# THE INVASION OF THE ASIATIC CLAM *(CORBICULA MANILENSIS* PHILIPPI) IN THE ALTAMAHA RIVER, GEORGIA

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## ABSTRACT

*The population of* Corbicula manilensis *Philippi in the Altamaha River, Georgia, increased considerably from October 1971 to November 1975. Density of* Corbicula *generally reached a maximum in late summer or fall and was at a minimum during winter and spring, a relation which was inversely related to river discharge. Generally, densities of older age classes were greater in areas of low current velocity, whereas densities of younger age classes were greater in areas of high velocity. Average* Corbicula *densities increased from a minimum of 0/m² in 1971 to a maximum of 10,000/m² in 1974. The invasion of* Corbicula *has been accompanied by a drastic decline in the populations of other bivalves. Several species of Unionidae endemic to the Altamaha River may be affected by* Corbicula *and are considered endangered.*

## INTRODUCTION

The Asiatic clam (*Corbicula manilensis* Philippi) has continued to spread in southeastern rivers since their discovery in the Tennessee River in 1959 (Sinclair and Ingram, 1961). Sickel (1969) studied mussel populations in the Altamaha River (Georgia) between river miles 113 and 118 and found nine species of unionids, three of them in great abundance, but no *Corbicula*. In 1971 Scott and Schindler, University of Georgia (personal communication) observed *Corbicula* in the Altamaha River near river mile 116. Sickel (1973) proposed that *Corbicula* was introduced into the Ocmulgee River, a tributary to the Altamaha River, by overland transfer from the Flint River (Apalachicola drainage) in 1968 or 1969.

Biologists at the Georgia Power Company have been sampling the Altamaha River between river miles 113 and 118 (Figure 1) since October 1971 as part of a comprehensive program to assess and monitor the biota near E. I. Hatch Nuclear Plant (Georgia Power Company, 1974). The purpose of


FIG. 1: *Major rivers of Georgia. Arrow indicates study area.*

this paper is to discuss changes in the populations of *Corbicula manilensis* and other bivalves that have occurred from October 1971 through November 1975.

## MATERIALS AND METHODS

Samples were collected at approximately six-week intervals from several stations between river miles 113 and 118 during the period of study. A modified Petersen dredge which sampled an area of .025 m² was used. In October 1971 stations were established at RM 113.4 and 117.8. Five to ten samples were obtained at each station. In May 1973 two new stations were added to the sampling program at RM 115.9 and 116.6. In 1974 the station at RM 113.4 was discontinued, and a new station was added at RM 115.5. In February 1975, the present method of sampling was adopted in which six samples were taken in a transect at each station (RM 117.8, 116.6, 115.9 and 115.5).

Samples were washed immediately in a field screen having ten meshes/cm and preserved with 10% formalin (4% formaldehyde). In the laboratory, bivalves from each sample were sorted and *Corbicula* were separated into size classes by washing them through a series of five U. S. standard soil sieves with openings of 2.00 mm, 4.75 mm, 9.50 mm, 12.50 mm and 19.00 mm. The number of *Corbicula* retained by each sieve was recorded, empty shells were excluded. Bivalves other than *Corbicula* were counted together but not identified. These were mainly Sphaeriidae, but included some Unionidae: *Lampsilis dolabraeformis* Lea, *Canthyria spinosa* Lea, and *Elliptio hopetonensis* Lea (Sickel, 1969).

## RESULTS AND DISCUSSION

Water temperature and discharge of the Altamaha River reported from a United States Geologic Survey station near Baxley are shown in Figure 2 (U. S. Department of the Interior, 1972, 1973, 1974, 1975). Water temperature ranged from 6.5°C (winter minimum) to 30°C (summer maximum) during the period of study. Mean annual water temperature for the Altamaha is about

