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Appendix A

FINAL REPORT

Endangered Species Project SE-3-1
Improving Status of Endangered Species in Missouri

DISTRIBUTION, ABUNDANCE, STATUS, AND HABITAT OF THE CURTIS' PEARLY MUSSEL *EPIOBLASMA FLORENTINA CURTISI* IN SOUTHERN MISSOURI

Missouri Department of Conservation

Larry R. Gale, Director

Charles A. Purkett, Jr., Assistant Director

Dan F. Dickneite, D-J Coordinator

James P. Fry, Chief, Division of Fisheries

Date Prepared:
December 1, 1983

Prepared by: Alan C. Buchanan
Water Quality Research Biologist

Approved by: James R. Whitley
Fisheries Research Superintendent

Abstract

One hundred and forty-six sites were sampled on twenty-six streams in southern Missouri during 1981 and 1982 to determine the distribution and status of *Epioblasma florentina curtisi*, a federally endangered species. *Epioblasma florentina curtisi* was not found in any new areas nor in areas of Black River and Cane Creek where it had been collected previously. No fresh specimens of *E. f. curtisi* have been found in Cane Creek or Black River since 1971. It occurs only in 6.1 miles of the Upper little Black River and 7 miles or less of the Castor River upstream from the Headwater Diversion Channel. These stream reaches should be considered critical habitat for *E. f. curtisi*. Most of the remaining *E. f. curtisi* occur in the Upper Little Black River. Management of this species should include periodic monitoring of populations, protection of critical habitat, searches for additional populations, reintroduction into areas from which it has disappeared, and introduction into other areas which appear suitable.

Introduction

The Curtis Pearly Mussel, *Epioblasma florentina curtisi*, is one of those species which is so uncommon that it is on the verge of extinction. Although it has never been common or widespread, the range of *Epioblasma florentina curtisi* has declined significantly since the early 1900s. Loss of habitat has been the primary cause of the decline of this species. This species requires shallow, flowing streams with stable substrates. Dam construction, sand and gravel dredging, and other activities have destroyed much of the habitat where this species originally occurred.

The Curtis Pearly Mussel was first described from specimens collected in the White River at Hollister, Missouri (Utterback 1915). In his "Naiad-geography of Missouri" (1917) Utterback listed this species as "abundant" in the White River Basin in southwestern Missouri and "scarce" in the Black River Basin in southeastern, Missouri. Johnson (1978) lists collection of this species taken from the White River near Forsyth, Missouri in the early 1900s. The White River has been impounded at both of the above White River sites, and *E. f. curtisi* no longer occurs in this stream.

More recently *E. f. curtisi* has been found in the Black and Castor rivers (Oesch in press; personal communication with Dr. David H. Stansbery, Director, Museum of Zoology, Ohio State University, Columbus, Ohio), Cane Creek, a tributary to the Black River (Oesch in press), and in the Little Black River (Buchanan 1979). Living *E. f. curtisi* had only been collected in the Little Black and Castor rivers since the early 1970s.

This study was undertaken to gather information on the present distribution and status of *E. f. curtisi* in Missouri. The objectives of this study, conducted during April, 1981 through November, 1982 were: 1. to determine the distribution and abundance of the Curtis Pearly Mussel; 2. to acquire information about its habitat; 3. to identify existing and potential threats to its survival; and 4. to develop recommendations for enhancing its status. This study was partially funded by the U. S. Department of the Interior, Fish and Wildlife Service.

Materials and Methods

Populations of *Epioblasma florentina curtisi* were assessed by field sampling in the Black, St. Francis, Castor, and White River basins in southern Missouri. Study sections included stream reaches where *E. f. curtisi* was found in the recent past and reaches believed likely to provide favorable habitat for this species, based on stream and basin characteristics such as area geology, topography, stream gradient, soil types, etc.

During April, 1981 through November, 1982, naiades were collected at 146 sites in 26 streams in southern Missouri (Fig. 1). Both stream reaches where *E. f. curtisi* had been found in the past and other reaches which appeared suitable for *Epioblasma florentina curtisi* were sampled. In most cases, a stream was sampled at 5-mile intervals in those reaches.

All habitat types were sampled at each site. Shells were collected by hand along shore, from muskrat and raccoon piles, and from the bottom of the stream. Live naiades were collected by hand while wading, and diving if necessary, until representatives of all species present were collected. The time spent collecting at each site ranged from 15 minutes to 7 1/2 hours; the average was 2 hours and 30 minutes.

The following information was recorded at each site: date, location, name(s) of collector(s), area covered by the site, bottom type(s) where

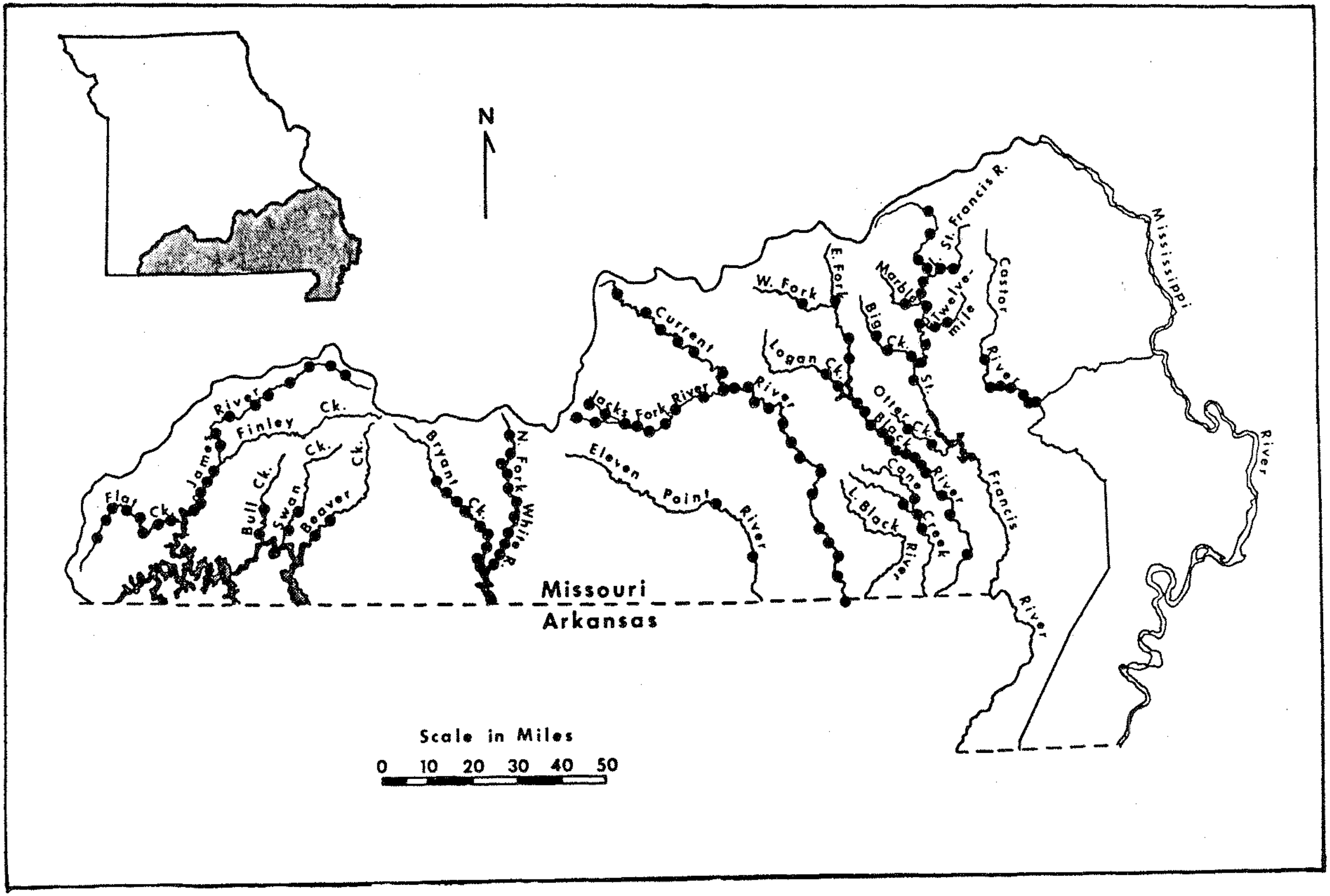

Figure 1. Sites sampled in southern Missouri.

living naiades were found, water temperature, water depth, collection techniques, the number of specimens of each species examined, and current velocity where living naiades were found. One or more specimens of all species except endangered species found at a site were retained as vouchers. Endangered species were photographed and returned unharmed to the habitat.

At each site, total hardness, pH, alkalinity, and dissolved oxygen were determined with a Hach kit, turbidity was measured with a Hach turbidimeter, and current velocity was measured with a Pygmy Current Meter. Current velocity was measured at mid-depth in water less than 6 inches deep and at surface and bottom in water greater than 6 inches deep.

Results and Discussion

Distribution and Abundance

Epioblasma florentina curtisi was not found in any new areas during this study. Also, no living specimens or fresh shell were found in areas of Black River and Cane Creek where it had been collected previously. No fresh material of _E. f. curtisi_ has been found in Cane Creek or Black River since 1971. Based on this study, and a study on the upper Little Black River (Buchanan 1982), this species presently occurs only in 6.1 miles of the upper Little Black River and 7 miles or less of the Castor River upstream from the Headwater Diversion Channel (Fig. 2). It is known from a total of only six sites in these two streams. Following is a description of the distribution of _E. f. curtisi_ in streams where it has been found both recently and historically.

White River

No _E. f. curtisi_ have been collected from White River since it was

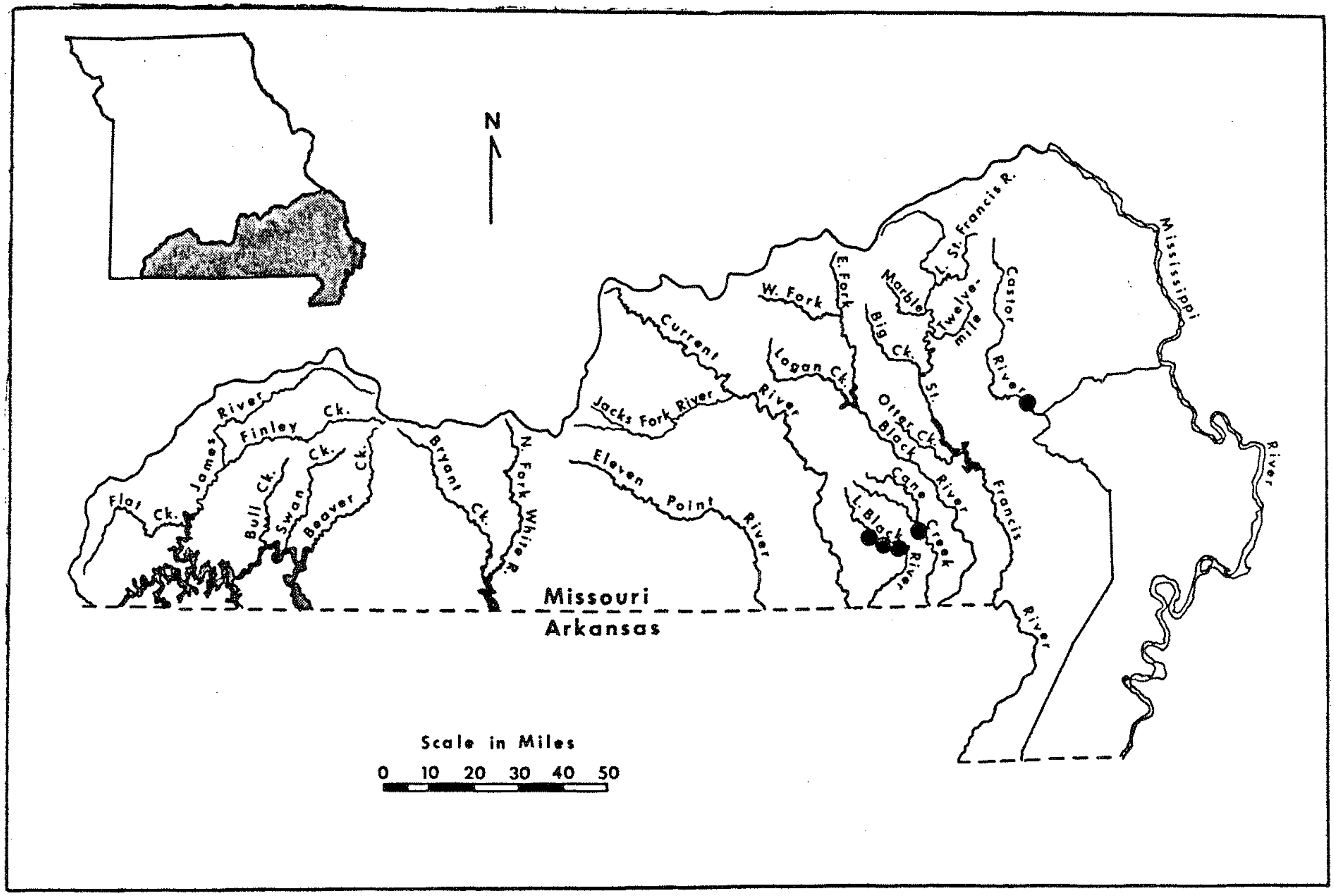

Figure 2. Distribution of Epioblasma florentina curtisi in southern Missouri.

impounded. Since E. f. curtisi is a riffle species, no sites were sampled on White River during this study. This species was not found in south-flowing tributaries sampled in southwestern Missouri during 1981-82, including James River, North Fork White River, and Swan, Bull, and Beaver creeks.

