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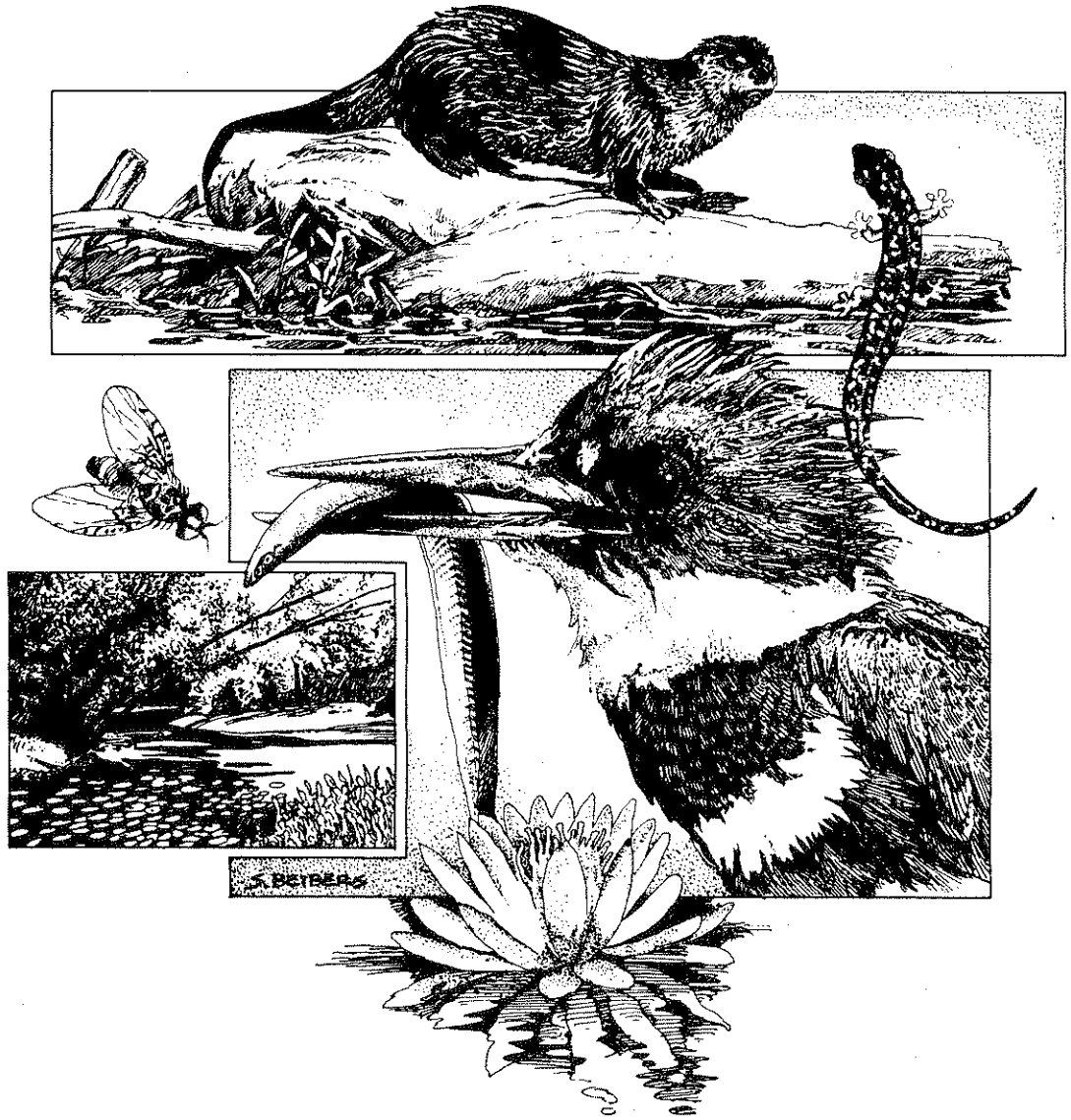
Population Status of Endangered Mussels in the Buttahatchee River, Mississippi and Alabama

Segment 1, 1989

Paul Hartfield and Robert Jones



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MISSISSIPPI ENDANGERED SPECIES PROJECT E-1, SEGMENT 5

RECOVERY FOR FIVE TOMBIGBEE RIVER MUSSELS

Study Title

POPULATION STATUS OF ENDANGERED MUSSELS IN THE BUTTAHATCHEE RIVER, MISSISSIPPI AND ALABAMA, SEGMENT 1

1989

by

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ABSTRACT

Epioblasma penita and Pleurobema taitianum, listed as endangered species by the U.S. Fish and Wildlife Service, are known to occur in the Buttahatchee River. A mussel survey in the lower 26 kilometers of the Buttahatchee River, Lowndes/Monroe Counties, Mississippi, resulted in the collection of 813 live unionid mussels in 26 species. Four other species that were freshly dead were found in muskrat middens. Mussel density, estimated by quadrat sampling at selected sites, ranged from 0.8 - 4.2/m^2. A comparison of these results with a 1977 mussel survey of the same area indicates that unionid mussels have been virtually extirpated from the mouth of the Buttahatchee to U.S. Hwy 45. Factors contributing to the decline are the Tenn-Tom Waterway and stream capture by abandoned and active gravel mines. Nine live and 42 fresh dead Epioblasma penita were collected. Pleurobema taitianum was not encountered.

INTRODUCTION

The Buttahatchee River provided habitat for at least two of the five species of freshwater mussels listed as endangered in the Tombigbee River drainage by the U.S. Fish and Wildlife Service in the Federal Register (52 FR 11162) of April 7, 1987. During a 1977 mussel survey, Yokley (1978) collected over 190 specimens of Epioblasma penita and four specimens of Pleurobema altum (=taitianum) from the Buttahatchee. Both species were collected alive from the river as recently as 1987 (Hartfield and Jones, 1987 unpublished collection). There are no records of Pleurobema marshalli, P. curtum or Quadrula stapes from the Buttahatchee drainage.

