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# AN ASSESSMENT OF SOME ENVIRONMENTAL CHANGES AT TVA'S SEQUOYAH NUCLEAR PLANT

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## Abstract

This study is concerned primarily with the results of thermal enrichment induced into the hydrosphere by a nuclear-fueled steam generating plant as it affects ectoparasites in certain fish. A minor description of the plant and its site is given. Criteria for studying the ectoparasitic protozoa are discussed.

Base data collection, specimen field collection techniques, and laboratory techniques have been established. Protozoans identified to date include species of Urciolariidae, Chlamydodontidae, and possible new taxa of the Odontostomatida.

## Introduction

Since the announcement by TVA of the construction of Sequoyah Nuclear plant, located at Tennessee River mile 484, there has been much controversy over suspected environmental changes which may take place upon the activation of this facility. All steam-generating plants must release heat to the environment as a consequence of producing electricity. The current technological state of nuclear plant development allows approximately two-thirds, and possibly up to three-fourths, of the heat produced in the reactor to be lost to the environment (TVA, 1974). The maximum water requirements set forth by the Tennessee Water Quality Control Board will not allow the temperature to exceed 3°C (5.4°F) difference relative to an upstream control point. The allowed temperature change of the water cannot exceed 2°C (3.6°F) per hour.

Treatment of cooling effluent at the Sequoyah Nuclear plant will be afforded through the use of natural draft cooling towers with open-helper-closed system capability. This means that the system can vary from once-through use of the river water to a completely closed re-circulating use of the cooling water. The type of cooling system used will depend upon input from atmospheric and hydrospheric monitors. The cooling water, tower blowdown and the boiler blowdown will be lagooned for additional cooling and then pumped out through a diffuser system emitting 11.2 million gallons per minute at a temperature rise of 29.5°F (16.5°C). These figures are based on 2-unit operation at a minimum river flow of 98.7 million gallons per minute. The mixing zone extends approximately 200 feet downriver from the diffuser discharge site of the Sequoyah Nuclear Plant. The reservoir in the vicinity of the Sequoyah Nuclear plant site includes areas of varying depth, blind non-flowing embayments, tributary streams, peninsulas, inundated reservoir shallows, and the navigation channel (old river bed). The area is characterized by embayments and shallow overbanks which alternate between right and left banks as the channel changes course. There are extensive shallow areas approximately two to four miles downstream from the plant site. Within two miles downriver of the plant's discharge diffusers, the heated water will have spread over the full width of the reservoir. This may result in some warming of spawning areas in the shallow embayments and overbank areas, although it is not expected to exceed the maximum allowed by the state standards. Additional cooling will be realized with the mixing action of the Chickamauga Dam hydroelectric production. Further specifics of the system may be found in the final environmental impact statement (TVA, 1974).

While variations in temperature of the atmosphere and hydrosphere are the normal result of variations in climatic and geologic phenomena, stenothermal aquatic organisms generally can tolerate only those temperature changes that lie within the relatively narrow range to which they are adapted. Significant changes of water temperature brought about by hot effluents are termed thermal pollution (or enrichment). Most biological parameters, including fish diseases, are sensitive to thermal pollution (Krenkel & Parker, 1969; Snieszko, 1974). For instance, at temperatures higher than the tolerance levels, eggs may degenerate. Fish parasites are also affected by water temperatures in all of their life cycle stages and must adapt themselves to fluctuations.

Another adverse effect will be the entrainment of plankton and planktonic fish eggs and larvae by the cooling water intake located at Tennessee River mile 484.5. Essentially all plankton and fish larvae passing through the plant cooling water system will be killed. The organic waste load resulting will tend to depress concentrations of dissolved oxygen in the reservoir water downstream from the plant. Secondarily treated sanitary waste from the permanent facility will also be discharged in the Chickamauga reservoir, thus adding to the thermal and organic enrichment already released to this environment, all of which is below the maximum allowed by state standards. Control data of these effluents, which may have some bearing on the host-parasite populations of the reservoir, are available for consideration (personal communication with Charles Steele of the Tennessee Department of Public

Health, Water Quality Control Division, Chattanooga office).

Studies on the ecology of parasites of freshwater fishes have shown that the parasites, like all living organisms, possess a different sensitivity to environmental conditions during various stages of development. If some unusual events occur in the environment of the parasites, the equilibrium between host and parasite may be disturbed, and an epizootic of one or more species of parasite may occur (Hoffman, 1967). This situation could lead to a serious loss of fishes if environmental standards are not realized before epizootic progression occurs.

