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FELSENTHAL REFUGE

January 9, 1998

Felsenthal National Wildlife Refuge
Mr. Dale Guthrie
P.O. Box 1157
Crossett, AR 71635

see pp 44

Dear Mr. Guthrie,

I have completed my thesis research on the Ouachita River which included a portion that fell within the Felsenthal National Wildlife Refuge. The thesis was completed and copies have been sent to the funding agencies, which include the U.S. Fish and Wildlife Service.

However, you requested a copy for the Felsenthal Refuge Office and I have included one for you. I appreciate the opportunity to study the benthic organisms on the refuge and enjoyed the scenery and wildlife of the refuge.

Thank you for the opportunity to complete the survey of the Ouachita River. If you have any questions, feel free to contact me at the above numbers.

Sincerely,

William Posey

William Posey
Ecologist II
Arkansas Department of Pollution Control and Ecology

File

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Location, Species Composition and Community Estimates for
Mussel Beds in the St. Francis and Ouachita Rivers in
Arkansas

William R. Posey II

178 Pages

May 1997

The objectives of this study were to map the areal extent and determine community characteristics of commercial quality mussel beds in the St. Francis and Ouachita Rivers in Arkansas.

An Abstract
of
Location, Species Composition and Community Estimates for
Mussel Beds in the St. Francis and Ouachita Rivers in
Arkansas

William R. Posey II

The objectives of this research were to locate and delimit the areal extent of commercial mussel beds in the St. Francis and Ouachita rivers. Secondary objectives were to analyze community structure within beds, locate and map distribution of endangered species, analyze size structure, analyze age and growth and determine the percent of legal harvestable mussels in each river.

Beds with fewer than 10 mussels/m² were sampled qualitatively only. Beds with ≥ 10 mussels/m² and between 100 and 499 m² in area are labeled minor beds (mbeds) and were sampled non-randomly in areas of greatest mussel density. Beds with ≥ 10 mussels/m² and greater than 500 m² in area were sampled randomly and are called major beds (Mbeds). Major beds were stratified for sampling when necessary based on river structure, depth and substrate.

Ten beds (4 M- and 6 mbeds) were located and sampled in the St. Francis River. Twenty-two species and 1522 individuals were collected from 84 m² quadrats. *Amblema plicata* was the dominant species and comprised 31.0% of all mussels collected. Subdominant taxa included *Quadrula pustulosa* and *Quadrula quadrula* comprising 26.7 and 23.2%, respectively.

The Ouachita River contained 61 beds (45 M- and 16 mbeds). Quadrat sampling yielded 34 species and 23,463 individuals from 868 quadrats. *Amblema plicata* was the dominant species and comprised 17.0% of all mussels collected. Subdominant species include *Fusconaia ebena* (14.5%) and *Fusconaia flava* (10.8%). No endangered species were encountered in the St. Francis River.

Three endangered species were found in the Ouachita River. *Quadrula fragosa*, an endangered species, was documented in Arkansas for the first time. Another species, previously thought extirpated from the state (*Cumberlandia monodonta*), was also found.

Four species each were analyzed for significant differences between regions within the St. Francis and

Ouachita rivers. All species except *Quadrula quadrula* showed a difference in size among regions in the St. Francis River. All species but *Fusconaia flava* in the Ouachita River showed size differences among regions.

Age/growth analysis was conducted on St. Francis River *Megalonaias nervosa* (n=48) and Ouachita River *Amblema plicata* (n=50). Age at minimum legal harvestable size for *Megalonaias nervosa* was determined to be 9.9 years, while *Amblema plicata* reached a minimum legal harvestable size at age 21.4 years.

Within the St. Francis River, 41.3% of all mussels were of minimum legal harvestable size. Mbeds contained 40.7% while mbeds contained 42.9% harvestable mussels. Mbeds contributed all of the legal harvestable mussels in the Ouachita River, which comprised only 0.3% of all mussels.

Location, Species Composition and Community Estimates for
Mussel Beds in the St. Francis and Ouachita Rivers in
Arkansas

A Thesis
Presented to the
Faculty of the Graduate School
Arkansas State University

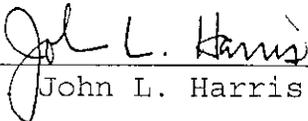
In Partial Fulfillment
of the Requirements for the Degree of
MASTER OF SCIENCE
Department of Biology

by
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ACKNOWLEDGMENTS

Anytime a project of this magnitude is attempted, it is impossible to accomplish solo. Therefore, it is with deep gratitude that I acknowledge the contributions of many.

I am particularly grateful to my wife, who seldom complained of my long absences while in the field. She also became my assistant when another could not be found and helped me to complete my research more quickly.

I wish to thank Dr. George L. Harp for giving an academically challenged student a chance to enter graduate school. His wisdom and advice were always key to my decision making and help even today in my new job. I don't think Dr. Harp would ever have allowed me into graduate school without the influence of Dr. John L. Harris. His honesty goes even further than his height (i.e. no trees in the White River and there's nothing below Camden). Even so, I thank him for his support in his recommendation to Dr. Harp. Additional thanks are sent to Dr. Jerry L. Farris for his help with thin sectioning and for serving as a committee member. The catalyst that began this process is Betty (Cochran) Crump. While under her supervision, I realized a larger world of Biology than offered by classrooms. She broadened my awareness of aquatic ecosystems and increased my interest in further studies.

Without the aid of my field assistants, this project would never have been completed. Al Christian, who witnessed my first black-water dive, was instrumental in my methodology of field work and book keeping and instructed me in mussel taxonomy. Additional field assistants include Joe Hockmuth, Lanny Thompson, Brady Richards, Patrick Daniel, and Chris Davidson, who was there to the bitter end.

Analysis of collected data would have been much more time consuming without the assistance of Brady Richards and J.D. Wilhide. Mr. Wilhide also assisted with thin sectioning and provided assistance in analyzing those data. Kim Joyce was instrumental in preparing museum specimens and Tony Hill created all of the maps in this document.

I thank my class and office mates for their support and advice. I am especially grateful to Lewis Hunt (Lew Bob) for countless hours of field collections for class projects. Without him, I would never have found wood frogs in Independence County or stayed out in the rain all night. I would also like to thank Steve Rice for computer assistance.

In addition, a project would be difficult without

funding. That was provided by the Arkansas Game and Fish Commission, U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. My appreciation is extended to these agencies.

For their assistance in locating commercial mussel beds, I thank K.C. Ward, Ed Kohal and J.T. Easter. Without them, this project would have taken at least one year longer to complete.

Thanks go to my parents who taught me to stick to something even if I did not like to do it ("building character"). Many times on a project this size, under extreme working conditions, it is easier to quit than to achieve the goal. Without them, no one would be reading this document.

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CHAPTER I

INTRODUCTION

FRESHWATER MUSSELS

Life History

Unionid mussels (Unionacea) are benthic, sessile planktivores, often living in dense aggregates of over 100 individuals/m² called beds. Mussels may occupy a wide range of habitats, but most are associated with lotic environments (Williams et al., 1993). Freshwater mussels are distributed world-wide but reach their greatest diversity in the United States with approximately 297 recognized taxa. Of these, 213 (71.7%) are considered endangered, threatened or of special concern with another 21 (7.1%) listed as endangered and possibly extinct (Williams et al., 1993). Adults range in length from four cm to more than 30 cm.

Mussel anatomy consists of two major components; hard, symmetrical exterior valves and an interior visceral mass. The primary function of the exterior valves is to protect the soft visceral mass. The valves are composed of four layers, three of which are secreted by the mantle. The outermost layer, the periostracum, is a proteinaceous layer that sometimes contains distinctive coloration. The next layer,

the prismatic layer, contains vertical prisms of CaCO_3 in the mineral form calcite. The thickest layer, mother-of-pearl (nacre), is composed of calcite and aragonite. The innermost layer is the hypostracum and is secreted by the major muscles that attach to the valves. The two valves, held together by a proteinaceous ligament, exert constant pressure to open the valves when the adductor muscles relax. The valves have concentric rings (annuli), beginning at the umbo and radiating to the margin of the shell.

The interior visceral mass includes the circulatory, digestive, respiratory, excretory, nervous, muscular, endocrine and reproductive systems. The mantle surrounds the visceral mass and attaches to the valves along the pallial line (Oesch, 1984).

Most mussel species have separate sexes, although a few species are hermaphroditic (Harris and Gordon, undated). Reproduction of North American mussels is a complex, highly specialized process. After gametogenesis, ova discharged into the suprabranchial chamber of the female are fertilized by exogenous sperm which enter the pallial cavity suspended in the incurrent water flow. The resulting zygotes are deposited in the lumina of the marsupial gills and undergo early cleavage stages. Often the embryos are embedded in a secreted, acellular matrix. Development proceeds to the glochidium, a bivalved larval stage. Glochidia are retained in the marsupia for either a short (tachytictic species) or

long (bradytictic species) period of time. Glochidia of most North American mussels are obligate parasites on fish hosts to metamorphose into juvenile mussels (Oesch, 1984).

Glochidia are of two types: hooked and hookless. The hooked forms attach to the fins or tail of the fish most frequently. The stimulation to attach appears to be tactile. When stimulated, the glochidium contracts, and the hooks are forced inward and downward, imbedding the hooks in the flesh. The hookless form reacts slightly to tactile stimulation but reacts violently to blood or fish mucus in the water. When blood or fish mucous concentrations in water are high enough, the glochidia have been observed to contract several times and finally snap shut (Oesch, 1984, Farris, pers. comm.).

Not all mussels are dependent on fish for metamorphosis. One species parasitizes an amphibian, *Necturus maculosus*, while two other species require no host. The time required for metamorphosis is variable, depending on water temperature, glochidial species and host species. Following metamorphosis, young mussels excyst and drop to the substrate to begin an existence as part of the benthic community. Parasitism is a mechanism for dispersal of young mussels (Gordon and Layzer, 1989).

Research and Status in Arkansas

Freshwater mussels in Arkansas were first catalogued by Call (1895) and known diversity has grown to 74 species (Posey et al., 1996). Eight species, *Potamilus capax*, *Lampsilis*

abrupta, *Lampsilis powelli*, *Lampsilis streckeri*, *Epioblasma florentina curtisi*, *Arkansia wheeleri*, *Quadrula fragosa* and *Epioblasma turgidula*, have been placed on the federal endangered or threatened species list (Harris and Gordon, 1987). Three other species, *Epioblasma triquetra*, *Cumberlandia monodonta* and *Potamilus alatus*, are considered as endangered within or extirpated from the state (Harris and Gordon, 1987), and an additional nine species are on the state threatened or special concern list. Distributional data for Arkansas mussels have been provided by Call (1895), Meek (1896), Wheeler (1918), Gordon et al. (1979), Gordon (1980) and Harris and Gordon (undated).

Meek (1896) first listed mussels occurring in the St. Francis River, and Stansbery and Stein (1982) searched for populations of *Potamilus capax* and other mussels to determine effects of a chemical spill. Bates and Dennis (1983) sampled 171 sites in the St. Francis River system of Arkansas and Missouri to locate additional populations of *P. capax*. Ecosearch, Inc. (1985) listed additional sites for *P. capax* and estimated the size of the post-juvenile population for this species. Harris (1986), due to a boat ramp construction, relocated 7,825 mussels from Madison, St. Francis County, including 82 specimens of *P. capax*. In 1986, a survey sponsored by the U.S. Army Corps of Engineers (USACOE) documented the distribution and abundance of *P. capax* in the St. Francis River and Floodway from Wappapello Reservoir (RM

~250) to the mouth (Ahlstedt and Jenkinson, 1987), in which qualitative and quantitative samples were intensively collected. Additional searches for *P. capax* were conducted by Jenkinson and Ahlstedt (1988) in the St. Francis and Cache rivers, and a relocation project was conducted on a four-mile reach by Jenkinson (1989). Ahlstedt and Jenkinson (1991) summarized the results of their surveys for *Potamilus capax* in the St. Francis River and Floodway. Harris (1997) assessed the impact of dredging on *P. capax* in a section of the St. Francis River Floodway.

Wheeler (1918) first listed mussels from the Clark County portion of the Ouachita River and first reported *Arkansia wheeleri* and *Cumberlandia monodonta* in Arkansas. Since then, Harris and Gordon (1985) searched for additional specimens of *Lampsilis orbiculata* (= *L. abrupta*) and *Arkansia wheeleri* in the Ouachita River. An additional survey in the vicinity of Arkadelphia, Ark. was conducted by Harris and Gordon (1985).

Other recently conducted community surveys in Arkansas rivers have been conducted by Harris et al. (1993), Rust (1993) and Christian (1995).

THREATS TO FRESHWATER MUSSELS

Many factors threaten macroinvertebrate biodiversity of lotic systems. Allan and Flecker (1993) listed six factors that contribute to the decline of mussel diversity in lotic systems: habitat loss and degradation, exotic species invasions, secondary extinctions, chemical and organic

pollution, global and climatic change and overharvesting.

Habitat Loss and Degradation

The second law of thermodynamics, dealing with dispersal of energy, states that natural systems tend to change until a stable environment with self-regulating mechanisms has developed. Over the last century, many river systems have been altered, and the biological communities are still adjusting to these changes (Hesse and Sheets, 1993).

Some water development projects carried out over the last century rank high among historical engineering marvels. However, dams and diversion channels represent some of the greatest threats to aquatic ecosystems. Although these water projects are reputed to serve several purposes, one overriding economics (flood control, water supply, navigation) stands out in each location (Hesse and Sheets, 1993). The St. Francis River has several diversion channels constructed to aid in flood control (Ahlstedt and Jenkinson, 1987). Dams on the Ouachita River have been built to provide hydroelectric power, navigation and recreation. Further channelization to aid in navigation occurs in the main stem Ouachita River from Camden, Ouachita Co., Ark., to its mouth.

Profound alterations of channel characteristics, habitat availability and flow regime are perhaps the most fundamental changes due to the placement of impoundments on river systems. They create unnatural conditions within the basin that very few mussels can tolerate. Hypolimnetic releases below some

impoundments cause the displacement of native host fish species, and most releases result in extensive scouring of the substrate near the release.

Resident fish populations are also affected within the impoundment. Lotic species tend to disappear, while lentic species become more abundant. The disappearance of lotic fish species limits mussel reproduction by the absence of a host. Glochidial dispersal is also limited by dams acting as a barrier to fish migrations. Furthermore, as impoundments age, organic debris sinks to the bottom, and subsequent decomposition lowers the pH of the substrate, leaching away the CaCO_3 shell of mussels. These sediments also cover the bottom with a light flocculent layer that impedes the movement of water and smothers bottom dwelling organisms (Oesch, 1984).

Dredging for navigational channels and flood control leaves unstable spoil piles that eventually erode into the river to potentially cover mussel beds. Removal of substrate may cause continual erosion in the channel upstream until a stable substrate equilibrium ends the erosion (head cutting). The very act of channel dredging removes any mussel inhabiting the substrate and replaces it on spoil.

Exotic Species Invasions

The introduction and spread of nonindigenous mollusks have contributed to the demise of native freshwater mussels. The Asian Clam (*Corbicula fluminea*) was first introduced to the United States on the West Coast in the 1930's. It has

become the most widespread nonindigenous naiad in North America and can be found in aggregates of thousands per square meter where it competes with native species for space and food (Williams et al., 1993).

As recently as 1986, another nonindigenous mollusk was introduced into the Great Lake's system through the ballast of an ocean vessel. The zebra mussel (*Dreissena polymorpha*), due to its wide range of ecological tolerances, high reproductive capacity, large feeding volumes and need to attach to hard surfaces, could lead to the demise of native mussel species. Zebra mussels remove from the water column large percentages of organisms providing primary productivity, along with nutrients and minerals. By doing so, they reduce turbidity and increase light penetration which could alter the ecosystem and the existing communities (Ludyanskiy et al., 1993). Zebra mussels are known to encrust native mussels in concentrations of up to 10,000 per naiad. This encrustation has been shown to cause decreased glycogen content, increase stress and even lead to mortality in some naiad species (Haage et al., 1993).