The primary objective of this two-year study was to determine the distribution and population densities of Epioblasma penita and Pleurobema taitianum in the Buttahatchee River. Additional objectives included characterization of habitat and associated species.

Rain and high water levels affected five of the six weeks of field work performed. An additional 11 scheduled field trips were cancelled because of high water. Due to adverse field conditions, only the lower 26 kilometers (km) of river from the Buttahatchee's confluence with the Tennessee Tombigbee Waterway (Tenn-Tom) upstream to R17W, T15S, NE/4, SE/4, Section 32, Lowndes/Monroe Counties, MS, approximately two km above Lawrence Bridge Road near Caledonia, MS, were adequately sampled and are the subject of this report.

STUDY AREA

The Buttahatchee River originates in the Fall Line Hills of northwest Alabama, and flows southwest to its confluence with the Tenn-Tom Waterway in northeast Mississippi. The drainage of approximately 870 square miles (E.J. Tharpe, USGS, 1989, personal communication) cuts through Cretaceous deposits of sand, gravel and clay of the Eutaw and Tuscaloosa formations. The river channel alternates between low and moderate gradients throughout the drainage and consists of long, slow pool reaches with sand and mud substrates connected by gravel and sandy gravel riffles and runs with swift currents.

One of the major water quality problems in the Buttahatchee River is high turbidity after rains (USDA, 1989). The primary source of the turbidity appears to be abandoned kaolin strip mines in Alabama, which deliver 27,000 tons of sediment per year into Camp Creek, a tributary of the Buttahatchee. It is estimated that between 1983 and 1988 over 100,000 cubic yards of kaolin sediments moved from the mines through Camp Creek and the Buttahatchee River into the Tenn-Tom Waterway. Stabilization of the abandoned mines has been recommended for authorization and funding by the Alabama Soil Conservation Service and the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers, 1989). Other water quality problems appear to be localized and are primarily the results of agricultural activities and sand and gravel mines in Alabama and Mississippi.

The Buttahatchee River channel appears to be relatively stable above U.S. Highway 45. Localized channel nicks, or

erosion points, occur primarily at a few cleared powerline and bridge crossings. Gravel mines border the channel below U.S. 45 and have created large ponding areas.

METHODS

The study area was divided into four segments for analysis and discussion of the results (Figures 1-3). Sampling stations were located at approximately 0.5 kilometer (km) intervals beginning at the confluence with the Tenn-Tom Waterway. Stations consisted of single transects in areas where conditions were not considered to provide good mussel habitat (i.e. deep sand/silt accumulations), or multiple transects at stations that appeared to provide good habitat (i.e., long, sediment free, riffle areas). One or two scuba divers searched areas over one meter (m) in depth, and three to four biologists searched shallower areas by wading and free-diving.

All mussels encountered were collected, identified and counted. Live mussels were returned to the substrate. Freshly dead specimens were retained and deposited at the Mississippi Museum of Natural Science. Notes were made on the condition of the channel banks, substrate type, water depth, and current at each station.

A minimum of ten quadrat samples were taken with a square 0.25 m^2 aluminum sampler whenever endangered mussels or their fresh remains were encountered. All material within the sampler was removed to a depth of approximately 10 cm and sorted on shore. Live and dead mussels were identified and counted.

FIGURES 1-3: BUTTAHATCHEE RIVER, LOWNDES AND MONROE COUNTIES, MISSISSIPPI.

Reach 1: Stations 1 - 11.

Reach 2: Stations 12 - 16.

Reach 3: Stations 17 - 52.

Reach 4: Stations 53 - 60.

FIGURE 1: Reaches 1 and 2.