Black River

Epioblasma florentina curtisi has disappeared from Black River. It was first collected from Black River during the early 1900s (Utterback 1915). Utterback (1917) listed this species as "scarce" in the Black River Basin. During the 1960s E. f. curtisi was collected from Black River near Markham Spring, at Williamsville, and at Hendrickson (Oesch in press; personal communication with Dr. David H. Stansbery). Fresh shell of this species was collected from the Black River near Hendrickson in 1964 (OSUM 13647) and 1967 (OSUM 26509), and from Black River near Markham Spring in 1971 (OSUM 33633). No fresh material of this species has been found in Black River since 1971. No E. f. curtisi were found at 13 sites sampled between Clearwater Dam and Poplar Bluff during 1981 and 1982 (Fig. 1). The site near Hendrickson where it previously occurred has been dredged for sand and gravel. Old subfossil shell of this species was found in a muskrat midden near Williamsville but no fresh material was found.

The reason for the decline in E. f. curtisi populations in Black River is unknown. Changes in flow patterns in Black River since construction of Clearwater Dam in 1948 have probably contributed to the decline of E. f. curtisi in this stream. Hydrograph records at Leeper, 6.0 miles downstream from Clearwater Dam, reflect these changes (USGS). Between 1922 and 1948, the maximum annual flow was less than 10,000 cubic feet per second (cfs) only 8 times and was less than 5,000 cfs only twice. Since construction of Clearwater Dam, the maximum annual flow at Leeper has never exceeded 10,000 cfs and has exceeded 5,000 cfs only twice. Periodicity of flows has been altered also. Mean daily flows at Leeper during April, May, and June were reduced by 357, 124, and 335 cfs, respectively, by Clearwater Dam. Mean daily flows during July, August, and September have been increased by 198, 160, and 126 cfs, respectively, by the dam. Clearwater Dam has also resulted in extremely low flow levels at Leeper. Between 1922 and 1948, annual minimum flows dropped below 200 cfs only 7 times, and the lowest flow was 133 cfs in August, 1934. Between 1949 and 1979 annual minimum flows dropped below 200 cfs 14 times and below 100 cfs twice. The lowest flows recorded were 70 cfs in November, 1959 and 62 cfs in September, 1966. The above flow changes could impact the time and bottom area available for fish, potential hosts for _E. f. curtisi_ and other naiades, to spawn. Very low flows may expose concentrations of naiades, causing desiccation, temperature stress, and increased susceptibility to predators.

Cane Creek

A single subfossil shell of _E. f. curtisi_ was collected in Cane Creek, a tributary to Black River, by Oesch (in press) in 1978. No other specimens of this species have been found in Cane Creek. None were found at three sites sampled between 21.5 miles and 29.0 miles upstream from the Arkansas border during 1980 and 1981. This stream changes rapidly from a headwater stream to a lowland stream and less than 5 miles of it provides potentially suitable habitat for _E. f. curtisi_. Naiad populations in Cane Creek are very limited. If _E. f. curtisi_ still occurs in Cane Creek, it is present in very low numbers.

Castor River

Utterback (1915, 1917) did not report finding E. f. curtisi in the Castor River. This species was first collected from the Castor River at Zalma during the 1960s by Frieda Schilling and Hessie Kemper (Oesch in press; personal communication with Dr. David H. Stansbery) (Fig. 2). The Ohio State University Museum (OSUM) has lots (OSUM 35918; OSUM 40480; OSUM 42223) containing a total of six specimens of E. f. curtisi collected at Zalma between 1973 and 1978. The Zalma site was last collected in 1978. At that time, E. f. curtisi occurred in very low numbers and only one specimen was found during 24 man-hours of effort. I felt no need to further disturb the site for the purposes of this study.

No E. f. curtisi were found at eight sites sampled in Castor River between 2.0 miles and 31.0 miles upstream from the Headwater Diversion Channel. Only about 6 miles, between 7.4 and 13.5 miles above the Headwater Diversion Channel, appear to provide suitable habitat for E. f. curtisi. Upstream from this 6-mile reach the stream becomes unstable, and downstream it becomes sluggish and lacks well-defined riffles. This species probably still occurs in Castor River in low numbers.

Little Black River

The bulk of the remaining E. f. curtisi occurs in 6.1 miles of the upper Little Black River. Buchanan (1979) first found this species at three sites in 5 miles of the upper Little Black River during a survey of that stream funded by the Soil Conservation Service. During a subsequent study (Buchanan 1982) the range, habitat, and abundance of E. f. curtisi in the upper Little Black River were further defined. *Epioblasma florentina curtisi* occurs between river miles 33.6 and 39.7 of this stream (Fig. 2).

Thirty living specimens of *E. f. curtisi* from the upper Little Black River, including 27 males and 3 females, were examined during 1979 through 1982, more specimens than have been found previously elsewhere. *E. f. curtisi*, however, is uncommon even in the Little Black River. Only 0.05 *E. f. curtisi* per square meter were found during quantitative sampling at three sites where this species is known to occur (Buchanan 1982). It comprised only 0.9 percent of the living naiades at those sites.

Habitat

Epioblasma florentina curtisi occurs in stream reaches which are transition areas between headwater and lowland stream reaches. It is found in order 4 to order 7 streams with gradients of 0.9 to 8.0 feet per mile, in stable substrates of sand and gravel to gravel, cobble and boulder, in riffles or runs. The mean particle size of the substrate where this species is found, based on substrate analysis in the Little Black River, ranges from small gravel to cobble (Buchanan 1982). It is found in 4 to 30 inches of water in slow (less than 0.02 m/sec. to 0.2 m/sec.) current.

Status

Epioblasma florentina curtisi is extremely uncommon in the less than 15 miles of streams where it occurs in southeastern Missouri. Only the upper Little Black River contains populations large enough to be effectively monitored and to serve as a source for reintroduction of *E. f. curtisi* into areas where it occurred previously. Loss of the Little Black River populations would probably result in extinction of the species. *Epioblasma* florentina curtisi probably still occurs in Castor River in very low numbers. The Little Black River between river miles 33.6 and 39.7, and the Castor River between river miles 7.4 and 13.5 should be considered critical habitat for E. f. curtisi. Any impacts upon existing populations of this species may prevent its recovery.

Threats

Habitat alteration has been and remains the principal threat to E. f. curtisi. This species requires shallow flowing water and a stable substrate. Consequently, stream impoundment and dredging have been the principal factors in the decline of E. f. curtisi. Impoundment caused the disappearance of E. f. curtisi from White River and impoundment and gravel dredging contributed to the decline of this species in Black River.

In the Little Black River E. f. curtisi may be impacted by proposed reservoir construction 4 to 6 miles upstream. The impact of an impoundment on the aquatic organisms downstream is not easily predicted. Any effect which an impoundment has upon water temperature, the chemical parameters of water, the types and amount of sediment in the water, flow volume, duration and periodicity, and other factors will ultimately impact naiades. Changes in the fish present may affect the chances of a naiad successfully reproducing. Changes in the microorganisms in the water may impact a naiad's food supply.

Encroachment due to home construction and agricultural activities may impact E. f. curtisi in both the Little Black and Castor rivers. Construction of buildings on the floodplains of these two streams may result in bank destabilization and alteration of the channel to reduce flooding damage to those buildings. Agricultural activities in the floodplain can cause bank destabilization and an increase in nutrient and sediment loads.

Recommendations

1. The Little Black River between river miles 33.6 and 39.7 and the Castor River between 7.4 and 13.5 miles above the Headwater Diversion Channel should be listed as critical habitat for _E. f. curtisi_.
2. Populations of _E. f. curtisi_ in the Little Black and Castor rivers should be monitored to detect changes which might affect the status of this species.
3. Portions of the habitat where _E. f. curtisi_ occurs should be protected, through purchase or other means, to assure survival of existing populations.
4. Activities which might adversely impact _E. f. curtisi_ in the Little Black and Castor rivers should be prevented.
5. Attempt to determine the reproductive cycle and host(s) of _E. f. curtisi_.
6. Continue to gather information on the habitat requirements for this species.
7. Identify stream reaches which may provide suitable habitat for _E. f. curtisi_.
8. Attempt to reestablish _E. f. curtisi_ in habitats where it previously occurred. Care must be taken, however, to avoid harming existing populations by removal of too many individuals.

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Appendix B

A Study of Epioblasma florentina curtisi (Utterback 1915), the Curtis Pearly Mussel, in the Upper Little Black River, Missouri.

by Alan C. Buchanan

Missouri Department of Conservation
Fish & Wildlife Research Center
1110 College Avenue
Columbia, Missouri

for the

U. S. Department of Agriculture
Soil Conservation Service

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INTRODUCTION

Epioblasma florentina curtisi, the Curtis Pearly Mussel, was first reported from the Upper Little Black River during a survey funded by the United States Department of Agriculture, Soil Conservation Service (Buchanan 1979). Although its presence was documented between river miles 33.6 and 38.5, its habitat requirements were not sufficiently described to evaluate the potential impacts of two proposed S.C.S. impoundments upon this species in the Upper Little Black River.

The primary objective of this study is to determine the distribution, abundance, habitat preference, and age structure of populations of *E. f. curtisi* in the Upper Little Black River and at selected sites in Cane Creek and the Castor River in Missouri. A secondary objective is to determine the reproductive success of *E. f. curtisi* in the above named streams. This study is being funded by the Columbia, Missouri office of the Soil Conservation Service to provide baseline data for evaluating the potential impacts of the two proposed S.C.S. impoundments (B-9 and C-7) upon the populations of *E. f. curtisi* in the Upper Little Black River.

STUDY AREA

The primary study area, in the Little Black River Basin in southeastern Missouri (Fig. 1), is the Little Black River between river mile 43.5 (T24N, R3E, Section 4) in Ripley County and river mile 29.0 (T24N, R4E, Section 26) in Butler County (Fig. 2). The Little Black River in the primary study area is characterized by long, shallow, gravel and cobble-bottomed riffles interspersed with long, deep, silt and sand-bottomed pools. This portion of the Little Black River serves as a transition zone between its headwater and lowland reaches. Water willow (*Justicia americana*) is found in dense stands from 0.6 to 1.5 inches long and from 4 to over 12 years old. Males were larger than females. They occurred in 4 inches to 30 inches of water, in slow (less than 0.2 yd/sec. to 0.26 yd/sec. at bottom) current, in a sand and gravel to a gravel, cobble and boulder substrate in or near riffles, in reaches of streams which serve as transition zones between headwaters and lowlands.

The populations of _E_. _f_. _curtisi_ found in the Upper Little Black River are the best populations of this species known. The Little Black River between river miles 33.6 and 39.7 may be considered habitat essential to the survival of _E_. _f_. _curtisi_ if no better populations of this species are found.

