1	6	2		
	L	*1					*1	2	10	5	4	*1	
Philopotamidae													
Chimarra aterrima			*1					*1			2		
Dolophilus moestus										*1			
Sortosa distinctus		2											*1
Psychomyiidae													
Polycentropus sp. cf. *cinereus*		2		*1	1	1	1			*1		*1	*1
Polycentropus sp.[5]								*1					
Hydropsychidae													
Cheumatopsyche sp.		7	2	3	*1	26	11	19	12	10	31	23	2
Hydropsyche bronta		2	3	*1	*1	5	10	8	4	4	9	4	3
Hydropsyche morosa			*1			3	*1	1			1	*1	
Hydropsyche sparna			3	*1		2	*1	1			*1		
Hydropsyche venularis		*1							*1				
Goeridae													
Goera calcarata	L							*1					
	P	*1		*1	2						*1		
Lepidostomatidae													

TABLE A-6 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Lepidostoma sp.								*1			*1		
Brachycentridae													
Microsema sp.										*1			
Coleoptera													
Elmidae													
Stenelmis sp.	A		*1				*1						
	L	1	1	*1	*1	1		1			*1		
Zaitzevia		*1											
Psephenidae													
Psephenus sp.		4	1	2	3	7	5	2	5	*1		4	*1
Diptera													
Blepharoceridae		*1									1		
Tipulidae													
Antocha saxicola	P	2										*1	
Antocha sp.		2	1	2	11	2	3	4	*1	*1	7	5	*1
Eriocera sp.						*1			*1				
Hexatoma sp.									*1				
Pedicia sp.							*1						
Tipula sp.						*1			*1			3	
Heleidae													
Palpomyia sp.		2			*1	1		*1			1	*1	
Rhaginiodae													
Atherix variegata			2	*1	*1					*1	1		
Simulidae	L	2		*1		*1		*1		5	*1		
Simulium sp.	P				*1	*1							
Tabanidae													
Tabanus sp.			*1										
Empididae	P			*1									
	L	*1			1	1	1	2			1	*1	*1
Chironomidae	A												*1
	P	4	2		2	2		*1	*1		1	*1	*1
	L	144	4	2	21	25	2	30	14	79	95	21	20

TABLE A-6 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Mollusca												
Gastropoda												
Ancylidae												
Ferrissia sp.		*1		*1	1		*1	1	*1	5	3	
Physidae												
Physa sp.												
Pleuroceridae												
Goniobasis sp.			*1									
Total numbers per surber	588	172	233	275	315	157	303	199	433	528	165	128
Mean number per sample date	196	57	78	92	105	52	101	66	144	176	88	46
Total taxa per sample date	35	24	26	26	35	25	33	25	32	36	24	19

[1] Known from adults and mature larvae.

[2] Early instars.

[3] Mature nymphs sharing some characters of *Stenonema rubrum* and *S. nepotellum*.

[4] Mature nymphs sharing some characters of *Stenonema pudicum* and *S. carolina*.

[5] Mature larvae presenting a second species.

*1 = mean values less than 1.

TABLE A-7. Mean Values (Rounded to the Nearest Whole Number) of Three Surber Samples Taken Monthly from May 1975 to May 1976, Middle Prong, Little Pigeon River, Station 2, River km 25.6

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes												
Turbellaria												
Planaria sp.								*1				
Nemertea												
Prostoma rubrum							*1				*1	
Nematoda												
Nematomorpha												
Gordius sp.				*1	*1	1	2		*1		*1	*1
Annelida												
Oligochaeta		*1			1	*1	2		*1			*1
Arthropoda												
Arachnoidea												
Hydracarina				*1	*1						*1	
Insecta												
Plecoptera												
Taeniopteryginidae												
Brachyptera sp.[2]		1										
Leuctridae												
Leuctra ferruginea[1]	*1	*1	*1	*1	*1		1	*1	*1		*1	*1
Perlidae												
Neoperla clymene						*1						
Neophasganophora capitata			*1		*1							
Acroneuria sp.[2]	*1					1						
Acroneuria abnormis		3	2	2	2	1	*1	2	*1	1	*1	
Acroneuria internata		*1				*1	*1					
Acroneuria ruralis			2									
Paragentina immarginata							*1				*1	
Perlesta placida		4	*1									10
Perlodidae												
Isoperla bilineata	*1										*1	

