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Canthyria morrisoni (new species) (Unionidae) and Other Mollusks of a Unique Ecosystem: the Tar River, North Carolina

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ABSTRACT

Clarke, Arthur H. *Canthyria morrisoni* (new species) (Unionidae) and Other Mollusks of a Unique Ecosystem, the Tar River, North Carolina. Smithsonian Contributions to Zoology, number 000, 00 pages, 5 figures, 5 tables, 1978.--The results of a survey conducted in 1977 are reported and compared with information gathered in previous years. Twenty-two species of freshwater mollusks were found including ~~a new spiny mussel~~ (*Canthyria morrisoni*) ~~which is endangered throughout its range~~ and at least seven other species which are either endangered, threatened, or of special concern in North Carolina. Populations of most species are shown to be small, partly because they have been recently reduced by damming and by pollution in different portions of the river. Ecological correlations and interspecific relationships are discussed. Evidence indicates that the survival of rare and sensitive species in this fragile ecosystem depends on constant protection from habitat disruption in two critical regions of the Tar River.

CONTENTS

Canthyria morrisoni (new species) (Unionidae) and Other Freshwater Mollusks of a Unique Ecosystem: the Tar River, North Carolina

by Arthur H. Clarke(1)

Introduction

The Tar River arises on the Piedmont Plateau of north-central North Carolina, flows in an east-southeasterly direction across the upper and lower Coastal Plain, and discharges into Pamlico Sound near Cape Hatteras. From Headwaters to mouth it spans about 125 miles. Its watershed drains approximately 2500 square miles and ranks with the Cape Fear and Neuse river systems as one of the three largest systems entirely within the state. A comprehensive and informative account of the drainage patterns and biotopes of North Carolina has been published by Cooper, Robinson, and Funderburg (1977). A useful report on the mollusks of the upper Neuse River system is also available (Walter 1956).

Mollusks from the Tar River have been collected and mentioned in the literature for many years (Lea, 1827; Rehder, 1949; Dawley, 1965; Johnson, 1970; Fuller, 1977) but no comprehensive investigations or quantitative studies of the whole mollusk fauna have been published. Such an effort seems desirable because the river has now been shown to be a cluster area for three species of mollusks, three species of fish, and one species of amphibian which are classified either as "endangered," "threatened," or "of special concern" (Fuller, 1977; Teulings and Cooper, 1977). Present information, in fact, indicates that the Tar River mollusks may be even more in need of protection than previously reported.

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Quantitative data on present populations are therefore necessary so that the need for conservation may be objectively assessed and so that future changes in the fauna may be evaluated.

Acknowledgments

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Materials and Methods

The Tar River was recently identified as an area of special interest when Carol B. Stein (personal communication, 1966) first reported having collected the rare, spiny mussel Canthyria in that river near Tarboro, North Carolina. This inspired several other freshwater mollusk specialists at that time, including the writer who then resided in Canada, to visit the river. My first opportunity to study the area in detail, however, came about in early 1977 after moving to eastern Virginia. Five trips were made to the Tar River in 1977 and twenty sites on the river distributed from the headwaters to near the mouth, and one on Fishing Creek, were systematically searched on one or more occasions. Water samples at some of these sites were also collected for analysis.

The locations of the study sites are shown on Figure 1 and described in Table 1. Some additional data are also given in Tables 1 and 2 and other data are cited elsewhere where pertinent.

Table 2 requires some explanation. The problem of accurately determining the size of freshwater mollusk populations has never been entirely solved. Freshwater mollusks ordinarily occur in groups separated by wide areas which contain very few, if any, other individuals. Sampling methods which utilize randomly-spaced quadrat or grab samples may therefore fail to detect some species which are present. Experience has indicated that a trained collector, operating under conditions of equal specimen accessability (i.e., satisfactory daylight and low water levels) and using the same collecting techniques, is able to accurately estimate the relative abundance and diversity of mollusks within collecting areas by comparing what he finds during equivalent periods of searching. Furthermore, if the sampling is done carefully and thoroughly, and if population density assessments are made within species clumps when they are encountered, the procedure provides a basis for approximate quantitative population estimates. That method has been used in this study.

In Table 2, the estimated values given for area searched have been determined by (a) visually estimating the area covered at the time the collections were made (stations 1521, 1524, 1525, 1526, 1530, 1544, 1549) or (b) calculating them shortly thereafter by multiplying the number of minutes spent searching by $2.0M^2$/minute. Two square meters is the approximate area ordinarily covered by the writer during each minute of brailing. The resulting total estimates are therefore only approximate but they are useful for calculating approximate species densities.

Initial inspection of the total hardness values (ppm $CaCO_3$ + $MgCO_3$) indicated an interesting trend. The highest values (ea. 135 ppm) were from the two farthest upstream localities, the next highest (ea. 70 ppm) were from an intermediate locality, and the lowest values (ea. 30 ppm) were from downstream localities and a mid-river tributary (Fishing Creek). In order to test the reality of that trend, between December 4 and 5, 1977 a more complete series of water samples were collected from the Tar River and several tributaries and analyzed both in the field and in the laboratory. As previously, total water hardness was determined through replicate tests using a Hach Chemical Company hardness testing kit. On this occasion, however, a technique using larger water samples was used and greater precision was achieved.

Because of recent rain, water levels were much higher than during earlier visits and hardness values were much lower and showed much reduced disparity (Table 2). Nevertheless, the new measurements support the conclusion that, because of the contribution of softer water from tributaries, water hardness in the Tar River tends to decrease as one proceeds downstream. The magnitude of this shift is highly variable, however, and varies from more than 100 ppm at times of low water to less than 5 ppm during periods of high runoff.

Before discussion of the results of the survey some comments about individual collecting stations are necessary. The specimens reported here were all collected during a period of relative drought. The effect of this was particularly pronounced at the headwater stations (1544, 1545, and 1519) where the river was reduced to a series of pools connected by very narrow, slow-flowing channels. Station 1544 was nearly dry and the rocky bottom there was thickly covered by tree leaves on the day it was searched. Collecting was therefore difficult and some species may have been present although none were observed. Station 1545 consisted of a few, deep, muddy, organically rich pools overhung by deciduous forest trees. The few species present were more densely packed than one usually sees. This may have been a result of crowding induced by downshore migration as water levels receded. Station 1519 also consisted of remnant pools but the bottom was almost entirely of clean sand. No overhanging trees were present and, except for a few specimens in one tiny, muddy area adjacent to a log, the area was nearly barren of mollusks.

Proceeding downstream, the next five stations were in areas of continuous river flow and no pollution was evident. Habitat diversity increased and was particularly noticable at station 1485 near Spring Hope. Here the river flows around a small island and riffles, sandy, muddy, and submerged, heavily vegetated areas are all present.

At the next locality (station 1526) a transition to slack-water conditions was evident. The bottom was principally of mud. The next two localities (stations 1525 and 1524) are at the edge of a large reservoir formed by a dam near Rocky Mount. Here the substrate is entirely of mud.

Below Rocky Mount (station 1482) river flow is uninterrupted but the water appears to be polluted. This condition becomes progressively alleviated as one continues downstream to Tarboro and below Tarboro (stations 1483 to 1530) the water appears to be unpolluted. (Station 1483 and station 1546 are at the same locality.) At the lowermost station (1530) a strong tidal influence is evident and the river bank is obscured by a tangle of cypress trees.

