

Technical Report EL-97-19 September 1997

**US Army Corps of Engineers** Waterways Experiment Station

## An Analysis of Freshwater Mussels (Unionidae) in the Quiver River and Bogue Phalia, Mississippi, 1994-95

by Andrew C. Miller, Barry S. Payne

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U.S. Army Corps of Engineers Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199

**Final report** 

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## Preface

A survey to assess community characteristics, density, population demography of dominant species, and the presence of rare or endangered species of mussels (Family: Unionidae) was conducted in the Quiver River and Bogue Phalia, Mississippi, for the U.S. Army Engineer District, Vicksburg. Results are being used to assess the economic value of mussels and to determine the environmental effects of proposed maintenance dredging. Research was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in the fall of 1994 and spring and summer 1995.

Divers were Messrs. Larry Neill, Robert T. James, Robert Warden, and Johnny Buchanan from the Tennessee Valley Authority. Assistance in the field was provided by Messrs. David Morrow, David Armistead, and Thomas Ussery, all from WES. Mr. Marvin Cannon, U.S. Army Engineer District, Vicksburg, assisted with the design of the survey and provided maps and other background information. Figures and tables were prepared by Ms. Geralline Wilkerson, Jackson State University, Jackson, MS.

During the conduct of this study Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Ecological Research Division, EL; and Dr. Alfred F. Cofrancesco, Jr., was Chief, Aquatic Ecology Branch (AEB), EL. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, AEB.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin.

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# **Conversion Factors, Non-SI Units of Measurement**

Non-SI units of measurement used in this report can be converted to SI units as follows:

| Multiply .            | Ву        | To Obtain  |
|-----------------------|-----------|------------|
| feet                  | 0.3048    | meters     |
| miles (U.S. nautical) | 1.852     | kilometers |
| pounds (mass)         | 0.4535924 | kilograms  |

# 1 Introduction

## Background

The U.S. Army Engineer District, Vicksburg, is considering channel modification in reaches of the Quiver River and Bogue Phalia, tributaries to the Big Sunflower River in west-central Mississippi. Channel alteration would be accomplished by selective dredging. District personnel need to determine if flood conveyance is economically feasible and environmentally sustainable.

Environmental studies are required in part because results of past surveys (Miller, Payne, and Hartfield 1992; Miller and Payne 1995) indicated that valuable stocks of freshwater mussels (Family: Unionidae) inhabit selected reaches of the nearby Big Sunflower River. District personnel and others considered it very likely that mussel stocks are in reaches of Bogue Phalia and Quiver River that could be affected by dredging.

Before the use of plastics, freshwater mussel shells were collected and used to manufacture pearl buttons (Coker 1919). Today, shells are used to culture pearls. Shells are cut into cubes, ground into spheres, and inserted into an oyster. The increased demand during the past 3 to 5 years has pushed the price of shells to about \$6 per pound on the Japanese market (Williams et al. 1992). The preferred shell for pearl making is thick, white, and free of blem-ishes. Because they are usually abundant and have thick shells, the threeridge (*Amblema p. plicata*) and washboard (*Megalonaias nervosa*) are in high demand by the industry. In 1991, the total tonnage of shells exported to Japan was 9,000 short tons, but demand has declined in the last 2 years and leveled to about 4,500 short tons (Baker, as cited by Williams et al. 1993). Recent concern over the spread of the exotic zebra mussel (*Dreissena polymorpha*) and its effects on native mussels could increase the demand and price for high-quality shell.

Freshwater mussels in Mississippi tend to be scattered and not found in discrete beds. Mussels are found in pools or runs stabilized by woody debris or aquatic macrophytes. Often they are locally abundant immediately upriver or downriver of a low-water dam or weir. Most surveys in Mississippi have been qualitative, with investigators collecting live mussels or shells by hand. Qualitative data on Mississippi bivalves have been obtained by Hinkley (1906), Frierson (1911), Isom and Yokley (1968), Grantham (1969), Stern (1976), Yokley (1979), Cooper and Johnson (1980), Hartfield and Rummel (1985), Hartfield and Ebert (1986), and Bogan, Hartfield, and Bogan (1987). In 1993, personnel of the U.S. Army Engineer Waterways Experiment Station (WES) surveyed the majority of the Big Sunflower River for mussels (Miller, Payne, and Hartfield 1992; Miller and Payne 1995). They found four distinctive beds with moderate- to high-density populations (Miller and Payne 1995). However, low-density populations of commercial shells were found along virtually the entire river.