TABLE A-7 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Isogenus hansoni								*1			*1	
Chloroperlidae												
Chloroperla sp.[2]											*1	
Chloroperla sp. cf. *cydippe*					*1	1	*1		1		*1	
Ephemeroptera												
Ephemeridae												
Potomanthus sp.						*1						
Baetidae	*1											
Baetis sp.[2]	3	*1	1								4	
Baetis sp. cf. *intercalaris*					5	7	*1					
Isonychia sp.		4	*1		1	3	1	*1	2		*1	2
Ephemerella sp.				*1							6	2
Ephemerella sp. cf. *cornutus*	2					*1						*1
Ephemerella sp. cf. *deficiens*												1
Ephemerella sp. cf. *dorothea*		4	*1	*1		*1				*1	3	1
Ephemerella sp. cf. *invaria*		*1						*1			3	
Ephemerella sp. cf. *simplex*											*1	
Ephemerella sp. cf. *temporalis*								*1				
Caens sp.		*1	*1	5	2		1					
Leptophlebia sp.				*1								
Centroptilium sp. cf. *rivularis*			*1									
Heptageniidae												
Rhithrogenia sp.[2]	3	*1									*1	*1
Rhithrogenia sp. cf. *pellucide*	8											
Heptagenia sp. cf. *maculipennis*		6	6	19	2	1	1					
Epeorus sp.								*1	2	2	1	1
Stenonema sp.		2		6			*1					2
Stenonema sp. cf. *rubrum*	*1	4	9	8	4	9	9	3	*1	1		1
Stenonema sp. cf. *pudicum*			2					3	2	2	1	2

TABLE A-7 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Stenonema sp. 1 3				1					2	2	*1		3
Stenonema sp. 2 4			2							1	*1		*1
Odonata													
Gomphidae													
Lanthus parvulus									*1			*1	
Megaloptera													
Corydalidae													
Corydalus cornutus						*1		*1	*1	*1	*1	*1	1
Trichoptera													
Rhyacophilidae													
Glossosoma nigrior	P								1	1	4		2
	L	*1						3	10	4	19	2	*1
Philopotamide													
Chimarra aterrima			*1					*1			1	*1	
Dolophilus moestus								*1		*1			
Sortosa distinctus		*1										*1	*1
Psychomyiidae													
Polycentropus sp. cf. *cinereus*		1			*1	2	*1	1			*1	3	1
Polycentropus sp.												*1	
Hydropsychidae													
Cheumatopsyche sp.		8	3	9		12	5	11	7	3	3	2	
Hydropsyche bronta		*1				*1							
Hydropsyche morosa			*1			2	*1		*1				
Hydropsyche sparna	P	1										23	
	L	*1				*1			*1		*1	*1	
Hydropsyche venularis								1			1	*1	
Goeridae													
Goera calcarata	L										1		
	P			*1									1
Lepidostomatidae													

TABLE A-7 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Lepidostoma sp.		*1		*1					*1				
Coleoptera													
Elmidae													
Optioservus sp.				*1									*1
Promoresia sp.			1					*1					
Stenelmis sp.	A		1			1	*1				*1		
	L		3		*1								*1
Psephenidae													
Psephenus sp.		*1	1	1	1	2	1	1	1	*1	1	1	1
Diptera													
Blepharoceridae		1											
Tipulidae													
Antocha saxicola	P												1
Antocha sp.	L		5		*1	2	1	3	*1	1	2	3	2
Tipula sp.				*1								*1	
Heleidae													
Palpomyia sp.													1
Rhagionidae													
Atherix variegata				*1	*1					*1	*1	1	
Simulidae						*1				*1		2	
Simulium sp.	P												
Emididae	P	*1	1		*1								
	L	1			1	3	3	2	1			3	1
Chironomidae	A		*1										
	P	3	1	*1	*1	2	2	*1	6	1		*1	*1
	L	9	3	2	16	31	33	27	92	236	50	27	70
Mollusca													
Gastropoda													
Ancyclidae													
Ferrissia sp.				1	*1	*1			1		*1		

TABLE A-7 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Physidae												
Physa sp.												*1
Pleuroceridae												*1
Goniobasis												
Total numbers per surber	128	162	124	165	244	241	202	302	788	278	273	375
Mean number per sample date	43	54	41	55	81	80	67	100	262	92	91	125
Total taxa per sample date	18	25	23	17	25	21	26	24	2o	24	33	30

[1] Known from adults and mature larvae.

[2] Early instars.

[3] Mature nymphs sharing characters of *Stenonema rubrum* and *S. nepotellum*.

[4] Mature nymphs sharing characters of *Stenonoma pudicum* and *S. carolina*.

[5] Mature nymphs representing a second species.

*1 = mean values less than 1.

