To the Graduate Council:

I am submitting herewith a thesis written by James P. Beets entitled "Population Dynamics of the Stoneroller Minnow, Campostoma anomalum (Rafinesque), in Streams of a Five-County Area in Upper East Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology.

David A. Etnier

David A. Etnier, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

L. Evan Roth

Vice Chancellor
Graduate Studies and Research

POPULATION DYNAMICS OF THE STONEROLLER MINNOW, *CAMPOSTOMA ANOMALUM* (RAFINESQUE), IN STREAMS OF A FIVE-COUNTY AREA IN UPPER EAST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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James P. Beets

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ABSTRACT

The population dynamics of the stoneroller minnow, *Campostoma anomalum* (Rafinesque), was examined in a five-county area in upper East Tennessee. The study was part of a two report project initiated by the Tennessee Wildlife Resources Agency to assess the impact of commercial bait fishing on the sport fishery for this cyprinid fish.

Two similar streams within the study area were intensively studied for *Campostoma* population information. A creel survey, conducted during the study, demonstrated that one stream incurred a high fishing pressure for *Campostoma* while the other stream incurred a low fishing pressure. Density and biomass were determined by direct enumeration. *Campostoma* was the dominant species in density and biomass in both streams. The population characteristics of *Campostoma* were similar in both streams. Large *Campostoma* adults, which are the preferred sport fish, were less abundant in the stream of high fishing pressure.

An investigation of the macroinvertebrate fauna in selected areas was accomplished to demonstrate the effect that habitat alteration and pollution had on the aquatic populations of the study area streams. Many streams have been adversely affected by perturbations which has resulted in depauperate aquatic communities.

Intense commercial fishing will affect *Campostoma* populations locally, however, a controlled commercial harvest can possibly exist with the sport fishery if regulations are enforced. Enforcement of stream alteration and pollution regulations would be extremely beneficial to the fishery.

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INTRODUCTION

This study was initiated by the Tennessee Wildlife Resources Agency (T.W.R.A.) to assess the impact of the commercial bait fishery on the sport fishery for Campostoma anomalum (Rafinesque), the stoneroller minnow, in a five-county area of upper East Tennessee. The study was contracted for two separate reports. One was concerned with aspects of life history of Campostoma anomalum, accomplished by Noel M. Burkhead. This part of the study was an investigation into aspects of the populations of the minnow in streams within the five county area.

Although Campostoma anomalum is an abundant cyprinid fish in most habitats of eastern North America (Pflieger, 1975; Smith, 1979; Trautman, 1957), it is not commonly considered an important sport and food species. However, the native, rural society of notheastern Tennessee in the Appalachian Mountains have long considered this minnow important for sport and food. In this area, the local common name for Campostoma anomalum is "Hornyhead". This is due to the large breeding tubercules which develop on the head and body of the male of the species during spawning season. Large breeding males are the preferred sport fish.

The conflict between sport fishermen and commercial bait fishermen did not arise until the Tennessee Valley Authority (T.V.A.) impoundments were completed in the area. Campostoma became the preferred bait species in the walleye and trout fisheries of Watauga Reservoir and trout and bass fisheries of South Holston Reservoir. Large numbers of Campostoma were being removed each year during the spawning season by commercial bait fishermen. The method of capture is conducive to removal of large numbers of individuals due to movements during the spawning period. Although the preferred bait size was approximately 3-5 inches, individuals were not returned and mortality was high during capture, transportation, and holding.

The conflict between sport and commercial fishermen became so intense that T.W.R.A. prohibited the commercial sale of Campostoma within the study area in 1975. Since that time, a large "black market" has developed and bait harvest continues to be intense.

CHAPTER I

LITERATURE SURVEY

I. POPULATION DYNAMICS

In recent years, the study of animal populations and their dynamics has received increased investigation. Much of this interest has been stimulated by the better methodology, sampling techniques, and equipment available as a result of the increased emphasis in attempting to define population changes in both natural and altered ecosystems. Such investigations are necessary if natural and anthropogenic changes are to be partially understood.

The study of aquatic populations has long been of interest to fishery scientists and the population dynamics of many freshwater game fish species have been investigated by many authors (Allen, 1951; Gerking, 1962; Chapman, 1965; Goodnight and Bjornn, 1971; Craig, 1974; Havey, 1974). Such investigations have been necessary for the determination of management practices so that the maximum yield of a species can be maintained. Sound management can only be intellectually realized through the use of good scientific investigation. Review and discussion of studies of animal populations have resulted in many good standard methods covered by various authors (Ricker, 1958, 1971; Gerking, 1967; Tanner, 1978).

Population studies of non-commercial and non-sport fish species have unfortunately received little investigation. A few species have been studied to assess their impact on commercial or sport fisheries

Petrosky and Waters, 1975; Jester, 1976). Most population studies in North America have been in lentic habitats while lotic environments have received less emphasis. The greater fishing pressure on lakes and reservoirs in North America has resulted in this emphasis. Lotic environments are presently receiving increased attention as evidenced by recent works (Hynes, 1970; Oglesby, et al., 1972). Most population studies have been autecological with little emphasis on the total community. Ecological studies on native cyprinids in North America are very few which is surprising in view of the fact that they usually account for much of the fish diversity and biomass in North American aquatic ecosystems. Most lotic and cyprinid population studies have been accomplished by European scientists (Mann, 1965; Williams, 1965; Mathews, 1971; Hunt and Jones, 1974).

Estimation of population size has received much emphasis and methodology has been widely accepted and standardized for many game species. Most estimates are based on marking fish and subsequent recaptures (Ricker, 1958; Tanner, 1978). These estimates are excellent for populations which meet the assumptions for the method and are not of small individual size and large population size, which makes marking tedious and extremely time consuming. Other methods of estimating population size of stream fishes are discussed by Cleary and Greenback (1954), Cooper and Lagler (1956), and Ricker (1971). Populations studies of cyprinids have been accomplished by determination of relative density, avoiding time consuming absolute estimates (Mann, 1971; Mathews, 1971; Hunt and Jones, 1974). Population studies of small, abundant cyprinids which occupy riffle habitats are non-existent.

Hunt and Jones (1974) presented a most relevant statement on the problems of cyprinid population research:

> Cormack (1968) stated that no technique will give accurate estimates unless the sampling technique is specifically aimed at the particular species under study and that the behavior of the species must be understood before any attempts are made to provide statistically valid estimates of the population parameters. Unfortunately, knowledge of the behavior, or any other aspect of the biology, of most of the Cyprinidae is sparse . . . .

Other authors (Williams, 1965; Mann, 1971; Mathews, 1971; Hunt and Jones, 1974) have indicated the problems in cyprinid population research such as schooling behavior, movement throughout the system, and changing distributional patterns.

II. CREEL SURVEY

The use and importance of the creel census and creel survey in fisheries biology has long been recognized; however, data accumulated from different methods have often yielded questionable results. For years creel data were presented in no standard form and followed no accepted technique. It is obvious that no single method can be indiscriminately applied to various situations, but an attempt is presently being made to standardize the format of creel data to yield an understandable base of data for comparative purposes. Lambou (1966) discussed the need for standardization and presented many useful definitions and recommendations.

Most creel studies have been accomplished on large lakes, reservoirs, and rivers. Some methods are inadequate for smaller stream surveys, but the widely accepted stratified creel survey with non-uniform probability sampling is appropriate. This method was discussed by Pfeiffer (1966) and Ware et al. (1972). Pfeiffer (1966) demonstrated that this method was more reliable than a complete two-hour survey or a total census and data were obtained more efficiently. Ware et al. (1972) discussed and compared this method with previously used methods and also found it more reliable.

III. EFFECT OF ENVIRONMENTAL ALTERATIONS OF AQUATIC COMMUNITIES

Much has been written in recent years on the effect of physical alterations and pollutants of stream communities. Water quality has often been obtained from periodic measurements, yielding data that may not show periods of maximum pollution and highest stress to the aquatic environment. It has been only in the past few years that effects on the total aquatic community have been investigated sufficiently to yield a base of literature concerned with biological analysis of aquatic perturbations. Although many early investigators such as Ellis (1937), Brinley (1942), and Bartsch (1948) recognized the need for a biological basis for water quality and published results, standard methods with good statistical results have been slow in derivation and acceptance. Much of this is due to the effect various pollutants have on different environments and different communities. Obviously, a habitat with low diversity and many resistant organisms will show less alteration than one of high diversity and large numbers of intolerant organisms. Accepted methods of biological analysis can be found in publications such as Weber (1973), Lloyd and Ghelardi (1964), and Lloyd, Zar, and Karr (1968). Howmiller and Scott (1977) have presented an interesting method utilizing a trophic index to assess pollution.

Fish are difficult to utilize as pollution indicators because of their ability to move quickly from a perturbed environment, tolerate many types and degrees of pollutants, and alter their interactions such as food habits (Hynes, 1960; Jones, 1964; Starnes, 1976). Other less mobile, tolerant, and adaptable organisms in the aquatic environment are, therefore, more useful in demonstrating stream perturbations. Aquatic macroinvertebrates are most often utilized in stream studies because of their ease of sampling and close association with their habitat, high numbers, diversity, and biomass per unit area (Hynes, 1962; Beck, 1954, Gaufin and Tarzwell, 1952, 1956; Gaufin, 1958; Patrick, 1949).

There are many problems and insufficiencies in the current biological analyses of pollution, especially in the use of indicator organisms, but as additional studies are completed the analyses should become more useful and accepted. Cairns (1974) believes that most problems in analysis can be avoided and that standard and valid methodology can be generated by analyzing the total community structure.

The effect of impoundments on fish populations inhabiting lotic environments, especially those closely associated with riffle and shoal habitats, is much more obvious than other types of perturbations. Once the diversity of microhabitats within the substrate of a rocky riffle or shoal is destroyed by converting the habitat into a more uniform pool habitat with subsequent siltation, the diversity of organisms adapted to the microhabitats is also greatly decreased. Changes in fish populations due to impoundments have been investigated and discussed by Etnier et al. (1979), Fitz (1968), and many other authors.

CHAPTER II

DESCRIPTION OF STUDY AREA

I. LAND USE

Most of the watersheds of the study streams are located in the mountainous counties of Johnson, Carter, and Unicoi in northeastern Tennessee. The headwaters of the five study streams lie within the Cherokee National Forest. A large portion of the Elk River watershed lies within Pisgah National Forest in North Carolina. The upper, higher gradient portions of the streams are of pristine quality and have nearly 100 percent forest cover. The lower portions of the study streams follow narrow valleys with varying amounts of farmland along their course. Roan Creek in Johnson County lies in the widest valley with the greatest amount of agriculture.

Although this area was the first settled by colonists in Tennessee in the 1700's, frequent flooding, limited agriculture area, and communication and transportation problems have resulted in low population densities and little industry (Table 1). The few industries in this three-county area are located around the urban areas of Mountain City, Johnson County; Elizabethton, Carter County; and Erwin, Unicoi County. Industry within the last two areas has a significant impact on aquatic systems.

Most streams within the valley area of Sullivan and Washington counties have lower gradient, high turbidity, and little cover. Much of the area in these two counties is agricultural. A large amount of industry is located in the urban areas of Kingsport and Bristol, Sullivan County, and Johnson City, Washington County. In this low relief terrain, there are larger population densities, increased industrial and agricultural area, and a significant decrease in water quality of all streams, especially the larger systems (Table 1). (All tables are located in Appendix.)

II. GEOGRAPHY AND GEOLOGY

The study area included five counties in northeastern Tennessee. County boundaries are mostly artificial except for the eastern boundaries which essentially follow the ridge line of the Unaka Range of the southern Appalachian Mountains. Physical statistics of the counties are in Table 1. A map of the study area is in Figure 1.

Three river systems of the Tennessee River drainage contained most of the drainage: South Fork Holston, Watauga, and Nolichucky rivers. Five reservoirs are located within the study area. Watauga and Wilbur reservoirs impound the Watauga River. South Holston, Boone, and Fort Patrick Henry reservoirs impound the South Fork Holston River. Physical statistics of rivers and reservoirs are in Table 2.

Two physiographic provinces are represented in the study area. The Ridge and Valley province with its characteristic lower gradient streams is represented approximately by the area in Sullivan and Washington counties. The Blue Ridge province is represented by the mountainous area in Johnson, Carter, and Unicoi counties. All five of the study streams were higher gradient streams located in the Blue Ridge province. All study streams were similar in mean gradient, size, and substrate. Physical statistics of the study streams are listed in Table 3.

The streams of the Ridge and Valley province in Sullivan and

FIGURE 1. DISTRIBUTION OF _CAMPOSTOMA ANOMALUM_.

A. MAP OF STUDY AREA
Large open circles: Population and life history study stations
Large closed circles: Life history study stations
Small closed circles: Relative abundance sample stations

B. MAP OF DISTRIBUTION OF _CAMPOSTOMA ANOMALUM_ IN TENNESSEE
Solid area indicates area of study
(By permission of D. A. Etnier)

C. MAP OF DISTRIBUTION OF _CAMPOSTOMA ANOMALUM_ IN NORTH AMERICA

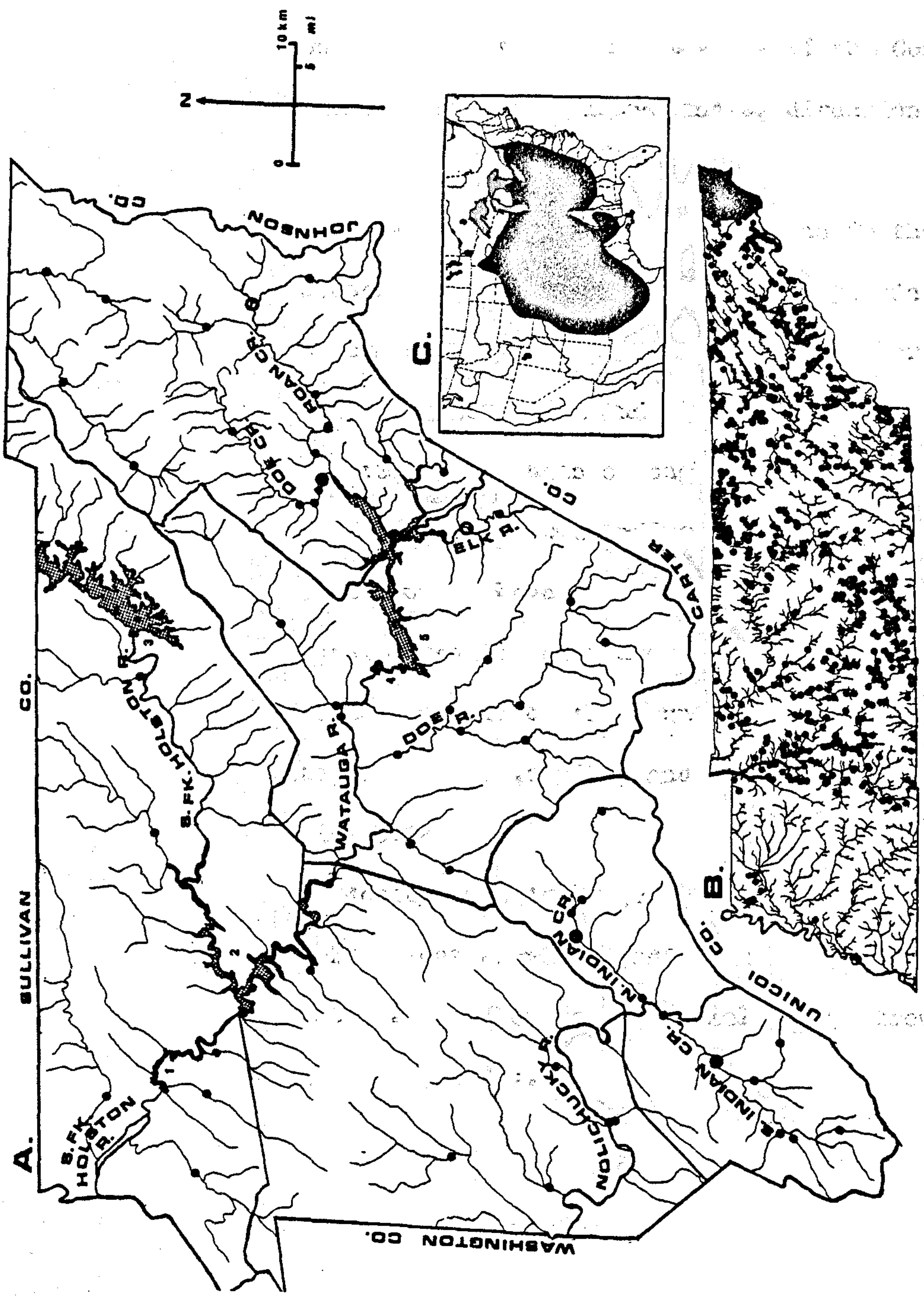
A.
B.
C.
SULLIVAN CO.
WASHINGTON CO.
UNICOI CO.
CARTER CO.
JOHNSON CO.
S. FK. HOLSTON R.
WATAUGA R.
DOE R.
ELK R.
DOE CR.
ROAN CR.
N. INDIAN CR.
S. INDIAN CR.
NOLICHUCKY R.
N
0
5 mi
10 km

FIGURE 1.

Washington counties are underlain predominantly by Sevier shale of the Chickamauga group and dolomite and magnesian limestone of the Knox group of the Ordovician. Narrow belts of shale and limestone of the Conasauga group of the upper Cambrian run in a northeast-trending direction across the valley.

The higher gradient streams of the Blue Ridge province in the mountainous counties of Johnson, Carter, and Unicoi are underlain by a large variety of dolomite, sandstone, shale, quartzite, and other clastic sedimentary rocks of the Rome formation and Chilhowee group of the lower Cambrian. These formations have been strongly folded and faulted, so that they crop out in narrow northeast-trending belts. The rock has been broken into thrust sheets which have moved many miles northwestward. A large portion of the higher elevation area along the Tennessee - North Carolina boundary is pre-Cambriam rock of the Mount Rogers group, Bakersville gabro, Beech granite, Cranberry granite, and Roan gneiss (King et al., 1944; Hardeman, et al., 1966).