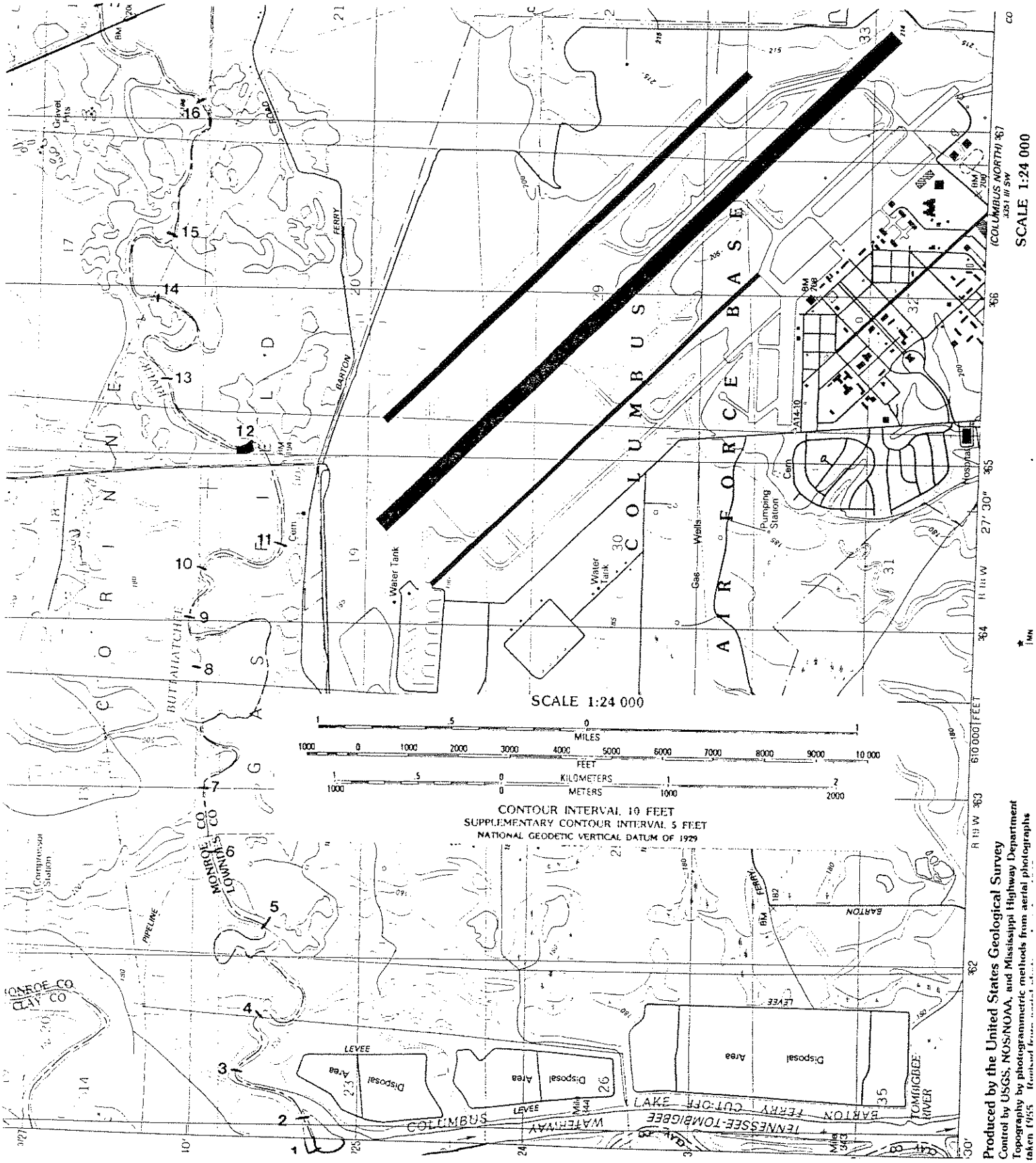


FIGURE 2: Reach 3

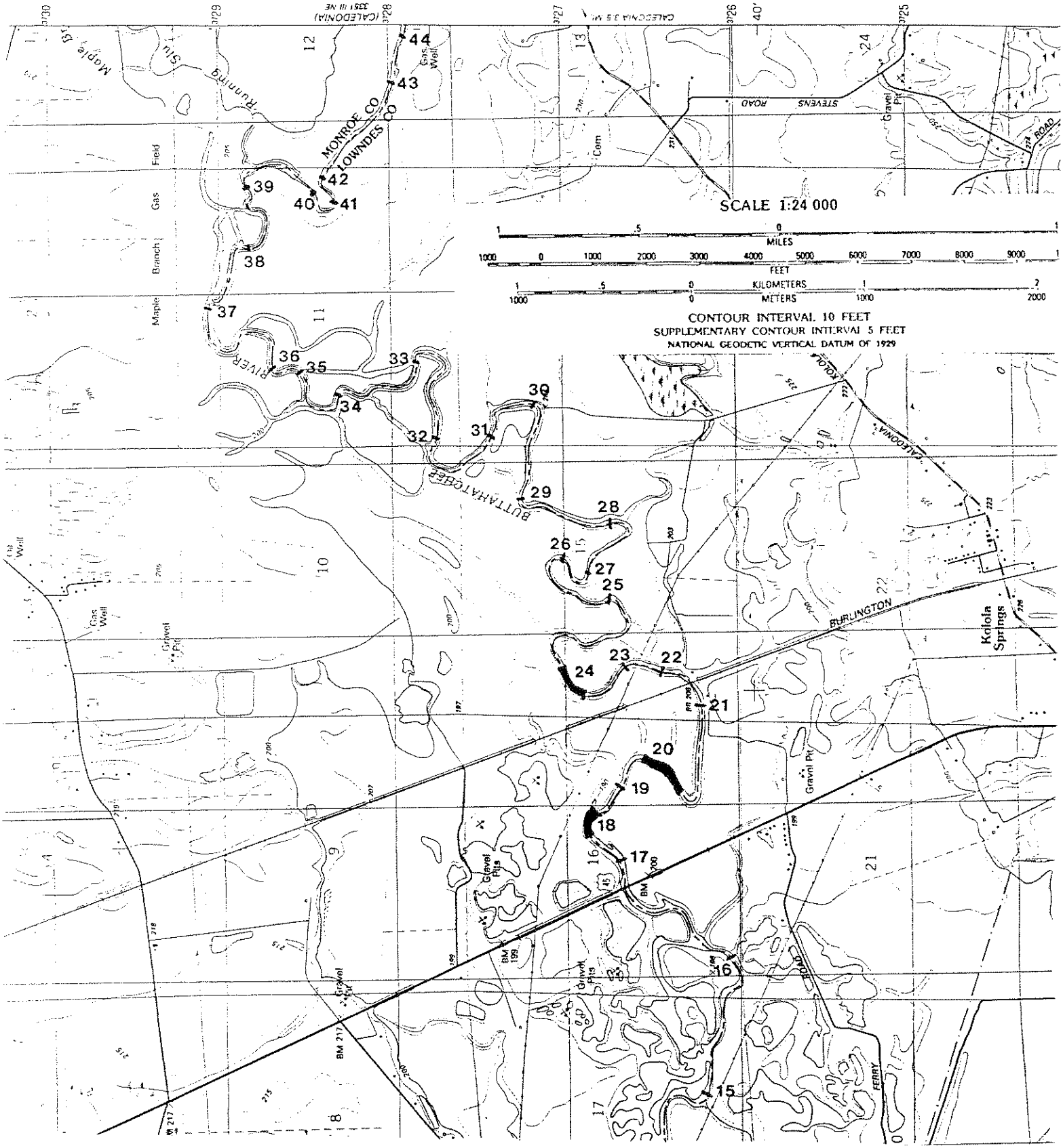
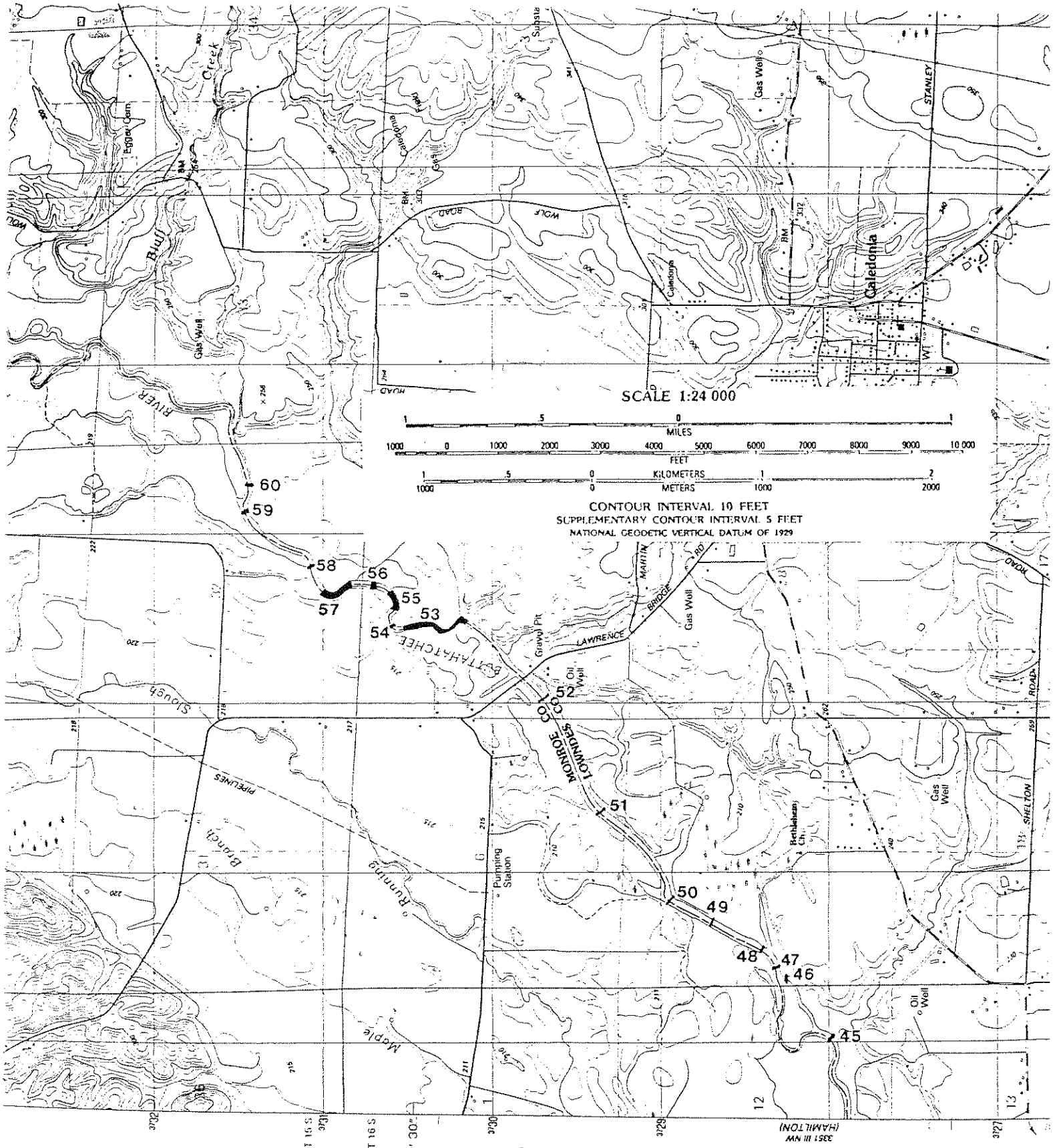


