FINAL REPORT

Endangered Species Project SE-3-2
Improving Status of Endangered Species in Missouri

ASPECTS OF THE LIFE HISTORY OF THE CURTIS' PEARLY MUSSEL, EPIOBLASMA FLORENTINA CURTISI (UTTERBACK 1915)

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FOREWORD

This report partially fulfills the last of the objectives of the Endangered Species Project: "Improving Status of Endangered Species of Missouri", Study SE-3-2, "The Abundance and Life History of the Curtis' Pearly Mussel, *Epioblasma florentina curtisi*, in Missouri." The objectives, as stated in the original project proposal, were: 1. To determine the abundance of populations of the Curtis' pearly mussel; 2. To outline its reproductive schedule and identify its host(s); 3. To identify sites for possible reintroduction; and 4. To prepare a recovery plan for enhancing its status.

Objectives 1 and 4 were accomplished and included in reports:

Buchanan, A. C. 1982. A study of *Epioblasma florentina curtisi* (Utterback 1915), the Curtis' pearly mussel, in the Upper Little Black River, Missouri. United States Department of Agriculture, Soil Conservation Service, Columbia, Missouri. 11 pp.

U. S. Fish and Wildlife Service. 1986. Curtis' Pearly Mussel Recovery Plan. U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 92 pp.

Objectives 2 and 3 will be discussed in this report.

INTRODUCTION

Management of populations of all aquatic organisms, including freshwater mussels, becomes progressively easier and more effective as we gain more information about their biology. Without knowledge of the life history of a species, we are handicapped by unknown processes which affect the species at some stage of its life. Freshwater mussels have a very unique life cycle in which the larval stage is parasitic on fish of one or more species. Thus we must know the life history and habitat needs of the hosts as well as the mussels. Habitat management where a mussel occurs must include management for the needs of the mussel's host as well. Predicting the potential impacts(s) of habitat changes, in turn, must take into consideration the impacts upon the host as well as the mussel itself.

The range of the Curtis' pearly mussel has declined significantly since the early 1900s. Epioblasma florentina curtisi (Utterback 1915) used to occur at scattered locations in the White and St. Francis River basins in southern Missouri and northern Arkansas (Utterback 1915; 1917; Johnson 1978; personal communication with Mr. Mark Gordon, University of Arkansas, Fayetteville, Arkansas). Due to dam construction, channelization, gravel dredging, and other factors, however, it is presently limited to less than 15 miles of streams in the Castor and Little Black rivers, and Cane Creek, a tributary to Black River (Buchanan 1983). Previous suitable habitat in the White and Black rivers has been dammed, dredged, or otherwise altered and this species no longer occurs there. This species requires shallow flowing water and occurs in stable riffles and runs in transitional stream reaches between headwater and lowland stream reaches. It has recently been found in 2 to 30 inches of water, in stable substrates of sand and gravel to gravel, cobble and boulder (Buchanan 1982; 1983).

The population density of the Curtis' pearly mussel is low where the species occurs. At three sites in Little Black River E. f. curtisi comprised only 0.9% of the living naiades found and occurred at a density of less than 0.1/yd.^{2}, based on quantitative sampling (sample size = 229.6 yd.^{2}, or 5.2% of the 300 yards of stream subsampled) (Buchanan 1982). In Castor River at the single site in Bollinger County, Missouri where E. f. curtisi is known to occur, none were encountered during qualitative sampling (sample size = 61.6 yd^2 or 3.0% of the 102 yards of stream subsampled) (Buchanan 1982). Estimates of E. f. curtisi density in Cane Creek have not been made because densities of naiades in the portion of this stream where this species occurs are so low that quantitative sampling would not yield reliable estimates. The bulk of the remaining known populations of this species occurs in 6.1 miles of upper Little Black River (Buchanan 1983). Recovery of this endangered species depends on knowledge of its fish host.

