To the Graduate Council:

I am submitting herewith a thesis written by Richard T. Bryant entitled "The Life History and Comparative Ecology of the Sharphead Darter, (Etheostoma acuticeps)." 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:

Arthur C. Echternacht

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THE LIFE HISTORY AND COMPARATIVE ECOLOGY OF THE SHARPHEAD DARTER (*ETHEOSTOMA ACUTICEPS*)

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Richard T. Bryant

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I would like to thank four people whose special knowledge of the sharphead darter proved invaluable. Noel Burkhead discovered the population in the South Fork Holston and aided me at the inception of this project. Dr. J. G. Carlson provided his field notes of the first (1930) collection of the sharphead darter. Dr. E. F. Menhinick provided information on his Cane River collections of the fish. Charlie Saylor provided information and discovered the Nolichucky River population which encouraged this study.

My thanks also to Jack Renner and family, who provided access to the Steele Island study site and allowed various bands of fish collectors to traipse upon their land.

ABSTRACT

A study of the sharphead darter, *Etheostoma acuticeps* Bailey, was conducted to determine its life history and competitive feeding relationships with both syntopic darters and other members of the subgenus *Nothonotus*. Information from this and other studies indicate that other *Nothonotus* (*E. maculatum*, *E. camurum*, and *E. rufilineatum*) have similar diets comprised of 66 to 78% Chironomidae and 10 to 24% Baetidae and Simuliidae. In sharp contrast to its relatives, *E. acuticeps* consumes 31% Simuliidae, 30% Baetidae, and only 26% Chironomidae. *Etheostoma blennioides*, a darter syntopic with *E. acuticeps*, consumes 80% Chironomidae, which is a function of the subterminal position of its mouth. Another darter common in *E. acuticeps* habitat, *E. zonale*, eats 47% Chironomidae and 39% Baetidae, which is associated with its plant-loving habits and subterminal mouth. The sharphead darter is unique in its forceps-like mouth, very precise feeding behavior, and preference for fast water over a substrate covered with *Podostemum*.

The sharphead darter breeds from late June until mid-August, making it one of the latest spawning darters. Fecundity varies from 100 eggs per 39-mm female to nearly 300 per 55-mm female. Eggs apparently are buried in sandy substrate next to rocks, as in *E. camurum* and *E. rufilineatum*. Breeding males display aggression by intense color changes and biting other males.

Sharphead darters live to an age of three years, males reaching a maximum standard length of almost 70 mm, while the females only reach

about 55 mm. Sexual maturity is achieved at one year.

Sharphead darters typically inhabit the swiftest portion of riffles, with a surface velocity of 2 m/sec. The substrate is rubble and small boulders 5 to 20 cm in diameter, usually well encrusted with <u>Podostemum ceratophyllum</u>. Depth is commonly 15 to 30 cm. Current distribution of the sharphead darter includes the lower 6 km of the Cane River in North Carolina, the lower Nolichucky River between Davy Crockett and Douglas reservoirs, and possibly the lower kilometer of two of the South Fork Holston River above South Holston reservoir in Virginia.

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INTRODUCTION AND HISTORY

The sharphead darter (*Etheostoma acuticeps* Bailey) is a poorly known percid of the subgenus *Nothonotus*. *Nothonotus* are highly evolved and colorful species of darters, generally inhabiting riffles in medium to large streams. Many *Nothonotus* are sympatric, some riffles supporting as many as 3 or 4 species. The coexistence of such closely related species within a small area seems to violate Gause's (1934) principle of competitive exclusion. This problem has been investigated among other species of *Nothonotus* by Stiles (1972). Lachner (1976) states that the taxonomy of most groups is well known, and that the major emphasis of future research should be on life history studies. The life history of most darters, including the darters in *Nothonotus*, is not known. Therefore, a study of the general life history and competitive interactions of a totally unknown fish such as *Etheostoma acuticeps* is justified. In addition, the ecological requirements, range, and status of *E. acuticeps* have been in question for some time and need to be clarified.

Until October 1975, only 37 specimens of the sharphead darter had ever been collected, and the species was considered to be extinct. The fish was not recognized as a distinct species until 1947, when Reeve M. Bailey found two specimens in the South Fork Holston River in Tennessee. An exhaustive attempt in 1949 to secure additional specimens of the fish prior to the impoundment of South Holston Reservoir resulted in only 4 additional specimens. This indicates that at the type locality, 11 km southeast of Bristol, *E. acuticeps* was an uncommon fish. The description was published by Bailey in 1959. At that time, only these 6 specimens were known, and the only known locality was under 58 m of water.

Work on the subgenus *Nothonotus* in the 1960's by L. W. Knapp and T. Zorach resulted in their independently discovering 4 misidentified collections of *E. acuticeps* totaling 28 specimens (in part, Zorach and Raney, 1967; Zorach, 1972). These collections had been misidentified by Fowler (1936a,b) as *Nothonotus rufilineatus*. The collections had been made in June, 1930 by J. G. Carlson (now a retired professor of Zoology at the University of Tennessee) and T. Kerr in the South Fork Holston River in Tennessee and the North Toe River in North Carolina. Apparently, their North Toe collections were not very exhaustive, as they collected only 6 of the 45 species known in the river. Nevertheless, the collection yielded 7 *E. acuticeps*, indicating a relatively healthy population, in contrast to that of the type locality. The South Fork Holston collections were made 6, 10 to 11 km above, and at, Bluff City, Virginia. These three collections yielded 1, 15, and 5 *E. acuticeps*, respectively. Fowler (1936a) reported on the fish from 10 to 11 km above Bluff City and reported only 9 species, 5 of which were represented by 2 or fewer specimens. This again suggests a small collection, but the 15 *E. acuticeps* included indicates a very healthy population.

The populations at these localities are also undoubtedly extinct. The South Fork Holston localities are either impounded or are tailwaters supporting only cold-adapted fishes such as brown trout (*Salmo trutta*) and sculpins (*Cottus* spp.)(Jenkins and

Burkhead, 1975). The North Toe River has been subject to extensive mica and feldspar siltation from mica strip mining. The sandy silt eliminates the interstitial microhabitat of the darters and may smother their eggs. In recent years, the siltation of the North Toe has been aggravated by highway construction that parallels the river virtually to its headwaters.

Repeated attempts by darter enthusiasts to find the sharphead darter in the Holston system resulted in only 3 specimens being collected by Jenkins and Burkhead (1975). These specimens were taken after an exhaustive effort in the South Fork Holston River, just above the impounded portion of South Holston Reservoir, where there apparently is enough habitat to support a small and extremely tenuous population. As this was the only known viable population of sharphead darters, the outlook for their continued existence was indeed bleak.

In the fall of 1975, however, Charles Saylor, Craig Harned, and a TVA field crew discovered the sharphead darter while looking for snail darters (*Percina tanasi*) in the Nolichucky River (Saylor and Etnier, 1976). Eventually, a large population of *E. acuticeps* was found to occupy at least 51 km of the lower Nolichucky between Davy Crockett and Douglas reservoirs. Davy Crockett Reservoir has acted as a settling basin and protected the lower Nolichucky River from the mica and feldspar tailings that have ruined the North Toe River. In fact, over 77% of the volume of Davy Crockett Reservoir is now silt (TVA, 1972), the dam has been decommissioned, and the "reservoir" is now only a slow stretch in the river. The discovery of such a healthy population led to a much better understanding of the exact microhabitat requirements of the sharphead darter and fueled speculation by Dr. David Etnier that the darter may exist in large, relatively unpolluted tributaries of the Nolichucky.

CHAPTER I

METHODS AND MATERIALS

I. STUDY SITE

The main objectives of this study required the collection of a representative number of *E. acuticeps* and all associated darters on about a monthly basis over a period of at least a year. The first objective was to find a riffle supporting a large population of *E. acuticeps*, in order not to deplete them significantly over the course of the study. A riffle in the east channel of the Nolichucky River at Steele Island was selected. Two persons working a 3-m seine could consistently collect at least ten sharphead darters per seine haul, indicating what must be an excellent habitat for this species. In addition, two other members of the subgenus *Nothonotus*, *E. camurum* and *E. maculatum*, were found on this site, although in much fewer numbers. Most of this study, especially as related to food habits, was centered on this site in order to provide continuity. Many other sites were collected, however, in order to determine the various combinations of species with which *E. acuticeps* is associated, and its exact range, habitats, and abundance.

II. COLLECTIONS

The method of collection varies from 4 persons working a 4-m seine to 1 person kicking into a 450-cm dip net. All nets used were ¼" (6 mm) mesh. Darters inhabiting riffles are generally easily captured due to the nature of their habitat. Merely dislodging the rubble and boulders by kicking causes the darters to be swept, or to flee, downstream into an awaiting net. Because sharphead darters characteristically inhabit swift water, a primary problem is the inability to hold a net in place during periods of high discharges. Fortunately, TVA has a gauging station on the Nolichucky at Embreeville, and the daily discharges are available by way of a pre-recorded telephone message. This proved invaluable, as the Nolichucky is known for periods of high water that are not at all predictable on the basis of Knoxville weather. It was generally found that a reading of 1500 cubic feet per second (cfs) at the Embreeville station was associated with the highest workable discharge. The low water of late summer was generally 300 to 500 cfs and the highest water during the study was in November, 1977, when the station at Davy Crockett recorded a peak of 81,200 cfs.

All fish to be preserved were placed in 10% formalin for a week, rinsed for several days, then stored in 40% isopropyl alcohol. Breeding fish kept for photographs were kept in the formalin with a few crystals of ionol, which aided slightly in color preservation. Darters brought back alive were kept in styrofoam coolers containing a few rocks for cover. A rough limit of 25 fish per species was collected per sample, in order to prevent depletion at the study site.

III. HABITAT

When Etheostoma acuticeps is the dominant darter at a locality, they seem to occupy virtually every type of current regime and a wide range of substrates. Although their preferred habitat is normally the swiftest portion of a riffle, they may be found in sluggish eddies with pool darters, such as E. simoterum and E. jessiae. Depth and substrate varied from 6 cm over gravel bars to 60 cm over large boulders. Perhaps the most meaningful description of their habitat is to measure not the full range of occupied habitats, but the habitat where E. acuticeps is found to be densest.

The current speed was measured by timing a floating object through a premeasured distance. Although some researchers have measured current velocity a certain distance above the substrate, this seems arbitrary in regard to the sharphead darter. These darters usually live either between or under boulders 9 to 25 cm in diameter, and are sheltered from the current. Measuring current velocity where the darters actually live is therefore next to impossible.

Measurements of substrate size and depth were made with steel ruler or yardstick, as depth was usually moderate. Water temperature was measured occasionally with an armored thermometer. All distances, altitudes, and gradients were calculated from USGS 7.5 minute quadrangle maps. In the interest of simplicity, localities were listed in river mileages.

Aquatic macrophytes were identified using Hotchkiss (1972) and Weldon, Blackburn, and Harrison (1973).

IV. FEEDING RELATIONSHIPS

This study is limited to darter species that share the same microhabitat as E. acuticeps. In order to obtain data on seasonal changes in food habits, fish were collected on a monthly basis, when-ever possible. The darters were preserved and their stomachs were not removed until the contents were to be analyzed. A slit on the right side from the anus to the breast allowed access to the entire alimentary tract, which was removed and separated into foregut and hindgut. Food data on the foregut and hindgut were kept separately in order to study food habits relative to time of day, and relative rates of digestion of the different taxa of food items. The gut contents of each fish were kept separate in case verification of prey identification was needed. The guts were slit lengthwise and the contents removed using #5 Peer jewelers forceps. The items were examined under an Olympus dissecting microscope, which allowed variable magnification from 7 to 60X. Identified items were stored in 70% isopropyl alcohol. Sources of information used in identifying the various taxa of food items included Usinger (1956), Pennak (1953), Ross (1944), Edmunds, Jensen and Berner (1976), Wiggins (1977), and Schuster and Etnier (1978). Although later authors have placed Ephemerella in its own family, Ephemerellidae, the classification scheme used in Usinger (1956) was used, in which Ephemerella, Baetis, and other genera are included in the family Baetidae. This is to facilitate direct comparisons with Stiles (1972), in which the earlier classification was used and identification was to the family level. Notes were also kept on non-food gut contents, such as sand and plant matter.

To provide baseline data on food availability, samples of benthic fauna were made with a Surber sampler. The sampler is most effective at high current velocity and a depth of only 20 or 25 cm. Its use was therefore limited to shallower E. acuticeps habitat. The sampler consists of two square foot frames, one to delineate a square foot of substrate with the net facing upstream such that invertebrates dislodged from within the sampling area are washed into the net. Rocks and plants from within the sample area are held in the mouth of the net, scrubbed free of invertebrates, and discarded. After the area is completely cleaned, the net contents are preserved in 70% isopropyl alcohol.

V. REPRODUCTION AND BEHAVIOR

To determine the extent of the breeding season, notes were kept on the color of the males and the size of the abdomen of females at the time of capture, as well as whether or not sperm or eggs could be elicited by gentle pressure on the abdomen of the fish. In addition, gonads of both sexes were removed at the same time as the alimentary tract. Ovaries were weighed on a Sartorius balance after excess liquid was blotted off. Ovarian weights were graphed versus the standard length of the fish for several months of the year, both at the peak of the breeding season and during the winter. Condition of the testes was also noted.

Fecundity was investigated by the dissection of several ovaries at the peak of the breeding season. Both ovaries were dissected if they appeared to be of different sizes, whereas if they were the same size, one was dissected and the results doubled in order to preserve one ovary. Eggs were divided into three groups and counted. The most mature eggs were large and yellowish. The second class of eggs were white and in a wide range of sizes. These were apparently in the process of maturing and would have matured in the breeding season during which the fish were captured. The third class were quite numerous, extremely small, and were not counted. Therefore, a total of the first two groups is assumed to represent the number of eggs that would be deposited in that breeding season. Number of mature and maturing eggs was graphed versus standard length of the fish.

On only a single date during the course of the study were darter eggs collected in _E. acuticeps_ habitat. These eggs were collected in the same manner as the fish: violent kicking of the substrate immediately upstream of the net. The eggs were always found in the same seine haul with breeding male and female _E. acuticeps_ and were collected late enough in the season (11 August, 1977) to indicate that they were _E. acuticeps_ eggs.

Fertilized eggs of both _E. acuticeps_ and _E. rufilineatum_ were also obtained by squeezing the eggs and sperm from ripe fish into a small watchglass. After allowing the sperm-rich fluid to mix with the eggs for several minutes, the eggs were transferred to a larger container.

All of the eggs were dept in shallow, well-aerated dishes filled with a mixture of Nolichucky River water and distilled water. A small amount of methelene blue was added and the water changed daily to retard fungus. The developing embryos were checked twice daily under the dissecting microscope to remove any fungus or dead eggs and to make detailed notes of their characteristics and development.

Observations of sharphead darter behavior were attempted by three methods. The most direct and accurate observations of other species of darters are usually made in their natural habitat. Unfortunately, snorkeling in the Nolichucky River was never successful, as the river is turbid at almost all times of the year, apparently as the result of agricultural runoff. In addition, the current velocity in E. acuticeps microhabitat made snorkeling virtually impossible. Even when conditions were acceptable, the darters were hard to find because of their hiding among deep accumulations of boulders. When a fish was found, it was so close to the observer that it usually fled.

A raceway in a small spring similar to that used by Howell (1971) was constructed. The clear water permitted unobstructed viewing. Unfortunately, E. acuticeps is too small a fish to allow detailed observations at this distance (at least 1 m), the current speed is unnaturally slow, and the type of substrate in which the darters naturally occur was not possible to duplicate. The first group of fish placed in the raceway disappeared, apparently eaten by belted kingfishers, Megaceryle alcyon. Before the next breeding season the raceway was destroyed by vandalism.

The only method that permitted any success was observation of of the fish in aquaria. This method involves many artifacts and the darters probably exhibit very little of their natural behavior in such an unnatural setting. Darters were kept all year in hopes they would develop and breed normally during the summer without the shock of acclimatization. Darters from the Nolichucky that were in the height of spawning condition were also brought back and put in aquaria. Photographs were taken of their behavior, to document the characteristic color changes. The aquaria had realistic sandy substrate overlain with large rocks. One aquarium had a water pump to provide a current. Rocks encrusted with Podostemum were brought in, but the plants died immediately.