These mountains are underlain mostly by quartzite and other clastic rocks. They project 1000-2000 feet above the adjacent lowlands and reach altitudes of over 5000 feet. They form parallel chains trending generally northeast (King et al., 1944).

CHAPTER III

MATERIALS AND METHODS

I. POPULATION STUDY

Five stations were established and sampled monthly for life history information. Two of these stations were selected for population information: Roan Creek in Johnson County with high fishing pressure and Elk River in Carter County with low fishing pressure. Due to the greater width of the Elk River, a channel on one side of a large island at the study station was selected for population samples.

Distribution and relative abundance of *Campostoma* and associated species were established in streams of all five counties. In obtaining relative abundance, each species was given a rating within each habitat sampled dependent upon the percentage of individuals per unit area sampled as follows: abundant (A), greater than 20%; common (C), 10-20%; uncommon (UC), 1-10%; or rare (R), less than 1%.

Most collections were attempted with the use of a small 1-H.P. gasoline operated backpack electrofishing unit, Model BP-1C from Coffelt Electronics and 6' x 12' seine with 3/8" stretch mesh. Collections were accomplished by electrofishing downstream into the seine and then lifting the specimens from the water (Jenkins and Burkhead, 1975). During times of equipment failure, seining and occasional spot ichthyocide application were utilized. The latter methods were avoided when possible. Seining proved much less efficient on the substrate in the study area. Fish toxicants are known to be detrimental and restrictive in their use. At the end of the study, a superior backpack electrofishing unit was purchased by T.W.R.A. This unit performed far more effectively in any position without failure. This backpack shocker utilized an Echo SRM-302-ADX gasoline engine coupled with a Tiny Tiger generator.

Population samples were accomplished with the use of ichthyocide. The method was modified from that of Eschmeyer and Clark (1939). Application method was modified from the prededures described in Hocutt et al. (1973) and Johnson and Pasch (1975). Two block nets, 50' x 6' x 1/2" stretch mesh, were utilized to block off 75-100 meters of stream in each population study area. The fish toxicant was applied approximately 5-10 meters above the upstream block net and allowed to mix and flow through the area. All fish were removed from the area, placed in one-gallon jars of 10 percent formaldehyde, and returned to the University of Tennessee Aquatic Biology Laboratory for analysis.

Population samples were taken seasonally from June, 1977 to June, 1978. In the winter months, population samples were not accomplished due to the ineffectiveness of the ichthyocide at lower temperatures.

Fish measurements were taken following method of Hubbs and Lagler (1958). Standard length was used and taken with a Helios dial caliper. Fish weights were taken with a Sartorios electronic balance. Common and scientific names of fishes collected follow Bailey et al. (1970) (Table 4).

Estimates of production (P) and instantaneous rate of growth (G) of the populations in Roan Creek and Elk River were calculated from density estimates utilizing the methods of Ricker (1971) and Mathews (1970). Estimates of the instantaneous rate of mortality (Z) followed that of

Ricker (1971).

A marking experiment was accomplished to determine the effectiveness of marking Campostoma with flourescent pigment. The results demonstrated significant mortality in young fish which was probably due to stress. Retention of marks was 100 percent for the ten days of the experiment. Due to the mortality incurred during the experiment and the violation of other assumptions, a mark-recapture method for estimating population size of Campostoma was avoided.

II. CREEL SURVEY

A creel survey, modified from the technique and design discussed by Pfeiffer (1966), and Wate et al. (1972), was employed to estimate the sport fishing pressure for Campostoma in the study area streams and to demonstrate the association of spawning period with sport and commercial fishing. The stratified creel survey with non-uniform probability sampling was initiated during the spawning season, April 1, 1978, and continued through the end of the spawning season until June 30, 1978. The method was derived by T.W.R.A. biologists and biostatistician.

One creel clerk was utilized during the three-month period to sample the two population study streams, Roan Creek and Elk River, in addition to another stream of known high fishing pressure, Doe River, Carter County. Weekly schedules with five work days were determined randomly by computer. Work days were divided into two work periods, sunrise to midday and midday to sunset, and given equal probability. Weekend days were always always surveyed and given greater probability of fishing than weekdays. Roan Creek and Doe River were sampled twice weekly and given equal probability, while Elk River was sampled once weekly and given a probability equal to half of the other two streams.

A pressure count was taken along the accessible portions of each stream once during each work period at a predetermined, randomly selected time. The remainder of the time during the work period was spent interviewing fishermen along the stream banks. The data collected included number of species caught, principle species fishes for, hours fishes, bait and equipment utilized, and environmental conditions. The creel clerk was requested to record any trapping information and number of wing dams in use, when possible.

Weekly fishing pressure in fishermen hours was estimated by substituting the fisherman count and probabilities used in drawing the schedules in the following formula;

$$\text{Estimated weekly pressure} = \frac{\text{Work area count} \times \dfrac{\text{No. of hours in work period}}{\text{Probability of work period}}}{\dfrac{\text{Probability of the day of the week}}{\text{Probability of the work area (stream)}}}$$

The method of capture utilized by commercial fishermen is quite efficient. Large numbers of *Campostoma* may be removed within a few hours due to their movements during the spawning periods. For a discussion of spawning behavior refer to Burkhead (1979). Since large aggregations of *Campostoma* move toward the spawning habitat of uniform gravel substrate at the head of riffle areas at night, commercial fishermen construct large wing dams downstream from the preferred spawning sites during the day. Large and small rock are used to construct the wing dams into a funnel-shaped design with a small opening on the upstream end (Figure 2). The dams are often constructed across the entire width of stream so that all individuals moving up to the spawning site will be

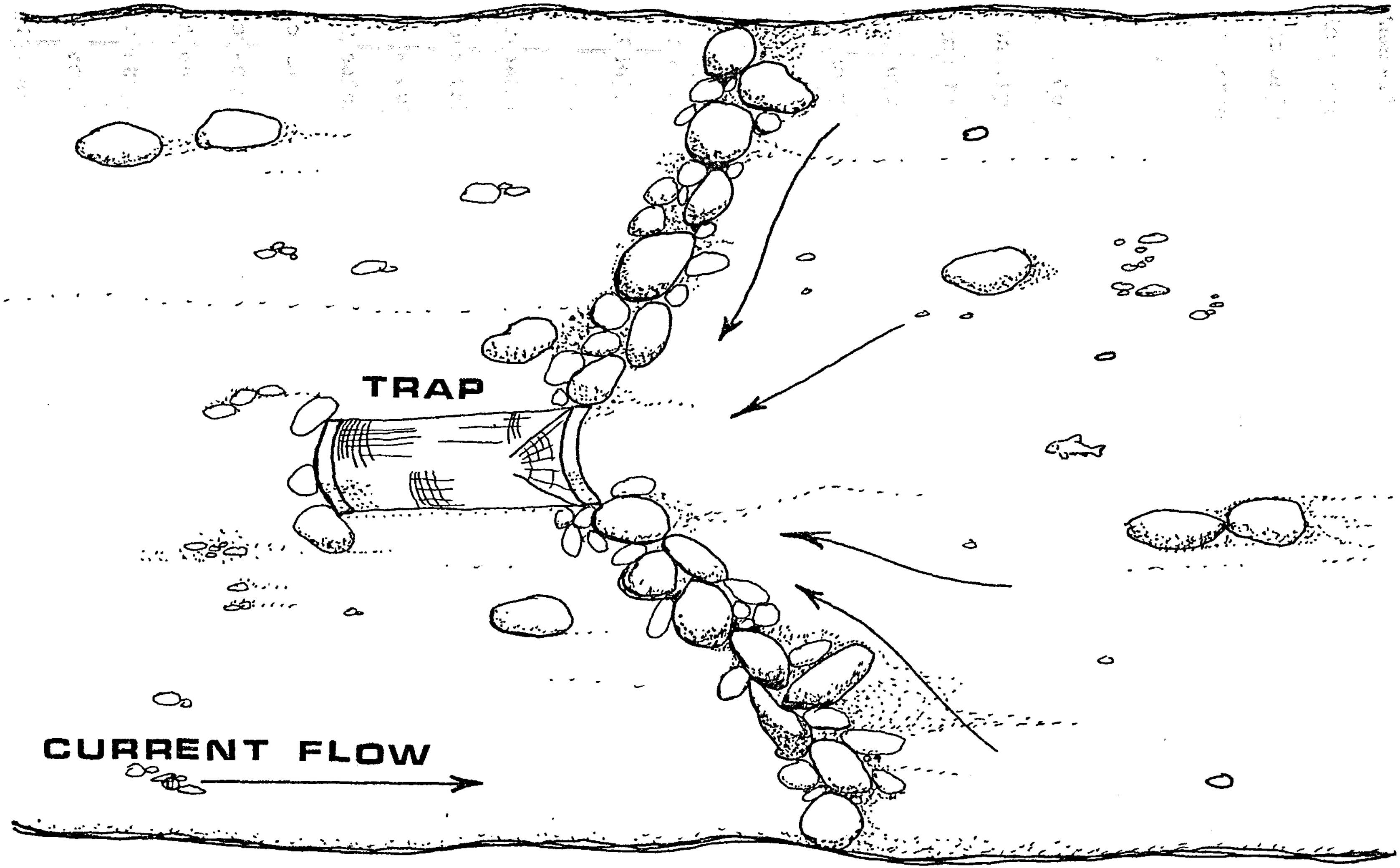

FIGURE 2. DIAGRAM OF WING DAM STRUCTURE IN SHALLOW RIFFLE WITH FUNNEL MINNOW TRAP.

funnelled into the area of capture. A large minnow trap or small seine is placed at the small upstream opening and individuals are removed periodically when the traps are filled. A large mortality is normally incurred in the traps and during transportation.

III. AQUATIC MACROINVERTEBRATE INVESTIGATION

Qualitative samples of aquatic macroinvertebrates were taken seasonally within the study stations to demonstrate the diversity of organisms in the areas of investigation. The organisms were collected with the use of kick screens, seines, and handpicking from stones. All specimens were preserved in 60 percent isopropanol and returned to the laboratory for identification. Keys used in identification were Brown (1976), Burks (1953), Edmunds et al. (1976), Merritt and Cummins (1978), Ross (1944), Schuster and Etnier (1978), Wiggins (1977), and Usinger (1956).

A quantative sample was taken in November, 1977, after intensive stream channelization was observed in several streams. Three samples were taken in similar cobble habitat at each study station with the use of a Surber square-foot sampler. The quantitive samples were biased to organisms inhabiting the shallow gravel and cobble habitats. In addition to the regular study stations, three other stations were sampled to investigate their relative degree of perturbation. The additional stations were (1) lower Roan Creek where large algal mats covered the substrate, (2) lower North Indian Creek below industrial effluents in Erwin, Unicoi County, and (3) Nolichucky River which is heavily affected by mica silt from mining operations in North Carolina. Samples were preserved and identified in the same manner as qualitative samples.

In the analysis of quantitative samples, the data from the richest samples were combined and recorded in Table 21. The data from the poorest sample was discarded and was always the sample which was taken on larger substrate and typified by low numbers and diversity.

Diversity and equitibility indices were calculated utilizing the methods described by Lloyd and Ghelardi (1964) and Weber (1973). Trophic indices were calculated utilizing the formula of Howmiller and Scott (1977). Pollution rating for each group follows that of Weber (1973). High relative diversity and equitability index values and a low trophic index value usually indicate a healthy macroinvertebrate community. These indices are of value in the assessment of water quality when used in association with other information.

CHAPTER IV

RESULTS

I. POPULATION STUDY

1. Relative abundance of fishes in study area streams

The results of the survey of streams within the study area to determine relative abundance of each species are presented in Table 5. The first five columns show the relative abundance of all species collected at the study stations. The following data are from other streams within the study area. A list of collection stations are listed in Table 6.

Campostoma were present in most habitats sampled although the abundance varied considerably between streams. *Campostoma* was normally the most abundant species collected in each sample. The greatest abundance of *Campostoma* occurred in clean stream sections of moderate gradient with a silt-free gravel or rubble bottom and abundant algal growth. Few *Campostoma* were collected in the high gradient streams sections with boulder and large rock substrate. A lower relative abundance also occurred in the lower gradient streams, especially those with increased turbidity and siltation.

A total of 60 species was collected during the study. Two of the largest unimpounded sections of streams, Elk and Watauga rivers above Watauga Reservoir, yielded the greatest diversity with 32 and 30 species, respectively. The other large unimpounded stream, Nolichucky River, had a depauperate ichthyofauna presumably due to mica mining siltation. The streams draining the mountainous counties of Johnson, Carter, and Unicoi showed higher diversities and apparently larger population densities than did the lower gradient streams in Sullivan and Washington counties.

Column 1 and 1a of Table 5 were stations located on Doe Creek, Johnson County. Station 1 was located upstream from a series of five gabion dams constructed beside County Route 2374 as habitat improvement structures for the trout fishery. Station 1a was located downstream from these structures. The gabion dams obstructed the entire width of the stream and channelled the entire stream flow over the middle portion of the dams. A narrow trough in each dam resulted in maintaining high water velocity and accounted for a vertical drop of over a foot.

It was noted that the trout populations were high in all sections of the stream, however, the total fauna was less diverse above the dams. The populations of smaller fishes, especially cyprinids, above the dams were depressed in comparison to populations downstream. During the study, November, 1977, severe flooding removed all of the structures and reopened the channel to upstream movement. Collections made above the dam sites, subsequent to flooding, yielded increasingly larger numbers and sizes of all species.

Numbers of individuals and species present at each study station were recorded monthly. The numbers fluctuated regularly for all species. *Campostoma* were always present and the most abundant fish at all study stations each month. Low numbers were obtained at the North and South Indian Creek stations following channelization. The channelization was accomplished after flooding occurred in November, 1977. *Campostoma* populations reestablished in approximately three months.

Winter collections yielded lower numbers and diversity due to difficulty in capture. Most riffle associated species moved into the deep pools during the winter months, making their capture extremely difficult. During January, 1978, no specimens were taken in the riffles. Approximately five centimeters of anchor ice occurred on the substrate. A water temperature of $-1^{\circ}C$ and air temperature of $0^{\circ}C$ were recorded. Campostoma and other fishes were observed sedentary on the bottom of pools in winter months.

2. Population dynamics of Campostoma anomalum

The results of the populations samples taken in Roan Creek and Elk River from June, 1977 to June, 1978 are presented in Tables 7 - 12. Density and biomass for all species are not available for the June 1977 samples since only Campostoma specimens were returned to the laboratory for analysis. The density, biomass, and percentages are given for each species represented in each sample. Totals for each family are included at the end of each table.

In the Roan Creek samples, Campostoma were always the most dominant fish in density ranging from 28.91 percent to 64.21 percent. Campostoma were also dominant in biomass except in the June 1978 sample in which a spawning aggregation of Moxostoma accounted for a greater biomass. Cyprinid density and biomass dominated all samples.

Campostoma density and biomass were consistantly dominant in the Elk River samples with ranges of 18.64 - 50.37 percent and 39.85 - 42.94 percent, respectively. Cyprinid density and biomass dominated all samples.

An attempt was made during the April 1978 samples to demonstrate the habitat preference of Campostoma and obtain ecological density estimates. The study stations were divided into riffle and pool sections with an additional block net prior to ichthyocide application. Many species demonstrated a definite habitat association such as the riffle-associated darters and pool-associated cyprinids, but Campostoma was shown to be the dominant species in both habitats. It should be emphasized that collection and observation has shown that Campostoma are usually closely associated with the riffle habitats during the warmer, active months and retreat to pools during the colder, sedentary periods of the year.

Estimates of Campostoma population densities are presented in Tables 13 and 14. The fluctuations in numbers and biomass are depicted graphically in Figure 3. It is obvious that the densities fluctuated dramatically between sampling periods and streams. The schooling behavior of Campostoma resulted in only part of an aggregation to be present at any time within a study section and, therefore, making accurate estimates difficult. This is not surprising in view of the schooling behavior of most cyprinids and results obtained from previous cyprinid studies (Williams, 1965; Mann, 1971; Mathews, 1971; Hunt and Jones, 1974).

In Roan Creek, densities ranged from 3143.14 individuals/hectare to 8925.59 individuals/hectare and biomass ranged from 34.16 kilograms/hectare to 114.80 kilograms/hectare. In Elk River, density and biomass ranges were 1474.84 - 8524.90 individuals/hectare and 14.13 - 33.43 kilograms/hectare. Roan Creek generally yielded a larger density with greater biomass. Densities were similar in June samples within the same stream and between streams. Females usually accounted for the largest percentage of the density and biomass per sample. Males accounted for a

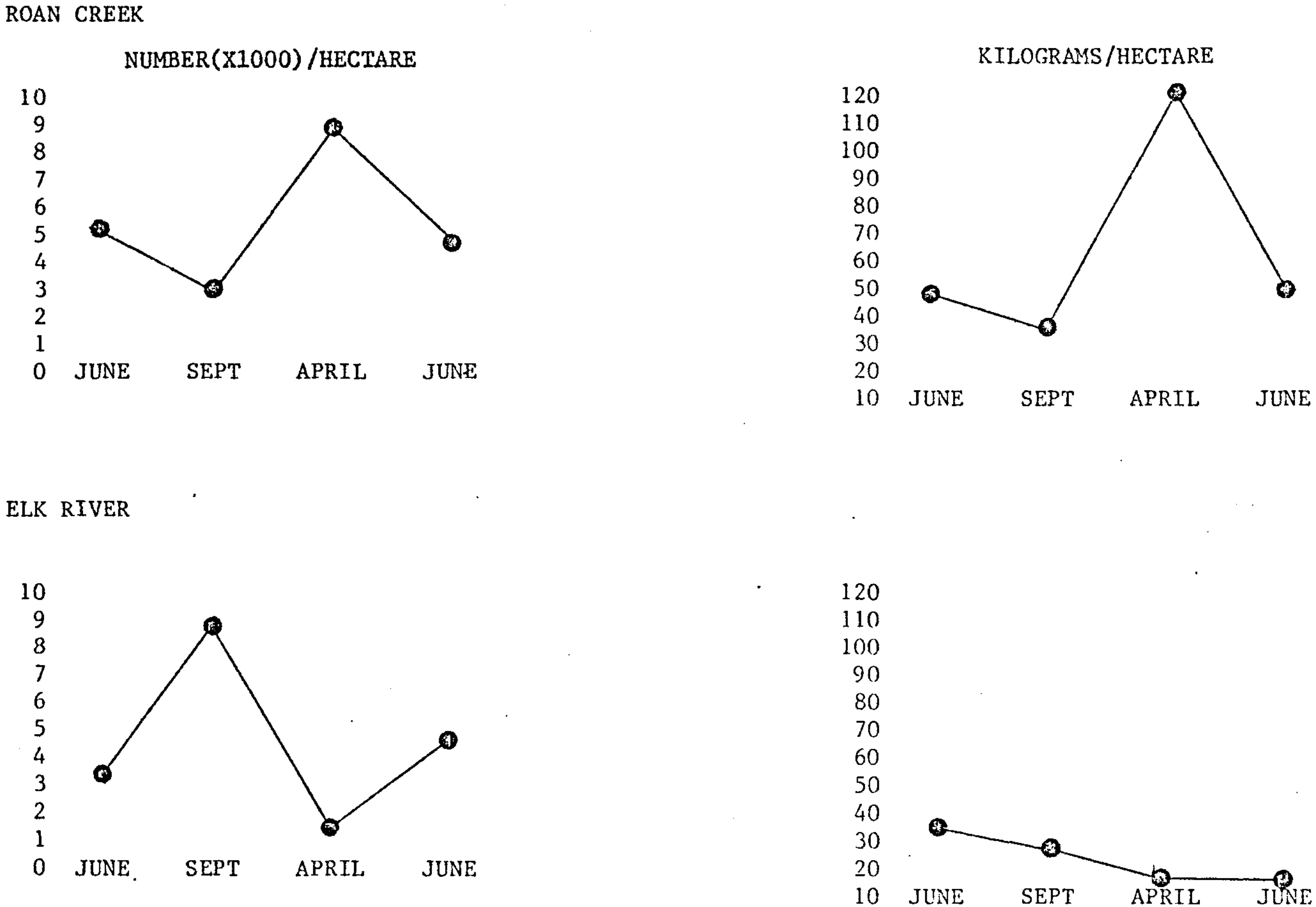

FIGURE 3. CHANGE IN DENSITY AND BIOMASS EACH SEASON AT THE POPULATION STUDY STATIONS: 1977-1978.

greater percentage of the biomass in two of the Elk River samples due to the presence of large age class IV+ males.

