Reprint from—
The Bulletin of the American Malacological
Union, Inc., 1980, pp. 13-17

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

Hugh J. Porter and Karen J. Horn
University of North Carolina at Chapel Hill, Institute of Marine Sciences
Morehead City, NC 28557

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 Further, glochidial descriptions and reproductive history of most naiads occurring within the lake and its basin are unpublished.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.

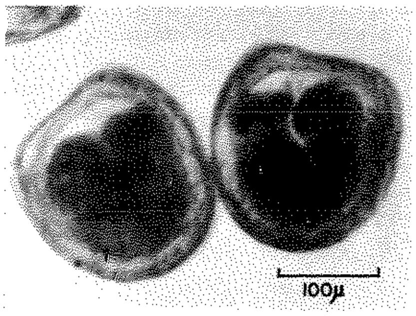
Glochidia used in this study were teased from portions of marsupia removed from the preserved naiads. "AGW", an ethyl alcohol glycerin mixture recommended by Dr. D.H. Stansbery, (pers. comm.) Ohio State University, was used to preserve all collected mollusks and naiad glochidia. Polaroid and 35 mm photographs 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.

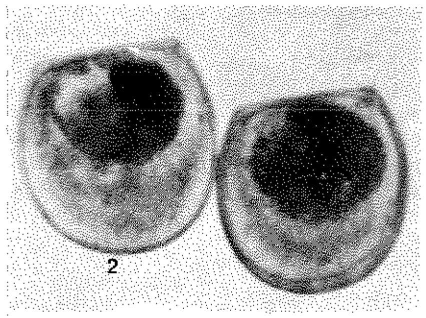
RESULTS

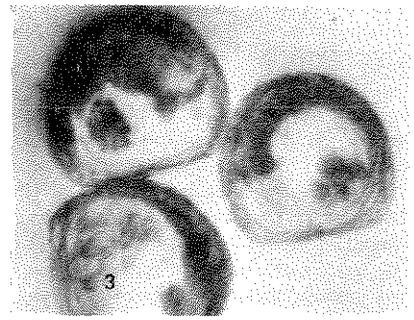
Glochidia were collected from marsupia of *Elliptio waccamawensis*, *E. fisheriana* (Lea, 1838), *E. raveneli* (Conrad, 1834), *Toxolasma pullus* (Conrad, 1838), *Lampsilis* sp., *Lampsilis crocata* (Lea, 1841), and *Leptodea ochraceus* (Say, 1817). Glochidia of *E. folliculata* (Lea, 1838), *E. Lanceolata* (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.

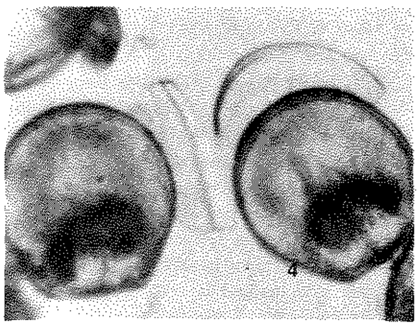
Elliptio waccamawensis glochidia (Figure 1): dimensions are found on Table 1. Hinge shape varies from straight to slightly concave. The suboval hookless glochidia are marginally bilaterally asymmetrical. Shape and size of this glochidium appears identical to that of *E. fisheriana*. Marsupia were observed 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.

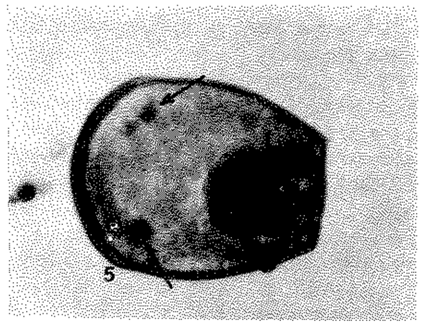
Area variation in reproductive period of *E. waccamawensis* was observed in the 1980 sampling. May trawl samples in the central deep-water, peat-bottom area contained numerous marsupia with glochidia while tissue-condition samples from peripheral areas in the southeast, northeast and northwest portions 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-