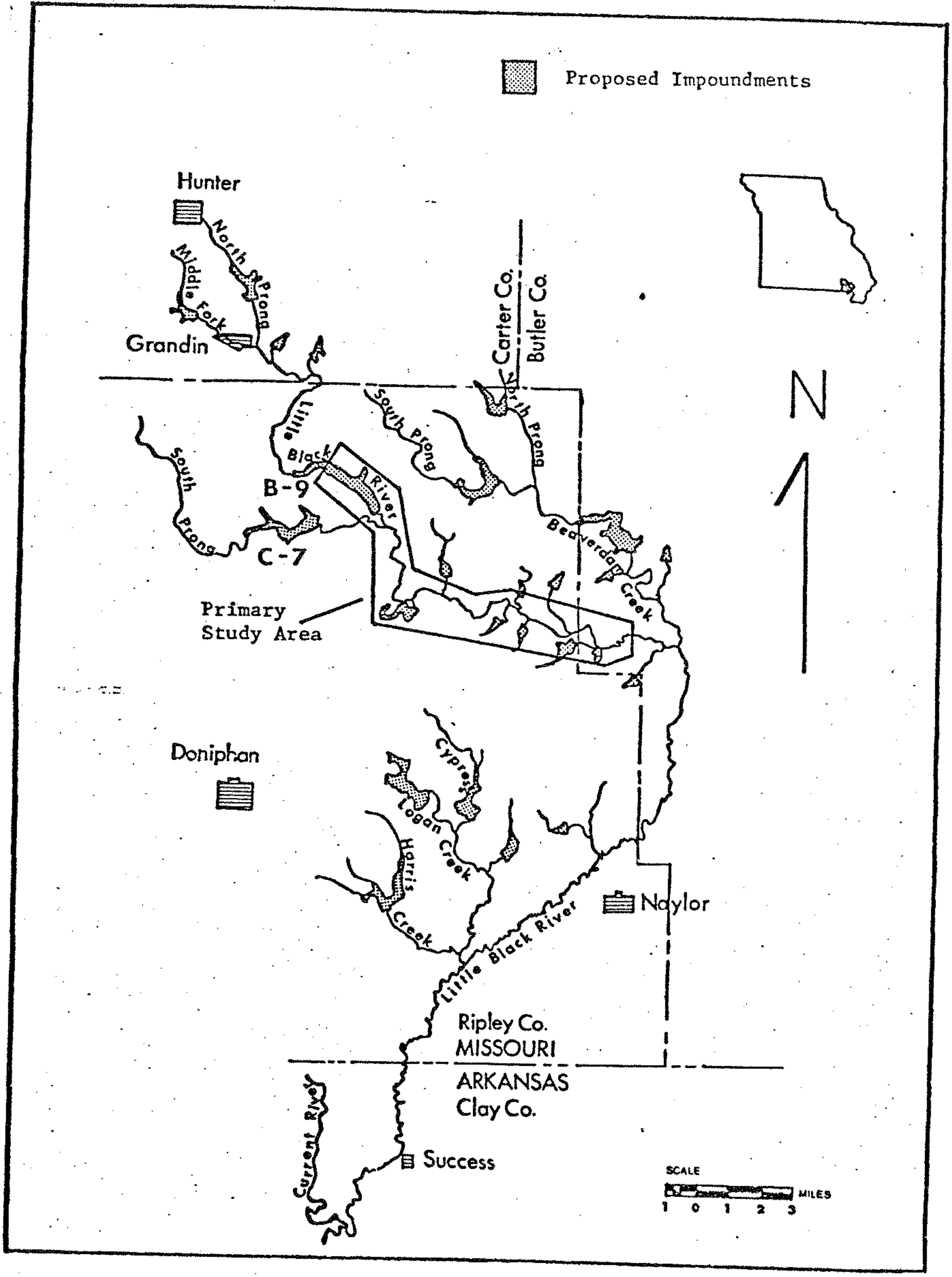

Figure 1. Little Black River Basin, Missouri and Arkansas.

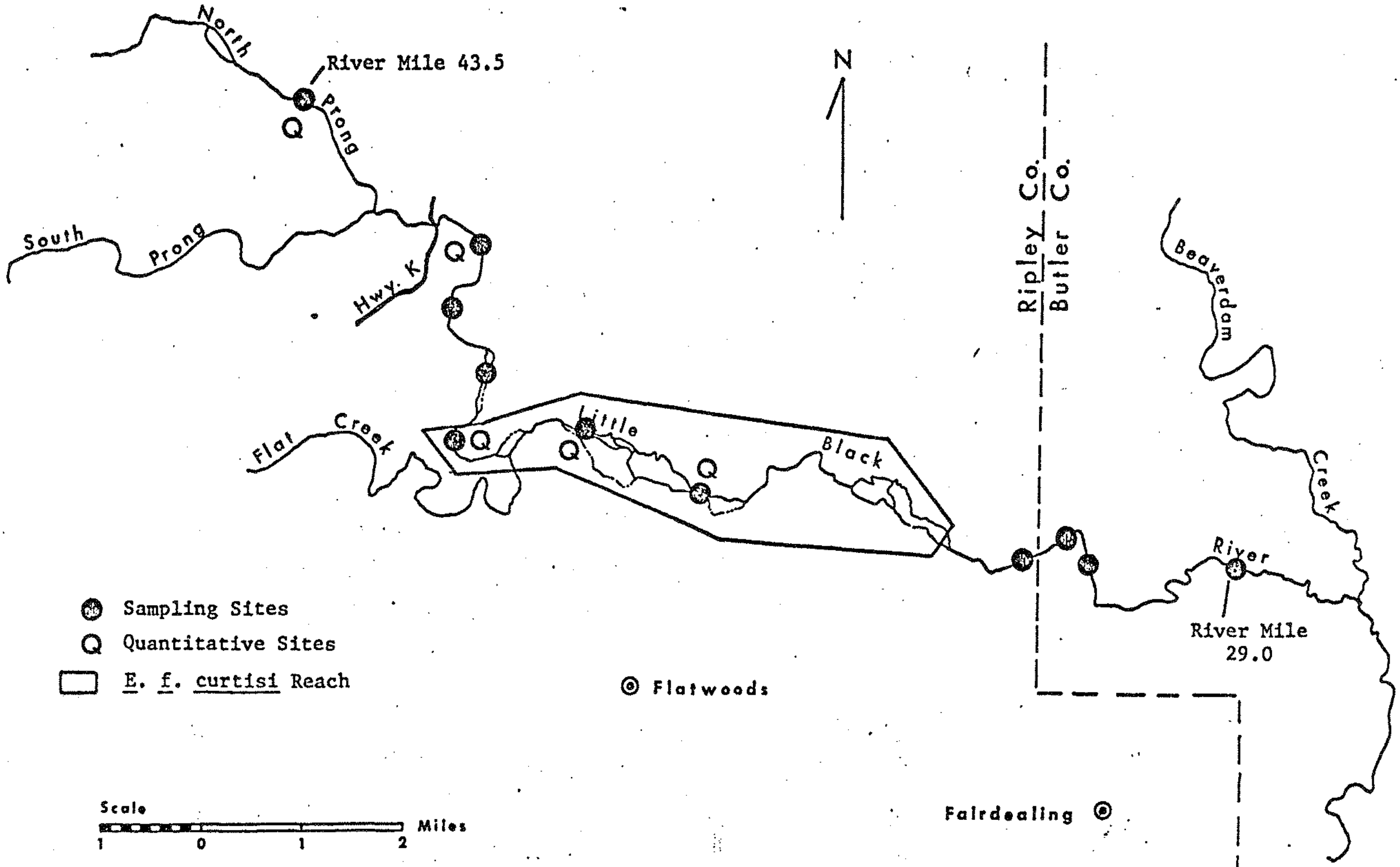

Figure 2. Sites sampled in the Upper Little Black River during 1980 and 1981.

along shore in riffle areas, and Spatterdock (Nuphar ozarkanum) and Pond week (Potamogeton sp.) are the most abundant plants in pools. The banks in most of the primary study reach are forested. Stream gradient ranges from 5.7 to 10.0 feet per mile.

The secondary study area is the Castor River between Highway 34 and the headwater diversion in Bollinger County, and Cane Creek between Highway PP and Highway 160 in Butler County (Fig. 3). These specific reaches of stream are transition zones between headwater and lowland streams habitats. Gradient in the study area of the Castor River ranges from 0.9 to 5.9 feet per mile. Cane Creek ranges in gradient from 2.5 to 5.9 feet per mile in the study reach. More specific water chemistry data for the above three stream reaches and Flat and Ten Mile creeks are listed in Table 6.

MATERIALS AND METHODS

Naiades were collected at 21 sites during May 1980 through November 1981, including 11 sites on the Little Black River, 4 sites on Castor River, 3 sites on Cane Creek, 2 sites on Flat Creek and 1 site on Ten Mile Creek (Fig. 3). Estimates of naiad density were made at 6 of the 21 sites (Fig. 3).

Initial sampling at 3 sites on the Castor River, 3 sites on Cane Creek, and 9 sites on the Little Black River was conducted to further delineate the distribution of E. f. curtisi in stream reaches from which it had previously been reported (Buchanan 1979) (including sites at approximately 1-mile intervals in the Little Black River between river miles 38.5 and 41.7 and between river miles 29.0 and 33.6). At these sites dead shells were collected by hand along shore, from muskrat and raccoon piles, and from the bottom of the stream. Live naiades were collected by hand while wading

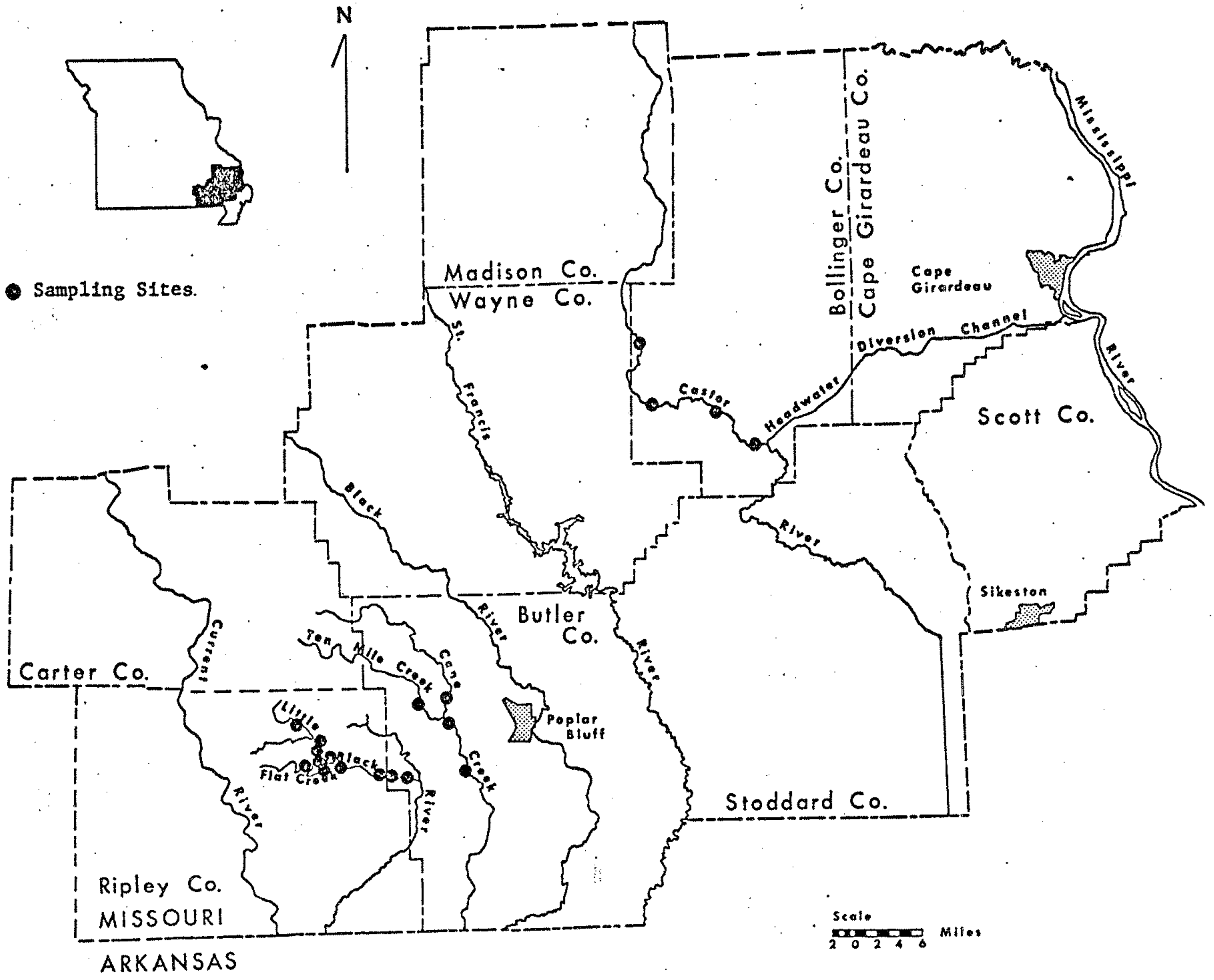

Figure 3. Sites sampled in the Little Black and Castor rivers, and Flat, Cane, and Ten-Mile creeks during 1980 and 1981.

until we were confident that representatives of all species present had been collected.

Estimates of the density of naiades and Asiatic clams (number per square yard) were made at 5 sites on the Little Black River and 1 site on the Castor River. At each of these sites, a 50 (45m) to 110 (100m) yard stretch of stream which appeared to provide potential habitat for _E. f. curtisi_ was marked off randomly (using a random numbers table) so that an average of one transect for every 3.3 yards (3m) of stream length was made. Along each transect, 1 to 7 quadrats (0.6 yd^2) were selected (1 quadrat per every 5.5 yards (5m) of stream width). The substrate was sampled twice to a depth of 4 to 6 inches in each quadrat and all naiades and Asiatic Clams (_Corbicula leana_) were counted. Naiades and _C. leana_ were counted in 600 quadrats on the Little Black River and in 92 quadrats in the Castor River.

Eleven to 20 randomly selected substrate samples were taken at the 5 sites on the Upper Little Black River where estimates of naiad densities were made. A 1-gallon can with one end removed was forced into the substrate as far as possible to obtain a substrate sample. These samples were frozen for later analysis.

Substrate samples were allowed to thaw and air-dry. Two randomly selected subsamples, each representing 1/8 of the original sample were taken for further analysis. The material was seived to separate each subsample into nine different particle sizes (Table 3). Each size fraction was weighed, and its percent of the total weight of the subsample was calculated. The relative percent of each particle size was used to calculate mean Phi diameter, a measure of the mean particle size of the substrate (Inman 1952).