VI. AGE AND GROWTH

In order to age the fish, five complete and undamaged scales were taken from each fish just below the lateral line near the tip of the pectoral fin. The scales were pressed between two glass slides, which were taped together at the ends. They could then be examined easily at 60, 80, and 100X under an Olympus SZ dissecting microscope, an Eberbach 2700 scale reader, and an Olympus BH compound microscope, respectively. Scales examined were from January, April, July, and October.

For growth studies, all E. acuticeps collected in the study were measured and sexed. Those whose gonads were not mature were classified as juveniles. Males and females were analyzed separately, to take into account possible differences in growth rates, and juveniles were included with both sexes. Standard lengths were broken into 2-mm increments and histograms drawn for the number of darters in each size class. In addition, the standard length of each fish was plotted versus date of its capture in an attempt to show the different year classes and rates of growth.

CHAPTER II

FEEDING RELATIONSHIPS

Food items were compared on a numerical, rather than volumetric or caloric basis. This was basically done in order to make the results directly comparable to other works on darter diets, notably Stiles' (1972) study of E. maculatum, E. camurum, and E. rufilineatum. This was especially important because of the paucity of other Nothonotus at the study site to compare with E. acuticeps. Numerical analyses are misleading in that they assign equal importance to a large food item, such as an Isonychia, and to a small food item, such as a Chironomidae. For the purposes of this study, however, volumetric or caloric comparisons may have been even more misleading due to the extreme disparity in the rates at which certain food items are digested. Ephemeroptera disappear rapidly, and were infrequently found in the hindgut, whereas Chironomidae head capsules digest very little and were obvious throughout the entire length of the gut. Although interspecific differences in diet are more noticeable among adults, stomachs of fish of all sizes were included in results in order to more accurately depict true feeding habits of the entire population.

Figures 1 through 16 include results of analyses of both stomach and Surber samples. Only stomach analyses for E. acuticeps, E. blennioides, and E. zonale are presented, as only a few specimens of E. maculatum and E. camurum were captured. Graphs were drawn for the 4 most important prey items, which usually accounted for at least 90%

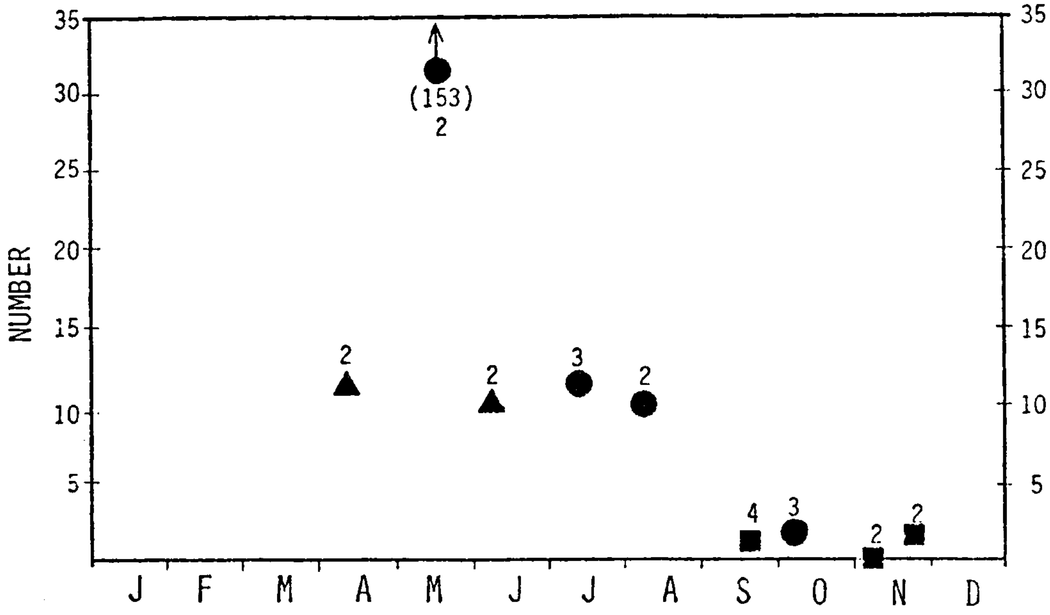

Figure 1. Average numbers of Chironomidae larvae per square foot. Numbers in body of graph indicate number of Surber samples.

■ = 1976 ● = 1977 ▲ = 1978

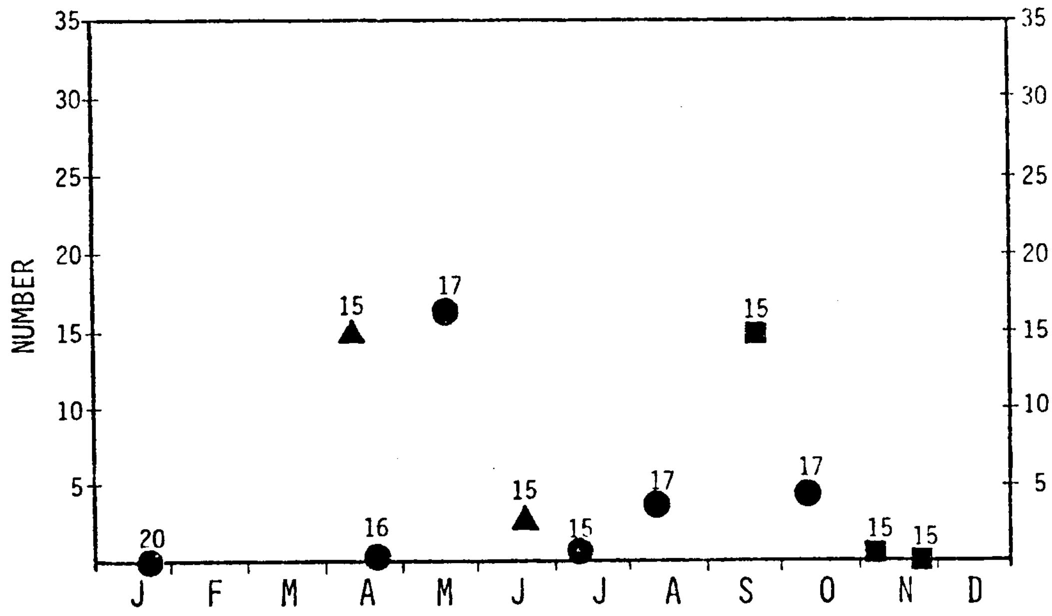

Figure 2. Average numbers of Chironomidae per *E. acuticeps* stomach. Numbers in body of graph indicate number of stomachs examined.

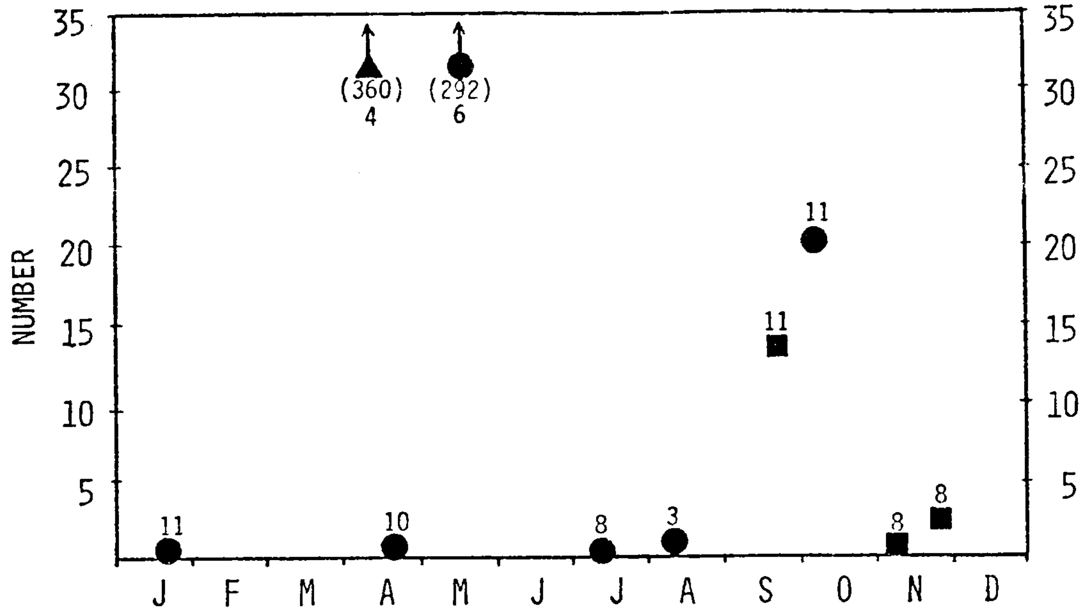

Figure 3. Average numbers of Chironomidae per E. blennioides stomach. Numbers in body of graph indicate number of stomachs examined.

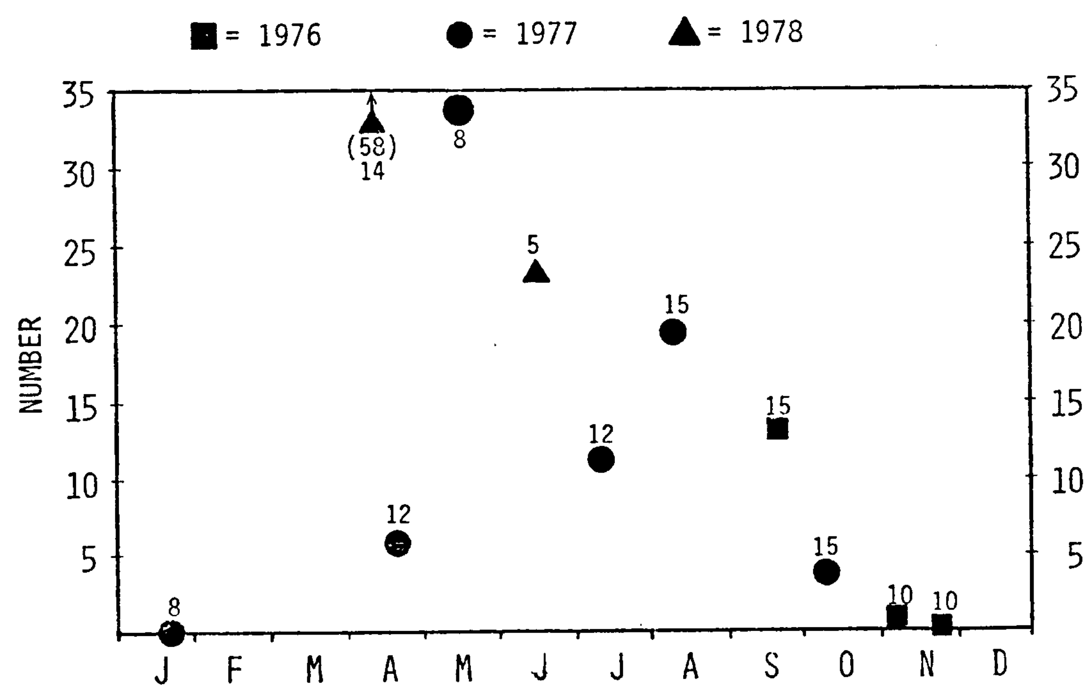

Figure 4. Average numbers of Chironomidae per E. zonale stomach. Numbers in body of graph indicate number of stomachs examined.

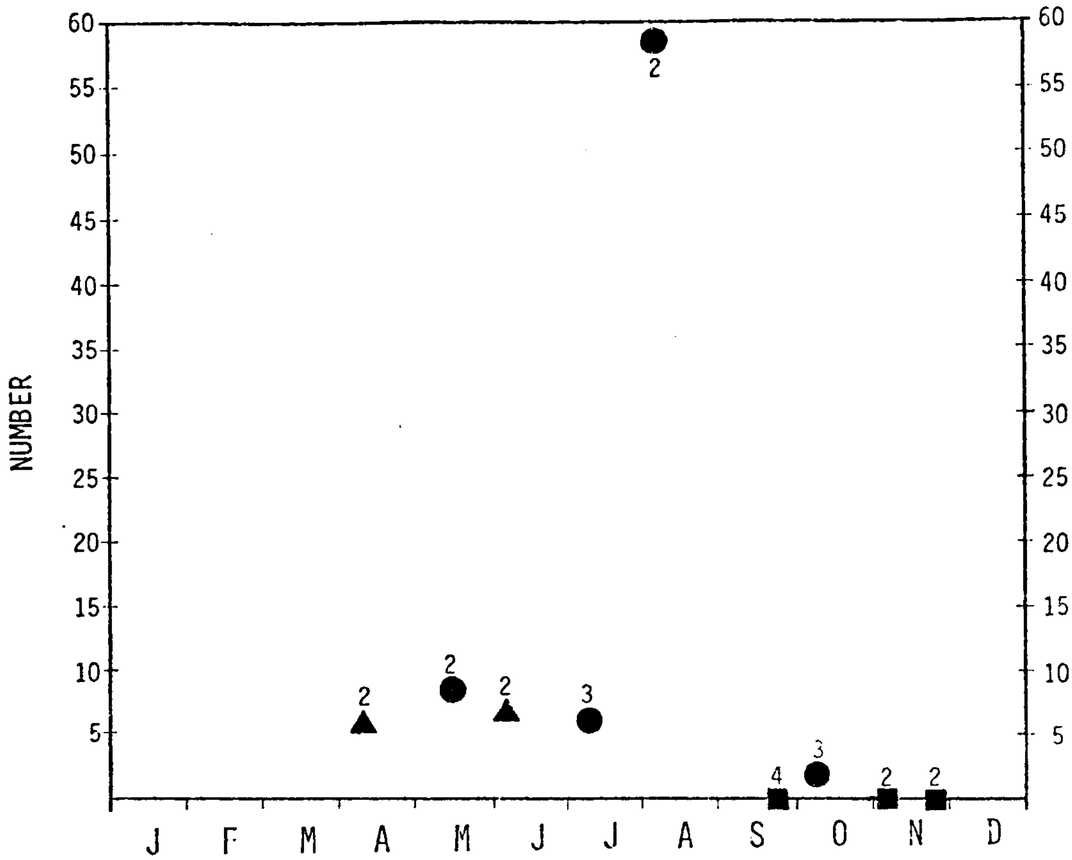

Figure 5. Average numbers of Simuliidae larvae per square foot. Numbers in body of graph indicate number of Surber samples.

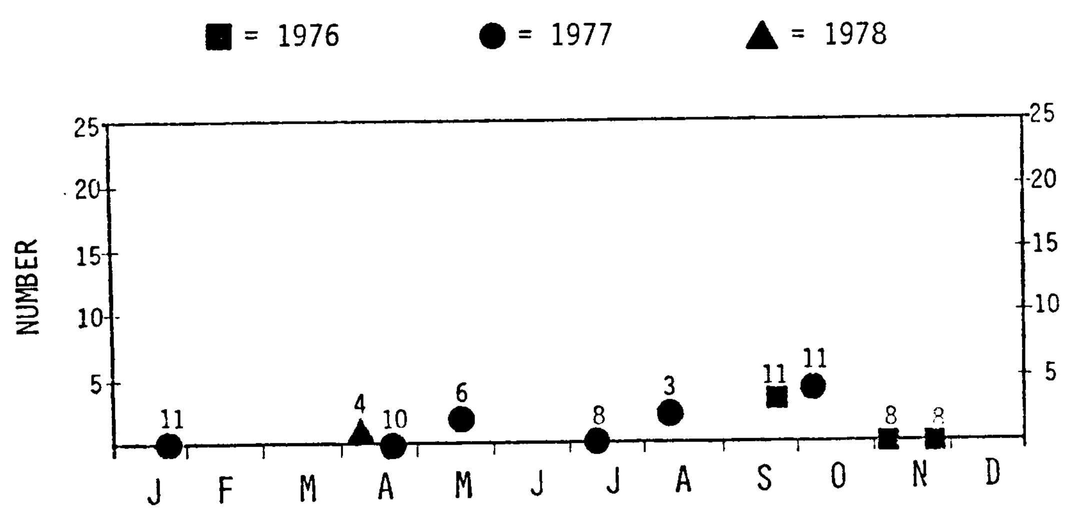

Figure 6. Average numbers of Simuliidae per E. blennioides stomach. Numbers in body of graph indicate number of stomachs examined.