FIGURE 3: Reaches 3 and 4.



Quadrat sampling was usually discontinued after ten samples if no other endangered species were found and five or more quadrats contained no unionid mussels.

RESULTS

A total of 749 live unionid mussels in 26 species were collected from the station transects (Table 1; Appendix). Four other species (Anodonta imbecillis, Arcidens confragosus, Elliptio arctata, Potamilus purpuratus), all freshly dead, were collected from muskrat and raccoon middens. Twelve species showed evidence of recruitment. Juvenile or subadult mussels (individuals estimated at less than 3 years of age) comprised six per cent of all live collections. No young of the year (small individuals attached by bysal threads) were encountered.

Mussel beds (10 or more individuals/ m^2) were not encountered during the survey. Estimated unionid densities at quadrat sampling sites ranged from 0.8 - 4.2/m^2 (Table 2). Most live collections and all shell middens were associated with gravel riffles. Below U.S. Highway 45, fresh middens were found only at Station B12. Above U.S. 45, middens were numerous between Stations B22-B24, Station B40, and between B55-B60.

For the purposes of this analysis, freshly dead and live mussel collections in four reaches of the surveyed portion of the river have been combined (Table 3). Eleven collections (Appendix: Stations 1-11) were made in Reach 1 from the mouth of the Buttahatchee upstream to the Mississippi Highway 373 bridge crossing (Figure 1). The lower two kilometers of the

TABLE 1: SPECIES, RELATIVE ABUNDANCE AND NUMBER OF JUVENILE UNIONID MUSSELS COLLECTED ALIVE FROM STATION TRANSECTS ON THE BUTTAHATCHEE RIVER, MISSISSIPPI, 1989.