TABLE A-8. Mean Values (Rounded to the Nearest Whole Number) of Three Surber Samples Taken Monthly from May 1975 to May 1976, Middle Prong, Little Pigeon River, Station 3, River km 18.5

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Platyhelminthes												
Turbellaria												
Planaria sp.					*1				*1			
Nemertea												
Prostoma rubrum						*1	1					
Nematomorpha												
Gordius sp.						*1	1	2	*1			
Annelida												
Oligochaeta				2	*1	3				*1	*1	1
Arthropoda												
Crustacea												
Isopoda												
Lirceus sp. cf. *brachyurus*[2]							*1					
Arachnoidea												
Hydracarina				*1		*1	1		*1		*1	
Insecta												
Plecoptera												
Taeniopteryginidae												
Taeniopteryx burksi							*1	*1				
Leuctridae												
Leuctra ferruginea[1]		*1	*1	*1	*1	*1						1
Perlidae												
Neoperla clymene			*1									
Neophasganophora capitata					1					*1		
Acroneuria sp.										*1		4
Acroneuria abnormis		2	11	2	3	1	3	3	*1	4	1	2
Acroneuria internata						*1						
Acroneuria ruralis											*1	
Perlesta placida	8											*1
Perlodidae												
Isoperla bilineata								*1				

TABLE A-8 (continued)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Isogenus decisus								2				
Chloroperlidae												
Chloroperla sp. cf. *cydippe*[2]							*1		1			
Ephemeroptera												
Ephemeridae												
Ephemera simulans			*1									
Potomanthus sp.				2	*1	*1						
Baetidae												
Baetis sp.[2]	3	2	*1		1	*1						*1
Baetis sp. cf. *intercalaris*			*1	2	*1	*1	1					
Isonychia sp.	*1				*1	1	*1	1		2	*1	6
Ephemerella sp.										*1	2	7
Ephemerella sp. cf. *bicolor*												*1
Ephemerella sp. cf. *cornutus*	*1											
Ephemerella sp. cf. *deficiens*							6	19	2		3	
Ephemerella sp. cf. *dorothea*	3	1		*1	*1	*1				1	*1	1
Ephemerella sp. cf. *invaria*								3	2		1	
Ephemerella sp. cf. *simplex*										1		
Ephemerella sp. cf. *temporalis*									*1			
Caenis sp.		2	1	6	2	*1						*1
Paraleptophlebia sp.[2]								*1				
Centroptilium sp. cf. *rivularis*			*1									
Pseudocleon sp.				*1								
Habrophlebia sp. cf. *vibrans*						*1						
Heptageniidae												
Rhithrogena sp.[2]		*1										*1
Rhithrogena sp. cf. *pellucida*	3											
Heptagenia sp.[2]	*1	2					*1					2
Heptagenia sp. cf. *maculipennis*	1	5	5	8		2						
Epeorus sp.		*1	*1						*1			

TABLE A-8 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Stenonema sp.			2								1		1
Stenonema sp. cf. *rubrum*		1	7	12	12	9	9	3	2	*1	*1	2	*1
Stenonema sp. cf. *pudicum*				*1	*1	2	5		1	1	1	*1	
Stenonema sp. 1 [3]					1						2	2	
Stenonema sp. 2 [4]									1	*1			3
Odonata													
Gomphidae													
Lanthus parvulus									*1				
Coenagrionidae													
Argia sp.					*1		*1						
Megaloptera													
Corydalidae													
Corydalus cornutus				1	1	*1	*1				1	*1	1
Nigronia serricornis			*1										
Trichoptera													
Rhyacophilidae													
Glossosoma nigrior	P									*1	3	*1	
	L						1	1	*1	10	3	*1	*1
Philopotamidae													
Chimarra aterrima							*1						*1
Sortosa distinctus		*1							*1				
Psychomyiidae													
Polycentropus sp. cf. *cinereus*		*1			*1	*1	*1			*1			
Polycentropus sp. [5]						*1							
Hydropsychidae													
Cheumatopsyche sp.		4	3	7	1	3	11	8	16	7	15	17	15
Hydropsyche bronta			*1				*1						
Hydropsyche morosa			1	*1	1	*1	*1	*1	*1	1	2	2	*1
Hydropsyche sparna	P	*1											
	L	1	*2					*1	*1			*1	
Hydropsyche venularis								2				*1	

TABLE A-8 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Limnephilidae													
Pycnopsyche sp.								*1					
Goeridae													
Goera calcarata	L			*1									
	P										1		
Lepidostomatidae													
Lepidostoma sp.									*1				
Brachycentridae													
Microsema sp.								*1	*1	2		*1	
Coleoptera													
Elmidae													
Dubrapha sp.									*1				
Optioservus sp.												3	
Promoresia sp.								1					
Stenelmis sp.	A		*1				1					*1	
	L								1				1
Zaitzevia sp.								1	*1				
Hydraenidae													
Ochthebius sp.									*1				
Psephenidae													
Psephenus sp.		*1	*1	2	*1	1		*1	*1	*1			
Dryopidae													
Helichus sp.								*1					
Diptera													
Blepharoceridae		*1							*1	*1		*1	
Tipulidae													
Antocha saxicola	P		*1										4
Antocha sp.	L	2	2	1	3		3	6	4	4	4	2	3
Tipula sp.	A											*1	
	L											1	

TABLE A-8 (continued)

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
Heleidae													
Palpomyia sp.													*1
Rhagionidae													
Atherix variegata			*1	*1					*1	*1			
Simulidae	L			*1				*1			*1		
Simulium sp.	P	*1					*1		*1	4		1	16
Empididae	P	*1											*1
	L					*1	1	1	*1	1	*1	1	*1
Chironomidae	P	*1			3		1	*1	3	*1	30	*1	1
	L	9	3	2	28	12	47	122	24	87	62	40	63
Mollusca													
Gastropoda													
Ancylidae													
Ferrissia sp.								*1					
Total numbers per surber		110	140	146	227	121	277	499	328	388	330	259	481
Mean number per sample date		37	47	49	76	40	92	166	109	129	110	86	157
Total taxa per sample date		18	21	20	21	20	29	26	31	24	24	27	26

[1] Known from adults and mature larvae.