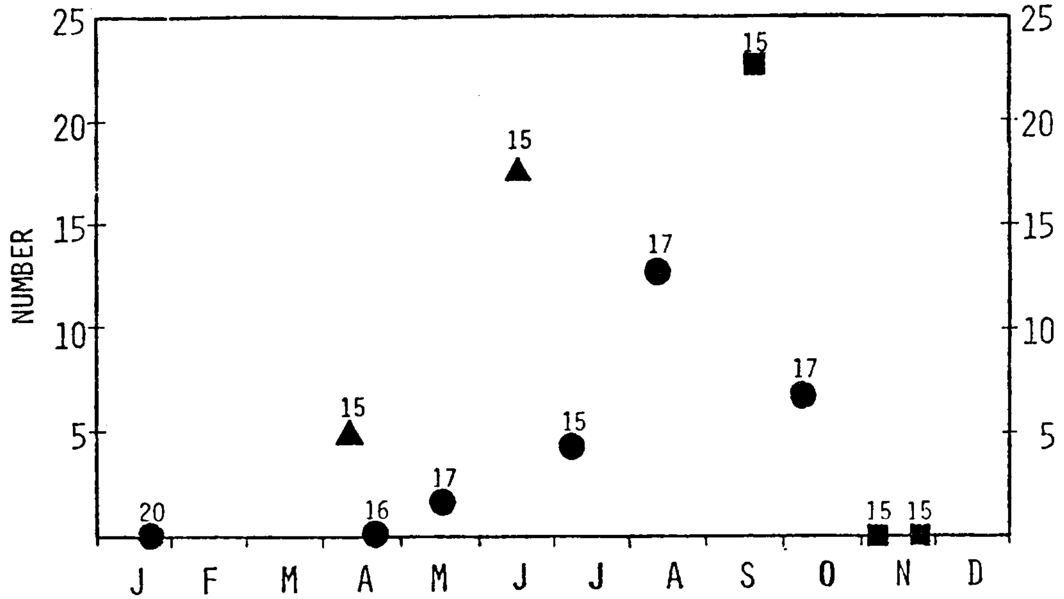

Figure 7. Average numbers of Simuliidae per E. acuticeps stomach.
Numbers in body of graph indicate number of stomachs examined.

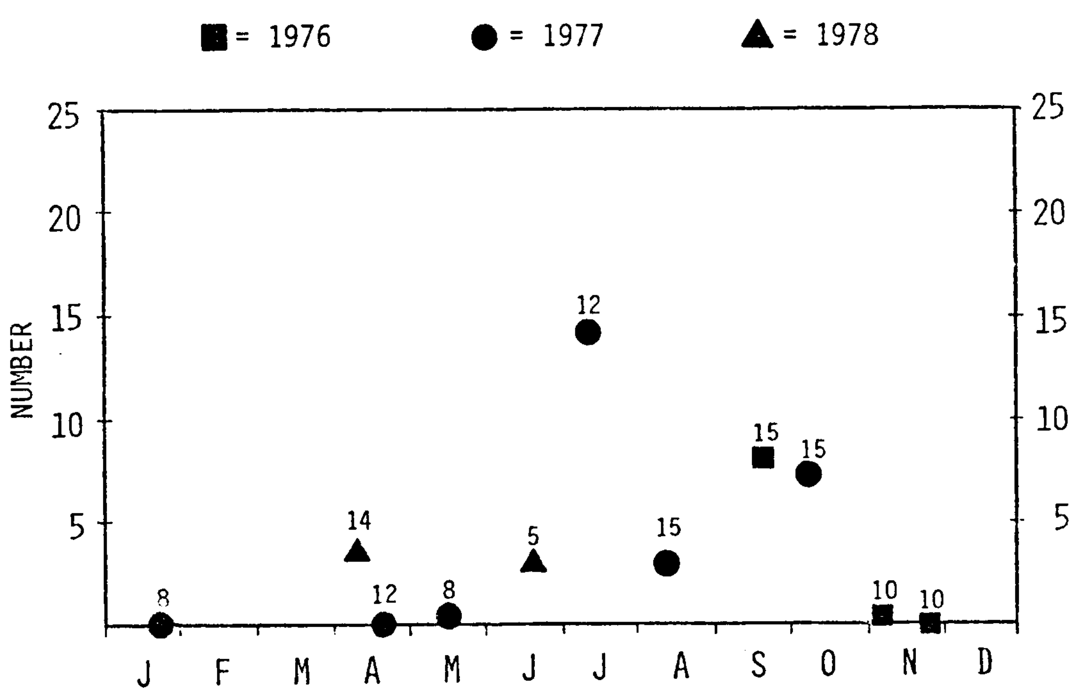

Figure 8. Average numbers of Simuliidae per E. zonale stomach.
Numbers in body of graph indicate number of stomachs examined.

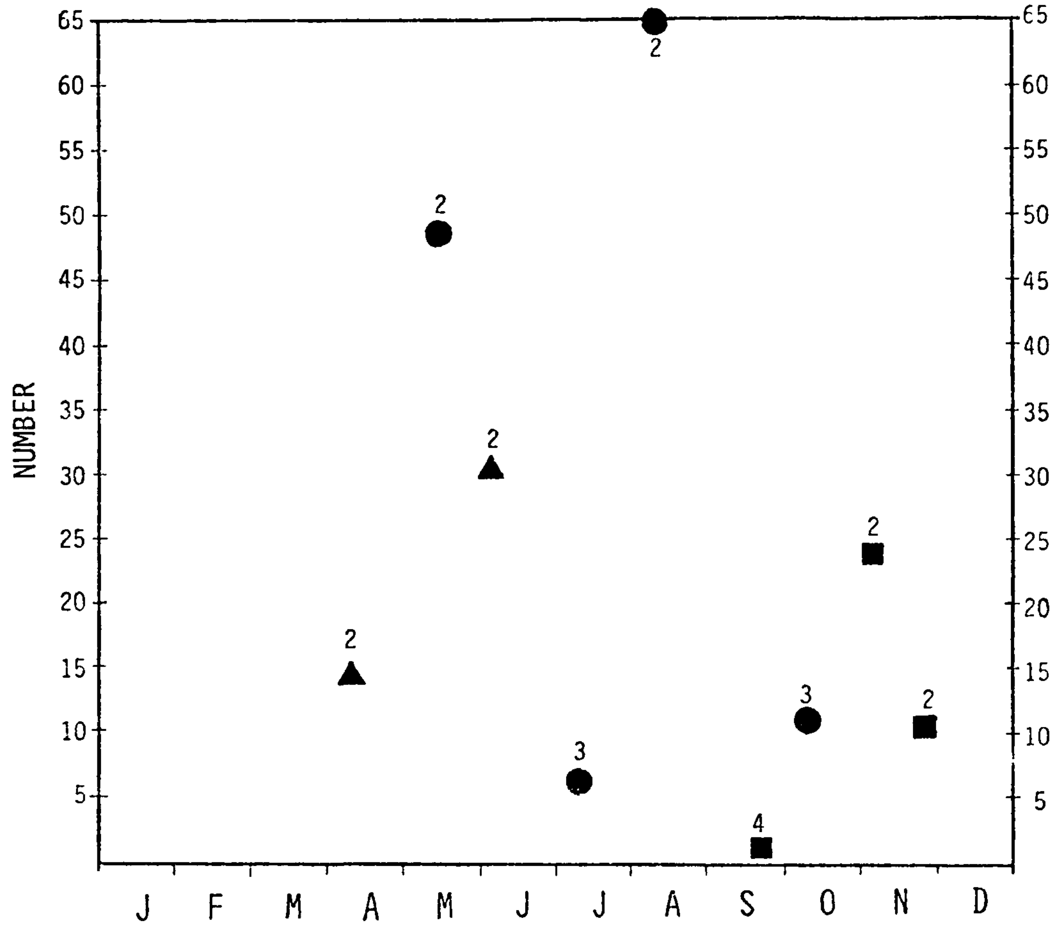

Figure 9. Average numbers of <u>Baetis</u> per square foot. Numbers in body of graph indicate number of Surber samples.

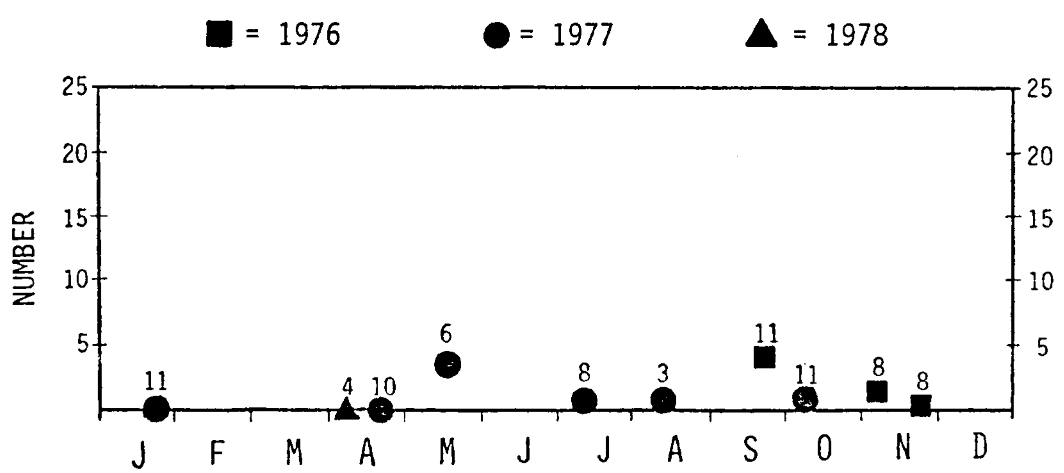

Figure 10. Average numbers of <u>Baetis</u> per <u>E. blennioides</u> stomach. Numbers in body of graph indicate number of stomachs examined.

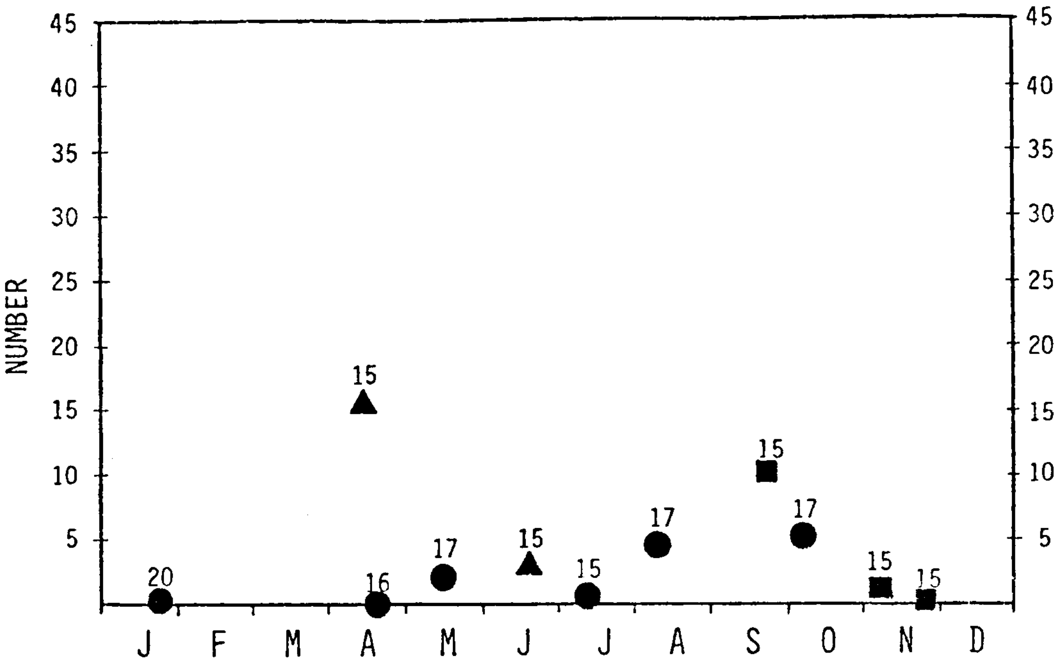

Figure 11. Average numbers of Baetis per E. acuticeps stomach. Numbers in body of graph indicate number of stomachs examined.

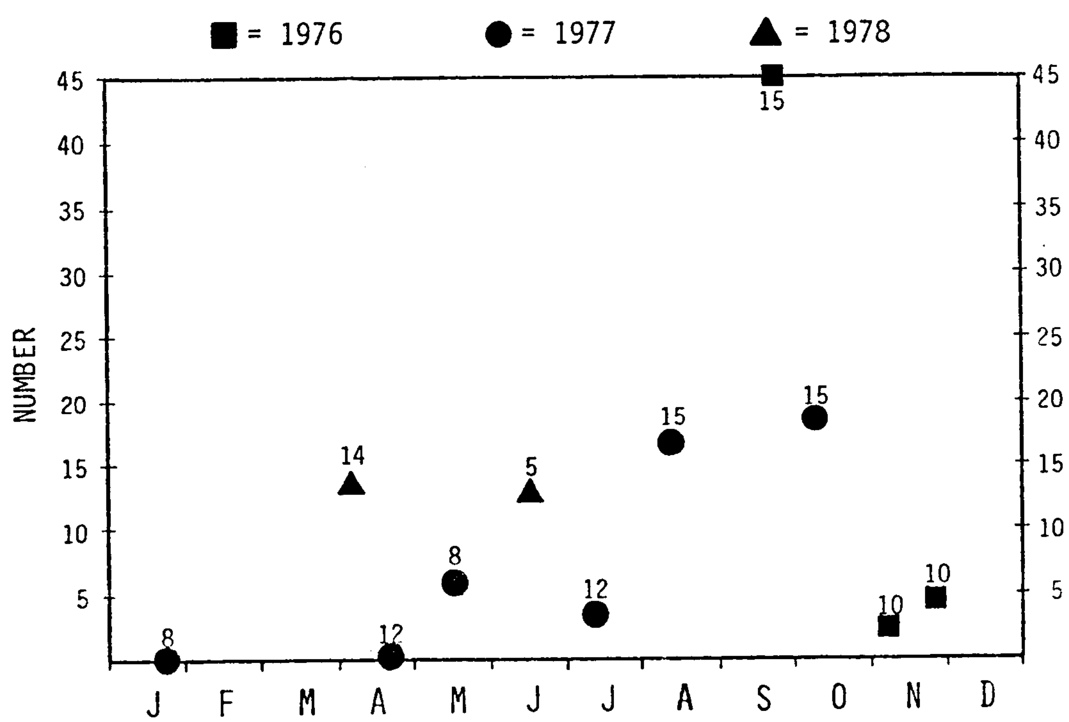

Figure 12. Average numbers of Baetis per E. zonale stomach. Numbers in body of graph indicate number of stomachs examined.