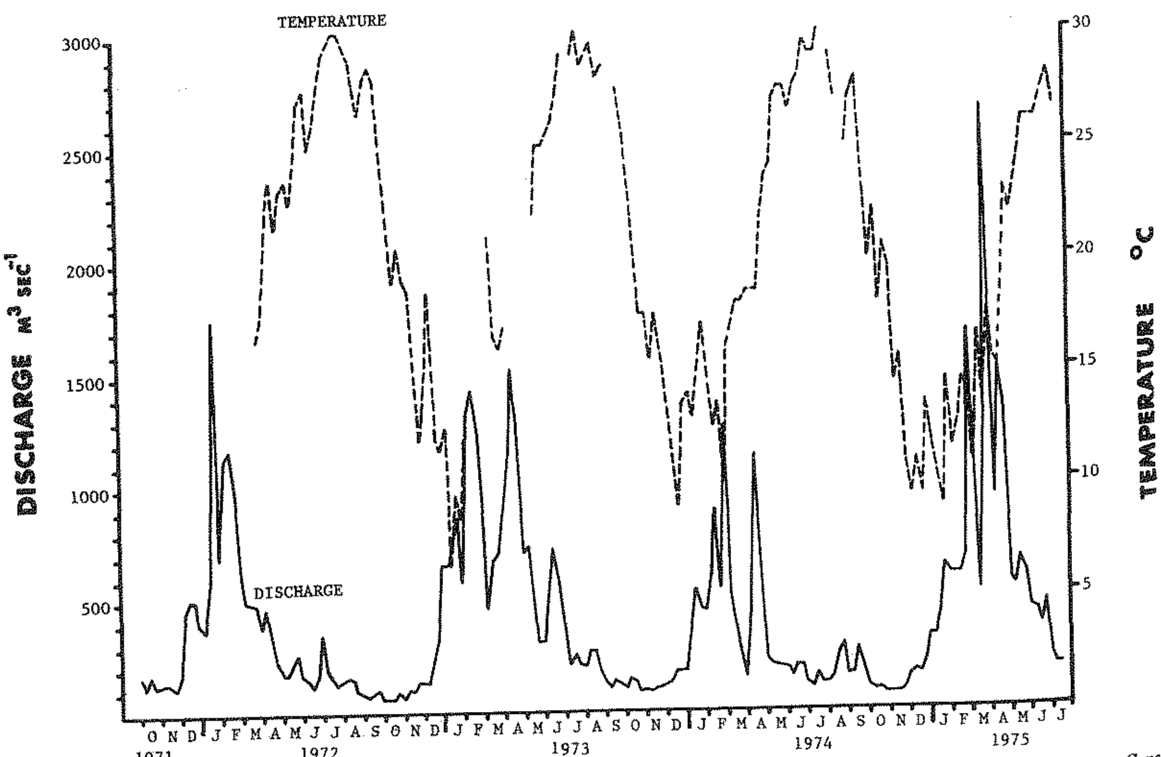


FIG. 2: *Mean daily discharge and temperature of Altamaha River near Baxley, Georgia (U. S. Geological Survey Data). Gaps in data indicate equipment malfunction.*