The objectives of this study were to outline the life history of the Curtis' pearly mussel, Epioblasma florentina curtisi (Utterback 1915), and determine its fish host(s), and recommend stream reaches for reintroduction. Because of its advanced phylogenetic position (Heard and Guckert 1970), the Curtis' pearly mussel was expected to be a long-term breeder. In other words, its eggs are fertilized during summer, and carried through the winter, with the developed larvae, glochidia, released the following spring. The hosts of several naiad species have been determined by holding gravid females in aquaria and exposing various native fish species to infection. The fish are either placed in aquaria or shallow dishes with glochidia in suspension, or glochidia are piped directly onto their gills (LeFevre and Curtis 1911; Howard 1913; D'Eliscu; Zale and Neves 1982; Neves et al. 1985; Waller et al. 1985; Yeager and Neves 1986; Hill 1986). In most cases, the researchers were studying species which could be obtained in sufficient numbers that mortality of individuals was acceptable. Unfortunately, due to the extreme rarity of the Curtis' pearly mussel, removing females from their natural habitat and thus exposing them to additional mortality, was not felt to be an option. It was therefore necessary to attempt to determine the host of this species in vivo. Stern (1978), Tedla and Fernando (1969), Wiles (1975), and Dartnall and Walkey (1979) had all previously identified hosts for freshwater naiades by collecting both fish and mussels from one or more streams at regular intervals and comparing the glochidia excised from gravid mussels to those excised from fish.

STUDY AREA

The study area is a portion of the Little Black River in Ripley County in southeastern Missouri (Fig. 1). This location was selected because of ease of access and relative abundance of the Curtis' pearly mussel based on previous studies (Buchanan 1982).

Little Black River is an order 4 stream in the study reach, with a gradient of 5.7 feet per mile. It is a small Ozark stream with a mean annual flow at Fairdealing, approximately 14 miles downstream from the study reach, of 2,120 cfs (United States Department of the Interior, Geological Survey 1976). The stream is characterized by long, shallow, gravel and cobble-bottomed riffles interspersed with long, shallow, gravel, cobble, and sand-bottomed runs, and long, deep, silt and sand-bottomed pools. Water willow (*Justicia americana*) is found in dense stands along shore in riffle areas and on gravel bars, and Spatterdock (*Nuphar ozarkanum*) occurs in slow current along shore in pools and runs.