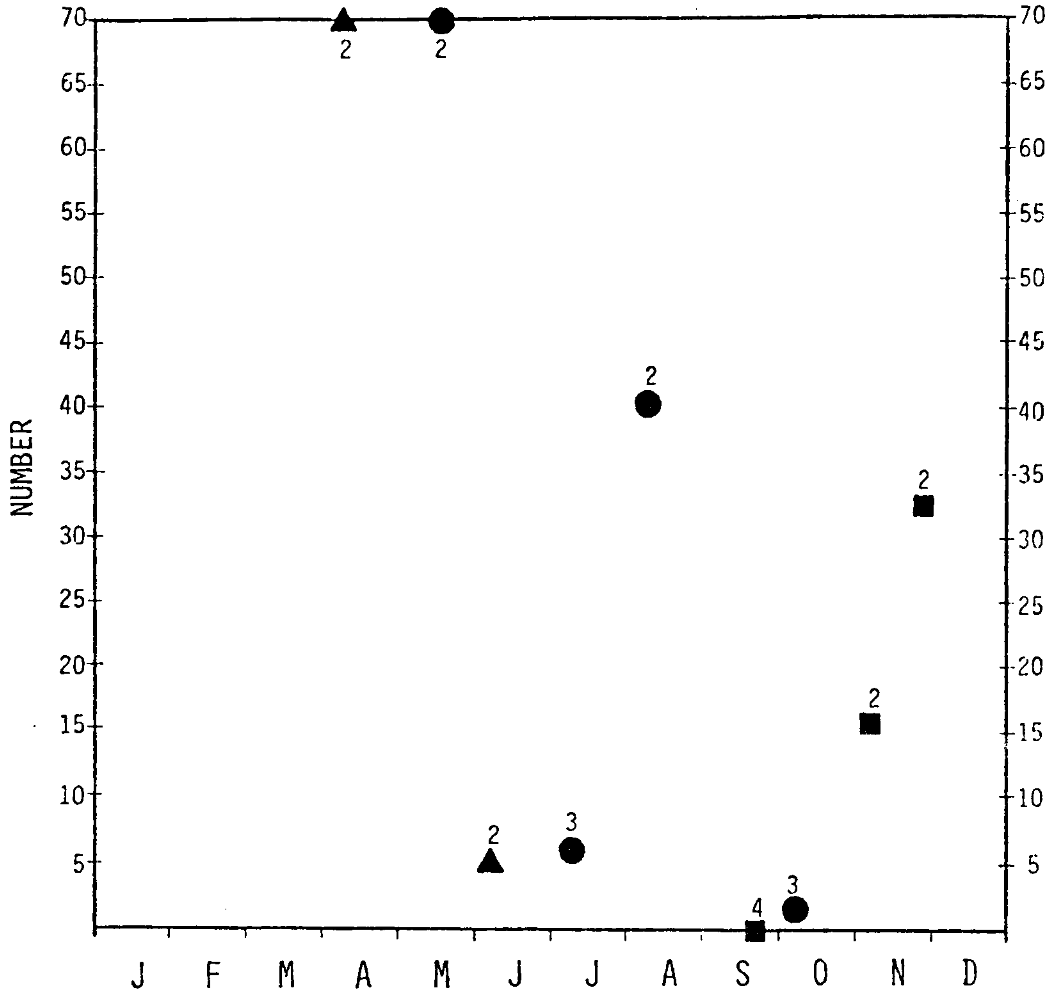

Figure 13. Average numbers of Ephemerella larvae per square foot. Numbers in body of graph indicate number of Surber samples.

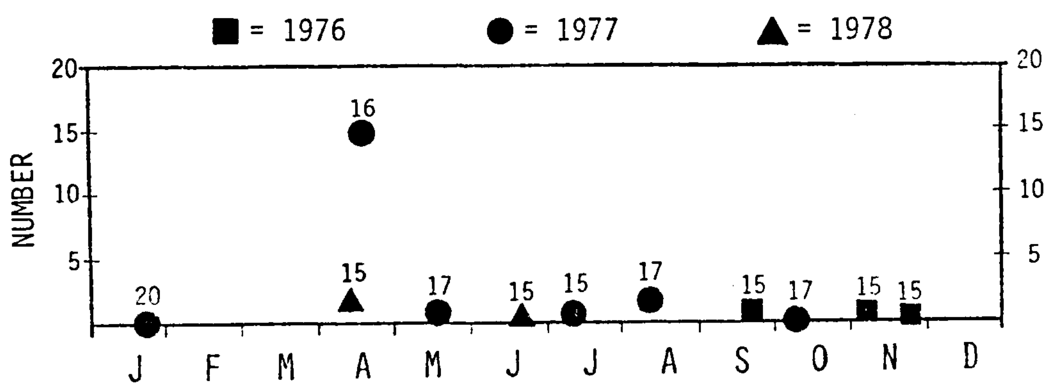

Figure 14. Average numbers of Ephemerella per E. acuticeps stomach Numbers in body of graph indicate number of stomachs examined.

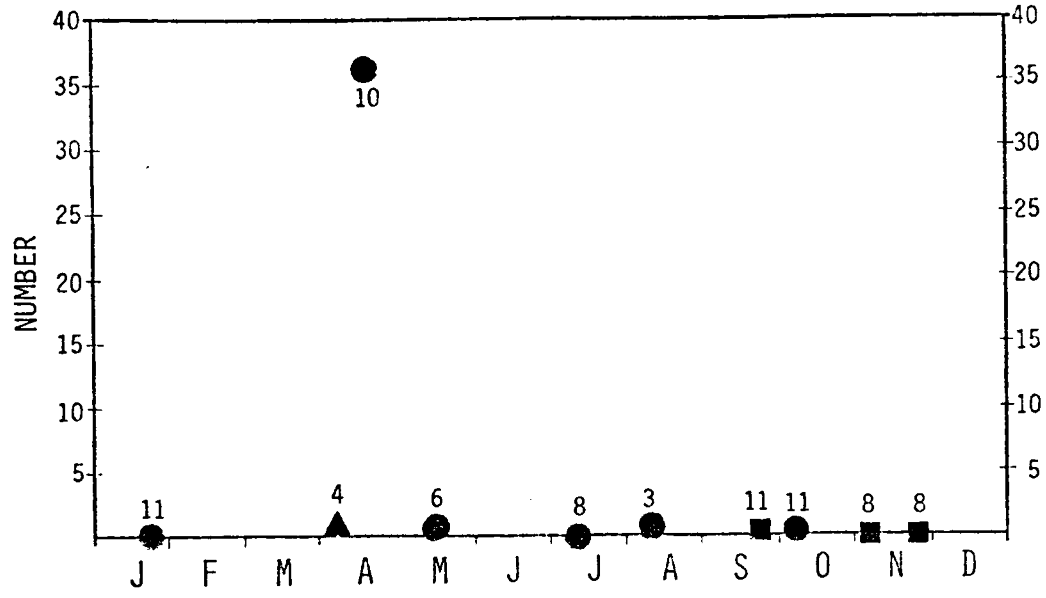

Figure 15. Average numbers of Ephemerella per E. blennioides stomach. Numbers in body of graph indicate number of stomachs examined.

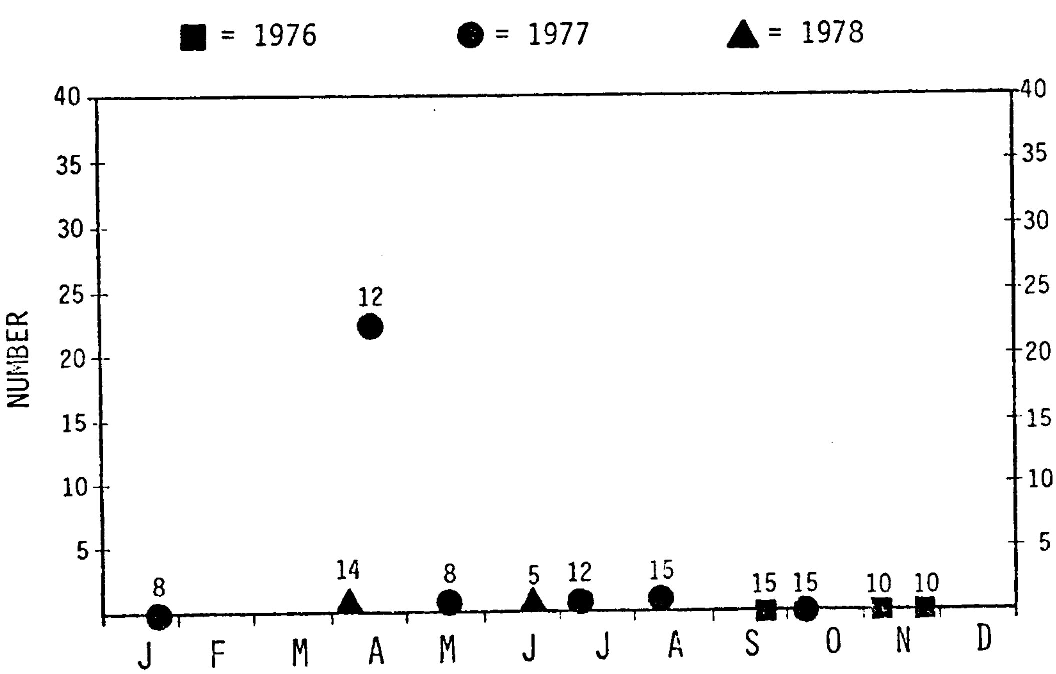

Figure 16. Average numbers of Ephemerella per E. zonale stomach. Numbers in body of graph indicate number of stomachs examined.

of the darters diet.

Figures 19 through 26 display relative percentages of major food items for the species in both this and Stiles' study. In order to allow direct comparisons with Stiles' study, only data from April through September is presented. In addition, feeding differences between darter species are more noticeable during the warmer months. All species studied exist predominantly on Chironomidae larvae during the cold months and eat practically nothing from November through March. High water in the Nolichucky during the colder months (Figs. 17,18) usually prevented comprehensive collecting, and a comparison with Stiles' data would only be fragmentary.

Figures 23 through 26 show the high degree of correlation between the feeding habits of the few *E. maculatum* and *E. camurum* that are available from this study and those from Stiles' study. what differences do exist may be associated with the small sample size. Another factor biasing results was that these *E. maculatum* were captured only in the early spring, whereas Stiles' were collected throughout the warmer months. This may have increased the proportion of Chironomidae in the stomachs from this study.

A comparison of Figures 1 through 16 shows the very poor correlation ($^{-}0.19 < r > 0.59$) between the seasonal abundances of the prey items and the reactions by the darters to the increased availability, as shown by increased numbers of prey consumed. This could be the result of the Surber sampler selecting insects of different sizes than the darters or the small number of samples and the

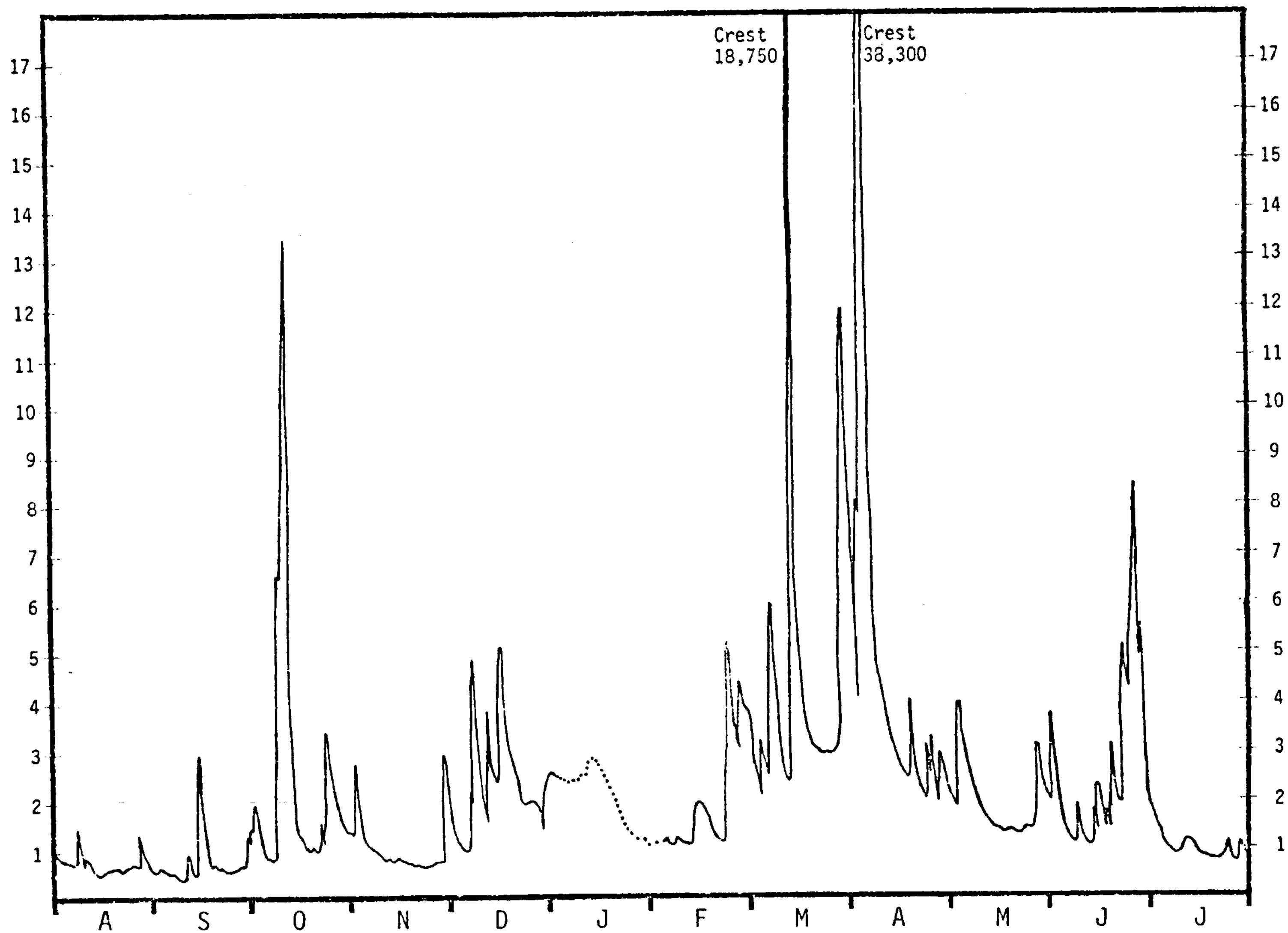

Figure 17. Discharge from Davy Crockett Lake in thousands of cfs from Aug., 1976 through July, 1977.

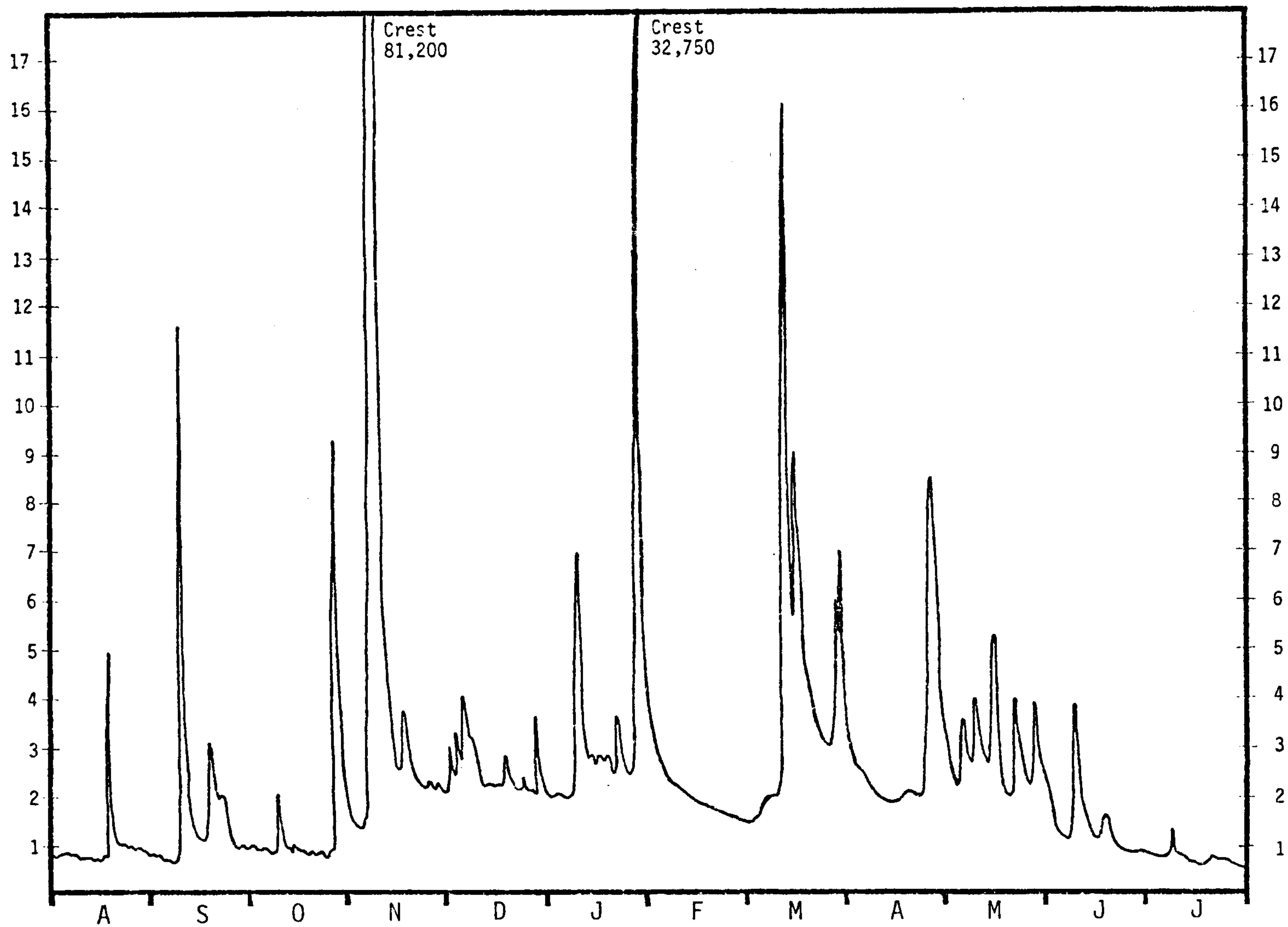

Figure 18. Discharge from Davy Crockett Lake in thousands of cfs from Aug., 1977 through July,1978.