Results

This survey resulted in the collection of 22 species of mollusks (Table 3). The specimens now form part of the Mollusks Collection in the National Museum of Natural History, Smithsonian Institution. One species, previously undescribed and unnamed, is described below.

Canthyria morrisoni, new species

Description: Shell up to about 56 mm long, 35 mm high, 28 mm wide, of moderate thickness, evenly rounded anteriorly, roundly pointed posteriorly, and bearing from one to three prominent spine-like processes on each valve. Periostracum pale orange-brown and covered with narrow and wide greenish rays in the juvenile; blackish-brown and unrayed in the adult. Beaks slightly elevated and placed approximately one third of the distance, or less than that, from the anterior to the posterior. Beak sculpturing consisting of about three rather short, strong, bars on each unbone. The first one or two bars are oblique and extend diagonally across the growth lines (the posterior end is closer to the hinge margin) and the later bars are slightly curved and nearly parallel with the growth lines. The beak sculpture of a North Carolina specimen of this species (as *Pleurobema collina*) has been illustrated by Boss and Clench (1967, figure 2).

The juvenile bears three, narrow, downward-curved spines on the right valve and two on the left. On the right valve two spines are 1.0 mm long, placed side by side, and located 2.7 mm below the beak and one is 2.3 mm long and located 6.2 mm below and behind the beak. On the left valve one spine is 1.0 mm long and located in a position corresponding to the gap between the two small spines on the right valve; the other is of similar size and position as the larger spine on the right valve. The adult (holotype) bears only one nearly straight spine on each valve, each originally 2.6 mm long, and located about 17 mm below and somewhat behind the umbone. The tip of the spine on the left valve was broken after it was collected.

The hinge teeth are medium-sized and strong. The pseudocardinal teeth are triangular, irregularly serrate, somewhat compressed: two in the right valve (the anterior one is much reduced) and two in the left. A thickened, low interdental projection in the right valve articulates with a shallow cavity in the left. The lateral teeth are straight, elevated, compressed and diagonally placed: one in the right valve and two in the left. The shell wall is slightly thicker anteriorly than posteriorly. The nacre is bluish white with an anterior suffusion of pink in fresh specimens. The muscle scars are impressed, especially the anterior ones. The pallial line is also impressed anteriorly (where it intersects the lower ends of numerous narrow grooves and wrinkles) but is indistinct posteriorly.

A living juvenile specimen 33.6 mm long has a long incurrent opening surrounded by about 30 large and small, gray, white-tipped tentacles and a shorter, somewhat produced excurrent siphon with its opening surrounded by about 12 small, gray, white-tipped tentacles. The supraanal opening is about as long as the incurrent and excurrent openings combined, it has no papillae but is bordered by a narrow zone of gray pigment, and it is separated from the excurrent siphon by a short mantle fusion. The foot and mantle edges are both pale yellow.

Comparisons: With respect to shell characters, as well as zoogeography, this species is intermediate between the other two species of the genus, i.e. Canthyria collina (Conrad) of the James River system in Virginia and C. spinosa (Lea) of the Altamaha River in Georgia. It is larger, heavier, and has stronger spines than C. collina but it is smaller, less robust and has weaker spines than C. spinosa. C. morrisoni is also intermediate in shell outline. In C. collina, for example, the shell is subrhomboid and resembles Elliptio complanata in outline: the posterior margin is obliquely truncate and at its junction with the dorsal margin there is a distinct angle. In C. morrisoni the posterior-dorsal angle is low and rounded and in C. spinosa no angle is present, i.e. the dorsal margin and the posterior margin form a continuous, slightly curved or straight line. The periostracum in C. collina is unrayed in all growth stages, in C. morrisoni it is rayed in the juvenile and unrayed in the adult, and in C. spinosa it is rayed in the juvenile and also rayed in many adult specimens. Finally, in fresh specimens the nacre of C. collina is white, in C. morrisoni it is pink and, according to Boss and Clench (1967:50), in C. spinosa it is purple.

Types: The holotype is in the National Museum of Natural History and bears catalog number 758667. It is from Station 1483, the Tar River at Old Sparta, 5 miles south of Tarboro, Edgecombe County, North Carolina. It was collected alive on May 18, 1977 by the author and his wife, Judith J. Clarke. The soft parts have been frozen for enzyme analysis. Another specimen, a paratype (USNM 758545) was collected by us at the same locality (Station 1546) on October 23, 1977. It, a juvenile, is being reared in an aquarium in the National Museum of Natural History.

Measurements (mm):

	Length	Height	Width (including spines)
Holotype	56.1	35.1	21.9
Paratype (on December 8, 1977)	33.6	21.4	15.9

Distribution: Known only from two localities in the Tar River in North Carolina, viz. at Old Sparta, Edgecombe County and according to Shelley (in Fuller, 1977) in the vicinity of Spring Hope, Nash County. Its interspecific relationships and its ecology are described elsewhere in this paper.

Remarks: This species is named in honor of Dr. Joseph P.E. Morrison, the distinguished former Associate Curator at the National Museum of Natural History. He was the first (Morrison, 1955) to recognize that an undescribed species, intermediate between C. collina and C. spinosa, exists in the Carolinas.

Canthyria morrisoni is very rare and is known to occupy only one or two restricted portions of a single river. If its habitat is disrupted by channelization or by damming, as has been recently proposed (Shelley (in) Fuller, 1977) this species will become extinct. It was decided that since a clear statement of its taxonomic status and its critical habitat would strengthen the case for habitat preservation, delay in publication of that information would be irresponsible.

The function of the spines in Canthyria is not known with certainty. Johnson (1970:304) and others have speculated that the spines in young C. spinosa may serve as grappling devices in maintaining stability in the substrate. In C. morrisoni, at least, this is unlikely because the species lives buried in fine sediments in areas of slow current. What may be more likely is that, evidenced by its discontinuous distribution even in a geologically stable area, and in accord with the Diversity Maturation Hypothesis (Clarke, 1978), it has evolved extreme morphological distinctness in response to the kind of intense biological selection in mixed-species communities which is characteristic of mature biomes. The south-to-north reduction in spinosity also correlates with that hypothesis but in this instance tactile selection of prey by predators may be more important than visual selection.

The placement of the spines in Canthyria also appears to be significant. The single small spine on the left umbone of C. morrisoni articulates with the space between the two small spines on the right umbone when the valves are widely open. This has obvious mechanical value in maintaining valve alignment. Beak sculpturing in this species and in other species of Unionidae appears to have the same mechanical function because early ridges on one umbone articulate with corresponding grooves between ridges on the opposite umbone when the valves are widely gaped, i.e., in situations where the gape is so wide that the hinge teeth are only loosely in contact. Such features might have special value in juvenile mussels with weakly-developed adductor muscles. The fact that beak sculpturing in unionids is not evenly concentric, and tends to be even more oblique in earlier-formed elements than in later, appears to support this view, but experimental evidence is needed to properly evaluate it.