Fish population surveys based upon complete sampling of 12 coves in 1970 yielded an average of 182 pounds of fish per acre. On the basis of number, 12 percent were game and pan fish, 33 percent were forage fish, and 55 percent were rough and commercial fish (TVA, 1974). Little is known concerning the ecto- and endo- parasites of the fishes of the Tennessee Valley Authority's Chickamauga impoundment (personal communications with Owens and Chance, Fisheries and Waterfowl Resources, Division of Forestry, Fisheries, and Wildlife Development, TVA; W. A. Rogers, Zoology-Entomology Department, Auburn University).

As a result of the Federal Water Pollution Control Act Amendment of 1972 (P.L. 92-500, sec. 316a) and requests of the Environmental Protection Agency, the TVA must provide information for existing facilities on the incidence of disease and parasitism and on the condition of fish inhabiting the thermal plume area, or the receiving body of water. These data must be compared with species in adjacent waters uninfluenced by a heated discharge. However, the TVA is not presently collecting these kinds of data prior to the operation of the Sequoyah Nuclear Power Plant on the Chickamauga impoundment.

The present study is designed to establish the kinds of ectoparasite populations cohabiting the most numerous game fishes of the TVA Chickamauga impoundment, namely the Centrarchidae, e.g., Bluegill, Redear, and White Crappie (Stalcup, 1974), prior to the operation of Sequoyah Nuclear-fueled plant.

## METHODS

Three sites have been selected for fish collection. Site number 1 is located on the north side of the Tennessee River at Mile 472. Site number 2 is the east side of the Tennessee River at Mile 483. Site number 3 is on the west side of the Tennessee River at Mile 483. Sites 2 and 3 are located adjacent to the effluent dispersal system, whereas site number 1 is 11 miles downriver (Fig. 1). Two collection methods have been utilized: 1) one hundred foot gill nets of 1½ inch mesh yield 10 lifts at each site for each collection week per quarter; 2) modified Wisconsin trap nets (1 inch pocket mesh; 1 inch wing mesh; each wing 150 feet long) provide 4 lifts (3 net nights) for each 2 week collection period per quarter.

The Bluegill (*Lepomis macrochirus* Rafinesque), Redear (*Lepomis microlophus* Gunther), and White Crappie (*Pomoxis annularis* Rafinesque) collected live are placed immediately into a 1:4000 formalin solution (Putz & Hoffman, 1963). This relaxes and kills the protozoans. One hour later the solution is raised to 5% (Wellborn, 1967). In the laboratory the fishes are removed from the fixative, slit open on the left ventromedial side, tagged and placed into new 5% formalin for future endoparasitic studies.