After sieving, all material less than 0.04 inches in diameter was combined from each subsample for determination of organic content. Each of these samples was dried at 100°C for 24 hours, weighed, ignited at 600°C for 2 hours and weighed again to determine percent loss at ignition.

Total hardness, pH, alkalinity, and dissolved oxygen were determined with a Hach kit, and turbidity was measured with a Hach turbidimeter at each site at which estimates of naiad density was made. These measurements were made quarterly during 1981. Current velocity was measured with a Pygmy Current Meter at locations where living E. f. curtisi were found. Current velocity was measured at mid-depth in water less than 6 inches deep, and at the surface and bottom in water greater than 6 inches deep.

RESULTS AND DISCUSSION

Epioblasma florentina curtisi was found 1.2 miles further upstream in the Little Black River during 1980 and 1981 than had been previously reported (Buchanan 1979). It was not, however, found any further downstream than previously reported. The Little Black River between river miles 30.4 and 33.6 appears to provide poor habitat for naiades and no naiad concentrations were found in that reach of the river. The known range of E. f. curtisi now extends from river mile 33.6 to river mile 39.7 (Fig. 2).

Twenty-three living specimens of E. f. curtisi, including 20 males and 3 females were found in the Upper Little Black River (Table 2). Males ranged from 0.6 to 1.5 inches long and from over 6 years old to over 12 years old. The 3 females were 0.9, 0.9, and 1.1 inches long and were all between 4 and 6 years old (Table 2). Twenty-one of the 23 specimens were found at river mile 37.9.

The composition of the substrate varied widely, both between sites and

Table 1. Naiades found at specific river miles sampled in the Little Black and Castor rivers, and Flat, Cane, and Ten Mile creeks during 1980 and 1981.

	Little Black River											Flat Creek		Cane Creek			Ten Mile Creek	Castor River			
Species River Mile:	29.0	31.3	31.6	32.1	36.7	37.9	39.7	40.5	41.3	42.1	43.5	0.25	2.5	32.0	36.6	39.8	3.0	3.6	9.8	20.0	30.3
Anodonta imbecillis													X								
Anodonta g. grandis													X		X						
Strophitus u. undulatus							X		X				X	X	X					X	
Alasmidonta viridis													X								
Lasmigona costata	X					X	X		X	X	X				X				X		
Tritogonia verrucosa	X		X			X								X				X			
Quadrula metanevra																			X		
Quadrula pustulosa										X								X			
Amblema p. plicata	X		X		X	X	X						X	X	X			X	X	X	
Fusconaia flava	X			X	X	X	X		X	X	X		X	X	X			X	X	X	
Cyclonaias tuberculata	X				X	X	X		X	X											
Pleurobema coccineum	X			X	X	X	X		X	X	X		X	X	X				X	X	
Elliptio dilatata	X		X	X	X	X	X		X	X			X		X			X	X	X	
Ptychobranchus occidentalis	X			X	X	X	X		X	X	X		X								
Cyprogenia aberti					X	X	X			X								X	X		
Actinonaias ligamentina carinata	X																	X	X	X	
Potamilus purpuratus																		X			
Toxolasma parvus					X	X	X			X	X		X								
Ligumia recta															X	X		X	X		
Ligumia subrostrata									X				X								
Villosa i. iris	X			X	X	X	X		X	X	X		X								
Villosa l. lienosa	X			X	X	X	X		X	X	X		X	X	X			X		X	
Lampsilis radiata luteola						X		X						X	X			X		X	
Lampsilis ventricosa	X	X		X		X	X		X	X	X		X	X	X			X		X	
Lampsilis reeviana brevicula	X	X		X	X	X	X		X	X	X	X	X		X		X			X	
Epioblasma florentina curtisi					+	X	X												+		

X = present
\+ = found previously

at any one site (Table 3). There was no significant difference in the composition of the substrates between sites and no significant difference in the composition of the substrates where E. f. curtisi was found and where it was not. The mean particle size of the substrate samples ranged from coarse sand (0.02 to 0.04 inches in diameter) to cobble (1.25 to 2.5 inches in diameter). Organics comprised less than 0.6% of all substrate samples, and less than 0.4% of the substrate samples where E. f. curtisi was found.

Epioblasma florentina curtisi was found in 4 to 30 inches of water, in slow (less than 0.2 yd/sec. to 0.26 yd/sec. at bottom) current, in a sand and gravel to a gravel, cobble and boulder substrate. The mean particle size of the substrate where E. f. curtisi was found ranged from small gravel (0.04 to 0.16 inches in diameter) to pebble (0.62 to 1.25 inches in diameter).

An average of 5.1 naiades and 74.4 Corbicula leana per square yard was found in the Little Black River at the 5 sites where estimates of naiad density were made (Table 4, Fig. 2). Naiades were found in 63.8% of the quadrats sampled and occurred at all 5 sites. Corbicula leana was found in 72.0% of the quadrats sampled and occurred at 4 of 5 sites sampled; none were found at the most upstream site. Seventeen naiad species were found, including E. f. curtisi, and Cyprogenia aberti (Table 1.).

Seven species comprised 89.1% of the living naiades found in the 600 quadrats sampled in the Upper Little Black River (Table 4): Elliptio dilatata (29.3%). Pleurobema coccineum (23.7%), Lampsilis reeviana brevicula (15.6%), Ptychobranchus occidentalis (8.4%), Villosa lienosa lienosa (5.7%), Fusconaia flava (3.9%), and Toxolasma parvus (2.5%). Epioblasma florentina curtisi was found in 8 of the 600 quadrats sampled and comprised only 0.6% of the living naiades found. E. f. curtisi was found at only 1 of the 5 sites

Table 2. Age, sex, and size of the *Epioblasma florentina curtisi* found in Upper Little Black River during 1980 and 1981.

	River Mile	Sex	Length (inches)	Age (years)
1980	39.7	M	1.3	10+
	37.9	M	1.2	9
		M	1.2	10
		M	1.4	10
		M	1.5	12+
		F	1.1	5+
	36.7	M	0.6	6+
1981	37.9	M	1.2	9
		M	1.3	9+
		M	1.3	10
		M	1.2	8+
		M	1.3	8+
		M	1.2	9
		M	1.3	10+
		M	1.2	7+
		M	1.3	8
		M	1.3	9
		M	1.3	9
		M	1.3	12
		M	1.2	7+
		M	1.1	9
		F	0.9	4+
		F	0.9	5

Table 3. Particle size and organic composition of the substrate at five sites in the Upper Little Black River.

River mile	Transect	Depth (inches)	% 4.8 inches to 2.50 inches	% 2.50 inches to 1.25 inches	% 1.25 inches to 0.62 inches	% 0.62 inches to 0.16 inches	% 0.16 inches to 0.04 inches	% 0.04 inches to 0.02 inches	% 0.02 inches to 0.01 inches	% 0.01 inches to 0.005 inches	% less than 0.005 inches	% organic	Mean Phi diameter
36.7	3A	13	11.6	30.9	19.4	18.4	10.6	4.7	3.6	0.4	0.3	0.1	-3.45
	4C	10	0.0	42.2	18.3	21.2	9.4	3.2	4.8	0.6	0.4	0.2	-3.68
	10B	5	0.0	46.2	22.2	15.0	6.3	3.2	5.9	0.7	0.3	0.1	-3.90
	12B	5	0.0	43.4	29.3	14.9	7.6	1.9	1.8	0.9	0.2	-	-3.98
	27 Mid	7	20.3	28.5	10.6	20.4	10.4	4.6	4.0	0.9	0.2	-	-3.72
	30E	7	0.0	22.1	14.0	24.7	9.8	8.0	18.4	1.4	0.4	0.2	-1.88
	31D	7	0.0	23.6	15.5	26.3	13.6	8.4	11.8	0.5	0.2	0.1	-2.35
	35D	6	0.0	22.6	31.4	24.2	8.9	5.3	7.1	0.4	0.1	0.1	-3.45
	42B	5	0.0	24.3	20.6	21.7	13.8	7.2	9.9	1.9	0.6	0.2	-2.50
	54 Left	12	25.9	19.4	18.4	18.4	7.3	3.8	5.0	1.4	0.3	-	-3.90
	61A	14	0.0	3.9	27.9	27.6	11.4	8.3	16.2	3.7	0.8	-	-1.55
	69A	17	12.6	24.0	17.8	18.3	9.8	7.1	9.0	0.8	0.5	0.2	-3.00
	74C	14	11.2	10.4	20.6	35.2	7.2	4.1	9.4	1.3	0.4	0.3	-3.10
	76D	9	0.0	12.4	27.6	32.1	10.8	5.7	9.2	1.9	0.3	0.1	-2.58*
	77E	4	0.0	2.0	9.7	32.8	14.9	16.7	20.4	3.0	0.5	0.1	-1.10*
	80E	2	0.0	0.0	7.3	31.3	15.7	19.9	24.2	1.1	0.4	0.3	-0.95
	82B	17	0.0	27.6	27.2	22.7	9.7	5.6	5.1	1.6	0.5	-	-3.05
	93D	13	0.0	33.5	20.3	23.5	8.4	5.0	8.3	0.6	0.3	0.1	-3.10
37.9	1BC	22	0.0	53.5	19.5	16.9	4.6	1.4	2.7	1.3	0.2	0.1	-4.01*
	3A	19	14.8	43.8	10.4	10.0	9.1	4.5	6.3	0.8	0.2	0.2	-3.85*
	20B	17	0.0	65.8	13.4	11.1	3.4	1.5	3.9	0.6	0.2	0.1	-4.28
	26A	18	0.0	0.0	0.0	24.0	34.6	22.2	15.9	2.7	0.5	-	-0.58
	28C	23	9.6	46.7	12.3	19.4	6.9	1.2	2.9	0.6	0.3	0.2	-4.30*
	38C	19	0.0	8.9	38.2	41.5	3.6	0.9	5.3	1.1	0.6	0.4	-3.62*
	40A	17	0.0	25.7	4.6	28.7	18.4	11.3	10.0	0.8	0.5	0.3	-2.35*
	41B	18	13.3	43.3	1.6	16.1	11.6	7.9	5.5	0.4	0.2	0.1	-3.42
	45A	20	0.0	28.6	11.8	32.0	12.5	4.2	7.8	1.8	0.3	0.3	-2.88*
	45B	22	6.7	23.6	6.7	21.4	15.2	11.9	11.4	2.6	0.5	0.3	-2.25*
	45C	9	15.2	17.1	8.7	30.8	11.1	6.6	8.2	2.0	0.2	0.2	-3.05*

Table 3 (continued). Particle size and organic composition of the substrate at five sites in the Upper Little Black River.

River mile	Transect	Depth (inches)	% 4.8 inches to 2.50 inches	% 2.50 inches to 1.25 inches	% 1.25 inches to 0.62 inches	% 0.62 inches to 0.16 inches	% 0.15 inches to 0.04 inches	% 0.04 inches to 0.02 inches	% 0.02 inches to 0.01 inches	% 0.01 inches to 0.005 inches	% less than 0.005 inches	% organic	Mean Phi diameter
38.5	-	13	0.0	22.6	8.9	21.0	17.4	9.7	12.0	7.2	1.0	0.2	-1.85*
39.7	3D	7	12.5	14.0	30.1	24.0	9.8	4.9	4.3	0.2	0.1	0.1	-3.75
	14E	11	0.0	42.9	15.9	16.6	9.2	7.3	7.2	0.4	0.4	0.3	-3.00
	19C	16	19.5	53.3	16.5	6.2	2.6	1.2	0.5	**	**	**	-5.20
	21F	13	0.0	18.0	14.7	31.2	8.1	10.0	16.4	1.0	0.5	0.4	-1.92
	23B	21	35.7	33.0	8.2	12.7	8.6	1.3	0.4	**	**	**	-4.70
	23D	11	59.2	21.6	8.5	5.8	2.0	1.3	1.4	**	**	**	-5.30
	28E	15	23.3	35.2	7.9	11.7	4.9	7.0	9.3	0.5	0.2	0.1	-3.10
	42D	21	0.0	49.1	9.1	23.9	11.1	4.4	2.0	0.2	0.2	0.2	-3.75
	52A	15	0.0	2.2	11.0	32.6	15.4	22.4	13.8	2.2	0.4	0.3	-1.30*
	55A	8	7.0	8.4	8.8	27.4	8.7	18.5	17.7	3.1	0.4	0.3	-1.80*
	58B	11	0.0	36.5	24.8	20.7	11.6	4.1	2.0	0.2	0.1	-	-3.70
	59C	18	18.9	24.3	24.5	17.5	9.4	4.0	1.2	0.1	0.1	0.1	-4.28
	61A	5	0.0	0.0	19.5	42.2	15.3	11.0	10.7	0.8	0.4	0.3	-1.80
	71B	9	42.1	21.6	14.6	12.9	6.7	1.5	0.5	0.1	**	-	-4.70
	74A	8	16.6	16.6	20.4	26.6	11.2	4.5	3.7	0.2	0.2	0.1	-3.90
	88B	13	0.0	21.1	19.0	25.5	23.7	7.2	3.1	0.3	0.1	0.1	-3.00
	89A	12	0.0	45.7	37.3	15.0	1.9	**	**	**	**	**	-4.60
	92C	8	18.7	20.2	20.3	18.0	12.1	5.5	4.6	0.4	0.2	0.1	-3.70
	95E	6	12.9	17.0	15.7	17.0	9.0	8.2	18.6	1.2	0.4	0.2	-2.85
	98E	6	0.0	40.0	14.3	23.7	5.8	3.6	10.8	1.3	0.3	0.2	-2.20
42.1	1F	15	0.0	19.4	6.0	28.9	12.7	13.6	17.3	1.3	0.9	0.4	-1.87
	3D	15	0.0	62.1	9.7	12.6	7.7	3.0	4.2	0.4	0.2	0.1	-3.90
	5A	9 1/2	0.0	0.0	23.9	21.2	11.2	21.1	20.2	1.2	1.0	0.6	-1.35
	12B	9	0.0	0.0	20.1	28.6	18.4	13.3	18.0	1.2	0.4	0.3	-1.45
	15D	5	0.0	16.9	22.7	21.4	17.1	8.0	11.0	2.6	0.3	-	-2.20
	17E	4 1/2	0.0	11.0	21.0	18.5	8.4	7.0	30.5	2.9	0.7	0.3	-1.50
	19C	6	0.0	50.6	11.5	15.5	10.1	4.2	7.0	0.7	0.3	0.2	-3.25
	20D	7 1/2	0.0	46.0	11.8	16.6	8.1	5.2	10.1	0.7	0.2	0.2	-2.52
	30C	8	25.3	38.8	5.6	15.3	9.1	2.7	2.5	0.5	0.1	-	-4.30

Table 3 (continued). Particle size and organic composition of the substrate at five sites in the Upper Little Black River.