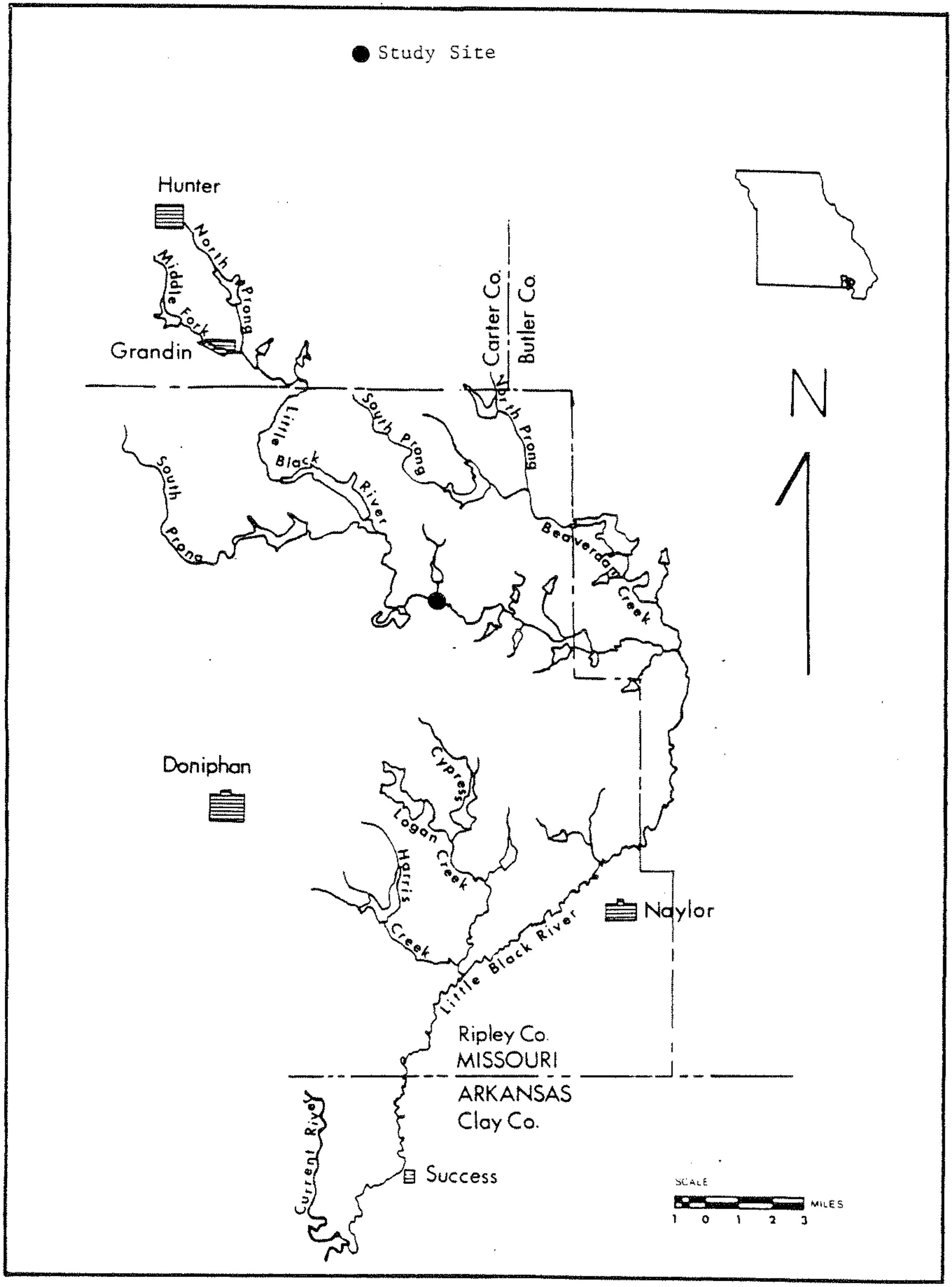

Figure 1. Study site on Little Black River.

The soils of the upper Little Black River basin consist primarily of dolomite and sandstone (United States Department of Agriculture, Soil Conservation Service 1974). The predominant basin cover type upstream from the study reach is oak/hickory forest; in the study reach the Little Black braids through old field and row crops, with a riparian belt of trees. Twenty-two species of mussels, including E. f. curtisi, and the asiatic clam occur in the study reach (Table 1).

MATERIALS AND METHODS

During 1983 through 1986, at a single site on Little Black River where the Curtis' pearly mussel is known to occur in assessable numbers, populations of the Curtis' pearly mussel were sampled to determine the time of glochidial release and the host of this species. The study reach was sampled seven times in 1983, twelve times in 1984, seven times in 1985, and three times in 1986. During 1984 and the spring of 1985, populations of E. f. curtisi were monitored, and fish were collected by seining, electroshocking, and angling, at approximately 2-week intervals. All specimens of E. f. curtisi encountered were measured, aged, sexed, marked, and returned immediately to the habitat from which they came. In females the state of gravidity was noted by gently prying the valves apart and examining the condition of the gills.

Initially, the location of all specimens was marked with a nail containing a tag with the number of the specimen on it driven into the bottom at the location where the specimen was returned to the habitat. Due to the difficulty of recapturing females marked in 1983 and 1984, attempts were made to limit their movement. A single female was tethered with 3 feet of monofilament, but the glue failed and during high flows the tethered specimen was pulled out of the substrate and flushed downstream. Beginning in 1984 and

Table 1. Naiad species found at the study site on Little Black River.

Anodonta g. grandis (Say 1829)
Strophitus u. undulatus (Say 1817)
Alasmidonta marginata (Say 1818)
Lasmigona costata (Rafinesque 1820)
Tritogonia verrucosa (Rafinesque 1820)
Amblema p. plicata (Say 1817)
Fusconaia flava (Rafinesque 1820)
Cyclonaias tuberculata (Rafinesque 1820)
Pleurobema coccineum (Conrad 1836)
Elliptio dilatata (Rafinesque 1820)
Ptychobranchus occidentalis (Conrad 1836)
Cyprogenia aberti (Conrad 1850)
Toxolasma parvus (Barnes 1823)
Toxolasma lividus glans (Lea 1831)
Ligumia subrostrata (Say 1831)
Villosa i. iris (Lea 1829)
Villosa l. lienosa (Conrad 1834)
Lampsilis radiata luteola (Lamarck 1819)
Lampsilis ventricosa (Barnes 1823)
Lampsilis reeviana (Simpson 1900)
Epioblasma triquetra (Rafinesque 1829)
Epioblasma florentina curtisi (Utterback 1915)

through 1985 and 1986, a more successful technique of recapturing females was used. When a female was captured, a hole was dug into the substrate nearby. Half of a wire mesh minnow trap (Fig. 2) containing the substrate removed from the hole was placed into the hole with approximately 1 inch of the basket exposed. The female was then placed into the basket. Using this technique I was able to relocate previously examined females and monitor their reproductive state.