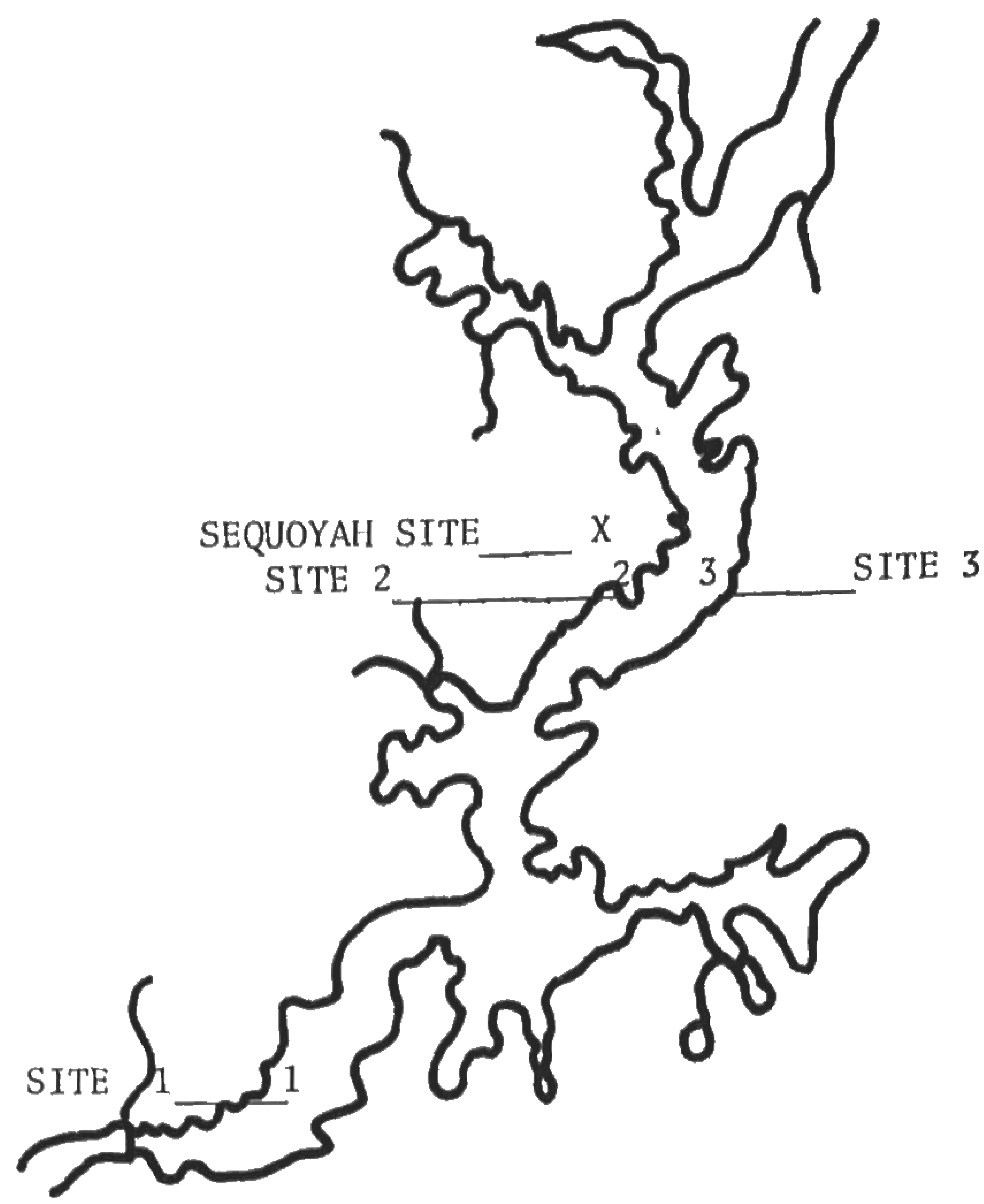


FIG. 1: *Collection site locations on the Tennessee Valley Authority Chickamauga impoundment.*

The field fixative is centrifuged and decanted to reduce the volume to 15 milliliters. Forty slides from each field sample are prepared upon a ringed slide, coverslipped, and sealed with a clear varnish. Each slide is surveyed, under oil, using phase microscopy. Present work involves the identification of specimens collected during the spring, summer, fall and winter quarters of 1975, and the spring and summer quarters of 1976. Techniques for this project have been worked out through initial support from the U. C. Foundation (grant no. 941011-4226 R95).

It is anticipated that field collections will continue from now until one year after the Sequoyah Nuclear plant is put into operation. Preliminary species identification should continue for one additional year beyond the present study. This will provide data for natural seasonal parasite population variations. The overall project may well extend to a five year period.

This study will continue with the identification of the most populous protozoan parasites of the TVA Chickamauga impoundment. These data will increase the base parameters available for future studies upon the lake ecosystem after the Sequoyah nuclear-fueled steam power generating plant is put into operation.

Efforts thus far have been concentrated upon field collections and perfection of laboratory techniques. Parasite specimens surveyed have included species of Urciolariidae, Chlamydodontidae, and possible new taxa of the Odontostomatida.

## ACKNOWLEDGMENTS

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# A PRELIMINARY CHECKLIST OF BENTHIC MACROINVERTEBRATE FAMILIES FROM BASKET SAMPLING DURING EARLY SUMMER IN THE WEST FORK OF STONE'S RIVER, TENNESSEE

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## ABSTRACT

Basket samplers filled with limestone rocks were used to survey the familial composition and abundance of macroinvertebrates in the West Fork of Stone's River, a stream that receives effluents from two wastewater treatment plants of the city of Murfreesboro, Rutherford County, Tennessee. From 25 May to 7 July 1973, seven stations and 10 samplers yielded 15 families belonging to 10 orders and two phyla, Arthropoda and Mollusca. Chironomidae was represented at all stations, composed greater than 50% of all specimens, and shared dominance with Hydropsychidae at one station. Heptageniidae was the major family at one of the stations. Psychomyiidae and Simuliidae were the only other families that comprised more than 10% of the collections at any one station. Fewer families were present at stations below the effluents than at those above the effluents.