There are no published records on mussels from the Quiver River or Bogue Phalia. Grantham (1969) recorded 13 species of mussels from the Yazoo Basin with only 2 (*Potamilus purpuratus* and *Amblema plicata plicata*) confirmed as occurring in the Big Sunflower River drainage.

## **Purpose and Scope**

The purpose of this report is to present information on the location, species composition, density, and economic value of mussels in selected reaches of the Quiver River and Bogue Phalia, Mississippi. Information will be used by personnel of the Vicksburg District to evaluate the impacts of channel maintenance.

# 2 Study Area and Methods

## **Study Area**

The study area includes a reach of Bogue Phalia and the Quiver River, two tributaries of the Big Sunflower River (Figure 1). Both are located in the Delta in the northwestern section of Mississippi. Both rivers are low gradient, and substratum consists of sand and silt with little or no gravel. Neither of these rivers has pool-riffle sequences that are characteristic of rivers in high-gradient terrain. Banks are often steep, poorly vegetated, and subject to erosion during high water. There are no aquatic plants in the river, although in some reaches there is considerable woody debris. Water velocity in the summer is usually less than 0.5 ft/sec,<sup>1</sup> although during high discharge velocities greater than 2 ft/sec are common.

The study area in the Quiver River includes a reach between its confluence with the Big Sunflower River, immediately north of Highway 82 in Sunflower County, to the Leflore-Tallahatchie county line. In the Bogue Phalia, the study area includes a reach between Highway 82 and Rosedale, west-central Bolivar County.

Sediments throughout the study area consist mainly of fine-grained sands and silt. In a typical sediment sample, 95-100 percent of the material is less than 0.65 mm. Partially decaying woody vegetation is usually found in depositional areas instead of sand or gravel. Gravel and sands, if present, are usually found downriver of a weir. Numerous weirs exist in the project area as part of previous flood-control projects. They act as low-water dams and hold water, causing slight deposition of fine-grained sediments. Downstream of the weirs, conditions are slightly erosional and sediments accumulate to a lesser extent.

Mussels were collected using quantitative and qualitative methods at 26 sites in the Quiver River and 11 sites in Bogue Phalia (Table 1). Sites were chosen to reflect the range of conditions in both rivers and include straight reaches, bends, and areas immediately upriver and downriver of weirs.

<sup>&</sup>lt;sup>1</sup> A table of factors for converting non-SI units of measurement to SI units is presented on page vi.



Figure 1. Map of the study areas showing sample locations

## **Methods**

## **Preliminary reconnaissance**

A preliminary reconnaissance of the study area was conducted prior to initiating intensive sampling. This was accomplished by two individuals who traversed the entire project area in a small boat. They stopped frequently and inspected the shore and shallow water for live mussels or dead shells. They also obtained information on substratum conditions, water velocity, and presence of instream cover. Field notes were recorded, and sites that appeared suitable for mussels were marked on topographic maps. Sites likely to support mussels were usually depositional areas immediately upriver of weirs,

| Table 1<br>Sites Surv<br>Project, 1 | veyed on the (<br>994-95 | Quiver River an     | d Bogue Phalia | , Yazoo Basin |  |
|-------------------------------------|--------------------------|---------------------|----------------|---------------|--|
| Site                                | RM                       | Date                | Qualitative    | Quantitative  |  |
|                                     |                          | Quiver              |                | ····          |  |
| 1                                   | 5.1                      | Aug 95              | x              |               |  |
| 2                                   | 6.1                      | Aug 95              | X              |               |  |
| 3                                   | 6.4                      | Aug 95              | X              | X             |  |
| 4                                   | 12.4                     | Aug 95              | X              | X             |  |
| 5                                   | 13.2                     | Aug 95              | X              |               |  |
| 6                                   | 15.0                     | Aug 95              | X              |               |  |
| 7                                   | 16.1                     | Aug 95              | X              |               |  |
| 8                                   | 18.0                     | Aug 95              | X              |               |  |
| 9                                   | 19.4                     | Aug 95              | x              |               |  |
| 10                                  | 19.7                     | Aug 95              | x              |               |  |
| 11                                  | 19.9                     | Aug 95              | X              | X             |  |
| 12                                  | 21.6                     | Aug 95              | X              |               |  |
| 13                                  | 22.7                     | Aug 95              | X              |               |  |
| 14                                  | 26.9                     | Aug 95              | X              |               |  |
| 15                                  | 26.9                     | Aug 95              | X              | X             |  |
| 16                                  | 27.2                     | Aug 95              | X              |               |  |
| 17                                  | 27.6                     | Aug 95              | X              |               |  |
| 18                                  | 28.7                     | Aug 95              | x              |               |  |
| 19                                  | 31.2                     | Aug 95              | X              |               |  |
| 20                                  | 31.6                     | Aug 95              | X              |               |  |
| 21                                  | 32.0                     | Jun 95              | х              |               |  |
| 22                                  | 33.5                     | <sup>-</sup> Jun 95 | x              |               |  |
| 23                                  | 34.4                     | Jun 95              | x              |               |  |
| 24                                  | 34.6                     | Jun 95              | X              |               |  |
| 25                                  | 35.4                     | Jun 95              | x              |               |  |
| 26                                  | 36.5                     | Jun 95              | ×              |               |  |
| Bogue Phalia                        |                          |                     |                |               |  |
| 1                                   | 23.7                     | Aug 95              | X              |               |  |
| 2                                   | 25.6                     | Aug 95              | X              |               |  |
| 3                                   | 27.4                     | Aug 95              | X              |               |  |
| 4                                   | 28.2                     | Aug 95              | X              |               |  |
| 5                                   | 32.2                     | Aug 95              | X              |               |  |
| 6                                   | 35.8                     | Aug 95              | X              |               |  |
| 7                                   | 39.8                     | Aug 95              | X              |               |  |
| 8                                   | 47.8                     | Aug 95              | X              |               |  |
| 9                                   | 59.5                     | Aug 95              | X              |               |  |
| 10                                  | 60.8                     | Aug 95              | X              |               |  |
| 11                                  | 66.9                     | Aug 95              | x              |               |  |

