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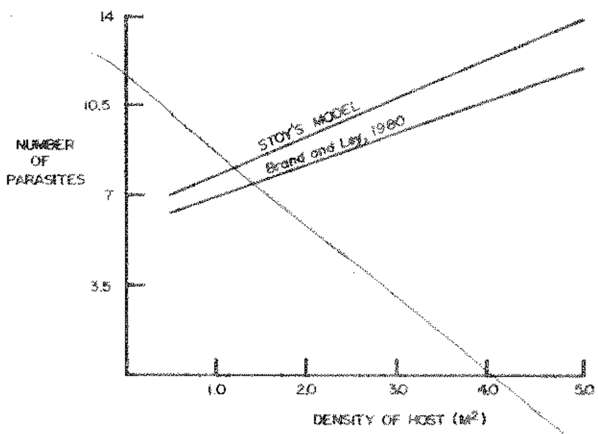

Figure 15. Relationship between number of parasites per host and host density, showing the close fit between the data and the model of Stoy (1932).

and decrease the host's ability to assimilate food items. Rarely, however, is the host killed. *Balcis catalinensis* infests the stomach of the holothurian *Brandtothuria arenicola*, which suggests the possibility that the parasite may interfere with the digestion or assimilation of food consumed by the host. Assimilation efficiencies of similarly sized holothurians collected from throughout the Bay of La Paz varied from 36% to 39%, increasing with the number of parasites/host (Fig. 14). The regression line explains 43% of the variability in the data, but is not significant at $p = .1$. It is therefore concluded that the presence of B. catalinensis does not inhibit the assimilation efficiency of *B. arenicola*. The effects of parasitism on productive output and respiration are currently being investigated.

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CORRELATION OF UNIONID MUSSELS WITH BOTTOM SEDIMENT COMPOSITION IN THE ALTAMAHA RIVER, GEORGIA

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INTRODUCTION

The Altamaha River system is the largest in Georgia with a drainage area of approximately 37,000 km^2 and average discharge of 400 m^3/sec (U.S. Geological Survey, 1974). The river is formed by the confluence of the Oconee and Ocmulgee Rivers southeast of Macon and flows 215 km through the Coastal Plain to the Atlantic Ocean between Darien and Brunswick, Georgia. The Altamaha is the southern most river of the zoogeographic region defined by H. and A van der Schalie (1950) and further elaborated by R.I. Johnson (1970) and known as the Southern Atlantic Slope region. Johnson (1970) listed 18 species of pearly freshwater mussels, Unionidae, occurring in the Altamaha, 6 of which are endemic.

Most investigators and collectors of freshwater mussels are aware of habitat preferences of various species inhabiting the same general areas of a river. Clench (1962) reported finding *Elliptio shepardiana* at "mud stations" and *Canthyria spinosa* on shallow sandbars in the Altamaha River. (*Canthyria spinosa* is commonly referred to in the literature as *Elliptio spinosa*, but, according to David H. Stansbery, pers. comm., the genus *Canthyria* is appropriate). Harman (1972) reported finding *Strophitus undulatus, Anodonta cataracta* and *Elliptio complanata* only in soft but firm sediment of sandy clay in central New York.

Coker *et al.* (1921) emphasized the importance of the bottom sediment on the occurrence of mussels in their statement, "It may, therefore, be supposed that fresh-water mussels, like other animals, are adapted rather definitely to particular conditions of the environment;... that a mud bottom supports certain species, while a firmer soil is required by others." They also point out the even more restrictive habitat requirements of the young mussels. "Adult mussels in some cases thrive, or continue to live at least, in environments where the young would perish, for delicately balanced conditions are required by very young mussels of many species, and only where these conditions exist can a mussel bed originate or perpetuate itself." Coker *et al.* (1921) listed 62 freshwater mussel species along with the general composition of the bottom in habitats where they occurred.