By inspection of density and biomass by age class, an interesting perspective may be obtained. Length ranges for each age class were taken from length-frequency data for each sample, accomplished by Burkhead (1979). In Elk River samples, the youngest age classes (I and II) consistently constituted more of the density and biomass per sample with the second age class accounting for much of the biomass. Individuals of age class IV were represented in two of the Elk River samples and accounted for over 30 percent of the biomass. In the Roan Creek samples, individuals of age class IV were significantly less represented, occurring in only one sample. The second and third age classes of the Roan Creek samples constituted much more of the percentage of density and biomass than in Elk River samples.

Instantaneous growth and mortality rates and estimates of annual production are presented in Table 15. Both methods yielded similar results for growth rate and production. Production was probably underestimated in the Elk River data using the Ricker method due to an underestimation of younger fish. Generally, growth and production were higher for all age classes in Roan Creek except for age class IV. The absence of age class IV individuals in most of the Roan Creek samples made estimations for them not possible and suggests that the population size and production of age class IV are low. A higher annual production was estimated in Roan Creek (5.43, 5.72 $g/m^2/yr$) than in the Elk River (2.69, 4.04 $g/m^2/yr$) due to the survival and abundance of younger fish. Mortality rates were higher in the Elk River for the younger age classes than in Roan Creek (Table 15).

II. CREEL SURVEY

The data accumulated from the three-month creel survey yielded many interesting facts about the *Campostoma* fishery. A summary of the results appear in Tables 16 - 19. Although the creel survey was not initiated before the onset of fishing for *Campostoma*, it is obvious that the fishery corresponds to the spawning season.

During April, usually the peak of the spawning season, the sport fishery was quite active with an estimated 3792.0 hours of fishing in the three streams sampled. Approximately 80 percent of the fishermen interviewed were fishing for *Campostoma* and success was 0.86 fish/hour. *Campostoma* was the most important fish in the fishery during this month and only the smaller bait species accounted for a higher catch and success rate. The high catch rate in Elk River was attributed to the large number of small bait fish. These bait species are cyprinids which are more readily caught than *Campostoma* in other seasons. Roan Creek had the highest fishing pressure, most *Campostoma* fishermen, and greatest success. Doe River was second in all categories during April, and Elk River was significantly lower in most categories.

In May, total fishing pressure declined by approximately 85 percent. The number of *Campostoma* fishermen declined to less than 8 percent, and catch rate for *Campostoma* fell to zero. Fishing for rock bass, trout, and bait minnows replaced the *Campostoma* fishery.

Fishing pressure declined slightly from May to June. *Campostoma* were neither fished nor taken. Fishing for trout predominated with increased emphasis on bait fishing. Fishing for rock bass decreased while a slight increase in smallmouth bass fishing was noted.

During the month of April, the creel clerk recorded wing dams, which are utilized by commercial bait fishermen, at several sites along Roan Creek and Doe River. No wing dams were observed at the few access points to Elk River. April was the only month during the creel survey that wing dams were observed. Although the commercial sale of Campostoma had been prohibited, the creel clerk was able to obtain trapping data on three occasions on Roan Creek. On April 1, 1978, two men were interviewed at night who were using eight wing dams and two traps. In a few hours, over 1500 Campostoma were trapped. The same night another man was interviewed. Utilizing one trap for four hours, he captured approximately 200 individuals. On April 7. 1978, one man had trapped over 120 individuals in one trap in a few hours. No fish were returned by the trappers. Approximately 15 percent died before trapping was completed. This mortality did not include mortality during transportation.

III. AQUATIC MACROINVERTEBRATE INVESTIGATION

Data from qualitative and quantitative samples are listed in Tables 20 and 21. Results of qualitative samples show that diversity of organisms in all sampling stations is high in these high gradient, pristine streams. The slight domestic and agricultural pollution in the study streams at the study stations have no great apparent effect on the diversity of organisms. Populations may be slightly increased due to organic enrichment. The Roan Creek and Elk River stations yielded fewer taxa, possibly due to perturbation but, also, to the greater uniformity of substrate. Doe Creek yielded the richest fauna which corresponds to its more diverse ichthyofauna. North and South Indian Creek stations showed similar diversity as expected. A few taxa were not collected during this study which were recorded during a previous study by Etnier et al. (1974, 1975). This may be due to the restricted area of collection during this study.

The quantitive data reveals several interesting aspects of the areas investigated. The Doe Creek station (1) in Table 21 showed the highest number of individuals and taxa. The relatively low diversity and equitability index values were biased due to the large number of hydropsychid larvae. The trophic index value was low as expected. The results suggest that the water quality of the stream is good.

The Roan Creek station (2) in Table 21 yielded very low numbers of individuals and taxa and a high trophic index value. Diversity and equitability index values were moderate. This is surprising in view of the good ichthyofauna. This may be partially explained by the habitat uniformity, especially small substrate size (sand and gravel), at the stream's confluence with Forge Creek.

The Elk River station (4) in Table 21 also showed low numbers of individuals, but higher number of taxa. The diversity and equitability index values were relatively high with a low trophic index value. This suggests good water quality with numbers typical of a more uniform habitat of small substrate.

The North Indian Creek station (5) in Table 21 yielded high numbers of individuals and taxa. As at the Doe Creek station, lower diversity and equitability index values were observed due to the large number of hydropsychid larvae. The trophic index value was low. The water quality and macroinvertebrate populations of North Indian Creek were good although the stream in this area had been channelized during the study.

The South Indian Creek station (6) in Table 21 showed low numbers of individuals and the lowest number of taxa although diversity and equitability index values were high. The trophic index was also relatively high. This was obviously due to the very recent channelization within the stream. This beautiful, pristine stream with alternating riffles and pools was reduced to nearly uniform habitat with high turbidity and siltation.

The three perturbed habitats sampled showed varying degrees of alteration. The lower Roan Creek sample (3) in Table 21, which was taken in an area of huge, green algal mats and scum with a very depauperate ichthyofauna (Table 5, Column 34), yielded an abundant macroinvertebrate fauna. The number of taxa and diversity index value were low, but number of individuals and equitability index value were high. The hydropsychid larvae populations were dominant. The resulting community structure was surmised to be due to the increase of agricultural nutrient input into the stream creating an altered habitat which is optimally utilized by adaptive organisms, while others disappear.

The lower North Indian Creek sample (6) in Table 21 presents results which exhibit extensive stream alteration. The lowest number of individuals was found with a low number of taxa represented. Diversity and equitability index values were the lowest and trophic index value the highest observed. The ichthyofauna at this station was also depauperate (Table 5, Column 44). This portion of the stream was marked by dull, green and brown algal mats and extensive detritus, heavy siltation, and oil floating on the water surface. Uncontrolled industrial effluents in the area most likely contribute to this habitat alteration.

The Nolichucky River sample (8) in Table 21 also demonstrated stream pertubation. Although the diversity and equitability index values were high and the number of taxa moderate, the trophic index value was high and the number of individuals low. Mica mining siltation has depressed aquatic populations in this stream for years (TWRA files, Region IV).

CHAPTER V

DISCUSSION

I. POPULATION STUDY

Population studies of fishes have long been of interest to scientists and, therefore, much knowledge has been accumulated. It is necessary to have an understanding of population densities which occur in various lotic habitats and environments before results have perspective. In most environments, a few species dominate, few are abundant, and a larger number are represented by a few individuals. MacArthur (1957) related this in his broken stick model. Campostoma anomalum is a species which dominates in density in environments of its range in which there is an abundance of preferred habitat.

Total density of fishes usually declines in a downstream direction. However, biomass usually remains approximately constant throughout the longitudinal distributional (Hynes, 1970). Populations of smaller "forage" species yield to the increasing populations of large "rough" and predatory species in a downstream direction. This may vary between habitats, however. The riffle habitats often maintain high densities and diversity in large rivers in the downstream areas.

Data in the literature seems to suggest that total biomass per unit area remains constant longitudinally within a river system, and that there is a general increase in total biomass toward the lower latitudes. However, this is complicated by localized nutrient input and varying environmental conditions. The streams of the present study have a high allocthonous input and, therefore, production and populations are probably higher than in other areas.

Population densities often relay little information if only one standing crop estimate is accomplished on a stream per unit time. Densities of all species are in constant change, especially fishes that move constantly throughout the system. Habitats throughout a stream will rarely produce the same population and production results. All habitats will vary in structure, nutrient input, and environmental conditions resulting in changing population sizes and primary and secondary production per unit area (Hynes, 1970). The differences between habitats are also in constant change. Longitudinal distribution of fishes and correlated habitats within a stream must also be taken into account (Burton and Odum, 1945; Jenkins and Freeman, 1972). Population size of each species changes in different portions of a stream. Cleary and Greenback (1954) stated that in view of changing conditions in streams, it is extremely difficult to define population aspects of many species.

As previously stated, population aspects of lotic species are complicated by the problem of estimating population size. Several methods have been attempted with various results. The assumptions necessary for obtaining estimates of population sizes by methods such as mark-recapture are unrealistic for many lotic species. Recruitment, immigration, and emigration are continuous and largely unpredictable, and the assumption that all fish have an equal probability of being caught is rarely fulfilled. Random movement which occurs in most lotic species, especially cyprinids (Hunt and Jones, 1974), cannot be assumed constant, especially considering environmental conditions, and estimation of immigation and emigration cannot be accurately obtained.

Complete counts taken with the use of ichthyocides have obvious effects even though it has been shown to be the most efficient method for obtaining estimates of all fish within a prescribed area (Boccardy and Cooper, 1963). The population is affected by loss locally even though the entire stream population may be large. It is unrealistic to assume that accurate estimates can be obtained in streams without several unit samples per stream per unit time. Complete removal using an ichthyocide would have extreme effects if sample numbers were large.

In situations where it is possible, the most reliable and accurate estimates for small stream species are obtained by utilizing the DeLury method (1958) or Seber and LeCren method (1967) (Williams, 1965; Mann, 1971; Mathews, 1971). These estimates are accomplished with the use of seines or electrofishing devices where only a percentage of the fish per unit area are removed and all specimens are returned after quick data collection. Estimates utilizing these methods have two distinct advantages: (1) many samples may be obtained per unit time increasing the reliability of the estimates, and (2) the collecting techniques can be utilized under many environmental conditions.

There are difficulties with different techniques. Ichthyocides can only be utilized in area of containment, low water volume, and warm temperatures, and they not only remove the populations under study but affect other aquatic species. Seines have limited utility on extremely rough substrate. Electrofishing devices are often unreliable for several hours use and may be problematic in obtaining samples of fish which have varying susceptibility to this method of capture. With the increase of more reliable electrofishing devices, this technique of capture in rough habitats should prove the most useful and reliable.

Production studies in lotic environments have been quite complicated and prolematic. Hynes (1970) discusses the problems of estimating total stream production and production at each trophic level. He emphasizes that few studies have been complete enough to give an accurate estimation. This is especially evident in primary and secondary production studies in which population sizes, turnover rates, energy transformation, and complexity of trophic levels complicate the results.

Estimates of fish production in lotic environments have also been problematic, but enough data exists for comparative purposes. Allen (1951) showed differences in production between habitats and obtained a small range. Horton (1961) and Mann (1971) showed that production can be different between similar streams. Although total production between streams may be similar, production of any given species may vary. Most lotic production studies have involved trout and show large differences in production. Davis and Warren (1965) demonstrated that maximum fish production was dependent on population size. In their study, the sculpin Cottus perplexus yielded greater production with lower densities. Growth and production may be maximized for the total population, however, the population and yield of large individuals may not be maximized.

In respect to Campostoma anomalum, population densities are highest in streams of good water quality, moderate gradient, and abundant gravel substrate. Stream surveys conducted in the Tennessee River drainage by the Tennessee Valley Authority (T.V.A) show that C. anomalum obtain the highest densities in moderate size streams of moderate gradient. Large streams in the lower gradient areas have smaller populations of C. anomalum (TVA, 1970b, 1971a, 1972, 1973, 1975). Likewise, very high gradient streams of the Blue Ridge province have lower densities of C. anomalum (TVA, 1971b; Lennon, 1960). Streams of similar size, gradient, and substrate on the Cumberland Plateau and Highland Rim have similar, but usually lower, densities of C. anomalum in comparison to data obtained in the present study (TVA, 1970a, 1971a, 1972, 1973, 1975). Lennon (1960) obtained large densities of C. anomalum within the Great Smoky Mountain National Park and defined the areas of highest density. He also collected many specimens of large size.

Since Campostoma is not a carnivore, population growth is not restricted to prey population fluctuations. Since Campostoma exist at such a low trophic level, a population can attain large size on abundant resources available, especially in the absence of or with decreased predation. In the mountainous streams of the present study, large piscivorous predators have low population levels resulting in large populations of "forage fish."

Many factors affect the density of Campostoma within an area. Any disturbance of the food source, the aufwuchs community, or spawning habitat will result in lower density. Removal of stream cover, increase in siltation, and habitat alteration are likely to decrease population densities. Campostoma densities may be increased by nutrient enrichment (Starnes, 1976). Higher densities of Campostoma may also occur following habitat alteration due to the fact that the aufwuchs community may recover faster than the macroinvertebrate community, favoring the rapid increase in Campostoma.

In the results, a difference in density was noted between streams. The heavily fished stream, Roan Creek, usually showed higher densities and biomass than Elk River. However, the absence of large individuals within the Roan Creek population was evident. Growth and production were higher in Roan Creek due to the abundance of young fish.

These differences could be attributed to two major possibilities: (1) the removal of a large number of fish, especially the large spawning males, during the spawning season by commercial fishermen, and (2) natural differences in productivity between the study streams. Inaccurate estimates due to sampling difficulties may account for part of the differences in estimates between streams. It is assumed that the impact of commercial fishing is significant in localized areas even though it is not as extensive as in previous years. Lennon (1960) demonstrated that annual partial removal of Campostoma from a stream caused a decline in population size. The loss of the large individuals in the Roan Creek population has probably resulted in the larger density and biomass of younger age classes. The loss of large numbers of individuals from a localized area would allow recruitment from surrounding areas.

The impact of sport fishing on the fishery is assumed slight due to the small number of individuals taken in comparison to the total stream population. During the fishing season, sport fishermen in Roan Creek remove a maximum of 0.02 fish/m^2, or 2.0 g/m^2. These maximum estimates were calculated utilizing the following assumptions: (1) the maximum catch rate occurred during the entire season sampled, (2) fishing was restricted to the length of stream sampled during the creel survey, and (3) the average weight of fish caught was approximately equal to the mean weight of age class IV individuals. This estimated removal of biomass by sport fishermen is much less than estimated annual production of Campostoma in Roan Creek (Table 15).

II. CREEL SURVEY

It is obvious from the creel survey data, population data, and life history data (Burkhead, 1979) that the sport and commercial fishing pressure corresponds to the spawning period. Unfortunately, it was not possible to have creel data from earlier months and years on the study streams. Sport and commercial fishing was observed in March and the Campostoma fishery was probably very similar to that of April depending on the environmental conditions of the year. There was some sport and commercial fishing in February which is quite dependent on environmental conditions (TWRA creel clerk, pers. comm.).

May is usually the last month of significant spawning activity as correlated to gonadal condition and field observation. Very little fishing for Campostoma occurs during this month. The creel data for June showed no Campostoma fishing. Spawning during this month is usually low.

It is evident that the Campostoma fishery is seasonal. Roan Creek and Doe River incur a high fishing pressure during April, while Elk River has much lower pressure. This is due to the ease of accessibility to the former streams and great inaccessibility to the latter stream. The accessibility yielded the ideal situation for comparison of the populations in the two population study streams, Roan Creek with high pressure and Elk River with low pressure.

Commercial trapping obviously accounts for removal of a large number of individuals within localized areas. Trapping is usually restricted to areas of uniform cobble substrate and, therefore, the impact to the fishery is localized. No data are available on trapping and population densities prior to the laws on commercial sale. In view of the observations by the creel clerk on commercial trapping, the large number of commercial trappers known to operate prior to the elimination of commercial sale of this popular bait species, and the results of the population study, it can be surmised that the commercial impact on the sport fishery for Campostoma was significant previously but localized.