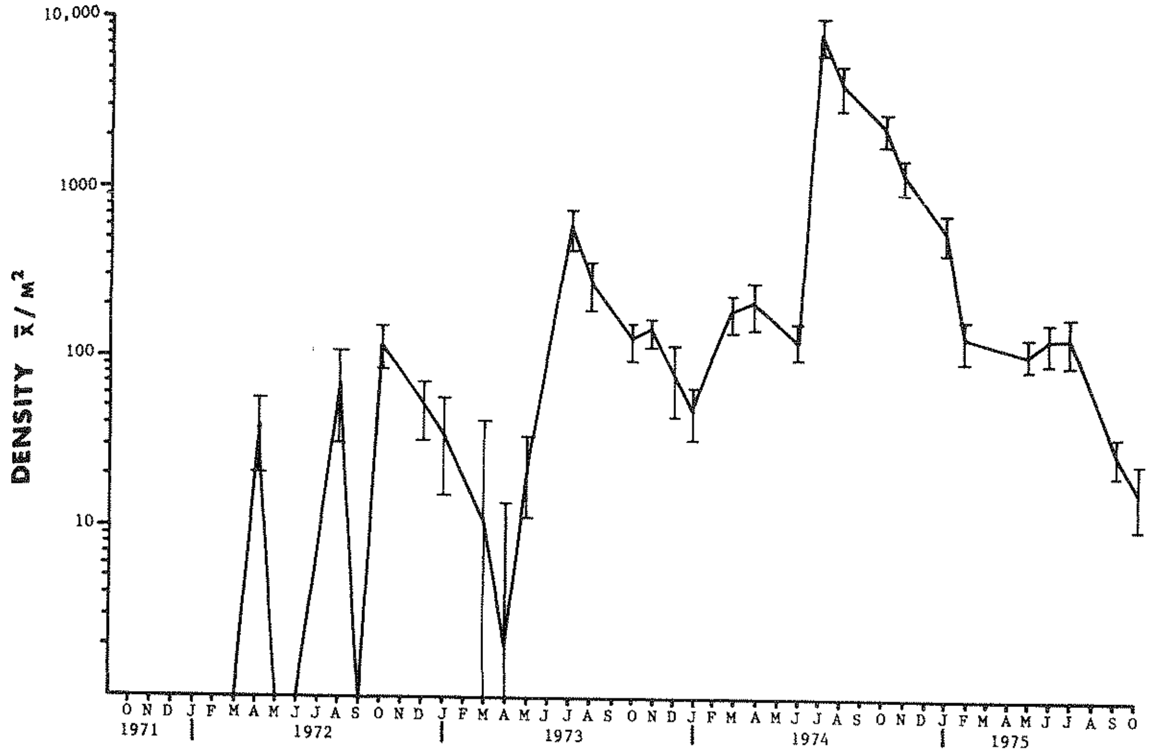


FIG. 3: *Mean (± SE) density of first year, sexually immature* Corbicula *in Altamaha River, October 1971 through October 1975.*

20°C. Mean annual discharge is 340 $m^3$/sec and ranged during the period of study from 80 $m^3$/sec (fall low) to a maximum of about 2,650 $m^3$/sec (spring 1975). Maximum discharges decreased each spring during the period 1971-1974, but reached a maximum of 2,650 $m^3$/sec in 1975. Total discharge for spring flood season was greater in 1973 and 1975 than in 1972 and 1974. The *Corbicula* spawning season begins when the water temperature reaches approximately 16-17°C (J. B. Sickel, personal communication) and continues until temperature falls below this, thus allowing a spawning season in the Altamaha River usually from April through November.

Shell lengths of *Corbicula* have been used to approximate age (Sinclair and Isom, 1963; Keup, Horning, and Ingram, 1963). The method used in this study to determine size and age classes was based on shell width and depth since these parameters determined the maximum cross sectional area that would pass through the sieve openings. Joy and McCoy (1975) found a strong correlation (r=0.99) between *Corbicula* shell length and width. Thus, the authors believe the sieve system to be a fairly accurate method for rapidly determining size and age classes, particularly when a large number of samples are involved. Size classes and their approximate year class (J. B. Sickel, personal communication) are shown in Table 1.

The population of *Corbicula* in the Altamaha River increased considerably during the period of

TABLE 1. Shell lengths retained by sieves and approximate age classes (J. B. Sickel, *personal communication*).

| *Sieve Size (mm)* | *Shell Length Retained (mm)* | *Approximate Age* |
|---|---|---|
| 2.00 | <7.5 | 1 yr. (sexually immature) |
| 4.75 | 7.5-13.5 | 1 yr. (sexually mature) |
| 9.50 | 13.4-18.5 | 2 yr. |
| 12.50 | 18.5-28.0 | 3 yr. |
| 19.00 | >28.0 | 4 + yr. |