The composition of bottom sediment is the major factor controlling the occurrence of benthic organisms (Hynes, 1970). Sediment composition along a river bottom results from the interaction of geological, topographical, climatic, edaphic and hydraulic characteristics of the drainage basin. Stream velocity has a major and immediate influence on the movement of sediments. The competence and capacity of the stream change with its load, and the load is often a direct result of man's mismanagement of the surface land. Biological activity within the river such as filtration by the Asiatic clam, *Corbicula*, also may affect sediment transport and composition (Prokopovich, 1969).

Alteration of any feature such as velocity, discharge or load or the invasion by *Corbicula* which influences sediment composition might selectively alter the competitive advantages of different species such that the community will undergo change.

In the study reported here, nine species of Unionidae were found to occur in varying densities within seven sample sites. The sediment characteristics of each site were determined, and the occurrence of each mussel species was related to the sediment composition.

METHODS AND MATERIALS

Collection sites in the Altamaha River were selected to include a range of sediment types from the coarse sand of the main channel to the fine silt and clay of the protected sloughs. The area of study extended from the U.S. 1 bridge north of Baxley, Georgia, on the Toombs and Appling County line to a point 4.9 km downstream from the bridge. Collections were made during the summer of 1968.

At each site either 100 m^2, 1 m^2 or 0.5 m^2 areas were marked off and all mussels within these areas were collected by hand. On shallow sandbars where the bottom was visible, 100 m^2 areas were marked off by ropes and stakes and mussels were collected by visually hand picking. In deeper water along the river bank and in sloughs a 0.5 m^2 frame was placed on the bottom and mussels were collected by first feeling the sediment surface and then digging in the sediment to a depth of 10 cm.

Sediment samples were collected at each site using an inverted tennis ball can as a coring device. It had holes drilled in the closed end and a rubber diaphragm affixed to allow water to exit as the can was being pushed into the sediment; as the can was withdrawn the diaphragm acted as a seal and provided suction. Cores were collected to a depth of 15 cm. For analysis 20 g dry weight subsamples were obtained by dividing the larger samples with a Jones sample splitter. After the sediment was dry, aggregates were broken by grinding them gently with a mortar and pestle. Samples were passed through a series of U.S. Standard brass sieves from 8.0 mm to 1.41 mm in half Phi intervals by hand shaking, and from 1.00 to 0.044 mm by automatic mechanical shaking for 15 minutes. (Phi is the negative log to the base 2 of the particle diameter). The portion of sediment retained in each sieve was weighed and the size distribution determined. Sediment with a grain size less than 0.44 mm in diameter was analyzed using the Bouyoucos hydrometer method. A 50 g sample was dispersed in 1 liter of water with 5 ml of 5% NaOH in a blender for 10 minutes before being placed in a cylinder with a hydrometer. Hydrometer readings were recorded at time intervals twice the previous interval and starting at 8 seconds. Sediment particle size distribution was calculated from the hydrometer readings based on settling time and Stokes' law (J.M. Huber Corporation, 1955).

The relationship between mussel species and sediment composition was determined by multiplying the density of each species at each site by the fractional distribution of sediment particle size at each site and summing the values for each half Phi interval.

OBSERVATIONS AND RESULTS

Nine species of Unionidae were collected: *Lampsilis dolabraeformis* (Lea), *Canthyria spinosa* (Lea), *Elliptio hopetonensis* (Lea), *Elliptio dariensis* (Lea), *Elliptio shepardiana* (Lea), *Lampsilis splendida* (Lea), *Alasmidonta arcula* (Lea), *Anodonta gibbosa* Say, and *Anodonta couperiana* (Lea). Assistance with identifications was obtained from Dr. Joseph P.E. Morrison, Smithsonian Institution, and Dr. Grace J. Thomas, University of Georgia. The percentage composition of each species at each of the seven collecting sites is shown in Table 1.