[2] Early instars.

[3] Mature nymphs sharing characters of *Stenonema rubrum* and *S. nepotellum*.

[4] Mature nymphs sharing characters of *Stenonema pudicum* and *S. carolina*.

[5] Mature nymphs representing a second species.

*1 = mean values less than 1.

APPENDIX B

TABLE B-1. Species List of Fish Collected During Little Pigeon Study: Common and Scientific Names

Common Name	Scientific Name
Rainbow Trout	*Salmo gairdneri* Richardson
Stoneroller	*Compostoma anomalum* (Rafinesque)
Bigeye Chub	*Hybopsis amblops* (Rafinesque)
Blotched Chub	*Hybopsis insignis* Hubbs and Crowe
River Chub	*Nocomis micropogon* (Cope)
Warpaint Shiner	*Notropis coccogenis* (Cope)
Common Shiner	*Notropis cornutus* (Mitchell)
Whitetail Shiner	*Notropis galacturus* (Cope)
Tennessee Shiner	*Notropis leuciodus* (Cope)
Silver Shiner	*Notropis photogenis* (Cope)
Rosey Face Shiner	*Notropis rubellus* (Agassiz)
Saffron Shiner	*Notropis rubricroceus* (Cope)
Spotfin Shiner	*Notropis spilopterus* (Cope)
Sand Shiner	*Notropis stramineus* (Cope)
Telescope Shiner	*Notropis telescopus* (Cope)
Stargazing Minnow	*Phenacobius uranops* (Cope)
Blacknose Dace	*Rhinichthys atratulus* (Hermann)
Longnose Dace	*Rhinichthys cataractae* (Valenciennes)
Creek Chub	*Semotilus atromaculatus* (Mitchell)
Northern Hogsucker	*Hypentelium nigricans* (LeSueur)
Black Redhorse	*Moxostoma duquesnii* (LeSueur)
Golden Redhorse	*Moxostoma erythrurum* (Rafinesque)
Yellow Bullhead	*Ictalurus natalis* (LeSueur)
Rockbass	*Ambloplites rurestris* (Rafinesque)
Redbreast Sunfish	*Lepomis auritus* (Linnaeus)
Smallmouth Bass	*Micropterus dolomieui* Lacepede
Greenside Darter	*Etheostoma blennioides* Rafinesque
Greenfin Darter	*Etheostoma chlorobranchium* Zorach
Fantail Darter	*Etheostoma flabellare* Rafinesque
Stripetail Darter	*Etheostoma kennicotti* (Putnam)
Redline Darter	*Etheostoma rufilineatum* (Cope)
Tennessee Darter	*Etheostoma simotorum* (Cope)
Swannanoa Darter	*Etheostoma swannanoa* Jordan and Everman
Banded Darter	*Etheostoma zonale* (Cope)
Tangarine Darter	*Percina aurantica* (Cope)
Logperch	*Percina caprodes* Rafinesque
Gilt Darter	*Percina evides* (Jordan and Copeland)
Banded Sculpin	*Cottus carolinae* (Gill)

TABLE B-2. Fish Collected Per Station by Cyanide Application, West Prong, Little Pigeon River, 1975-76

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
			Station 1				
Salmo gairdneri							
Campostoma anamalum	46	169		36	37	1	24
Hybopsis amblops			1				
Hybopsis insignis							
Nocomis micropogon			6				2
Notropis coccogenis							3
Notropis cornutus							
Notropis galacturus			1				
Notropis leuciodus	9	6					1
Notropis rubellus							
Notropis rubricroceus			21	1	5		4
Notropis stramineus							
Notropis spilopterus							
Notropis telescopus							
Phenacobius uranops							
Rhinichthys atratulus	4		2				
Rhinichthys cataractae			43	20	18	6	29
Semotilus atromaculatus							
Hypentelium nigricans	8	21	24	1	1	2	3
Moxostoma duquesnii							
Moxostoma erythrurum							
Ictalurus natalis							
Ambloplites ruperstris							
Micropterus dolomieui							
Etheostoma blennioides							
Etheostoma chlorobranchium	3	8	6				
Etheostoma kennicotti							
Etheostoma rufilineatum							
Etheostoma simoterum	2						
Etheostoma swannanoa	7	31	1				
Etheostoma zonale							
Percina aurantica							
Percina caprodes							
Percina evides							
Cottus carolinae		3					
Number of individuals	79	238	125	58	61	9	66
Number of species	7	6	9	4	4	3	7