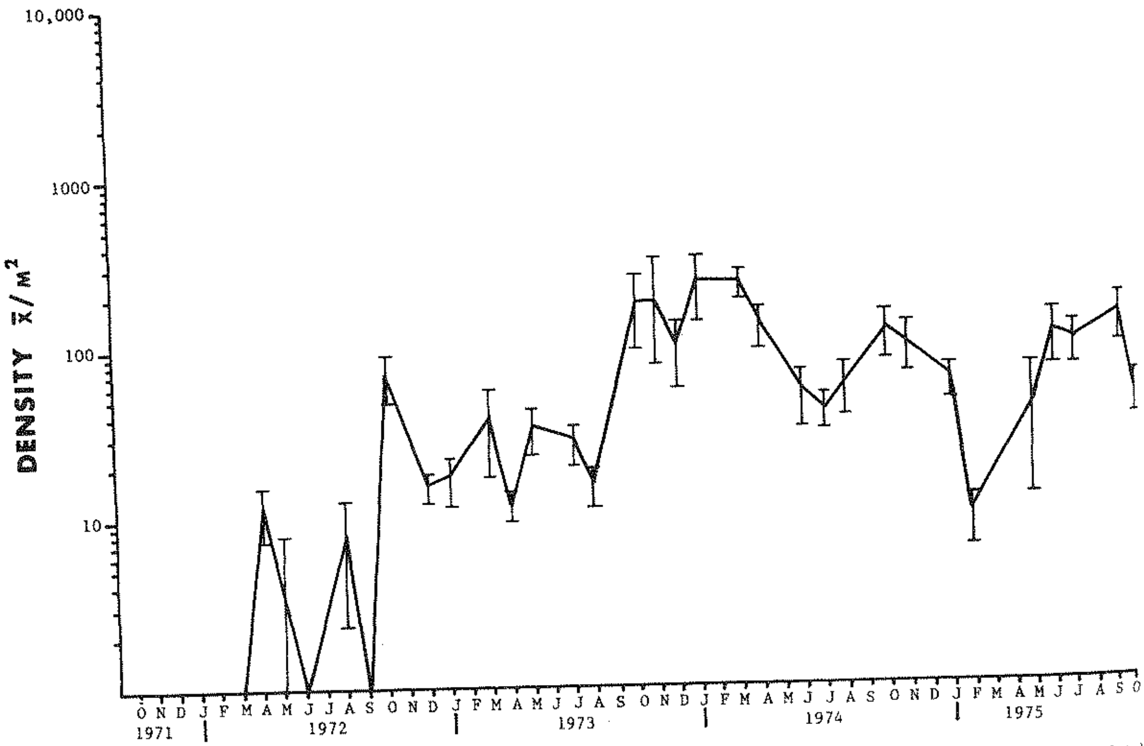


FIG. 4: *Mean (± SE) density of first year, sexually mature* Corbicula *in Altamaha River, October 1971 through October 1975.*

study. Mean densities of *Corbicula* for all year classes are shown in Figures 3-6. Density of *Corbicula* generally reached a maximum in late summer or fall and was at a minimum during winter and spring. In contrast, Villadolid and Rosario (1930), Bickel (1966), Fast (1971), and Taylor (1975) found *Corbicula* to be at maximum in winter and minimum in summer. One explanation for the high density in the Altamaha during the late summer low water periods is that less substrate is available at these times, thereby concentrating the organisms. The width of the river ranges from 100-200 m during the low water period and is often greater than 2 km during flood stage. The available substrate surface area is about ten times greater at high water than at low water. This could account, in part, for the differences in *Corbicula* density, which is roughly a change of the same magnitude. Maximum discharge (Figure 2) occurred simultaneously with low densities in *Corbicula* (Figures 3-6). Seasonal variations in density diminished with increasing size of the clams. Apparently the smaller clams were probably picked up and swept by the current during flood season more readily than were the larger ones. Small *Corbicula* shells were found deposited in the flood plain and along exposed sand bars indicating their presence during high water.

Sexually immature *Corbicula* (Figure 3) usually were found in greatest density in summer. Maximum density of this group increased by a factor of 10 each year during the summers 1972-1974, reaching an average density of 9,257/m² in July 1974. The largest sample collected on this date contained 1,527 *Corbicula* or 61,080/m². Winter and spring densities were about 100/m² each year since 1973. First year sexually mature clams (Figure 4) fluctuated greatly since 1972, but generally reached maximum density in fall. Recruitment into this size class from sexually immature *Corbicula* is evident in 1973 and 1974, occurring 4-6 months after the maximum density of immature clams. Average density of sexually mature first year *Corbicula* was about 70/m² for 1974 and 1975.

Density of second year *Corbicula* (Figure 5) fluctuated irregularly in 1971-1972, probably because of sampling bias and clumped distribution, but rose steadily in 1973 and 1974. Density of this size clam reached a maximum of 40/m² in summer 1973, and a maximum of 100/m² in summer 1974. Average density for second year *Corbicula* was approximately 70/m² for 1974 and 1975. Figure 6 shows average densities of third and fourth year class *Corbicula*. Third year clams were first collected in October 1972, but were not consistently present until spring 1973. Maximum density reached 100/m² in fall 1974. Average density for three year clams was about 70/m² in 1974 and 1975. *Corbicula* in the fourth year class were not collected until summer 1974. Very few four year clams were collected in dredge samples, however larger clams were collected in qualitative samples.