Fish captured by seining, electrofishing, or angling were examined for glochidia. The gills, oral cavities, and fins of larger fish (greater than 6 inches total length) were examined in the field and uninfected fish were returned immediately to the stream. Smaller fish were preserved in buffered formaldehyde and returned to the laboratory for examination under a binocular microscope. Long-term storage of fish was in 70% ethanol. Glochidia excised from the gills of fish were measured (height, length, and hinge length) and photographed.

During 1984 and 1985, mussels of all species were examined at the study site for gravidity. Of the 22 species known from the site, I was able to obtain, measure, and photograph mature glochidia from only 12 species. A portion of the contents of the gill was excised from one or more female *E. f. curtisi* demonstrating some gill expansion on August 2, 1984, September 20, 1984, February 14, 1985, March 8, 19, and 28, 1985, and April 23, 1985. Glochidia excised from naiades were compared with glochidia excised from the gills of fish to determine hosts.

Depth, flow velocity, and substrate type were also recorded in locations where specimens of *E. f. curtisi* were examined. Water temperature, dissolved oxygen, alkalinity, pH, and total hardness of the water were recorded for each sampling date.

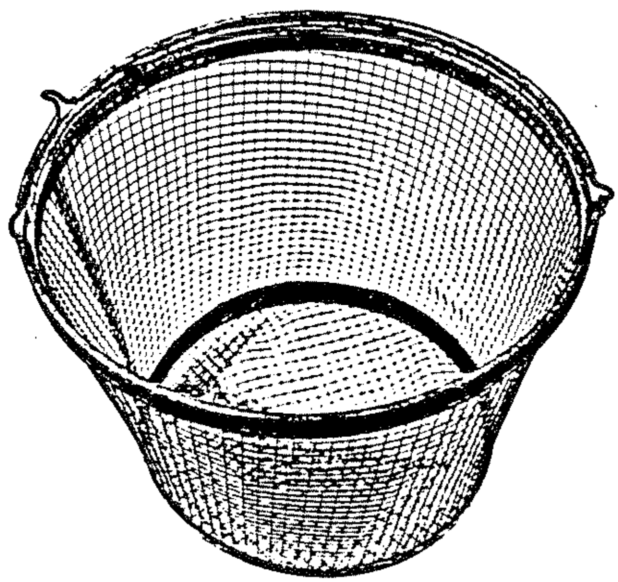

Figure 2. Wire basket used to limit the movement of female Epioblasma florentina curtisi.

RESULTS AND DISCUSSION

Reproductive cycle of E. f. curtisi

The results of this study are similar to those of other reproductive studies of species in the genus Epioblasma. The suspected host, timing of fertilization and glochidia release, and mode of glochidia release for E. f. curtisi are similar to that of other species of Epioblasma.

Due to the difficulty in locating and recapturing female E. f. curtisi, it was difficult to outline its reproductive cycle. An average of 31 person-hours was required to find a single female of this species; they were easiest to find during glochidial release in the Spring. Eleven females were examined during this study, but due to difficulties in recapturing them, only a few were examined more than once. I was able to monitor the reproductive cycle of only a single specimen for more than one year.

Epioblasma florentina curtisi was determined to be a long-term breeder, as suspected, during this study. Females of this species have their eggs fertilized during late summer or fall, the eggs develop into mature glochidia during the fall and winter months, and mature glochidia are released during late March to mid-April, when water temperatures are above 10°C, and probably between 12 and 20°C (Appendix A). Hill (1986) reports that Epioblasma brevidens, E. capsaeformis, and E. triquetra were all gravid with mature glochidia in May or June and were spent by mid-July; all three released their glochidia when the water temperature was between 15 and 20°C. Like E. brevidens, E. capsaeformis, and E. triquetra, only the outer gills of E. f. curtisi served as marsupia.

Epioblasma florentina curtisi females move up onto the surface of the substrate and lie on their sides to release their glochidia. Hill (1986) reports that E. brevidens, E. capsaeformis, and E. triquetra were found lying gaping on the surface of the substrate or only partially buried during the release of glochidia. Of the three, only E. capsaeformis exhibited an obvious mechanism for attracting fish; the mantle is a bright shiny blue and fish were observed striking it. No lure was apparent in E. f. curtisi.