TABLE B-2 (continued)

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
			Station 2				
Campostoma anomalum	43	3	121	8	2	4	6
Hybopsis amblops			2				
Hybopsis insignis							
Nocomis micropogon	2	2	13				3
Notropis coccogenis		4	1				7
Nortopis cornutus							
Notropis galacturus							
Notropis leuiodus	5	15	10				13
Notropis rubellus							
Notropis rubricroceus			8				
Notropis stramineus							
Notropis spilopterus							
Notropis telescopus		1				1	
Phenacobius uranops							
Rhinichthys atratulus			1				
Rhinicythys cataractae			3	3	1	1	1
Semotilus atromaculatus •							
Hypentelium nigricans	17		29		3	10	3
Moxostoma duquesnii							
Moxostoma erythrurum							
Ictalurus natalis							
Amblopites ruperstris			1				
Micropterus dolomieui							
Etheostoma blennioides	1		14				
Etheostoma chlorobranchium	2		5				
Etheostoma kennicotti							
Etheostoma rufilineatum		1					
Etheostoma simoterum	8		5		2		
Etheostoma swannanoa	1	4	12	2	7	1	14
Etheostoma zonale							
Percina aurantica							
Percina caprodes							
Percina evides							
Cottus carolinae	1						
Number of individuals	80	30	225	13	15	17	47
Number of species	9	7	14	3	5	5	7

TABLE B-2 (continued)

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
				Station 3			
Campostoma anomalum	1		1	2	45	36	
Hybopsis amblops							1
Hybopsis insignis	2	1	8	2			3
Nocomis micropogon							
Notropis coccogenis							1
Notropis cornutus							1
Notropis galacturus	1		3				
Notropis leuciodus			1				
Notropis rubellus		1					
Notropis rubricroceus							
Notropis stramineus	1						
Notropis spilopterus		1					
Notropis telescopus							1
Phenacobius uranops		1	6	4	1		
Rhinichthys atratulus							
Rhinichthys cataractae			1				
Semotilus atromaculatus	1						
Hypentelium nigricans	2		1	1		3	3
Moxostoma duquesnii							
Moxostoma erythrurum							
Ictalurus natalis							
Ambloplites rupestris							
Micropterus dolomieui				1			
Etheostoma blennioides		1					
Etheostoma chlorobranchium							
Etheostoma kennicotti							
Etheostoma rufilineatum	28	12	9	7	5	1	6
Etheostoma simoterum	3	1		1			
Etheostoma swannanoa	1			2			
Etheostoma zonale							
Percina aurantica							
Percina caprodes							
Percina evides	2	6				3	
Cottus carolinae							
Number of individuals	41	24	30	20	51	40	19
Number of species	9	8	8	8	3	3	8

TABLE B-2 (continued)

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
				Station 4			
Campostoma anomalum	5	26	6	9	7	29	
Hybopsis amblops							
Hybopsis insignis	3	14	6	5	6		
Nocomis micropogon							
Notropis coccogenis							
Notropis cornutus							
Notropis galacturus		5					
Notropis leuciodus							
Notropis rubellus		1					
Notropis rubricroceus							
Notropis stramineus							
Notropis spilopterus							
Notropis telescopus				1			
Phenacobius uranops		1	5	2	7		
Rhinichthys atratulus							
Rhinichthys cataractae							
Semotilus atromaculatus							
Hypentelium nigricans	2	4	9	1	2	10	3
Moxostoma duquesnii					1		
Moxostoma erythrurum		5					1
Ictalurus natalis							
Ambloplites ruperstris							
Micropterus dolomieui							
Etheostoma blennioides	5	24	14	8	7	15	8
Ethestoma chlorobranchium							
Etheostoma kennicotti							
Etheostoma rufilineatum	56	172	23	32	41	5	57
Etheostoma simoterum		1					1
Etheostoma swannanoa							
Etheostoma zonale	1	7					
Percina aurantica							
Percina caprodes							
Percina evides			4	1			
Cottus carolinae							
Number of individuals	72	260	67	59	71	59	69
Number of species	6	11	7	8	7	4	4

TABLE B-3. Fish Collected Per Station by Cyanide Application, Middle Prong, Little Pigeon River, 1975-76