Secondary Extinctions

Secondary extinctions may occur when the removal of one species has cascading effects throughout the species assemblage of the area, so that species unaffected by the original extinction event become rare or uncommon. Such effects are often mediated through the food web, but there are examples where the primary species affects habitat structure

in a manner that influences other members of the community (Allan and Flecker, 1993). For instance, when a fish species becomes extinct, it is no longer accessible as a glochidial host. Without the host species, reproduction ceases and the mussel becomes extinct.

Chemical and Organic Pollution

Pollution of rivers and streams has not been proven to cause the extinction of a river dwelling naiad. However, it is one of the most visible threats to the ecological health of the system and the biota found there (Allan and Flecker, 1993).

Pollution of rivers and streams can come from a point or non-point source. Point source pollution refers to a clearly defined source such as a ditch or pipe. This is the easiest type of pollution to detect but not always the easiest to control. Non-point source pollution comes from the watershed and may reach the water at any point. Non-point pollution can be erosional due to deforestation, poor agricultural practices or destruction of riparian zones. Chemical pollutants may enter a stream from pesticide overapplication. Other chemicals may also enter a system such as through spills or poor maintenance practices of petroleum powered engines (Allan and Flecker, 1993).

Global Climate Change

Effects of global climate change are the hardest of the six factors to predict. Climatic change will most likely

affect species in higher altitudes where the water will warm and the cold water fauna will be replaced by warm water fauna. The effects on the mussel species would likely involve the previously discussed secondary extinctions.

Global climate change in Arkansas will probably not be manifested as greatly as in northern states. The local Arkansas fauna is normally temperate except in areas below cold tailwater release dams where nonindigenous fish species are stocked.

Overharvesting

There appear to be no instances where overharvesting has led to the extinction of stream-dwelling taxa in the temperate zone (Allan and Flecker, 1993). Overharvesting is usually secondary to habitat destruction such as alteration of flow regime resulting in loss of stability of the ecosystem.

As evidenced from Native American middens, mussels were used as both a source of food and tools. In the mid-1850's, attention was brought to freshwater mussels when a large pearl found in a man's meal resulted in a widespread search for mussels as a source of pearls. In 1891, a German immigrant began collecting and processing mussels for buttons in the upper Mississippi River at Muscatine, Iowa (Madison, 1985). With the advent of plastics following World War II, mussels lost their value to the button industry.

The Japanese cultured pearl industry blossomed after World War II, resulting in a resurgence of mussel harvesting.

Thick mussel shells are cut into cubes, rounded in a tumbler, polished and introduced into an oyster as a nucleus for cultured pearls. Mussel shell jewelry provides a secondary market (Harris and Gordon, undated).

Japan purchased 9,000 short tons of shells from the U.S. in 1991, but over the last few years the tonnage has dropped to approximately 4,500 short tons (Williams et al., 1993). In 1995, a previously unharvested area in Bayou Macon contributed 36.3% of the Arkansas mussel harvest (AGFC, 1996). Otherwise, the number of licenses issued and harvest in Arkansas have followed this supply and demand trend (Tables 1-2).

Harvesting larger individuals from the population leaves space for younger mussels to inhabit and grow. While this is potentially beneficial, removing too many reproductive individuals from the population can lead to decreased recruitment in the population and result in a reduced genepool.

RIVERS STUDIED

St. Francis River

The St. Francis River originates in southeastern Missouri and flows southward 760 km before joining the Mississippi River near Helena, Phillips County, Arkansas. It flows through eastern Arkansas bordered on the west by Crowley's Ridge and the east by the Mississippi River (Figure 1) and drains 13,466 km² of which 10,266 km² occur in Arkansas (USGS,

Table 1. Number of commercial shell taking licenses and tons of mussel shells harvested in Arkansas from 1985-1995 (AGFC, 1996).

Year	Resident Licenses	Non-Resident Licenses	Tons Harvested	\$Value
1985	70	7	23	10,800
1986	60	6	142	99,926
1987	136	15	103	68,566
1988	151	75	223	195,150
1989*	263	64	299	330,200
1990**	687	13	1,117	1,854,220
1991**	842	2	982	1,473,063
1992	766	0	226	256,759
1993	289	0	191	278,901
1994	291	0	225	368,929
1995	106	0	1,096	2,589,782

* = Fees for non-resident licenses increased from \$50 to \$100

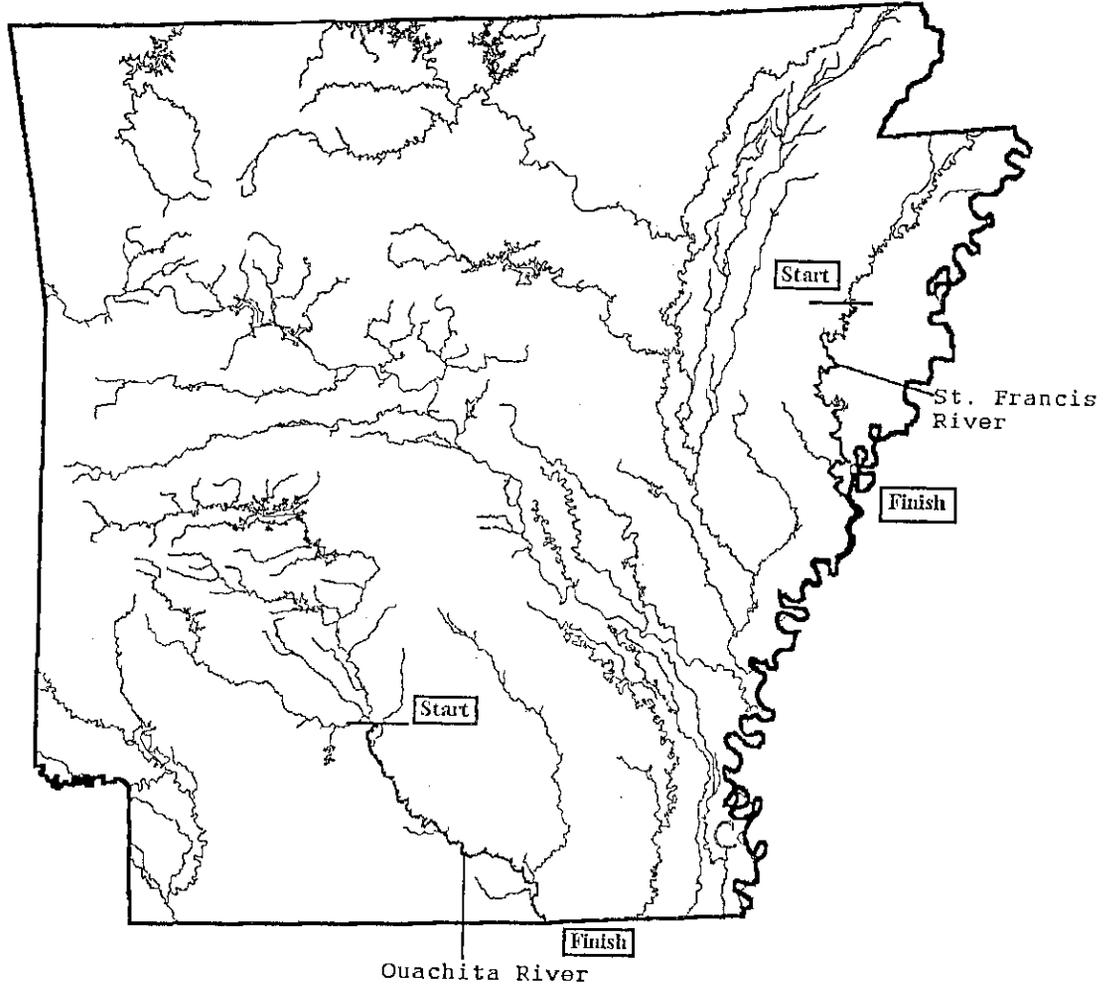
** = Non-resident harvest prohibited: non-resident buyers only.

Table 2. Mussels harvested (kg) from the St. Francis River (AGFC, 1991, 1992, 1993, 1994, 1995, 1996).

Species	1990	1991	1993	1994	1995
<i>Actinonaias ligamentina</i>	4,417	0	17	356	29
<i>Amblyma plicata</i>	143,394	139	3,902	20,308	7,484
<i>Fusconaia ebena</i>	37,191	682	39	887	5
<i>Megalonaias nervosa</i>	309,320	118,433	530	10,701	25
<i>Potamilus purpuratus</i>	25,780	25,080	102	1511	205
<i>Quadrula quadrula</i>	24,530	3,703	0	176	36
Mixed Shells	19,875	185	652	2,132	750
Total	564,507	148,222	5,242	35,071	8,534

No commercial harvest report in 1992.

Figure 1. Rivers studied in Arkansas, 1992-1996.



1972).

The river has been substantially altered by local interests and the USACOE to drain adjacent agricultural land in the extremely flat watershed. Numerous manmade water courses, such as the Oak Donnicks-St. Francis Floodway, divide the river into two separate channels from Marked Tree (RM 155) to the confluence of L'Anguille River (RM 11.45). Large siphons, located above Marked Tree, remove water from the dredged channel and place it in the natural channel. Areas above and below Marked Tree include both unmodified reaches and areas that have been straightened and dredged. Bottomland hardwood is the dominant forest type of this area, but clearing for agriculture has removed most of this timber (ADPCE, 1987). The St. Francis River study area includes 200 mainstem km (125 mi.) downstream of Marked Tree, Arkansas. Four additional sites were surveyed in the Oak-Donnicks Floodway.

Ouachita River

The Ouachita River originates in west-central Arkansas near the Oklahoma-Arkansas state line (Figure 1). The headwaters are found along the northern slope of the Ouachita Mountains. The river flows in an easterly direction for approximately 136 air km before turning southeast to enter the Tensas and Little rivers near Jonesville, Louisiana. It crosses the state line in the south central part of Arkansas (RM 221).

Total length of the river is 816 km with 510 occurring in Arkansas. There are 17,411 km² of Ouachita River watershed in Arkansas (USGS, 1979). The elevation drops from 492 m mean sea level (msl) at its origin to 15.2 m msl at the mouth. The highest gradient occurs upstream of Malvern, Ark. After flowing over rocks of the Paleozoic age above Malvern, the river leaves the Ouachita Mountain Ecoregion and enters the Gulf Coastal Plain to flow over the less resistant rock of the Cretaceous and Tertiary ages (ADPCE, 1979).

Native vegetation includes loblolly and shortleaf pines and bottomland hardwoods. Much of the natural forest has been converted to loblolly pine monoculture. Land use in the research area is primarily silviculture followed by agriculture (ADPCE, 1987).

A series of locks and dams are operated in the lower Ouachita River by the USACOE for navigational purposes. These structures provide a 3 m x 30 m navigation channel from the Red River in eastern Louisiana to Camden, Ouachita County, Arkansas. The most upstream structure, H.K. Thatcher Lock and Dam, is near Calion, Union County, Arkansas (RM 281). This structure provides a 4.0 m lift. The most downstream structure occurring in Arkansas, Felsenthal Lock and Dam, is located approximately 3.1 km upstream from Louisiana. This structure provides a 6.0 m lift for 40.6 km upstream to H.K. Thatcher L&D. The Felsenthal L&D also provides a 1.6 m fluctuating seasonal fish and wildlife pool necessary for the

management of the 289 km² Felsenthal National Wildlife Refuge (USACOE, 1987).

The research area includes the segment of the Ouachita River extending from the confluence of the Little Missouri River (RM 376) to the Louisiana state line (RM 221.6).

STATEMENT OF THE PROBLEM

Due to the benthic, somewhat sessile existence of freshwater mussels, they are exposed to many environmental factors affecting their life history. They seem to reflect the impact of habitat loss and degradation, introduction of exotic species, secondary extinctions, pollution and overharvesting in their immediate vicinity due to their benthic existence.

To date, baseline data are available for mussel assemblages in Lake Chicot (Harris et al., 1993), the Black Current, Spring and Strawberry rivers (Rust, 1993), and the White and Cache rivers (Christian, 1995). Additional data from the remaining major Arkansas streams are needed to determine community relationships and to aid in the management of this natural resource. Also, since the Ouachita River is not commercially harvested, it may provide insight into the pressures placed on mussel populations in other streams due to commercial harvesting.

Effects of harvesting legal size mussels on reproductive success are unknown. Many commercial shellers believe they are actually improving the population by harvesting.

Additional data on chronological growth are also needed to aid in the management of this natural resource.

PURPOSE OF THE STUDY

The purpose of this thesis research is to locate and define the dimensions and community structure of all commercial quality unionacean mussel beds within the St. Francis River from Marked Tree to its mouth and of all unionacean mussel beds within the Ouachita River from Tate's Bluff Access near Camden, Ouachita Co., Ark., to the Louisiana state line. Techniques have been developed for large river mussel sampling by Harris et al. (1993), Rust (1993) and Christian (1995). Collectively, the results of these studies provide a large repository of standardized data on Unionacea.

Thin section age-growth analysis will be conducted to determine the age and growth rates of the commercially important species *Megalonaias nervosa* (St. Francis River) and *Amblema plicata* (Ouachita River). Statistical analysis of inventoried beds will provide community and population density estimates. Endangered, threatened and newly reported species distributional data will be provided for management of these organisms.

CHAPTER II

METHODS AND MATERIALS

FIELD METHODS

A questionnaire was sent to every licensed shelltaker in Arkansas during 1990 to gather information on commercial mussel bed locations in Arkansas. Interviews with reputable shelltakers added specific information for mussel beds in the St. Francis River. These beds were marked on 7.5' topographic maps for field verification. Very few data are available for the Ouachita River since mussels are not commercially harvested from this river.

Mapped and unmapped habitats were searched in the field using a surface based, oil-less air compressor. Air was supplied to the diver via a hose attached to a regulator. All field equipment and personnel were transported in a 4.88 m boat powered by a 25 h.p. outboard motor.

Since collections were made under blackwater conditions, searches for mussels were conducted by a diver who would descend to the substrate and feel for embedded mussels. When an area with an estimated average density of 10 mussels/m² was encountered, either the midriver or bank side bed edge was located and a curvature bobber released to the surface. The

diver would then search laterally across the area until the number of individuals ceased to average $10/\text{m}^2$. At this point a second bobber was released, and the two bobbers marked the width of the mussel bed. The diver returned to the surface to report substrate, species composition and average densities. Locations of searches were marked on 7.5' topographic maps. Water depth (determined by a Hummingbird™ Depth Finder), river structure (bend, straight or meander), and general information from the diver were also recorded. This process was continued downstream at 50 m intervals until the densities ceased to average $10/\text{m}^2$. The length of the bed was then determined with a standardized range finder.

After the initial survey was completed, the area was categorized and sampled using one of three methods. Qualitative notes on species composition, relative abundance and densities were taken in areas with densities less than $10/\text{m}^2$. Only qualitative data were taken at these sites.

The second level of sampling intensity was for minor beds (mbeds), containing densities of 10 mussels/ m^2 or more and occupying a minimum area of 100 m^2 but less than 500 m^2 . Five 1.0 m^2 quadrats were collected non-randomly from the areas of greatest density in the bed.

The greatest level of sampling intensity was for major beds (Mbeds), containing densities of 10 mussels/ m^2 or greater in an area larger than 500 m^2 . Sample sizes for beds were determined based on bed area. Ten quadrats were taken for

beds of 500-999 m², and 25 quadrats were collected for beds of 2,500 m² or greater. Beds with areas between 1,000 m² and 2,500 m² were sampled by taking a one percent subsample of the area. If appropriate, the bed was stratified by depth, substrate or river structure (bendway or straightway). Random numbers were utilized to select Mbed sample sites, and the number of samples collected reflected the proportion of the stratum size. A minimum of two quadrats was collected from each stratum.