Glochidia excised from a gravid female E. f. curtisi on March 28, 1985 were subcircular in shape and apparently released singly (i.e. not in a conglutinate) (Fig. 3). Mean dimensions of 100 mature glochidia were: 0.226 mm (S.D. = 0.0087) in length, 0.208 mm (S.D. = 0.045) in height (hinge to ventral margin), and 0.152 mm (S.D. = 0.0036) hinge length. The glochidia shells were hookless. Glochidia of E. f. curtisi were similar in size and shape to those of other Epioblasma species. Glochidia of E. brevidens, E. capsaeformis, and E. triquetra were, respectively, 0.24, 0.25, and 0.22 mm long, 0.23, 0.23, and 0.22 mm in height, and with a 0.17, 0.17, and 0.16 mm hinge (Hill 1986).

Gravid female E. f. curtisi enountered during this study were between 5 and 7 years old. It is not known at what age E. f. curtisi becomes sexually mature.

Host of E. f. curtisi

Four thousand and eighty-five fish, including 38 species, were examined for mussel glochidia (Table 2). Only thirteen species were infected with glochidia (Ozark minnow, redfin shiner, telescope shiner, striped shiner, bigeye shiner, smallmouth bass, spotted sunfish, longear sunfish, rock bass, greenside darter, rainbow darter, orange throat darter, and orange spotted sunfish). With the exception of the redfin shiner and orange spotted sunfish, all of the above species were present in a majority of collections.

Figure 3. Glochidia excised from female Epioblasma florentina curtisi (Utterback 1915) on March 28, 1985 (150X).

Table 2. Species and numbers of fish examined for glochidia during 1983 through 1985.

Species	Number Examined	With Glochidia?
Ichthyomyzon castaneus	1	No
Esox niger	1	No
Pimephales notatus	51	No
Pimephales promelas	2	No
Semotilus atromaculatus	2	No
Nocomis bigguttatus	26	No
Campostoma sp.	92	No
Notropis nubilis	935	Yes
Notropis umbratilis	15	Yes
Notropis telescopus	1,001	Yes
Notropis zonatus	68	No
Notropis chrysocephalus	390	Yes
Notropis boops	469	Yes
Erimyzon oblongus	1	No
Hypentelium nigricans	11	No
Moxostoma sp.	31	No
Noturus albater	11	No
Noturus exilis	14	No
Aphredoderus sayanus	4	No
Fundulus olivaceus	195	No
Labidesthes sicculus	73	No
Cottus bairdi	15	No
Micropterus salmoides	1	No
Micropterus punctulatus	4	No
Micropterus dolomieui	19	Yes
Lepomis gulosus	4	No
Lepomis cyanellus	9	No
Lepomis punctatus	22	Yes
Lepomis megalotis	112	Yes
Lepomis macrochirus	1	No
Lepomis humilis	1	Yes
Ambloplites rupestris	23	Yes
Etheostoma blennioides	63	Yes
Etheostoma zonale	19	No
Etheostoma stigmaeum	5	No
Etheostoma flabellare	42	No
Etheostoma caeruleum	103	Yes
Etheostoma spectabile	248	Yes
Ictalurus melas	2	No

Based on the sampling done during spring, 1983 and spring, 1984 through spring, 1985, fish were most often infected with glochidia from early April to early June (Table 3). One species was infected in March, seven in April, ten in May, six in June, four in July, and one in September. No fish collections were made during October through February because most naiades, including *E. f. curtisi*, release glochidia during spring and early summer, and few naiades release glochidia during winter.

Only the rainbow darter, *Etheostoma caeruleum*, of the fish examined during this study, contained glochidia which resembled those excised from gravid *E. f. curtisi*. Rainbow darters were found infected with glochidia resembling those of *E. f. curtisi* on May 17, 1984, March 28, 1985, and April 22, 1985. Other fish may also serve as hosts, but none contained glochidia similar to those of *E. f. curtisi*. Due to the low number of *E. f. curtisi* females in Little Black River and elsewhere, the likelihood of capturing fish infected with glochidia of this species under natural conditions may be low.