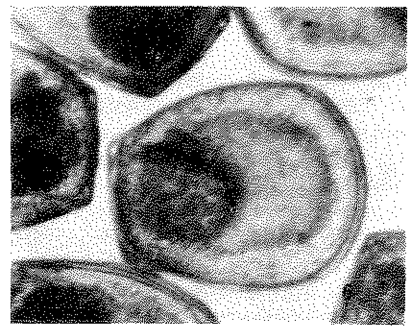












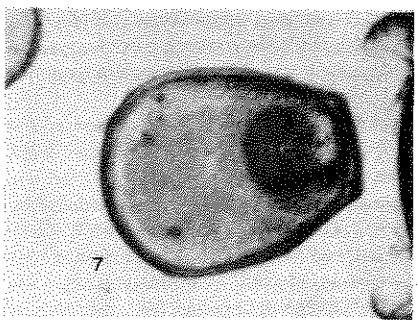


FIGURE LEGENDS

Photographs of Lake Waccamaw and Waccamaw River glochidia.

Figure 1. *Elliptio waccamawensis.*
Figure 2. *Elliptio fisheriana.*
Figure 3. *Elliptio raveneli.*
Figure 4. *Toxolasmus pullus.*
Figure 5. *Lampsilis* sp. (arrow designates eye spot).
Figure 6. *Lampsilis crocata.*
Figure 7. *Leptodea ochracea.*

Scale indicated in Figure 1 applies to all figures.

supium and 65% of the marsupia contained glochidia. Tissue-condition samples in June and July from the northeastern and northwestern lake areas had six or fewer percent with a marsupium present and, when glochidia were present, the glochidia seemed in poor condition. June and July data were unavailable for the central area of the lake. No adequate explanation has been formulated for this disparity between areas in relation to percent marsupial occurrence.

Elliptio fisheriana[1] *glochidia* (Figure 2): dimensions are found on Table 1. As suggested earlier, these measurements and ratios appear identical to those of *E. waccamawensis.* The hinge shape is a straight line; the hookless suboval glochidia appear somewhat bilaterally asymmetrical. Comparison of photographs and camera-lucida drawings of the two species suggested no recognizable shape difference; however, the adductor mussel may be closer to the hinge line in *E. fisheriana* than in *E. waccamawensis.* The validity of this as a distinguishing characteristic is unresolved. Recent nonrecorded observations of a number of glochidia show variability in the distance of the adductor muscle from the hinge line within the same species. Glochidia were observed only in July, 1978.

Elliptio raveneli glochidia (Figure 3): dimensions are found on Table 1. Hinge is straight to moderately convex. Shape of this hookless suboval glochidium is slightly bilaterally asymmetrical. Lengths and heights of *E. raveneli* are smaller and rarely overlap the data range of *E. waccamawensis* and *E. fisheriana* (Table 1). Hinge lengths of all three Elliptios are similar. Hinge length/length and hinge length/height ratios of *E. raveneli* are greater than those of the other two Elliptios and the height/length ratio is smaller.

For the sake of accuracy, it must be pointed out that while all *E. waccamaw* and *E. fisheriana* glochidia data are from Lake Waccamaw specimens, the above *E. raveneli* glochidia are from specimens collected August, 1979 in the Waccamaw River. Gravid *E. raveneli* have not been collected in Lake Waccamaw by the authors.

Toxolasmus[2] *pullus* glochidia (Figure 4): dimensions are found on Table 1. Hinge shape is straight with a weak convexity caused by the valve umbos extending slightly above the hinge line. Glochidia are hookless, approximately the same size as *E. waccamawensis* and *E. fisheriana*, and distinguishable by their globose shape. This globose condition is caused partly by a relatively short hinge length. Hinge

---

[1]Stansbery (pers. comm.) has recently suggested that a better name for this Lake Waccamaw species might be *Elliptio producta* (Conrad, 1836).