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
				Station 1			
Salmo gairdneri				2			
Campostoma anomalum	24	3	154	5	68	2	43
Hybopsis amblops							
Hybopsis insignis		3					
Nocomis micropogon	1		3	2			2
Notropis coccogenis			3				3
Notropis cornutus							
Notropis galacturus		1					
Notropis leuciodus	8		27		8	1	19
Notropis rubellus							
Notropis rubricroceus							
Notropis stramineus							
Notropis spilopterus							
Notropis telescopus			20	1			8
Phenacobius uranops							
Rhinichthys atratulus							
Rhinichthys cataractae		1					
Semotilus atromaculatus							
Hypentelium nigricans						4	
Moxostoma duquesnii							
Moxostoma erythrurum							
Ictalurus natalis							
Ambloplites rupestris							
Micropterus dolomieui			6		2		
Etheostoma blennioides		1				1	
Etheostoma chlorobranchium	6		12	7	10		
Etheostoma kennicotti							
Etheostoma rufilineatum	56	76	12	4	4		10
Etheostoma simoterum			3		4	1	2
Etheostoma swannanoa	2	1	27		22	2	16
Etheostoma zonale							
Percina aurantica		1					
Percina caprodes							
Percina evides		2					
Cottus carolinae			3			1	1
Number of individuals	97	89	270	21	118	12	104
Number of species	6	9	11	6	7	7	9

TABLE B-3 (continued)

	Jun	Jul	Aug	Sep	Oct	Nov	May
				Station 2			
Salmo gairdneri							
Campostoma anomalum	2	4			2	6	3
Hybopsis amblops							
Hybopsis insignis	1	2	6				3
Nocomis micropogon							
Notropis coccogenis				1			
Notropis cornutus							
Notropis galacturus							
Notropis leuciodus	1	2	24			7	12
Notropis rubellus							
Notropis rubricroceus							
Notropis stramineus							
Notropis spilopterus							
Notropis telescopus				1	1		2
Phenacobius uranops				1			1
Rhinichthys atratulus							
Rhinichthys cataractae							
Semotilus atromaculatus							
Hypentelium nigricans		2	1		1		1
Moxostoma duquesnii							
Moxostoma erythrurum							
Ictalurus natalis		1					
Ambloplites ruperstris							
Micropterus dolomieui							
Etheostoma blennioides					2		
Etheostoma chlorobranchium		1					
Etheostoma kennicotti		2					
Etheostoma rufilineatum	74	66	91	36	8	5	44
Etheostoma simoterum		1				1	1
Etheostoma swannanoa		1		1	1	1	3
Etheostoma zonale							
Percina aurantica							
Percina caprodes							1
Percina evides	1	3	6	1			2
Cottus carolinae	1					3	
Number of individuals	80	85	128	41	15	27	73
Number of species	6	11	5	6	6	7	11

TABLE B-3 (continued)

Species	Jun	Jul	Aug	Sep	Oct	Nov	May
			Station 3				
Salmo gairdneri		3			2		3
Campostoma anomalum	18	5	5	7	2		
Hybopsis amblops							
Hybopsis insignis			4	2	1		
Nocomis micropogon							
Notropis coccogenis							2
Notropis cornutus							
Notropis galacturus							1
Notropis leuciodus	28		17	5			2
Notropis rubellus							4
Notropis rubricroceus							
Notropis stramineus							
Notropis spilopterus		2					
Notropis telescopus	1	1	3	1			5
Phenacopius uranops			1	1			
Rhinichthys atratulus							
Rhinichthys cataractae							
Semotilus atromaculatus							
Hypentelium nigricans			2		1		
Moxostoma duquesnii							
Moxstoma erythrurum							
Ictalurus natalis							
Ambloplites rupestris							
Micropterus dolomieui							
Etheostoma blennioides			3				2
Ethestoma chlorobranchium	10	8					
Etheostoma kennicotti							
Etheostoma rufilineatum	3	2	14	11	19		116
Etheostoma simoterum				1			4
Etheostoma swannanoa	6	3	1				6
Etheostoma zonale			1				1
Percina aurantica			3	2			2
Percina caprodes							
Percina evides			7				1
Cottus carolinae	1			1			
Number of individuals	68	22	63	31	23		149
Number of species	7	6	13	9	4		13

TABLE B-4. Selected Collections of Fish by Carl Hubbs in 1947 and 1940. Collections are from the Middle and West Prongs of the Little Pigeon River