natural constrictions, or sharp bends. Some reaches immediately downriver of weirs were also chosen for detailed study. In addition to potentially productive sites, others were chosen simply to reflect overall conditions in the project area.

Qualitative and quantitative sampling was accomplished using divers in water deeper than 1 m and by waders in shallow water. Methods used were the same regardless of whether or not divers or waders did the collecting.

#### Qualitative mussel samples

Qualitative samples were obtained by having two or three individuals collect at a site simultaneously. Each diver placed a specific number of live mussels in each of four nylon bags; five mussels were placed in one bag and 20 were placed in each of the other three bags. Collections were made without bias toward size or type. Workers attempted to exclude the Asiatic clam, *Corbicula fluminea*. If *C. fluminea* was inadvertently collected, it was later eliminated. The total time spent searching was recorded so that the number of mussels collected per minute could be determined.

All mussels were brought to the surface, counted, and identified. Data were recorded on standard data sheets and returned to the laboratory for analysis and plotting. Shells of voucher specimens for each species were placed in plastic zipper-lock bags and labeled with high rag content paper. Mussels not needed for voucher were returned to the river. Methods for sampling mussels are based on techniques described in Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), Miller and Payne (1988), and Miller et al. 1993. Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962), Parmalee (1967), Starrett (1971), and Burch (1975). Taxonomy is consistent with Williams et al. (1992).

### Quantitative mussel samples

In addition to qualitative samples, quantitative samples (that included unionids as well as C. *fluminea*) were obtained at selected sites. Quantitative techniques were typically used only where density was high enough (usually at least 10 to 20 individuals/square meter) to provide good estimates of species richness and density. In some cases, quantitative samples were taken to adequately characterize conditions in low-density areas.

Quantitative samples were taken by placing either five or ten 0.25-sq m quadrats approximately 1 m apart. At River Mile (RM) 12.4 in the Quiver River, five quadrats were collected. At RM 6.4, 19.7, and 27.0 in the Quiver River and at RM 41.72 in Bogue Phalia, 10 quadrat samples were taken at each site. All sand, gravel, shells, and live bivalves to a depth of 10-15 cm were excavated. Material was placed in a bucket and transported to shore.

Sediment was washed through a series of three screens. All live mussels (including *C. fluminea*) removed from samples were placed in  $4-\ell$  zipper-lock bags. Each bivalve was then identified and total shell length (SL) measured to the nearest 0.1 mm with digital calipers. Mussels identified and measured in the field were returned to the river unharmed.

#### **Data analysis**

Species diversity was determined with the following formula:

 $H' = -p_i \log p_i$ 

where  $p_j$  is the proportion of the population that is of the  $j^{th}$  species (Shannon and Weaver 1949). Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988). All calculations were done with programs written in BASIC or SAS (Statistical Analytical System) on a personal computer. Discussion of statistical procedures that were used can be found in Green (1979) and Hurlbert (1984). Species area curves and dominancediversity curves were constructed from qualitative and quantitative biological data.