Divers collected mussels within a 1 m² quadrat delineated by 2.5 cm diameter PVC pipe which was weighted by sand. All mussels within the quadrat were removed from the substrate, placed into a collecting bag and transported to the surface. On the surface, mussels were identified, measured for length, width and/or depth in mm by vernier calipers, and mass was recorded in grams using an electronic balance. The measured axis reflected the "legal dimension" for a particular mussel species (Table 3). Ten percent of the St. Francis River *Megalonaias nervosa* and Ouachita River *Amblema plicata* individuals encountered were measured by length, depth, width and mass. After measurement, all mussels were returned to the substrate. All endangered species were individually replaced in the substrate in life position. Data were recorded on data sheets in the field and entered into a Lotus 123™ spreadsheet.

STATISTICAL TREATMENT

Summary statistics of collected data were calculated

Table 3. Legal dimensions for commercial species (mm) in Arkansas, and parameters measured for all species. Equivalent inch measurements are shown parenthetically.

Species	Parameter	Minimum legal size
<i>Actinonaias ligamentina</i>	length	101.6 (4.00)
<i>Amblema plicata</i> *	length	
	depth	69.8 (2.75)
	width	
<i>Arcidens confragosus</i>	length	NC
<i>Cyprogenia aberti</i>	depth	NC
<i>Ellipsaria lineolata</i>	depth	63.5 (2.50)
<i>Elliptio dilatata</i>	length	101.6 (4.00)
<i>Fusconaia</i> spp.	depth	63.5 (2.50)
<i>Lampsilis abrupta</i> **	length	
	depth	ES
	width	
<i>Lampsilis cardium</i>	length	NC
<i>Lampsilis hydiana</i>	length	NC
<i>Lampsilis teres</i>	length	101.6 (4.00)
<i>Lasmigona costata</i>	length	NC
<i>Lasmigona complanata</i>	length	NC
<i>Leptodea fragilis</i>	length	NC
<i>Ligumia recta</i>	length	101.6 (4.00)
<i>Megalonaias nervosa</i> *	length	
	depth	95.2 (3.75)
	width	
<i>Obliquaria reflexa</i>	depth	63.5 (2.50)
<i>Obovaria</i> spp.	depth	63.5 (2.50)
<i>Plectomerus dombeyanus</i>	length	101.6 (4.00)
<i>Pleurobema</i> spp.	depth	63.5 (2.50)
<i>Potamilus ohioensis</i>	length	NC
<i>Potamilus purpuratus</i>	length	101.6 (4.00)
<i>Ptychobranchus occidentalis</i>	length	NC
<i>Pyganodon grandis</i>	length	NC
<i>Quadrula cylindrica</i>	length	101.6 (4.00)
<i>Quadrula metanevra</i>	depth	63.5 (2.50)
<i>Quadrula nodulata</i>	depth	63.5 (2.50)
<i>Quadrula pustulosa</i>	depth	63.5 (2.50)
<i>Quadrula quadrula</i>	depth	69.8 (2.75)
<i>Strophitus undulatus</i>	length	NC
<i>Tritogonia verrucosa</i>	length	101.6 (4.00)
<i>Truncilla</i> spp.	depth	NC

* = Collected for age/growth analysis

** = Same measurements for *Arkansia wheeleri* and *Quadrula fragosa*

ES = Endangered species

NC = No commercial value

using a program developed in a Lotus 123™ spreadsheet. Total individuals, minimum, maximum and mean density, variance and standard deviation were calculated for each species and each quadrat sampled in each bed.

Species diversities were calculated at base 2 logarithm using the AQUATIC ECOLOGY-PC program of Oak Leaf Systems, Decorah, IA. Simpson's Index of Diversity calculates the probability of randomly selecting pairs of individuals that must be drawn from a community in order to have an even chance of obtaining a pair with both individuals of the same species. The index increases from a value of 1.0 for a community containing only one species to an infinite number in which every individual belongs to a different species. A Shannon-Weiner Diversity Index describes the average degree of uncertainty of predicting the species of a given individual picked at random from a community. This uncertainty increases both as the number of species increases and as the individuals are distributed more and more equitably among the species already present (Cox, 1980).

Population and community estimates were calculated according to Sampford (1962) as modified by Huebner et al. (1990) which is summarized below. The total number of mussels is:

$$[1] X = \sum_0^i y_i * g_i$$

where X is the total number of mussels in a bed, i is the number of strata, y_i is the sample total (total number of organisms encountered in all the n_i sampling units) and g_i is the raising factor ($g_i = 1/f_i$, where f_i is the fraction sampled, and is defined by n_i/N_i with n_i being the number of sampling units counted in the i th stratum, and N_i the total potential number of sampling units in the i th stratum).

The 95% confidence interval (CI) around the total number of mussels in a bed is given by:

$$[2] \quad X \pm \left(t * \sqrt{\sum_0^i N_i^2 * S^2 y_i * \frac{1-f_i}{n_i}} \right)$$

where $S^2 y_i$ is the sample variance computed from raw counts in the n_i sampling units in the i th stratum, and t is the Student's t for the effective degrees of freedom (Huebner et al., 1990).

One-way analysis of variance (ANOVA), calculated using Quattro Pro™, was used to analyze mean dimensions of selected species from each river. Comparisons were made between regions of the St. Francis and Ouachita rivers to determine if mean dimensions varied significantly.

The Tukey-Kramer Procedure was used to determine significantly different mean dimensions between individual segments (Sokal and Rohlf, 1981). The mean variance (MS_{within}) is calculated by:

$$[3] MS_{within} = \sum (n_i - 1) (S^2)$$

where n_i is the number of individuals per segment and S^2 is the variance of each segment squared. This product is divided by:

$$[4] \sum (n_i - 1)$$

to determine the MS_{within} .

The standard error among means (SE_{ij}) is determined by:

$$[5] SE_{ij} = \sqrt{\frac{MS_{within} \left(\frac{1}{n_i} + \frac{1}{n_j} \right)}{2}}$$

where MS_{within} is the mean variance from all segments and n_i and n_j are the number of individuals in the segment. The SE_{ij} is then compared to the absolute value of means of i and j .

CURATION

Voucher specimens, representing each species encountered per river, were collected for curation into the Arkansas State University Museum of Zoology-Unionacea Collection. Live mussels were fixed in 10% formalin and later moved to 40% isopropyl alcohol.

A catalog number was assigned to each specimen in the laboratory. The information from each specimen was entered into the Unionacea Catalog and later transferred to a Dbase IV file. The visceral mass was then removed from the valves, affixed with a water-proof tag including catalog number, date and location, and placed in a punctured Ziploc™ bag.

The paired valves were assigned a catalog number corresponding with that of their associated visceral mass. The valves were then washed in soap and water, often using a wire or nylon brush, and then rinsed. A rapidograph pen with permanent ink was used to label valves with catalog number, date and location. Valves were then dipped in a xylene/paraffin solution, air dried and placed by numerical sequence in museum cabinets.

AGE DETERMINATION

Forty-eight *Megalonaias nervosa* and 50 *Amblema plicata* specimens were collected for age determination from the St. Francis and Ouachita rivers, respectively. An attempt was made to collect all age classes present. A modified version of thin sectioning was implemented for age determination (Neves and Moyer, 1988).

Thin sections were cut using a Felker Geological saw equipped with a diamond composite blade. A cut was made from the umbo along the vector of maximum growth. A second parallel cut was then made, leaving a 2.0 cm slice. The side cut first was hand polished with 400 grit aluminum oxide to remove irregularities left by the blade. This side was then fixed to a frosted, 27 mm x 46 mm, petrographic slide with Loctite Ultraviolet adhesive. Slices longer than 46 mm were cut between exiting annuli to allow mounting on separate slides, with each piece occupying a single slide. After placing slices on a slide with adhesive, the adhesive was hard

cured using a U-V light source (350-380 nm) for 20 minutes. Slides were marked with a diamond-tipped scribe for organization.

After the adhesive was cured, the slices were cut to a workable size on an Ingram Thin-section saw equipped with a petrographic vacuum chuck. The slice was thinned to a thickness of 200-380 microns on an Ingram Grinder, also equipped with a petrographic vacuum chuck.

Each slide was hand polished with 400 then 600 grit aluminum oxide until the grinder marks were removed. Slides were then polished in a Minimet® 1000 Grinder/Polisher equipped with thin section attachment. Each slide was polished with Metadi II® pastes of 6 micron and 4 micron diamond polish, then 0.3 micron alpha alumina Miropolish®, in that sequence.

All slides were viewed under a compound microscope, and each annulus was counted as it exited the outer periostracum. Thin section results were compared to external annuli.

Depth and age determinations were paired, and correlation coefficients (r) were calculated for all specimens. The correlation coefficient indicates the type of linear relationship (positive or negative) and the strength of the relationship. The correlation coefficient used is defined as the following:

$$[4] \quad r = \frac{n\sum XY - (\sum X)(\sum Y)}{[\sqrt{n\sum X^2 - (\sum X)^2}][\sqrt{n\sum Y^2 - (\sum Y)^2}]}$$

where n is the number of individuals thin sectioned, X is the depth in mm and Y is the age in years. This correlation coefficient (r) was then squared to determine the amount of explained versus unexplained variability (Witte, 1993).

The least squares prediction equation was used to predict the age at minimum legal harvest size for the species selected. It was defined by the following equation:

$$[5] Y' = bX + a$$

Where Y' represents the predicted value; X represents the minimum legal harvestable size. In solving for "b", the following equation was used:

$$[6] b = \frac{S_y}{S_x}(r)$$

where S_y represents the standard deviation for all observations along Y ; and S_x represents the standard deviation for all observations along X . The equation for "a" was:

$$[7] a = \bar{Y} - b\bar{X}$$

where \bar{Y} and \bar{X} referred to the means for all observations along Y and X . The standard error of prediction ($S_{y/x}$), which is a rough measure of the average amount of predictive error, was determined using the following equation:

$$[8] S_{x|y} = S_y\sqrt{1 - (r)^2}$$

and the predictive error value was expressed in terms of \pm to Y' ($Y' \pm S_{y/x}$) (Witte, 1993).

STUDY AREA

St. Francis River

The lower 200 km were surveyed on the St. Francis River from Marked Tree, Cross Co., Arkansas, to the confluence with the Mississippi River near Helena, Phillips Co., Arkansas (Figure 1). Field work was conducted in May and June 1993 and required 40 person-days to complete.

Ouachita River

Research on the Ouachita River was conducted on the lower 248 km occurring in Arkansas (Figure 1). Permission was granted by the U.S. Fish and Wildlife Service to survey that portion within the Felsenthal National Wildlife Refuge.

Research began in October 1992 and was finally completed in September 1995. A total of 236 person days was required to complete the Ouachita River Mussel Survey.

CHAPTER III

COMMUNITY COMPOSITION

With so many anthropogenic factors negatively impacting freshwater mussels, community composition data are vital to properly manage this resource. Extensive data are not available for the St. Francis River, and Ouachita River data are few. Extensive harvest pressure during the early 1990's and a concomitant deterioration of habitat for mussels make these data particularly important.

ST. FRANCIS RIVER

Results

Interviews with commercial shelltakers combined with data by Jenkinson and Ahlstedt (1988) identified 63 sites for field reconnaissance in the survey area. Of the 63 potential sites, four Mbeds and six mbeds were defined (Figure 2), from which 22 species were collected (Table 4). *Strophitus undulatus* was collected only during qualitative surveys while *Cyprogenia aberti* and *Lampsilis cardium* were collected as relics only.

Most beds began at the head of a lateral scour pool (bend) where the area upstream was usually covered in deep layers of silt and lacked mussel life (Figure 3). At the upper part of the lateral scour pool, the current velocity increased, removing the thick silt layer, leaving a more

Figure 2. Location of mussel beds in the St. Francis River, Arkansas.

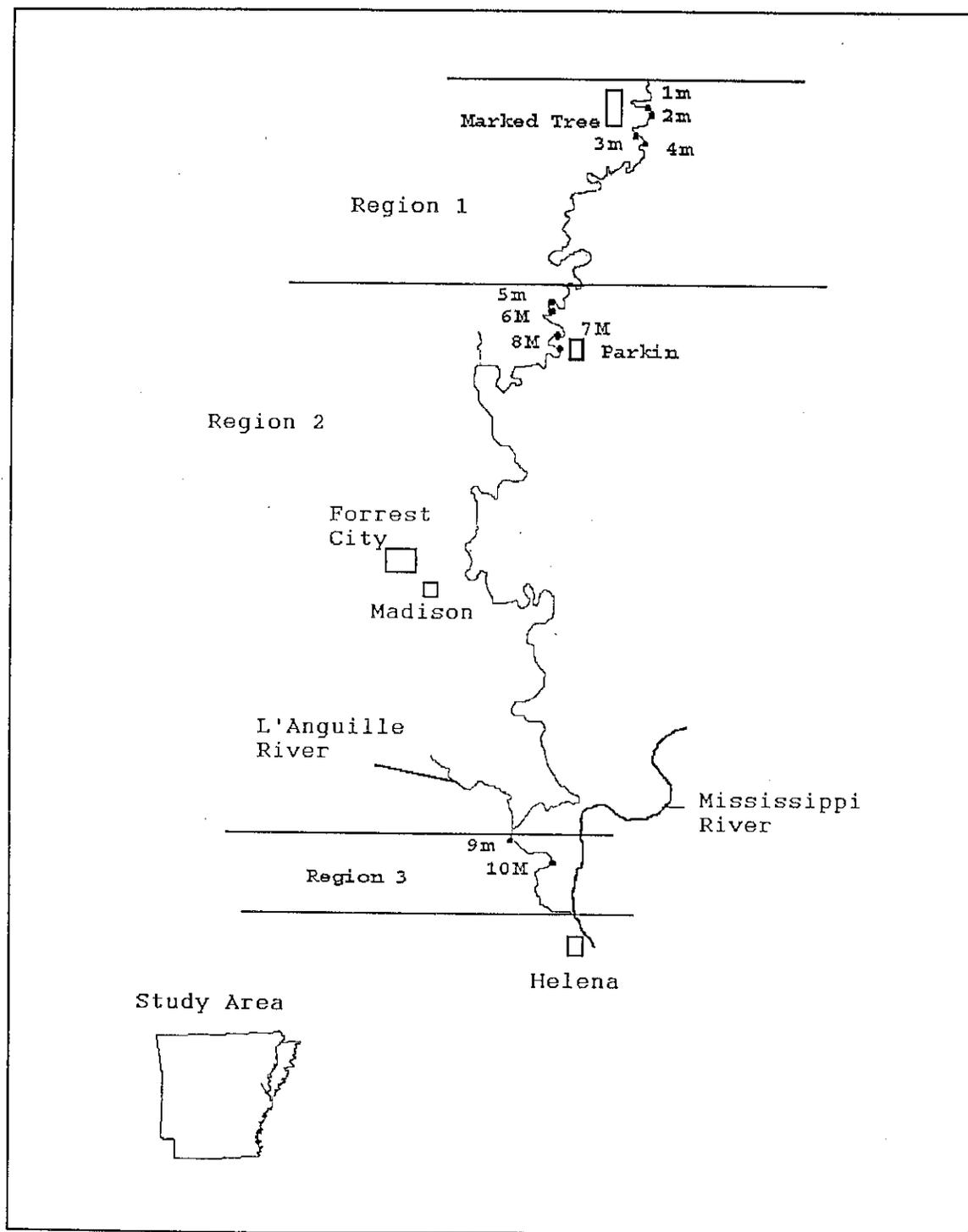
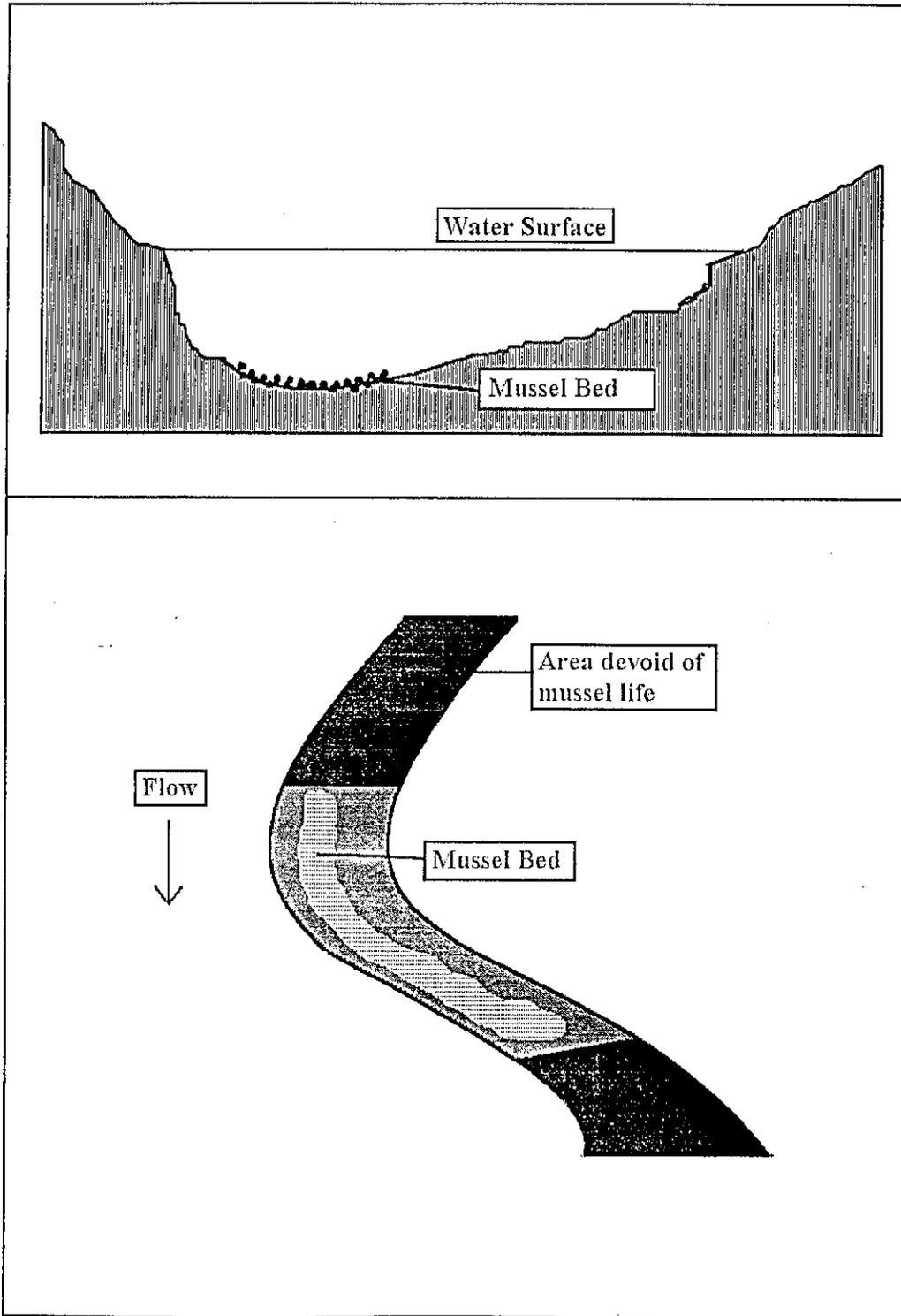