River mile	Transect	Depth (inches)	% 4.8 inches to 2.50 inches	% 2.50 inches to 1.25 inches	% 1.25 inches to 0.62 inches	% 0.62 inches to 0.16 inches	% 0.16 inches to 0.04 inches	% 0.04 inches to 0.02 inches	% 0.02 inches to 0.01 inches	% 0.01 inches to 0.005 inches	% less than 0.005 inches	% organic	Mean Phi diameter
	33B	4	11.9	10.2	12.8	22.4	18.1	11.3	11.3	1.9	0.2	-	-2.42
	36C	6	36.5	8.2	10.5	23.6	11.0	4.4	5.2	0.4	0.2	0.1	-3.90
	40D	6	0.0	24.9	3.6	29.0	16.5	9.4	15.3	0.9	0.4	0.2	-2.08
	46E	5	0.0	17.3	28.0	17.6	10.3	5.9	17.5	2.9	0.4	-	-1.85
	47B	7	0.0	11.0	21.0	18.5	8.4	7.0	30.5	2.9	0.7	0.2	-2.55
43.5	3C	14	0.0	8.8	2.0	0.7	6.9	20.0	47.1	11.9	2.6	-	+0.42
	5E	9	0.0	46.2	12.2	20.6	13.0	3.4	3.5	0.6	0.5	0.2	-3.48
	8F	13	0.0	0.0	3.7	38.4	17.8	11.3	26.9	1.4	0.5	0.5	-0.72
	11D	7	0.0	34.6	14.1	25.9	15.5	3.7	4.4	1.3	0.4	-	-3.20
	17A	21	16.6	10.7	9.6	3.1	10.5	19.1	26.3	2.5	1.6	0.6	-2.18
	19E	21	22.8	40.3	8.3	11.9	5.4	3.4	6.4	1.0	0.6	0.2	-4.20
	20C	14	0.0	45.7	19.6	11.5	6.8	3.1	10.6	1.6	1.1	0.4	-2.28
	37E	14	0.0	39.9	14.9	11.4	8.6	7.5	14.7	1.7	1.1	0.6	-2.00
	40E	16	25.6	45.2	14.5	5.9	1.7	1.2	4.4	1.2	0.3	-	-5.05
	41A	13	11.1	15.7	10.1	32.9	15.1	7.9	6.0	0.9	0.2	-	-2.95
	42C	18	43.6	28.7	11.2	7.0	4.0	2.6	2.1	0.5	0.3	0.1	-4.45
	55E	6	0.0	28.0	19.0	25.5	13.9	5.0	7.3	0.8	0.5	0.2	-3.00
	57B	14	16.9	18.3	12.9	23.3	18.9	4.8	2.9	1.3	0.6	-	-3.55
	64C	15	39.6	24.9	9.3	11.5	6.0	4.1	3.8	0.6	0.2	-	-4.30
	73A	5	15.7	38.7	10.9	18.4	8.9	2.6	4.1	0.5	0.2	0.1	-4.10
	75D	18	33.8	31.6	11.3	11.1	4.5	2.3	4.3	0.8	0.2	-	-4.45

* _Epioblasma_ _florentina_ _curtisi_ found in this substrate.

** Less than 0.1%.

\- Sample lost after sieving; no organic analysis possible.

Table 4. A comparison of naiades found in association with *Epioblasma florentina curtisi* in the Little Black River (quantitative samples only) during 1980 and 1981.

Species	Sites where E.f. curtisi found (three)				2 Sites where E.f. curtisi not found (two)				Total			
	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)
Lasmigona costata	2.2	10	*	0.8	2.9	8	*	1.1	2.5	18	*	0.9
Tritogonia verrucosa	2.2	8	*	0.6	0	0	0	0.0	1.3	8	*	0.4
Amblema p. plicata	6.1	34	0.2	2.8	0	0	0	0.0	3.7	34	0.1	1.8
Fusconaia flava	10.5	50	0.2	4.1	10.9	26	0.2	3.7	10.7	76	0.2	3.9
Cyclonaias tuberculata	4.7	21	0.1	1.7	6.7	20	0.1	2.8	5.5	41	0.1	2.1
Pleurobema coccineum	39.1	346	1.5	28.2	24.7	111	0.7	15.7	33.3	457	1.2	23.7
Elliptio dilatata	25.2	378	1.6	30.8	18.0	188	1.2	26.7	22.3	566	1.5	29.3
Ptychobranchus occidentalis	14.7	102	0.4	8.3	16.7	60	0.4	8.5	15.5	162	0.4	8.4
Cyprogenia aberti	4.2	23	0.1	1.9	2.5	7	*	1.0	3.5	30	0.1	1.6
Actinonaias ligamentina carinata	0.3	1	*	0.1	0	0	0	0.0	0.2	1	*	*
Toxolasma parvus	3.6	26	0.1	2.1	5.8	23	0.2	3.3	4.5	49	0.1	2.5
Villosa i. iris	3.0	13	0.1	1.1	5.8	18	0.1	2.6	4.2	31	0.1	1.6
Villosa l. lienosa	8.3	91	0.4	7.4	5.4	19	0.1	2.7	7.2	110	0.3	5.7
Lampsilis radiata luteola	0.8	3	*	0.2	0.4	1	*	0.1	0.7	4	*	0.2
Lampsilis ventricosa	5.0	23	0.1	1.9	2.9	8	*	1.1	4.2	31	0.1	1.6
Lampsilis reeviana brevicula	16.3	86	0.4	7.0	51.0	216	1.4	30.6	30.2	302	0.8	15.6
Epioblasma florentina curtisi	2.2	11	*	0.9	0	0	0	0.0	1.3	11	*	0.6
Naiad totals	57.9	1,226	5.3	100.0	72.8	705	4.6	100.0	63.8	1,931	5.1	100.0
Corbicula leana	93.9	22,160	96.5		38.9	6,216	40.9		72.0	28,376	74.4	
Area sampled		4,437.7 yd^2				3,009.5 yd^2				7,447.2 yd^2		
Sample size		229.6 yd^2				152.0 yd^2				381.6 yd^2		
Percent of area sampled		5.2%				5.1%				5.1%		
Length of stream sampled		300 yd				150 yd				450 yd		

* = less than 0.1%

during quantitative sampling in 1980 and 1981, even though it had previously been found at 3 of these 5 sites (Buchanan 1979). This species comprised only 1.6% of the living naiades found at that site.

The mean density of naiades ranged from 1.9 to 21.7 naiades per square yard at river miles 36.7 and 37.9, respectively. There was little difference, however, between the mean density of naiades at the 3 sites at which *E. f. curtisi* occurs and the 2 sites where it does not occur (5.3/yd^2 and 4.6/yd^2, respectively). *E. f. curtisi* was most abundant at the site which had the greatest concentration of all naiades.

There were few differences in species composition and relative abundance between the *E. f. curtisi* sites and the non-*E. f. curtisi* sites. Five species, *E. dilatata*, *P. coccineum*, *P. occidentalis*, *L. r. brevicula*, and *F. flava* comprised 78.4% of the living naiades found at the 3 *E. f. curtisi* sites and 85.2% of the living naiades found at the 2 non-*E. f. curtisi* sites (Table 4). *L. r. brevicula*, typically a headwater species, was the most abundant species at river mile 43.5 (Table 5). It comprised a progressively smaller portion of the naiad population, however, further downstream. *Elliptio dilatata* and *P. coccineum* were the most abundant species at the 3 *E. f. curtisi* sites and were second and third in abundance, respectively, at the 2 non-*E. f. curtisi* sites (Table 4).

Measures of water quality were similar at all sites in the Little Black River (Tables 6 and 7). Dissolved oxygen ranged from 5.5 to 13.2 mg/l, alkalinity from 0 to 137 mg/l, total hardness from 86 to 205 mg/l, pH from 7.0 to 8.5, and specific conductance from 110 to 165 μmhos/cm^2. No distinctive trends were evident between upstream and downstream portions of the primary study area.

Quarterly measurements of water quality made during 1981 and early 1982 revealed little difference among the 5 sites that were quantitatively sampled in the Upper Little Black River (Table 7). Alkalinity, total hardness, and water temperature were highest during summer and lowest during winter, dissolved oxygen and total nitrogen were highest during winter, and pH was lowest during winter.

Flat Creek

Fifteen species of naiades were found in Flat Creek at the 2 sites sampled (Table 1). No *E. f. curtisi* were found. No attempt was made to estimate naiad densities in Flat Creek.

Castor River

Seventeen naiad species were found at the 4 sites sampled in the Castor River during 1980 and 1981 (Table 1). Although *E. f. curtisi* has been found as recently as 1978 in the Castor River at Zalma (river mile 9.8), none were found at that site or at the other 3 sites sampled during 1980. Habitat at river miles 20.0 and 30.3, upstream from Zalma, appeared to be too unstable for *E. f. curtisi*. The Castor River at river mile 3.6, downstream from Zalma, is a slow, sluggish, turbid lowland stream and not suitable habitat for *E. f. curtisi*.

Estimates of naiad density in the Castor River at river mile 9.8 revealed an average of 12.3 naiades and 242.2 *Corbicula leana* per square yard (Table 8). Nine species were found in quadrats sampled at this site. *Elliptio dilatata* (76.9%) and *Actinonaias ligamentina carinata* (9.5%) comprised 86.4% of the naiades found.

able 5. Numbers and relative abundance of naiad species found at each site sampled quantitatively in the Upper Little Black River during 1980 and 1981.

Species	River Mile 36.7				River Mile 37.9				River Mile 39.7			
	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)
asmigona costata					12.2	8	0.3	1.2	1.3	2	*	0.6
ritogonia verrucosa					14.3	7	0.2	1.0	0.2	1	*	0.3
mblema p. plicata	0.6	1	*	0.5	42.9	33	1.1	4.9				
usconaia flava	3.8	6	0.1	3.1	46.9	34	1.1	5.0	5.9	10	0.1	2.8
yclonaias tuberculata	2.5	4	*	2.1	10.2	6	0.2	0.9	5.2	11	0.1	3.1
leurobema coccineum	41.5	114	1.1	59.1	77.6	157	5.0	23.3	24.2	75	0.8	20.9
lliptio dilatata	14.5	29	0.3	15.0	93.9	307	9.8	45.5	14.4	42	0.4	11.7
tychobranchus occidentalis	8.8	15	0.2	7.8	26.5	19	0.6	2.8	17.0	68	0.7	19.0
yprogenia aberti	0.6	1	*	0.5	8.2	4	0.1	0.6	6.5	18	0.2	5.0
ctinonaias ligamentina carinata					2.0	1	*	0.1				
oxolasma parvus					10.2	6	0.2	0.9	5.2	20	0.2	5.6
illosa i. iris	3.1	6	0.1	3.1	10.2	6	0.2	0.9	0.2	1	*	0.3
illosa l. lienosa	3.8	6	0.1	3.1	16.3	17	0.5	2.5	10.4	68	0.7	19.0
ampsilis radiata luteola					6.1	3	0.1	0.4				
ampsilis ventricosa					26.5	15	0.5	2.2	3.3	8	0.1	2.2
ampsilis reeviana brevicula	6.3	11	0.1	5.7	51.0	41	1.3	6.1	15.7	34	0.3	9.5
Epioblasma florentina curtisi					16.3	11	0.4	1.6				
aiad totals	56.6	193	1.9 ± 0.3 c.i.		100.0	675	21.7 ± 4.1 c.i.		45.8	358	3.7 ± 1.2 c.i.	
orbicula leana		4,027	39.8 ± 5.3			7,751	248.4 ± 25.8			10,382	106.7 ± 21.5	
rea sampled		2,007.7 yd^2				577.8 yd^2				1,852.2 yd^2		
ample size		101.1 yd^2				31.2 yd^2				97.3 yd^2		
ercent of area sampled		5.0%				5.4%				5.2%		
ength of stream sampled		120 yd				54 yd				120 yd		

Table 5. (continued). Numbers and relative abundance of naiad species found at each site sampled quantitatively in the Upper Little Black River during 1980 and 1981.