III. EFFECT OF ENVIRONMENTAL ALTERATIONS ON AQUATIC COMMUNITIES

In view of the presented data, it is apparent that much stream alteration has occurred in the area of study, including the mountainous, rural counties. Most species in the streams within the valley counties of Sullivan and Washington showed lower relative abundance. This is due partially to habitat differences but also to massive alteration of the total ecosystem. Removal and alteration of habitat along the streams as well as within has resulted in decreased populations of all organisms.

The most obvious areas of perturbation occurred below industrial point sources of pollution. The problem areas have been recognized and are listed in the Water Quality Management Plans published by the Tennessee Department of Public Health. These basin plans include existing water quality below each point source, the current status of each source, and wastewater permit conditions and criteria (Anon., 1977a,b). Although most of these point sources of pollution are recognized and supposedly legally controlled within limits, their effect on the aquatic communities are still devastating. Water quality standards are still deficient in sound biological criteria. It is beyond the scope of this study to present data on pollution output of industries within the study area, yet a few facts give an indication of stream alterations.

The North Fork Holston River has long been recognized as highly polluted. In 1970, fishing was closed in Virginia due to high mercury levels in fish tissue. The pollutants are the result of mining operations in Saltville, Virginia. Subsequent studies have reported hazardous levels of mercury in fish tissue (TWRA files, Region IV).

On the South Fork Holston River, industries in the City of Kingsport have been responsible for the poorest water quality in the Holston River basin. Tennessee Eastman Company, Department of Defense - Holston Army Ammunition Plant, Mead Corporation, and City of Kingsport Waste Water Treatment Plant are the major sources of pollutants (Anon., 1977b).

Several streams in Bristol, Tennessee and surrounding area in Sullivan County have been investigated by state agencies. These studies reported that most streams in the area are adversely affected by industrial pollution. Several fish kills are also documented (TWRA files, Region IV).

On the Watauga River, industries in the City of Elizabethton have been responsible for much of the depressed aquatic fauna. Studies and reports on file list the effluents of plants operated by Beaunit Fiber and Bemberg, Incorporated, as the major point sources of organic and inorganic pollution. These industries have a listed unsatisfactory status with the Stream Pollution Control Board and are in violation of the Federal Water Pollution Control Act. Municipal sewage of Johnson City is also listed unsatisfactory. The high amount of pollution in the Watauga River has yielded a very depauperate fauna which is evident in the collection made in the lower Watauga River during this study (Table 5, Column 18). At least nine fish kills have been reported in the lower Watauga River since 1955. Two stone companies in Carter County have also been cited as violators (TWRA files, Region IV; Anon., 1977b).

Nolichucky River has been affected by mica mining siltation for several years. Heavy siltation exists from the headwater streams in North Carolina to Davy Crockett Reservoir in Greeneville, Tennessee. The reservoir is presently filled with silt. Downstream from the reservoir, Nolichucky River is a unique stream of good water quality and high diversity of aquatic organisms. A survey accomplished in 1971 by TWRA biologists demonstrated that the aquatic community was depressed up to the effluent of Deneen Mining Company in Micaville, North Carolina on the South Toe River. Collections made during this study yielded low numbers and diversity typical of a perturbed fauna.

Several smaller streams within the study area have reported perturbations. Fish kills resulting from chemical spills, massive releases from effluents, and stream channelization have been reported in North and South Indian Creeks. A study above and below the water treatment plant located on North Indian Creek at stream mile 7 revealed that the aquatic community was disturbed downstream to the mouth. Lower North Indian Creek has been investigated several times due to the perturbations caused by Hoover Ball Division and Clinchfield Railroad (TWRA files, Region IV; Anon., 1977a).

The preceding information emphasizes the impact that man has on the total environment. As long as localized catastrophies occur, aquatic populations are constantly in a state of recolonization and stabilization. The time necessary for repopulation and stabilization is dependent on the type of pollutant and degree of perturbation. With stream perturbations occurring commonly, aquatic populations are continually depressed, especially in accessible areas. This is often unrealized by the sportsmen who question the status of the fishery relative to previous years.

The data presented in the aquatic macroinvertebrate investigation yields some insight into the differences between habitats and the effect that perturbations have on these aquatic environments. The problem observed in lower Roan Creek is common in areas of agricultural nutrient overloading. All populations were disturbed including Campostoma. Some species, including Campostoma, are able to increase population size with various amounts of nutrient input, such as the hydropsychid larvae, while other populations are depressed or removed.

The problem of industrial pollution in lower North Indian Creek is common in many areas and has an obvious effect. All populations of aquatic organisms within that environment were depressed. Chemical pollution is the most devastating and affects all organisms at all trophic levels. Many organisms which are more tolerant to certain pollutants may exist in a disturbed habitat while consumers which are higher in the food web may not be able to shift their food source and are removed.

An interesting observation noted in the perturbed portion of lower North Indian Creek was that species of trichopteran genus Hydropsyche, which were collected in no other sample during the study, appeared as the populations of the species of the closely related genus Symphitopsyche declined.

The effects of channelization have been documented (Elser, 1978; Tarplee et al., 1971; Etnier, 1972). Siltation has the largest effect on most species. In regard to Campostoma, siltation covers their food source on the substrate and may also eliminate oxygen to eggs during incubation in the gravel substrate as occurs in other species (Rasmussen, 1955; Hynes, 1962).

The populations of Campostoma were depressed in much of the study area due to pollutants from various sources. Although many authors have demonstrated the effects of certain pollutants on aquatic populations (Katz and Gaufin, 1953; Allan et al., 1958; Herbert, 1965), pollutants responsible for the decline or removal of populations within the study area have not been identified and studied in most instances. Much research is needed to obtain tolerances of aquatic organisms so that the effect on the aquatic environment will not be so devastating and maximum production may be maintained.

CHAPTER VI

CONCLUSION

In view of the information available and results of this study, it is obvious that populations of Campostoma have been reduced in much of the study area due to various perturbations. The ability of commercial bait fishermen to remove large numbers of individuals within localized areas is evident from the data presented. The impact of the removal of individuals may result in a reduction of large individuals within localized areas. Lennon (1960) demonstrated that Campostoma populations could decline if a large number of individuals were removed annually. The present level of commercial fishing seems to have little effect on the total density and biomass in streams of heavy pressure although there appears to be a smaller number of large adults. However, due to the efficiency of the technique utilized by commercial fishermen, their impact would be more obvious and possibly quite detrimental to the popular sport fishery if their harvest was to attain sizes of previous years.

Loss and destruction of habitat along with other alterations has resulted in a large decrease of all aquatic populations within the study area. These anthropogenic effects have contributed more to the existing conflict than any other factor. The amount of suitable habitats and water quality has been reduced to a few small areas. The conflict between commercial and sport fishing would be decreased if stream perturbations could be controlled to allow an increase in populations.

The effect of habitat improvement structures on the total ichthyofauna must be emphasized. Whenever it becomes necessary to construct structures in a stream, such as the dams in Doe Creek, the total environmental effect should be considered along with the desired effects. "Improving" the habitat for one species can adversely affect other populations as observed in Doe Creek. Assessment of a habitat prior and subsequent to such alteration should be accomplished. Structures altering the entire stream width and flow does affect fish movement and stream populations. Structures should be modified to allow for small fish movement. Obstruction of the entire width of a stream is poor design unless a decrease in small fish populations is desirable. The destruction of the structures in Doe Creek will allow increased population growth of *Campostoma* and the reestablishment of the fishery in the stream.

In the final consideration, the possibility of a controlled harvest by commercial fishermen could be possible if certain regulations were enforced. The *Campostoma* populations are sufficiently large within the area, and the biology of the species is conducive for a coexistence of the commercial and sport fisheries. This can only be maintained by enforcement of regulations and preservation and improvement of water quality. A direct conflict can be avoided by regulation since the preferred bait size is much smaller than the preferred sport fish.

The following are a few management suggestions:

1. Enforcement of a possession limit (75-100) of *Campostoma* during the spawning season;
2. Restriction of the trap size utilized by commercial fishermen (maximum length - 3-4 feet; maximum mesh size - 3/4 inch;

maximum funnel diameter - 1 1/2 inches) and length of wing dams utilized (not to exceed one-fourth to one-half of stream width);

3. Return of all fish over a given length (4-5 inches) by commercial fishermen, decreasing the impact on the sport fishery;
4. An educational campaign directed to commercial fishermen supplying information on correct technique of transportation and holding of bait species;
5. Enforcement of pollution and stream alteration regulations;
6. Periodic assessment of the fishery to assist in maintaining maximum yields and evaluate management techniques.

LIST OF REFERENCES

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Allan, I. R. H., D. W. M. Herbert, and J. S. Alabaster. 1958. "A Field and Laboratory Investigation of Fish in a Sewerage Effluent." Fishery Investigation Series I 6(2): 1-76 HMSO.

Allen, K. R. 1951. "The Horokiwi Stream: A Study of a Trout Population." New Zealand Marine Dept. Fisheries Bull. No. 10. 231 pp.

Anonymous. 1977a. Water Quality Management Plan for the French Broad River Basin. Division of Water Quality Control, Tennessee Dept. of Public Health. 139 pp. + Appendices.

Anonymous. 1977b. Water Quality Management Plan for the Holston River Basin. Division of Water Quality Control, Tennessee Dept. of Public Health. 178 pp. + Appendices.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. A List of Common and Scientific Names of Fishes from the United States and Canada. (Third edition). American Fisheries Society Special Publication No. 6. Washington, D. C. 150 pp.

Bartsch, A. F. 1948. "Biological Aspects of Pollution." Sewerage Works Journal 20: 292-302.

Beck, W. M. 1954. "Studies in Stream Pollution Biology. 1. A Simplified Ecological Classification of Organisms." Quarterly Journal of the Florida Academy of Sciences 17(4): 211-227.

Beck, W. M. 1955. "Suggested Method for Reporting Biotic Data." Sewerage and Industrial Wastes 27(10): 1193-1197.

Boccardy, J. A. and E. L. Cooper. 1963. "The Use of Rotenone and Electrofishing in Surveying Small Streams." Trans. Am. Fish. Soc. 92: 307-310.

Brinley, F. J. 1942. "Biological Studies, Ohio River Pollution Survey. 1. Biological Zones in a Polluted Stream." Sewerage Works Journal 14(1): 147-152.

Brown, H. P. 1976. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U. S. Environmental Protection Agency, Office of Research and Development. Water Pollution Control Research Series 18050 ELD04/72. 82 pp.

Burks, B. D. 1953. The Mayflies or Ephemeroptera of Illinois. Entomological Reprint Specialists. Los Angeles. 216 pp.

Burton, G. W. and E. P. Odum. 1945. "The Distribution of Stream Fish in the Vicinity of Mountain Lake, Virginia." Ecology 26, 182-193.

Burkhead, N. M. 1979. Life History of the Stoneroller Minnow, _Campostoma anomalum_ (Rafinesque), in Upper East Tennessee. M.S. Thesis. University of Tennessee. Knoxville.

Cairns, John Jr. 1974. "Indicator Species vs the Concept of Community Structure as an Index of Pollution." Water Resource Bulletin. Vol. 10. No. 2., Pp. 338-347.

Chapman, D. W. 1965. "Net Production of Juvenile Coho Salmon in Three Oregon Streams. Trans. Am. Fish. Soc. 94, 40-52.

Chapman, D. W. 1971. Production. In: W. E. Ricker. _Methods for Assessment of Fish Production in Freshwaters_. I. B. P. Handbook No. 3. Blackwell Scientific Publications. Oxford. Pp. 199-214.

Cleary, R. E. and J. Greenback. 1954. "An Analysis of Techniques Used in Estimating Fish Populations in Streams with Particular Reference to Large Non-trout Streams." J. Wildl. Man. 18(4): 461-477.

Cooper, G. P. and K. F. Lagler. 1956. "Appraisal of Methods of Fish Population Study - Part III. The Measurement of Fish Population Size." Trans. 21st North Amer. Wildl. Conf. Wildlife Management Institute., Washington, D. C. Pp. 281-297.

Craig, J. F. 1974. "Population Dynamics of Perch, _Perca fluviatilis_ L., in Slapton Ley, Devon." Freshwater Biol. 4: 417-444.

Davis, G. E. and C. E. Warren. 1965. "Trophic Relations of a Sculpin in Laboratory Stream Communities." J. Wildl. Man. 29: 846-871.

Delury, D. B. 1958. "The Estimation of Population Size by a Marking and Recapture Procedure." J. Fish. Res. Bd. Can. 8, 281-307.

Edmunds, G. F., S. L. Jensen, and L. Berner. 1976. _The Mayflies of North and Central America_. University of Minnesota Press. Minneapolis. 330 pp.

Ellis, M. M. 1937. "Selection and Measurement of Stream Pollution." U. S. Bureau of Fisheries Bulletin. 48, 365.

Elser, A. A. 1968. "Fish Populations of a Trout Stream in Relation to Major Habitat Zone and Channel Alterations." Trans. Am. Fish. Soc. 97(4): 389-397.

Eschmeyer, R. W. and O. H. Clark. 1939. "Analysis of the Populations of Fish in the Waters of the Mason Game Farm, Mason, Michigan." Ecology 20(2); 272-286.

Etnier, D. A. 1972. "The Effect of Annual Rechanneling on a Stream Fish Population." Trans. Am. Fish. Soc. 101(2): 372-375.

Etnier, D. A., J. L. Wilson and D. H. Jones. 1974. Corridor Area Aquatic Habitat Study, Appalachian Corridor "B", Washington, Carter, and Unicoi Counties, Tennessee. Phase I: Erwin to Johnson City, Buffalo Creek and North Indian Creek. Transportation Center,, University of Tennessee. Knoxville. 211 pp.

Etnier, D. A., W. C. Dickinson, M. Hughes and D. H. Jones. 1974. Corridor Area Aquatic Habitat Study, Appalachian Corridor "B", Washington, Carter, and Unicoi Counties, Tennessee. Phase II: Erwin to Sam's Gap, South Indian Creek and Sam's Creek. Transportation Center,, University of Tennessee. Knoxville. 112 pp.

Etnier, D. A., W. C. Starnes and B. H. Bauer. 1979. "Whatever Happened to the Silvery Minnow (Hybognathus nuchalis) in the Tennessee River?" Southeastern Fishes Council Proceedings 2(3).

Fitz, R. B. 1968. "Fish Habitat and Population Changes Resulting from Impoundment of Clinch River by Melton Hill Dam." J. Tenn. Acad. Sci. 43(1): 7-15.

Gaufin, A. R. and G. M. Tarzwell. 1952. "Aquatic Invertebrates as Indicators of Stream Pollution." Public Health Report 67. Washington, D. C.

Gaufin, A. R. and G. M. Tarzwell. 1956. "Aquatic Macroinvertebrate Communities as Indicators of Organic Pollution in Lytle Creek." Sewerage and Industrial Wastes 28(7): 907-924.

Gaufin, A. R. 1958. "The Effects of Pollution on a Midwestern Stream." Ohio Journ. Sci. 58: 197-208.

Gerking, S. D. 1962. "Production and Food Utilization in a Population of Bluegill Sunfish." Ecol. Monog. 32: 31-78.

Gerking, S. D. 1967. The Biological Basis of Freshwater Fish Production. Blackwell Scientific Publications. Oxford.

Goodnight, W. H. and T. C. Bjornn. 1971. "Fish Production in Two Idaho Streams." Trans. Am. Fish. Soc. 100(4): 769-780.

Hardeman, W. D., R. A. Miller and G. D. Swingle. 1966. Geologic Map of Tennessee. East Sheet. State of Tennessee. Dept. of Conservation. Division of Geology.

Havey, K. A. 1974. "Population Dynamics of Landlocked Salmon, Salmo salar, in Love Lake, Maine." Trans. Am. Fish. Soc. 103(3): 448-456.

Hocutt, C. H., P. S. Hambrick, and M. T. Masnik. 1973. "Rotenone Methods in a Large River System." Arch. Hydrobiol. 72(2): 245-252.

Herbert, D. W. M. 1965. Pollution and Fisheries. In: G. T. Goodman and J. M. Lambert. Ecology and the Industrial Society. Blackwell Scientific Publications. Oxford. Pp. 173-195.

Horton, P. A. 1961. "The Bionomics of Brook Trout in a Dartmoor Stream." J. Anim. Ecol. 30; 311-338.

Howmiller, R. P. and M. A. Scott. 1977. "An Environmental Index Based on Relative Abundance of Oligochaete Species." J.W.P.C.F. 49: 809-815.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes Region. Cranbrook Institute of Science. Bulletin 26. 213 pp.

Hunt, P. C. and J. W. Jones. 1974. "A Population Study of Barbus barbus (L.) in the River Servern, England." J. Fish. Biol. 6(3): 255-278.

Hynes, H. B. N. 1960. The Biology of Polluted Waters. Liverpool Univ. Press. Liverpool. 202 pp.

Hynes, H. B. N. 1962. "The Significance of Macroinvertebrates in the Study of Mild River Pollution." Biological Problems in Water Pollution. U. S. Public Health Service Report 235. Washington, D. C.

Hynes, H. B. N. 1970. The Ecology of Running Waters. Liverpool Univ. Press. Liverpool. 555 pp.

Jenkins, R. E. and C. A. Freeman. 1972. "Longitudinal Distribution and Habitat of Fishes of Mason Creek, an Upper Roanoke River Drainage Tributary, Virginia." Va. Jour. Sci. 23(4): 194-202.

Jenkins, R. E. and N. M. Burkhead. 1975. "Recent Capture of the Sharp-Head Darter, Etheostoma acuticeps, an Endangered Percid Fish of the Upper Tennessee River Drainage." Copeia, No. 4, 731-740.

Jester, D. B. 1976. Production of Rough or Commercial Fishes in Elephant Butte Lake, New Mexico." Trans. Am. Fish. Soc. 105(2); 222-231.

Johnson, T. L. and R. W. Pasch. 1975. "Improved Rotenone Sampling Equipment for Streams." Proc. Twenty-ninth Ann. Conf. S. E. Ass. Game and Fish Comm. Pp. 46-57.