Richardson Cove, Hubbs Coll., M37-9086 Middle Prong	Below Pigeon Forge Bridge, Hubbs Coll., M37-909, West Prong	Walden Creek below Gatlinburg, Hubbs Coll., M40-217
Campostoma anomalum	*Campostoma anomalum*	*Compostoma anomalum*
Hybopsis amblops	*Hybopsis amblops*	*Hybopsis amblops*
Nocomis micropogon	*Hybopsis insignis*	*Nocomis micropogon*
Notropis coccogenis	*Nocomis micropogon*	*Notropis coccogenis*
Notropis cornutus	*Notropis coccogenis*	*Nortopis cornutus*
Notropis galacturus	*Notropis cornutus*	*Notropis galacturus*
Notropis leuciodus	*Notropis galacturus*	*Notropis leuciodus*
Notropis photogenis	*Notropis leuciodus*	*Notropis lirus*
Notropis telescopus	*Notropis photogenis*	*Notropis rubricroceus*
Notropis volucellus	*Notropis rubellus*	*Notropis spilopterus*
Phenacobius uranops	*Notropis spilopterus*	*Notropis stramineus*
Rhinichthys atratulus	*Notropis telescopus*	*Notropis telescopus*
Hypentelium nigricans	*Notropis volucellus*	*Notropis volucellus*
Moxostoma duquesnii	*Phenacobius uranops*	*Catostomus commersoni*
Moxostoma erythrurum	*Hypentelium nigricans*	*Hypentelium nigricans*
Ambloplites rupestris	*Moxostoma duquesnii*	*Moxostoma erythrurum*
Micropterus dolomieu	*Noturus eleutherus*	*Ambloplites ruperstris*
Etheostoma blennioides	*Moxostoma erythrurum*	*Lepomis megalotis*
Etheostoma chlorobranchium	*Fundulus catenatus*	*Micropterus dolomieu*
Etheostoma rufilineatum	*Lepomis megalotis*	*Micropterus punctulatus*
Etheostoma simoterum	*Micropterus dolomieu*	*Etheostoma blennioides*
Percina aurantica	*Etheostoma blennioides*	*Etheostoma simoterum*
	Etheostoma kennicotti	*Etheostoma jessiae*
	Etheostoma maculatus	
	Etheostoma rufilineatum	
	Etheostoma simoterum	
	Etheostoma jessiae	
	Etheostoma zonale	
	Percina macrocephala	

TABLE B-5. Results of Qualitative Collection at Control Station on West Prong of the Little Pigeon River Above Gatlinburg

Species	Numbers
Salmo gairdneri	1
Campostoma anomalum	8
Notropis leuciodus	1
Notropis rubricroceus	6
Rhinichthys atractulus	2
Rhinichthys cataractae	4
Hypentelium nigricans	5
Etheostema flabellare	10
Etheostema swannanoa	2
Cottus carolinae	6

TABLE B-6. Fish Collected by Dr. D. A. Etnier at Two Stations on the West Prong Little Pigeon River, 1968 and 1969

1968 Station 3 (Below 441 Bridge Pigeon Forge)		1969 Near Station 1 (At Norton Creek Road)	
Campostoma anomalum	40	*Salmo gairdneri*	2
Hybopsis amblops	677	*Salmo trutta*	1
Hybopsis insignis	50	*Campostoma anomalum*	29
Notropis cornutus	41	*Hybopsis amblops*	18
Notropis coccogenis	2	*Nocomis micropogen*	4
Notropis galacturus	16	*Notropis coccogenis*	18
Notropis leuciodus	26	*Notropos leuciodus*	3
Notropis lirus	10	*Notropis rubricroceus*	5
Notropis photogenis	21	*Notropis telescopus*	1
Notropis rebellus	87	*Rhinichythys cataractae*	63
Notropis rubricroceus	1	*Semotilus atromaculatus*	1
Notropis spilopterus	3	*Hypentelium nigricans*	1
Notropis stramineus	25	*Etheostoma blennioides*	26
Notropis telescopus	116	*Etheostoma chlorobranchium*	109
Phenacobius uranops	4	*Etheostoma flabellare*	1
Rhinichthys cataractae	1	*Etheostoma rufilineatum*	12
Semotilus atromaculatus	1	*Etheostoma simoterum*	12
Hypentelium nigricans	8	*Etheostoma swannanoa*	46
Moxostoma duquesnii	6	*Etheostoma maculatum*	1
Moxostoma erythrurum	1	*Cottus carolinae*	41
Ambloplites rupestris	3		
Lepomis auritus	1		
Etheostoma blennioides	23		
Etheostoma kennicotti	2		
Etheostoma rufilineatum	62		
Etheostoma simoterum	98		
Etheostoma jessiae	7		
Etheostoma swannanoa	7		
Etheostoma zonale	4		
Percina caprodes	5		
Percina evides	5		

APPENDIX C

TABLE C-1. Water Quality Analysis of 1958 Samples at Selected Comparative Stations on the Little Pigeon River