Table 4. Species collected and frequency of bed occurrence for St. Francis River mussels.

Species	mbeds (6)	Mbeds (4)
<i>Amblema plicata</i>	6	4
<i>Arcidens confragosus</i>	1	2
<i>Ellipsaria lineolata</i>	0	2
<i>Fusconaia ebena</i>	1	4
<i>Fusconaia flava</i>	3	3
<i>Lampsilis teres</i>	1	0
<i>Lasmigona complanata</i>	2	2
<i>Leptodea fragilis</i>	5	2
<i>Megalonaias nervosa</i>	5	4
<i>Obliquaria reflexa</i>	5	4
<i>Plectomerus dombeyanus</i>	1	3
<i>Pleurobema coccineum</i>	0	2
<i>Pleurobema pyramidatum</i>	1	2
<i>Potamilus purpuratus</i>	4	3
<i>Pyganodon grandis</i>	2	0
<i>Quadrula metanevra</i>	0	3
<i>Quadrula nodulata</i>	4	4
<i>Quadrula pustulosa</i>	6	3
<i>Quadrula quadrula</i>	6	4
<i>Tritogonia verrucosa</i>	5	3
<i>Truncilla donaciformis</i>	0	2
<i>Truncilla truncata</i>	1	3
Total	18	20
Total for river		22

() = Number of defined beds.

Figure 3. General location of mussel beds in a river channel.



stable substrate in the deepest part of the channel (thalweg) such as clay or gravel. The width of the thalweg increased and current decreased as the lateral scour pool transcended into a run.

Major Beds

A total of 1,039 mussels was collected from 54 quadrats yielding 20 species. Mean densities for four Mbeds ranged from 6.1-24.4 mussels/m², while the mean for all samples was 19.2 mussels/m² with a standard deviation of 16.0. *Amblema plicata* was the dominant species, comprising 42.2% of all mussels collected. *Quadrula pustulosa* (24.2%) and *Quadrula quadrula* (13.1%) also constituted a large portion of the community. *Ellipsaria lineolata*, *Quadrula metanevra* and *Truncilla donaciformis* were found only in Mbeds. Data for each major bed are summarized in Appendix 1.1.

Minor Beds

A total of 483 mussels was collected from 30 quadrats. Mean densities for six mbeds ranged from 9.2-21.8 mussels/m², while the mean for all samples was 16.1 mussels/m² (SD=22.7). A total of 18 species was collected (Table 4), with *Amblema plicata* comprising 31.1% and dominating all species (Table 5). The second most abundant species was *Quadrula pustulosa* (26.7%), and *Quadrula quadrula* was third most numerous with 23.2%. The other 15 species combined to comprise the remaining 19.0% of all mussels sampled from mbeds. Data for each minor bed are summarized in Appendix 1.2.

Table 5. Relative abundance, in percent of total, of selected mussel species from St. Francis River mbeds.

Species	Region			$\Sigma \bar{X}$
	1	2	3	
<i>Amblema plicata</i>	37.1 (118)	44.0 (430)	13.1 (8)	31.0 (556)
<i>Quadrula pustulosa</i>	33.0 (105)	25.7 (251)	**	26.7 (356)
<i>Quadrula quadrula</i>	6.0 (19)	9.6 (94)	68.9 (42)	23.2 (155)
<i>Megalonaias nervosa</i>	6.5 (5)	3.2 (35)	11.5 (7)	2.1 (47)
<i>Pleurobema pyramidatum</i>	1.6 (5)	3.6 (35)	**	1.4 (40)
<i>Leptodea fragilis</i>	8.2 (26)	1.7 (18)	**	5.6 (44)
Others	7.6 (40)	8.3 (5)	2.8 (3)	10.0 (48)
Total***	100.0 (318)	100.0 (868)	100.0 (60)	100.0 (1246)

** = Species not found in this region

*** = Includes all species.

() = Number of collected individuals.

Regions

The 200 km study area of the St. Francis River was divided into three regions due to the aggregation of mussel beds into three distinct areas designated as 1, 2 and 3 in a downstream sequence.

Region 1

Region 1 originates at Marked Tree (RM 125) and extends downstream to Woods Bend (RM 100). This region contains four mbeds (67% of the total for this river) but no Mbeds.

Minor Beds

The mbeds ranged in size from 200-400 m² with a mean of 280 m². Twenty quadrats were collected yielding 318 mussels representing 18 species. The number of species/bed ranged from 10-12. Mean densities ranged from 9.0-28.0 mussels/m² with a mean density of 15.6 mussels/m². Substrates were silt to soft clay.

Amblema plicata was the most abundant species, contributing 37.1% of all mussels collected in Region 1, and was dominant in 50% of the mbeds. *Quadrula pustulosa* was the second most abundant species at 33.0%. This percentage was slightly higher in this region than for its overall abundance in mbeds (Table 5). *Leptodea fragilis* was the third most abundant species, comprised 8.2% of all mussels collected and was dominant in 25% of all mbeds in this region. Shannon-Weiner Diversity Index values ranged from 1.897-2.900 (Table 6).

Table 6. Ecological indices for M- and mbeds of the St. Francis River.

Bed	Simpson Diversity	Simpson Dominance	Shannon Diversity	Hmax'	Evenness
Mbeds					
6M	0.806	0.194	2.923	4.00	0.731
7M	0.682	0.318	2.295	4.00	0.574
8M	0.691	0.309	2.342	4.169	0.562
10M	0.502	0.498	1.501	2.807	0.535
mbeds					
1m	0.563	0.437	1.897	3.322	0.571
2m	0.849	0.151	2.900	3.458	0.839
3m	0.630	0.370	2.053	3.584	0.573
4m	0.694	0.306	2.196	3.322	0.661
5m	0.708	0.292	2.202	3.322	0.663
9m	0.276	0.724	0.910	2.584	0.352

Region 2

Region 2 extends from Woods Bend (RM 100) to Huxtable Dam (RM 11.5), near the confluence with L'Anguille River. Three Mbeds and one mbed were found in this region of the river (Figure 2). The substrates were similar to those of Region 1 except in the area affected by Huxtable Dam where the substrate consisted of silt over 75 cm thick.

A total of 50 quadrats was collected, yielding 1,038 mussels representing 20 species. *Amblema plicata* was the most abundant species, representing 43.7% of all mussels collected. *Quadrula pustulosa* was the second most abundant species at 26.3% and was followed in abundance by *Quadrula quadrula* at 9.4%. Estimated community numerical standing crop ranged from 14,100-53,198 mussels/m². Shannon-Weiner Diversity Index values ranged from 2.295-2.923 (Table 6).

Major Beds

A total of 978 mussels representing 20 species was collected from 45 quadrats. Individual densities ranged from 1.0-79.0 mussels/m², while mean densities ranged from 20.1-24.4 mussels/m² with an overall mean of 21.7 mussels/m². The number of species per bed ranged from 16-18. Total area of beds ranged from 600 to 2700 m², and substrate particle sizes ranged from sand to soft clay.

Amblema plicata was the dominant species in Region 2, comprised 44.0% of all mussels collected, and was dominant in 66.7% of the beds (Table 7). *Quadrula pustulosa* was the

Table 7. Relative abundance, in percent of total, of selected mussel species from St. Francis River Mbeds.

Species	Region			Total
	1	2	3	
<i>Amblema plicata</i>	*	44.0 (430)	13.1 (8)	42.2 (438)
<i>Quadrula pustulosa</i>	*	25.7 (251)	**	24.2 (251)
<i>Quadrula quadrula</i>	*	9.6 (94)	68.9 (42)	13.1 (136)
<i>Megalonaias nervosa</i>	*	3.2 (35)	11.5 (7)	3.6 (42)
<i>Pleurobema pyramidatum</i>	*	3.6 (35)	**	3.4 (35)
<i>Leptodea fragilis</i>	*	1.8 (18)	**	1.7 (18)
Others (14 species)	*	11.7 (115)	5.0 (3)	11.8 (118)
Total	*	100.0 (978)	100.0 (60)	100.0 (1039)

* = No major beds in Region 1

** = Species not found in this region

() = Number of individuals

second most abundant species, comprised 25.7% of all unionids collected and was dominant in 33.3% of the beds. *Quadrula quadrula* and *Pleurobema pyramidatum* were also present, comprising 9.6% and 3.6%, respectively.

Minor Beds

Sampling one mbed yielded 60 mussels representing 10 species. The substrate was sand at center channel, transitioning to soft clay at the bank. Individual densities ranged from 7.0-18.0 mussels/m² with a mean of 12.0 mussels/m². The dominant species, *Amblema plicata*, comprised 40.0% of all mussels collected in this bed. *Quadrula pustulosa* comprised 36.7% of all mussels collected while *Quadrula quadrula* comprised 6.7% of all mussels collected (Table 5).

Region 3

This region extends from Huxtable Dam (RM 11.5) to its confluence with the Mississippi River (MRM 670.0) near Helena, Phillips County, Arkansas (Figure 2). The substrate consisted of hard packed clay, shifting sand and silt.

One Mbed and one mbed were defined and sampled (Figure 5). A total of 15 quadrats was collected, yielding 165 mussels representing nine species. *Quadrula quadrula* was the most abundant taxon collected, comprised 78.9% of all mussels collected, and was dominant in both beds. This dominance was much higher for Region 3 than for its overall abundance. *Amblema plicata* comprised 9.6% of all unionids collected followed by *Megalonaias nervosa* at 6.0%. Shannon-Weiner

Diversity Indices were 1.501 and 0.910 for beds 10M and 9m, respectively (Table 6).

Major Bed

One Mbed was found, at Egg Bar Bend (RM 6.0). A total of 60 mussels representing seven species was collected from 10 quadrats in the 900 m² bed. *Quadrula quadrula* was the dominant taxon in this bed and comprised 68.9% of all mussels collected (Table 7). *Amblema plicata* was second in abundance and comprised 13.1% of all mussels collected. Individual densities ranged from 0.0-13.0 mussels/m² with an overall mean of 6.0 mussels/m². The substrate consisted of soft clay over hard-packed clay.

Minor Bed

One mbed was found, approximately 50m below the confluence of L'Anguille and St. Francis rivers (RM 11.45). Five quadrats were collected from the 240 m² bed yielding 105 individuals of seven species. *Quadrula quadrula* was the dominant species, comprising 84.8% of all mussels sampled in this bed. *Amblema plicata* was the second most abundant species (7.6%) of all unionids collected. *Megalonaias nervosa* comprised 2.9% and was the third most abundant species. The five remaining species comprised the remaining 4.7%.

Endangered Species

Although the endangered *Potamilus capax* is well documented within the St. Francis River, no living or relic specimens were encountered during this investigation.

Ahlstedt and Jenkinson (1987) found this species at 24 sites. They concluded that this species is found in man-made portions of the river but is absent from its natural portions. Most of the research area in this study was in the natural reaches of the river.

Discussion

Community parameters for the St. Francis River are difficult to compare and discuss due to the small number of major and minor beds. The low number may be associated with the intense harvest pressure placed on these organisms. Local game wardens have observed tractor trailers loaded with harvested mussels leaving one boat landing during extreme harvest times. Another factor may be extensive channel alterations that this part of the river has undergone. Finally, it is possible that the slower current velocities and increased silt load may have eradicated habitats suitable for a wide variety of species (Stansbery and Stein, 1982).

Mussel beds in Regions 1 and 2 were aggregated into the least modified areas. The substrate varied little longitudinally in Region 1 and upper portion of Region 2. The substrate in the lower region of Region 2 was too unstable to support dense mussel colonies due to the impoundment formed by Huxtable Dam. Loose aggregates of sub-legal sized *Quadrula quadrula* were located in the reaches immediately above the dam where historically mussel beds have occurred (K.C. Ward, pers. comm.)

Amblema plicata, the dominant species of the St. Francis River, is a generalist and is found in small to large rivers with various types of substrates. It has a wide range of ecological tolerances and glochidial hosts.

Quadrula pustulosa, the second most abundant species in the river, is a generalist and inhabits a wide variety of substrates and current velocities. *Quadrula quadrula* is most often found in large streams and rivers. Its glochidial host is *Pylodictis olivaris* and is often the dominant species in substrates consisting of deep silt found in some lacustrine systems (Parmalee, 1967). Its dominance in Region 3 is probably due to the unstable hydrology found in this region as well as the substrate.

Very few live *Plectomerus dombeyanus* were collected in this study, and this was also reported by Stansbery and Stein (1982) and Ahlstedt and Jenkinson (1991). Many dead *P. dombeyanus* were found in Regions 1 and 2, evidence that this river once supported a larger population of this species. The demise of this species may be related to the unstable hydrology of the river. Often, relic *P. dombeyanus* were found on the ascending near bank of a lateral scour pool where they may have been stranded during low flow and died or may have succumbed to vertebrate predation.