Jones, J. R. E. 1964. Fish and River Pollution. Butterworth, Inc. Washington. 203 pp.

Katz, M. and A. R. Gaufin. 1953. "The Effect of Sewerage Pollution on the Fish Population of a Midwestern Stream." Trans. Am. Fish. Soc. 82; 156-165.

King, P. B., H. W. Ferguson, L. C. Craig and J. Rogers. 1944. Geology and Manganese Deposits of Northeastern Tennessee. State of Tenn. Dept. of Conservation. Division of Geology Bulletin 52. Nashville.

Lambou, V. W. 1966. Recommended Method of Reporting Creel Survey Data for Reservoirs. Okla. Fishery Res. Lab. Univ. of Okla. Bull No. 4.

Lee, M. L. and M. Williams. 1977. Tennessee Statistical Abstract 1977. (Fourth ed.) Univ. of Tenn. Center for Business and Economic Research. Knoxville.

Lennon, R. E. and P. S. Parker. 1960. "The Stoneroller, Campostoma anomalum (Rafinesque), in Great Smoky Mountains National Park." Trans. Am. Fish. Soc. 89(3): 263-270.

Lloyd, M. and R. J. Ghelardi. 1964. "A Table for Calculating the 'Equitability' Component of Species Diversity." J. Anim. Ecol. 33: 217-225.

Lloyd, M., J. H. Zar and J. R. Karr. 1968. "On the Calculation of Information - Theoretical Measures of Diversity." Am. Midl. Nat. 79(2): 257-272.

MacArthur, R. H. 1957. "On the Relative Abundance of Bird Species," Proc. Nat. Acad. Sci., Washington. 43: 293-295.

Mann, R. H. K. 1965. "Energy Transformations by a Population of Fish in the River Thames." J. Anim. Ecol. 34: 253-275.

Mann, R. H. K. 1971. "The Populations, Growth, and Production of Fish in Four Small Streams in Southern England." J. Anim. Ecol. 40: 155-190.

Mathews, C. P. 1970. "Estimates of Production with Reference to General Surveys." Oikos 21: 129-133.

Mathews, C. P. 1971. "Contribution of Young Fish to Total Production of Fish in the River Thames near Reading." J. Fish. Biol. 3: 157-180.

Merritt, R. W. and K. W. Cummins. 1978. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publ. Co. Dubuque, Iowa. 441 pp.

Oglesby, R. T., C. A. Carlson and J. A. McCann, 1972. River Ecology and Man. Academic Press. New York. 465 pp.

Patrick, R. 1949. "A Proposed Biological Measure of Stream Conditions Based on a Survey of the Connestoga Basin, Lancaster County, Penn." Proc. Acad. Nat. Sci. Phil. 101: 277-341.

Petrosky, C. E. and T. F. Waters. 1975. "Annual Production by the Slimy Sculpin Population in a Small Minnesota Stream." Trans. Am. Fish. Soc. 104(2): 237-244.

Pfeiffer, P. W. 1966. "The Results of a Non-uniform Probability Creel Survey on a Small State Owned Lake." Proc. Twentieth Ann. Conf. S. E. Ass. Game and Fish Comm. Pp. 409-412.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Dept. of Conservation. 343 pp.

Rasmussen, C. J. 1955. "On the Effects of Silage Juice in Danish Streams." Ver. Int. Ver. Limnol. 12; 819-822.

Ricker, W. E. 1958. Handbook of Computations for Biological Statistics of Fish Populations. Bull. Fish. Res. Bd. Can. 119. 300 pp.

Ricker, W. E. (ed.) 1971. Methods for Assessment of Fish Production in Fresh Waters. I. B. P. Handbook No. 3. Blackwell Scientific Publications. Oxford. 348 pp.

Ross, H. H. 1944. The Caddisflies or Trichoptera of Illinois. Entomological Reprint Specialists. Los Angeles. 326 pp.

Schuster, G. A. and D. A. Etnier. 1978. A Manual for the Identification of the Larvae of the Caddisfly Genera Hydropsyche Pictet and Symphitopsyche Ulmer in Eastern and Central North America (Trichoptera: Hydropsychidae). U. S. Environmental Protection Agency. Office of Research and Development. Environmental Monitoring and Support Laboratory. U. S. EPA-600/4-78-060.

Seber, G. A. F. and E. D. LeCren. 1967. "Estimating Population Parameters from Catches Large Relative to the Population." J. Anim. Ecol. 36: 631-643.

Smith, P. W. 1979. The Fishes of Illinois. Ill. Nat. Hist. Surv. Univ. of Ill. Press. Urbana. 314 pp.

Starnes, L. B. 1976. Comparison of Fish and Benthic Faunal Compositions in Polluted Forks of a Mountain River. (Univ. of Tenn. M. S. Thesis). T.W.R.A. Technicial Report No. 77-55 PCAN 0061. 102 pp.

Tanner, J. T. 1978. Guide to the Study of Animal Populations. Univ. of Tenn. Press. Knoxville. 186 pp.

Tarplee, W. H., D. E. Louder and A. J. Weber. 1971. Evaluation of the Effects of Channelization on Fish Populations in North Carolina's Coastal Plain Streams. N. C. Wildl. Res. Comm. Report. 22 pp.

Tennessee Valley Authority. 1970a. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. The Emory River. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 18 pp.

Tennessee Valley Authority. 1970b. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Powell River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 18 pp.

Tennessee Valley Authority. 1971a. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Flint River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 18 pp.

Tennessee Valley Authority. 1971b. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Upper Little Tennessee River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 19 pp.

Tennessee Valley Authority. 1972. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Sequatchie River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 16 pp.

Tennessee Valley Authority. 1973. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Buffalo River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 17 pp.

Tennessee Valley Authority. 1975. Tennessee Valley Streams: Their Fish, Bottom Fauna, and Aquatic Habitat. Duck River Drainage Basin. Division of Forestry, Fisheries, and Wildlife Development. Fisheries and Waterfowl Resources Branch. 21 pp.

Trautman, M. B. 1957. The Fishes of Ohio. Ohio State Univ. Press. Columbus. 683 pp.

Usinger, R. L. 1956. Aquatic Insects of California. Univ. of California Press. Berkeley. 508 pp.

Ware, F. J., W. V. Fish and L. Prevatt. 1972. "Five Year Creel Survey of Two Florida Lakes." Quart. Jour. Fla. Acad. Sci. 35(1): 31-48.

Weber, C. I. (ed.) 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. U. S. Environmental Protection Agency. Office of Research and Development. Environmental Monitoring Series EPA-670/4-73-001.

Wiggins, G. B. 1977. Larvae of the North American Caddisfly Genera (Trichoptera). Univ. of Toronto Press. Toronto. 401 pp.

Williams, W. P. 1965. "The Population Density of Four Species of Freshwater Fish, Roach (*Rutilus rutilus* (L.)), Bleak (*Alburnus alburnus* (L.)), Dace (*Leuciscus leuciscus* (L.)), and Perch (*Perca fluviatilis* L.) in the River Thames at Reading. J. Anim. Ecol. 34: 173-185.

APPENDIX

TABLE 1. COUNTY STATISTICS

County	Population	Population/ Unit Area #/Km^2(#/Mi^2)	% Rural	Area Km^2(Mi^2)	Land Area Km^2(Mi^2)	Inland Water Area Km^2(Mi^2)	Percent Commercial Forest Area	Total Land Area In Farming
Carter	42,575	47.26 (122.4)	71.2	919.45 (355)	901.06 (347.9)	18.39(7.1)	64	23.6
Johnson	11,569	15.21 (39.4)	100.0	774.41 (299)	759.91 (293.4)	14.25(5.5)	65	34.9
Sullivan	127,329	118.96 (308.1)	44.2	1108.52 (428)	1070.45 (413.3)	37.81(14.6)	40	39.0
Unicoi	15,254	31.85 (82.5)	52.6	479.15 (185)	479.15 (185)	--	80	16.8
Washington	73,924	88.22 (228.5)	54.3	846.93 (327)	837.37 (323.5)	9.32(3.6)	29	62.1

Source: Lee and Williams (1977)

TABLE 2. RIVER AND RESERVOIR STATISTICS

RIVER STATISTICS		RIVER					
		N. Fk. Holston	S. Fk. Holston		Watauga		Nolichucky
Drainage Area:	In Sullivan Co.	13.39 (5.17)	1071.51 (413.71)	72.77	46.57 (17.89)	2.69	53.87
	In Washington Co.		114.66 (44.27)	7.79	213.03 (82.25)	12.32	527.32 (203.6)
$Km^2 (Mi^2)$ %	In Johnson Co.		268.89 (103.82)	18.26	529.63 (204.49)	30.64	
	In Carter Co.		17.46 (6.74)	1.19	899.22 (347.19)	52.02	46.13
	In Unicoi Co.				40.17 (15.51)	2.32	461.64 (174.38)
	TOTAL	13.39 (5.17)	1472.52 (568.54)		1728.62 (667.42)		978.97 (377.98)
River Lengths Km(Mi)		8.0 (5.0)	101.4 (63.0)		88.5 (55.0)		53.1 (33.0)

RESERVOIR STATISTICS *	RESERVOIR				
	Ft. Patrick Henry	Boone	S. Holston	Wilbur	Watauga
Area at normal max. pool $Km^2 (Mi^2)$	3.52 (1.36)	17.43 (6.73)	30.67 (11.84)	0.28 (0.11)	26.03 (10.05)
Length of river impounded by reservoir Km(Mi)	S. Fk. Holston 16.7 (10.4)	S. Fk. Holston 28.0 (17.4) Watauga 24.6 (15.3)	S. Fk. Holston 38.13 (23.7)	Watauga 2.9 (1.8)	Watauga 26.2 (16.3)

*Source: T.V.A. Office Engineering Section

TABLE 3. PHYSICAL CHARACTERISTICS OF STUDY STREAMS.
DATA COLLECTED DURING PERIODS OF MODERATE STREAM FLOW

Station	Length Km(mi)	Width* M(ft.)	Mean Gradient M/Km(ft./mi)	Discharge M^3/SEC(ft^3/SEC)	Drainage Area Km^2(mi^2)
Doe Creek	22.4(14)	11.0(36)	20.4(107.1)	1.73 (61.17)	114.7 (44.3)
Roan Creek	49.6(31)	11.0(36)	10.4 (54.8)	1.21 (42.74)	285.2(42.74)
Elk River (In Tenn.)	22.4(14)	12.8(42)	16.3 (85.7)	1.10 (38.85)	75.7 (29.2)
Total	44.8(28)	--	33.9(178.6)	--	120.5 (46.5)
North Indian Creek	28.2(17.5)	7.0(28)	16.2 (85.7)	0.98 (34.58)	156.0 (60.2)
South Indian Creek	25.7(16)	17.7(58)	17.8 (93.8)	3.33(117.65)	209.5 (80.9)

*Mean width at study station.

TABLE 4. SPECIES LIST OF FISH COLLECTED DURING THE STUDY: COMMON AND SCIENTIFIC NAMES

Common Name	Scientific Name
	Petromyzontidae
Ohio lamprey	Ichthyomyzon bdellium (Jordan)
Allegheny brook lamprey	I. greeleyi Hubbs and Trautman
American brook lamprey	Lampetra lamottei (Lesueur)
	Clupeidae
Gizzard shad	Dorosoma cepedianum (Lesueur)
	Salmonidae
Rainbow trout (I)	Salmo gairdneri Richardson
Brown trout (I)	S. trutta Linnaeus
Brook trout	Salvelinus fontinalis (Mitchill)
	Cyprinidae
Central stoneroller	Campostoma anomalum (Rafinesque)
Carp (I)	Cyprinus carpio Linnaeus
Bigeye chub	Hybopsis amblops (Rafinesque)
Blotched chub	H. insignis Hubbs and Crowe
River chub	Nocomis micropogon (Cope)
Golden shiner	Notemigonus crysoleucas (Mitchill)
Warpaint shiner	Notropis coccogenis (Cope)
Common shiner	N. cornutus chrysocephalus (Rafinesque)
Whitetail shiner	N. galacturus (Cope)
Tennessee shiner	N. leuciodus (Cope)
Silver shiner	N. photogenis (Cope)
Rosyface shiner	N. rubellus (Agassiz)
Saffron shiner	N. rubricroceus (Cope)
Mirror shiner	N. spectrunculus (Cope)
Spotfin shiner	N. spilopterus (Cope)
Telescope shiner	N. telescopus (Cope)
Fatlips minnow	Phenacobius crassilabrum Minckley and Craddock
Mountain redbelly dace	Phoxinus oreas (Cope)
Bluntnose minnow	Pimephales notatus (Rafinesque)
Blacknose dace	Rhinichthys atratulus (Hermann)
Longnose dace	R. cataractae (Valenciennes)
Creek chub	Semotilus atromaculatus (Mitchill)
	Catostomidae
White sucker	Catostomus commersoni (Lacepede)
Nothern hogsucker	Hypentelium nigricans (Lesueur)
Black redhorse	Moxostoma duquesnei
Golden redhorse	M. erythrurum (Rafinesque)
Shorthead redhorse	M. macrolepidotum (Lesueur)
	Ictaluridae
Yellow bullhead	Ictalurus natalis (Lesueur)
Channel catfish	I. punctatus (Rafinesque)
Margined madtom (I)	Noturus insignis (Richardson)

TABLE 4. CONT.

Common Name	Scientific Name
	Centrarchidae
Rock bass	Ambloplites rupestris (Rafinesque)
Redbreast sunfish	Lepomis auritus (Linnaeus)
Green sunfish	L. cyanellus Rafinesque
Bluegill	L. macrochirus Rafinesque
Longear sunfish	L. megalotis (Rafinesque)
Smallmouth bass	Micropterus dolomieu Lacepede
Largemouth bass	M. salmoides (Lacepede)
	Percidae
Rainbow darter	Etheostoma caeruleum Storer
Greenside darter	E. blenniodes Rafinesque
Greenfin darter	E. chlorobranchium Zorach
Fantail darter	E. flabellare Rafinesque
Redline darter	E. rufilineatum (Cope)
Tennessee snubnose darter	E. simoterum (Cope)
Swannanoa darter	E. swannanoa Jordan and Evermann
Tangerine darter	Percina aurantiaca (Cope)
Logperch	P. caprodes (Rafinesque)
Gilt darter	P. evides (Jordan and Copeland)
Olive darter	P. squamata (Gilbert and Swain)
	Cottidae
Black sculpin	Cottus baileyi Robins
Mottled sculpin	C. bairdi Girard
Banded sculpin	C. carloinae (Gill)

(I = Introduced)

TABLE 5. FISHES COLLECTED WITHIN STUDY AREA WITH RELATIVE ABUNDANCE IN STATION SAMPLED (NUMBERS CORRESPOND TO LOCALITY DATA ON FOLLOWING PAGES - TABLE 6) I = INTRODUCED; A = ABUNDANT; C = COMMON; UC = UNCOMMON; R = RARE

			STUDY STATIONS									SOUTH FORK HOLSTON										WATAUGA					
	1	1a	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Ichthyomyzon bdellium						UC																						
I. greeleyi				UC																								
Lampetra lamottei				UC	UC																							
Salmo gairdneri (I)	C	C	UC	UC	UC	UC	UC						UC	UC				C						UC				
S. trutta (I)			UC	UC																								
Salvelinus fontinalis																												
Dorosoma cepedianum													UC															
Campostoma anomalum	UC	A	A	A	A	A	A	C	UC	UC	C	UC	A	A	C	A	UC		UC	A		A	A	UC	A	A	A	C
Cyprinus carpio (I)													UC															
Hybopsis amblops		UC	UC	C	UC	UC							C									UC						
H. insignis																												
Nocomis micropogon			UC	C	UC	UC	C	UC					UC	UC								UC			UC		C	
Notemigonus crysoleucas													UC															
Notropis coccogenis			UC	C	UC	UC	C	C	UC				C									UC			C		C	
N. cornutus chrysocephalus			UC					C	C				UC															
N. galacturus			UC	UC		UC	UC					UC															UC	
N. leuciodus			UC	A		A	C															A			A		C	
N. photogenis			UC	C			UC															C			UC			
N. rubellus						UC																						
N. rubricroceus		C	C	C	C	C							UC	C								C			A		C	
N. spectruculus						UC																						
N. spilopterus			UC	UC		UC	C												UC	UC								
N. telescopus			UC	A	C	C	C															A			C			
Phenacobius crassilabrum		UC	UC	UC		UC																C						
Phoxinus oreas															UC													
Pimephales notatus				UC			C						UC															
Rhinichthys atratulus	UC	C	C	UC	C	UC				UC	C	UC		C	C	C	UC			C	C	UC	C	C		C		C
R. cataractae					C	C								C									C		UC	C	UC	
Catostomus commersoni	UC	UC	UC		UC	UC	C					UC	UC		UC	UC												
Hypentelium nigricans	UC	C	C	C	C	C	C	UC	UC	UC	UC	UC	UC	UC	UC			C			UC	C	C			C	UC	UC

TABLE 5. CONT.

	WATAUGA																NOLICHUCKY									
	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Ichthyomyzon bdellium																										
I. greeleyi								UC																		
Lampetra lamottei		UC																	UC							
Salmo gairdneri (I)			C		UC												UC					UC	C	C	UC	C
S. trutta (I)	UC																									
Salvelinus fontinalis																								C		
Dorosoma cepedianum																										
Campostoma anomalum	C	UC	C	A	C	UC	UC	A	A	A	A	C	C	UC	A	UC	UC	C	C	C	A	C	UC		C	
Cyprinus carpio (I)																										
Hybopsis amblops								UC		UC	UC										UC					
H. insignis																	UC									
Nocomis micropogon							UC	UC					UC	UC	UC		UC				UC	UC			UC	
Notemigonus crysoleucas																										
Notropis coccogenis							UC			UC	UC			C	C						UC	C	UC		C	
N. cornutus chrysocephalus										UC		C	UC													
N. galacturus							UC																			
N. leuciodus							UC	A	C	UC				UC	UC		UC				A		UC			
N. photogenis							UC			UC	UC															
N. rubellus													UC		UC						A		UC			
N. rubricroceus			UC	C					C	A	C				C							C				
N. spectrunculus																										
N. spilopterus					UC			C		C			C	C	UC								UC			
N. telescopus		UC	UC				UC		C	UC					C						C					
Phenacobius crassilabrum							UC	UC	UC					UC							UC					
Phoxinus oreas																										
Pimephales notatus								UC		UC			UC		UC						UC					
Rhinichthys atratulus	UC			C	UC	UC				UC	UC	A						C	UC	C			UC	C	C	C
R. cataractae			UC												UC			C	UC	C	UC		UC		UC	
Semotilus atromaculatus										UC	UC	C														
Catostomus commersoni												UC						UC			UC					
Hypentelium nigricans	UC		UC	C			C			C	UC	UC			UC		UC	C			UC	UC			C	

TABLE 5. CONT.