Population Distributions and Densities

A correlation of observed molluscan density (living specimens per square meter of area searched) with locality, and a correlation of species diversity with locality, are both shown in Figure 2. Excluding the anomalous density valves observed at headwater stations 1544, 1545, and 1519, for the reasons discussed above, two areas of relatively high density and high diversity are evident: (1) the upper mid-stream area between stations 1520 and 1485 (and to some extent including station 1526) and (2) the shorter, lower stream area between stations 1483 and 1528. The mid-river stations affected by damming (stations 1525, 1524 and, in part, station 1526) exhibit low diversity and very low molluscan densities. The polluted localities (stations 1482, 1547, and 1548) also show low densities and reduced diversity.

Comparison of the data in Tables 1 to 3, and Figure 1, indicates the existence of several trends, as follows:

All six species of prosobranch gastropods are limited to the free-flowing portion of the Tar River above the Rocky Mount reservoir. This is in accordance with observed ecology. That part of the river is shallow, undoubtedly well-oxygenated, almost certainly unpolluted, and has good habitat diversity. The two pulmonate gastropod species are also more frequently seen there although they also occur in a marginal pool at Tarboro. The more abundant species there, Physa hetrostropha, is well known for its resistance to organic pollution and to low oxygen concentrations.

The two sphaeriid species were also found in this upper mid-stream area. Both of these, and species of *Pisidium*, may be more widely distributed than the data indicate, however. Small infaunal species could be easily missed by brailing and other techniques designed principally for unionid and gastropod collecting.

Among the freshwater mussels, *Elliptio complanata* was found nearly everywhere. *Alasmidonta undulata* was rare but was also found throughout the river, and *Strophitus undulatus* was also rare and somewhat similarly distributed. Five species (*Elliptio lanceolata*, *Alasmidonta heterodon*, *Lasmigona subviridis*, *Lampsilis ochracea*, and *Villosa constricta*) are entirely, or nearly, restricted to the upper river, while three species (*Canthyria morrisoni*, *Uniomerus tetralasmus*, and *Lampsilis cariosa*) are entirely, or nearly, restricted to the lower river below Tarboro. *Anodonta imbecilis* is characteristic of fine, muddy substrates. It thrives in the Rocky Mount reservoir and it also occurs sparingly on mud bottoms above the reservoir.

Ecology and Community Structure

Table 4 shows the observed relationships between species occurrences and five ecological variables. it is believed that such information contributes toward a better understanding of the ecological tolerances of the species concerned within the biome under consideration. More samples are desirable for greater confidence of results but ecological information from other biomes cannot automatically be included because interactions with different species there may alter the relationships which are observed.

Figure 4 is a dendrogram plot of the occurrence relationships of the 22 species found in this survey. The plot is based on the simple presence/absence coefficient of Jaccard (Sneath and Sokal, 1973), viz.

$$S_j = \frac{a}{a+b+c}$$

in which a represents the number of stations at which any two species (say x and y) occur together, b is the number of stations at which x occurs but y does not, and c is the number of stations at which y occurs but x does not. A value of $S_j = 1$ indicates that the two species have always been found together, values close to 1 indicate frequent association, and lesser values indicate progressively more infrequent association. The values therefore define relative expected frequency of co-occurrence as based on available data and, as such, define molluscan communities in the Tar River. Other coefficients are available and the choice of which one to use is arbitrary. The Jaccard coefficient is a widely used and uncomplicated one, however, and it produces straightforward comparitive results.

Faunal Changes

Local fishermen report that mussels used to be much more abundant in the Tar River than they are now. Although data are lacking to demonstrate this trend in general, two specific and striking examples of recent changes in the fauna can be documented.

In 1966, H.D. Athearn collected one specimen of *Canthyria morrisoni* and other species in the Tar River from sand bars at Tarboro. A.H. Clarke also visited that locality (and others) on August 21, 1966 and found abundant *Elliptio lanceolata* there and several other species but not *Canthyria morrisoni*. A visit to the same locality in 1977 (Station 1548) at a time of low water levels produced only specimens of the pollution tolerant pulomonate *Physa heterostropha*, one *Helisoma anceps*, and an old shell fragment of *Elliptio complanata*.

The faunal changes at Tarboro are presumably attributable to recent pollution. Municipal officials at Tarboro report that sewage treatment facilities were substantially upgraded in 1975. United States Geological Survey records show that fecal coliform counts (colonies per 100 ml.) have decreased from a maximum of 15000 in 1974 to 7100 in 1975 to a maximum of 120 in the summer of 1976. Biological oxygen demand (BOD) measurements also show some improvement since 1974. (Coliform counts and other pollution monitoring by the Geological Survey began in 1974). Municipal officials in Rocky Mount also report substantial upgrading of their sewage treatment facilities in 1958 and 1966, with final chlorination added in 1966.

It is likely that these improvements will have a beneficial effect on the fauna and that the diverse and dense molluscan assemblages formerly seen at Tarboro may become re-established. The prospects for improvement in the fauna between Rocky Mount and Tarboro are also encouraging.

On July 11, 1971, J.P.E. Morrison collected mollusks in the Tar River 1/4 mile south of the highway 58 bridge, 9 miles south of Nashville in Nash County. This locality is close to our Station 1526. In 1971 the river was free-flowing over rapids at that locality and Dr. Morrison collected the following living species: Elliptio complanata (63 specimens), E. lanceolata (49), Strophitus undulatus (1), Lampsilis ochracea (6) and Villosa constricta (22).

In September 1972, a dam was constructed above Rocky Mount and a large lake was formed above it. The lake bottom is now composed entirely of mud. The water also backs up over Station 1526 and Morrison's locality and the bottom there is also mud. The lake now supports a thriving colony of the Anodonta imbecilis and a sparse population of the ubiquitous Elliptio complanata (see Tables 2 and 3, Stations 1524 and 1525). At Station 1526 a diverse community of mussels still exists but Villosa constricta is now absent, Elliptio lanceolata is much less abundant, and Anodonta imbecilis (absent in 1971), although not yet dominant, is now the second most abundant species.

In general, the Tar River mollusks fauna appear to be in danger from both water pollution and stream flow alteration. Improvements are being made in sewage treatment facilities in at least some municipalities and this will be beneficial. Damming must also be curtailed, however, if further impoverishment of the fauna is to be avoided. Fishing pressure in the river also appears to be high and fish are said to be much less abundant now than in the recent past. The possible effect of this on freshwater mussel populations, through scarcity of host fishes, is undoubtedly significant.

Conclusions

Fuller (1977) listed 13 species of freshwater mollusks as endangered, threatened, or of special concern in North Carolina. Of these, six are now known to occur in the Tar River, viz. Lioplax subcarinata ("endangered"), "Canthyria" sp. (= Canthyria morrisoni, "endangered"), Elliptio "lanceolata" ("special concern"), "Lampsilis" ochracea ("special concern"), Prolasmidonta heterodon (= Alasmidonta heterodon, "endangered"), and Villosa constricta ("special concern"). We may also add Goniobasis virginica (endangered) to the North Carolina list because it occurs in that state in only one short stretch of the Tar River (see Tables 2 and 3). One species, Canthyria morrisoni, certainly qualifies for inclusion on the official United States list of endangered species since its only extant population is a sparse one in the Tar River.