## INTRODUCTION

Burdick et al. (1973) determined the waste assimilative capacity of the West Fork of Stone's River during the early summer in order to assist Murfreesboro in formulation of long-range plans for improvement of water quality. Because no recent data on benthic macroinvertebrates were available, the investigation included a survey of familial composition and abundance of macroinvertebrates at different stations. The purpose of the present paper is to report the results of that survey, since it was not included in Burdick et al. (1973) due to the considerable time required to identify and count the invertebrates.

## DESCRIPTION OF STUDY AREA

The West Fork of Stone's River drains approximately 128 mi² (331.4 km²) entirely within Rutherford County, Tennessee, and extends about 33.5 river mi (53.6 km) from its origin some 12 mi (19.2 km) south of Murfreesboro to its confluence with the East Fork to form Stone's River (Fig. 1). During the study period, the mean daily discharge ranged from a low of

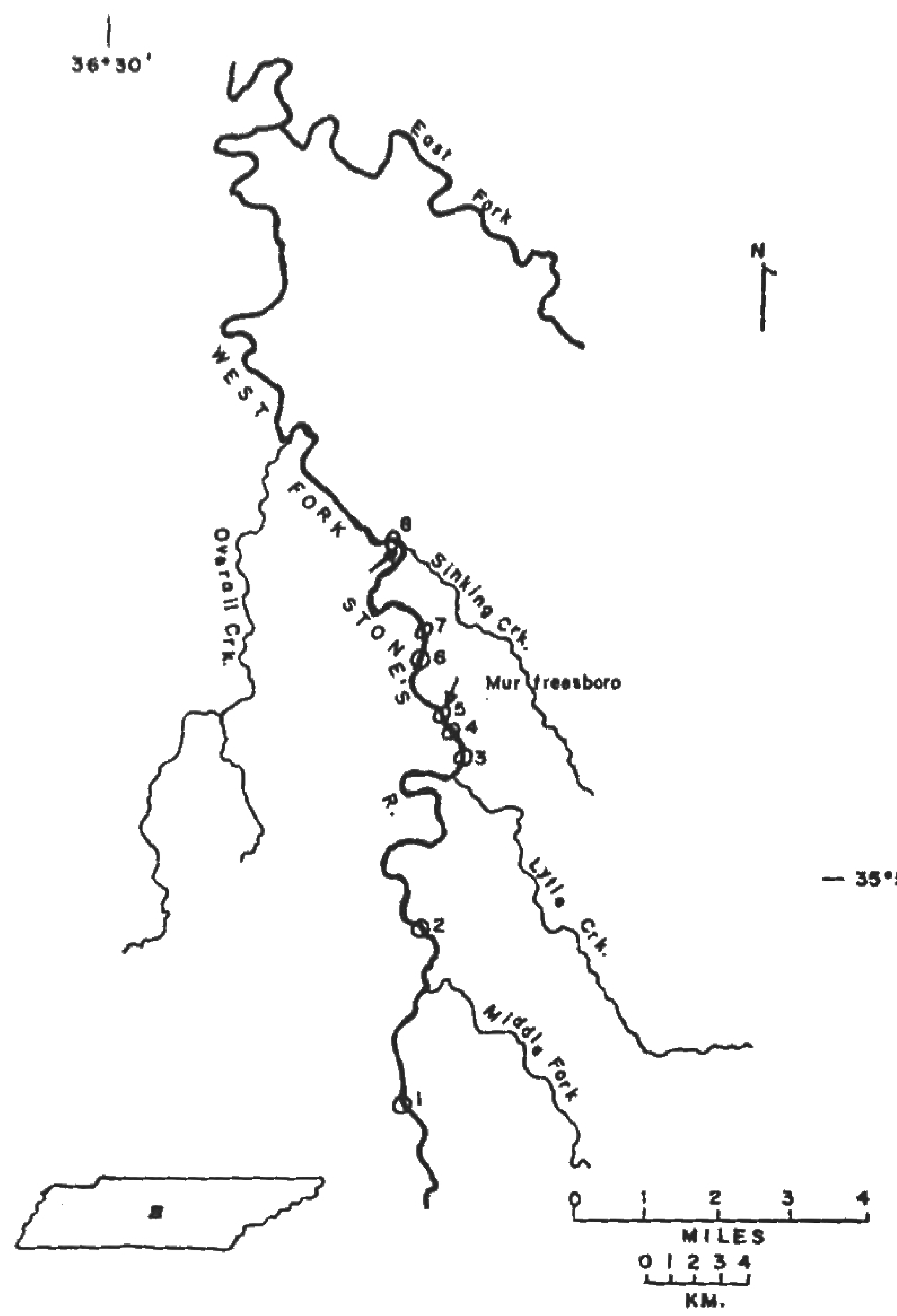


FIG. 1: *Location of stations (Arabic numerals) for collection of benthic macroinvertebrates in the West Fork of Stone's River, Rutherford County, Tennessee, 25 May to 7 July 1973. Arrows indicate effluent entry from wastewater treatment plants.*

TABLE 1: *Ranges and means of physicochemical features from 32 daily samples of the West Fork of Stone's River, 25 May through 6 July 1973 (modified from Merville (1974)).*

| Station | Temp °C | pH | Dissolved Oxygen, mg/1 | Nitrate mg/1 | Total Alkalinity, mg/1 Ca $CO_3$ |
|---|---|---|---|---|---|
| 2 | 19.0-27.5<br>x=23.9 | 7.0-8.5<br>x=7.8 | 6.8-10.9<br>x=8.1 | 4.1-16.4<br>x=7.9 | 90-190<br>x=136.7 |
| 4 | 19.0-28.5<br>x=24.0 | 7.0-8.8<br>x=7.8 | 6.0-10.9<br>x=8.0 | 3.1-16.6<br>x=8.0 | 85-190<br>x=127.6 |
| 7 | 19.0-28.0<br>x=24.1 | 7.0-8.2<br>x=7.7 | 5.4-10.9<br>x=7.8 | 4.5-17.0<br>x=6.8 | 85-210<br>x=127.8 |
| 8 | 19.0-28.0<br>x=24.1 | 6.9-8.4<br>x=7.7 | 6.0-11.2<br>x=7.7 | 3.1-16.2<br>x=7.1 | 76-210<br>x=128.2 |