Table 1. Percentage species composition at each site

	Total Area Covered	Total Number Counted	Number per m^2	Percent: *L. dolabraeformis*	*L. splendida*	*C. spinosa*	*E. hopetonensis*	*E. shepardianus*	*E. dariensis*	*A. arcula*	*A. gibbosa*	*A. couperiana*
Site 10	500m^2	158	0.3	55	–	38	4.7	0.9	–	1.9	–	–
Site 12	400m^2	85	0.2	75	–	25	–	–	–	–	–	–
Site 6	8m^2	145	18	95	0.7	0.7	0.7	2.7	–	–	–	–
Site 8	7m^2	84	12	93	–	6	–	1.1	–	–	–	–
Site 11	7.5m^2	88	12	66	4.5	–	22	–	1.1	4.6	–	2.3
Site 15	13m^2	304	23	23	3.3	0.3	69	0.7	1.6	2.0	–	–
Site 18	20m^2	12	0.6	–	–	–	–	–	–	–	83	17

Sites 10 and 12 were sandbars adjacent to the main channel and had predominately coarse to very coarse sand sediment. Sites 6 and 8 were at the upstream ends of sandbars near the river bank and consisted primarily of medium to fine sand. Sites 15 and 11 were along the river bank among overhanging willow trees and consited of fine sand and silt. Site 18 was in a slough with silt and clay sediment. Fig. 1 shows the sediment size distribution at each site.

The number of mussels of each species found at each site was multiplied by the sediment size fractions at the sites and the resulting numbers were summed for all sites. This operation provided a value for the abundance of each species relative to the sediment size distribution (Fig. 2).

DISCUSSION AND CONCLUSIONS

Some species of mussels are more habitat restricted than others. *Anodonta gibbosa* was found only in a protected slough with a sediment consisting primarily of silt and clay. *Anodonta couperiana* occurred at the same site as *A. gibbosa* but also in areas of the main river consisting of fine sand and silt. *Alasmidonta arcula* was less restricted and occurred along with *A. couperiana* in the main river. Young *A. arcula* were found on sandbars of coarse sand, but most occurred near the riverbank in finer sediments.

Elliptio dariensis and *E. hopetonensis* generally occurred together in highest densities along the protected river banks in fine sand to coarse silt sediment. *E. Hopetonensis* dominated those areas with only a few *E. dariensis* being found. *Canthyria spinosa* was found only on sandbars of very coarse to fine sand. It appeared to be restricted to swiftly flowing

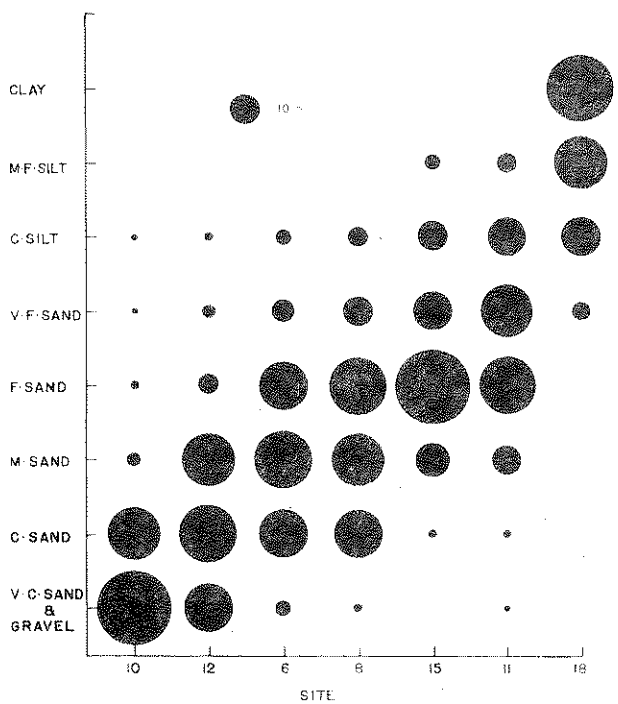

Figure 1. Sediment particle size distribution for the Altamaha River collection sites. The area of each dot represents the percentage of the sediment by weight having the indicated particle size. A standard area is indicated by the dot marked 10%. The abbreviations V.F, F, M, C, and V.C represent very fine, fine, medium, coarse, and very coarse particle size designations used by Hynes (1970).