Other researchers have successfully identified the hosts of species of *Epioblasma* by infecting fish with glochidia in the laboratory and monitoring glochidial development to determine success. The fish hosts for *Epioblasma brevidens*, *E. capsaeformis*, and *E. triquetra* were determined in this manner (Hill 1986). Four darters, *Etheostoma blennioides*, *E. maculatum*, *E. rufilineatum*, and *E. simoterum*, the logperch, *Percina caprodes*, and the banded sculpin, *Cottus carolinae* served as hosts for *E. brevidens*, three darters, *E. maculatum*, *E. rufilineatum*, *Percina sciera*, and *C. carolinae* were hosts for *E. capsaeformis*, and *P. caprodes* and *C. carolinae* were hosts for *E. triquetra*. Therefore one or more darters might be expected to serve as host(s) for *E. f. curtisi*. The mottled sculpin, *Cottus bairdi*, a species closely related to *C. carolinae*, occurs in Little Black River in low numbers and was rarely

Table 3. Dates on which fish were infected with glochidia.

Species and Sample Date	Dionda nubila	Notropis umbratilis	Notropis telescopus	Notropis chrysocephalus	Notropis boops	Micropterus dolomieui	Lepomis punctatus	Lepomis megalotis	Lepomis humilis	Ambloplites rupestris	Etheostoma blennioides	Etheostoma caeruleum	Etheostoma spectabile
May 10-12, 1983	X	X		X	X		X	X				X	
May 17, 1984					X							X	
May 25, 1984	X		X	X	X			X	X	X			
July 3, 1984	X						X						
July 26, 1984													
August 15, 1984													
Aug. 29-30, 1984													
Sept. 20, 1984	X												
March 19, 1985													
March 28, 1985												X	X
April 11, 1985	X		X					X			X		X
April 22, 1985					X			X				X	
May 7, 1985	X		X		X			X					
June 6, 1985	X		X	X	X	X					X		

encountered during the present study. *C. bairdi* may also be a host for *E. f. curtisi*.

Due to the difficulty in finding *E. f. curtisi* glochidia on fish in vivo, it may be necessary to expose fish to glochidia of this species under laboratory conditions in order to define its hosts. Fish to be infected should include the rainbow darter, *Etheostoma caeruleum*, orangethroat darter, *E. spectabile*, fantail darter, *E. flabellare*, speckled darter, *E. stigmaeum*, banded darter, *E. zonale*, greenside darter, *E. blennioides*, and mottled sculpin, *Cottus bairdi*.

The majority of glochidia excised from fish gills during this study have yet to be identified other than determining whether or not they are glochidia of *E. f. curtisi*. Since we can identify glochidia of only 12 of the 22 naiad species which occur at the study site, many of the glochidia excised from fish do not match our reference glochidia. The identify of those glochidia and hosts will be determined and described in a later report.

Reintroduction Sites for *E. f. curtisi*

Since using adults from Little Black River to augment existing populations or reintroduce this species to streams where it previously occurred is not a viable option due to the low numbers of this species in Little Black River, it will be necessary to artificially culture juveniles using techniques developed by Tennessee Valley Authority (Hudson and Isom 1984; Isom and Hudson 1982). Black River between Clearwater Dam (river mile 81.5) and Hendrickson, Missouri (river mile 55.0), in areas with the least disturbance by gravel dredging, etc., is the stream where reintroduction of juveniles is most likely to be successful. Castor River near Zalma, Missouri contains low populations of this species which might benefit from stocking additional individuals, but such stocking would probably eliminate the existing gene pool in Castor River, which may be important for the survival of this species.

SUMMARY AND RECOMMENDATIONS

1. *Epioblasma florentina curtisi* is a long-term breeder whose eggs are fertilized during late summer or fall, the eggs develop into glochidia during fall and winter, and mature glochidia are released between late March and mid-April when water temperatures are above 10°C. Its reproductive cycle is similar to that of other *Epioblasma* species.

2. Glochidia of *E. f. curtisi* have a mean (N=100) length of 0.226 mm, a mean height of 0.208 mm, and a mean hinge length of 0.152 mm. They are subcircular in shape and are hookless.

3. During glochidial release, gravid female *E. f. curtisi* lie on top of the substrate with their valves gaped open. No lure is evident.

4. Of the 38 species, including 4,085 specimens, of fish examined, only 13 species contained naiad glochidia; only one species, *Etheostoma caeruleum*, the rainbow darter, contained glochidia which closely resembled those excised from *E. f. curtisi*. Those glochidia were encysted on the gills.

5. Approximately 31 man-hours were required to find a single female *E. f. curtisi*. It was necessary to cage females in order to relocate them to monitor their reproductive cycle.