OUACHITA RIVER

Results

A total of 61 mussel beds was located within the

Ouachita River study area. Of these, 45 (73.8%) were Mbeds and 16 (26.2%) were mbeds.

A total of 868 quadrats was collected, yielding 23,463 mussels representing 34 species (Table 8). Three additional species, *Cumberlandia monodonta*, *Toxolasma texasensis* and *Utterbackia imbecillis*, were encountered during qualitative analysis. Two species collected during the survey were identified by Dr. David Stansbery of Ohio State University as *Quadrula apiculata* and the endangered *Quadrula fragosa*. While *Q. apiculata* was recorded for this river by Wheeler (1918) near Arkadelphia, it has not been recorded since. *Quadrula fragosa* is a new state record and a substantial southern range extension.

Amblema plicata was the most abundant taxon in the Ouachita River, composed 18.1% of all mussels collected and was present in every bed. *Pleurobema pyramidatum* (16.0%) was the second most abundant species followed by *Fusconaia ebena* (14.1%), *Quadrula pustulosa* (14.1%) and *Fusconaia flava* (10.8%). Of the 38 species collected, *Lasmigona costata*, *Potamilus ohioensis*, *Ligumia recta*, *Alasmidonta marginata* and the endangered *Arkansia wheeleri* were represented by single individuals.

Major Beds

Quadrat sampling yielded 21,457 mussels representing 32 species from 788 quadrats. Mean densities were 11.3-52.9 mussels/m² with an overall mean density of 27.2 mussels/m².

Table 8. Species collected and frequency of bed occurrence for Ouachita River mussels.

Species	Minor (16)	Major (45)
<i>Actinonaias ligamentina</i>	7	25
<i>Amblema plicata</i>	16	45
<i>Arcidens confragosus</i>	1	2
<i>Arkansia wheeleri</i>	0	1
<i>Cyprogenia aberti</i>	1	4
<i>Ellipsaria lineolata</i>	7	26
<i>Elliptio dilatata</i>	7	21
<i>Fusconaia ebena</i>	13	45
<i>Fusconaia flava</i>	11	45
<i>Lampsilis abrupta</i>	1	7
<i>Lampsilis cardium</i>	7	42
<i>Lampsilis hydiana</i>	1	9
<i>Lampsilis teres</i>	2	13
<i>Lasmigona costata</i>	0	1
<i>Leptodea fragilis</i>	2	30
<i>Ligumia recta</i>	1	0
<i>Megalonaias nervosa</i>	14	44
<i>Obliquaria reflexa</i>	14	44
<i>Obovaria</i> sp.	1	12
<i>Plectomerus dombeyanus</i>	13	45
<i>Pleurobema pyramidatum</i> *	9	36
<i>Potamilus ohioensis</i>	1	0
<i>Potamilus purpuratus</i>	6	39
<i>Ptychobranchus occidentalis</i>	2	13
<i>Pyganodon grandis</i>	1	2
<i>Quadrula cylindrica</i>	1	5
<i>Quadrula metanevra</i>	5	24
<i>Quadrula nodulata</i>	4	23
<i>Quadrula pustulosa</i>	6	45
<i>Quadrula quadrula</i>	10	42
<i>Strophitus undulatus</i>	5	17
<i>Tritogonia verrucosa</i>	7	42
<i>Truncilla donaciformis</i>	1	18
<i>Truncilla truncata</i>	10	33
Total Species	32	32
Total species for river		34

() = Number defined by beds.

* = series complex containing possibly more than one species (Stansbery, pers. comm.)

Amblema plicata was numerically dominant, comprising 17.0% of all mussels collected (Table 9). This dominance was slightly lower for Mbeds than for all beds. *Pleurobema pyramidatum* (16.1%) was the second most abundant species, followed by *Fusconaia ebena* (14.5%) and *Quadrula pustulosa* (14.5%). Bed areas ranged from 600-11,000 m² and occupied a variety of substrates including pure gravel to sand and gravel.

Minor Beds

A total of 2,006 mussels representing 32 species was collected from 80 quadrats. Mean densities for mbeds were 10.2-75.6 mussels/m² with an overall mean of 25.1 mussels/m². The greatest density recorded from an individual sample was 155.0 mussels/m². Again, *Amblema plicata* was found numerically dominant, comprising 29.7% of all mussels collected (Table 10). Also abundant were *Pleurobema pyramidatum*, *Fusconaia flava* and *F. ebena* at 15.0%, 10.4%, and 10.0%, respectively. Bed areas ranged from 150-480 m² with substrates similar to those of Mbeds.

The 249 km research area was divided into Regions 1-4 based on community composition, river characteristics and other abiotic factors. The Lower Ouachita River Work Group (LORWG) (1993) divided the river into eight segments to compare physicochemical parameters, toxicity and other biological factors among segments. The regions covered by this research include LORWG Segments 4-8. LORWG segments 4, 5 and 6 are equivalent to Regions 1, 2 and 3 and LORWG

Table 9. Relative abundance, in percent of total, of selected mussel species from Ouachita River Mbeds.

Species	Region				Total
	1	2	3	4	
A. p.*	7.1 (278)	7.1 (575)	34.6 (331)	29.7 (2467)	17.0 (3651)
F. e.*	2.7 (106)	11.4 (932)	31.3 (299)	21.4 (1781)	14.5 (3118)
F. f.*	14.2 (562)	15.0 (1223)	4.0 (38)	5.9 (492)	10.8 (2315)
P. p.*	32.8 (1294)	26.1 (2125)	0.8 (8)	0.2 (18)	16.1 (3445)
Q. p.*	14.4 (567)	14.4 (1173)	7.4 (71)	15.7 (1302)	14.5 (3113)
Others	28.8 (1143)	26.0 (2119)	21.9 (209)	27.1 (2258)	27.1 (5729)
Total	100.0 (3950)	100.0 (8147)	100.0 (956)	100.0 (8318)	100.0 (21371)

A. p.* = *Amblyma plicata*

F. e. = *Fusconaia ebena*

F. f. = *Fusconaia flava*

P. p. = *Pleurobema pyramidatum*

Q. p. = *Quadrula pustulosa*

Table 10. Relative abundance, in percent of total, of selected mussel species from Ouachita River mbeds.

Species	Region				Total
	1	2	3	4	
A. p.*	5.1 (45)	14.3 (9)	48.5 (204)	52.9 (337)	29.7 (595)
F. e.*	7.3 (65)	0.0 (0)	1.9 (8)	19.9 (127)	10.0 (200)
F. f.*	20.3 (180)	1.6 (1)	0.7 (3)	3.8 (24)	10.4 (208)
P. p.*	33.9 (300)	0.0 (0)	0.0 (0)	0.0 (0)	15.0 (300)
Q. p.*	8.8 (78)	15.9 (10)	13.1 (55)	3.5 (22)	9.6 (165)
Others	24.5 (217)	68.2 (43)	35.9 (151)	19.9 (127)	25.5 (538)
Total	99.9 (885)	100.0 (63)	100.1 (421)	100.0 (637)	100.2 (2006)

A. p.* = *Amblyma plicata*
 F. e. = *Fusconaia ebena*
 F. f. = *Fusconaia flava*
 P. p. = *Pleurobema pyramidatum*
 Q. p. = *Quadrula pustulosa*

segments 7 and 8 are equivalent to Region 4.

Regions

Region 1, beginning at the confluence of the Little Missouri River and continuing downstream to Camden, Ark., has a total length of 51.2 km and a mean gradient of 0.2 m/km. This region is not currently maintained by the USACOE for navigation.

Region 2 begins at Camden, Ark. and continues downstream to Smackover Creek near Calion, Ark. This region is 73.3 km in length and Camden is the upper limit of navigation maintenance by the USACOE. The mean gradient is 0.04 m/km.

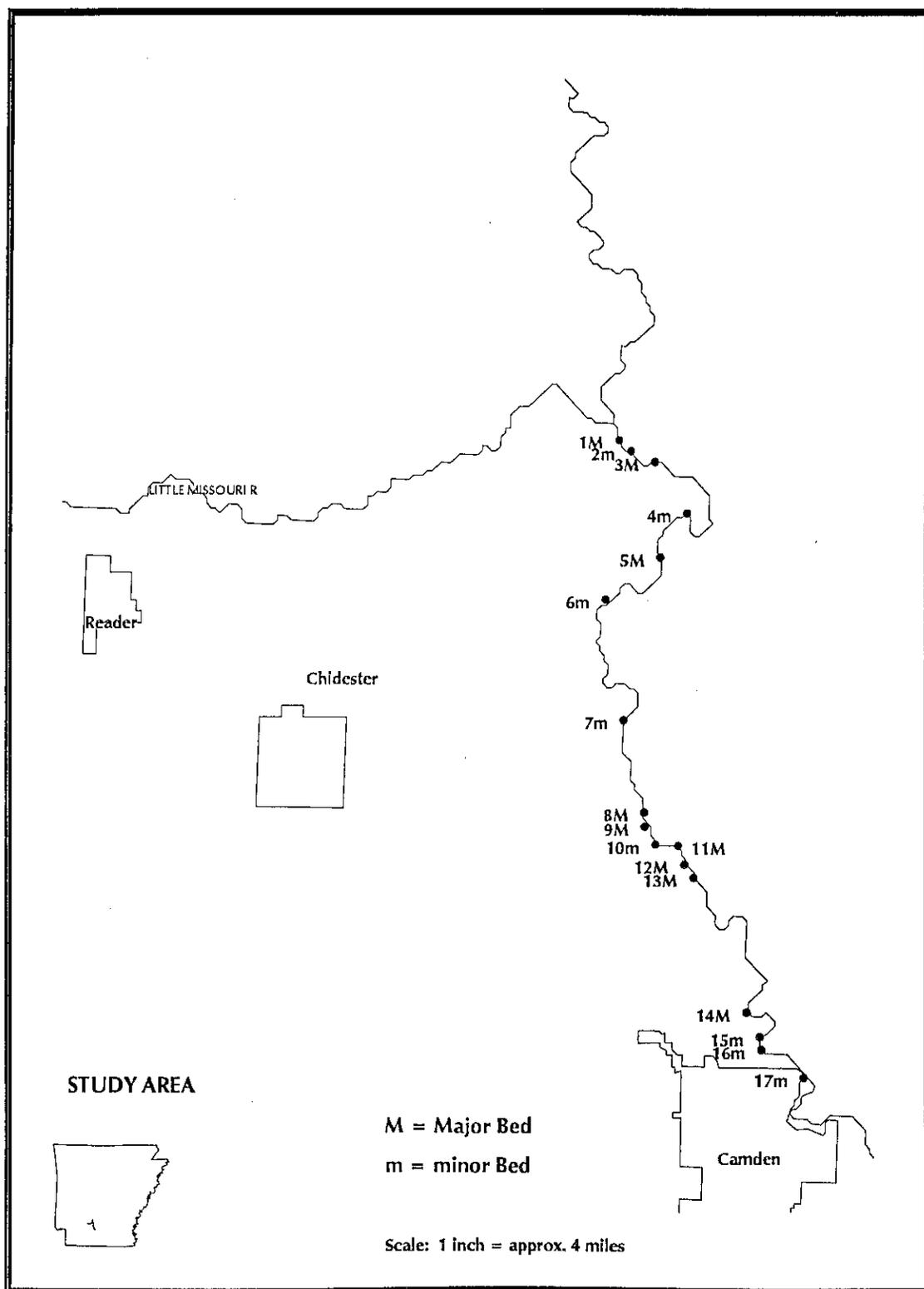
Region 3 continues from Smackover Creek downstream to the upper portion of Felsenthal Lake and includes 70.7 river km which are flooded periodically to help manage the 162.5 km² Felsenthal National Wildlife Refuge. The mean gradient is 0.06 m/km.

Region 4 encompasses Felsenthal National Wildlife Refuge and the 7.8 river km below Felsenthal Lock and Dam to the state line. The 162.5 km² refuge is periodically flooded for water fowl management. This region contains 53.8 river km with a mean gradient of 0.07 m/km.

Region 1

Seventeen beds were delineated in Region 1 (Figure 4). A total of 4,835 mussels representing 31 species was collected from 185 quadrats.

Figure 4. Location of mussel beds in Region 1, Ouachita River, Arkansas.



Major Beds

Ten Mbeds were located and sampled within this region. A total of 3,950 mussels representing 31 species was collected from 153 quadrats. Species richness ranged from 17-31 species/Mbed. Mbed areas ranged from 600-6,375 m² with a mean of 1841 m². Mean densities were 16.2-36.8 mussels/m² with an overall mean density of 30.4 mussels/m². *Pleurobema pyramidatum* numerically dominated 16 of 17 beds and composed 32.8% of all mussels collected. *Quadrula pustulosa* was second most abundant followed by *Fusconaia flava* and *Amblema plicata* at 14.4%, 14.2% and 7.1%, respectively. *Quadrula pustulosa* was also numerically dominant in one Mbed found in Region 1. Shannon-Weiner Diversity Indices ranged from 2.565-3.558 in Mbeds of this region (Table 11).

Minor Beds

Forty quadrats were collected from eight mbeds yielding 885 individuals and 26 species. The number of species per mbed ranged from 9-17, and five of these species were represented by single individuals. Densities for individual quadrats ranged from 4.0-52.0 mussels/m² with an overall mean density of 25.3 mussels/m². Minor bed areas ranged from 210-480 m² with a mean of 317 m².

Again, *Pleurobema pyramidatum* numerically dominated all mussels encountered. It was the most abundant species in all mbeds and comprised 33.9% of all mussels collected from mbeds in Region 1. *Fusconaia flava* (20.3%) was second most abundant

Table 11. Ecological indices for M- and mbeds in the Ouachita River.

Bed	Simpson Diversity	Simpson Dominance	Shannon Diversity	Hmax'	Evenness
Mbeds					
1M	0.897	0.103	3.558	4.322	0.823
3M	0.832	0.168	2.986	4.169	0.716
5M	0.699	0.301	2.520	4.322	0.584
8M	0.874	0.126	3.345	4.322	0.774
9M	0.866	0.134	3.358	4.392	0.765
10M	0.829	0.171	3.133	4.392	0.713
11M	0.800	0.200	2.996	4.086	0.733
12M	0.690	0.310	2.565	4.169	0.615
13M	0.803	0.197	2.993	4.322	0.693
14M	0.860	0.140	3.259	4.245	0.768
18M	0.755	0.245	2.565	4.322	0.593
19M	0.813	0.187	2.983	4.322	0.690
20M	0.744	0.256	2.511	4.322	0.581
21M	0.866	0.114	3.541	4.584	0.772
22M	0.806	0.194	2.993	4.521	0.662
23M	0.864	0.136	3.375	4.392	0.769
24M	0.887	0.113	3.554	4.392	0.809
25M	0.874	0.126	3.445	4.245	0.811
26M	0.850	0.150	3.222	4.392	0.734
27M	0.871	0.129	3.388	4.458	0.760
28M	0.846	0.154	3.408	4.392	0.776
29M	0.859	0.141	3.189	4.086	0.780
30M	0.877	0.113	3.618	4.392	0.824
32M	0.876	0.124	3.412	4.245	0.804
36M	0.757	0.243	2.521	4.000	0.630
38M	0.802	0.198	2.820	4.086	0.690
39M	0.784	0.216	2.734	3.907	0.700
40M	0.794	0.206	2.731	3.807	0.717
41M	0.837	0.163	3.063	4.086	0.750
42M	0.804	0.196	2.770	4.245	0.653
43M	0.806	0.194	2.824	4.000	0.706
44M	0.827	0.173	2.983	4.322	0.690
46M	0.744	0.256	2.455	3.697	0.664
47M	0.809	0.197	2.840	3.907	0.740
48M	0.828	0.172	2.986	4.000	0.747
49M	0.835	0.165	2.890	3.907	0.740
50M	0.815	0.185	2.927	3.907	0.749
51M	0.824	0.176	2.907	3.807	0.764
52M	0.837	0.163	3.096	4.245	0.729
53M	0.837	0.163	3.030	4.169	0.727
54M	0.788	0.212	2.604	3.907	0.667
55M	0.834	0.166	2.993	4.086	0.733
56M	0.798	0.202	2.704	3.807	0.710
58M	0.813	0.187	2.850	3.907	0.730
59M	0.803	0.197	2.777	4.000	0.694

Table 11 con't.