[2]Baker (1928) states that the name *Toxolasma* is not valid and should be replaced by *Carunculina.*

length/length and hinge length/height ratios of *T. pullus* are considerably smaller than those of the Elliptios. Glochidia were collected June, 1979.

Lampsilis sp. glochidia (Figure 5): dimensions are found on Table 1. Hinge shape is straight with the valve umbos extending slightly above the hinge line, giving the line sometimes a false convex appearance. The purse-shaped valves are bilaterally symmetrical and hookless. Eye spots (called "outer hair cells" by Arey, 1920) are evident near the ventral border. Glochidia were collected in April and June, 1979.

Lampsilis crocata glochidia (Figure 6): dimensions are found on Table 1. Hinge shape is straight with valve umbos extending occasionally just beyond hinge line. Valves are bilaterally symmetrical, hookless, and purse-shaped. Eye spots are present near ventral border. Glochidial size and shape approximates that of *Lampsilis* sp. The hinge length is generally larger than that present in *Lampsilis* sp.; this slightly larger conditon correspondingly reflects in somewhat higher hinge length/length and hinge length/height ratio values for *L. crocata*: Glochidia were collected in June, 1979.

Leptodea ochracea[3] glochidia (Figure 7): dimensions are found on Table 1. Hinge line is slightly convex with valve umbos generally not quite reaching hinge line. Valves are bilaterally symmetrical, hookless, and purse shaped. Eye spots are near the ventral border. Glochidial size and shape approximates that of *Lampsilis* sp. and *Lampsilis crocata*. Hinge length values and the ratio hinge length/length and length/height values are smaller in *Leptodea ochracea* than present in the two *Lampsilis* species. Marsupia containing glochidia have been collected only in April and June, 1979.

DISCUSSION

Glochidia of seven of the naiads inhabiting Lake Waccamaw and its basin are described in the preceding, some for the first time. This description should enable progress towards identification of encysted glochidia

[3]Bereza and Fuller (1975) state that *ochracea* is not in the Genus *Leptodea* but closer related to the Genus *Lampsilis*.

Table 1. LAKE WACCAMAW GLOCHIDIA MEASUREMENT AND MEASUREMENT RATIO DATA. Measurements expressed in "μ" (.000 mm); N = numbers of glochidia measured.

SPECIES OF GLOCHIDIA	N	LENGTH Range of data	LENGTH X̄	HEIGHT Range of data	HEIGHT X̄	HINGE LENGTH Range of data	HINGE LENGTH X̄	HINGE LENGTH/LENGTH Range of data	HINGE LENGTH/LENGTH X̄	HEIGHT/LENGTH Range of data	HEIGHT/LENGTH X̄	HINGE LENGTH/HEIGHT Range of data	HINGE LENGTH/HEIGHT X̄
Elliptio waccamawensis (4 specimens)	22	199.9-219.4	209.9	209.8-228.4	217.0	124.9-153.3	144.0	0.57-0.74	0.69	0.97-1.09	1.04	0.59-0.72	0.66
Elliptio fisheriana (1 specimen)	6	202.9-212.2	208.6	213.9-227.4	221.4	142.5-154.5	148.1	0.68-0.74	0.70	1.03-1.09	1.06	0.63-0.70	0.67
Elliptio raveneli (3 specimens)	17	177.0-201.7	188.5	165.6-185.0	176.7	129.1-160.7	142.2	0.68-0.82	0.76	0.88-0.98	0.94	0.72-0.89	0.81
Toxolasmus pullus (1 specimen)	12	194.4-207.1	199.2	212.2-230.3	219.5	104.5-113.5	110.4	0.52-0.58	0.55	1.06-1.14	1.10	0.47-0.52	0.50
Lampsilis sp. (4 specimens)	17	211.1-234.3	221.7	264.8-288.7	275.5	111.0-132.0	120.2	0.50-0.58	0.54	1.18-1.28	1.24	0.40-0.46	0.44
Lampsilis crocata (3 specimens)	8	219.2-235.8	227.4	268.4-294.2	279.7	126.0-143.6	132.8	0.55-0.62	0.58	1.18-1.29	1.23	0.43-0.50	0.48
Leptodea ochracea (3 specimens)	13	213.9-239.8	227.0	263.3-286.9	277.3	102.6-113.9	109.4	0.46-0.50	0.48	1.16-1.28	1.22	0.38-0.42	0.40