	NO.	%	JUV.
Amblema plicata	1	*	
Elliptio arca	105	14	1
E. crassidens	82	11	
Epioblasma penita	7	*	2
Fusconaia cerina	71	9	5
F. ebena	1	*	
Lampsilis ornata	45	6	2
L. perovalis	2	*	
L. claibornensis	40	5	2
L. teres	8	1	2
Lasmigona complanata	8	1	
Leptodea fragilis	19	2	7
Medionidus acutissimus	2	*	
Megalonaias nervosa	24	3	
Obliquaria reflexa	2	*	
Obovaria jacksoniana	5	*	
O. unicolor	2	*	1
Plectomerus dombeyanus	1	*	
Pleurobema decisum	51	7	3
P. perovatum	4	*	
Quadrula asperata	156	21	15
Q. rumphiana	31	4	
Strophitus subvexus	4	*	
Tritogonia verrucosa	64	8	6
Truncilla donaciformis	9	1	1
Villosa lienosa	5	*	
TOTAL INDIVIDUALS	749		47
TOTAL SPECIES	26		12

* = <1%

TABLE 2: NUMBER OF MUSSELS COLLECTED BY SPECIES IN THE BUTTAHATCHEE RIVER, MS QUADRAT SAMPLES, 1989. (j = juvenile or subadult mussels)

	STATION								
	12	18	24	35	53	54	55	56	57
E. arca		1	2+1j				1		
Epioblasma penita							1j		1
F. cerina			1+1j	1			1		1
L. ornata	2			1		1	1+1j		
L. claibornensis				1				1	
L. complanata			3						
L. fragilis	1						1j		
O. jacksoniana							1		1
P. decisum		1	3+1j						
P. perovatum			1						
Q. asperata		4	5	3	1j		4+1j	1	2j
S. subvexus							2		
T. verrucosa					1	2	1	1	
T. donaciformis							1		2
C. fluminea			18	21	1	6	11		1
# UNIONID SPECIES	2	3	7	4	2	2	10	3	5
TOTAL UNIONIDS	3	6	18	6	2	3	16	3	7
NUMBER QUADS	10	10	24	10	10	10	15	10	15
MEAN NO./QUAD.	0.3	0.6	0.75	0.6	0.2	0.3	1.06	0.3	0.46

TABLE 3: NUMBERS AND RELATIVE ABUNDANCE OF ALL MUSSEL COLLECTIONS FROM THE BUTTAHATCHEE RIVER, 1989.

	REACH 1		2		3		4		TOTAL
	#	%	#	%	#	%	#	%	
A. plicata					1	*			1
A. imbecillis	1	6			1	*			2
A. confragosus					2	*			2
E. arctata					8	*			8
E. arca			1	2	213	14	9	*	223
E. crassidens					91	6	4	*	95
Epioblasma penita			3	5	12	*	33	3	48
F. cerina			2	3	167	11	60	6	229
F. ebena					3	*			3
L. ornata	2	13	20	33	29	2	64	6	115
L. perovalis					8	*	1	*	9
L. claibornensis	4	27	3	5	40	3	20	2	67
L. teres	2	13	2	3	3	*	5	*	12
L. complanata					6	*	7	*	13
L. fragilis	3	20	4	6	11	*	17	2	35
M. accutissimus					1	*	2	*	3
M. nervosa	2	13			26	2			28
O. reflexa					8	*	2	*	10
O. jacksoniana					21	1	23	2	44
O. unicolor							2	*	2
P. dombeyanus					3	*			3
P. decisum					180	12	21	2	201
P. perovatum					8	*	5	*	13
P. purpuratus					2	*			2
Q. asperata	1	6	14	23	408	27	512	51	935
Q. rumphiana			1	2	123	8	31	3	155
S. subvexus			1	2	11	*	10	*	22
T. verrucosa			5	8	108	7	153	15	266
T. donaciformis			4	6	7	*	7	*	18
V. lienosa					8	*	5	*	13
TOTAL	15		60		1509		993		2577
TOTAL SPECIES	7		12		29		22		30

* = <1%

Buttahatchee have been impounded and cut off by the Tenn-Tom Waterway and an additional kilometer of river above the Waterway is directly influenced by the impoundment. The river channel has also been altered by an abandoned gravel mine within the reach and numerous abandoned and active gravel mines located immediately upstream. Only five mussels of three species were collected alive. Ten additional mussels and four additional species were found freshly dead. No middens were found, and Epioblasma penita was not encountered.

Reach 2 extends from MS 373 to US 45 (Figure 2). Throughout most of this reach, abandoned and active gravel mines have captured the river channel resulting in extensive ponding areas connected by unstable riffles. Only 60 mussels in 12 species were collected from five Stations (12-16) in Reach 2. Of these collections, 70% were from Station 12, a stable gravel riffle below the gravel mines. Over 40 mussels were collected from this station in a small area along the south bank. At least half of these were freshly dead specimens on a low gravel island, including two Epioblasma penita. Twenty mussels were collected alive (Appendix: Station 12), including a single E. penita at the margin of the island. The most abundant live species was Lampsilis ornata. Ten 0.25 m^2 quadrats at this station yielded only three unionids of two species (Table 2). Most of the remaining mussels collected in Reach 2 were from a small midden at Station 14.

Reach 3 extends from the U.S. 45 bridge upstream to the Lawrence Bridge Road near Caledonia, MS, a distance of approximately 16 river kilometers (Figures 2 & 3). Over 1500

live and fresh dead mussels in 29 species were collected from 31 stations (22-52). Numerous middens were found between Station 22 and 29, but only 22 fresh dead shells and 337 live mussels were found above this point in Reach 3.

Epioblasma penita was collected at four stations in Reach 3. One live and two fresh dead specimens were taken at Station 18 on a low gradient armored gravel bar. Unionid mussel densities were low. Ten quadrat samples taken in the vicinity resulted in the collection of only six mussels in three species (Table 2). An additional hour of collecting by four people recovered 33 live unionids in 13 species (Appendix: Station 18).

Two fresh dead E. penita were found in a midden at Station 23, and seven were taken from middens just upstream at Station 24. Twenty four quadrats taken in the vicinity of Station 24 resulted in the collection of 18 unionids in seven species (Table 2). Random collections and quadrats revealed that the majority of mussels in this fast, shallow, gravel run were along the margin of the south bank in fast currents, but out of the main current.

A transect search at Station 35 resulted in the collection of a single live E. penita in 120 cm of water at the upstream margin of a lateral gravel bar in a fast run. Eight other species of mussels were identified in the transect search. Ten quadrats collected only six unionids in four species (Table 2).