# 3 The Bivalve Community

## **Characteristics of the Mussel Resource**

#### **Quiver River**

A total of 22 species of native freshwater mussels were collected in the Quiver River, 19 using qualitative methods and 18 using quantitative methods (Table 2). Twenty-six sites were sampled using qualitative methods, and a total of 2,238 mussels were collected (Appendix A, Table A1). The dominant mussel was *Amblema p. plicata*, which comprised over 67 percent of the fauna (Table 3). *Plectomerus dombeyanus* comprised 20 percent of the mussels. The remaining 17 species accounted for less than 15 percent of the assemblage.

Seven hundred and twelve minutes were spent searching for mussels at the 26 sites (Table 3; Table A1, Appendix A). Collecting rate ranged from a low of 0.13 individuals/minute to a high of 6.25 individuals/minute; the overall mean was 3.14/minute.

Quantitative samples were collected at four locations (Table 1), RMs 6.4, 12.4, 19.7, and 27.0 (Tables 4 and 5). Two hundred and thirty 0.25-m<sup>2</sup> quadrats were taken at the four locations. Overall, the species diversity (0.67 to 0.90) was low, mainly because of the dominance of the threeridge, *Amblema p. plicata*. This species comprised 76 percent of the collection and was found in nearly 50 percent of all samples. Evidence of recent recruitment was low; only at RM 27.0 were individuals collected with a total SL less than 30 mm. Approximately 7 percent of the species and 0.15 percent of the individuals collected were less than 30 mm total SL (Table 4).

There was a tremendous range in total mean mussel density in the Quiver River (Table 6). At RM 6.4, the total density in three samples was less than 1 individual/square meter. At RM 19.7, mean density ranged from 4 to 276.8 individuals/square meter, and overall density was 92.3 individuals/ square meter.

|                                       | Bogue Phalia | Quiv  | er River |
|---------------------------------------|--------------|-------|----------|
| Species                               | Quai         | Quai  | Quant    |
| Arcidens confragosus (Say)            |              | x     | ×        |
| Anodonta suborbiculata Say            |              | x     |          |
| Amblema p. plicata (Say)              | x            | x     | x        |
| Ellipsaria lineolata (Rafinesque)     |              |       | x        |
| Glebula rotundata (Lamarck)           |              | x     | x        |
| Elliptio crassidens (Lamarck)         |              |       | x        |
| Fusconaia flava (Rafinesque)          |              | x     | x        |
| Lampsilis teres (Rafinesque)          | ×            | х     | x        |
| Ligumia subrostrata (Say)             | x            |       |          |
| Leptodea fragilis (Rafinesque)        | x            | x     | x        |
| Lasmigonia c. complanata (Barnes)     |              | x     |          |
| Megalonaias nervosa (Rafinesque)      |              | x     | ×        |
| Obliquaria reflexa (Rafinesque)       |              | x     | x        |
| Plectomerus dombeyanus (Valenciennes) | x            | ×     | x        |
| Pleurobema pyramidatum (I. Lea)       |              | x     |          |
| Potamilus pupuratus (Lamarck)         | x            | x     | x        |
| Pyganodon <i>grandis</i> (Say)        | x            | x     | x        |
| Quadrula p. pustulosa (i. Lea)        |              | х     | x        |
| Quadrula quadrula (Rafinesque)        | x            | x     | x        |
| Quadrula nodulata (Rafinesque)        | x            | ×     |          |
| Tritogonia verrucosa (Rafinesque)     |              | x     | x        |
| Truncilla truncata Rafinesque         |              |       | x        |
| Uniomerus declivus (Say)              |              |       | x        |
| Uniomerus tetralasmus (Say)           |              | x     |          |
| Utterbackia imbecillis Say            | x            |       |          |
| Total species                         | 10           | 19    | 18       |
| Total individuals                     |              | 2,238 | 2,260    |

#### Table 3

Percent Species Abundance for Freshwater Bivalves Using Qualitative Methods at 26 Locations at the Quiver River, Mississippi, 8 August 1995 (Summary for all sites)

| Species           | Total for All Sites |
|-------------------|---------------------|
| A. p. plicata     | 67.34               |
| P. dombeyanus     | 20.29               |
| Q. quadrula       | 2.28                |
| M. nervosa        | 2.14                |
| G. rotunda        | 1.88                |
| P. purpuratus     | 1.56                |
| Q. p. pustulosa   | 0.94                |
| C. pyramidatum    | 0.85                |
| F. flava          | 0.80                |
| L. fragilis       | 0.54                |
| A. confragosus    | 0.36                |
| Q. nodulata       | 0.27                |
| P. grandis        | 0.22                |
| O. reflexa        | 0.18                |
| L. complanata     | 0.09                |
| U. tetralasmus    | 0.09                |
| L. teres          | 0.09                |
| T. verrucosa      | 0.04                |
| A. suborbiculata  | 0.04                |
| Total individuals | 2,238               |
| Total species     | 19                  |
| Total search time | 712                 |
| Mussels/minute    | 3.14                |