Species	River Mile 42.1				River Mile 43.5			
	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance (%)
Lasmigona costata	2.1	2	*	0.4	3.4	6	0.1	3.1
Tritogonia verrucosa								
Amblema p. plicata								
Fusconaia flava	8.5	8	0.1	1.6	12.4	18	0.2	9.3
Cyclonaias tuberculata	17.0	20	0.3	3.9				
Pleurobema coccineum	48.9	94	1.6	18.4	9.0	17	0.2	8.8
Elliptio dilatata	45.7	188	3.1	36.7				
Ptychobranchus occidentalis	37.2	55	0.9	10.7	3.4	5	*	2.6
Cyprogenia aberti	6.4	7	0.1	1.4				
Actinonaias ligamentina carinata								
Toxolasma parvus	9.6	18	0.3	3.5	3.4	5	*	2.6
Villosa i. iris	10.6	13	0.2	2.5	2.8	5	*	2.6
Villosa l. lienosa	8.5	12	0.2	2.3	3.4	7	0.1	3.6
Lampsilis radiata luteola	1.1	1	*	0.2				
Lampsilis ventricosa	4.3	5	0.1	1.0	2.1	3	*	1.6
Lampsilis reeviana brevicula	47.9	89	1.5	17.4	53.1	127	1.4	65.8
Epioblasma florentina curtisi								
Naiad totals	80.8	512	8.6 ± 7.8 c.i.		67.5	193	2.1 ± 0.4 c.i.	
Corbicula leana	98.9	6,216	109.8 ± 12.9		0	0	0	0
Area sampled		1,167.1 yd^2				1,842.3 yd^2		
Sample size		59.8 yd^2				92.2 yd^2		
Percent of area sampled		5.1%				5.0%		
Length of stream sampled		55.2 yd				90 yd		

c.i. = 95% confidence interval.

Table 6. Water quality measurements at sites sampled in the Little Black and Castor rivers, and Flat, Cane, and Ten-Mile creeks during 1980 and 1981.

	Little Black River											Flat Creek		Cane Creek			Ten-Mile Creek	Castor River			
River Mile:	29.0	31.3	31.6	32.1	36.7	37.9	39.7	40.5	41.3	42.1	43.5	0.25	2.5	32.0	36.6	39.8	3.0	3.6	9.8	20.0	30.3
Water Temperature (°C)	14	10			7	6	20		21	25	7		22	17	19	17	21	20		16	18
Dissolved Oxygen (mg/l)	7.7	8.8			11.0	9.9	13.0		13.0	12.1	9.9		12.2		6.6	11.0	11.0	6.6		11.0	13.0
pH	8.0	8.0			8.5	8.5	8.5		8.5	8.5	8.0		8.5		8.5	8.0	9.0	7.5		8.5	9.0
Alkalinity (mg/l)	88	137			120	120	120		137	137	85		154	86	85	86	103	86		103	103
Total Hardness (mg/l)	154	188			154	137	154		154	171	137		171	120	171	103	103	103		120	120
Turbidity (JTU's)		1.7			1.8	1.1	1.5		5.0	2.0	1.6		4.5	8.0	5.4	4.0	2.5			2.6	1.1
Specific Conductance (µmhos/cm^2)		158			129	125	142			117	110					51					
Gradient (ft./mi.)	2.4	6.0	6.0	6.0	7.7	5.7	5.7	10.0	10.0	10.0	12.5	23.3	30.8	2.5	5.6	5.9	7.2	0.9	0.9	2.4	5.9

Table 7. Water quality measurements at six sites in the Upper Little Black River during April, 1981 through January, 1982.

River Mile:	33.6	36.7	37.9	39.7	42.1	43.5
<u>April 10, 1981</u>						
Water temperature (^{o}C)	20	20	20	19	18	18
Dissolved oxygen (mg/l)	9.9	7.7	7.7	7.7	7.7	7.7
pH	8.5	8.5	8.0	8.0	8.0	8.0
Alkalinity (mg/l)	86	86	86	86	68	68
Total hardness (mg/l)	137	137	120	120	103	103
Turbidity (JTU'S)	-	-	-	-	-	-
<u>June 21, 1981</u>						
Water temperature (^{o}C)	23	24	24	23	23	23
Dissolved oxygen (mg/l)	7.7	6.6	5.5	6.6	6.6	6.6
pH	8.0	7.5	7.5	7.5	7.5	7.5
Alkalinity (mg/l)	68	68	68	51	68	51
Total hardness (mg/l)	120	120	120	103	103	86
Turbidity (JTU'S)	-	-	-	-	-	-
<u>August 8-12, 1981</u>						
Water temperature (^{o}C)	22	23	23	24	-	26
Dissolved oxygen (mg/l)	7.7	6.6	5.5	6.6	-	7.7
pH	8.5	8.0	8.0	8.5	-	8.0
Alkalinity (mg/l)	120	120	137	137	-	120
Total hardness (mg/l)	171	205	171	154	-	154
Total nitrogen (mg/l)	0.185	0.159	0.217	0.155	0.142	0.173
Total phosphorus (mg/l)	0.034	0.036	0.030	0.034	0.033	0.030
Turbidity (JTU'S)	3.8	3.5	3.6	4.1	2.2	2.7
<u>October 19-22, 1981</u>						
Water temperature (^{o}C)	13	14	15	13	15	15
Dissolved oxygen (mg/l)	7.7	7.7	7.7	8.8	8.8	7.7
pH	8.5	8.5	8.5	8.0	8.0	8.5
Alkalinity (mg/l)	68	68	34	68	68	51
Total hardness (mg/l)	188	171	188	171	171	154
Total nitrogen (mg/l)	0.118	0.104	0.118	0.152	0.105	0.145
Total phosphorus (mg/l)	0.018	0.008	0.016	0.020	0.002	0.021
Turbidity (JTU'S)	3.0	1.3	2.5	1.4	3.3	4.9
<u>January 12, 1982</u>						
Water temperature (^{o}C)	0	0	-	0	0	0
Dissolved oxygen (mg/l)	12.1	12.1	-	11.0	13.2	12.1
pH	7.5	7.5	-	7.5	7.5	7.0
Alkalinity (mg/l)	0	0	-	0	0	0
Total hardness (mg/l)	120	103	-	103	103	103
Total nitrogen (mg/l)	0.470	0.510	-	0.517	0.517	0.617
Total phosphorus (mg/l)	0.011	0.014	-	0.011	0.012	0.015
Turbidity (JTU'S)	3.5	3.0	-	2.6	2.7	2.3
Conductivity	165	150	-	135	145	120

Cane Creek

Thirteen species of naiades were found at the 3 sites sampled in Cane Creek during 1980 and 1981 (Table 1). No *E. f. curtisi* were found. Oesch (in press) reported taking *E. f. curtisi* from Cane Creek at Highway M, but none were found at that site during this study. This species is very uncommon in Cane Creek and it probably occurs in only a short reach of this stream. Naiad densities were not estimated in Cane Creek.

Ten Mile Creek

Lampsilis reeviana brevicula was the only naiad species found at the single site sampled in Ten Mile Creek during 1980; no *E. f. curtisi* were found (Table 1).

SUMMARY AND RECOMMENDATIONS

Naiad collections were made at 11 sites in the Upper Little Black River, 2 sites in Flat Creek, 4 sites in the Castor River, 3 sites in Cane Creek, and at 1 site in Ten Mile Creek to further delineate the distribution of *Epioblasma florentina curtisi* in these streams. *Epioblasma florentina curtisi* was not found in Flat Creek or Ten Mile Creek, or at any new sites in Cane Creek or the Castor River. *Epioblasma florentina curtisi* was found 1.2 miles further upstream in the Upper Little Black River than previously reported, and its known range now extends from river mile 33.6 to river mile 39.7.

Epioblasma florentina curtisi was found in slow (less than 0.02 yd/sec. to 0.26 yd/sec. at bottom) current in 4 to 30 inches of water in a sand and gravel to gravel, cobble, and boulder substrate. The mean particle size of the substrate where *E. f. curtisi* was found, based on substrate analysis,

Table 8. Numbers and relative abundance of naiad species found at River Mile 9.8 in the Castor River during 1980.

Species	Percent occurrence in quadrats	Number found	No./yd^2	Relative abundance(%)
Lasmigona costata	1.1	1	*	0.4
Quadrula metanevra	4.3	5	0.1	1.8
Amblema p. plicata	12.0	14	0.2	5.1
Fusconaia flava	2.2	2	*	0.7
Pleurobema coccineum	2.2	2	*	0.7
Elliptio dilatata	52.2	210	3.4	76.9
Cyprogenia aberti	9.8	11	0.2	4.0
Actinonaias ligamentina carinata	21.7	26	0.4	9.5
Ligumia recta	2.2	2	*	0.7
Naiad Totals	64.1	273	4.5	100.0
Corbicula leana	95.6	14,788	242.2	

Area sampled	2051.6 yd^2
Sample size	61.1 yd^2
Percent of area sampled	3.0%
Length of stream sampled	102 yd

* = less than 0.1%

ranged from small gravel to cobble. The particle size and organic composition of the substrate where E. f. curtisi was found was similar to that where it was not found in the Upper Little Black River.

The 20 male and 3 female E. f. curtisi found during 1980 and 1981 ranged from 0.6 to 1.5 inches long and were determined to be from more than 4 to over 12 years old.

An average of 5.1 naiades and 74.4 Corbicula leana per square yard were found in the Upper Little Black River at the 5 sites where estimates of naiad densities were made. At 3 sites where E. f. curtisi is known to occur, an average of less than 0.1 E. f. curtisi per square yard were found.

The abundance, relative abundance, and species composition of naiades were similar at sites where E. f. curtisi occurred and sites where this species did not occur in the Upper Little Black River. Measures of water quality were similar at sites where E. f. curtisi occurred and sites where this species did not occur.

Epioblasma florentina curtisi, in both the Little Black River and other streams from which it is known, occurs in stream reaches which represent transition areas between headwater and lowland stream reaches. It is found in stream reaches of order 4 to order 7, with gradients from 0.9 to 8.0 feet per mile, in stable substrates of sand and gravel to gravel, cobble and boulder, in riffles or runs.

Habitat and population characteristics examined during this study do not explain why E. f. curtisi occurs where it does in the Upper Little Black River nor do they enable us to predict what impact proposed S.C.S. impoundments might have on this species in the Upper Little Black River. This study does underline, however, the importance of these populations to the species as a whole. The populations of _E. f. curtisi_ in the Upper Little Black River are the largest known populations of this species. The Upper Little Black River between river miles 33.6 and 39.7 should be considered essential habitat for the survival of _E. f. curtisi_ unless ongoing studies (Buchanan 1982) of the distribution, abundance, and status of this species in Missouri reveal larger populations of _E. f. curtisi_ elsewhere.

Ongoing studies on nearby Fourche Creek in southwestern Ripley County, Missouri may reveal some of the downstream changes which will occur in a small stream after impoundment. Fajen (1979) is studying the fish populations and physical characteristics at 7 sites on Fourche Creek, and the United States Geological Survey is monitoring flow and water temperature.

Future research in the Upper Little Black River should concentrate on establishing baseline water quality data for a period of several years, and further study of the life history and populations of _E. f. curtisi_. Populations of _E. f. curtisi_ should continue to be monitored to determine population trends.

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Appendix C

An Evaluation of the Potential Impacts of SCS Structures B-9 and C-7 Upon the Curtis Pearly Mussel, *Epioblasma florentina curtisi* (Utterback 1915), in the Upper Little Black River, Missouri.

Alan C. Buchanan
Missouri Department of Conservation
1110 College Avenue
Columbia, Missouri 65201

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Introduction

Epioblasma florentina curtisi is one of those species which is on the verge of extinction. Based on recent information, *E. f. curtisi* occurs in less than 15 miles of streams in Missouri and nowhere else in the world. Without proper management and protection of this species and its habitat, it is unlikely to survive this century. *E. f. curtisi* was listed as "Endangered" on the United States List of Endangered and Threatened Wildlife and Plants (United States Department of the Interior, Fish and Wildlife Service 1976) on July 1, 1975. This review is based upon information regarding the distribution and biology of *E. f. curtisi*, information on the characteristics of proposed structures B-9 and C-7, and literature on the impacts of impoundments on the physical, chemical and biological characteristics of streams.