*Corbicula* have been reported occurring in a wide variety of substrates. Sinclair and Isom (1963) found *Corbicula* common in rock-gravel substrates and black clay substrates in the Tennessee River. Fast (1971) found a positive correlation between *Corbicula* density and sediment particle size in a Southern California reservoir. Fuller and Powell (1973) reported *Corbicula* living in a shifting sand bar in the Savannah River, Georgia, and in a variety of substrates including mud and fine gravel in the Delaware River. Rhinne (1974) found greatest densities on rock and rubble substrates in an Arizona reservoir. Diaz (1974) found *Corbicula* in a variety of substrates in the James River, Virginia, but mainly in silt-clay sediment. Sickel and Burbank (1974) in a substrate preference experiment, found that larval *Corbicula* settled on fine sand, coarse sand, and mud in decreasing order of preference. In the present study, Altamaha River *Corbicula* were found on a variety of substrates. A substrate preference was not clearly determined by our sampling. In general, more *Corbicula* were found on substrates consisting of sand in combination with mud or detritus than on substrates which were predominantly mud or detritus.

Analysis of variance of 1974 and 1975 data was used to compare densities of *Corbicula* from high

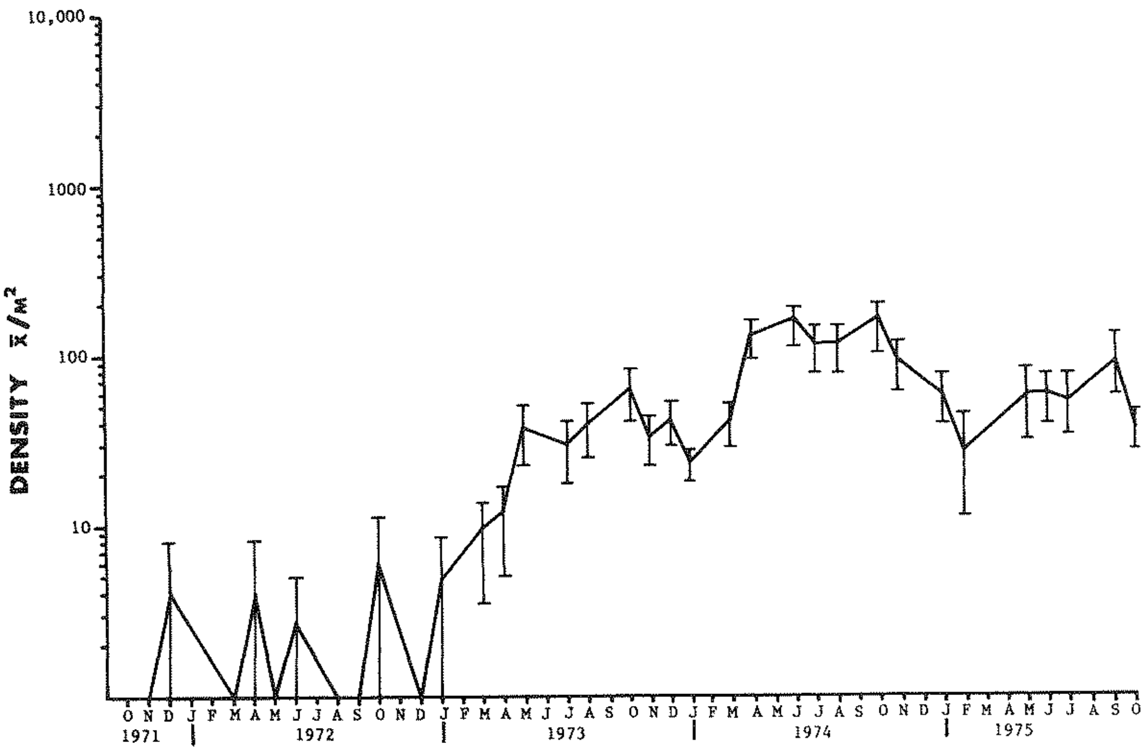


FIG. 5: *Mean (± SE) density of second year* Corbicula *in Altamaha River, October 1971 through October 1975.*