Table 2. *Lampsilis* sp. (Lake Waccamaw) vs. *Lampsilis radiata* (various references): COMPARISON OF GLOCHIDIAL MEASUREMENT AND MEASUREMENT RATIO DATA. Measurements expressed in "μ" (.000 mm).

SPECIES OF GLOCHIDIA AND REFERENCE	LENGTH Range of data	LENGTH X̄	HEIGHT Range of data	HEIGHT X̄	HINGE LENGTH Range of data	HINGE LENGTH X̄	HINGE LENGTH / LENGTH Range of data	HINGE LENGTH / LENGTH X̄	HEIGHT / LENGTH Range of data	HEIGHT / LENGTH X̄	HINGE LENGTH / HEIGHT Range of data	HINGE LENGTH / HEIGHT X̄
Lampsilis sp.[1]	211.1-234.3	221.7	264.8-228.7	275.5	111.0-132.0	120.2	0.50-0.58	0.54	1.18-1.28	1.24	0.40-0.46	0.44
Lampsilis radiata radiata (Wiles, 1975)[2]	263.45		315.48				0.47		1.20 1.17		0.40	
Lampsilis radiata (Tedla and Fernando, 1969)[2]	273		316						1.16			
Lampsilis radiata (Calloway and Turner, 1978)[3]	243.38		286.03		127.21		0.52		1.18		0.44	
Lampsilis radiata (Ortmann, 1919)[2]	220-230		270-280									
Lampsilis luteola - possible syn. of *Lampsilis radiata* (Ortmann, 1919)[2]	230 250		280 290						1.20 1.16			
Lampsilis radiata siliquoidea (Clarke, 1973)[2]	240-260		260-300									

[1]Repeated from Table 1.

[2]Length and height measurements as published, ratio values calculated as part of present study.

[3]Values calculated from measurements made from glochidial photograph.

in fish species from the lake and its basin. Consequent identification of fish hosts of some of these endangered naiads may result, facilitating appropriate conservation methods capable of perpetuating viable populations of these species.

The glochidia of three *Elliptio* species are described. Only the glochidia of *E. raveneli* (Plate 3) seem separable from *E. waccamawensis* and *E. fisheriana*. The glochidia of this species are smaller in length, height, and height/length ratio than the other two species.

The glochidia of two Elliptios - *E. folliculata* and *E. lanceolata*, occurring in Lake Waccamaw, have yet to be seen. Johnson (1970) lists *E. fisheriana*, *E. folliculata*, and *E. producta* as synonyms of *E. lanceolata*. Accordingly, it is expected that all of these species will have similar glochidia, glochidia which may be indistinguishable from that of *E. waccamawensis*. Further observations and study are clearly needed with this group.

Glochidia of *E. fisheriana* may have been observed before. Ortmann (1919) gives a glochidial length of 0.2 mm (200u) for *E. cupreus* (Rafinesque, 1820)[4], which he suggests may be a synonym of *E. fisheriana*. This is a smaller height than we observed and the consequent height/length ratio (1.00) is fractionally smaller than our data indicates. Reardon (1929) includes a drawing of glochidium of an *E. producta*, a possible senior synonym of *E. fisheriana* (Stansbery, pers. comm.). This glochidium has the following ratios: hinge length/length = 0.81, height/length = 0.96, and hinge length/height = 0.85. These ratios are considerably different than the *E. fisheriana* ratios in this study (Table 1).