Fusconaia masoni ("threatened" in Fuller's list) has been recorded by Johnson (1970:303) from the Tar River at Providence, Granville Co. and at Bruce, 9 mi NW of Greenville, Pitt Co., and from Chilcod Creek, 8 mi W of Greenville. The Tar River localities correspond to stations 1545 and 1528 of the present survey. Chilcod Creek, a tributary of the Tar River, was not searched by me. I have examined the specimens at the Museum of Comparative Zoology on which the Tar River system records are based and I believe that the Providence and the Chilcod Creek specimens belong to other species. One specimen collected by R.I. Johnson in 1964 from "Tar River, bridge above Bruce, 9 mi NW of Greenville, Pitt Co., N.C." (the locality of our station 1528) appears to be F. masoni, but since the species has not been found in the Tar River since (or prior to) 1964 by other workers it is here considered a doubtful present resident of that river.

Another species of interest here is *Alasmidonta undulata*. The populations in the Tar and the Neuse rivers appear to be significantly different from those from more northern localities. The writer is now studying this species complex throughout its range but no decision about the taxonomic status of the Tar and Neuse river populations can be made at this time. The Tar River populations are distinct, however, and they merit protection.

Based on all of the foregoing, two regions of the Tar River qualify as sensitive, critical areas (see Figure 5). Area 1 extends from 5 miles above Station 1519 (at Hwy. 15 about 8 mi N of Creedmore, Granville 37
Co.,) downstream to Station 1526 (the head of the reservoir near Rocky Mount, Nash Co.). This region contains the following critical species: *Lioplax subcarinata*, *Goniobasis virginica*, *Elliptio lanceolata*, *Alasmidonta undulata* (Tar River form), *Alasmidonta heterodon*, *Lampsilis ochracea*, *Villosa constricta*, and possibly *Canthyria morrisoni*. Area 2 extends from 5 miles above Station 1483 (Old Sparta, Edgecombe Co.) to 5 miles below Station 1528 (1 mi E of Falkland, Pitt Co.). It contains *Elliptio lanceolata*, *Canthyria morrisoni*, the Tar River population of *Alasmidonta undulata*, and possibly *Fusconaia masoni*. These regions also correspond to the density and diversity peaks evident in Figure 2. 38

The information in Table 4 shows clearly that the populations of these critical species are sparse at this time and that some are probably declining toward the critical minimum beyond which survival is unlikely. Further ecological disruption will surely be disasterous. Channelization will greatly restrict habitat diversity by eliminating riffles and other important mid-stream, shallow water habitats. Dams have been proposed for two localities on the Tar River, viz. Gray Rock (near Oxford) in Granville County and near Spring Hope in Nash County. These dams would be disasterous for critical species in those areas because the same effects can be expected that have produced already above Rocky Mount, i.e. the substrate will become overlain with mud, the fauna will become dominated by Anodonta imbecilis, molluscan density will drastically decrease, and many species will be eliminated. It is therefore recommended that a moratorium be placed on all dam construction and channelization projects within the critical areas of the Tar River shown on Figure 5 and that all appropriate federal, state, and municipal agencies cooperate to ensure that pollution or other ecological disruption in those regions is not allowed to occur.

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Table 1

Temporal and Locational Data

Station Number	Date (1977)	Searching Time (hours)	Headwater to Mouth Sequence	Location
1481	May 18	1.0	-	Fishing Creek, 2 mi E of Leggett, Edgecombe Co.
1482	May 18	0.5	12	Tar R., 8 mi E of Rocky Mount (in Edgecombe Co.).
1483	May 18	1.5	15	Tar R., Old Sparta, Edgecombe Co. (above bridge at Hwy 42).
1485	May 20	2.0	8	Tar R., 4 mi S of Spring Hope, Nash Co. (Hwy 581).
1519	Aug 27	1.0	3	Tar R., 8 mi N of Creedmore, Granville Co. (Hwy 15) (water very low).
1520	Aug 27	1.0	4	Tar R., 5 mi N of Wilton, Granville Co. (water very low).
1521	Aug 28	1.2	5	Tar R., 3.8 mi N of Franklinton, Franklin Co. (Hwy 1).
1523	Aug 28	1.0	6	Tar R., 3 mi N of Bunn, Franklin Co. (2.3 mi E of Raynor).
1524	Aug 29	0.3	11	Reservoir on Tar R. above dam, 4 mi W of Rocky Mount, Nash Co. (bank broadly exposed by low water).
1525	Aug 29	0.4	10	Reservoir on Tar R. at road, 4.5 mi W of Rocky Mount (mud flats broadly exposed).
1526	Aug 29	0.4	9	Tar R., 10 mi SW of Rocky Mount, Nash Co. (Hwy 58) (bank broadly exposed).
1527	Aug 29	0.7	17	Tar R., Penny Hill, 8 mi SE of Tarboro (in Pitt Co.) (Hwy 33).
1528	Aug 29	0.8	18	Tar R., 1 mi E of Falkland, Pitt Co.
1529	Aug 30	1.2	16	Tar R., Old Sparta, Edgecombe Co. (below bridge at Hwy 42).
1530	Aug 30	0.5	19	Tar R., Grimesland, Pitt Co.
1544	Oct 23	0.5	1	Tar R., 2 mi W of Berea, Granville Co. (Hwy 158) (water very low but covered by tree leaves).

[illegible]	Oct 23	0.5	2	Tar R., 2 mi SE of Berea (water low, partly leaf covered).
1546	Oct 23	1.0	15	Tar R., Old Sparta, Edgecombe Co. (collected above bridge, repeat of Sta. 1483).
1547	Oct 24	1.0	13	Tar R., 2 mi NNW of Tarboro, Edgecombe Co. (Hwy 44).
1548	Oct 24	1.5	14	Tar R., Tarboro (water low but visibility poor).
1549	Oct 24	0.4	7	Tar R., 2 mi SW of Spring Hope, Nash Co. (steep bottom, poor specimen access).

TABLE 2
Ecological and Logistical Station Data

Headwater to Mouth Sequence	Station Number	Estimated Area Searched (M)	Max. depth Searched (M)	Dominant Substrates [2]	Secondary Substrates [2]	On Specimen Collection Date		On Dec. 4-5, 1977		No. of Species Observed	Live Specimens Observed	Empty Shells Collected
						Approximate Stream Width (M)	Water Hardness (ppm)	Approximate Stream Width (M)	Water Hardness (ppm)			
1	1544	10	0.3	bld	m	4	135	9	27	0	0	0
2	1545	2	0.5	m	m	8	---	12	27	3	6	0
3	1519	120	0.6	cs sd	f sd	5	---	12	27	4	8	3
4	1520	120	1.0	cob	f sd	5	---	23	27	6	106	1
5	1521	18	0.9	cs sd	m	8	135	17	27	5	19	3
6	1523	120	1.2	cs sd	m	20	---	29	27	8	64	2
7	1549	15	0.6	m	m	25	---	30	--	9	23	10
8	1485	240	0.9	m	f sd	15	70	27	27	11	102	65
9	1526	1000	2.0[1]	sd m	m	25	---	45	--	6	23	19
10	1525	1000	1.0[1]	m	m	200	---	200	--	2	28	1
11	1524	600	1.0[1]	f sd	m	200	---	200	--	2	0	3
12	1482	60	1.2	m sd	cs sd	30	---	38	24	1	0	7
13	1547	120	0.9	gvl	f sd	22	---	40	24	3	9	27
14	1548	180	0.6	cs sd	m sd	30	---	54	24	3	12	1
15	1483	180	0.9	cs sd	m sd	30	30	60	24	3	31	0
15	1546	120	1.0	cs sd	m sd	30	---	60	--	4	9	7
16	1529	144	1.0	m	cs sd	30	---	60	24	2	41	7
17	1527	84	0.8	cs sd	m	45	---	60	24	2	51	1
18	1528	96	1.0	m	cs sd	60	---	60	24	3	13	0
19	1530	10	2.0	m	m	100	---	75	--	0	0	0
---	1481	120	1.0	m sd	m	25	30	27	24	1	27	0

(1) Specimens collected in situ on river banks exposed by drought-induced low water. Depth below normal water level is given here.