Most reports documenting impacts of impoundments on aquatic organisms downstream dealt with large deep reservoirs with either surface (epilimnial) or bottom (hypolimnial) releases. Deep reservoirs with epilimnial releases generally discharge water which is warmer and lower in nutrients than waters downstream. Reservoirs with hypolimnial releases generally discharge water which is higher in nutrients and dissolved inorganic matter, lower in oxygen, and colder than waters downstream. Proposed structures B-9 and C-7 would create relatively small (298 and 136 acres, respectively), shallow (26 and 18 feet maximum depth, respectively), reservoirs with multilevel discharges (United States Department of Agriculture, Soil Conservation Service 1975). The potential impacts of these structures on the water quality of the Little Black downstream are thus expected to be much less drastic than those of large, deep reservoirs with single-level releases.

This evaluation is divided into two parts: 1) the potential impacts of structures B-9 and C-7 on the chemical, physical, and biological characteristics of the Little Black River downstream; and 2) the relative importance of Little Black populations of *E. f. curtisi* to the survival of the species as a whole.

Impacts of Structures B-9 and C-7 on Chemical, Physical, and Biological Characteristics of the Little Black River Downstream.

Chemical Factors

Dissolved Oxygen

Dissolved oxygen levels downstream from structures B-9 and C-7 would be at or near saturation. Although both reservoirs would stratify during summer months, water would be released from the reservoirs near the surface where dissolved oxygen levels would be expected to be high enough to support aquatic life. Turbulence immediately below the dam would restore any low-oxygen water released to saturation within a short distance downstream.

Alkalinity, Hardness, pH, and Conductivity

The impact which structures B-9 and C-7 would have on alkalinity, hardness, and pH downstream is unknown. The Little Black River is relatively well-buffered (alkalinity 34 to 137 ppm). Alkalinity dropped to 0 ppm in January, 1982 in the study reach because of rainfall runoff at a time when the ground was frozen. During normal flow conditions, however, the Little Black probably remains well-buffered. Little Black waters are also moderately hard (86 to 205 ppm total hardness) with a pH usually above 8.0 (7.0 to 8.5).

The reservoirs created by both structures B-9 and C-7 would be expected to stratify during summer. During stratification in eutrophic hard water reservoirs (which both of these reservoirs would be) there usually is a reduction of total carbon dioxide in the epilimnion due to photosynthesis by vascular plants and algae (Hutchinson 1957; Ruttner 1963; Wetzel 1975). With a removal of carbon dioxide there is a precipitation of calcium carbonate and a concurrent rise in pH. The pH would not be expected to greatly exceed 9.0, however. In the hypolimnion there is a progressive increase in carbon dioxide, due to respiration and release from the sediments, with a resultant reduction in pH and rise in bicarbonate. Again, the pH would be expected to remain relatively moderate and not drop below 7.0.

Since water would be drawn from the epilimnion in both reservoirs and released downstream, this water would be near or above the pH of water in the stream below. Total hardness and alkalinity in the water released from this level would be less than downstream. The conductivity of the water released from structures B-9 and C-7 would also be expected to be lower than ambient levels downstream since reservoirs generally reduce the conductivity of water. The effect that an increase in pH and a reduction in alkalinity, hardness, and conductivity would have on benthic macroinvertebrates in Little Black River is expected to be minimal.

There would also be fluctuation in levels of pH, alkalinity, hardness, and conductivity in the reservoirs during the seasons. During spring and fall overturn, when there is a mix of surface and bottom water within the reservoirs, levels of pH, alkalinity, hardness, and conductivity would be similar from surface to bottom. Thus, in water released from the reservoirs, the pH would be lower and the alkalinity, hardness, and conductivity higher than during times of stratification. The effect that these annual fluctuations would have on the biota of the Little Black River 3.5 to 6 miles downstream from these structures is not known.

Below Fourche Dam #1 on Fourche Creek, a tributary to Current River in Ripley County, Missouri, there was a reduction in conductivity, total alkalinity, and total hardness within and immediately below the lake as compared to above and 5 miles below the lake (Missouri Department of Conservation memo from Rich Wehnes to Stan Michaelson dated November 28, 1978). There was no change in pH within the reservoir. This information is based on a single set of measurements made in November, 1978.

Nutrients

Reservoirs generally serve as nutrient sinks, with nutrients in the incoming waters being trapped in the bottom sediments. A review of the literature suggests that there would be a reduction of nutrients in waters released from structures B-9 and C-7 in comparison to levels in the Little Black River entering the reservoirs. Levels of nitrogen, phosphorus, iron, and zinc would probably be reduced.

Turner et al. (1983) reported a mean loss over a 3-year period of 44.8% of the total phosphorus and 10% of the total nitrogen from water entering Lake Talquin in northwestern Florida. The amount of phosphorus and nitrogen lost to the reservoir was inversely related to the flushing rate in any given year. The flushing rate in Lake Talquin ranged from 8 to 16 times per year. Lake Talquin had no significant effect on silicates or chloride in water passing through it.

In a review of the literature, Turner et al. (1983) found that phosphorus and nitrogen are frequently reduced by reservoirs. They found that phosphorus was reduced by 25% or more from the inflow to the outflow of 20 of 27 reservoirs examined. In 3 of the 27 reservoirs phosphorus was reduced by more than 50% and in 2 others by more than 75%. Nitrogen was also retained by reservoirs but to a lesser extent than phosphorus. Ten of thirteen reservoirs examined by Turner et al. (1983), retained 10% or more of the total nitrogen entering them. Seven reservoirs retained 25% or more of the total nitrogen entering them. Although there was a trend toward greater retention of nitrogen and phosphorus in reservoirs with longer retention times, especially in those with retention times of more than a year, there was no significant correlation between retention time and retention of nitrogen and phosphorus by reservoirs.

Several other studies report significant retention of nitrogen and phosphorus by reservoirs. In Bighorn Lake, Montana (Soltero et al. 1973, 1974) there was a reduction of phosphorus by 86% and of nitrogen by 25% from the inflow to the outflow. Higgins (1978) reported a reduction of total nitrogen and total phosphorus from the inflow to the outflow in five Tennessee Valley Reservoirs over a 10-year period. Although nutrients are frequently reduced by reservoirs, they are not necessarily reduced to levels that would be limiting to the streams below.

Frequently the reduction of nutrients in the outflow of water from a reservoir is seasonal, generally during summer stratification. During fall overturn, there is often an increase in phosphorus and nitrogen in the outfall due to the mixing of hypolimnial water, which is higher in these nutrients, with water from the epilimnion. Thus there are seasonal fluxes of nutrients to the stream below the reservoirs.

The impact of B-9 and C-7 upon the nutrient levels of the Little Black River 3.5 to 6 miles downstream is unknown. Due to the expected short retention time of water in these reservoirs, there will probably be a minimal retention of nutrients. The seasonal fluctuation of nutrients in water released from the reservoirs would affect benthic macroinvertebrates immediately below the dams, but might have little effect on benthos 3.5 to 6 miles downstream.

Dissolved Solids

Higgins (1978) reported that total dissolved solids were lower in the outflow than in the inflow of five Tennessee Valley Authority reservoirs. Total dissolved solids were slightly lower in the outflow than the inflow in Bighorn Lake, Montana (Soltero et al. 1973, 1974). Dissolved solids will be reduced by the reservoirs formed by structures B-9 and C-7. The impact, if any, downstream would be minimal.

Physical Factors

Temperature

Due to the arrangement of release ports on structures B-9 and C-7, little or no change in downstream temperature would be expected. The only direct effects may be a retarding of spring warming and fall cooling. Retarding the spring increase in water temperatures might impact _E_. _f_. _curtisi_ if it occurs during the spawning period for this species. The likelihood of impact is proportional to the amount spring warming is retarded. Studies on other small reservoirs, such as those on Fourche Creek may provide additional information on the impact of small reservoirs on the rate of spring warming and fall cooling of receiving streams. Both reservoirs would be expected to stratify thermally in the summer and possibly in the winter.

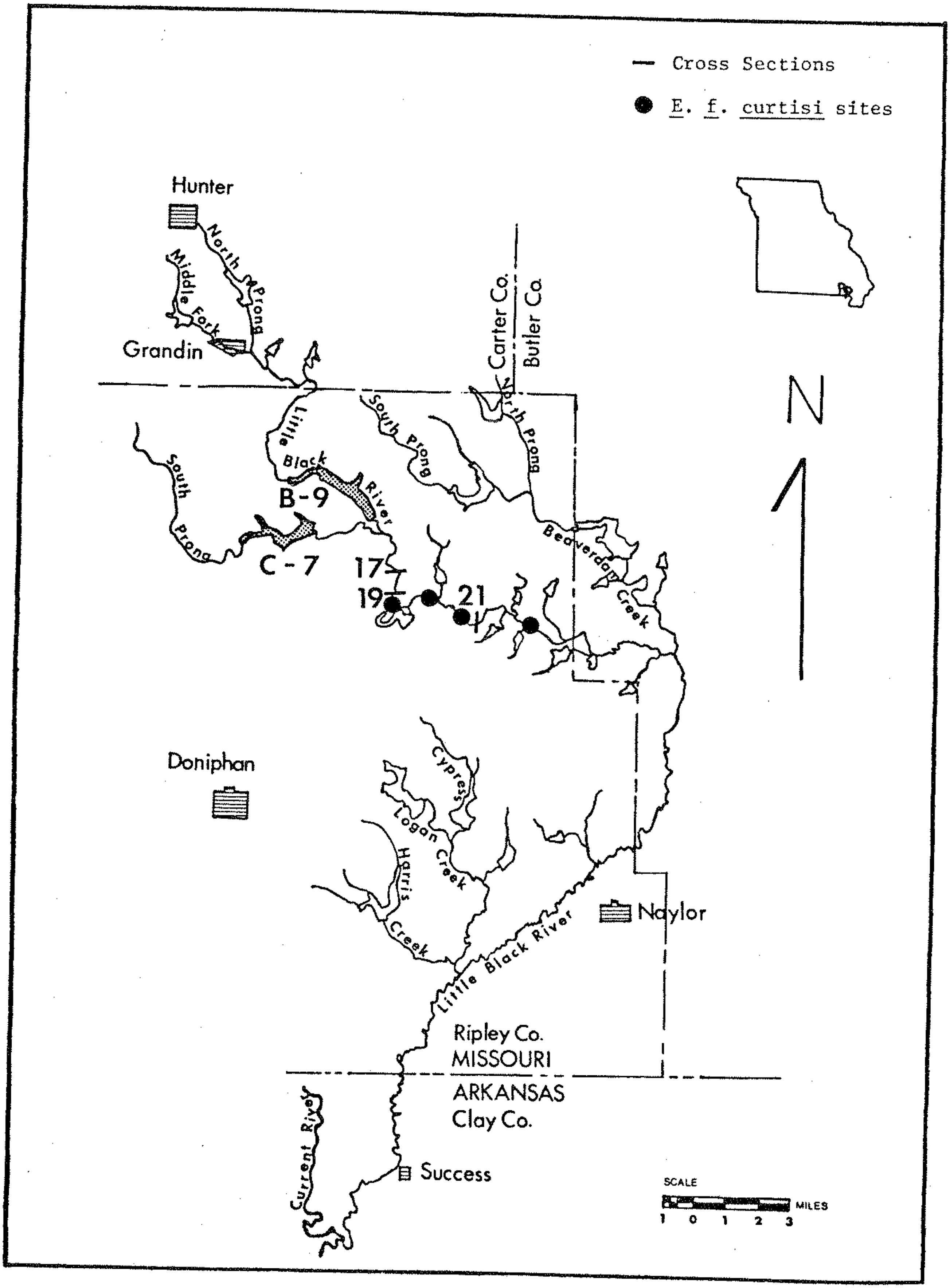

Figure 1. Little Black River Basin, Missouri.

Summer surface temperatures in the reservoirs would be significantly higher than that of inflowing waters. Consequently, the reservoirs would support a different biotic fauna than the stream.

Downstream Flows

Peak flows would be reduced by construction of structures B-9 and C-7. Peak flows 2 1/2 miles downstream from Highway K, (cross section 19, Fig. 1) near the reach where _E_. _f_. _curtisi_ occurs, would be reduced from 12,500 cfs to 2,800 cfs for a 25-year frequency flood, and from 3,000 cfs to 1,400 cfs for a 1-year frequency flood (United States Department of Agriculture, Soil Conservation Service, unpublished data). Bank full at this site is 3,000 cfs. Two miles further downstream (cross section 21, Fig. 1), in the reach where the best populations of _E_. _f_. _curtisi_ occur, peak flows would be reduced from 14,000 cfs to 3,600 cfs for a 25-year frequency flood, and from 1,325 cfs to 900 cfs for a 1-year frequency flood. Bank full at this latter site is 1,830 cfs.