All E. penita collected in Reach 3 were associated with fast currents and stable, armored gravel substrates. This type of habitat occured between Stations 18 and 40. Above Station 40 a

series of long pools with low density and diversity of unionids extended to approximately 0.5 kilometers above the Lawrence Bridge Road.

Reach 4 extends from the Lawrence Bridge Road to a gravel bar approximately 2.6 kilometers (1.6 miles) upstream (Figure 3). The lower portion of the reach was characterized by a short pool -long riffle/run sequence. Numerous, large middens were found associated with the riffle/runs.

A live E. penita was collected from the first set of riffles above the Lawrence Bridge Road (Station 53), and live specimens were found at every collection up to Station 57 (Table 3). Freshly dead specimens were taken from middens throughout the reach. All E. penita were associated with low-gradient, shallow point and lateral gravel bars and armored gravel to sandy-gravel substrates. Two specimens were collected from quadrat samples.

In general, quadrat samples in Reach 4 showed low unionid density and diversity. Station 55 had the highest densities encountered during the study with an average of 4.24 unionids/ m^2.

A total of nine live Epioblasma penita were identified from the combined transect searches and quadrat samples in all four reaches (Table 4). An additional 42 freshly dead specimens were collected.

Seven of the nine live individuals were males. Two females were collected in proximity to one another at station 55. Both females were small individuals, with two and one faintly

TABLE 4: EPIOBLASMA PENITA COLLECTED ALIVE FROM THE

BUTTAHATCHEE RIVER, 1989.

STATION	SEX	MEASUREMENTS (LxHxW, mm)	DEPTH (cm)	CURRENT m/sec.	HABITAT & POSITION
B12	M		2	0	Lying on margin of low-gradient gravel island.
B18	M		6	.3	Partially embedded at the end of trail on low-gradient gravel bar.
B35	M		120	.5-2	Partially embedded near margin of lateral gravel bar.
B53	M	48.3x28x16.6	28	1.7	Partially embedded in loose gravel near lateral gravel bar.
B54	M	40.7x33.1x22.1	6	0	Lying near margin of sandy-gravel point bar.
B55	F	33.4x22.4x13	60	1.8-2	Partially embedded in loose sandy-gravel near margin of lateral bar.
B55	F	23.2x15x9.7	60	1.8-2	Same as above.
B56	M	39.1x31.3x19.7	51		Partially embedded in armored gravel near margin of fast run.
B57	M	48.4x39.5x28.1	51	.4	Partially embedded in loose sandy-gravel below point bar.

visible growth rings, respectively. Two of the E. penita collected were lying on their sides in shallow water at the end of distinct shallow trails. Neither was deeply embedded and both had at least 50% of their shells exposed to the currents above the substrate.

All live collections of Epioblasma penita were associated with low gradient point and lateral gravel bars, or in the shallows along the margins of fast runs. Water currents ranged from 0.3-2 m/s. Depths of collection ranged from two to 120 cm.

Pleurobema taitianum was not encountered during the survey.

DISCUSSION

A total of 42 species and subspecies of unionid mussels have been reported from the Buttahatchee River (Yokley, 1978; Schultz, 1981; Hartfield and Jones, 1987 unpublished collection of Ligumia recta). The most comprehensive collection of the river to date was by Yokley (1978) in which he listed species collections by river reach (Table 5). Yokley's lower four reaches coincide with the four reaches of the river collected during the present survey.

Yokley's study revealed a rather uniform pattern of compositional dominance/codominance throughout the lower four reaches of the Buttahatchee River. In comparison, the 1989 survey reveals a change to significant compositional heterogeneity within the lower river reaches (Table 6).

The greatest difference between the two studies has been a decline in mussel diversity and abundance accompanied by a major shift in compositional dominance in the lower two reaches.

TABLE 5: NUMBERS AND RELATIVE ABUNDANCE OF MUSSELS COLLECTED FROM THE BUTTAHATCHEE RIVER IN 1977 (YOKLEY, 1978).

	REACH 1		2		3		4		TOTAL
	#	%	#	%	#	%	#	%	
A. plicata					1	*			1
A. grandis	1	*	1	*			1	*	3
A. confragosus							1	*	1
E. arctata			4	*	1	*	1	*	6
E. arca	12	4	34	3	109	10	48	3	203
E. crassidens	3	1	3	*	15	1	4	*	25
E. lineolata							1	*	1
Epioblasma penita	35	12	57	6	25	2	4	*	121
F. cerina	12	4	69	7	67	6	75	5	223
F. ebena			2	*	1	*	5	*	8
L. ornata	27	9	42	4	33	3	35	2	137
L. perovalis					1	*			1
L. claibornensis	22	7	22	2	18	2	40	3	102
L. teres			6	*	4	*	7	*	17
L. complanata					1	*	1	*	2
L. fragilis	1	*	1	*	1	*	1	*	4
M. accutissimus	2	*	8	*	38	4	2	*	50
M. nervosa	1	*			3	*			4
O. reflexa			2	*	2	*	3	*	7
O. jacksoniana	39	13	188	19	215	20	400	29	842
O. unicolor	10	3	28	3	1	*	61	4	100
P. decisum	3	1	29	3	65	6	43	3	140
P. perovatum			8	*	12	1	9	*	29
P. taitianum					4	*			4
Q. asperata	106	36	351	36	327	31	450	32	1234
Q. metanevra			1	*					1
Q. rumphiana			48	5	51	5	81	6	180
S. subvexus					3	*	5	*	8
T. parva							2	*	2
T. verrucosa	8	3	24	2	12	1	45	3	89
T. donaciformis	1	*	3	*	3	*			7
V. lienosa	14	5	39	4	39	4	64	5	156
V. vibex	1	*	4	*	8	*	5	*	18
TOTAL NUMBER	298		974		1060		1395		3726
TOTAL SPECIES	18		25		29		29		33

* = < 1 %

TABLE 6: COMPOSITIONAL CHANGES IN UNIONID MUSSEL COMMUNITIES BY DOMINANT SPECIES IN THE BUTTAHATCHEE RIVER, 1977 AND 1989. DOMINANCE IS DETERMINED BY RELATIVE FREQUENCY (rf) OF SPECIES FROM ALL COLLECTIONS.