(2) Substrate code: 1, m (mud); 2, sd m (sandy mud); 3, m sd (muddy sand); 4, f sd (fine sand); 5, cs sd (coarse sand); 6, gvl (gravel); 7, cob (cobbles); 8, bld (boulder); 9, brk (bedrock).

Table 3

Species Occurrences

Taxon No.	Name	Stations and Number of Finds (alive/dead)
010	*Campeloma decisum*	1485 (14/1), 1523 (8/0), 1526 (1/0), 1545 (4/0), 1549 (2/0)
040	*Lioplax subcarinata*	1485 (4/0), 1523 (1/0)
100	*Gillia altilis*	1520 (2/0), 1549 (1/0)
200	*Goniobasis virginica*	1485 (25/0), 1523 (6/0), 1549 (11/0)
201	*Goniobasis catenaria dislocata*	1485 (25/0), 1519 (2/0), 1520 (60/0), 1523 (43/0)
300	*Mudalia carinata*	1485 (25/0), 1520 (15/0)
450	*Helisoma anceps*	1520 (26/1), 1545 (1/0), 1548 (1/0)
500	*Physa heterostropha*	1520 (2/0), 1521 (2/0), 1548 (11/0), 1549 (1/1)
650	*Elliptio complanata*	1481 (27/0), 1482 (0/7), 1483 (27/0), 1485 (3/48), 1519 (5/0), 1521 (0/2), 1523 (0/1), 1524 (0/1), 1525 (2/0), 1526 (13/11), 1527 (51/0), 1528 (12/0), 1529 (40/7), 1545 (1/0), 1546 (5/0), 1547 (8/20), 1548 (0/1), 1549 (27/4)
651	*Elliptio lanceolata*	1485 (0/2), 1521 (11/0), 1523 (2/0), 1526 (3/2), 1549 (0/3)
660	*Canthyria morrisoni*	1483 (1/0), 1546 (1/0)
670	*Uniomerus tetralasmus*	1528 (0/1), 1546 (1/0), 1547 (0/1)
700	*Alasmidonta undulata*	1521 (2/1), 1523 (2/1), 1525 (0/2), 1527 (0/1), 1528 (1/0)

Taxon No.	Name	Stations and Number of Finds (alive/dead)
705	_Alasmidonta heterodon_	1519 (1/0)
720	_Lasmigona subviridis_	1519 (1/0)
750	_Anodonta imbecilis_	1524 (0/2), 1525 (26/1), 1526 (4/4), 1549 (0/1)
780	_Strophitus undulatus_	1523 (0/1), 1526 (0/1), 1547 (0/1)
850	_Lampsilis ochracea_	1483 (3/0), 1529 (1/0), 1546 (2/1), 1549 (0/1)
851	_Lampsilis cariosa_	1485 (0/13), 1519 (0/3), 1521 (2/0), 1526 (2/1)
870	_Villosa constricta_	1485 (3/1)
900	_Sphaerium striatinum_	1485 (2/0)
920	_Musculium transversum_	1485 (1/0), 1520 (1/0)

TABLE 4

Some Correlations of Species Occurrences with Station and Microhabitat Characteristics

Species	Stations (N)	Station Width (M)	Station Current (M/m)	Station Veget. Abund. (footnote A)	Microhab. Dominant Substrate (footnote B)	Microhab. Secondary Substrate (footnote B)
Campeloma decisum	5	8.0-(18.0)-25.0 SD 7.23	0.0-(1.8)-6.4 SD 2.71	0.0-(1.6)-5.0 SD 2.30	1.0-(1.0)-1.0 SD 0.00	1.0-(1.6)-3.0 SD 0.89
Lioplax subcarinata	2	15.0-(17.5)-20.0 SD 3.54	2.0-(4.2)-6.4 SD 3.11	0.0-(2.5)-5.0 SD 3.54	1.0-(1.0)-1.0 SD 0.00	1.0-(1.5)-2.0 SD 0.71
Gillia altilis	2	5.0-(15.0)-25.0 SD 14.14	0.0-(4.0)-8.0 SD 5.66	0.0-(2.5)-5.0 SD 3.54	1.0-(1.0)-1.0 SD 0.00	1.0-(1.0)-1.0 SD 0.00
Goniobasis virginica	3	15.0-(20.0)-25.0 SD 5.00	0.0-(2.8)-6.4 SD 3.27	0.0-(1.67)5.0 SD 2.89	1.0-(4.0)-7.0 SD 3.00	1.0-(5.7)-9.0 SD 4.16
G. catenaria dislocata	4	5.0-(11.3)-20.0 SD 7.50	2.0-(5.4)-8.0 SD 2.55	0.0-(3.3)-5.0 SD 2.36	4.0-(5.8)-7.0 SD 1.50	3.0-(5.8)-9.0 SD 2.75
Mudalia carinata	2	5.0-(10.0)-15.0 SD 7.07	6.4-(7.2)-8.0 SD 1.13	5.0-(5.0)-5.0 SD 0.00	7.0-(8.0)-9.0 SD 1.41	4.0-(6.5)-9.0 SD 3.54
Helisoma anceps	3	5.0-(14.3)-30.0 SD 13.65	0.0-(3.3)-8.0 SD 4.16	3.0-(4.3)-5.0 SD 1.15	1.0-(3.7)-7.0 SD 3.06	1.0-(2.7)-4.0 SD 1.53
Physa heterostropha	4	5.0-(17.0)-30.0 SD 12.35	0.0-(2.9)-8.0 SD 3.51	0.0-(2.5)-5.0 SD 2.89	1.0-(2.2)-4.0 SD 1.50	1.0-(1.8)-3.0 SD 0.96
Elliptio complanata	18	5.0-(44.9)200.0 SD 57.90	0.0-(2.8)-8.0 SD 3.00	0.0-(1.6)-5.0 SD 1.89	1.0-(2.7)-5.7 SD 1.74	1.0-(2.6)-5.0 SD 1.69