Bed	Simpson Diversity	Simpson Dominance	Shannon Diversity	Hmax'	Evenness
mbeds					
2m	0.886	0.114	3.352	3.907	0.858
4m	0.695	0.305	2.202	3.169	0.695
6m	0.850	0.150	3.05	3.807	0.801
7m	0.780	0.220	2.412	3.169	0.761
15m	0.785	0.214	2.671	3.697	0.722
16m	0.874	0.126	3.322	4.086	0.813
17m	0.783	0.217	2.837	4.169	0.680
31m	0.821	0.179	2.717	3.322	0.818
33m	0.794	0.206	2.621	3.584	0.731
34m	0.769	0.231	2.395	3.169	0.756
35m	0.511	0.489	1.910	3.807	0.502
37m	0.706	0.294	2.408	3.584	0.672
45m	0.720	0.280	2.438	4.086	0.597
57m	0.833	0.167	2.747	3.169	0.867
60m	0.357	0.643	1.203	2.807	0.428
61m	0.370	0.630	1.269	3.000	0.423

followed by *Quadrula pustulosa* (8.8%) and *Fusconaia ebena* (7.3%).

Region 2

Fifteen beds in this region (Figure 5) yielded 8,210 mussels from 309 quadrats and a mean density of 26.6 mussels/m². A total of 30 species was found.

Major Beds

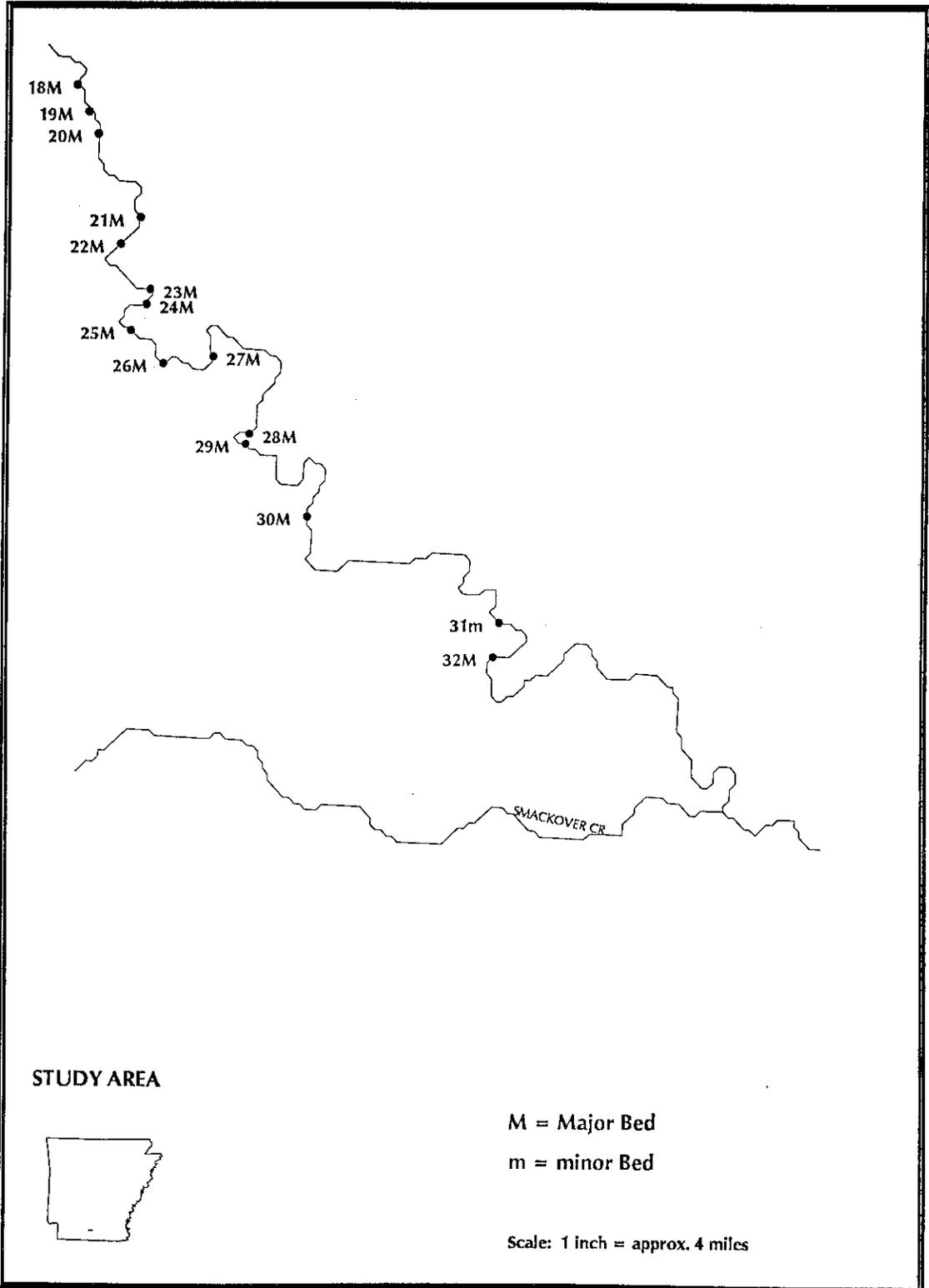
Fourteen Mbeds yielded 8,147 mussels from 304 quadrats with an overall mean density of 26.8 mussels/m². Mean densities ranged from 11.2-52.9 mussels/m². Of 30 species of freshwater mussels found, three were represented by single individuals. Shannon-Wiener Diversity Indices ranged from 2.565 to 3.618 (Table 11). Mbed areas ranged from 1,200-11,000 m² with a mean area of 4,143m². Ten Mbeds (71.4%) were larger than 2,500 m², and five (35.7%) were larger than 5,000 m². As in the previous region, *Pleurobema pyramidatum* was numerically dominant and comprised 26.1% of all mussels collected. This species was the most abundant species in 64.2% (8 of 14) Mbeds. Other numerically abundant species included *Fusconaia flava* (15.0%), *Quadrula pustulosa* (14.4%), and *Amblema plicata* (7.1%).

Minor Beds

The single mbed located in this region provided a total of 63 mussels representing 10 species from five quadrats. The mean density was 12.6 mussels/m², and the bed area was 200 m².

Quadrula quadrula was the most abundant species in this

Figure 5. Location of mussel beds in Region 2, Ouachita River, Arkansas.



mbed and made up 33.3% of all mussels collected. *Megalonaias nervosa* and *Quadrula pustulosa* were also numerically abundant, each comprising 15.9%.

Region 3

A total of five beds was delineated and sampled in this region (Figure 6). Forty-five quadrat samples yielded 1,377 mussels and 25 species, of which six were represented by single individuals. The mean density for the region was 30.6 mussels/m².

Major Beds

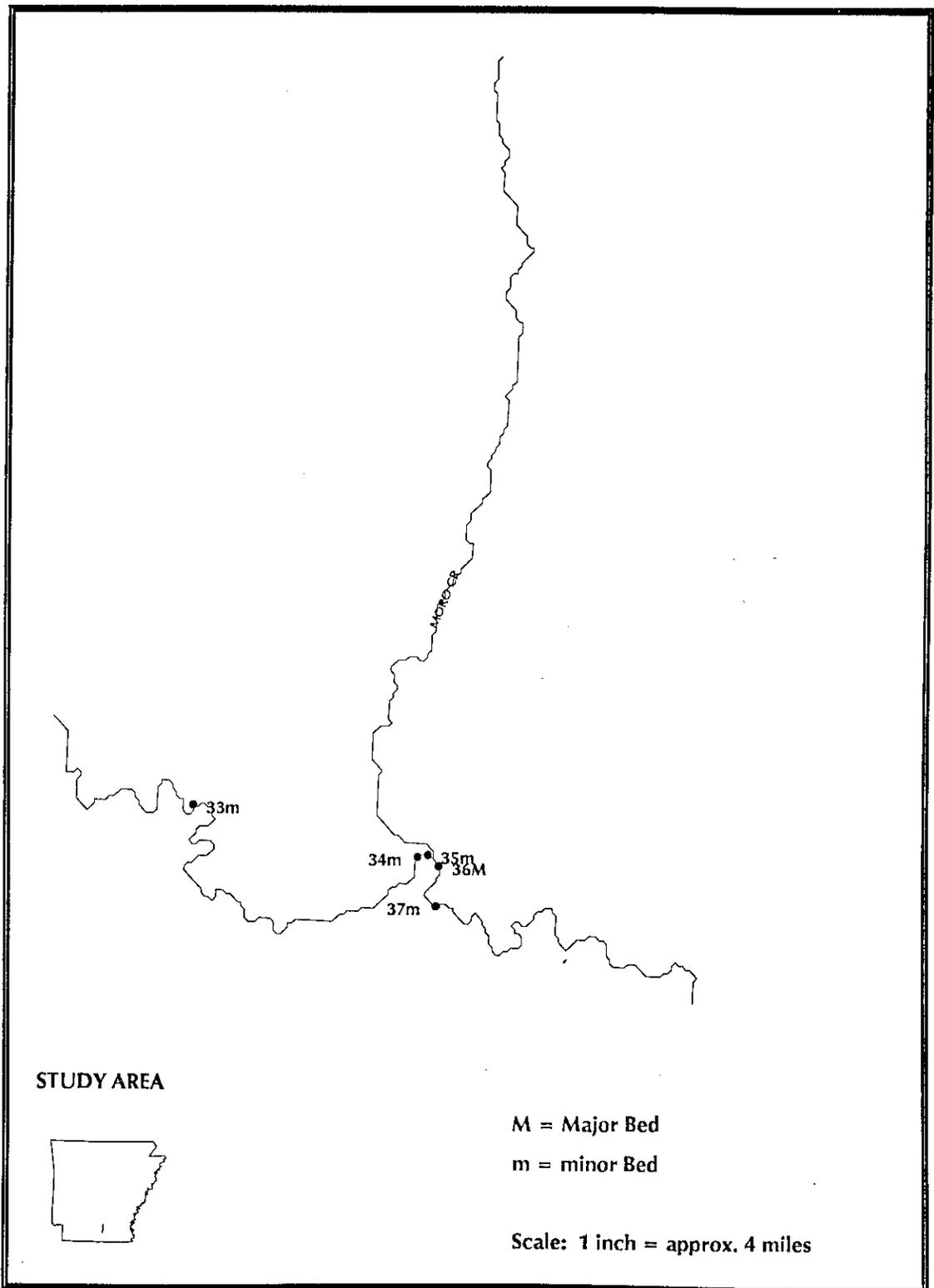
One Mbed was delineated, and 25 quadrats yielded 956 mussels from the 3,750 m² bed. The range of densities was 14.0-93.0 mussels/m² and the mean density was 38.2 mussels/m². Twenty-five species were identified from this Mbed and *Elliptio dilatata*, was represented by one individual.

Amblema plicata comprised 34.6% of all mussels collected, while *Fusconaia ebena* and *Plectomerus dombeyanus* represented 31.3% and 13.1% of the total, respectively. *Quadrula pustulosa* comprised only 7.4% of the total. The Shannon-Weiner Diversity Index value was 2.521 (Table 11).

Minor Beds

Four mbeds were delineated and 20 quadrats yielded 421 individuals with a mean of 21.1 mussels/m². *Amblema plicata* numerically dominated all beds and comprised 48.5% of mussels collected. *Quadrula quadrula* and *Quadrula pustulosa* were also abundant at 13.7% and 13.1%, respectively. Shannon-Weiner

Figure 6. Location of mussel beds in Region 3, Ouachita River, Arkansas.



Diversity Indices ranged from 1.910-2.621 (Table 11) and 18 species were found.

Region 4

Region 4 had the most M- and mbeds (24) (Figure 7). A total of 8,937 mussels was collected from 371 quadrats yielding a mean of 24.1 mussels/m². Twenty-seven species were collected with four species represented by single individuals.

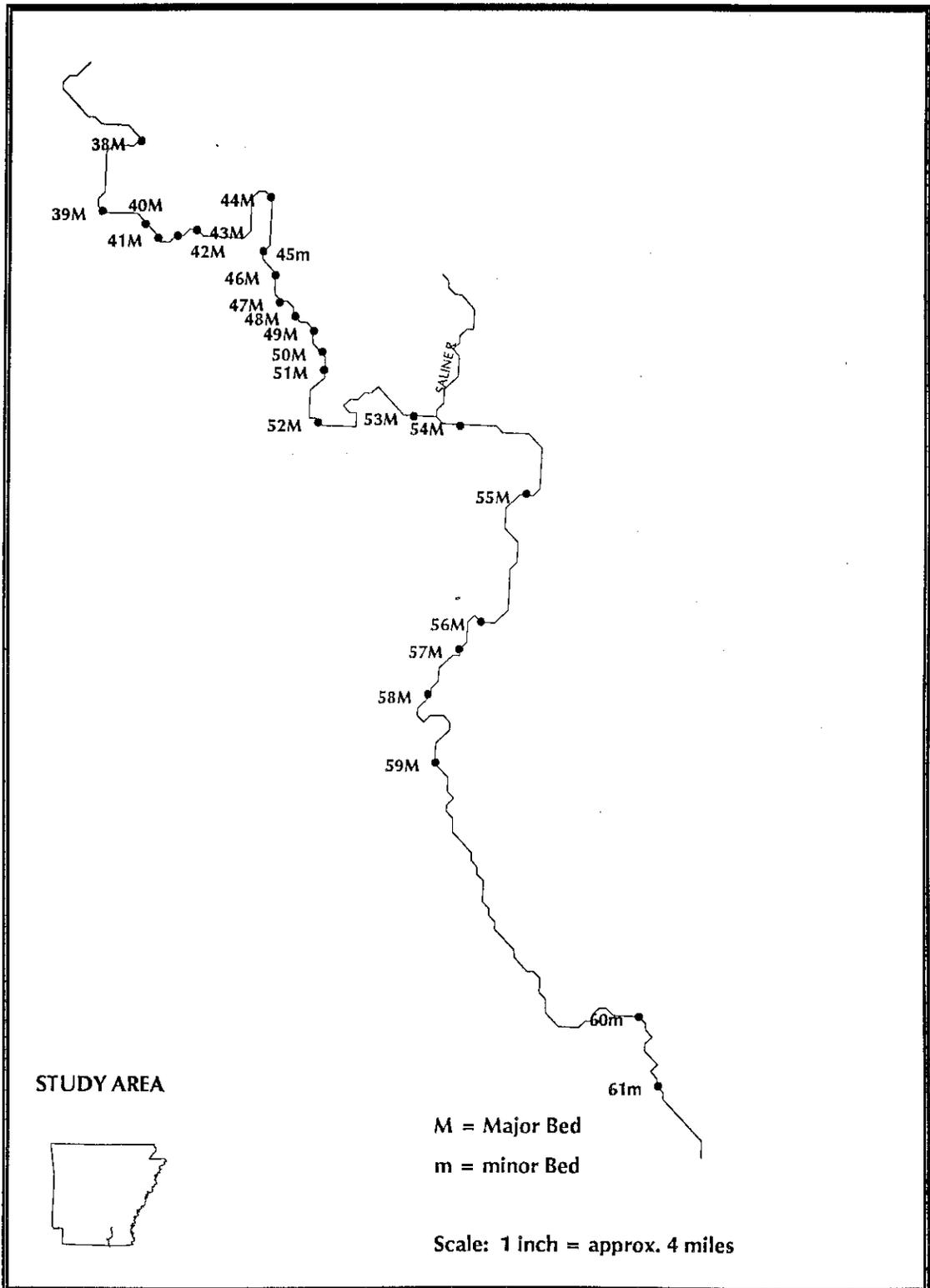
Major Beds

Twenty Mbeds were delineated with areas ranging from 800-6,950 m² with an overall mean of 2,498 m². A total of 351 quadrats yielded 8,318 mussels, and mean Mbed densities ranged from 15.2-40.0 mussels/m². The mean density was 23.7 mussels/m². Twenty-four species were present, each represented by two or more individuals. *Amblema plicata* comprised 29.7% of mussels collected and was most abundant in 14 of 20 Mbeds. *Fusconaia ebena* was also abundant, totaling 21.4% of all mussels collected, and was numerically dominant in four of 20 beds. *Quadrula pustulosa* numerically dominated one Mbed and was third most abundant overall at 15.7%. Following *Q. pustulosa* was *Fusconaia flava* comprising 5.9% of all mussels collected. Shannon-Weiner Diversity Indices ranged from 2.455-3.096 (Table 11).