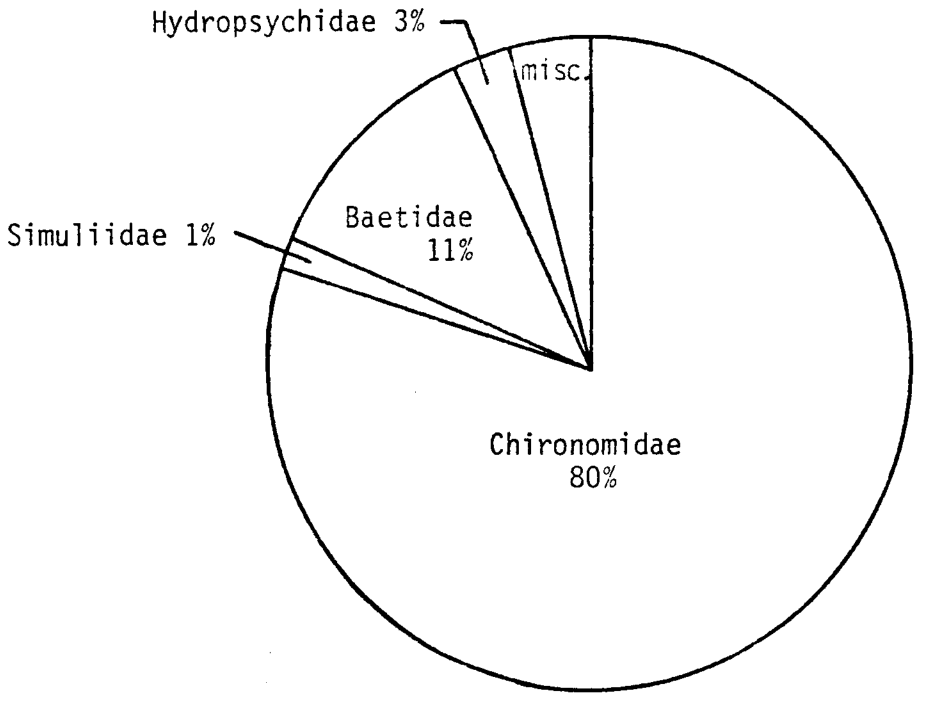

Figure 19. Total food budget for E. blennioides, April-September. (N=42, Nolichucky River)

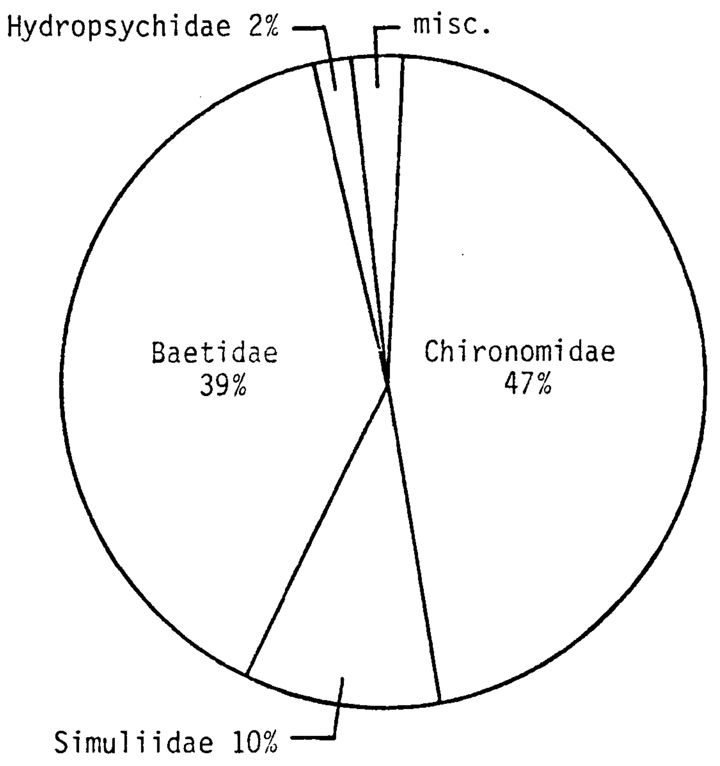

Figure 20. Total food budget for E. zonale, April-September. (N=81, Nolichucky River)

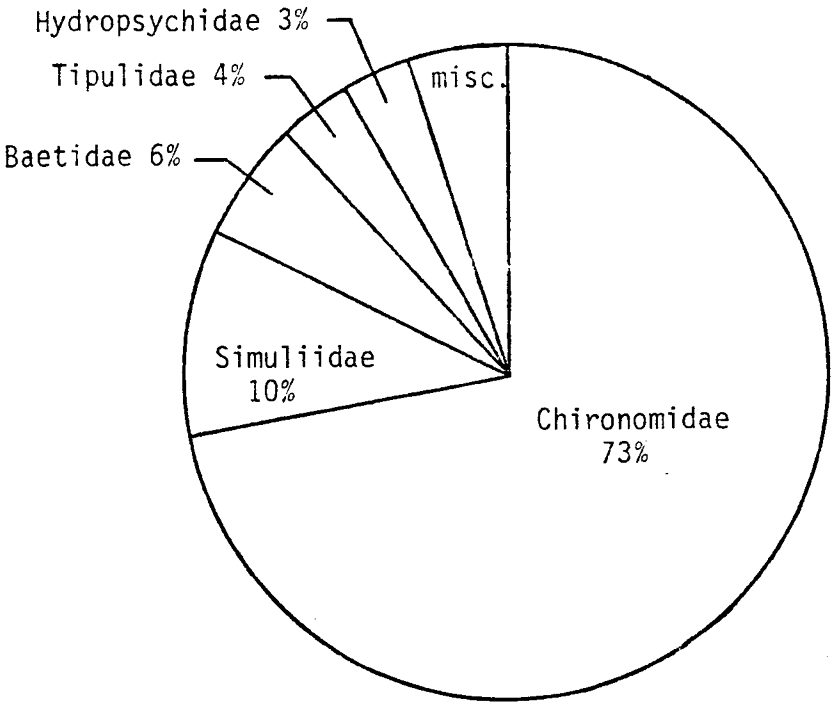

Figure 21. Total food budget for E. rufilineatum, April-September (Stiles, 1972). (N=50, Little River)

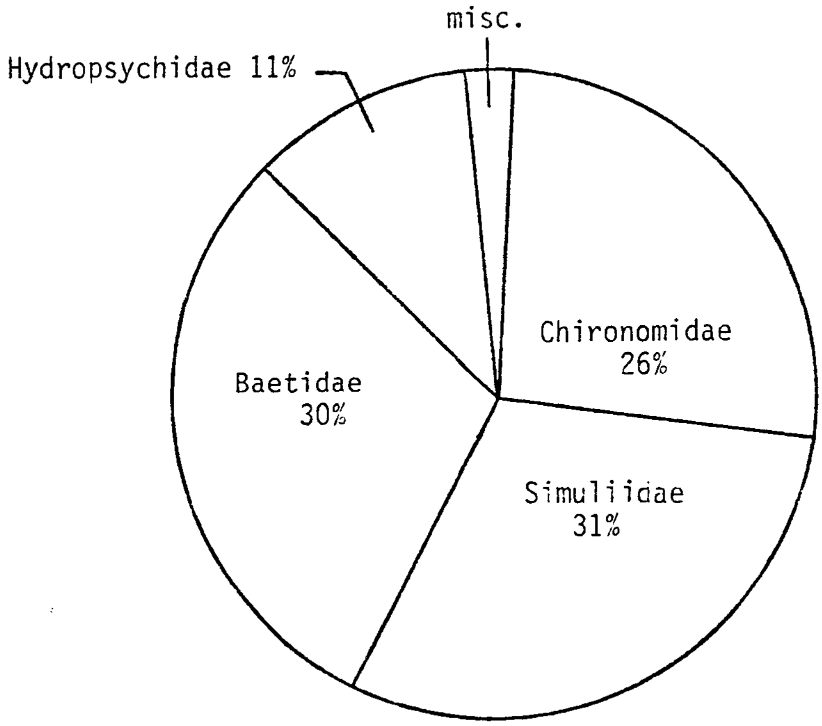

Figure 22. Total food budget for E. acuticeps, April-September. (N=110, Nolichucky River)

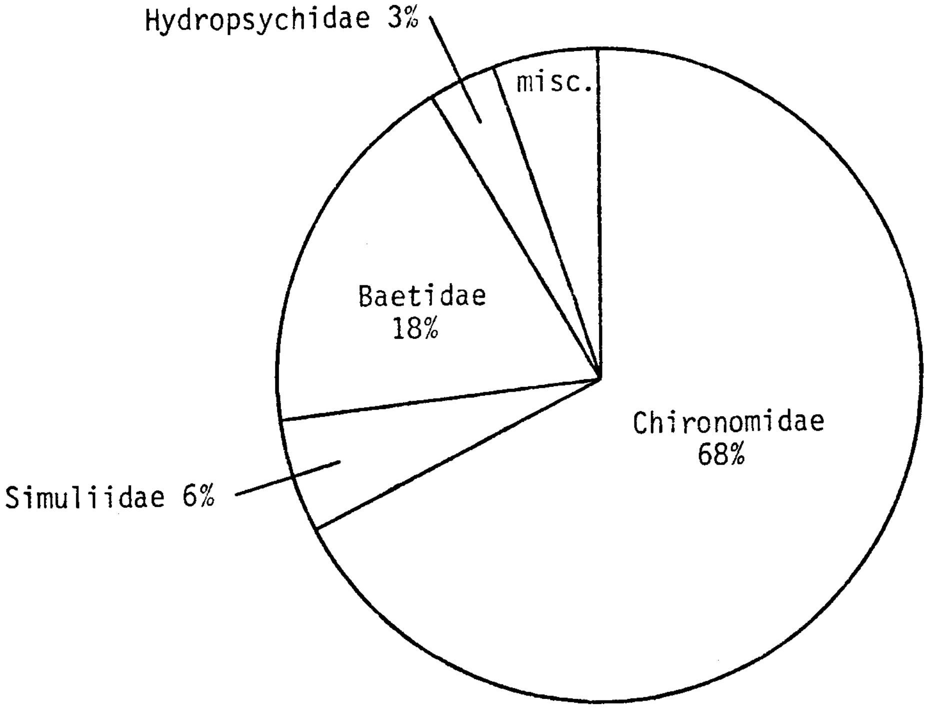

Figure 23. Total food budget for E. camurum, April-September. (N=18, Nolichucky River)

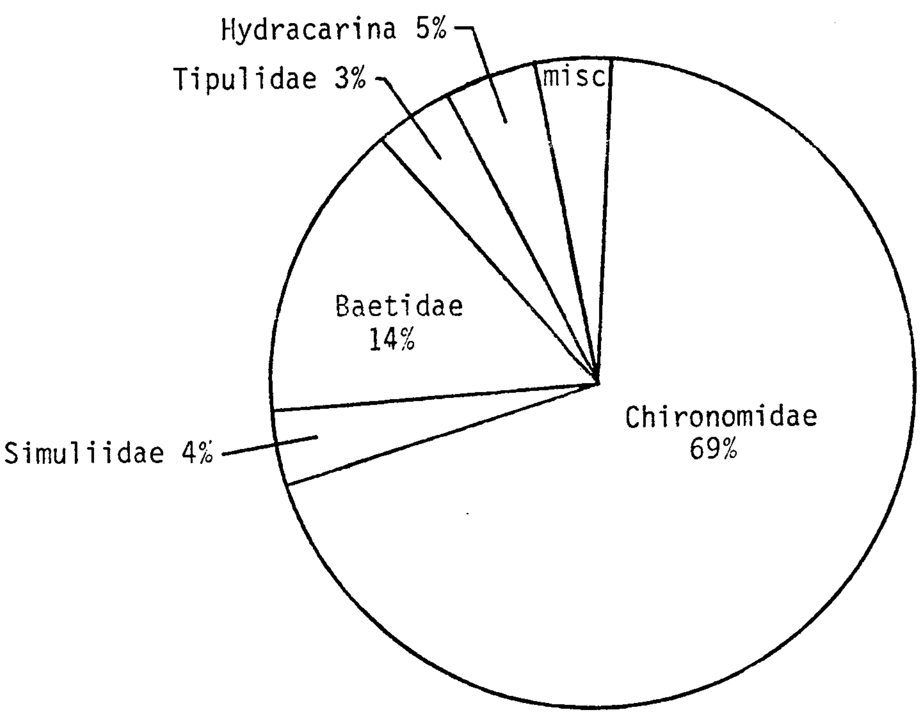

Figure 24. Total food budget for E. camurum, April-September (Stiles, 1972). (N=50, Little River)

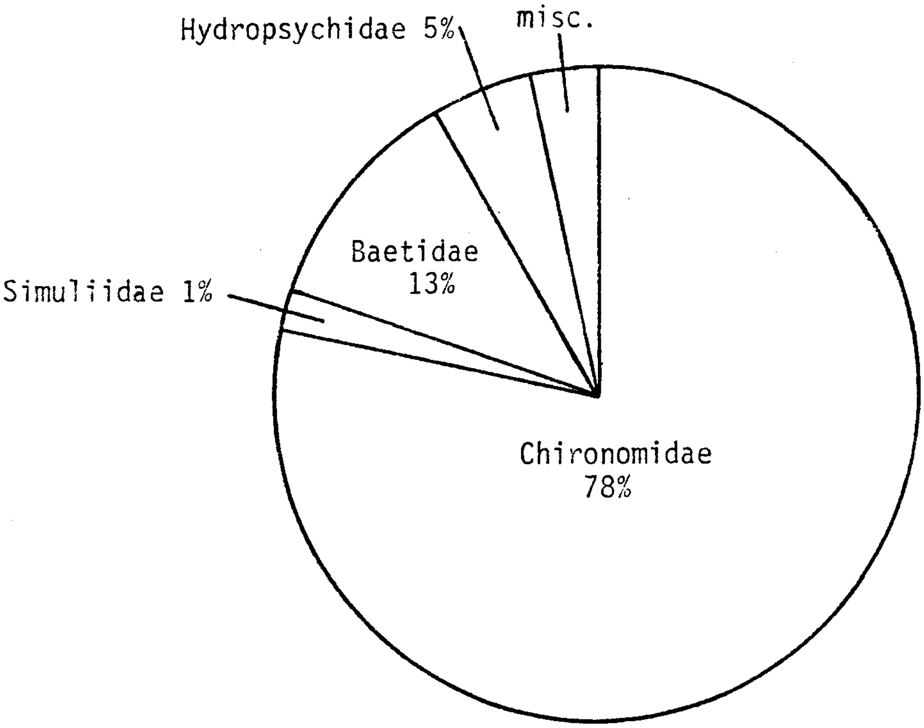

Figure 25. Total food budget for E. maculatum, April-September. (N=8, Nolichucky River)

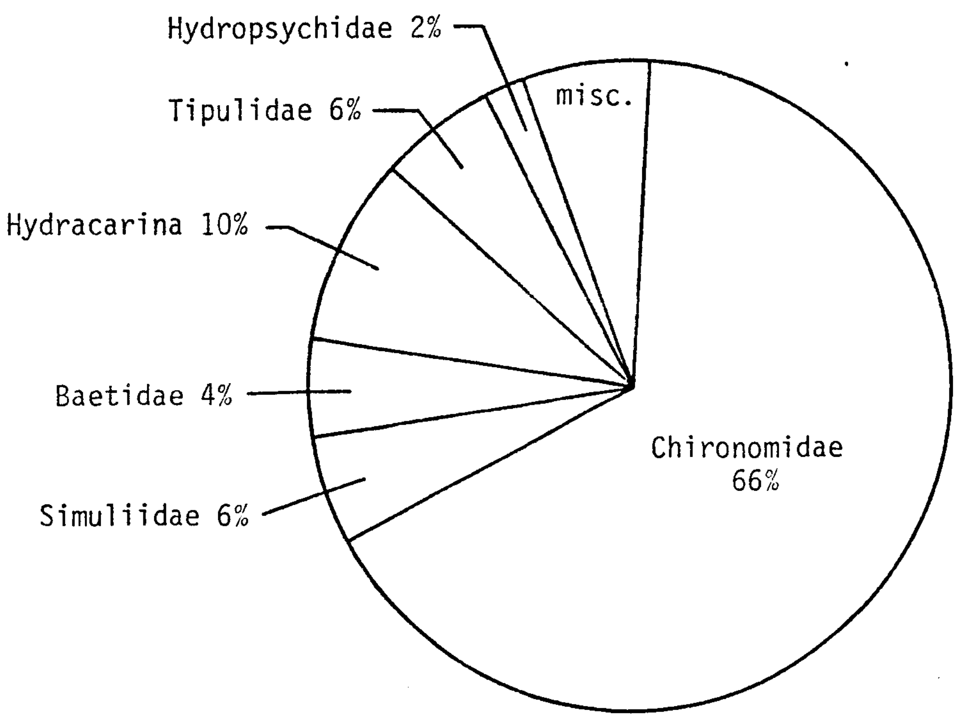

Figure 26. Total food budget for E. maculatum, April-September (Stiles, 1972). (N=54, Little River)

patchiness of the riffle bottom. Often the two or three samples from the same collection yielded drastically different numbers. Although all samples were from E. acuticeps habitat, this habitat varied from shallow riffles with small substrate and no plant growth, to deeper chutes with larger substrate heavily encrusted with Podostemum. The thick Podostemum network provides shelter from the swift current and supports a tremendous number of insect larvae. The shallower areas have few macrophytes and shelter very few insects, presumably because they spend some time of the year out of the water.