	STUDY STATIONS									SOUTH FORK HOLSTON											WATAUGA							
	1	1a	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Moxostoma duquesnei			UC	UC		UC	UC	UC	UC													UC					UC		
M. erythrurum			UC	UC			UC																						
M. macrolepidotum																													
Ictalurus punctatus												UC																	
I. natalis							UC																						
Noturus insignis (I)							C																						
Ambloplites rupestris			UC	UC		UC		UC			UC		UC					C									UC		
Lepomis auritus (I)					UC		UC	UC																					
L. cyanellus							UC						UC																
L. macrochirus				UC			UC	UC					C		UC			UC											
L. megalotis													UC																
Micropterus dolomieui			UC	UC			UC																						
M. salmoides				UC			UC					UC																	
Etheostoma caeruleum		R																											
E. blenniodes				UC		UC	C	UC														UC					UC		
E. chlorobranchium				UC	UC	C	UC																	UC			UC		
E. flabellare	A	A	A	A		C	UC								C	C	C	UC					UC	C			C	UC	UC
E. rufilineatum			UC	C			UC	UC					C																
E. simoterum		C	UC		C	C			UC		C		C		C		C	UC		A		UC							
E. swannanoa		UC	UC	UC	UC	UC				UC				UC										UC			UC	C	C
E. zonale				UC			UC																						
Percina aurantiaca		UC					UC																						
P. caprodes		UC	UC	C			A			UC																			
P. evides			UC			UC																							
P. squamata							UC																						
Cottus carolinae	C	C												C	UC		C												
C. baileyi	A	A	A	A	C	C	UC							A	UC	C	C				C		C	C		C	C		
C. bairdi								UC				UC	C							C									

TABLE 5. CONT.

	WATAUGA										NOLICHUCKY														
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Moxostoma duquesnei						UC		UC													UC			UC	
M. erythrurum																									
M. macrolepidotum						UC																			
Ictalurus punctatus																									
I. natalis																									
Noturus insignis (I)																									
Ambloplites rupestris														UC										UC	
Lepomis auritus (I)														UC	UC										
L. cyanellus																									
L. macrochirus					UC																				
L. megalotis																				UC					
Micropterus dolomieui														UC						UC					
M. salmoides																									
Etheostoma caeruleum																									
E. blenniodes									UC					C	UC	UC				UC					
E. chlorobranchium			UC																	UC				UC	
E. flabellare			A	C						C															
E. rufilineatum						UC			UC																
E. simoterum			UC							UC				C	UC		C							UC	
E. swannanoa							UC			UC											C	UC		UC	
E. zonale																				UC					
Percina aurantiaca																									
P. caprodes						C	UC								UC										
P. evides																				C					
P. squamata																									
Cottus carolinae																									
C. baileyi	UC		C	C		UC	C			UC				UC		UC	UC	C	C		UC	UC		C	C
C. bairdi		A																							

TABLE 6. LIST OF STATIONS SAMPLED FOR RELATIVE ABUNDANCE OF FISHES

1. Doe Creek above gabion dams from 1.5 Rd. Mi. NE jct. co. rts. 2374-2576 to bridge on St. Rt. 67, Johnson Co. (Prior to flooding)

1a. Doe Creek of Co. Rt. 2374, 0.7 Rd. Mi. NE jct. Co. Rts. 2374-2576, below gabion dams, Johnson Co.

2. Roan Creek at mouth of Forge Creek, off Rts. 34-421, 2.3 air Mi. SSE ctr. Mountain City, Johnson Co.

3. Elk River above second bridge above Watauga reservoir Co. Rt. 2520, 10.2 air Mi. E. ctr. Hampton, Carter Co.

4. North Indian Creek of unnumb. co. rt., 4.0 air Mi. NNE ctr. Erwin, Unicoi Co.

5. South Indian Creek at mouth of Granny Lewis Creek, off rts. 19W-23, 5.7 air Mi. SSW Erwin, Unicoi Co.

6. Watauga River at end of unnumb. co. rt. off Rt. 321, approximately 1.5 stream Mi. below Tn-N.C. state line, (Watson's Islands), 14.6 air Mi. SSW ctr. Mountain City, Johnson Co.

<u>South Fork Holston</u>

7. Reedy Creek at Co. Rt. 2851 bridge in city limits of Kingsport, Sullivan Co. NMB 364.

8. Horse Creek at unnumb. co. rt. bridge at Sullivan Gardens, 5.7 air Mi. SSW. ctr. Kingsport, Sullivan Co. NMB 363.

9. Kendricks Creek off unnumb. co. rt., 5.8 air Mi. WNW Boone reservoir dam, Sullivan Co. NMB 460.

10. Sinking Creek at Rts. 23-36 bridge, 2.3 air Mi. NW Boone reservoir dam, Sullivan Co. NMB 362.

11. Beaver Creek at Thomas bridge, 8.3 air Mi. SW ctr. Bristol, Sullivan Co. NMB 461.

12. Sinking Creek at unnumb. co. rt. bridge, 7.1 air Mi. ENE ctr. Bluff City 4.8 air Mi. SE ctr. Bristol, Sullivan Co., TN. NMB 462.

13. Beaver Dam Creek at mouth of Fagall Branch, 7.2 air Mi. NW ctr. Mountain City, Johnson Co. NMB 466.

14. Beaver Dam Creek at Rt. 421-35 bridge, 7.5 air Mi. WNW ctr. Mountain City, Johnson Co. NMB 465.

15. Laural Creek just off St. Rt. 91, 8.4 air Mi. NNW ctr. Mountain City, Johnson Co. NMB 469.

16. Laural Creek just off St. Rt. 91, 5.2 air Mi. N ctr. Mountain City, Johnson Co. NMB 468.

TABLE 6. CONT.

Watauga

17. Boone Creek at unnumb. co. rt. bridge, 5.7 air Mi. NNW ctr. Johnson City, Washington Co. NMB 458.

18. Watauga River approximately 2 river Mi. below Washington-Carter Co. line off unnumb. Co. Rt., Washington Co. NMB 459.

19. Buffalo Creek at St. Rt. 67 bridge, 4.2 air Mi. SW ctr. Elizabethton, Carter Co. JPB 4-2-78.

20. Buffalo Creek off St. Rt. 67A at unnumb. co. rt. bridge, Carter Co. NMB 440.

21. Doe River on north side of island above bridge on St. Rt. 67 and jct. with Co. Rt. 2515 in Elizabethton, Carter Co. JPB 4-2-78.

22. Laural Fork Creek in Hampton, Carter Co. NMB 431.

23. Laural Fork Creek at unnumb. co. rt. bridge in Dennis Cove, 3.8 air Mi. ESE ctr. Hampton, Carter Co. NMB 430.

24. Doe River just off Rt. 37, just above Hampton at confluence of Little Doe River and Doe River, Carter Co. NMB 381.

25. Little Doe River at Tiger Valley just off St. Rt. 37 at Co. Rt. 2379 bridge, 4.0 air Mi. S. ctr. Hampton, Carter Co. NMB 432.

26. Doe River off St. Rt. 37, 3.8 air Mi. SSE ctr. Hampton, Carter Co. NMB 433.

27. Shell Creek off St. Rt. 37 at unnumb co. rt. bridge, 1.4 air Mi. ESE ctr. Roan Mountain (city), Carter Co. NMB 434.

28. Doe River at Rt. 143 bridge, 2.6 air Mi. SSE Roan Mtn. (city), Carter Co. NMB 435.

29. Watauga River below Wilbur Reservoir at St. Rt. 91 bridge, 3.0 air Mi. E. ctr. Elizabethton, Carter Co. NMB 434.

30. Big Stoney Creek approximately 0.25 air Mi. above confluence with Watauga River, just off St. Rt. 91. Carter Co. NMB 463.

31. Big Stoney Creek at unnumb. co. rt. bridge in Carter, 9.0 air Mi. NE ctr. Elizabethton, Carter Co. NMB 464.

32. Big Dry Run Creek off Co. Rt. 2461 across from Dry Run School, 12.0 air Mi. SW ctr. Mountain City, Johnson Co. NMB 405.

33. Doe Creek just off Rt. 67 at Co. Rt. 2458 bridge, 5.3 air Mi. WSW Mountain City, Johnson Co. NMB 334.

34. Roan Creek off Co. Rt. 2374, 1.3 road Mi. NE jct. off Co. Rts. 2374-2576 8.8 air Mi.. SW ctr. Mountain City, Johnson Co. NMB 475.

TABLE 6. CONT.

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35. Roan Creek at small bridge off Co. Rt. 2374, 2.2 air Mi. E. jct. off Co. Rts. 2374-2576, Johnson Co. NMB 417.

36. Roan Creek off Co. Rt. 2374 behind church, upstream from mouth of Hopper Creek, 8.4 air Mi. SW ctr. Mountain City, Johnson Co. JPB 4-1-78.

37. Roan Creek at Co. Rt. 2461 bridge, 9.4 air Mi. SSW ctr. Mountain City, Johnson Co. NMB 311.

38. Town Creek at mouth of Furnace Creek just off Rt. 421 in Mountain City, Johnson Co. NMB 403.

39. Roan Creek at lower falls off Rt. 34-421, 2.9 air Mi. SE ctr. Mountain City, Johnson Co. NMB 310.

Nolichucky

40. Big Limestone Creek at St. Rt. 2348 bridge, 5.6 air Mi. W ctr. Jonesboro, Washington Co. NMB 365.

41. Limestone Creek at Co. Rt. 2387 bridge, approximately 1.3 stream Mi. above confluence with Nolichucky River, Washington Co. NMB 366.

42. Clarks Creek at confluence with Nolichucky River just off Rt. 107, 9.3 air Mi. SSW Jonesboro, Washington Co. NMB 306, 368.

43. Cherokee Creek at unnumb. co. rt. bridge, 6.2 air Mi. S. ctr. Jonesboro, Washington Co. NMB 367.

44. North Indian Creek approximately 200 yards above confluence with Nolichucky River, Unicoi Co. NMB 472.

45. Scioto Creek at confluence with North Indian Creek at St. Rt. 107 bridge in Unicoi, Unicoi Co. NMB 470.

46. North Indian Creek off unnumb co. rt. off Rt. 107, 5.2 air Mi. NNE ctr. Erwin, Unicoi Co. NMB 297.

47. North Indian Creek just off Rt. 107, 9.4 air Mi. NE ctr. Erwin, Unicoi Co. NMB 471.

48. Nolichucky River at mouth of South Indian Creek at city limits of Erwin, just off Rt. 19W-36, Unicoi Co. NMB 302.

49. Spivey Creek at Rts. 19W-36 bridge, 7.7 air Mi. SSW ctr. Erwin, Unicoi Co. NMB 443.

50. Spivey Creek just off Rt. 19W-36 at unnumb co. rt. bridge 7.9 air Mi. SSW ctr. Erwin, Unicoi Co. NMB 444.

51. Rocky Fork off unnumb. co. rt., 0.25 road Mi. NNW jct. with Rt. 19W Unicoi Co. NMB 361.

TABLE 6. CONT.

52. Devils Fork at unnumb. co. rt. bridge just off U.S. Rt. 23, Unicoi Co. NMB 473.
53. Sams Creek at U.S. Rt. 23 bridge, 1.4 air Mi. S. Flag Pond, 13.0 air Mi. SW Erwin, Unicoi Co. NMB 474

TABLE 7. POPULATION SAMPLE RESULTS. ROAN CREEK, SEPT., 1977. DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Cyprinidae								
Campostoma anomalum	314	3143.14	1272.01	64.21	3412.11	34155.26	30.47	73.66
Hybopsis amblops	15	150.15	60.76	3.07	59.4	594.59	0.53	1.28
Notropis coccogenis	7	70.07	28.36	1.43	99.6	997.00	0.89	2.15
N. galacturus	18	180.18	72.92	3.68	114.5	1146.16	1.02	2.47
N. leuciodus	2	20.02	8.10	0.41	6.3	63.06	0.06	0.14
N. photogenis	1	10.01	4.05	0.20	5.0	50.05	0.04	0.11
N. rubricroceus	20	200.20	81.02	4.09	51.2	512.51	0.46	1.11
N. telescopus	2	20.02	8.10	0.41	8.9	89.09	0.08	0.19
Phenacobius crassilabrum	28	280.28	113.43	5.73	167.8	1679.68	1.50	3.62
Rhinichthys atratulus	27	270.27	109.38	5.52	122.9	1230.23	1.10	2.65
Semotilus atromaculatus	7	70.07	28.36	1.43	30.8	308.31	0.28	0.66
Catostomidae								
Hypentelium nigricans	7	70.07	113.43	5.73	359.3	3596.60	3.21	7.76
Catostomus commersoni	1	10.01	4.05	0.20	8.7	87.09	0.08	0.19
Moxostoma duquesnei	1	10.01	4.05	0.20	3.3	33.03	0.03	0.19
Centrarchidae								
Ambloplites rupestris	1	10.01	4.05	0.20	12.3	123.12	0.11	0.27
Micropterus dolomieui	2	20.02	8.10	0.41	26.7	267.27	0.24	0.58
Percidae								
Etheostoma flabellare	13	130.13	52.66	2.66	29.0	290.29	0.26	0.63
E. rufilineatum	2	20.02	8.10	0.41	9.6	96.10	0.09	0.21
E. simoterum	1	10.01	4.05	0.20	.7	7.01	0.01	0.02
E. swannanoa	12	120.12	48.61	2.45	57.7	577.58	0.52	1.25
Percina caprodes	1	10.01	4.05	0.20	11.8	118.12	0.11	0.25
Cottus bairdi	7	70.07	28.36	1.43	34.5	345.36	0.31	0.74
TOTAL	489	4894.89	1980.94		4632.11	46367.47	41.37	
Cyprinidae	441	4414.41	1786.49	90.18	4078.51	40825.95	36.42	88.05
Catostomidae	9	90.09	36.46	1.84	371.3	3716.72	3.32	8.02
Centrarchidae	3	30.03	12.15	0.61	39.0	390.39	0.35	0.84
Percidae	29	290.29	117.48	5.93	108.8	1089.09	0.97	2.35
Cottidae	7	70.07	28.36	1.43	34.5	345.36	0.31	0.74

TABLE 8. POPULATION SAMPLE RESULTS. ROAN CREEK, APRIL, 1978.
DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
RIFFLE SAMPLE								
Cyprinidae								
Campostoma anomalum	280	9342.68	3780.93	65.12	4399.53	146797.80	130.97	86.45
Phenacobius crassilabrum	38	1267.93	513.13	8.84	250.2	8348.35	7.45	4.92
Rhinichthys atratulus	45	1501.50	607.65	10.47	186.5	6222.89	5.55	3.66
Semotilus atromaculatus	4	133.47	54.01	0.93	14.8	493.83	0.44	0.29
Catostomidae								
Hypentelium nigricans	1	33.37	13.50	0.23	69.9	2332.33	2.08	1.37
Percidae								
Etheostoma flabellare	49	1634.97	661.66	11.40	116.9	3900.57	3.48	2.30
E. rufilineatum	3	100.10	40.51	0.70	12.8	427.09	0.38	0.25
E. simoterum	2	66.73	27.01	0.47	3.2	106.77	0.10	0.06
E. swannanoa	7	233.57	94.52	1.63	33.2	1107.77	0.99	0.65
Cottidae								
Cottus bairdi	1	33.37	13.50	0.23	2.2	73.41	0.07	0.04
TOTAL	430	14347.68	5806.43		5089.23	169810.81	151.50	
POOL SAMPLE								
Cyprinidae								
Campostoma anomalum	255	8441.78	3416.34	50.40	2481.59	82802.47	73.87	58.27
Hybopsis amblops	26	867.53	351.09	5.14	115.4	3850.52	3.44	2.71
Nocomis micropogon	1	33.37	13.50	0.20	51.0	1701.70	1.52	1.20
Notropis coccogenis	7	233.57	94.52	1.38	84.4	2816.15	2.51	1.98
N. cornutus	6	200.20	81.02	1.19	167.1	5575.58	4.97	3.92
N. galacturus	7	233.57	94.52	1.38	44.5	1484.82	1.32	1.04
N. leuciodus	2	66.73	27.01	0.40	8.7	290.29	0.26	0.20
N. photogenis	65	2168.84	877.72	12.85	597.5	19936.60	17.79	14.03
N. rubricroceus	76	2535.87	1026.25	15.02	262.7	8765.43	7.82	6.17
N. telescopus	3	100.10	40.51	0.59	14.4	480.48	0.42	0.34
Phenacobius crassilabrum	20	667.33	270.07	3.95	103.4	3450.12	3.08	2.43
Rhinichthys atratulus	15	500.50	202.55	2.96	60.5	2018.69	1.80	1.42
Semotilus atromaculatus	15	500.50	202.55	2.96	70.9	2365.70	2.11	1.66
Catostomidae								
Hypentelium nigricans	5	166.83	67.52	.99	192.1	6409.74	5.72	4.51
Percidae								
Etheostoma flabellare	1	33.37	13.50	.20	1.7	56.72	0.05	0.04
E. simoterum	2	66.73	27.01	0.40	3.1	103.44	0.09	0.07
TOTAL	506	16883.55	6832.68		4258.99	142108.44	125.79	