Minor Beds

The four mbeds ranged from 300-400 m² in area. A total of 20 species was collected from 20 quadrats which yielded 619 mussels. Mean densities were 16.4-75.6 mussels/m² with an

Figure 7. Location of mussel beds in Region 4, Ouachita River, Arkansas.



overall mean of 31.0 mussels/m². Again, *Amblema plicata* was numerically dominant with 53.6% of all mussels collected and was numerically most abundant in three mbeds. *Fusconaia ebena* was second most abundant overall at 19.4%, and *Quadrula pustulosa* was third most abundant at 7.4% and numerically dominated one mbed. Shannon-Weiner Diversity Indices ranged from 1.203-2.747.

Endangered Species

Three species listed as endangered by the U.S. Fish and Wildlife Service were collected during this survey. A single *Arkansia wheeleri* was located in bed 27M (Region 2). Five specimens of *Lampsilis abrupta* were found, one each in beds 5M, 9M, 11M, 13M and 16M (Region 1), and three specimens in beds 21M (2) and 27M (1) (Region 2). An additional specimen was located during qualitative analysis at RM 375.0. *Quadrula fragosa*, a new state record, was not recognized until after the field survey was complete. Therefore, all locations for this species are imprecise. At least one specimen each was found in beds 3M and 14M. An additional four specimens were collected without exact location data. All specimens were found in Regions 1 and 2. This species was mistaken for *Quadrula quadrula* and treated as such in all statistics.

Discussion

Since the Ouachita River is not currently commercially shelled, very little interest has been afforded the unionacean community in the river. This river was commercially harvested

historically for the button industry, but with the advent of plastics, commercial shelling stopped.

Diversity

Watershed size plays a role in the number of fish species in a stream (Sheldon, 1968, Watters 1993). Since mussels are dependent on fishes as glochidial hosts, one can assume that a more diverse fish community will manifest itself in a more diverse mussel community when factors are favorable.

The LORWG (1993) collected 82 species of fishes in the lower Ouachita River. Of these, 40 species were found in Region 1 of this survey, which was also the most speciose region for mussels. The lower regions contained fewer species of fishes and somewhat mirrored the species composition of mussels there. Gordon et al. (1979) listed 50 unionacean taxa for the entire Arkansas portion of the Ouachita River drainage, 38 for the Arkansas portion of the Black River drainage, and 50 for the Arkansas portion of the White River drainage. Thirty-eight species of mussels were collected from the lower mainstem Ouachita River in Arkansas during this survey. The Arkansas portion of the Ouachita River has 17,411 km² of watershed. Rust (1993) reported 34 species from the mainstem Black River with a total watershed size of 22,165 km², while Christian (1995) reported 36 species from the mainstem White River with a total watershed size of 75,520 km².

As evidenced by the above comparisons, diversity is based

on more than watershed size and glochidial hosts alone. The author believes that substrate particle size and habitat diversity play a role in the greater species diversity in the Ouachita River. Substrate particle sizes ranged from boulder to silt in various portions of the Ouachita River. The overall major substrate type was gravel ranging from cobble to pebble with sand and silt in the interstices.

Unlike the Black and White rivers, Ouachita River mussels are not commercially harvested. Fewer disturbances within beds could lead to the less common species surviving over a longer period of time. Also, without commercial harvesting, reproductive individuals are not removed in the numbers associated with commercial harvesting.

Region 1 had the highest gradient and was the most speciose of all regions sampled in the Ouachita River with 31 species. Additionally, this region had the second highest estimated community numerical standing crop (CNSC) of all regions and the greatest diversity. This portion of the river is not currently maintained for navigation or other purposes. The lack of maintenance allows for pool-riffle complexes to form and remain. The greatest diversity of habitats occurs within riffles where substrate particle size and current velocities vary.

Region 1 yielded the only collections for *Cyprogenia aberti*, *Cumberlandia monodonta*, *Quadrula cylindrica*, *Alasmidonta marginata* and *Ptychobranthus occidentalis*.

Cyprogenia aberti inhabits small to large streams with good water quality, moderate to swift current, and sand-gravel to sand-rock substrates (Harris and Gordon, undated). The presence of riffle-pool complexes seems to be imperative for this higher gradient species.

Wheeler (1918) last reported *Cumberlandia monodonta* in Arkansas, and it was thought to be extirpated from the state (Harris and Gordon, 1987). Two specimens were collected in Region 1. Both specimens were found under overhanging cover at the margin where current was reduced. This species is normally found in large rivers among boulders or cobble outside at the margin where the current of the mainstream is reduced (Oesch, 1984, Cummings and Mayer, 1992).

Quadrula cylindrica is distributed throughout the state but is never abundant. It usually inhabits small to large streams receiving constant flow with sand-gravel substrates (Harris and Gordon, undated). *Alasmidonta marginata* inhabits medium sized streams with gravel or mixed sand-gravel substrates (Cummings and Mayer, 1992). *Ptychobranchnus occidentalis* usually inhabits small to large streams with gravel or gravel sand substrate and is abundant in the upper Ouachita, Caddo and Saline rivers (Harris and Gordon, undated).

Density

Region 1 ranked second in mean density/bed and mean estimated CNSC. The mean density within beds increased from

upstream to downstream except for 5M, which had the highest mean density (36.8 mussels/m²) of all beds in Region 1. Bed 5M was the fourth smallest bed in this region. All beds less than 1200 m² contained mean densities greater than 27.0 mussels/m², which was higher than beds with areas larger than 1200 m². A correlation could be made since 10-12 quadrats were collected in these smaller beds and 13-25 quadrats collected in larger beds, a greater number of densities and habitats were sampled in larger beds than in smaller beds.

Region 2 was the second most speciose region in the lower Ouachita River with a range of species diversity indices similar to Region 1. Region 2 had the highest mean estimated CNSC of any region in the lower Ouachita River. River gradient decreased from 0.2 m/km in Region 1 to 0.04 m/km in Region 2. The lower gradient results in current velocity decreasing, and suspended nutrients settling out more than in the previous region. The river structure also differed in Region 2 with longer lateral scour pools and a more homogenous substrate.

Region 3 ranked fourth in number of species. The substrate within Region 3 generally consisted of unstable sand or sand/pea gravel, except near Moro Bay State Park (RM 273.1). At the mouth of Moro Bayou, the substrate was sand with gravel and cobble. The only Mbed in this region was at the confluence with Moro Bayou and three of the mbeds were located within 3.2 km of this site.

Dominance

Amblema plicata was the dominant species in Regions 3 and 4. This species has a broad tolerance to environmental factors and a broad range for glochidial hosts. Holland-Bartels (1990) also found *A. plicata* dominating in beds of the upper Mississippi River in impoundments behind locks and dams.

The dominant species from Regions 1 and 2 (*Pleurobema pyramidatum*) was very seldom found in Regions 3 or 4 (Figure 8). This author feels that the presence of H.K. Thatcher Lock and Dam slows the current in Regions 3 and 4 to a point that *P. pyramidatum* is not able to exist. *Fusconaia flava* was also abundant in the upper two regions, but its abundance also decreased in the lower two regions (Figure 9) and *Fusconaia ebena* contributed a greater percentage of the total community. This may be due to the loss of glochidial hosts or the presence of the homogenous sand-silt substrate.

The number of species per region decreased while moving downstream. This is probably due to the changing physical characteristics of the river, reducing available habitat for mussels as well as glochidial host species.

Figure 8. Percent of total of *Amblyema plicata* and *Pleurobema pyramidatum* in the Ouachita River, Arkansas.

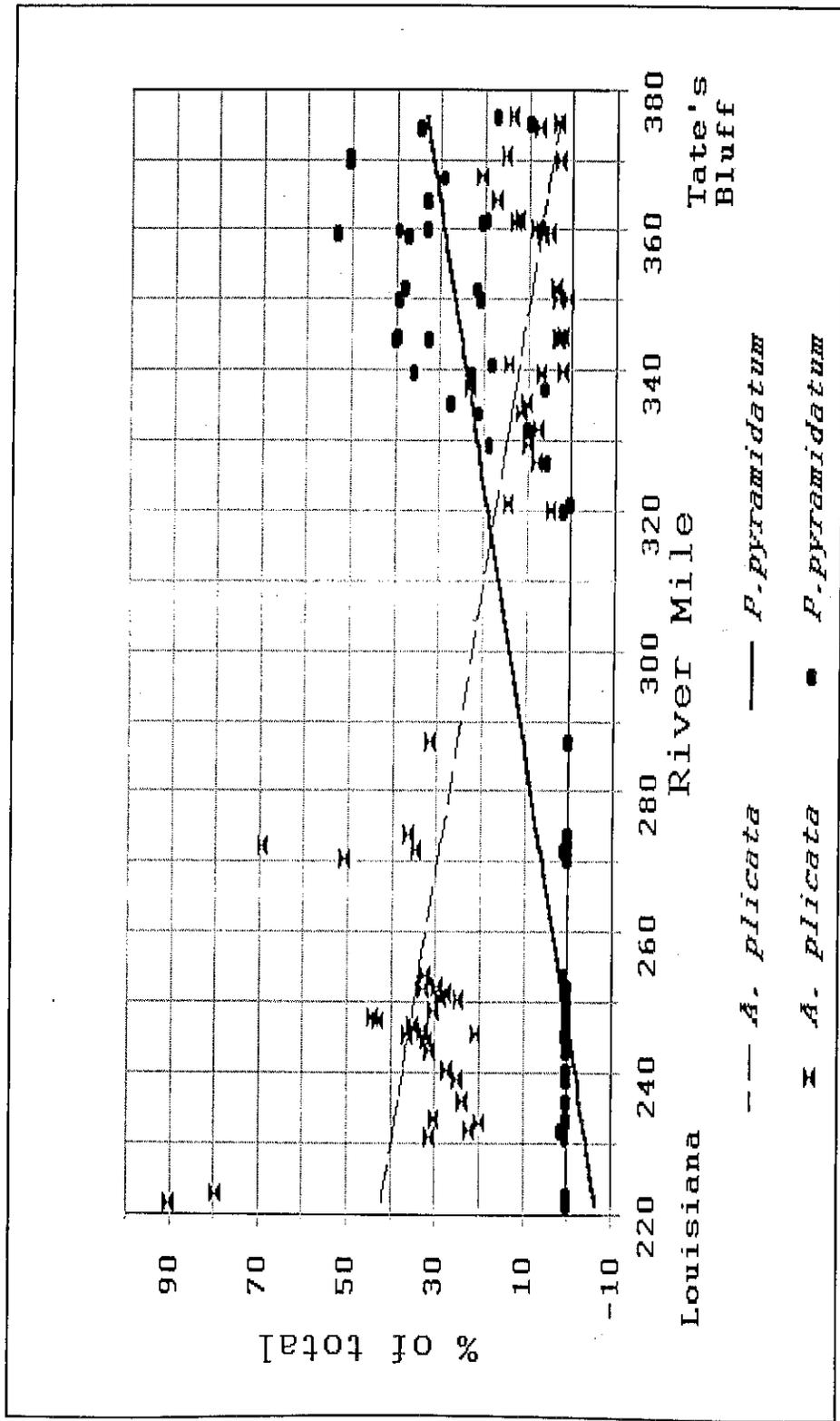
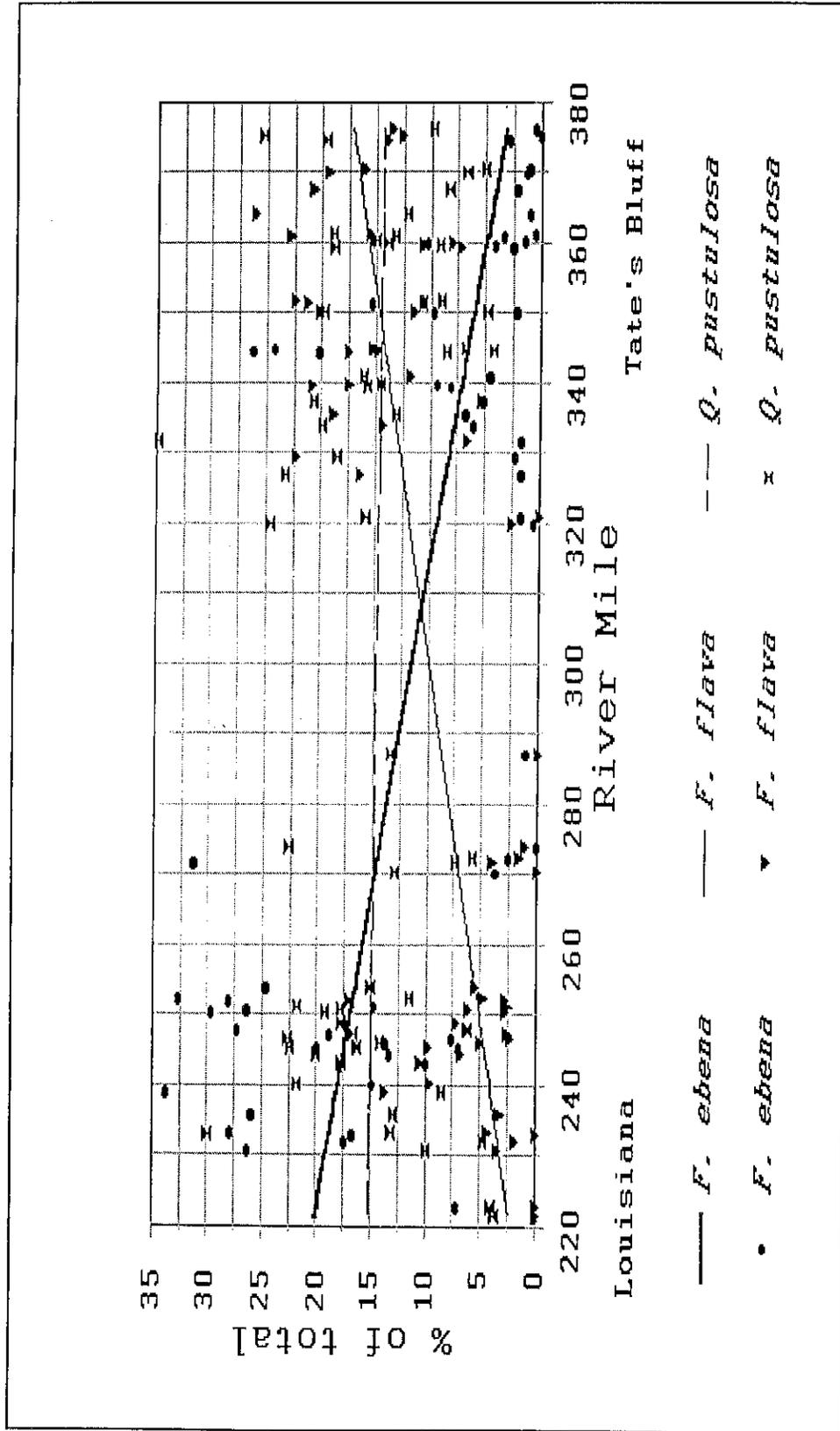


Figure 9. Percent of total of *Fusconaia ebena*, *Fusconaia flava* and *Quadrula pustulosa* in the Ouachita River, Arkansas.