Some mayflies are known to have more than one peak occurrence per year (Burks, 1953). Figures 9 and 13 demonstrate 2 or 3 peaks for Baetis and Ephemerella, whereas the dipteran families Simuliidae and Chironomidae (Figs. 1,5) have only one peak.

Although large numbers of Ephemerella (Figs. 13-16) are present in early spring, August, and late fall, the only significant response to this presence occurred in the 20 April, 1977 collection. With this single exception, Ephemerella constituted an insignificant portion of the diet for all three species.

Etheostoma blennioides made almost no use of either Baetis or Simuliidae, but consumed tremendous numbers of Chironomidae, especially in the spring (Figs. 3, 6, 10).

The feeding habits of Etheostoma zonale are more complex. Figures 4, 8, and 12 show that E. zonale feeds predominantly on Chironomidae in spring, Simuliidae in summer, and Baetis in fall.

Etheostoma acuticeps is unusual in its utilization of these 3 items throughout the warmer part of the year (Figs. 2, 7, 11). Baetis and Chironomidae peak in importance in the spring and again in September. Simuliidae, while also peaking in importance in September, are fed upon fairly heavily throughout the summer.

A comparison of the total food budgets (Figs. 19-26) shows how drastically E. acuticeps differs from the other members of Nothonotus. Although there were significant differences between E. maculatum, E. camurum, and E. rufilineatum (Stiles, 1972), there were also great similarities. In each, Chironomidae was the most numerous food item and ranged from 66 to 78% of the total food budget. Simuliidae and Baetidae together comprised an additional 10 to 24%. E. maculatum and E. rufilineatum consume more Simuliidae than Baetidae, but E. camurum eats a much higher proportion of Baetidae than Simuliidae. Tipulidae and Hydracarina ranged from 2 to 10% in the Little River collections, but were practically nonexistent in fish from the Nolichucky.

In sharp contrast to its relatives, E. acuticeps consumes nearly equal numbers of Chironomidae, Simuliidae, and Baetidae, the percentages being 26, 31, and 30, respectively. Hydropsychidae, at 11%, also comprise an unusually high percentage of the E. acuticeps food budget. E. rufilineatum utilizes the second highest percentage of Hydropsychidae, with only 3%.

The most common darters in the E. acuticeps habitat at the study site were not Nothonotus, however, but members of the subgenus Etheostoma: E. blennioides and E. zonale. While these species were usually very common, during certain times of the year they were rare in E. acuticeps habitat, apparently moving into deeper water to spawn.

The most important food for E. blennioides is Chironomidae, which accounted for fully 80% of their total food budget (Fig. 19). The various Baetidae, mostly Ephemerella, make up 11% of their diet. E. zonale consumes the greatest percentage of Baetidae (39%), mostly Baetis, and significant amounts of Simuliidae (10%). Figure 20 shows that Chironomidae (47%) are far less important to E. zonale than it's close relative E. blennioides.

The relationship between snout structure and function (feeding habits) has been investigated on other darter species, including E. blennioides and E. zonale (Wehnes, 1973). In addition, microhabitat preference has been shown to determine which foods are available to the darter (Stiles, 1972). An explanation of the heavy reliance of E. acuticeps on Simuliidae larvae involves both of these factors. Of these six species of darters, E. acuticeps consumes by far the greatest proportion of Simuliidae (31%). Simuliidae larvae are inhabitants of the swiftest parts of a stream, where they cling tightly to rocks. Etheostoma acuticeps also inhabits the swiftest portion of riffles, and their sharp snouts must be ideal for picking the small, tenacious larvae off of rocks. The accuracy of E. acuticeps in feeding was first mentioned by Jenkins and Burkhead (1972). This is attested to by the low amounts of sand and other extraneous matter found in their gut. During the course of this study, 177 E. acuticeps stomachs were examined, only 3 or 4 contained any foreign matter at all. In contrast, E. blennioides, and to a much lesser extent E. zonale, regularly contained large amounts of both sand and plant detritus.

Etheostoma acuticeps also consumes the greatest amount of Hydropsychidae larvae (11%). The darter which most closely resembles E. acuticeps in both snout shape and in microhabitat preference is E. rufilineatum, which consumes the second largest amount (3%). Although the sample size was too small to make any definite conclusions, E. maculatum and E. camurum from the Nolichucky have much higher numbers of Hydropsychidae in their stomachs than those from the Little River. This suggests that there are more Hydropsychidae in the Nolichucky, and that E. rufilineatum may eat a proportion more similar to that of E. acuticeps when in the same stream. Hydropsychidae are also found in areas of swift current, where they make funnel-like silken nets in which to trap food. These nets are built in cracks between rocks or between strands of Podostemum.

Like Hydropsychidae, Baetidae were more numerous in the E. maculatum and E. camurum stomachs from the Nolichucky than those from the Little River. Baetidae are most often encountered crawling among the mesh of Podostemum growth. Etheostoma zonale is a darter almost always associated with macrophytes, which may explain why they consume a larger proportion of Baetidae (39%) than the other darters. Baetidae form 30% of the items eaten by E. acuticeps. Etheostoma acuticeps is usually found in areas of thick Podostemum growth, which makes available to them large quantities of both Baetidae and Hydropsychidae. Hydropsychidae do not form an important part of the E. zonale diet, perhaps because their snout is not properly formed to pick the larvae from their net. Baetidae are not an important item for *E. rufilineatum*, either because they are not particularly attracted to *Podostemum*, or simply because there were fewer Baetidae available in the Little River.

Chironomidae are the most important food source for all of these darters, except *E. acuticeps*. Chironomidae larvae live in sand and detritus cases which they make in the substrate between rocks. The larvae stick their heads out of the cases, exposing themselves to predation by darters. *Etheostoma blennioides* has a downward-facing, subterminal mouth that is adapted to vacuuming up large quantities of Chironomidae larvae. The orientation of their mouth and the fact that 80% of their food budget is Chironomidae explains why there is so much sand and detritus in *E. blennioides* stomachs. In contrast, *E. acuticeps* consumes only a third as many Chironomidae as *E. blennioides* and less than half as many as the other *Nothonotus*. Typical *E. acuticeps* habitat has a profusion of tightly packed large rocks in swift current, which may not allow enough interstitial substrate accumulation to support as large a Chironomidae population as elsewhere. In addition, with the tremendous Baetidae and Hydropsychidae populations existing in the *Podostemum* network, *E. acuticeps* may have sufficient food available without utilizing Chironomidae.

CHAPTER III

REPRODUCTION AND BEHAVIOR

As shown in Figure 27, the development of sharphead darter eggs begins during April. This is indicated by ovarian weights, which increase as yolk is accumulated in the eggs. Ovarian weights peak in late June, then decrease during July and August as the mature eggs are deposited. Male breeding color develops about the same time as the ovaries. A blue-green wash on the males' fins in the spring intensifies to a dark blue-green over most of the body during June and July, abruptly disappearing in late August or early September. *Etheostoma acuticeps* were collected in breeding condition from late June until 15 August, 1976, making it one of the, if not the, latest spawning darters (Etnier, pers. comm.). Members of the subgenus *Nothonotus* are late spawning darters, generally spawning between the last week of May and the first week of August (Stiles, 1972). On 8 August, 1978 no breeding darters could be found, apparently as the result of a flood that occurred a week before, confirming Stiles' observation that breeding may be suspended as the result of inclement weather.

Several ovaries from the collection of 24 June, 1978 were dissected and numbers of mature and maturing eggs were counted. Totals of these two groups probably represent the number of eggs to be deposited during the breeding season, as research on several other

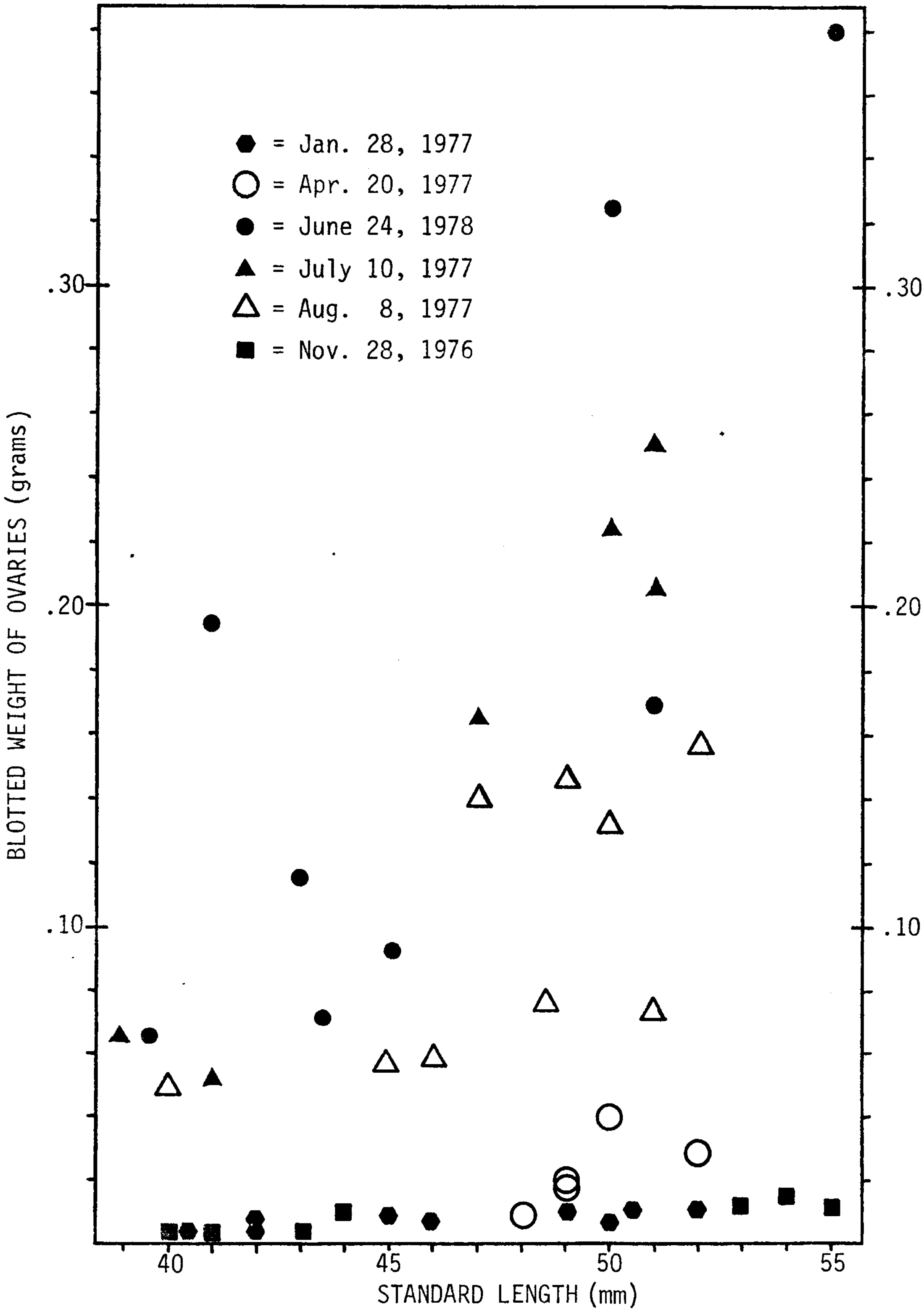

Figure 27. Ovarian weight vs. length for Etheostoma acuticeps at six times of the year.

darters (Winn, 1958) has shown that all eggs that mature are deposited. The number of eggs produced increases with the length of the female (Fig.28). A large female of 55 mm produced nearly 300 eggs whereas a fish of 39 mm produced only about 100.

All E. acuticeps larvae died within several days of hatching. later attempts to raise other darters resulted in greater success. A successful method consisted of placing the eggs in a large (10 gal.) tank containing only clean water, an airstone, and a slight growth of algae. After the darters hatched and began swimming, they were fed freshly hatched brine shrimp. The young could be raised to maturity by feeding them progressively larger plankton from either natural sources or aquarium stores. The E. acuticeps lived to approximately 300 hours post-fertilization. The Nolichucky River was about 77°F (25°C) when the eggs were found, and the eggs were raised at 73°F (23°C). The following is a chronological account of the major characteristics of the developing embryo. Times are measured post-fertilization.

24 hours. Only visible structure is yellow oil globule.

48 hours. Optic vesicles visible, but colorless.

64 hours. Optic vesicles prominant. Heartbeat (100 to 150 bpm) visible, structures indistinguishable. Some structure of brain visible. Tail long, reaching around yolk sac to snout.