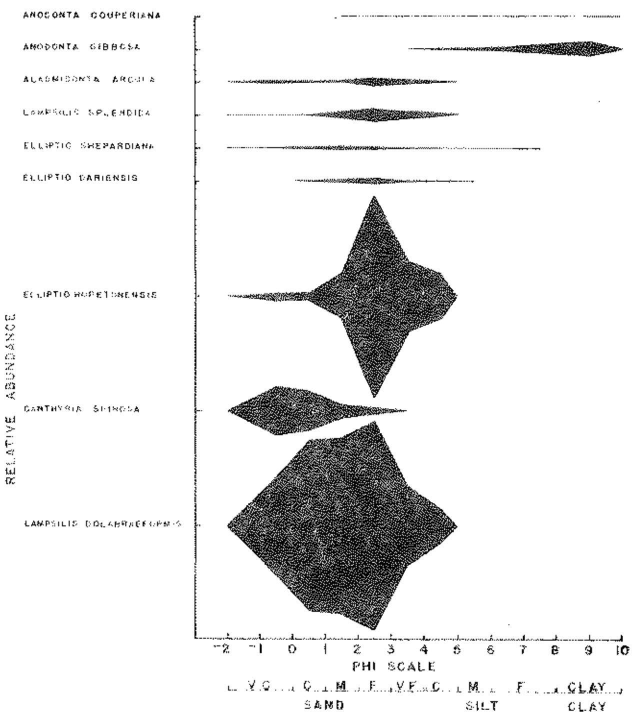

Figure 2. Relative abundance of freshwater mussels with respect to sediment particle size in the Altamaha River. Particle size is indicated on the Phi scale where Phi is the negative base 2 logarithm of the particle diameter in mm. Sand and silt are subdivided into very coarse, V.C, coarse, C, medium, M, fine, F, or very fine, V.F, according to Hynes (1970).

water on sandbars. *Lampsilis splendida* was found in association with *E. hopetonensis* primarily near the river banks in fine sand with some coarse silt.

The most abundant mussel was *Lampsilis dolabraeformis* which was found generally distributed throughout the main river on sandbars and along the river banks. It occurred in highest densities in coarse to fine sand and was the most mobile mussel, frequently being seen migrating to deeper water.

Those species of mussel with the greatest restriction of habitat are the most likely to be affected by habitat alterations. *Canthyria spinosa* might be highly susceptible to siltation.

This study provides distributional data and habitat characteristics of six endemic mussels of the Altamaha River, Georgia, in 1968 when the mussels were plentiful. Since the study was completed changes have occurred which have resulted in a marked decline in the mussels. A nuclear steam electric plant was constructed at the study area, and the Asiatic clam, *Corbicula fluminea*, invaded (Gardner, et al., 1976, Sickel, 1979) and became abundant during the period of mussel decline. Changes in sediment composition appear to have occurred. Additional studies are needed to determine if any reproducing populations of mussels remain in the Altamaha River and also to support a petition to place the six endemic species on the federal endangered species list. The six endemic species which have undergone a drastic decline in number are *Canthyria spinosa, Lampsilis dolabraeformis, Elliptio hopetonensis, Elliptio shepardiana, Alasmidonta arcula* and *Anodonta gibbosa*.

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FRESHWATER MUSSEL GLOCHIDIA FROM LAKE WACCAMAW, COLUMBUS COUNTY, NORTH CAROLINA

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INTRODUCTION

Lake Waccamaw, an elliptical lake approximately 58 kilometers west of Wilmington in Columbus County, North Carolina, is the largest natural lake in the state, encompassing about 3,600 hectometers. It has a maximum depth approaching 3.3 meters. A detailed physical description of the lake and the relationship of it to the other North Carolina bay lakes is found in Frey (1948, 1949) and Louder (1958).