1977 (rf)	1989 (rf)
REACH 1	
Q. asperata (36)	L. claibornensis (27)
O. jacksoniana (13)	L. fragilis (20)
E. penita (12)	
REACH 2	
Q. asperata (36)	L. ornata (33)
O. jacksoniana (19)	Q. asperata (23)
F. cerina (7)	T. verrucosa (8)
REACH 3	
Q. asperata (31)	Q. asperata (27)
O. jacksoniana (20)	E. arca (14)
E. arca (10)	P. decisum (12)
REACH 4	
Q. asperata (32)	Q. asperata (51)
O. jacksoniana (29)	T. verrucosa (15)
Q. rumphiana (6)	L. ornata (6)

Epioblasma penita, along with most other unionid mussels, have all but dissapeared from Reaches 1 and 2 (below U.S. Highway 45). These changes in the fauna can be attributed to alteration of the stream channel by impoundment in the extreme lower reach, and the impact of stream capture by gravel mines below U.S. 45.

Although overall mussel diversity and abundance in Reaches 3 and 4 (above U.S. 45) were similar in 1977 and 1989, patterns of secondary dominance have changed. In 1977, Obovaria jacksoniana was a codominant species, second in abundance only to Quadrula asperata. In 1989, this species was relatively uncommon, forming only one and two percent, respectively, of mussel collections from these two reaches. There was also an increase in the relative frequency of occurrence of Fusconaia cerina, Tritogonia verrucosa and Pleurobema decisum and a decrease in Villosa lienosa.

These less striking changes in species relative abundance between the two studies might be explained by differences in collecting effort and methods, or they could simply be natural population fluctuations. However, the dramatic decline of Obovaria jacksoniana from an abundant species in these reaches in 1977 to an uncommon one in 1989 can not be so readily discounted.

A variety of factors could be responsible for this shift in secondary dominance, as well as other changes in the mussel community composition, during the 12 year interval between the two studies. Impoundment of rivers may restrict the movement of migratory host fish causing decline or elimination of host-specific unionid species. Unfortunately, the host-fish relationships of O. unicolor, E. penita, P. taitianum, as well as

that of many other species in the Buttahatchee have not been determined. There has been no attempt to document changes in the fish community of the Buttahatchee above the influence of Columbus Lake since construction of the Tenn-Tom Waterway.

Other factors that might affect community composition in unionid populations include hydrology, channel substrate and water chemistry altered by land use changes and point and non-point pollution. However, it is often difficult to associate these with direct observable effects on mussel species. In the Buttahatchee, one such factor is the tremendous quantity of suspended sediment moving through the system from abandoned kaolin mines in the headwaters. Sedimentation has repeatedly been associated with declines in freshwater mussel communities (Ellis, 1931, 1936; Scruggs, 1960; Dennis, 1984). Most of these studies have dealt with sediment deposition on mussel habitat. Although silt deposition was observed in the pool reaches of the Buttahatchee River, it was not considered to be a problem in the higher gradient riffles and runs where the majority of mussels were found. Some investigators, however, have found that small quantities of silt, while harmless to most adult mussels, could affect recruitment (Ellis, 1931; Negus, 1966). Ellis (1936) also suggested that suspended sediments could suffocate mussels by clogging their gills, or interfere with feeding. Dennis (1984) found that food intake of some mussel species is reduced as much as 80 percent by high concentrations of suspended sediments. The effects of suspended sediments on the mortality and reproduction of Obovaria jacksoniana is

unknown, and it is not possible at this time to identify kaolin sediments as the factor, or as a contributor to a combination of factors, that might be responsible for the changes in relative abundance and patterns of dominance in these two reaches.

ENDANGERED SPECIES

No Pleurobema taitianum were encountered during this survey. Yokley found four specimens in Reach 3 during his 1977 survey. Schultz (1981) collected additional specimens from the lower portion of Reach 3 in 1979. In 1987, the authors collected a single live specimen tentatively identified as Pleurobema taitianum in the same reach approximately 0.6 km above US Hwy 45. Confirmation of the identification would have required the sacrifice of the mussel. Habitat apparently identical to that encountered in the previous collections still exists in this portion of the Buttahatchee River.

Only isolated collections of P. taitianum have been made from tributaries of the Tombigbee River, and the species was more common in the main channel of the river. It is possible that the tributaries offered only marginal habitat for P. taitianum and tributary populations were dependent on main channel populations and infected host fish migration for periodic repopulation. Alternatively, the reproductive requirements of this species may be very specific, with conditions allowing successful recruitment in tributary populations occurring only sporadically. Periodic surveys will be necessary to determine whether P. taitianum still exists in the lower Buttahatchee River and, if so, its reproductive success and potential. Because of the low numbers encountered in recent collections, it is extremely unlikely that

enough individuals can be located to determine host fish species and other aspects of its reproductive biology.

The limited observations of Epioblasma penita that were made during this study indicate it is a riffle species preferring moderate to strong currents. It remains partially exposed above the substrate and appears to move in response to changes in current speed. This species may respond to stranding, elevated temperatures, and/or absence of currents by ejecting from the substrate.

The number of live E. penita found during the survey, including just two subadult females, suggests that the reproductive biology of the species will be difficult to determine if larger populations are not discovered. However, the limited number of live specimens observed may be due to excessive periods of high water throughout 1989. For example, in 1987 the authors collected from a large stable gravel riffle approximately 0.6 km above US Hwy 45 (Reach 3) which extended across the river. Mussels were abundant and occurred in dense beds (more than $10/m^2$ estimated) just above the steeper portion of the riffle in shallows along the south bank. In this bed, two live E. penita and one P. taitianum were found along with 13 other species of live unionids. The senior author and U.S. Fish and Wildlife Service biologists had previously collected 25 species from this bar in 1984. Neither live or freshly dead mussels were found at this location during the current survey, and the riffle, although still present, had been reworked by extensive flooding during the spring and early summer. The 1989 floods marked the end of an

extended drought. Several years of moderate rainfall may allow this riffle and similar areas to repopulate and, perhaps facilitate the collection of live Epioblasma penita.