73 hours. Optic vesicles appear gray, pigment also developing on yolk sac near head and near center of tail near anus. Oil globule noticeably smaller. Myomeres and otic vesicles visible

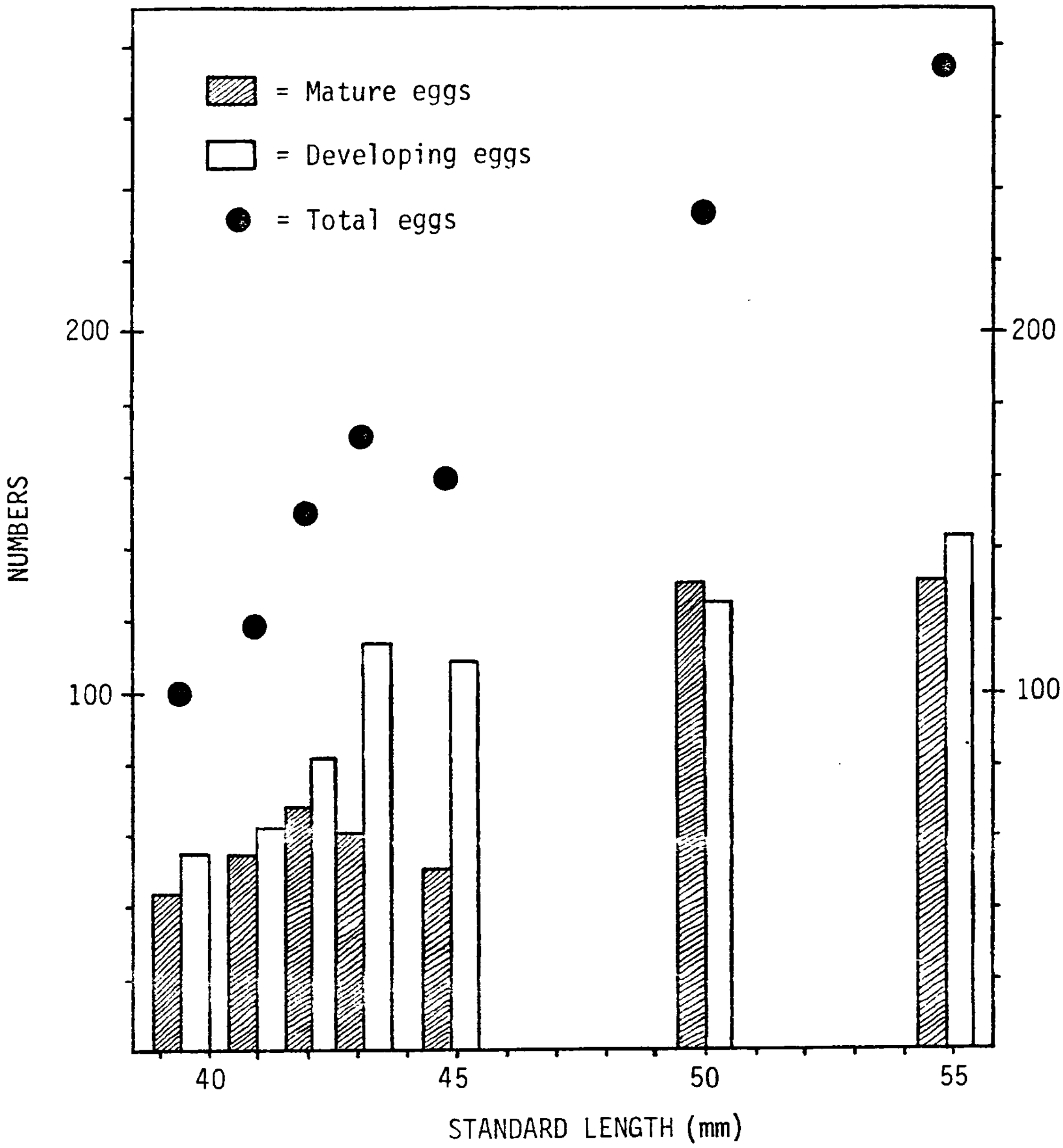

Figure 28. Numbers of mature, developing, and total eggs vs. length of Etheostoma acuticeps on 24 June, 1978.

Large vein on ventral side of yolk sac runs straight from vicinity of anus to heart.

100 hours. Large vein now sinusoidal instead of straight. Retinas are darkly pigmented. Limb bud behind otic vesicle developing. Heart structure visible, appears to be red and popping as it fills up and contracts. Tail now long enough to reach eye.

120 hours. Eyes have a purplish reflectance.

146 hours. Otic vesicles are triangular and contain 3 small, spherical bodies. Dorsal aorta visible in tail. Melanophores in tail distributed along each myomere, with a new row of melanophores developing just ventral to old row.

173 hours. Retina black, with silver-gold reflectance from outside and rosy reflection from inside. Eyes twitch irregularly. Mouth visible but indistinct. Otic vesicles have dark spot. Limb bud forms pectoral fin, and is now as long as diameter of eye.

195 hours. Nostrils appear to be ciliated, movement of particles at openings is apparent. Structure of brain is complex. Tail reaches beyond main portion of body nearly to anus.

220 hours. Hatching occurs. The young rest on the bottom and swim at sporadic intervals.

245 hours. Actively swimming. Mouthparts and gills moving and clearly distinguishable. Pigmentation becomes denser.

272 hours. Vertebrae visible. Melanophores on tail coalescing into lines and melanophores on dorsal half of larvae developing. Apparently there are blood sinuses in abdomen, between the eyes, and between the otic vesicles.

Within a few days of hatching, the larvae succumbed, apparently to starvation. Comparisons between the prolarvae of *E. acuticeps* and *E. rufilineatum* revealed only minor differences. The melanophores near the anus in *E. acuticeps* appeared as a series of stellate spots, whereas in *E. rufilineatum* the melanophores appeared more quadrate and coalesced into a well defined band. This observation may be the result of the *E. acuticeps* being less developed, as they did not live as long as *E. rufilineatum*.

Observations of sharphead darters in aquaria have shown them to be very aggressive during the breeding season. They would line up head to tail about 3 cm apart, change colors, and erect all of their fins. The vertical bars on the sides of the fish darkened, becoming quite prominent, and the dorsal surface of the fish darkened, the darkness extending through the eyes, giving the appearance of a mask. The fish remained head to tail for several seconds flexing their fins, then lunged at the other's caudal fin in an attempt to bite it. Stiles (1972) observed that biting is rare among *E. camurum*, *E. maculatum*, and *E. rufilineatum*. Biting occurred regularly in the *E. acuticeps* display, and apparently is not limited to aquaria. Many male sharpheads captured during the breeding season had bite wounds, in the form of a tattered, white lower lobe of the caudal fin. Occasionally one of the fish would swim around the tank in what appeared to be some sort of displacement activity, only to return and again challenge the other fish.

This aggressive display is more likely territoriality than the maintenance of a personal space. Within each aquarium there was usually a "preferred" spot underneath a rock, and the display was always associated with this spot. The display was only observed 3 or 4 times in 2 years. It only occurred among breeding males that were approximately the same size and were new to the aquarium. Usually there was no aggression of any kind among the darters, even though 5 or 6 would occupy the same space underneath a rock. No other behavior related to reproduction was observed.

CHAPTER IV

AGE AND GROWTH

Dispite viewing the scales by several different methods, no reliable ages could be assigned to any of the larger fish. The scales of fish less than 2 years old were fairly easy to read. The first annulus was easily distinguished on the basis of the differential spacing of circuli in the anterior field of the scale and the recognition of cutting over of circuli. In fish older than this, no consistant pattern of circuli spacing could be determined, even of the first annulus, which is so obvious in the young. Because the age of any of the larger fish could not be determined without resorting to statistical methods, even though 5 complete and unregenerated scales were studied from each, it was felt this method was inapplicable and other methods should be used.

Figures 29 and 30 illustrate the lengths of all E. acuticeps captured during the course of this study, plotted against the date of their capture. It was hoped that the age classes would appear and that their growth throughout the year would be obvious. Research on other darters (Wolfe, Bauer, and Branson, 1978) has shown that the females reach a smaller adult size than the males, but grow faster in relation to their own adult size when they are young. This tends to obscure the difference in age classes, as shown by length frequency analysis. Males, however, continue growing and the differences between the age classes are more obvious.

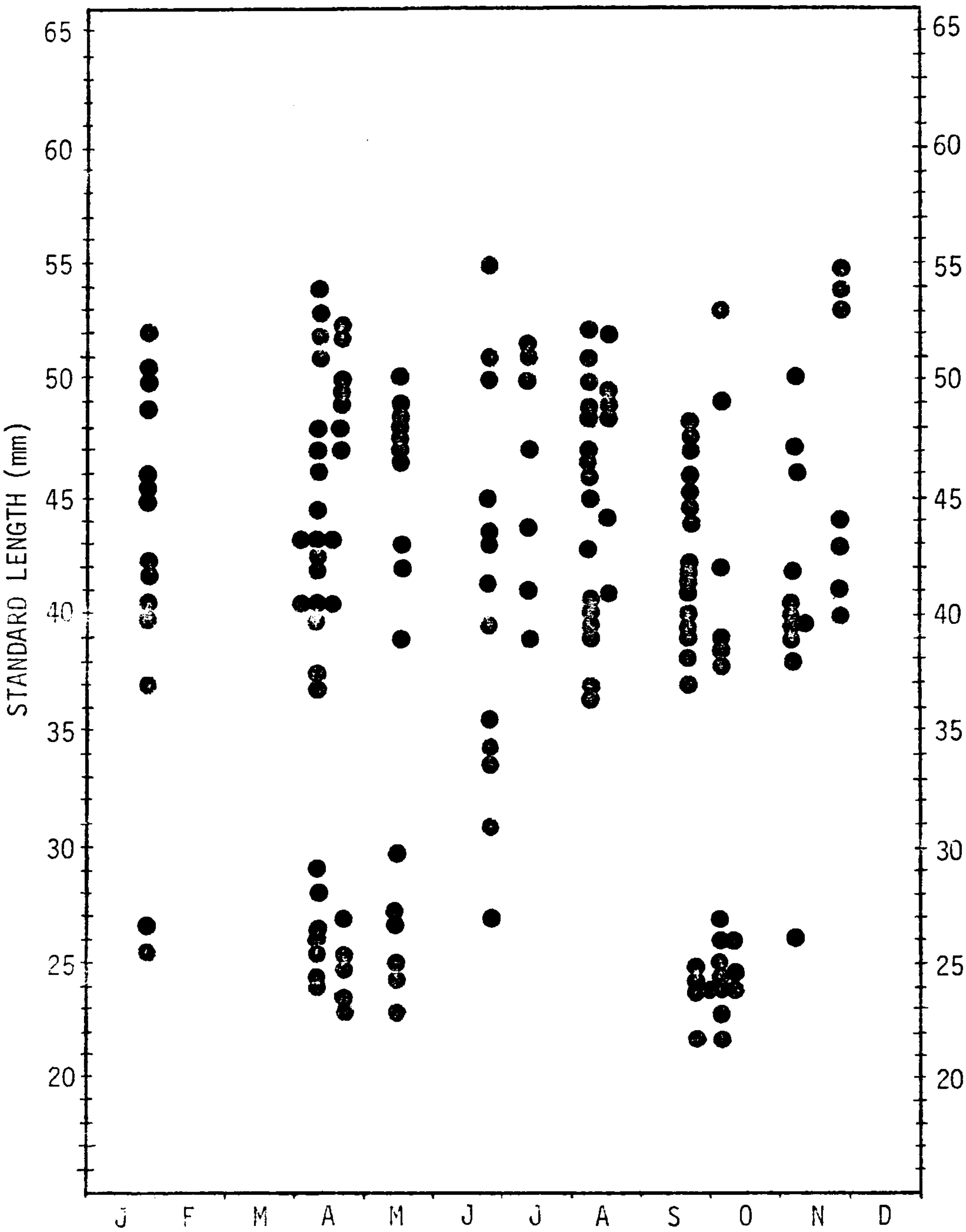

Figure 29. Standard length vs. collection date for all female and juvenile <u>Etheostoma acuticeps</u>.

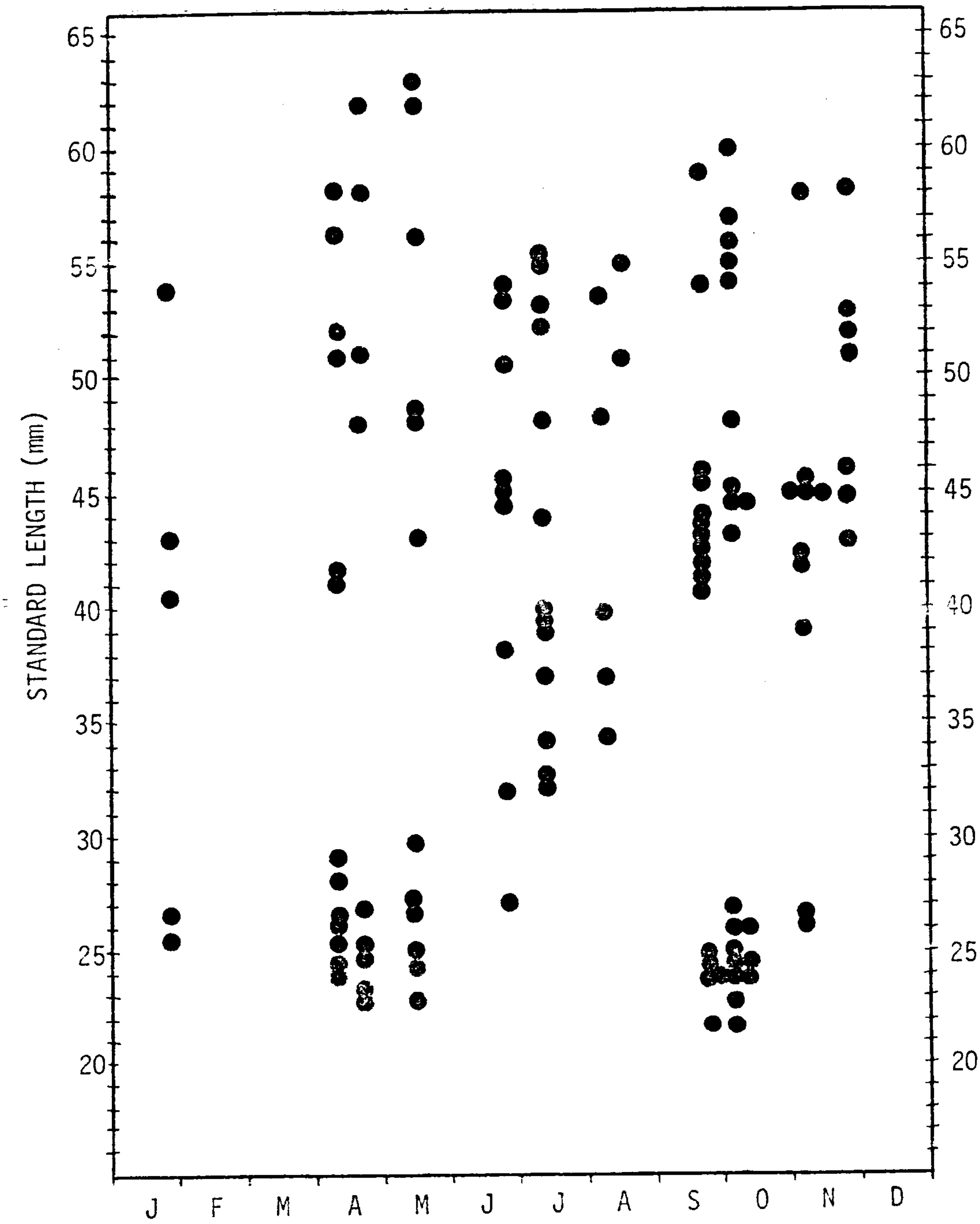

Figure 30. Standard length vs. collection date for all male and juvenile <u>Etheostoma acuticeps</u>.

Figure 30 shows that the juveniles begin appearing in collections in September. Of course, the ¼" mesh nets only collect darters above a certain size (about 22 mm) and the collections represent the larger, not the average young. Fall juveniles are around 24 mm, and do not grow much during the winter, appearing in the January, April, and May collections at nearly the same size. Males then grow from this size to between 42 and 47 mm by the following September. The gonads are maturing and are identifiable as either male or female at about 32 to 35 mm and are therefore becoming sexually active at the age of exactly one year. Males grow from around 45 mm to about 55 or 60 mm during the next season. They approach the age of three years at a length of greater than 60 mm, but these darters were uncommon, or very difficult to capture. Based on length frequency data, there is little reason to believe that these fish live over three years. Figure 29 demonstrates the lack of obvious age classes among the females, and that their adult length seldom exceeds 55 mm.

Figure 31 is the data from Figures 29 and 30 in histogram form. It shows the lack of distinct size classes among the older females. The males are spread out over a wider range of sizes, and the size classes are more apparent. The graph would be more reliable had a huge number of darters been collected on a single date, but a single large collection was unavailable, and all of the collections were totaled to obtain a reasonable sample size.