TABLE 8. CONT.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
COMBINED SAMPLES								
Cyprinidae								
Campostoma anomalum	535	8925.59	3612.14	57.16	6881.12	114800.13	102.42	73.61
Hybopsis amblops	26	433.77	175.54	2.78	115.4	1925.26	1.72	1.23
Nocomis micropogon								
Notropis coccogenis	7	116.78	47.26	0.75	84.4	1408.07	1.26	0.90
N. cornutus	6	100.10	40.15	0.64	167.1	2787.79	2.49	1.79
N. galacturus	7	116.70	47.26	0.75	44.5	742.41	0.66	0.48
N. leuciodus	2	33.37	13.50	0.21	8.7	145.15	0.13	0.09
N. photogenis	65	1084.42	438.86	6.94	597.5	9968.30	8.89	6.39
N. rubricroceus	76	1267.93	513.13	8.12	262.7	4382.72	3.91	2.81
N. telescopus	3	50.05	20.25	0.32	14.4	240.24	0.21	0.15
Phenacobius crassilabrum	58	967.63	391.60	6.20	353.6	5899.23	5.26	3.78
Rhinichthys atratulus	60	1001.00	405.10	6.41	247.0	4129.79	3.68	2.64
Semotilus atromaculatus	19	316.98	128.28	2.03	85.7	1429.76	1.28	0.91
Catostomidae								
Hypentelium nigricans	6	100.10	40.51	0.64	262.0	4371.04	3.90	2.80
Percidae								
Etheostoma flabellare	50	834.17	337.58	5.34	118.6	1978.65	1.77	1.27
E. rufilineatum	3	50.05	20.25	0.32	12.8	213.55	0.19	0.14
E. simoterum	4	66.73	27.01	0.43	6.3	105.11	0.09	0.07
E. swannanoa	7	116.78	47.26	0.75	33.2	553.89	0.49	0.36
Cottidae								
Cottus bairdi	1	16.68	6.75	0.11	2.2	36.70	0.03	0.02
TOTAL	936	15,615.62	6,319.55		9,348.22	155959.63	139.14	
Cyprinidae	865	14,431.10	5,840.19	92.41	8,913.12	148700.70	132.66	95.35
Catostomidae	6	100.10	40.51	.64	262.0	4371.04	3.90	2.80
Centrarchidae								
Percidae	64	1,067.73	432.11	6.84	170.9	2851.18	2.54	1.83
Cottidae	1	16.68	6.75	.11	2.2	36.70	0.03	0.02

TABLE 9. POPULATION SAMPLE RESULTS. ROAN CREEK, JUNE, 1978.
DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Salmonidae								
Salmo gairdneri	17	408.36	165.26	2.51	103.8	2493.39	2.22	0.64
Cyprinidae								
Campostoma anomalum	196	4708.14	1905.36	28.91	2084.08	50061.97	44.66	12.90
Nocomis micropogon	3	72.06	29.16	0.44	113.9	2736.01	2.44	0.71
Notropis photogenis	6	144.13	58.33	0.88	68.8	1652.65	1.47	0.43
N. rubricroceus	16	384.34	155.54	2.36	33.0	792.70	0.71	0.20
Phenacobius crassilabrum	1	24.02	9.72	0.15	3.7	88.88	0.08	0.02
Rhinichthys atratulus	68	1633.44	661.04	10.03	240.4	5774.68	5.15	1.50
Semotilus atromaculatus	5	120.11	48.61	0.74	89.4	2147.49	1.92	0.55
Catostomidae								
Catostomus commersoni	4	96.08	38.88	0.59	505.3	12137.88	10.83	3.13
Hypentelium nigricans	25	600.53	243.03	3.69	1828.5	43922.65	39.19	11.32
Moxostoma duquesnei	8	192.17	77.77	1.18	8164.8	196127.79	174.98	50.54
M. erythrurum	2	48.04	19.44	0.29	775.0	18616.38	16.61	4.80
Centrarchidae								
Ambloplites rupestris	7	168.15	68.05	1.03	1101.6	26461.67	23.61	6.82
Micropterus dolomieui	3	72.06	29.16	0.44	1260.9	30288.25	27.02	7.81
Etheostoma flabellare	140	3362.96	1360.97	20.65	249.7	5998.08	5.35	1.55
E. simoterum	3	72.06	29.16	0.44	4.1	98.49	0.09	0.03
E. swannanoa	14	336.30	136.10	2.06	51.5	1237.09	1.10	0.32
Cottidae								
Cottus bairdi	160	3843.38	1555.40	23.60	737.0	17703.58	15.79	4.56
TOTAL	678	16286.33	6590.99		16154.58	388051.41	346.21	
Salmonidae	17	408.36	165.26	2.51	103.8	2493.39	2.22	0.64
Cyprinidae	295	7086.24	2867.76	43.51	2633.28	63254.38	56.43	16.30
Catostomidae	39	936.82	379.13	5.75	11273.60	270804.71	241.60	69.79
Centrarchidae	10	240.21	593.56	1.47	2362.50	56749.94	50.63	14.62
Percidae	157	3771.32	1526.23	23.16	305.30	7333.65	6.54	1.89
Cottidae	160	3843.38	1555.40	23.60	737.0	17703.58	15.79	4.56

TABLE 10. POPULATION SAMPLE RESULTS, ELK RIVER, SEPT., 1977. DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Cyprinidae								
Campostoma anomalum	623	8524.90	3449.98	47.34	1936.12	26493.16	23.64	42.24
Hybopsis amblops	37	506.29	204.89	2.81	00.5	1375.21	1.23	2.19
Nocomis micropogon	102	1395.73	564.84	7.75	373.4	5109.47	4.56	8.15
Notropis coccogenis	31	424.19	171.67	2.36	83.0	1135.74	1.01	1.81
N. leuciodus	43	588.40	238.12	3.27	44.8	613.03	0.55	0.98
N. galacturus	10	136.84	55.37	0.76	73.3	1003.01	0.89	1.60
N. photogenis	13	177.89	71.99	0.99	62.2	851.12	0.76	1.36
N. spilopterus	18	246.31	99.68	1.37	64.3	879.86	0.78	1.40
N. telescopus	65	889.44	359.95	4.94	129.1	1766.56	1.58	2.82
Phenacobius crassilabrum	7	95.79	38.76	0.53	4.8	65.68	0.06	0.10
Pimephales notatus	127	1737.82	703.29	9.65	220.6	3018.61	2.69	4.81
Catostomidae								
Hypentelium nigricans	47	643.13	260.27	3.57	657.6	8998.36	8.03	14.35
Moxostoma duquesnei	4	54.73	22.15	0.30	69.9	956.49	0.85	1.53
M. erythrurum	7	95.79	38.76	0.53	28.2	385.88	0.43	0.62
Centrarchidae								
Ambloplites rupestris	8	109.47	44.30	0.61	118.2	1617.41	1.44	2.58
Lepomis macrochirus	8	109.47	44.30	0.61	107.9	1476.46	1.32	2.35
Micropterus dolomieui	11	150.52	60.91	0.84	79.1	1082.38	0.97	1.73
M. salmoides	1	13.68	5.54	0.08	8.7	119.05	0.11	0.19
Percidae								
Etheostoma flabellare	30	410.51	166.13	2.28	46.9	641.76	0.57	1.02
E. blenniodes	8	109.47	44.30	0.61	21.0	287.36	0.26	0.46
E. rufilineatum	1	13.68	5.54	0.08	1.3	17.79	0.02	0.03
E. chlorobranchium	1	13.68	5.54	0.08	2.7	36.95	0.03	0.06
E. swannanoa	6	82.10	33.23	0.46	9.9	135.47	0.12	0.22
Percina caprodes	89	121784	492.85	6.76	213.4	2920.09	2.61	4.66
Cottidae								
Cottus bairdi	19	259.99	105.22	1.44	126.5	1730.98	1.54	2.76
TOTAL	1316	18007.66	7287.60		4583.42	62717.84	55.96	

TABLE 10. CONT.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Cyprinidae	1076	14723.59	5958.56	81.76	072.12	42311.44	37.75	67.46
Catostomidae	58	793.65	321.19	4.41	755.70	10340.72	9.23	16.49
Centraridae	28	383.14	155.06	2.13	313.90	4295.29	3.83	6.85
Percidae	135	1847.29	747.59	10.26	295.20	4039.41	3.60	6.44
Cottidae	19	259.99	105.22	1.44	126.5	1730.98	1.54	2.76

TABLE 11. POPULATION SAMPLE RESULTS. ELK RIVER, APRIL, 1978.
DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
RIFFLE SAMPLE								
Cyprinidae								
Campostoma anomalum	29	882.00	356.94	46.77	322.4	9805.35	8.75	49.41
Nocomis micropogon	2	60.83	2.47	3.23	3.3	100.36	0.09	0.51
Notropis coccogenis	2	60.83	2.47	3.23	2.7	82.12	0.07	0.41
N. leuciodus	2	60.83	2.47	3.23	6.7	203.77	0.18	1.03
N. telescopus	6	182.48	73.85	9.68	14.4	437.96	0.39	2.21
Phenacobius crassilabrum	8	243.31	98.47	12.90	47.4	1441.61	1.29	7.26
Catostomidae								
Hypentelium nigricans	2	60.83	2.47	3.23	90.6	2755.47	2.46	13.89
Centrarchidae								
Ambloplites rupestris	1	30.41	12.31	1.61	85.0	2585.16	2.31	13.03
Percidae								
Etheostoma flabellare	3	91.24	36.92	4.84	5.8	176.40	0.16	0.89
Percina caprodes	6	182.48	73.85	9.68	45.2	1374.70	1.23	6.93
Cottidae								
Cottus bairdi	1	30.41	12.31	1.61	10.9	331.51	0.30	1.67
TOTAL	62	1885.6	763.11		652.5	19844.89	17.71	
POOL SAMPLE								
Cyprinidae								
Campostoma anomalum	67	2037.71	824.65	14.79	787.25	23943.13	21.36	36.61
Hybopsis amblops	65	1976.89	800.03	14.35	132.1	4017.64	3.58	6.14
Nocomis micropogon	34	1034.06	418.48	7.51	86.6	2633.82	2.35	4.03
Notropis coccogenis	15	456.20	184.62	3.31	33.7	1024.94	0.91	1.57
N. leuciodus	79	2402.68	972.35	17.44	113.0	3436.74	3.07	5.25
N. photogenis	25	760.34	307.71	5.52	173.5	5276.76	4.71	8.07
N. spilopterus	17	517.03	209.24	3.75	44.5	1353.41	1.21	2.07
N. telescopus	70	2128.95	861.58	15.45	130.8	3978.10	3.55	6.08
Phenacobius crassilabrum	10	304.14	123.08	2.21	53.6	1630.17	1.45	2.49
Pimephales notatus	25	760.34	307.71	5.52	94.1	2861.92	2.55	4.38
Catostomidae								
Hypentelium nigricans	7	212.90	86.16	1.55	118.8	3613.14	3.22	5.52
Moxostoma duquesnei	1	30.41	12.31	.22	2.9	88.20	0.08	0.13

TABLE 11. CONT.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Centrarchidae								
Ambloplites rupestris	6	182.48	73.85	1.32	199.8	6076.64	5.42	9.29
Percidae								
Etheostoma flabellare	5	152.07	61.54	1.10	10.6	322.38	0.29	0.49
Percina caprodes	25	760.34	307.71	5.52	161.6	4914.48	5.42	9.29
Cottidae								
Cottus bairdi	2	60.83	24.62	0.44	7.6	231.14	0.21	0.35
TOTAL	453	13777.37	5575.63		2150.45	65402.98	58.35	
COMBINED SAMPLES								
Cyprinidae								
Campostoma anomalum	96	1459.63	590.70	18.64	1109.65	16871.67	15.05	39.85
Hybopsis amblops	65	988.29	399.96	12.62	132.1	2008.51	1.79	4.74
Nocomis micropogon	36	547.36	221.51	6.99	89.9	1366.88	1.22	3.23
Notropis coccogenis	17	258.48	104.60	3.30	36.4	553.44	0.49	1.31
N. leuciodus	81	1331.56	498.40	15.73	119.7	1819.98	1.62	4.30
N. photogenis	25	153.83	380.11	4.85	173.5	2637.98	2.35	6.23
N. spilopterus	17	258.48	104.60	3.30	44.5	676.60	0.24	1.60
N. telescopus	76	1155.54	467.64	14.76	145.2	2207.69	1.97	5.21
Phenacobius crassilabrum	18	273.68	110.75	3.50	101.0	1535.65	1.37	3.63
Pimephales notatus	25	380.11	153.83	4.85	94.1	1430.74	1.27	3.38
Catostomidae								
Hypentelium nigricans	9	136.84	55.38	1.75	209.4	3183.82	2.84	7.52
Moxostoma duquesnei	7	106.43	43.07	1.36	2.9	44.09	0.04	0.10
Centrarchidae								
Ambloplites rupestris	1	15.20	6.15	0.19	284.8	4330.24	3.86	10.23
Percidae								
Etheostoma flabellare	8	121.64	49.23	1.55	16.4	249.35	0.22	0.59
Percina caprodes	31	471.34	190.75	6.02	206.8	3144.29	2.81	7.43
Cottidae								
Cottus bairdi	3	45.61	18.46	0.58	18.5	281.28	0.25	0.66
TOTAL	515	7830.32	3168.89		2784.85	42342.25	37.78	
Cyprinidae	456	6933.25	2805.85	88.54	2046.05	31109.17	27.75	73.47
Catostomidae	16	243.27	98.45	3.11	212.30	3227.92	2.88	7.62
Centrarchidae	1	15.20	6.15	0.19	284.80	4330.24	3.86	10.23
Percidae	39	592.98	239.97	7.57	223.2	3393.64	3.03	8.01
Cottidae	3	45.61	18.46	0.58	18.5	281.28	0.25	0.66

TABLE 12. POPULATION SAMPLE RESULTS. ELK RIVER, JUNE, 1978.
DENSITY, BIOMASS, AND PERCENTAGE FOR EACH SPECIES COLLECTED

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Salmonidae								
Salmo gairdneri	1	10.95	4.43	0.12	2.4	26.28	0.02	0.08
Cyprinidae								
Campostoma anomalum	409	4477.78	1812.13	50.37	1290.28	14162.12	12.60	42.94
Nocomis micropogon	41	448.87	181.66	5.05	146.7	1606.09	1.43	4.88
Hybopsis amblops	68	744.47	301.28	8.37	157.0	1718.85	1.53	5.22
Notropis coccogenis	19	208.01	84.18	2.34	58.3	638.27	0.57	1.94
N. leuciodus	56	613.09	248.12	6.90	65.2	713.82	0.64	2.17
N. photogenis	4	43.79	17.72	0.49	18.4	201.45	0.18	0.61
N. spilopterus	1	10.95	4.43	0.12	5.0	54.74	0.05	0.17
N. telescopus	72	788.26	319.04	8.87	121.0	1324.72	1.18	4.03
Phenacobius crassilabrum	4	43.79	17.72	0.49	17.3	189.40	0.17	0.58
Pimephales notatus	19	208.01	84.18	2.34	75.8	829.87	0.74	2.52
Catostomidae								
Hypentelium nigricans	19	208.01	84.18	2.34	427.1	4675.94	4.17	14.21
Moxostoma duquesnei	1	10.95	4.43	0.12	7.6	83.21	0.07	0.25
Centrarchidae								
Ambloplites rupestris	5	54.74	22.15	0.62	267.2	2925.33	2.61	8.89
Moxostoma dolomieui	2	21.90	8.86	0.25	94.9	1038.98	0.93	3.16
Percidae								
Etheostoma blenniodes	4	43.79	17.72	0.49	16.3	178.45	0.15	0.54
E. chlorobranchium	1	10.95	4.43	0.12	1.7	18.61	0.02	0.06
E. flabellare	15	164.22	66.46	1.85	27.8	304.36	0.27	0.93
E. rufilineatum	9	98.53	39.88	1.11	20.3	222.25	0.20	0.68
Percina caprodes	12	131.38	53.17	1.48	69.7	763.08	0.68	2.32
Cottidae								
Cottus bairdi	50	547.41	221.53	6.16	115.2	1261.22	1.13	3.83
TOTAL	812	8889.86	3597.68		3005.18	32901.03	29.35	

TABLE 12. CONT.