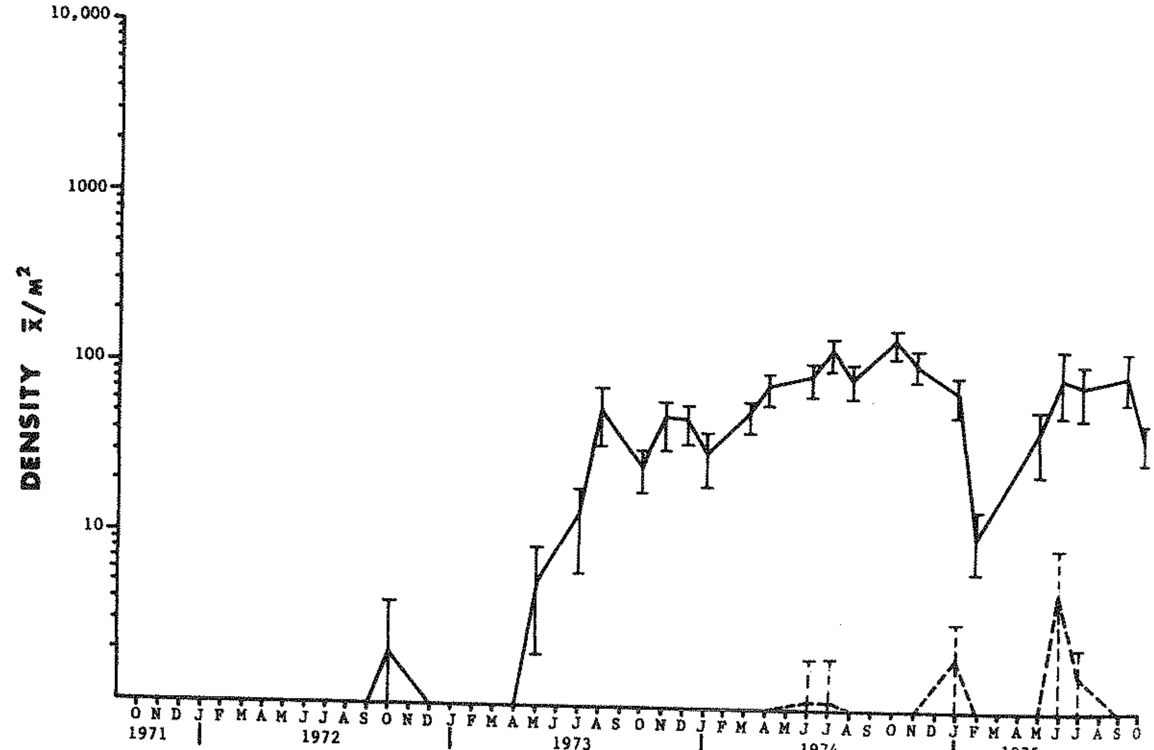


FIG. 6: *Mean (± SE) density of third year (solid line) and fourth year (dashed line)* Corbicula *in Altamaha River, October 1971 through October 1975.*

and low current velocity habitats. To meet criteria for homogeneity of variances the densities were transformed by $\log_{10}$ (X + 1). The results indicated that first year *Corbicula* showed no preference for either habitat, but older *Corbicula* (two to three years) were found in greater numbers in low velocity areas. Mean densities of immature and mature first year *Corbicula* were greater in high velocity areas than in low velocity areas, but the differences between the means were not significant at the .05 level. Second year clams were slightly more abundant in low velocity areas, but the difference between the means was not significant at the .05 level. Mean densities of third and fourth year *Corbicula* were both significantly greater in low velocity habitats at the .001 and .05 levels respectively.

In October 1975 several shells from dead *Corbicula* were found deposited on a sand bar at river mile 113.4. Some of these were as large as 38 mm, and were probably six years old. It is possible that the older clams prefer habitats away from the main channel, such as sand bars and sloughs. None of the sampling stations were placed so that they were over sand bars or sloughs on high water because these habitats could not be sampled during low water. Another possibility is that the larger clams were imported from an older population upstream during the unusually high water in spring 1975. If the clams were established first upstream by overland transport as Sickel (1973) speculates, one would expect to find larger individuals upstream.

The invasion of *Corbicula* in the Altamaha River since 1971 has been accompanied by a drastic decline in populations of other bivalves (Figure 7). *Corbicula* density fluctuated greatly from late 1971 through summer 1972, indicating their aggregated distribution. By late fall 1972 *Corbicula* were collected consistently. Other bivalves (Sphaeriidae and some Unionidae) maintained average densities of approximately 200/m² during late 1971 and 1972. In October 1972 average *Corbicula* density in areas sampled increased to almost 200/m² and the density of other bivalves fell sharply. During winter and spring of 1973 densities of *Corbicula* fell to 60/m² and the density of other bivalves rose to 80-90/m². Concurrently, much dead *Corbicula* tissue was collected in drift samples (unpublished data), indicating a large die-off. This phenomenon has been reported by Sinclair and Isom (1963) and Bickel (1966). In August 1973 *Corbicula* density rose above the peak for the previous year reaching nearly 700/m², while the density of other bivalves again fell sharply. In summer 1974 *Corbicula* reached a density of almost 10,000, and other bivalves disappeared from our samples. These inverse fluctuations in 1972 and 1973 may be due to sampling bias as a result of clumped distribution of both *Corbicula* and other bivalves but may also indicate some form of competition. In the Flint River, Sickel (1973) observed that "where *Corbicula* were most dense there were no unionids, even though the habitat appeared suitable." He further suggested that "this indicated some form of competition, which was unlikely to be simply spatial competition since the size of *Corbicula* and its density did not appear to be great enough to exclude the much larger unionids."