Although peak flows would be reduced by structures B-9 and C-7, duration of flood flows would be increased significantly. The project is designed to reduce the volume and duration of out-of-bank flows, but would increase the length of time of bank-full and above normal in-bank flows. The change in duration of a 25-year flood event which would result from the projects is as follows (cross section 17, Fig. 1): Without structures B-9 and C-7 it takes 10.25 hours for the waters to overflow the banks. Flows remain out-of-bank for 19.75 hours, and return to normal (7 cfs) 43.5 hours after the initial increase. With structures B-9 and C-7 in place, it would take 13.5 hours for the waters to overflow the banks. They would remain out-of-bank for 10 hours, and return to 450 cfs in 72.5 hours. It could take up to 10 days for flows to return to normal (7 cfs) after the beginning of the flood event (United States Department of Agriculture, Soil Conservation Service unpublished data). The change in duration of flows for 10- and 100-year floods would be very similar to that described for the 25-year flood event.

The impact of a combination of reduced peak flows and reduced duration of out-of-bank flows, and an increase in duration of above normal in-bank flows is unknown. While a reduction in peak flows would tend to reduce scouring downstream, increased duration of above normal in-bank flows would have the opposite effect. Based on unpublished data provided by the United States Department of Agriculture, Soil Conservation Service, bedload transport during 25-year and 1-year flood events would be reduced by factors of 6 and 3, respectively, at cross section 19 (Fig. 1). This would result in aggradation of the streambed below the proposed reservoirs if a source of bed material were available. Structures B-9 and C-7 and other structures in the basin will severely reduce the source of bedload material, however, and degradation is expected.

While a reduction in peak flows would reduce scouring of the streambed and banks and reduce exchange of nutrients and organic matter between the stream and floodplain, extended duration above normal in-bank flows would tend to increase bed scouring and bank scouring and sloughing. The net impact upon instream vegetation and bank stability is not known. With a decrease in out-of-bank flows, riparian vegetation will probably change to species characteristic of more advanced successional stages.

The net impact upon benthic macroinvertebrates downstream is also not known. Evidence from at least one previous study indicates that changes in flows, particularly elimination of seasonal peak flows may cause significant changes in the species composition and abundance of benthic macroinvertebrates.

Williams and Winget (1979) found an increase in aquatic macrophytes and epiphytic algae below Soldier Creek Dam, a small impoundment on the Strawberry River, a high gradient stream in Utah. Although there was no change in diversity as indicated by the Shannon Weaver Index, there was a change in taxonomic composition of benthic macroinvertebrates. Numbers of low-flow tolerant species increased significantly, while some species disappeared entirely. They attributed these changes to a reduction in habitat heterogeneity due to reduced seasonal flows. A reduction in peak flows in the Strawberry River also allowed the proliferation of beaver dams which were previously washed out annually by spring flooding. Beaver dams backed water over riffles, reducing riffle flow velocity and allowing the accumulation of finer sediments in riffles.

An increase in duration of above normal in-bank flows during a flood event would result in an increase in duration of above normal turbidity, which may limit the spawning success of _E. f. curtisi_. This species spawns in the spring, when high flows are most common. Extended periods of valve closure by naiades because of increased turbidity may reduce the time available to release glochidia (larval naiades). Glochidia and juvenile naiades are more susceptible to silt and other turbidity than adults and would be adversely affected by extended periods of above normal levels of turbidity.

Suspended Sediment

Water released downstream from structures B-9 and C-7 would contain less sediment than the water presently contains. A reduction in sediment downstream could, ultimately, alter the composition of the substrate. Water released from the above structures would be "sediment hungry." This could increase bed-cutting and reduce the fines in the substrate downstream. Either change may adversely impact naiades because substrate quality appears to be critical for most species. The mean particle size of the substrate where E. f. curtisi occurs ranges from small gravel to pebble (0.04 to 1.25 inches in diameter).

Biological Changes

The most important, yet most difficult to predict, downstream changes which may occur in a stream after construction of an impoundment are changes in the biological constituent of the stream. Potential changes include increases or reduction in numbers of organisms present, a change in species dominance, and addition or loss of one or more species.

An impoundment creates an environment suited to lake species but poorly suited for many riverine species which occur in the stream before impoundment. Thus, impoundments contain a different array of organisms than streams. Consequently, the organisms which pass from a reservoir into the stream below are generally much different than those occupying the stream.

Cummins (1979), in a discussion of stream ecosystems as continuums, discussed impacts which impoundments have upon stream reaches downstream from the impoundments. A stream is a continuum from its headwaters to its mouth. In its headwaters (orders 1 to 3) the stream is most impacted by inputs from outside the channel. As you move downstream, the influx of materials from upstream in-channel sources becomes progressively more important and out-of channel inputs progressively less important. While coarse particulate matter processing is most important in the upper reaches of a stream, fine particulate organic matter processing is most important in large rivers. Impounding a stream has the effect downstream similar to increasing the stream order; the continuum is interrupted. Organisms and organic matter processing below an impoundment change to resemble that of communities much farther downstream. Impoundments impart a stability to downstream reaches which is more characteristic of larger stream reaches. This may alter not only the plankton and benthos of the downstream reach, but also the fish which feed upon them. E. f. curtisi has been found only in stream reaches which serve as transition areas between headwater and lowland reaches. Therefore, any change in stream characteristics which resemble a change in stream order would impact this species.

Several authors have described differences between the organisms present immediately downstream from a reservoir and those in unimpacted portions of the stream further downstream. Lowe (1979) found that phytobenthos downstream from reservoirs increased because of increased light penetration and regular flows. Armitage and Capper (1976) documented the transport of lake zooplankton downstream from reservoirs. They found that the amount of lake plankton in a stream below a reservoir was inversely related to the distance below the reservoir, turbulence, and amount of vegetation present. The relative size of the reservoir and the stream into which it emptied, and the season of the year were also important. In nine cases discussed, lake species comprised from 100% of the plankton in Maple Creek 35 feet downstream from Douglas Lake to 1% in the Huron River 4.5 miles downstream from Portage Lake. In the Marais River, lake species comprised 96% of the zooplankton 7.75 miles downstream from Tiber Reservoir.

The type of plankton and other microorganisms present in a stream affects not only the food available for naiades, which feed on plankton and organic matter, but also the kinds of fish present which act as potential hosts for the glochidia of naiades. Changing the amounts and types of microorganisms may thus impact the survival of naiades downstream. The reach of the Little Black River which supports _E. f. curtisi_ is approximately 3.5 and 6.0 miles, respectively, downstream from the proposed sites of B-9 and C-7. It is not known with certainty whether these projects would impact the biological component of the Little Black this far downstream. Unfortunately, neither the host(s) nor the specific food of the Curtis Pearly Mussel are known.

Epioblasma, the genus of which the Curtis Pearly Mussel is a member, is the most recently evolved genus of freshwater naiades, and one of the most specialized. Species of this genus are found only in riffles, in stable substrates, in waters of relatively high quality. Because members of this genus are so specialized, they have been severely impacted by human activities since the Industrial Revolution. Only one species in the genus, _Epioblasma triquetra_, is not in immediate danger of extinction. Holden (1979) in reference to fish in regulated streams, stated that the most specialized species of fish disappear first when a stream is altered. This also appears to be true in the case of naiades. If structures B-9 and C-7 produce any significant downstream changes, _E. f. curtisi_ would be one of the first species impacted.

The Relative Importance of the Little Black Populations of _Epioblasma florentina curtisi_

Any impacts which structures B-9 and C-7 might have on populations of _Epioblasma florentina curtisi_ in the Upper Little Black River become more significant when the relative importance of the Little Black River population of _E. f. curtisi_ to the species as a whole is considered.

E. f. curtisi has not been found outside of Missouri in recent times. The best populations known of this species occur in approximately 6 miles of the Upper Little Black River. During the past 5 years, over 60 specimens of E. f. curtisi have been examined in the Little Black River, more than have been found previously throughout its entire range. Outside of the Little Black River, specimens of this species have been found at only one site each in Cane Creek (Oesch in press) and the Castor River, and at several sites in Black River (Dr. David H. Stansbery, Ohio State University Museum of Zoology personal communication) during the past 15 years.

A recent survey of E. f. curtisi in southern Missouri (Buchanan 1983) failed to expand the range of this species. More importantly, no fresh material of this species was found during extensive sampling in Black River and E. f. curtisi probably no longer occurs in Black River. The last fresh material of E. f. curtisi collected from Black River was collected in 1970 (Dr. David H. Stansbery personal communication). E. f. curtisi is now known to occur only in 6.1 miles of the Upper Little Black River, 5 miles or less of the Castor River, and one site in Cane Creek. Population levels remain very low in Castor River and Cane Creek.

The disappearance of E. f. curtisi from Black River may be tied to human activities, including the construction of Clearwater Dam, which was closed in 1948. Since closure of Clearwater Dam, flow characteristics in Black River downstream have changed drastically. Hydrographic records at Leeper, 6.0 miles downstream from Clearwater Dam, reflect these changes (United States Geological Survey unpublished data). Between 1922 and 1948, the maximum annual flow was less than 10,000 cubic feet per second (cfs) only 8 times and was less than 5,000 cfs only twice. Since construction of Clearwater

Dam, the maximum annual flow at Leeper has never exceeded 10,000 cfs and has exceeded 5,000 cfs only twice. Periodicity of flows has been altered also. Mean daily flows at Leeper during April, May, and June were reduced by 357, 124, and 335 cfs, respectively, by Clearwater Dam. Mean daily flows during July, August, and September have been increased by 198, 160, and 126 cfs, respectively, by the dam. Clearwater Dam has also resulted in extremely low flows by Leeper. Between 1922 and 1948, annual minimum flows dropped below 200 cfs only 7 times, and the lowest flow was 133 cfs in August, 1934. Between 1949 and 1979 annual minimum flows dropped below 200 cfs 14 times and below 100 cfs twice. The lowest flows recorded were 70 cfs in November, 1959 and 62 cfs in September, 1966. The above flow changes could impact the time and bottom area available for fish, potential hosts for _E. f. curtisi_ and other naiades, to spawn. Very low flows may expose concentrations of naiades, causing desiccation, temperature stress, and increased susceptibility to predators. Changes in flow periodicity may also impact reproduction in benthic macroinvertebrates.

Summary and Recommendations

1. Structures B-9 and C-7 are not expected to have a significant impact upon water temperature or the levels of dissolved oxygen downstream.
2. The impact of B-9 and C-7 upon nutrient levels downstream would depend upon annual temperature and rainfall regimes, and characteristics of the reservoirs created, including flushing rates, level and duration of stratification, and other factors. Nutrient levels in the outflow from these reservoirs would change during each year as the reservoirs stratify and destratify from season to season.

3. Although stratification related changes in pH and alkalinity within the reservoirs created by B-9 and C-7 would be expected, the Little Black is relatively well-buffered and no significant impacts are expected downstream.
4. Structures B-9 and C-7 would act as sediment traps, reducing the load of sediments passing downstream. This may have an impact on substrate composition and stability downstream. The extent of downstream impact, if any, is not known.
5. The impact of the combination of reduced peak flows and extended duration of above normal in-bank flows created by structures B-9 and C-7 is not known. While reducing peak flows and the duration of out-of-bank flows would tend to reduce scouring and bank-cutting, extending the duration of above normal in-bank flows would have the opposite effect. The net impact would probably be degradation of the streambed downstream due to entrapment of sediments behind B-9 and C-7 and other structures in the basin, possibly altering the composition of the substrate.
6. Longer duration above normal in-bank flows would be expected to be accompanied by longer periods of above normal turbidity. Since peak flows in the Little Black River normally occur in the spring when _E_. _f_. _curtisi_ is releasing glochidia, extended duration above-normal flows may result in longer periods of above-normal turbidity at a very crucial time for this species. Glochidia and juvenile naiades are particularly sensitive to silt, and higher turbidity may reduce the chances for successful reproduction.
7. Impoundments frequently alter the biota of the streams into which they empty. Previous studies have documented changes in periphyton, vegetation, plankton, benthic macroinvertebrates, and fish populations

downstream from reservoirs. Water passing from reservoirs usually contains organisms quite different from those occupying flowing waters downstream. Changes in the plankton available might alter the food supply and a change in fish populations might reduce the number of potential hosts for E. f. curtisi.

8. Populations of E. f. curtisi in the Upper Little Black River are the best known. This species has experienced a serious reduction in numbers and range since the early 1900s, primarily due to dam construction. Outside of the Little Black River, E. f. curtisi occurs in very low numbers in Castor River and Cane Creek, and nowhere else. Disappearance from Black River since 1970 may be at least partially attributed to altered flows below Clearwater Dam since its construction in 1948.
9. Sensitive species such as E. f. curtisi are generally the first species to disappear when a change takes place in a stream. Any change which impacts E. f. curtisi in the Upper Little Black River will impact the existence of this species as a whole. Disappearance of this species from the Little Black River will probably lead to its extinction.
10. Since construction of structures B-9 and C-7 on the Upper Little Black River may impact E. f. curtisi, they should not be built until the survival of this species can be assured.

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