6. Several species of fish known to inhabit the reach of Little Black River where *E. f. curtisi* occurs should be infected with glochidia of this species under laboratory conditions to define the host. Species which should be included are: the rainbow darter, *Etheostoma caeruleum*, orangethroat darter, *Etheostoma spectabile*, fantail darter, *Etheostoma flabellare*, speckled darter,

Etheostoma stigmaeum, banded darter, Etheostoma zonale, greenside darter, Etheostoma blennioides, and mottled sculpin, Cottus bairdi. These are species which might be expected to carry glochidia of E. f. curtisi, based on results of other host studies of Epioblasma species.

7. Due to low numbers of E. f. curtisi in Little Black River and throughout its range, sufficient numbers do not exist to reintroduce this species to areas of Black River where it has been extirpated or other suitable habitats. Juveniles raised in artificial culture media should be stocked to augment populations in Cane Creek and Castor River, and to reintroduce this species to portions of Black River between Clearwater Dam (river mile 81.5) and Hendrickson, Missouri (river mile 55.0).

REFERENCES CITED

Buchanan, A. C. 1982. A study of Epioblasma florentina curtisi (Utterback 1915), the Curtis' pearly mussel, in the Upper Little Black River, Missouri. United States Department of Agriculture, Soil Conservation Service, Columbia, Missouri. 11p.

Buchanan, A. C. 1983. Distribution, abundance, status, and habitat of the Curtis' pearly mussel Epioblasma florentina curtisi in southern Missouri. United States Department of the Interior, Fish & Wildlife Service. Endangered Species Project SE-3-1. 10p.

Coker, R. E., A. F. Shira, H. W. Clark, and A. D. Howard. 1919-1920. Natural history and propagation of fresh-water mussels. Bull. U.S. Bur. Fish. pp. 75-181.

Dartnall, H. J. G. and M. Walkey. 1979. The distribution of glochidia of the Swan mussel, Anodonta cygnea (Mollusca) on the three-spined stickleback Gasterosteus aculeatus (Pisces). J. Zool., London 189:31-37.

D'Eliscu, P. N. 1972. Observation of the glochidium, metamorphosis, and juvenile of Anodonta californiensis Lea, 1857. The Veliger 15(1):57-58.

Heard, W. H. and R. H. Guckert. 1970. A re-evaluation of the recent Unionacea (Pelecypoda) of North America. Malacologia 10(2):333-355.

Hill, D. M. 1986. Cumberlandian mollusk conservation program. Activity 3: Identification of hosts. Tennessee Valley Authority, Norris, Tennessee. 57p.

Howard, A. D. 1913. The catfish as a host for freshwater mussels. Trans. Am. Fish. Soc. 42:65-69.

Hudson, R. G. and B. G. Isom. 1984. Rearing juveniles of the freshwater mussels (Unionidae) in a laboratory setting. The Nautilus 98(4):129-135.

Isom, B. G. and R. G. Hudson. 1982. In vitro culture of parasitic freshwater mussel glochidia. The Nautilus 96(4):147-151.

Johnson, R. I. 1978. Systematics and zoogeography of Plagiola (= Dysnomia = Epioblasma), an almost extinct genus of freshwater mussels (Bivalvia: Unionidae) from Middle North America. Bulletin of the Museum of Comparative Zoology 148 (6):239-321.

LeFevre, G. and W. C. Curtis. 1910. Studies on the reproduction and artificial propagation of freshwater mussels. Bur. Fish. Doc. No. 756 (1912) or Bull. Bur. Fish. 30(1910):109-201.

Neves, R. J., L. R. Weaver, and A. V. Zale. 1985. An evaluation of host fish suitability for glochidia of Villosa vanuxemi and V. nebulosa (Pelecypoda: Unionidae). Am. Midl. Nat. 113(1):13-19.

Stern, E. M. 1978. Identification of host fishes for four species of freshwater mussels (Bivalvia: Unionidae). Amer. Midl. Nat. 100(1):233-236.

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

United States Department of Agriculture, Soil Conservation Service. 1974. Upper Little Black Watershed. Final Work Plan. Soil Conservation Service, Columbia, Missouri.

United States Department of the Interior, Geological Survey. 1976. Water Resources Data for Missouri. 300p.

United States Fish and Wildlife Service. 1986. Curtis' pearly mussel recovery plan. U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 92pp.

Utterback, W. I. 1915. The naiades of Missouri. Am. Midl. Nat. 4(3-8): 200pp.