Date	Strm Flow	Fec. Coli. (100ml)	Color	Fe (µg/l)	pH	BOD	DO	SiO2	Cl	Total				Residue	
										PO4	Na	Ca	Mg	Total	Diss.
						------	------	------	------	mg/l	------	------	------	------	------
Middle Prong (River km, 18.5; 266.2 sq km = station 3)															
68/1/8	310	10k	5	70	7.1	1.0k	13.3	7.8	1k	.05	1.1	2.0	1.0	30	10k
68/3/11	154	10k	5	50	7.2	1.7	11.0	4.6	1k	.04	1.0	1.0	.5k	10k	10k
68/5/9	190	--	10	50k	7.4	1.1	10.6	5.8	1	.06	2.6	1.0	1.5	40	30
68/6/3	510	3400	25	260	7.0	1.0k	9.0	3.7	3	.08	1.9	2.0	1.0	--	--
68/7/29	112	400	10	170	7.6	1.0k	8.3	4.7	2	--	1.2	2.0	1.0	40	40
West Prong (River km, 31.3; 57.6 sq km = above Gatlinburg)															
68/1/8	96	10k	5	50	6.8	1.0	13.0	5.8	1k	--	.8	1.5	.5	30	30
68/3/11	57	10k	5	50k	6.8	1.8	11.0	3.9	1k	.01k	1.2	.5k	.5	--	--
68/5/9	41	--	15	50k	7.3	1.1	10.3	3.7	2	.06	1.8	--	--	30	30
68/6/3	47	10k	10	50k	6.7	1.0k	10.6	2.0	1	.03	1.3	1.0	.5k	10	10k
68/7/29	54	20	15	80	7.1	1.0	9.0	2.3	4	.04	.8	1.0	.5	20	20
West Prong (River km, 25.7; 153.3 sq km = station 1)															
68/1/8	240	160	5	60	7.0	1.0k	12.8	6.3	1k	.13	1.4	1.5	.5	30	30
68/3/11	143	2000	5	50k	7.2	1.8	10.8	5.2	1	.23	1.6	1.5	1.0	--	-0
68/5/9	101	---	15	50k	7.3	2.6	10.5	6.0	1	.73	---	---	---	120	60
68/6/3	124	8000	20	220	7.4	1.0	9.6	5.0	2	.63	1.3	3.0	1.0	60	100

TABLE C-1 (continued)

Date	Strm Flow	Fec. Col. (100ml)	Color	Fe (μg/l)	pH	BOD	DO	SiO2	Cl	Total PO4	Total Na	Total Ca	Total Mg	Residue Total	Residue Diss.
						mg/l									
68/7/29	137	21000	20	150	7.2	2.0	8.0	9.4	3	.70	1.4	2.5	.5	40	30
68/8/23	92	103000					8.3								
Model Prediction[1]			7	3	6.8			5.5	1		1	4.9	.6		30
Ave. Blue Ridge[2]						1.4				.2				50	

[1]Betson and McMaster, 1975.

[2]Betson, 1976.

TABLE C-2. Water Quality Analysis of Samples Taken October 27, 1975

Parameter	Middle Prong at Park	Middle Prong Station 1	Middle Prong Station 3	West Prong Control	West Prong Station 1	West Prong Station 4
Alkalinity, total mg/l	10	16	17	10	25	45
Hardness, mg/l	9	14	14	10	17	46
Color	1	1	2	1	1	1
pH	6.7	6.7	6.7	6.6	6.6	7.1
Conductivity @ 25°C	22	27	36	60	70	140
Chloride, mg/l	2	2	25	1	4	5
Cyanide, mg/l	0	0	0	0	0	0
Fluoride, mg/l	.46	.40	.35	.40	.40	.48
Sulfate, mg/l	0	0	0	0	1	5
Ammonia, mg/l	.10	.10	.10	.11	.11	.11
Calcium, mg/l	1.8	2.6	4.4	2.1	2.1	12.5
Iron, mg/l	0	0	0	0	.015	.054
Lithium, mg/l	.2	.2	.5	.3	.3	.5
Magnesium, mg/l	.8	.9	1.8	.8	1.3	2.3
Potassium, mg/l	.2	.3	.4	.3	1.0	1.2
Silica, mg/l	2.8	3.3	3.6	2.8	3.6	3.9
Zinc, mg/l	0	0	0	0	.010	0
Sodium, mg/l	1.8	2.4	4.9	2.0	2.6	4.9
Aluminum, mg/l	0	0	0	0	0	0
Arsenic, mg/l	0	0	0	0	0	0
Barium, mg/l	0	0	0	0	0	0
Cadmium, mg/l	0	0	0	0	0	0
Chromium, mg/l	0	0	0	0	0	0
Copper, mg/l	0	0	0	0	0	0
Lead, mg/l	0	0	0	0	0	0
Manganese, mg/l	0	0	0	0	0	0
Mercury, mg/l	0	0	0	0	0	0
Nickel, mg/l	0	0	0	0	0	0
Silver, mg/l	0	0	0	0	0	0
Strontium, mg/l	0	0	0	0	0	0

VITA

Lynn Betson Starnes was born in Milwaukee, Wisconsin, on July 6, 1950. She resided there until 1952, moving to Louisville, Tennessee. She attended schools in Alcoa and graduated from Alcoa High School of Blount County in June, 1968. She entered the University of Tennessee, Knoxville in September 1968 and received the Bachelor of Science Degree in Zoology in June 1972. She then joined the Peace Corps teaching Biology in The Gambia, West Africa for two years. She returned to the University of Tennessee, entering the Graduate Program in Ecology in September 1974. She received her Master of Science degree in Ecology in December 1976.

She is married to Wayne C. Starnes of Knoxville, Tennessee.