*Canthyria spinosa* and *L. dolabraeformis* were collected commonly as late as October, 1974 but have rarely been found since then by the authors or by local fishermen who use the mussels for bait. In November 1975 a survey was made of sandbars and sloughs once described (Sickel, 1969) as having an abundant population of *L. dolabraeformis*, *E. hopetonensis*, and *C. spinosa*. No *L. dolabraeformis* or *C. spinosa* were found. A single *E. hopetonensis* was found near an area from which Sickel (1969) observed densities up to 16/m². *Corbicula* was found in abundance in these areas and in one slough the density was 710/m². Scattered along the sandbars and in shallow waters nearby were empty shells of *E. shepardianus*, *E. hopetonensis*, *L. dolabraeformis*, *L. splendida*, and *C. spinosa*. Most of the shells were found with both halves intact, and some had bits of dried mantle attached, indicating relatively recent death. In December 1975 one of our coworkers discovered a small bed of *L. dolabraefor-*

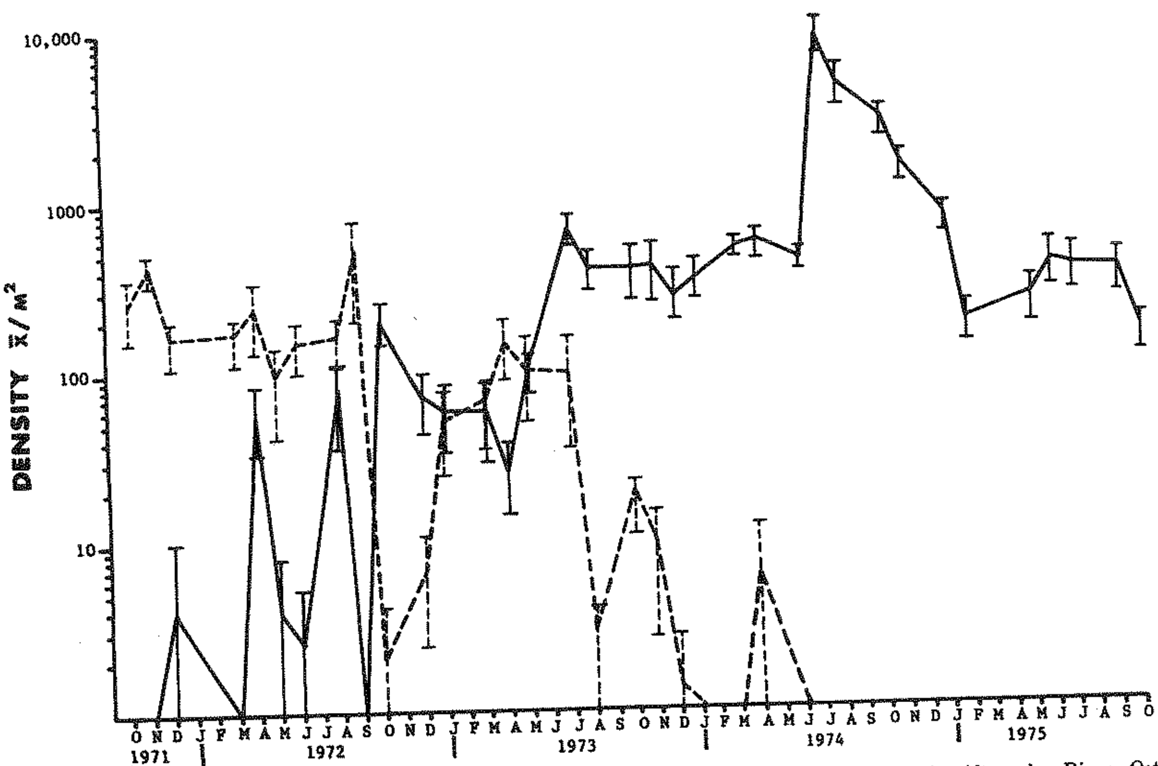


FIG. 7: *Mean (± SE) density of total* Corbicula *(solid line) and other bivalves (dashed line) in Altamaha River, October 1971 through October 1975.*

*mis* on the north bank just above a sand bar (RM 114). Most of the shells examined were empty. A few live *L. dolabraeformis* were found but were observed to be extremely emaciated. It is interesting to note that all of the above species except *L. splendida* are endemic to the Altamaha River and are listed as endangered species by the Georgia Department of Natural Resources (1974). Additional endemic species listed as endangered but not collected during this study include *Alasmidonta arcula* Lea, *Elliptio dariensis* Lea, and *Anodonta gibbosa* Lea.