47 cfs (1.41 $m^3$/sec) on 30 June 1973 to a high of 8350 cfs (250.5 $m^3$/sec) on 27 May 1973 (Water Resources Division, USGS, personal communication). The West Fork receives runoff from agricultural land developed on Ordovician limestone via seven main tributaries and effluent from two wastewater treatment plants of Murfreesboro. The oldest plant has been in operation since 1936 and presently treats about 75% industrial wastes and 25% domestic sewage. The newest plant was opened in February 1972 and treats mainly domestic sewage.

Eight sampling stations were established in the following order from upstream to downstream (river mi and km from mouth): Station 1 (24.4 mi, 39.0 km), below bridge on Barfield Road; Station 2 (21.6 mi, 34.6 km), below bridge on state highway 99; Station 3 (16.7 mi, 26.7 km), below bridge on Manson Pike; Station 4 (16.0 mi, 25.6 km), above effluent of old wastewater treatment plant; Station 5 (15.8 mi, 25.3 km), at effluent of old wastewater treatment plant; Station 6 (15.1 mi, 24.2 km), below bridge on U.S. highway 41; Station 7 (14.5 mi, 23.2 km), adjacent to American Legion post; and Station 8 (12.1 mi, 19.4 km), 30 m below effluent of new wastewater treatment plant (Fig. 1). Stations 1, 2, 4, 5, 7, and 8 were characteristically riffle areas during the study period and had substrates of large rocks, rubble, and bedrock. Stations 3 and 6 were predominantly pooled areas with silt and rubble substrates. Ranges and means of physicochemical parameters at stations 2, 4, 7, and 8 are presented in Table 1.

## METHODS AND MATERIALS

On 25 May 1973, cylindrical wire basket samplers, each 17.8 cm in diameter and 27.9 cm long, were filled with clean limestone rocks (2.5 cm to 7.6 cm in diameter) to serve as a substrate for invertebrates (Mason et al., 1967). Two samplers were anchored to the stream bottom at each station; one sampler in midstream, another near the stream bank. On 27 May, 8.5 cm of rain fell in Murfreesboro in about 10 hrs, and the river rose rapidly to flood stage. As a result both samplers were lost at Station 1, eliminating this as a study site, and one sampler was lost at each of Stations 4, 5, 7, and 8.