CHAPTER IV

SIZE AND AGE ANALYSIS

To properly manage a biological resource, aspects of its life history must be considered. For example, reduction in the number of reproductive adults could lead to the demise of a species. The Arkansas Game and Fish Commission has selected minimum sizes at which mussels may be harvested. However, these size limits were selected without age/growth or CNSC data (Table 2).

SIZE ANALYSIS

Size analysis helps to describe population structure within and between beds and between regions containing different abiotic factors. The mathematical mode is determined by the value or range of values occurring with the most frequency from a sample. Therefore, the mode was used as a reference point to compare size classes between regions of the St. Francis and Ouachita rivers. Additionally, the mode may help to identify impacts of commercial harvesting on a certain size class of mussels.

St. Francis River

The mean depth for *Amblema plicata* shells in the three St. Francis River regions ranged from 68.3-78.6 mm (Table 12). The depth interval mode varied from 60-69.9 to 70-79.0 mm

Table 12. Mean values (\bar{X}) \pm 1.0 standard deviation of the mean (S) using dimensions derived by the Arkansas Game and Fish Commission for selected mussel species, St. Francis River, Arkansas.

Species	Region 1			Region 2			Region 3		
	N	\bar{X}	S	N	\bar{X}	S	N	\bar{X}	S
	Depth (mm)								
<i>Ambema plicata</i>	118	68.3	8.5	454	73.7	5.9	16	78.6	4.6
<i>Megaloniaias nervosa</i>	5	111.9	3.1	33	108.4	20.9	10	113.6	7.0
<i>Quadrula pustulosa</i>	105	59.7	6.8	273	53.5	6.4	2	57.3	1.8
<i>Quadrula quadrula</i>	19	63.4	10.1	98	61.5	6.5	131	62.8	5.7
	Mass (g)								
<i>Ambema plicata</i>	118	281.8	119.4	454	301.9	68.5	16	356.7	64.8
<i>Megaloniaias nervosa</i>	5	746.2	163.0	33	557.4	182.8	10	822.0	169.3
<i>Quadrula pustulosa</i>	105	157.9	43.0	273	99.4	32.9	2	129.5	15.5
<i>Quadrula quadrula</i>	19	174.6	59.1	98	142.0	40.9	131	152.1	28.7

(Tables 13-15) in the three regions, and there were significant differences in mean depth between Regions 1 and 2 (Tables 16-17).

Depth interval modes for *Megalonaias nervosa* ranged from 100-109.9 to 110-119.9 mm (Tables 13-15) in the three regions and mean depth ranged from 108.4-113.6 mm (Table 12). There was no significant difference in mean depth between regions (Tables 16-17).

Quadrula pustulosa shell depth interval modes ranged from 50-59.9 to 60-69.9 mm in the three regions (Tables 13-15). Mean depth in the three regions, for this species, varied from 53.5-59.7 mm (Table 12), and a significant difference in mean depth was found between Regions 1 and 2 (Tables 16-17).

Quadrula quadrula shell depth interval modes were 60-69.9 mm in all three regions (Tables 13-15). The mean depth ranged from 61.5-63.4 mm (Table 12), and there were no significant differences in depth among regions (Tables 16-17).

Discussion

Amblema plicata specimens were larger in Regions 1 and 2 than in Region 3. Region 3 is below a dam and the mouth of the L'Anguille River. During low flow events, this region of the river will undergo greater environmental stress (low dissolved oxygen, low nutrients and higher temperatures) than the upper regions due to the dam partially blocking flow. *Megalonaias nervosa* and *Quadrula pustulosa* were larger in Region 1 than in Regions 2 and 3. The reason for this is

Table 13. Depth frequency distributions of selected unionid species, Region 1 of the St. Francis River, Arkansas, 1994.

Increment (mm)	A. p.*	M. n.*	Q. p.*	Q. q.*
0-09.9				
10-19.9				
20-29.9			1	
30-39.9			3	2
40-49.9	3		2	1
50-59.9	1		35	1
60-69.9	23		**44	**11
70-79.9	**78			4
80-89.9	8			
90-99.9				
100-109.9		1		
110-119.9		**4		
Total	113	5	85	19

- * A. p. = *Amblyma plicata*
 * M. n. = *Megaloniaias nervosa*
 * Q. p. = *Quadrula pustulosa*
 * Q. q. = *Quadrula quadrula*
 ** = Interval Mode

Table 14. Depth frequency distributions of selected unionid species, Region 2 of the St. Francis River, Arkansas, 1994.

Increment (mm)	A. p.*	M. n.*	Q. p.*	Q. q.*
0-09.9				
10-19.9				
20-29.9	1			
30-39.9			6	
40-49.9	1		63	4
50-59.9	4		**164	29
60-69.9	84		38	**61
70-79.9	**287		1	5
80-89.9	63	4		
90-99.9	1	9		
100-109.9		**17		
110-119.9		9		
Total	441	39	272	99

-
- * A. p. = *Amblema plicata*
 * M. n. = *Megalonaias nervosa*
 * Q. p. = *Quadrula pustulosa*
 * Q. q. = *Quadrula quadrula*
 ** = Interval Mode

Table 15. Depth frequency distributions of selected unionid species, Region 3 of the St. Francis River, Arkansas, 1994.

Increment (mm)	A. p.*	M. n.*	Q. p.*	Q. q.*
0-09.9				
10-19.9				
20-29.9				
30-39.9				2
40-49.9				12
50-59.9			**2	18
60-69.9	**11			**58
70-79.9	5			2
80-89.9				
90-99.9				
100-109.9		**5		
110-119.9		**5		
Total	16	10	2	92

- * A. p. = *Amblema plicata*
 * M. n. = *Megalonaias nervosa*
 * Q. p. = *Quadrula pustulosa*
 * Q. q. = *Quadrula quadrula*
 ** = Interval Mode

Table 16. Analysis of variance of selected species, with regard to the Arkansas Game and Fish Commission legal dimension, when compared between St. Francis River regions.

<i>Amblema plicata</i>				
Source	SS	df	MS	F
Between Regions	1219879	2	609940	1172.5*
Error	702305	1350	520	
Total	1922184	1352		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Megalonaias nervosa</i>				
Source	SS	df	MS	F
Between Regions	167312	2	83656	53.7*
Error	154176	99	1557	
Total	321488	101		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Quadrula pustulosa</i>				
Source	SS	df	MS	F
Between Regions	386983	2	193491	624.0*
Error	253022	816	310	
Total	640005	818		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Quadrula quadrula</i>				
Source	SS	df	MS	F
Between Regions	196338	2	98169	222.7*
Error	173260	393	441	
Total	369598	395		

* = Significance inferred at $\alpha = 0.05$ level.

Table 17. Minimum Significant Difference (MSD) and $|\bar{Y}_i - \bar{Y}_j|$ values for selected species found in St. Francis River segments. MSD values are found above the tick marks.

<i>Amblema plicata</i>			
Regions	1	2	3
1	—	1.58*	4.06
2	8.07	—	3.88
3	3.22	3.22	—
* = Significance inferred at $\alpha = 0.05$ level.			
<i>Megalonaias nervosa</i>			
Regions	1	2	3
1	—	21.49	34.51
2	3.55	—	16.33
3	1.71	5.26	—
<i>Quadrula pustulosa</i>			
Regions	1	2	3
1	—	1.78*	11.06
2	6.23	—	10.99
3	2.40	3.83	—
* = Significance inferred at $\alpha = 0.05$ level.			
<i>Quadrula quadrula</i>			
Regions	1	2	3
1	—	3.82	3.71
2	1.90	—	2.03
3	0.61	1.29	—

Differences larger in absolute value than their MSD value are inferred at $\alpha = 0.05$ level.

unclear, but may be related to niche requirements, nutrition, bed density or flow requirements that are currently not understood. *Quadrula quadrula* showed no differences in size among regions. Christian (1995) found that *Q. quadrula* exhibited the same longitudinal size patterns between three regions of the Cache River. This species exists in a broad range of habitats and is often the dominant species in areas of environmental stress such as the lacustrine environment above Huxtable Dam. These factors may explain the consistency of the variance and why there were no significant longitudinal differences (Oesch, 1984).

OUACHITA RIVER

Results

Shell depth interval modes of four species were calculated. *Amblema plicata* ranged from 40-49.9 to 50-59.9 mm (Tables 18-21) among the four Ouachita River Regions. The mean depth for this species ranged from 47.1-55.7 mm (Table 22), and there were significant differences in depth between Regions 1-2, 1-3, and 2-4 (Tables 23-24).

Fusconaia ebena shell depth interval mode ranged from 40-49.9 to 50-59.9 mm (Tables 18-21). The mean depth for this species ranged from 43.2-51.4 mm with the largest mean in Region 1 (Table 22), and there were significant differences in depth between all regions (Tables 23-24).

The depth interval mode for *Fusconaia flava* remained constant longitudinally (Tables 18-21). The mean depth ranged

Table 18. Depth frequency distributions of selected unionid species, Region 1 of the Ouachita River, 1992-1995.

Increment (mm)	A.p.*	F.e.*	F.f.*	Q.p.*
0-09.9				
10-19.9	4		9	19
20-29.9	20	1	64	82
30-39.9	30	4	201	252
40-49.9	49	57	**400	**302
50-59.9	**97	**118	66	42
60-69.9	25	5	1	1
70-79.9	6			
80-89.9	2			
Total	233	185	741	698

* A.p. = *Amblema plicata*
 F.e. = *Fusconaia ebena*
 F.f. = *Fusconaia flava*
 Q.p. = *Quadrula pustulosa*
 ** = Mode Interval

Table 19. Depth frequency distributions of selected unionid species, Region 2 of the Ouachita River, 1992-1995.

Increment (mm)	A.p.*	F.e.*	F.f.*	Q.p.*
0-09.9			1	
10-19.9	2	29	3	4
20-29.9	9	19	65	148
30-39.9	16	386	139	321
40-49.9	170	**527	**716	**635
50-59.9	**289		299	72
60-69.9	31			2
70-79.9	7			
80-89.9				
Total	524	961	1223	1182

* A.p. = *Amblema plicata*
 F.e. = *Fusconaia ebena*
 F.f. = *Fusconaia flava*
 Q.p. = *Quadrula pustulosa*
 ** = Mode Interval

Table 20. Depth frequency distributions of selected unionid species, Region 3 of the Ouachita River, 1992-1995.

Increment (mm)	A.p.*	F.e.*	F.f.*	Q.p.*
0-09.9				
10-19.9	8		1	4
20-29.9	20	1		30
30-39.9	39	6	8	**47
40-49.9	**147	**233	**27	36
50-59.9	99	68	5	4
60-69.9	56	3		
70-79.9	2			
80-89.9				
Total	371	311	41	121

* A.p. = *Amblema plicata*

F.e. = *Fusconaia ebena*

F.f. = *Fusconaia flava*

Q.p. = *Quadrula pustulosa*

** = Mode Interval

Table 21. Depth frequency distributions of selected unionid species, Region 4 of the Ouachita River, 1992-1995.

Increment (mm)	A.p.*	F.e.*	F.f.*	Q.p.*
0-09.9		2		
10-19.9	49	40	13	57
20-29.9	132	105	17	248
30-39.9	292	79	174	**448
40-49.9	**1357	**1552	**334	271
50-59.9	885	153	14	4
60-69.9	83	2		1
70-79.9				
80-89.9				
Total	2798	1933	552	1029

* A.p. = *Amblema plicata*
 F.e. = *Fusconaia ebena*
 F.f. = *Fusconaia flava*
 Q.p. = *Quadrula pustulosa*
 ** = Mode Interval

Table 22. Mean values (\bar{X}) \pm 1.0 standard deviation of the mean (S) using dimensions derived by the Arkansas Game and Fish Commission for selected mussel species, Ouachita River, Arkansas.

Species	Region 1			Region 2			Region 3			Region 4		
	N	\bar{X}	S	N	\bar{X}	S	N	\bar{X}	S	N	\bar{X}	S
	Depth (mm)											
<i>Amblema plicata</i>	323	52.5	12.0	584	55.7	8.1	535	51.0	12.8	2804	45.7	8.9
<i>Fusconaia ebena</i>	171	21.4	5.4	932	49.6	6.0	307	47.3	6.7	1908	43.2	18.7
<i>Fusconaia flava</i>	742	41.0	7.8	1224	45.6	12.1	41	43.8	6.3	516	40.5	6.2
<i>Quadrula pustulosa</i>	645	39.0	8.3	1183	41.2	16.1	119	35.4	8.7	1324	35.5	20.2
	Mass (g)											
<i>Amblema plicata</i>	323	*	*	584	109.0	58.1	535	92.2	51.0	2804	68.1	33.8
<i>Fusconaia ebena</i>	171	80.3	41.7	932	79.4	22.0	307	87.1	44.2	1908	30.4	24.9
<i>Fusconaia flava</i>	742	65.5	43.2	1224	60.5	23.1	41	95.3	48.2	516	46.6	17.5
<i>Quadrula pustulosa</i>	645	49.2	53.1	1183	39.5	22.2	119	99.3	61.0	1324	27.2	14.3

* = Data not available.

Table 23. Analysis of variance of selected species, with regard to the Arkansas Game and Fish Commission legal dimension, when compared between Ouachita River regions.

<i>Amblema plicata</i>				
Source	SS	df	MS	F
Between Regions	2602741	3	2.15	748.1*
Error	13021529	11228	1160	
Total	15624270	11231		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Fusconaia ebena</i>				
Source	SS	df	MS	F
Between Regions	1763277	3	587759	2.0*
Error	154176	99	1557	
Total	1917453	102		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Fusconaia flava</i>				
Source	SS	df	MS	F
Between Regions	1223619	3	407873	1521.9*
Error	1312160	4896	268	
Total	2535779	4899		

* = Significance inferred at $\alpha = 0.05$ level.

<i>Quadrula pustulosa</i>				
Source	SS	df	MS	F
Between Regions	983491	3	327830	988.5*
Error	1763064	5316	332	
Total	2746555	5319		

* = Significance inferred at $\alpha = 0.05$ level.

Table 24. Minimum Significant Differences (MSD) and $|\bar{Y}_i - \bar{Y}_j|$ values for selected species found in Ouachita River segments. MSD values are found above the tick marks.

<i>Amblema plicata</i>				
	1	2	3	4
1	—	5.73*	5.89*	4.03
2	12.56	—	6.60	5.01*
3	7.84	4.71	—	5.21
4	3.97	8.59	3.87	—

* = Significance inferred at $\alpha = 0.05$ level.

<i>Fusconaia ebena</i>				
	1	2	3	4
1	—	3.15	3.60*	4.18*
2	1.77	—	2.47	1.51*
3	4.05	2.28	—	2.31*
4	8.72	6.41	4.13	—

* = Significance inferred at $\alpha = 0.05$ level.

<i>Fusconaia flava</i>				
	1	2	3	4
1	—	1.17*	4.07	1.42
2	4.64	—	4.01	1.29*
3	2.87	1.76	—	4.09
4	0.43	5.07	3.31	—

* = Significance inferred at $\alpha = 0.05$ level.

<i>Quadrula pustulosa</i>				
	1	2	3	4
1	—	2.02*	4.18	1.98
2	2.23	—	4.03*	4.03*
3	3.58	5.81	—	4.02
4	3.46	5.70	0.12	—

* = Significance inferred at $\alpha = 0.05$ level.

Differences larger in absolute value than their MSD value are inferred at $\alpha = 0.05$ level.