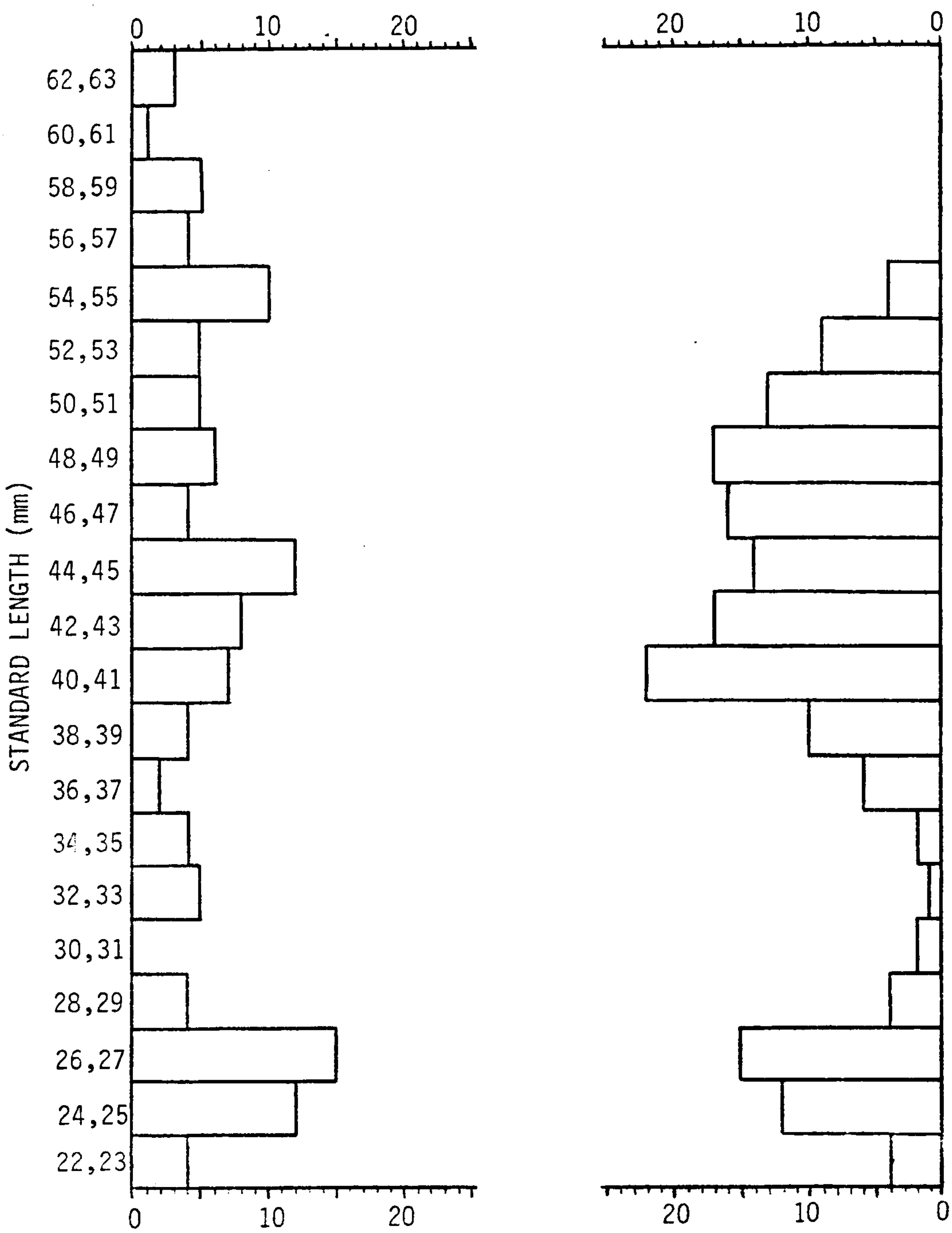

Figure 31. Frequencies of lengths of Etheostoma acuticeps. Males plus juveniles on left; females plus juveniles on right.

The sex ratio of all 211 sexed darters was 83 males to 128 females or 39 to 61%. The ratio changed radically throughout the year as the males and females moved in and out of the areas that were being collected heavily. Reasons for this variation may be the sexes avoiding each other and occupying different ecological niches, or perhaps differential mortality during the breeding season. The energetic expenditure of the females in the form of eggs is surely a significant drain on their health, perhaps resulting in increased mortality. Sample size undoubtably played a role also, as none of the collections included over 25 fish.

CHAPTER V

HABITAT AND DISTRIBUTION

In addition to the previously known populations in the South Fork Holston and Nolichucky rivers, the sharphead darter also inhabits the lower 6 km of the Cane River in North Carolina, a tributary of the Nolichucky (Bryant, Beets, and Ryon, 1979). Both the Cane and the South Fork Holston populations represent the natural upstream extent of the darter, but the original downstream distribution is not known due to impoundments and pollution. Upstream limits of the fish in Cane River seem to be more a function of altitude, whereas the limits in the South Fork Holston appear to be more a function of higher gradient. Sharpheads in the Cane River range to an altitude of 645 m, but only to 536 m in South Fork Holston. The South Fork Holston has a much steeper gradient, however, dropping 3.6 m/km while the Cane only drops 2.3 m/km. In comparison, the lower Nolichucky just above Douglas Reservoir drops 0.6 m/km.

The habitat in South Fork Holston was described by Bailey (1959) and Jenkins and Burkhead (1975) as fairly mountainous. The darters were captured in swift riffles with a velocity ranging from 0.8 to 1.5 m/sec. Substrate varied considerably. Bailey noted that substrate at the type locality was 90% rubble and boulder whereas Jenkins and Burkhead found smoother substrates at their locality, which was farther upstream. Much of the stream bed was bedrock and impacted rubble, although the riffle proper contained rubble and small boulders that had sufficient spaces underneath them to support a population of darters. The depth was estimated by Bailey as 25 to 36 cm, and 15 to 30 cm by Jenkins and Burkhead. In contrast to the Nolichucky River system localities, neither of the Holston sites had any aquatic macrophytes.

The riffle at Steele Island in the lower Nolichucky River (fourth site upstream in Nolichucky, Figure 32) represents the densest known E. acuticeps population, and is probably "ideal" habitat. Although the stream here is low gradient (0.8 m/km) the current velocity at the surface is about 2 m/sec. Substrate is rubble and small boulders, 5 to 20 cm in diameter, piled loosely to provide a large amount of interstitial space both between and under the rocks. Depth is typically 15 to 30 cm. Rocks are heavily encrusted with Podostemum, supporting a tremendous insect community. In August the highest temperature was recorded, 26^{0} C, and during the winter the temperature dropped to 0^{0} C.

The Cane River habitat is basically similar to the Nolichucky, particularly in the thick Podostemum growth, although the gradient is much higher and the substrate is slightly larger. Above the US highway 19W bridge, where no E. acuticeps have been found, the gradient is even higher and there is very little Podostemum.

The occurrence of the sharphead darter in the Holston and Nolichucky river systems indicates what must have been a widespread ancestral population that had access to many large upper Tennessee rivers. On the basis of their reproductive behavior, lack of

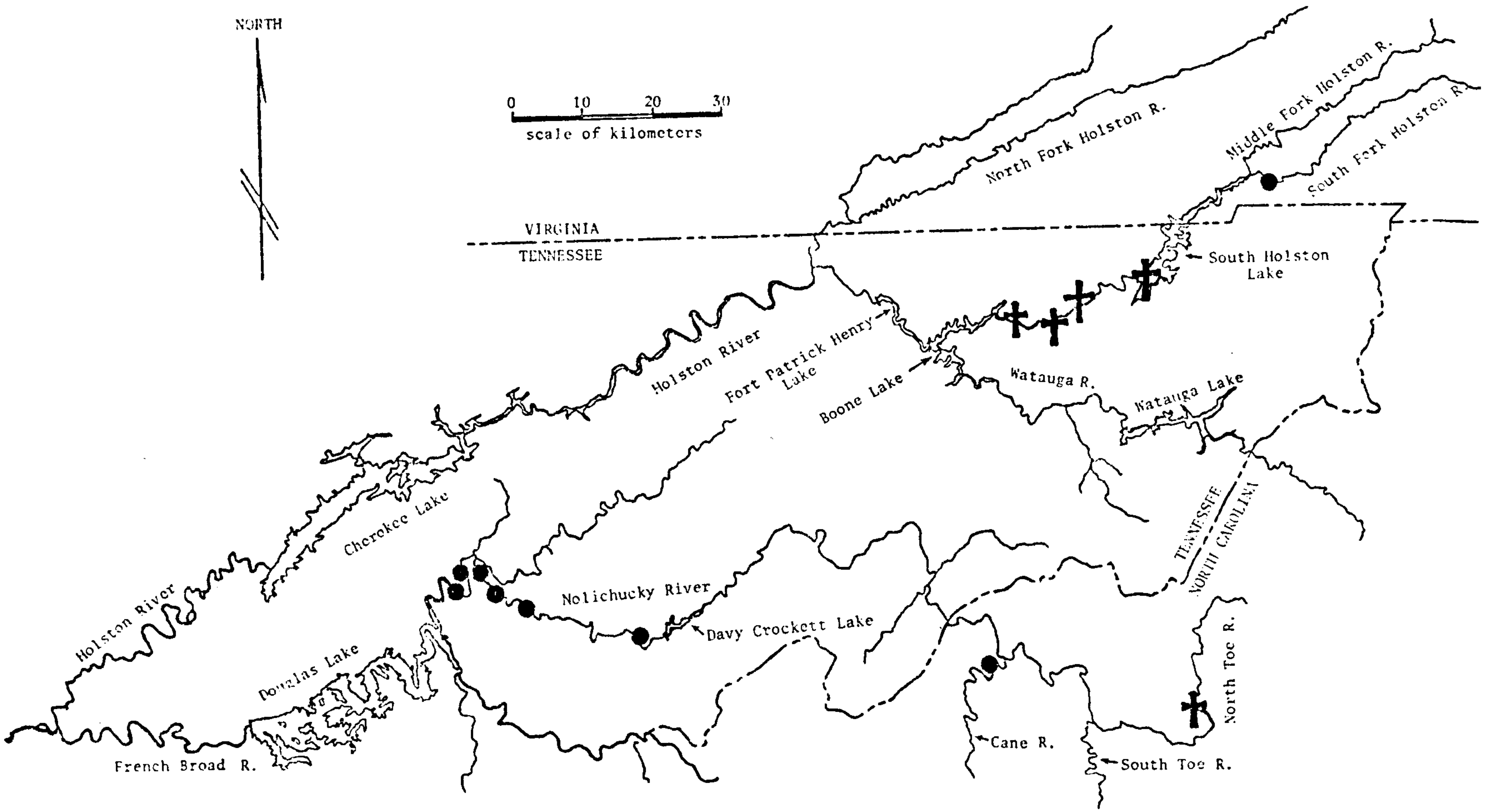

Figure 32. Distribution of <u>Etheostoma acuticeps</u>. ✝ indicates extirpated population.

sexual dimorphism, and general body characteristics, E. acuticeps is probably more closely related to E. camurum and E. rufilineatum than to the E. maculatum species group. It does not appear very closely related to either, and its ancestral divergence from their predecessors was likely long ago. Sharphead darters are not more widely distributed for a variety of reasons, including the impoundment and pollution of most large rivers, possible competition with other darters, and simply unsuitable microhabitats within the few undisturbed large rivers.

The future of the sharphead darter is uncertain. That of the South Fork Holston population is extremely precarious as it occupies a very marginal microhabitat within only a kilometer or two of stream. Sharphead darters in the Cane River are not numerous, as they are also at the upstream limits of their range, and are restricted to only the lower 6 km of the river. The Cane is also the site of two gravel washing operations, one of which was the source of a 5 km-long fish kill. The Toe River is incredibly polluted with mica and feldspar silt from strip mining. Much of this silt has been captured by Davy Crockett Reservoir, which was 77% silted in by 1970 (TVA, 1972). The ability of Davy Crockett to continue functioning as a settling basin is therefore seriously impaired. Tremendous amounts of silt remain in the Toe River, moving inexorably downstream, towards the lower Nolichucky. Thus the Nolichucky population, although currently very healthy, may rightfully be considered threatened within the state of Tennessee. The tenuous existence of the South Fork Holston and Cane

Rivers suggests that they should be given endangered status within the states of Virginia and North Carolina, in order to protect this unique and beautiful form of life.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. There were two objectives to this study: to study the life history of a little known species of darter, and to look at the competitive feeding interactions between it and several other species of darters. Food habits were compared on the basis of stomach analysis. Several of these syntopic darters are members of the same subgenus, Nothonotus, which should indicate a high degree of competition as a result of similar physiognomy and habits.

2. Diets of the few E. maculatum and E. camurum that are available from this study correspond well enough with those studied by Stiles (1972) to allow a direct comparison between E. maculatum, E. camurum, E. rufilineatum, and E. acuticeps. Feeding data from these studies indicate that although there are significant differences between the feeding habits of E. maculatum, E. camurum, and E. rufilineatum, there are even greater similarities. A typical diet for these species includes 66 to 78% Chironomidae and 10 to 24% Baetidae and Simuliidae.

3. E. acuticeps consumes 31% Simuliidae, 30% Baetidae, and only 26% Chironomidae, in sharp contrast to the other Nothonotus. It seems that E. acuticeps is separated by its preference for fast water from E. camurum and E. maculatum, by its mouth position from

E. camurum, and by its association with Podostemum from E. rufilineatum. These differences in habitat and physiognomy are in turn reflected by the relative percentages of the different taxa of food items in their stomachs. Unfortunately, it is not known to what degree the darters actually compete for food, or whether food is even a limiting factor for any of these species. It could well be that any real competition between E. camurum, E. rufilineatum, and E. acuticeps is most intense over nesting sites (see below).

4. Etheostoma acuticeps' diet is also different from the species that are commonly found in its habitat, two members of the subgenus Etheostoma: E. blennioides and E. zonale. Etheostoma blennioides consumes 80% Chironomidae, which is correlated with the subterminal position of its mouth. Etheostoma zonale eats 47% Chironomidae and 39% Baetidae, which is associated with its subterminal mouth and its habit of inhabiting areas of plant growth. For the most part, these darters are found in the slightly slower, deeper portions of riffles. Thus, E. acuticeps is different in its preference for faster water, its terminal mouth position, and its very precise feeding behavior.

5. Etheostoma acuticeps is a very aggressive darter during the breeding season. Breeding males display territoriality by intense color changes and the biting of other males. Biting is rare among the other Nothonotus (Stiles, 1972), whereas color changes are typical.

6. Like _E. camurum_ and _E. rufilineatum_, _E. acuticeps_ apparently bury their eggs in sandy substrate between rocks, rather than attaching the eggs to the underside of flat rocks, as _E. maculatum_ does. On the basis of this, its lack of sexual dimorphism, and its general body characteristics, _E. acuticeps_ is believed to be more closely related to _E. camurum_ and _E. rufilineatum_, rather than the _E. maculatum_ species group. The common ancestor of these three species probably inhabited the Tennessee river system a relatively long time ago, as these species are widely divergent and limited to the Tennessee and Cumberland river drainages.

7. The sharphead darter appears to have a typical _Nothonotus_ life history. Gonad development begins in April, and breeding occurs from about late June to at least the middle of August, making it one of the latest spawning darters. Most _Nothonotus_ spawn from late May to the first week of August (Stiles, 1972). Fecundity increases with length from 100 eggs per 39-mm female to nearly 300 eggs per 55-mm female. Early development of embryos and prolarvae were recorded. Very minor differences between prolarvae of _E. acuticeps_ and _E. rufilineatum_ were noted.

8. Based on length frequency data of males, _E. acuticeps_ seems to live to an age of three years. Sexual maturity is achieved at one year. Maximum standard length of males is 65 to 70 mm, and about 55 mm for females.

9. *Etheostoma acuticeps* ranges to an altitude of 645 m in the Cane River, and only 536 m in the South Fork Holston River. The gradient in the South Fork Holston (3.6 m/km) is much steeper, however, than in the Cane (2.3 m/km). The darter may also be limited by poor substrate in the South Fork Holston and by the paucity of *Podostemum* in the higher reaches of the Cane River.

10. The densest *E. acuticeps* populations are found in the swifter parts of riffles where the current velocity is about 2 m/sec. The substrate is rubble and small boulders 5 to 20 cm in diameter. Depth is around 15 to 30 cm. The rocks are typically heavily encrusted with *Podostemum ceratophyllum*. When *E. acuticeps* is abundant, they may be found in virtually all portions of a riffle, from deeper, slower areas to shallow, bare gravel bars that serve as nurseries for the young.

11. In view of the tenuous nature of the Cane and South Fork Holston populations, and the uncertain future of the lower Nolichucky River with regard to siltation, it is felt the sharphead darter warrants threatened status nationally and in the state of Tennessee, and endangered status in the states of North Carolina and Virginia.

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