On 7 July 1973, 10 samplers were removed from all stations. Each basket was lifted carefully from the stream bed and placed in a bucket of stream water. Invertebrates were picked off each rock with forceps and removed with a soft brush so that they remained in the bucket of water. Contents of the bucket were passed through a U.S. standard number 30 sieve, and sample were preserved in 70% ethanol. In the laboratory, separation of invertebrates from debris was accomplished with a sugar flotation technique (Anderson 1959) and by hand picking with forceps. Each sample was examined under a binocular microscope, and invertebrates were identified to family, counted, and preserved in fresh 70% ethanol.

## RESULTS

Fifteen families belonging to 10 orders and two phyla, Arthropoda and Mollusca, were represented in 10 basket samplers from seven stations (Table 2). Five families dominated the collections in terms of a family constituting more than 10% of the specimens at any one station. Chironomidae (midge larvae) occurred at each station and was dominant at riffle Stations 4, 5, 7, and 8, where it constituted 79.8%, 94.9%, 67.0%, and 87.5% of the specimens, respectively. At Station 6, a pooled area, chironomids accounted for 54.5% of the invertebrates. Mayfly nymphs of Heptageniidae dominated (75.8%) the two samplers at Station 3, and they were the second most abundant group (13.3%) at Station 4. Hydropsychidae (caddisfly larvae) was most prevalent (47.4%) at Station 2, where Chironomidae was next in abundance (43.5%), and it assumed some importance (13.5%) at Station 7. Blackfly larvae (Simuliidae) comprised 1% of the invertebrates at Station 2; but at Station 7, below the sewage outfall, they comprised 16.3% of the collection. Only 11 invertebrates occurred in two basket samplers at Station 6, and 90.9% of these were Chironomidae and Psychomyiidae (caddisfly larvae) (Table 2).

Riffle beetles (larvae and adults of Elmidae) were in greatest number and percent at upstream and downstream Stations 2 (104, 1.3%) and 8 (78, 2.1%), and Simuliidae was present only at Stations 2 and 7. Dance fly larvae (Empididae) occurred only at downstream Stations 7 and 8, and crayfish (Astacidae) were found in samplers from Stations 2 and 3 only (Table 2).

The family Empididae was represented by only one genus, *Hemerodromia,* and the genera *Hydropsyche* and *Cheumatopsyche* dominated the Hydropsychidae. Other representative genera occasionally identified were *Pleurocera* and *Goniobasis* (Pleuroceridae), *Stenonema* (Heptageniidae), *Stenelmis* (Elmidae), and *Orconectes* (Astacidae).

Eleven families were represented at Station 7, Stations 2 and 4 each yielded 10 families, and eight families were at Station 3. The fewest number of families, three, was found from Station 5 at the old treatment plant effluent and from Station 6, a large pooled area 1.1 mi (1.8 km) below this effluent.

Of 15,099 specimens from all collections, Stations 2, 7, and 8 had the greatest percentage of these (97.2%), and Station 2 had over 50% of all specimens.

TABLE 2: *Taxa, number and percent composition of macroinvertebrates, and number of samplers for each station in the West Fork of Stone's River, 25 May to 7 July 1973.*