Time of occurrence of glochidia in the preceding *Elliptios* suggested a tachytictic condition (short-term breeder). Aforesaid data of *E. waccamawensis* does suggest that the time of breeding is not constant but may vary from season to season, and in Lake Waccamaw, between different ecological zones in the same season. As stated earlier, glochidia of *E. waccamawensis* have been found May through July, although marsupia have also been observed in April and August.

Glochidia of *Toxolasmus pullus* have a closer resemblance to glochidia of the Elliptios of Lake Waccamaw than to other naiad species. They are readily distinguishable from the Elliptios by a globular shape and a shorter hinge line. Hinge length/length and hinge length/height ratios (smaller than in the Elliptios - Table 1) are useful for identification. Ortmann (1919), describing the closely related *Toxolasma parvum* (Barnes, 1823), gives a glochidial length of 0.18 mm (180μ) and a height of 0.20 mm (200μ which results in a height/length ratio of 1.11. Surber (1915) for the same species has a drawing with a length of 170u and a height of 195u (length ratio = 1.16). These figures approximate those recorded for *T. pullus* (Table 1). The shape of *Lampsilis parva* glochidia, as pictured by Surber (1915), similarly approximates that of *T. pullus* (Figure 4).

Glochidia of the two *Lampsilis* species and *Leptodea ochracea* are similar in general appearance. Their purse-shaped profile easily enables them to be set apart from the globular *Toxolasmus* and the suboval Elliptios. Glochidial separation of the *Lampsilis* species and *Leptodea ochracea* seems best accomplished through a comparison of their hinge lengths and the ratios - hinge length/length, hinge length/height. *Lampsilis crocata* is the largest in all three of the above data catagories, *Lampsilis* sp. is intermediate in data range, and *Leptodea ochracea* has the smallest values (Table 1).

[4]Johnson (1970) believes *E. cupreus* to be a synonym of *E. dilatus* (Rafinesque, 1820).

Lampsilis sp. is believed to correspond to that which Fuller (1977) listed as " '*Lampsilis*' *radiata* (Gmelin, 1791) and *Lampsilis radiata siliquoidea* (Barnes, 1823) have been documented by a number of authors (Table 2). Data presented in Table 2 suggests a possible greater height/length ratio for *Lampsilis* sp. than for the glochidia of *Lampsilis radiata*.

A *Leptodea ochracea* glochidium is pictured by Reardon (1929). Value ratios determined from this drawing are: hinge length/length ratio = 0.71, height/length ratio = 1.32, and hinge length/height ratio = 0.54. Comparison of these figures with the *Leptodea ochracea* data in this study (Table 1) suggest that the Reardon picture is not representative of the *Leptodea ochracea* glochidia found in Lake Waccamaw.

A characteristic of the Genus *Leptodea* is very small glochidia (Baker, 1928). Baker lists the following dimensions for glochidia of *Leptodea fragilis* (Raf., 1820) (type species of *Leptodea*): length = 0.07-0.08mm (70-80 u), height = 0.09-0.095mm (90-95 u). These dimensions are approximately 1/3 the size we describe for *Leptodea ochracea* (Table 1). The shape of *fragilis*, also illustrated in Baker (1928), is more oval than that of the Waccamaw *ochracea* (Figure 7). Thus, the Waccamaw *ochracea* glochidia, both in size and shape, are nearer to glochidia described for the Genus *Lampsilis* than for the Genus *Leptodea*. This strengthens the contention of Bereza and Fuller (1975) that the species *ochracea* is closer related to *Lampsilis* than to *Leptodea*.