Elliptic lanceolata	5	8.0-(18.6)-25.0 SD 7.23	0.0-(2.1)-6.4 SD 2.54	0.0-(1.0)-5.0 SD 2.24	1.0-(3.2)-5.0 SD 2.05	1.0-(3.2)-5.0 SD 2.05
Canthyria morrisoni	2	30.0-(30.0)-30.0 SD 0.00	8.0-(8.0)-8.0 SD 0.00	3.0-(3.0)-3.0 SD 0.00	3.0-(3.0)-3.0 SD 0.00	3.0-(3.0)-3.0 SD 0.00
Uniomerus tetralasmus	3	22.0-(37.3)-60.0 SD 20.03	2.0-(6.0)-8.0 SD 3.46	0.0-(2.0)-3.0 SD 1.73	3.0-(3.3)-4.0 SD 0.58	3.0-(3.3)-4.0 SD 0.58
Alasmidonta undulata	5	8.0-(66.6)200.0 SD 77.3	0.0-(3.1)-8.0 SD 3.08	0.0-(0.0)-0.0 SD 0.00	1.0-(4.2)-5.0 SD 1.79	1.0-(4.2)-5.0 SD 1.79
Alasmidonta heterodon	1	5.0	5.0	3.0	3.0	3.0
Lasmigona subviridis	1	0.6	0.0	0.0	1.0	1.0
Anodonta imbecilis	4	25.0(112.5)200.0 SD 101.04	0.0-(0.1)-0.5 SD 0.25	0.0-(0.0)-0.0 SD 0.00	1.0-(1.0)-1.0 SD 0.00	1.0-(1.0)-1.0 SD 0.00
Strophitus undulatus	3	20.0-(22.3)-25.0 SD 2.52	0.5-(1.5)-2.0 SD 0.87	0.0-(1.0)-3.0 SD 1.73	1.0-(1.7)-3.0 SD 1.15	1.0-(1.7)-3.0 SD 1.15
Lampsilis ochracea	4	25.0-(28.0)-30.0 SD 2.50	0.0-(4.5)-8.0 SD 4.12	0.0-(2.2)-3.0 SD 1.50	1.0-(2.5)-5.0 SD 1.91	1.0-(2.0)-3.0 SD 1.15
Lampsilis cariosa	4	5.0-(13.2)-25.0 SD 8.88	0.5-(3.4)-6.4 SD 2.78	0.0-(2.0)-5.0 SD 2.45	1.0-(2.8)-5.0 SD 1.71	1.0-(3.2)-5.0 SD 1.71
Villosa constricta	1	15.0	6.4	5.0	2.0	4.0
Sphaerium striatinum	1	15.0	6.4	5.0	2.0	4.0
Musculium transversum	2	5.0-(10.0)-15.0 SD 7.07	6.4-(7.2)-8.0 SD 1.13	5.0-(5.0)-5.0 SD 0.00	2.0-(2.0)-2.0 SD 0.00	2.0-(2.0)-2.0 SD 0.00

Table 5

Estimated Maximum and Average Population Densities of Critical Species(1)

	Lioplax subcarinata	*Goniobasis virginica*	*Elliptio lanceolata*	*Canthyria morrisoni*	*Alasmidonta heterodon*	*Alasmidonta undulata*	*lampsilis ochracea*	*Villosa constricta*
1544	–	–	–	–	–	–	–	–
1545	–	–	–	–	–	–	–	–
1519	–	–	–	–	1 / <0.1	–	(1) / (<0.1)	–
1520	–	–	–	–	–	–	–	–
1521	–	–	1 / 0.6	–	–	(1) / (<0.1)	1 / 0.1	–
1523	2 / <0.1	5 / <0.1	1 / <0.1	–	–	1 / <0.1	–	–
1549	–	30 / <0.7	(1) / (<0.1)	–	–	–	–	–
1485	2 / <0.0	10 / 0.1	(1) / (<0.1)	–	–	–	(1) / (<0.1)	1 / <0.1
1526	–	–	1 / <0.1	–	–	–	1 / <0.1	–
1525	–	–	–	–	–	(1) / (<0.1)	–	–
1524	–	–	–	–	–	–	–	–
1482	–	–	–	–	–	–	–	–
1547	–	–	–	–	–	–	–	–

	Lioplax subcarinata	Goniobasis virginica	Elliptio lanceolata	Canthyria morrisoni	Alasmidonta heterodon	Alasmidonta undulata	Lampsilis ochracea	Villosa constricta
1548	-	-	-	-	-	-	-	-
1483(2)	-	-	1 / <0.1	1 / <0.1	-	-	-	-
1529	-	-	-	-	-	-	-	-
1527	-	-	-	-	-	(1) / (<0.1)	-	-
1528	-	-	-	-	-	1 / <0.1	-	-
1530	-	-	-	-	-	-	-	-

(1) Maximum density within colonies is shown in Roman type. Average density (total specimens/ area searched) is in italics. Parenthesis indicate empty shells only.

(2) Includes station 1546.

Figure Captions

Figure 1. (no caption necessary)

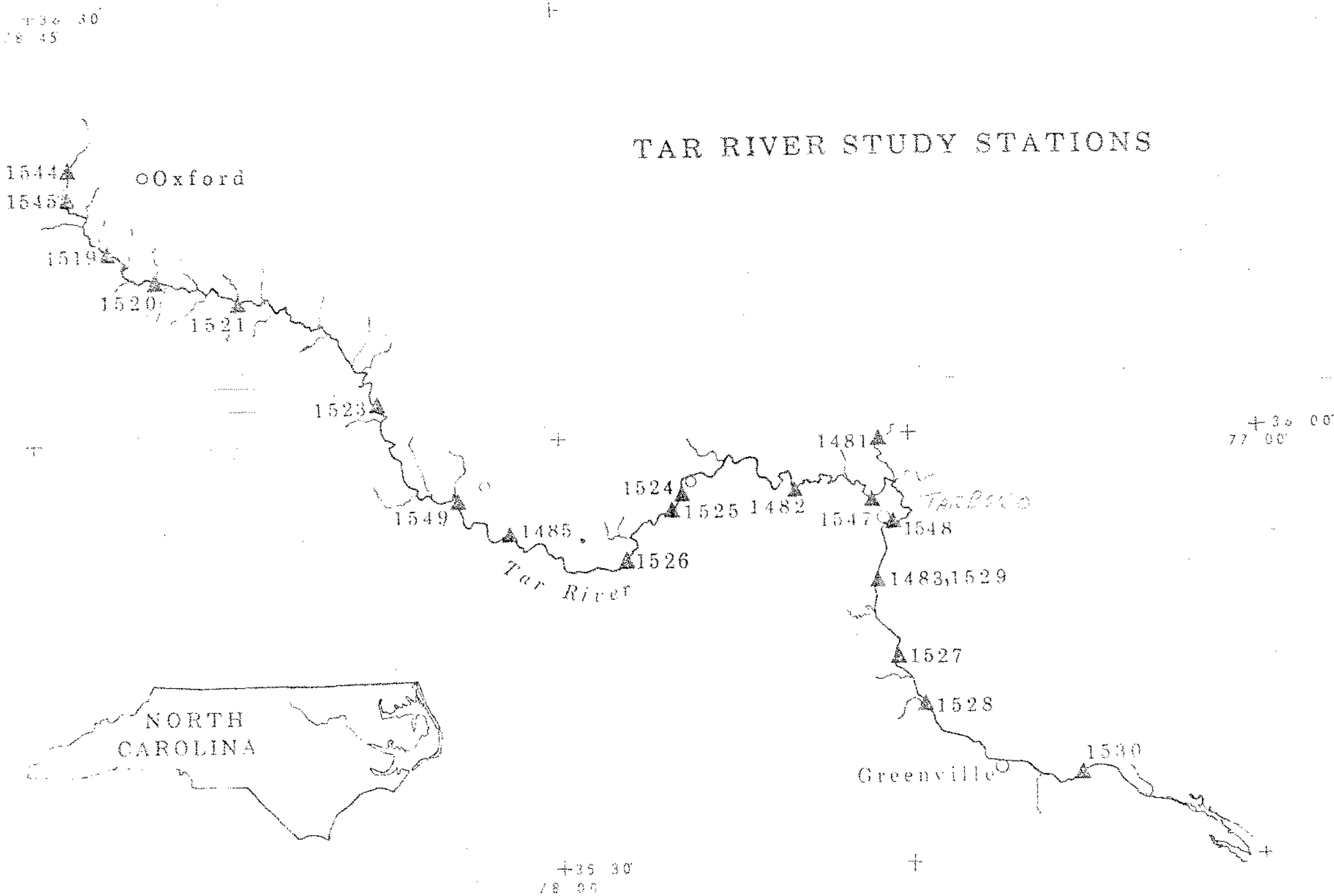
Figure 2. The species of *Canthyria*: A-C, F, G, *C. morrisoni* (new species), holotype, length 56.1 mm; D, E, *C. morrisoni*, paratype, length 33.6 mm; H, J, *C. collina*, Rivanna River, 3 mi SE of Palmyra, Va., MCZ 263 049, length 33.6 mm; I, *C. collina*, North River, Va., MCZ 37040, length 35.6 mm; K, L, M, *C. spinosa*, Darien, Georgia, USNM 84374, length 61.7 mm.