The known molluscan fauna of the lake includes eleven naiad and three gastropod species, several of which are endemic to the lake (Stansbery and Clench, 1978). The uniqueness of this molluscan fauna and its description have been discussed by Jennewein (1971), Fuller et al. (1976), Fuller (1977), and Tuelings and Cooper (1977); however, the biology, ecology and molluscan interrelationships of the Waccamaw endemics are poorly understood.

Fuller (1977) stressed a need to know the glochidial hosts of the Lake Waccamaw endemic naiads as a means of being able to conserve such species. At present no fish species (in the lake) has been documented as the host for any Lake Waccamaw naiad species. Further, glochidial descriptions and reproductive history of most naiads occurring within the lake and its basin are unpublished. Recognition of a fish as infected with a specific mussel glochidia is difficult without an adequate morphological description of the glochidia of each available mussel species and knowledge of the reproductive periodicity of each. The purpose of this paper is to describe glochidia recently found during a present ongoing survey of the Lake Waccamaw molluscan fauna.

METHODS

Modified, randomized, benthic samples from Lake Waccamaw are taken at quarterly intervals using a suction-lift type dredge. Collecting bags, of either 1.6 or 6.4 mm stretch-bar mesh screening, are attached to the dredge and substrate is screened within either 1/16 or 1/4 m^2 sampling frames to a depth of 15 cm. Non-dredge but quantitative shallow water substrate samples occasionally are taken. Monthly tissue-condition studies of *Elliptio waccamawensis* (Lea, 1863) (50 individuals each from several differing lake locations) furnish additional information concerning marsupial presence. Data from preserved specimens collected in 1978 by the senior author and from a 1979 Waccamaw River collecting trip are included in the data here.

Glochidia used in this study were teased from portions of marsupia removed from the preserved naiads. "AGW", an ethyl alcohol glycerin mixture recommended by Dr. D.H. Stansbery, (pers. comm.) Ohio State University, was used to preserve all collected mollusks and naiad glochidia. Polaroid and 35 mm photographs were taken through a Wild M5 stereomicroscope using a Wild MKa4 camera. Classification of Atlantic drainage North Carolina naiads is in an unsettled state at present. Lake Waccamaw naiad names used in this paper are those proposed by D.H. Stansbery (pers. comm.); naiad identifications were authenticated also by D.H. Stansbery.

RESULTS

Glochidia were collected from marsupia of *Elliptio waccamawensis*, *E. fisheriana* (Lea, 1838), *E. raveneli* (Conrad, 1834), *Toxolasma pullus* (Conrad, 1838), *Lampsilis* sp., *Lampsilis crocata* (Lea, 1841), and *Leptodea ochraceus* (Say, 1817). Glochidia of *E. folliculata* (Lea, 1838), *E. Lanceolata* (Lea, 1828), *Villosa ogeecheensis* (Conrad, 1849), and *Anodonta teres* Conrad, 1834 were not seen; however, these latter species have been collected infrequently during this program. *Uniomerus obesus* (Lea, 1831), found by Dr. D.H. Stansbery in Lake Waccamaw (pers. comm.), has yet to be found in any of our Waccamaw samples.

Elliptio waccamawensis glochidia (Figure 1): dimensions are found on Table 1. Hinge shape varies from straight to slightly concave. The suboval hookless glochidia are marginally bilaterally asymmetrical. Shape and size of this glochidium appears identical to that of *E. fisheriana*. Marsupia were observed in May, June and August 1979. May and August 1979 marsupia were not examined for glochidia, but glochidia were observed in June. In 1980, marsupia containing both eggs and glochidia, were present in May, June and July; no marsupia were observed in August.

Area variation in reproductive period of *E. waccamawensis* was observed in the 1980 sampling. May trawl samples in the central deep-water, peat-bottom area contained numerous marsupia with glochidia while tissue-condition samples from peripheral areas in the southeast, northeast and northwest portions of the lake contained no *E. waccamawensis* with marsupia. In June, 46% of the southeastern tissue-condition sample had a marsupium; of those with a marsupium, 35% contained glochidia. This same location in July had 34% with a mar-