| | STATIONS AND (NO. SAMPLERS) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2(2) | | 3(2) | | 4(1) | | 5(1) | | 6(2) | | 7(1) | | 8(1) | |
| TAXA | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Coleoptera | | | | | | | | | | | | | | |
| Elmidae | 104 | 1.3 | 0 | 0 | 2 | 1.0 | 0 | 0 | 0 | 0 | 11 | 0.4 | 139 | 3.7 |
| Diptera | | | | | | | | | | | | | | |
| Ceratopogonidae | 2 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.04 | 0 | 0 |
| Chironomidae | 3582 | 43.5 | 13 | 10.8 | 162 | 79.8 | 75 | 94.9 | 6 | 54.5 | 1813 | 67.0 | 3276 | 87.5 |
| Empididae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | 2.3 | 200 | 5.3 |
| Simuliidae | 82 | 1.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 441 | 16.3 | 0 | 0 |
| Ephemeroptera | | | | | | | | | | | | | | |
| Baetidae | 170 | 2.0 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 5 | 0.2 | 3 | 0.08 |
| Heptageniidae | 365 | 4.4 | 91 | 75.8 | 27 | 13.3 | 3 | 3.8 | 0 | 0 | 0 | 0 | 8 | 0.2 |
| Odonata | | | | | | | | | | | | | | |
| Coenagrionidae | 0 | 0 | 1 | 0.8 | 1 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0.04 | 0 | 0 |
| Trichoptera | | | | | | | | | | | | | | |
| Hydropsychidae | 3902 | 47.4 | 2 | 1.7 | 3 | 1.5 | 0 | 0 | 1 | 9.1 | 366 | 13.5 | 103 | 2.8 |
| Psychomyiidae | 0 | 0 | 2 | 1.7 | 1 | 0.5 | 0 | 0 | 4 | 36.4 | 3 | 0.1 | 0 | 0 |
| Amphipoda | | | | | | | | | | | | | | |
| Gammaridae | 0 | 0 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Decapoda | | | | | | | | | | | | | | |
| Astacidae | 5 | 0.06 | 8 | 6.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Isopoda | | | | | | | | | | | | | | |
| Asellidae | 0 | 0 | 1 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.04 | 0 | 0 |
| Gastropoda | | | | | | | | | | | | | | |
| Pleuroceridae | 22 | 0.3 | 2 | 1.7 | 2 | 1.0 | 1 | 1.3 | 0 | 0 | 2 | 0.07 | 15 | 0.4 |
| Pelecypoda | | | | | | | | | | | | | | |
| Sphaeriidae | 1 | 0.01 | 0 | 0 | 3 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total number specimens | 8235 | | 120 | | 203 | | 79 | | 11 | | 2707 | | 3744 | |
| % of specimens | 54.5 | | 0.8 | | 1.3 | | 0.5 | | 0.07 | | 17.9 | | 24.8 | |
| No. families | 10 | | 8 | | 10 | | 3 | | 3 | | 11 | | 7 | |

## Discussion

Evaluation of these results must consider effectiveness of the method, substrate preference by macroinvertebrates, and the effect of flooding (spates) on the benthic community. Dickson et al. (1971) evaluated the use of basket samplers in the New River, Virginia for 21 days and concluded that at least five samplers per station were needed to ensure 95% confidence that at least 50% of the total taxa were collected. Mason et al. (1970) studied macroinvertebrates with basket samplers in the Klamath River, Oregon for four months out of the year and removed samplers at the end of each month. Mason et al. (1967) indicated that six weeks' exposure of baskets was adequate for collecting invertebrates. Although the exposure time for baskets in the present study seemed adequate, the limited number of samplers available at the time for each station partially accounted for the absence of taxa one might expect for a stream of this area.

The type of substrate is a major factor influencing the distribution of stream invertebrates (Hynes, 1970). Crisp and Crisp (1974) found that boulder-rubble substrate (7.5 to 30 cm diameter) was preferred by Ephemeroptera, Trichoptera, and Diptera, and families of these orders were most abundant in samplers of the present study. This indicates that the artificial substrate of limestone rubble may have a selective effect. Indeed, several taxa collected previously from West Fork by other methods were conspicuously absent from samplers: Plecoptera, Megaloptera, Hemiptera, Hirudinea, Lumbriculidae, and Tricladida. All of these taxa except Plecoptera, however, were reported from basket samplers in the polluted Klamath River, Oregon (Mason et al., 1970).

Flooding often reduces the abundance and diversity of macroinvertebrates (Hynes, 1970). The high discharge of 27 May in West Fork certainly had some effect in producing the relatively low diversity of families and higher taxa, since some macroinvertebrates (e.g., Turbellaria, Oligochaeta) can be scoured from stones and are slow to recolonize these areas.

Although a definite assessment of water quality using biological data needs determination of invertebrate species, some indication of general conditions is possible using higher taxa and numbers of invertebrates (Cairns & Dickson, 1971). A comparison of riffle stations shows that 2, the farthest upstream, had a large percentage of chironomids and hydropsychids, 43.5 and 47.4, respectively. Many species of chironomids are usually pollution-tolerant or facultative, whereas caddisflies, in general, are sensitive to pollu-