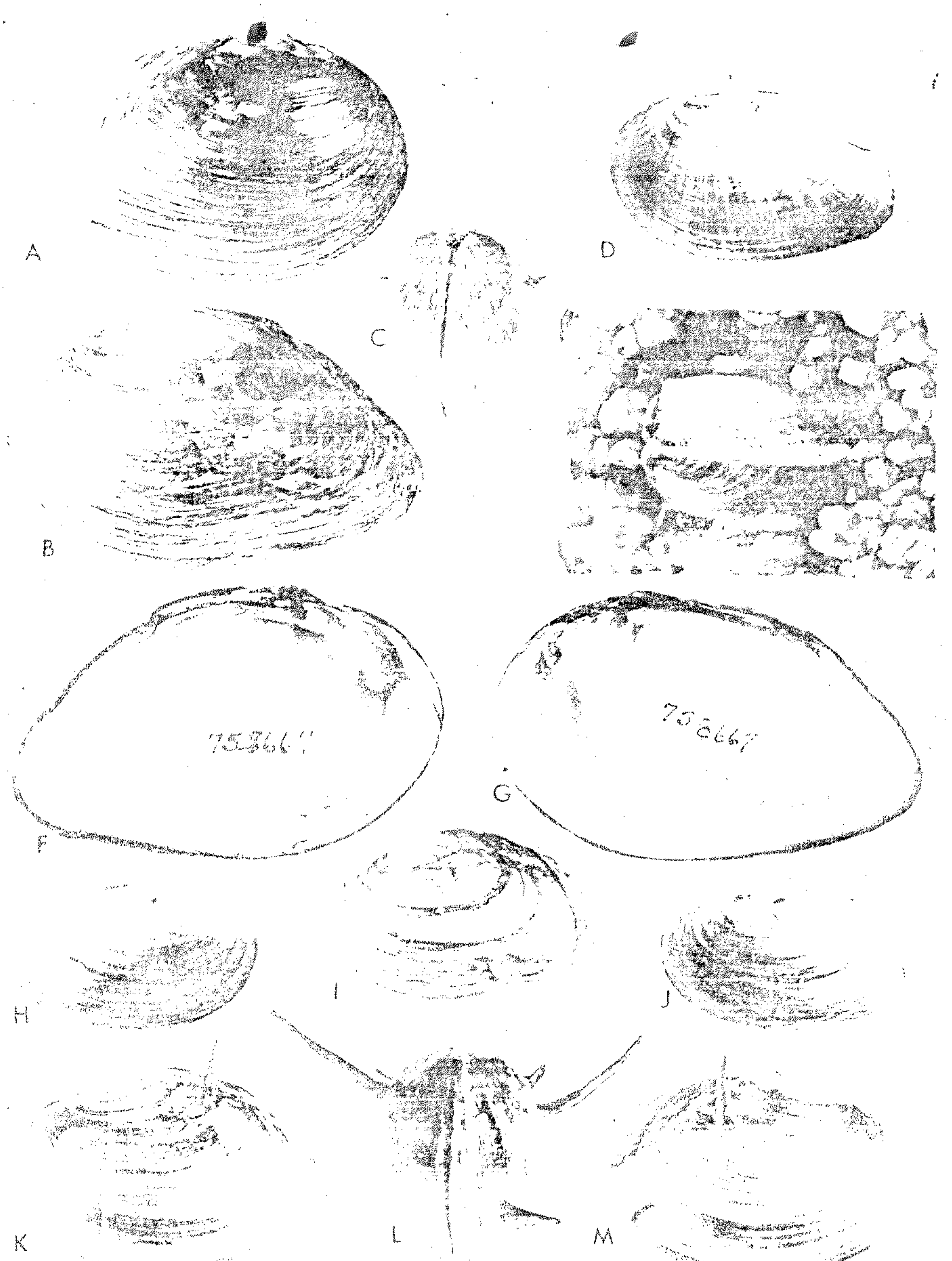
Figure 3. Average specimen density and total number of species at each Tar River study station.

Figure 4. Dendrogram plot of Tar River mollusk species by joint occurrence at 19 stations using the Jaccard coefficient of similarity.

Figure 5. Critical areas of the Tar River. See text.