ACKNOWLEDGEMENTS

The authors are grateful to Lorilyn A. Howie, Glenn Safrit and Lisa L. Wood who aided in the project and to Bill Link for photographic aid. Special appreciation is given to Dr. David G. Lindquist, University of North Carolina at Wilmington for trawl-collected specimens and to Dr. David H. Stansbery, Museum of Zoology, Ohio State University for advice freely given concerning this project. This research was supported jointly by the North Carolina Wildlife Resources Commission, Project Number: E-1, Study Number: VI, Job Number: VI-7 (Federal aid grant funds made available under provision of the Federal Endangered Species Act of 1973) and the University of North Carolina at Chapel Hill, Institute of Marine Sciences.

LITERATURE CITED

Arey, L.B. 1921. An experimental study on glochidia and the factors underlying encystment. J. Exp. Biol. 33: 463-499.

Baker, F.C., 1928. The fresh-water Mollusca of Wisconsin. Pt. 2. Pelecypoda. Bull. Univ. Wisconsin, Serial No. 1527. 495 p.

Bereza, D.J., and S.L.H. Fuller. 1973. Notes on "*Lampsilis*" *ochracea* (Say) (Mollusca: Bivalvia). ASB Bull. 22: 42.

Calloway, C.B. and R.D. Turner. 1978. New techniques for preparing shells of bivalve larvae for examination with the scanning electron microscope. Bull. Am. Malacol. Union, Inc. 1978:17-24.

Clarke, A.H. 1973. The freshwater molluscs of the Canadian Interior Basin. Malacologia 13:1-509.

Frey, D.G. 1948. A biological survey of Lake Waccamaw. Wildl. North Carolina 7:4-6.

Frey, D.G. 1949. Morphometry and hydrography of some natural lakes of the North Carolina coastal plain: the bay lake as a morphometric type. J. Elisha Mitchell Sci. Soc. 65:1-37.

Fuller, S.L.H. 1977. Freshwater and terrestrial mollusks, pp. 143-194.

In: Cooper, J.E., S.S. Robinson, and J.B. Funderberg, 1977, Endangered and Threatened Plants and Animals of North Carolina. North Carolina State Museum of Natural History, Raleigh. pp. 1-444.

Fuller, S.L.H., M.J. Imlay, and J.D. Williams. 1976. Engangered or threatened freshwater mussels (Mollusca: Bivalvia: Unionidae) of the Waccamaw River basin of the Carolinas. ASB Bull. 23:60.

Jennewein, P. 1971. Lake Waccamaw's mystery. Wildl. North Carolina 35(4):10-12.

Johnson, R.I. 1970. The systematics and zoogeography of the Unionidae (Mollusca: Bivalvia) of the southern Atlantic slope region. Bull. Mus. Comp. Zool. 140:263-450.

Louder, D.E. 1958. Lake Waccamaw. Wildl. North Carolina 22(7):5-7.

Ortmann, A.E. 1919. A monograph of the naiades of Pennsylvania. Part III. Systematic account of the genera and species. Mem. Carnegie Mus. 8:1-384.

Reardon, L. 1929. A contribution to our knowledge of the anatomy of the freshwater mussels of the District of Columbia. Proc. U.S. Nat. Mus. 75:1-11.

Stansbery, D.H. and W.J. Clench. 1978. The mollusca of Lake Waccamaw in North Carolina. Bull. Am. Malacol. Union, Inc. 1978:63.

Surber, T. 1915. Identification of the glochidia of freshwater mussels. Appendix V, Rep. U.S. Fish Com., 1914. pp 1-9.

Tedla, S. and C.H. Fernando. 1969. Observations on the glochidia of *Lampsilis radiata* (Gmelin) infesting yellow perch, *Perca flavescens* (Mitchill) in the Bay of Quinte, Lake Ontario. Can. J. Zool. 47:705-712.

Teulings, R.P. and J.B. Funderberg, 1977, Endangered and Threatened plants and Animals of North Carolina. North Carolina State Museum of Natural History, Raleigh. pp. 1-444.

Wiles, M. 1975. The glochidia of certain Unionidae (Mollusca) in Nova Scotia and their fish hosts. Can. J. Zool. 53(1):33-41.