It is possible that *Corbicula* may have a higher rate of filtration than mussels. Mattice and Dye (1975) reported a filtration rate for *Corbicula* of 1 liter/hr. Stanczykowska, Lawacz, and Mattice (1973) found that filtration rates ranged from 10-100 ml/hr for *Dreissena polymorpha* Pallas and from 60-490 ml/hr for Unionidae. However, Habel (1970) found a lower filtration rate of 11 ml/hr for *Corbicula*. *Corbicula* have been found to be tolerant of a variety of adverse conditions. Mattice and Dye (1975) found *Corbicula* tolerant of high and low extremes in water temperature. Sinclair and Isom (1963) reported *Corbicula* tolerant of intense water level fluctuations in the Tennessee River. Habel (1970) found *Corbicula* strongly resistant to low DO. Diaz (1974) found a high density of *Corbicula* in the James River below an area receiving 90,000 lbs BOD/day.

Several features of the *Corbicula* reproductive cycle (Sinclair and Isom, 1963) give them a definite competitive advantage. *Corbicula* are monoecious, incubatory and attain sexual maturity in less than one year. Unionidae, most of which are dioecious, have a weakness in that larval parasitism of fish is required for development to maturity. Although many glochidia may be produced, very few are able to find a suitable host, and the period of development to sexual maturity is often extended more than one season (Storer and Usinger, 1957). Although sphaeriids, like *Corbicula*, are monoecious and incubatory, they may have a definite disadvantage of fragility. The authors have observed, especially in young individuals, that the sphaeriid shells appear to be thinner and may not withstand scouring caused by extreme river discharge as well as *Corbicula*.

Density of sexually immature *Corbicula* (Figure 3) did not reach a maximum in fall 1975 of the magnitude reached in 1973 and 1974. The extreme river discharge in spring 1975 may have exerted a flushing or diluting effect on the *Corbicula*. Another possibility is the attainment of *Corbicula* carrying capacity in the river after an initial overshoot. It is evident from Figure 7 that the average density of *Corbicula* in 1974 and 1975 was about the same as the density that other bivalves were prior to fall 1972, which indicates the replacement of other bivalves with *Corbicula*.

A combination of factors probably was responsible for the success of *Corbicula* and the decline of other bivalves in the Altamaha River. Clearly, more investigation is necessary to determine the magnitude and extent of the invasion in the upper and lower reaches of the Altamaha drainage system. Additional research, such as determinations of relative filtration rates, food particle size preference, and spatial interactions is needed to elucidate the nature of competition between *Corbicula* and other bivalves.

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# *SUCCINEA RAOI* NEW NAME FOR *SUCCINEA ARBORICOLA* RAO, 1925 (STYLOMMATOPHORA : SUCCINEIDAE)

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Mousson (1887) described a new species, *Succinea arborea* from Kalaruri (=Kalahari), Southeast Africa. As the name was preoccupied by *Succinea arborea* Adams and Angas (1863) from South Australia, Connolly (1912) proposed the new name, *Succinea arboricola* for the South African species.

During the course of our studies on molluscs from Poona District, Maharashtra, we have come across a species of succineid, *Succinea arboricola* Rao, the type specimens of which were collected by Dr. S. L. Hora, during August, 1924, on the bark of mango trees in the compound of Hamilton Hotel at Lonavla, Poona District. Signifying its peculiar habitat, Rao (1925) named the new species as *Succinea arboricola* which, however, is distinct from the South African and South Australian succineids. Since *Succinea arboricola* Rao is a junior homonym of *Succinea arboricola* Connolly, it is necessary to propose a new name for the Indian species. We take this opportunity to propose the new name *Succinea raoi,* for *Succinea arboricola* Rao, in honour of late Dr. H. S. Rao, who made significant contributions to Indian malacology.

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