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APPENDIX:

Transect Collections of Live Mussels

j = juvenile

20+1 = adults + juveniles

	STATION								
	1	2	3	4	5	6	7	8	9
A. plicata									
A. grandis									
A. imbecillis									
A. suborbiculata									
A. confragosus									
E. arctata									
E. arca									
E. crassidens									
E. lineolata									
Epioblasma penita									
F. cerina									
F. ebena									
L. ornata									
L. perovalis									
L. claibornensis			2+1j						
L. teres				1					
L. complanata									
L. fragilis									
L. recta									
M. accutissimus									
M. nervosa								1	
O. reflexa									
P. taitianum									
P. purpuratus									
Q. asperata		5		1	1	1		13	13
Q. metanevra									
Q. rumphiana						2			11
S. subvexus									
T. parva									
T. verrucosa		1				2	2	2	4+2j
T. donaciformis		1							1
V. lienosa									
V. vibex									
C. fluminea		few		abun	few	few		few	abun
TOTAL SPECIES	-	11	0	4	4	9	8	8	11

	STATION								
	28	29	30	31	32	33	34	35	36
A. plicata									
A. grandis									
A. imbecillis									
A. suborbiculata									
A. confragosus									
E. arctata									
E. arca	5		55	4	8		20	4	2
E. crassidens	1		29	1	7	3	21	3	
E. lineolata									
Epioblasma penita								1	
F. cerina	10	2	16	4	5		6		1
F. ebena							1		
L. ornata			5	1	2	1	4		3
L. perovalis							1		
L. claibornensis	4		1	2	1	1	1		
L. teres							1j	1	
L. complanata									
L. fragilis							1j	1	
L. recta									
M. accutissimus									
M. nervosa		2			1		2		
O. reflexa		1							
O. jacksoniana	1			1			1		
O. unicolor									
P. dombeyanus									
P. decisum	2+1j	1	13	2	9		4	2	
P. perovatum	1								
P. taitianum									
P. purpuratus									
Q. asperata	19	2	20+1	16+3	11+2	1	10	6+1j	2
Q. metanevra									
Q. rumphiana		5	2	3	2		1		
S. subvexus			2		1				
T. parva									
T. verrucosa	2		6		1		3	2+3j	1
T. donaciformis			1						
V. lienosa									
V. vibex									
C. fluminea			abun		abun		abun		abun
TOTAL SPECIES	9	6	11	9	11	4	15	7	5

	STATION								
	37	38	39	40	41	42	43	44	45
A. plicata									
A. grandis									
A. imbecillis									
A. suborbiculata									
A. confragosus									
E. arctata									
E. arca									
E. crassidens		1							
E. lineolata									
Epioblasma penita									
F. cerina	1								
F. ebena									
L. ornata									
L. perovalis									
L. claibornensis							1		
L. teres									
L. complanata	1								
L. fragilis									
L. recta									
M. accutissimus									
M. nervosa	6								
O. reflexa									
O. jacksoniana									
O. unicolor									
P. dombeyanus	1								
P. decisum									
P. perovatum									
P. taitianum									
P. purpuratus									
Q. asperata	1		1	1	1				
Q. metanevra									
Q. rumphiana	2								
S. subvexus									
T. parva									
T. verrucosa				1	2				
T. donaciformis									
V. lienosa									
V. vibex									
C. fluminea		few							
TOTAL SPECIES	6	1	1	2	2	0	1	0	0

	STATION								
	46	47	48	49	50	51	52	53	54
A. plicata									
A. grandis									
A. imbecillis									
A. suborbiculata									
A. confragosus									
E. arctata									
E. arca									
E. crassidens		2						1	
E. lineolata									
Epioblasma penita								1	1
F. cerina									1j
F. ebena									
L. ornata									1
L. perovalis									
L. claibornensis								1	1
L. teres									
L. complanata									
L. fragilis								2j	
L. recta									
M. accutissimus									
M. nervosa	1								
O. reflexa									
O. jacksoniana									
O. unicolor									1j
P. dombeyanus									
P. decisum									
P. perovatum									
P. taitianum									
P. purpuratus									
Q. asperata									
Q. metanevra									
Q. rumphiana	1								
S. subvexus									1
T. parva									
T. verrucosa		1						1	
T. donaciformis									
V. lienosa									
V. vibex									
C. fluminea									
TOTAL SPECIES	2	2	0	0	0	0	0	5	6

	STATION								
	55	56	57	58	59	60			
A. plicata									
A. grandis									
A. imbecillis									
A. suborbiculata									
A. confragosus									
E. arctata									
E. arca					1				
E. crassidens	2								
E. lineolata									
Epioblasma penita	1j	1							
F. cerina		1	2+1j		1+2j				
F. ebena									
L. ornata	1+1j		2		1				
L. perovalis									
L. claibornensis	1	1	4+1j	1	1				
L. teres			1j	1					
L. complanata		1		2					
L. fragilis			4+1j		1				
L. recta									
M. accutissimus			1						
M. nervosa									
O. reflexa					1				
O. jacksoniana									
O. unicolor					1				
P. dombeyanus									
P. decisum									
P. perovatum									
P. taitianum									
P. purpuratus									
Q. asperata		2+1j	6	1	8+1j				
Q. metanevra									
Q. rumphiana				2					
S. subvexus									
T. parva									
T. verrucosa	1	3	9	3	4+1j				
T. donaciformis			1	1	2				
V. lienosa	1			4					
V. vibex									
C. fluminea									
TOTAL SPECIES	6	6	9	8	10				