	Total Number	Number/ Hectare	Number/ Acre	Percent	Total Weight	Grams/ Hectare	Lbs./ Acre	Percent
Salmonidae	1	10.95	4.43	.12	2.4	26.28	.02	.08
Cyprinidae	693	7587.04	3070.43	85.36	1956.98	21403.33	19.10	65.05
Catostomidae	20	218.96	88.13	2.46	434.7	4759.14	4.25	14.47
Centrarchidae	7	76.65	31.01	.86	362.1	3964.31	3.54	12.05
Percidae	41	448.87	181.66	5.05	135.8	1486.75	1.33	4.52
Cottidae	50	547.41	221.53	6.16	115.2	1261.22	1.13	3.83

TABLE 13. NUMBER AND BIOMASS OF CAMPOSTOMA BY AGE CLASS AND SEX IN THE ROAN CREEK POPULATION SAMPLES: 1977-1978

AGE	MALES NO./ HECTARE	MALES Kg/ HECTARE	MALES $\bar{w}$(g.)	FEMALES NO./ HECTARE	FEMALES Kg/ HECTARE	FEMALES $\bar{w}$(g.)	TOTAL NO./ HECTARE	TOTAL Kg/ HECTARE	TOTAL $\bar{w}$(g.)	SEX RATIO
JUNE 1977										
III	283.55	8.32	29.35	212.67	4.54	21.38	496.22	12.87	25.93	1:0.75
II	378.07	4.41	11.67	1110.59	14.33	12.91	1488.66	18.75	12.60	1:2.44
I	1016.07	5.28	5.20	2292.06	11.39	4.97	3308.13	16.68	5.04	1:2.26
TOTAL	1677.69	18.02	10.74	3615.01	30.28	8.28	5293.01	48.29	9.12	1:2.15
SEPT. 1977										
III	50.05	2.18	43.53				50.05	2.18	43.53	5:0
II	270.27	8.60	31.82	50.05	1.33	26.61	320.32	9.93	31.00	1:0.19
I	420.42	5.46	12.98	970.97	13.40	13.80	1391.39	18.86	13.55	1:2.31
0	610.61	1.51	2.48	770.77	1.67	2.17	1381.38	3.19	2.31	1:1.26
TOTAL	1351.35	17.75	13.13	1791.79	16.41	9.16	3143.14	34.16	10.87	1:1.33
APRIL 1978										
IV	116.78	9.33	79.93				116.78	9.33	79.93	7:0
III	450.45	18.76	41.65	250.25	8.73	34.89	700.70	27.49	39.24	1:0.56
II	784.12	11.36	14.48	3286.62	52.74	16.05	4070.74	64.10	15.75	1:4.19
I	2202.20	8.36	3.79	1835.17	5.52	3.01	4037.37	13.88	3.44	1:0.83
TOTAL	3555.55	47.81	13.45	5538.87	66.99	12.09	8925.59	114.80	12.86	1:2.51
JUNE 1978										
III	216.19	8.24	38.11	192.17	4.73	24.63	408.36	12.97	31.77	1:0.89
II	288.25	3.16	10.97	1441.27	21.21	14.72	1729.52	24.36	14.09	1:5
I	816.72	4.28	5.24	1753.54	8.43	4.80	2570.26	12.71	4.95	1:2.15
TOTAL	1321.16	15.68	11.87	3386.98	34.38	10.15	4708.14	50.06	10.63	1:2.56

TABLE 14. NUMBER AND BIOMASS OF CAMPOSTOMA BY AGE CLASS AND SEX IN THE ELK RIVER POPULATION SAMPLES:1977-1978

AGE	MALES NO./ HECTARE	MALES Kg/ HECTARE	MALES $\bar{w}$(g.)	FEMALES NO./ HECTARE	FEMALES Kg/ HECTARE	FEMALES $\bar{w}$(g.)	TOTAL NO./ HECTARE	TOTAL Kg/ HECTARE	TOTAL $\bar{w}$(g.)	SEX RATIO
JUNE 1977										
IV	115.31	10.12	84.74				115.31	10.12	84.74	
III	129.72	4.14	31.93	14.41	0.31	21.45	114.13	4.45	30.88	9:1.10
II	187.37	2.11	11.28	331.51	3.58	10.81	518.88	5.70	10.98	1:1.77
I	980.11	5.12	5.22	1599.88	8.05	5.03	2579.99	13.16	5.10	1:1.63
TOTAL	1412.51	21.49	15.21	1145.81	11.94	6.14	3358.32	33.43	9.95	1:1.38
SEPT. 1977										
III	13.68	0.51	37.17				13.68	0.51	37.17	1:0
II	13.68	0.30	22.18	191.57	3.44	19.56	205.25	3.75	18.26	1:14.00
I	396.83	2.85	7.17	218.94	1.81	8.25	615.76	4.65	7.56	1: 0.55
0	2928.30	7.18	2.45	4761.90	10.41	2.19	7690.20	17.58	2.29	1:1.63
TOTAL	3352.49	10.83	3.23	5172.41	15.66	3.03	8524.90	26.49	3.11	1:1.54
APRIL 1978										
IV	60.82	5.93	97.55				60.82	5.93	97.55	4:0
III	30.41	0.94	31.00	30.41	0.75	24.70	60.82	1.69	27.85	1:1
II	167.25	1.98	11.83	334.50	4.72	14.12	501.75	6.70	13.36	1:2
I	425.73	1.56	3.67	425.73	0.98	2.30	851.45	2.54	2.97	1:1
TOTAL	684.20	10.42	15.22	790.63	6.46	8.17	1474.84	16.87	11.44	1:1.16
JUNE 1978										
III	10.95	0.29	26.60	10.95	0.23	20.80	21.90	0.52	23.70	1:1
II	109.48	1.36	12.46	197.07	2.09	10.62	306.55	3.46	11.28	1:1.8
I	722.57	3.70	5.18	974.38	4.93	5.06	1696.96	8.67	5.11	1:1.35
0							2452.38	1.48	0.60	
TOTAL	843.00*	5.40*	6.40*	1182.40*	7.25*	6.13*	4477.78	14.13	3.15	1:1.40*

*Immature specimens (age class 0) not included in total.

TABLE 15. INSTANTANEOUS GROWTH RATE(G), ANNUAL PRODUCTION(P), AND INSTANTANEOUS MORTALITY RATE(Z) OF CAMPOSTOMA IN ROAN CREEK AND ELK RIVER FROM JUNE 1977-JUNE 1978

AGE CLASS	G (g/g/yr) RICKER METHOD	G (g/g/yr) MATHEWS METHOD	P ($g/m^2/yr$) RICKER METHOD	P ($g/m^2/yr$) MATHEWS METHOD	Z (n/n/yr)
ROAN CREEK					
IV+	--	--	--	--	--
III-IV	1.12	1.13	0.70	0.73	10.81
II-III	0.92	0.72	1.46	1.14	1.29
I-II	1.03	0.92	2.11	1.63	0.64
0-I	2.29	2.31	1.45	1.93	4.04
TOTAL			5.72	5.43	
ELK RIVER					
IV+	0.14	0.14	0.07	0.07	--
III-IV	1.01	1.00	0.72	0.70	9.58
II-III	0.77	1.03	0.24	0.50	3.17
I-II	0.79	0.76	0.65	1.24	2.13
0-I	2.32	2.30	1.01	1.53	4.61
TOTAL			2.69	4.04	

TABLE 16. FISHING PRESSURE, CATCH RATE, AND SUCCESS ON THREE STREAMS DURING THREE MONTHS OF CREEL SURVEY, APRIL - JUNE, 1978

	April				May				June			
	Roan Creek	Doe River	Elk River	Avg.	Roan Creek	Doe River	Elk River	Avg.	Roan Creek	Doe River	Elk River	Avg.
Estimated fishing pressure in fishermen hours	1856	1232	704	--	224	352	0	--	32	176	224	--
	(Total = 3792)				(Total = 576)				(Total = 432)			
Number of fish caught per hour	1.14	0.87	4.02	1.24	2.61	0.53	--	1.23	0.48	0.27	8.14	1.54
Percent of fishermen successful at interview time	39.44	32.91	6.25	37.34	35.29	26.47	--	29.41	30.0	44.44	100.0	47.83

TABLE 17. PERCENTAGE OF FISHERMEN FISHING FOR EACH TAXON BY MONTH

	April				May				June			
	Roan Creek	Doe River	Elk River	Total	Roan Creek	Doe River	Elk River	Total	Roan Creek	Doe River	Elk River	Total
Salmonidae	4.23	24.05	37.50	15.82	5.88	50.00	0	35.29	70.00	77.78	0	60.87
Campostoma anomalum	91.55	72.15	50.00	79.75	11.76	5.88	0	7.84	0	0	0	0
Semotilus atromaculatus	0	2.53	12.50	1.90	29.41	0	0	9.80	10.00	22.22	25.00	17.39
Other Cyprinidae	0	1.27	0	0.63	0	0	0	0	0	0	50.00	8.70
Moxostoma spp.	2.82	0	0	1.27	5.88	0	0	1.96	0	0	0	0
Ambloplites rupestris	0	0	0	0	35.29	44.12	0	41.18	10.00	0	25.00	8.70
Micropterus dolomieui	1.41	0	0	0.63	11.76	0	0	3.92	10.00	0	0	4.35
Percina caprodes	0	0	12.50	0.63	0	0	0	0	0	0	0	0

TABLE 18. THE STONEROLLER FISHERY BY MONTH AS MEASURED BY INTENT OF FISHERMEN

	April				May				June			
	Roan Creek	Doe River	Elk River	Avg.	Roan Creek	Doe River	Elk River	Avg.	Roan Creek	Doe River	Elk River	Avg.
Interviewed fishermen fishing for stonerollers	65	57	4	--	2	2	0	--	0	0	0	--
Percent of total fishermen fishing for stonerollers	91.55	72.15	50.00	79.75	11.76	5.88	0	7.84	0	0	0	0
Percent of total stonerollers caught by stoneroller fishermen	100.00	96.43	--	98.55	0	0	--	0	--	--	--	--
Stonerollers per hour of stoneroller fishermen	1.04	0.74	0	0.86	0	0	--	0	--	--	--	--
Percent stonerollers in creel of stoneroller fishermen	92.13	91.53	0	83.95	0	0	--	0		--	--	--
Percent of stoneroller fishermen successful at interview time	32.31	28.07	0	29.37	0	0	--	0		--	--	--

TABLE 19. MONTHLY SPECIES COMPOSITION, ACTUAL CREEL DATA

	April				May				June				
	Roan Creek	Doe River	Elk River	Total	Roan Creek	Doe River	Elk River	Total	Roan Creek	Doe River	Elk River	Total	Grand Total
Salmo gairderi	11	13	11	35		4		4		2		2	41
Salmo trutta		8	1	9		2		2					11
*Salvelinus fontinalis		4	4										4
Campostoma anomalum	82	56		138									138
Cyprinus carpio					1			1					1
Semotilus atromaculatus			27	27	75	16		91		6	3	8	17
Other Cyprinidae	2	12		14	1			1					1
Hypentelium nigricans	1	1		2									2
Moxostoma spp.	3	1		4									4
Catostomus commersoni	3	1		4									4
Ambloplites rupestris					4	10		14	1	1	1	3	17
Micropterus dolomieui	1			1	2			2	1			1	4
Percina caprodes			24	24									24
TOTALS	103	92	67	262	82	32	0	114	8	6	69	83	459

*Caught in small tributary.

TABLE 20. AQUATIC MACROINVERTEBRATE INVESTIGATION-QUALITATIVE RESULTS
X=COLLECTED DURING THE STUDY; *=COLLECTED BY ETNIER, 1974-1975.

	1	2	3	4	5
Annelida					
Oligocheata		x			
Arthopoda					
Crustacea					
Astacidae					
Cambarus	x	x	x	x	x
Insecta					
Ephemeroptera					
Siphlonuridae					
Ameletus	x			*	x
Isonychia	x	x	x	x	x
Siphlonurus			x		
Baetidae					
Baetis	x		x	x	x
Pseudocloeon	x	x		x	
Heptageniidae					
Cinygmula					x
Epeorus	x	x	x	x	x
Stenacron	x				
Stenonema	x	x	x	x	x
Leptophlebiidae					
Paraleptophlebia	x			x	
Ephemerellidae					
Ephemerella		x	x	x	x
Caenidae					
Caenis	x				
Baetiscidae					
Baetisca	x			*	x
Ephemeridae					
Ephemera				*	*
Hexagenia				*	
Odonata					
Gomphidae					
Gomphus			x	*	x
Lanthus				x	x
Aeschnidae					
Aeschna			x		
Boyeria	x			x	x
Agrionidae					
Agrion	x			x	x
Cordulegasteridae					
Cordulegaster			x	x	x

TABLE 20. CONT.

	1	2	3	4	5
Plecoptera					
Pteronarcidae					
Pteronarcys	x	x	x	x	x
Peltoperlidae					
Peltoperla	x	x		x	x
Taeniopterygidae					
Brachyptera				*	
Taeniopteryx	x	x	x	x	x
Nemouridae					
Nemoura	x	x			x
Capniidae					
Allocapnia				*	
Perlidae					
Acroneuria	x	x	x	x	x
Paragnetina				x	
Perlodidae					
Isogenus	x	x			x
Isoperla	x	x	x	x	x
Chloroperlidae					
Alloperla					x
Chloroperla					*
Hemiptera					
Corixidae			x		
Gerridae	x	x	x	x	x
Megaloptera					
Corydalidae					
Corydalus cornutus	x			x	*
Nigronia	x		x	x	x
Sialidae					
Sialis			x		x
Coleoptera					
Carabidae				*	
Dryopidae					
Helichus					x
Elmidae					
Stenelmis	x	x	x	x	
Haliplidae					
Haliplus				*	
Hydrophilidae					
Tropisternis				*	
Psephenidae					
Psephenus herricki	x	x	x	x	x
Trichoptera					
Philopotamidae					
Chimarra	x			x	
Dolophilodes	x				x
Polycentropodidae					
Polycentropus				*	
Nyctiophylax	x				x
Hydropsychidae					
Cheumatopsyche	x	x	x	x	x
Diplectrona	x			x	x
Hydropsyche betteni					
H. venularis					

TABLE 20. CONT.

	1	2	3	4	5
Macronema	x				
Symphitopsyche bronta	x		x	x	x
S. cheilonis	x	x	x		
S. morosa	x	x	x	x	x
S. sparna	x	x	x	x	x
Rhyacophilidae					
Rhyacophila	x			x	x
Glossomatidae					
Glossosoma nigrior	x	x	x	x	x
Limnephilidae					
Goera			x		
Neophylax	x			x	*
Pycnopsyche	x	x	x	x	x
Diptera					
Blephariceridae					
Blepharicera				*	*
Chironomidae	x	x	x	x	x
Empididae	x			x	
Rhagionidae					
Atherix variegata	x		x	x	x
Simuliidae					
Simulium	x	x	x	x	
Tanyderidae					
Protoplasa fitchi				*	*
Tipulidae					
Antocha	x	x	x	x	x
Dicronta				*	
Eriocera				*	
Limnophila				*	
Pedicia				*	
Tipula	x		x	x	x
Mollusca					
Gastropoda					
Pleuroceridae					
Ancylidae				x	
Ferrisia					

Station Number	Study Station	Locality Number in Table 6
1	Doe Creek	1a
2	Roan Creek	2
3	Elk River	3
4	North Indian Creek	4
5	South Indian Creek	5

TABLE 21. AQUATIC MACROINVERTEBRATE INVESTIGATION-QUANTITATIVE RESULTS MEAN VALUES OF SURBER SAMPLES TAKEN AT THE STUDY AREAS, ACTUAL NUMBERS COLLECTED

Pollution Rating		1	2	3	4	5	6	7	8
	Annelida								
T	Oligochaeta		2				12		
	Arthropoda								
	Crustacea								
	Astacidae								
I	*Cambarus*			1	1				
	Insecta								
	Ephemeroptera								
	Siphlonuridae								
I	*Isonychia*	58	2	84	3	22			2
	Baetidae								
I	*Baetis*			3					4
I	*Pseudocloeon*	52	11			13			4
	Heptageniidae								
I	*Stenacron*	4							
I	*Stenonema*	78	13	72	52	94	1	9	13
	Leptophlebiidae								
I	*Paraleptophlebia*	19				1			
	Ephemerellidae								
I	*Ephemerella*		2		1	2		3	1
	Caenidae								
F	*Caenis*	2							
	Plecoptera								
	Pteronarcidae								
F	*Pteronarcys*					11			
	Peltoperlidae								
F*	*Peltoperla*					4			
	Taeniopterygidae								
I	*Taeniopteryx*	8	86	3	1	3	2		3
	Nemouridae								
F*	*Nemoura*		4					6	
	Perlidae								
F	*Acroneuria*	3			4				
F*	*Paragnetina*					1			
	Megaloptera								
	Corydalidae								
F	*Corydalus*	1		12		3	2		1
F*	*Nigronia*				1				
	Coleoptera								
	Psephenidae								
	Psephenus	2		1	2			3	
I	Elmidae								
	Stenelmis	9	1		1	6	1		
F	Trichoptera								
	Philopotamidae								
I	*Chimarra*	1				5			
I	*Dolophilodes*	11							
	Hydropsychidae								
F	*Cheumatopsyche*	1344	8	764	206	286	2	211	89

TABLE 21. CONT.

Pollution Rating		1	2	3	4	5	6	7	8
F	*Hydropsyche betteni*						1		
F	*H. venularis*						14		
I	*Macronema*	1							
F*	*Symphitopsyche bronta*	63		9	51	796	2	247	5
F*	*S. cheilonis*	45	1	614	8		3		3
F*	*S. morosa*	42	3	26	32	12	6	25	92
F*	*S. sparna*	76	22	61	7	91		74	97
	Rhyacophilidae								
I	*Rhyacophila*					4			
	Glossosomatidae								
F*	*Glossosoma nigrior*		17		2	9		81	21
	Limnephilidae								
F*	*Goera*				1				
F*	*Pycnopsyche*				1				
	Diptera								
T	Chironomidae	123	228	36	19	21	142	78	107
F	Empididae	3				1			1
	Rhagionidae								
F*	*Atherix variegata*	4				7		6	1
	Simuliidae								
I	*Simulium*	15	8		1	5			4
	Tipulidae								
F*	*Antocha*	60	9	58	34	9	2	10	12
F	*Tipula*					3			
	Mollusca								
	Gastropoda								
F	Pleuroceridae	5			1	6			
	Ancylidae								
T	*Ferrisia*						1		
	TOTAL NUMBER OF INDIVIDUALS	2029	417	1744	429	1415	191	753	460
	TOTAL NUMBER OF TAXA	25	16	14	21	25	14	12	18

	1	2	3	4	5	6	7	8
DIVERSITY INDEX	2.1654	2.2588	2.1236	2.5835	2.2012	1.5992	2.5524	2.8270
EQUITIBILITY INDEX	0.2390	0.4024	0.4140	0.3923	0.2460	0.0201	0.6698	0.5494
TROPHIC INDEX	0.94	1.26	0.94	0.90	0.91	1.80	1.08	1.16

*No pollution rating in literature; therefore, given a rating of F which cancels in the trophic index equation.

Station Number	Station	Locality Number in Table 6
1	Doe Creek Study Station	1a
2	Roan Creek Study Station	2
3	Lower Roan Creek	34
4	Elk River Study Station	3
5	North Indian Creek Study Station	4
6	Lower North Indian Creek	44
7	South Indian Creek Study Station	5
8	Nolichucky River	48

VITA

James Patrick Beets was born on September 2, 1952. He was educated in the town of Morristown, Tennessee, where he graduated from Morristown-Hamblen High School-East in June, 1970. He attended the University of Tennessee and received his B.A. in 1974 with a major in biology.

After spending time traveling and walking the Appalachian Trail from Georgia to Maine in 1975, Mr. Beets worked with the Tennessee Wildlife Resources Agency as a fisheries technician until starting in the Graduate Program in Ecology at the University of Tennessee in 1976. He received his M.S. in Ecology in August, 1979.

While attending graduate school at the University of Tennessee, Mr. Beets was employed as a Research Assistant and assisted in several research projects and contracts at the Aquatic Biology Laboratory. His major academic interests were in aquatic ecology and population biology.

Mr. Beets has an active interest in most outdoor activities. He attributes his academic stimulation to his friends and professors. He attributes all other accumulation of knowledge to friends and allies who have assisted in the perceptions of reality.