TAR RIVER STUDY STATIONS

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D
C
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I
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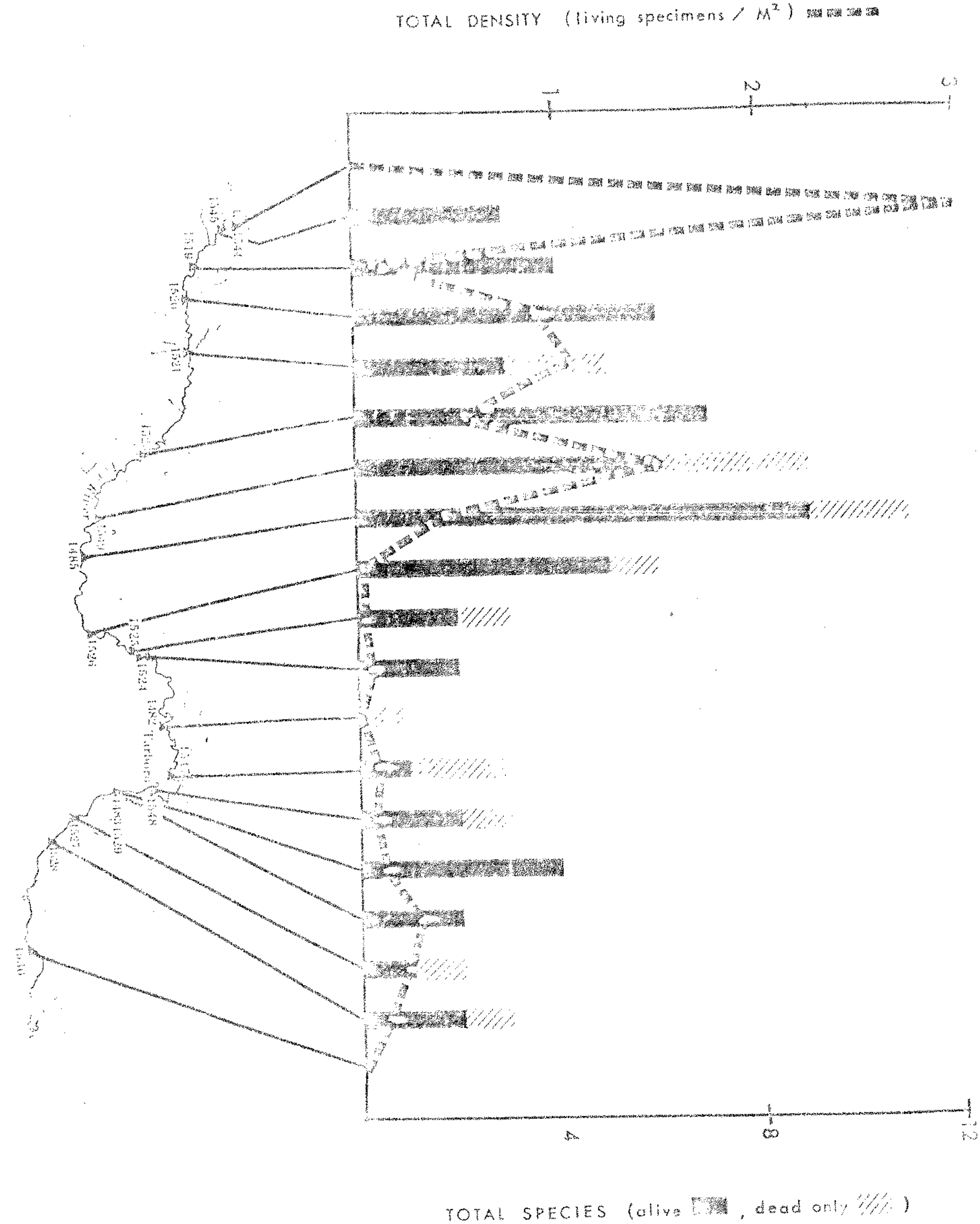
K
L
M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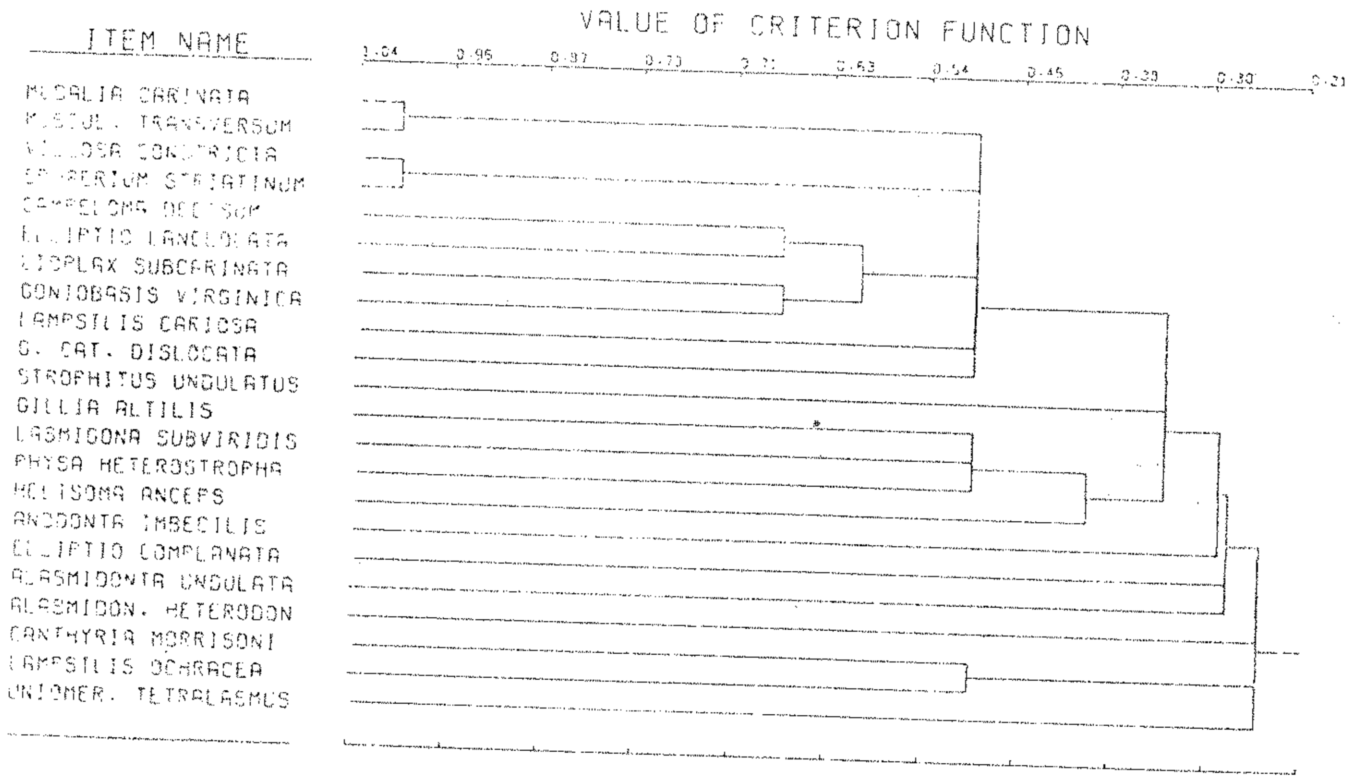
2
3
4
8
12
TOTAL SPECIES (alive , dead only)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VALUE OF CRITERION FUNCTION
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0.87
0.79
0.71
0.63
0.54
0.45
0.38
0.30
0.21
MUDALIA CARINATA
MUSCUL. TRANSVERSUM
VILLOSA CONSTRICTA
SPHAERIUM STRIATINUM
CAMPELOMA DECISUM
ELLIPTIO LANCEOLATA
LIOPLAX SUBCARINATA
GONIOBASIS VIRGINICA
LAMPSILIS CARIOSA
G. CAT. DISLOCATA
STROPHITUS UNDULATUS
GILLIA ALTILIS
LASMIGONA SUBVIRIDIS
PHYSA HETEROSTROPHA
HELISOMA ANCEPS
ANODONTA IMBECILIS
ELLIPTIO COMPLANATA
ALASMIDONTA UNDULATA
ALASMIDON. HETERODON
CANTHYRIA MORRISONI
LAMPSILIS OCHRACEA
UNIOMER. TETRALASMUS

Oxford
Tar River
Greenville
36°00′
77°00′