Utterback, W. I. 1917. Naiadgeography of Missouri. Am. Midl. Nat. 5(1): 26-30.

Waller, D. L., L. E. Holland, L. G. Mitchell, and T. W. Kammer. 1985 Artificial infestation of largemouth bass and walleye with glochidia of Lampsilis ventricosa (Pelecypoda: Unionidae). Freshwat. Invertebr. Biol. 4(3):152-153.

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

Yeager, B. L. and R. J. Neves. 1986. Reproductive cycle and fish hosts of the rabbit's foot mussel, *Quadrula cylindrica strigillata* (Mollusca: Unionidae) in the upper Tennessee River drainage. Am. Midl. Nat. 116(2):329-340.

Zale, A. V. and R. J. Neves. 1982. Reproductive biology of four freshwater mussel species (Mollusca: Unionidae) in Virginia. Freshwat. Invert. Biol. 1:17-28.

APPENDIX

A summary of *Epioblasma florentina curtisi* captured, their reproductive condition, and the water temperature at the time of examination.

One female was captured in mid-May, 1983; it was not recaptured and no notes were taken on its reproductive condition. No further females were captured during 1983.

On March 27, 1984, two females (Z1 and Z2) were captured. Both were gravid, exhibiting a thickened dark mantle and the outer gills of both were charged with glochidia. Both were marked with a number and returned to the location from which they came; the location of each was marked with a numbered nail. The water temperature was 10.5°C. We were unable to find either Z1 or Z2 again. Z3 was captured on May 3, 1984 (17°C). It was returned to the habitat after being tethered by gluing 3 feet of monofilament line to it and to a nail subsequently driven into the bottom. The reproductive condition of this specimen was not noted, and on May 16, 1984 the nail and monofilament were found but Z3 was not. High flows had presumably flushed this specimen downstream and it was not encountered again. Z4 and Z5 were captured on July 2, 1984 (26°C), marked, and placed in cages in the substrate. On July 16-18, 1984 (27.5°C) both specimens were found dumped out on the bottom and the cages had been taken by a fisherman; both specimens were placed in new, better-hidden cages. The outer gills of both Z4 and Z5 were thickened slightly on July 30-August 2, 1984 (23°C). A portion of the gill contents excised from Z4 contained only organic matter; no eggs or glochidia were present. By August 15-17, 1984 (25.5°C) the posterior outer gills of Z5 were thickened and beaded, while those of Z4 showed no signs of gravidity. On August 29-31, 1984 (28°C), neither specimen showed any signs of gravidity. The posterior outer gills of Z5 were slightly thickened again on September 19, 1984 (22°C), but were not beaded; only a few poorly developed eggs and undifferentiated organic matter were found in material excised from the gill. Z6, found on September 19, 1984, exhibited thickened outer gills which were not beaded. Specimens Z4, Z5, and Z6 were not found again.

Specimens Z7 and Z8 were captured on February 13-14, 1985 (3.5°C) and caged in separate baskets. The mantle was well developed in Z7 but the gills were not inflated. The outer gills of Z7 and Z8 were inflated on February 13-14, 1985, and part of the gill contents were excised; no eggs or glochidia were present. Z7 was not found again, and Z8 was last recaptured on March 8, 1985, but its reproductive condition was not examined. On March 8, 1985 (10°C), Z9 was captured. Its outer gill was gravid and a portion of its contents were excised; the gill was charged with glochidia with little organ development (i.e. immature). Z9 was still gravid on March 28, 1985 (19°C). Internal organ development of glochidia excised from Z9 at this time still appeared to be poor. On April 23, 1985 (15°C) Z9 had spawned out; the gill was mostly empty and all glochidia recovered were dead and fully open. Z9 was the only female examined more than one year; all others could not be found consistently. Z9 was gravid again on February 26, 1986 (9.5°C) but still imbedded in the substrate. On March 26, 1986 (13.5°C) Z9 was gravid and lying on her side on the stream bottom gaping, presumably releasing glochidia. On March 31-April 1, 1987, Z9 was gravid in one gill, and by April 22, 1987 no longer showed any signs of gravidity. No material was excised from the gill on either date. Z10 was found on March 19, 1985 (12°C) and glochidia excised from the gravid gill; the gill was charged with glochidia which showed good organ development. On March 28, 1985 the outer gills of Z10 were still charged with mature glochidia. This specimen was not captured again.