#### **Bogue Phalia**

Qualitative collections for mussels were made at 11 sites on Bogue Phalia (Table 1). In comparison with the Quiver River, this river exhibited low density and low species richness. A total of 215 mussels were collected using qualitative methods in 220 min (Table 7 and also Appendix B). As with the Quiver River, the fauna was dominated by A. p. plicata, which comprised 78 percent of the collection. Plectomerus dombeyanus comprised nearly 11 percent of the fauna, and the remaining eight species were each less than 3 percent of the collection. In addition to the thickshelled species (A. p. plicata and P. dombeyanus), thinshelled species such as Pyganodon grandis, Leptodea fragilis, and Utterbackia imbecillis, typically found in fine-grained substratum, were collected.

Quantitative samples were collected at RM 41.72 on Bogue Phalia in October 1995 (Table 8). At the four sites, total mean density ranged from 0.0 to 3.2 individuals/ square meter; the overall mean was 1.33 individuals/ square meter. The fauna was dominated by *A. p. plicata*, which comprised 70 percent

of the collection. The other three species (Q. quadrula, P. purpuratus, and A. confragosus) each comprised 10 percent of the fauna.

| Percent Abundance<br>Quiver River Mile Sa<br>1995 | of Freshw<br>mpled Us | vater Mus<br>ing Quant | sels at All<br>titative Me | Sites on •<br>ethods, Au | the<br>Igust |
|---|-----------------------|------------------------|----------------------------|--------------------------|--------------|
| Species   | RM 6.4                | RM 12.4                | RM 19.7                    | RM 27.0                  | Total        |
| A. p. plicata                                     | 81.48                 | 71.71                  | 77.02                      | 74.19                    | 76.11        |
| P. dombeyanus                                     | 8.33                  | 13.82                  | 20.30                      | 17.53                    | 18.54        |
| M. nervosa  | 0.93                  | 3.95                   | 1.16                       | 1.62                     | 1.46         |
| Q. pustulosa                                      | 0.93                  | 7.24                   | 0.29                       | 0.81                     | 0.93         |
| F. flava  | 0.00                  | 0.00                   | 0.07                       | 2.44                     | 0.71         |
| Q. quadrula                                       | 0.00                  | 0.00                   | 0.36                       | 1.14                     | 0.53         |
| P. purpuratus                                     | 0.00                  | 0.66                   | 0.29                       | 0.81                     | 0.44         |
| L. fragilis                                       | 0.93                  | 0.66                   | 0.22                       | 0.49                     | 0.35         |
| P. pyramidatum                                    | 4.63                  | 0.00                   | 0.00                       | 0.00                     | 0.22         |
| P. grandis  | 0.93                  | 1.32                   | 0.00                       | 0.00                     | 0.13         |
| T. truncata                                       | 0.93                  | 0.00                   | 0.00                       | 0.16                     | 0.09         |
| E. lineolata                                      | 0.00                  | 0.00                   | 0.00                       | 0.16                     | 0.04         |
| A. confragosus                                    | 0.93                  | 0.00                   | 0.00                       | 0.00                     | 0.04         |
| G. rotundata                                      | 0.00                  | 0.66                   | 0.00                       | 0.00                     | 0.04         |
| O. reflexa  | 0.00                  | 0.00                   | 0.22                       | 0.16                     | 0.18         |
| E. crassidens                                     | 0.00                  | 0.00                   | 0.00                       | 0.16                     | 0.04         |
| L. teres  | 0.00                  | 0.00                   | 0.00                       | 0.16                     | 0.04         |
| T. verrucosa                                      | 0.00                  | 0.00                   | 0.07                       | 0.00                     | 0.04         |
| U. declivus                                       | 0.00                  | 0.00                   | 0.00                       | 0.16                     | 0.04         |
| Total individuals                                 | 108                   | 152                    | 1,384                      | 616                      | 2,260        |
| Total species                                     | 9                     | 8                      | 10                         | 14                       | 19           |
| Menhinik's Index                                  | 0.87                  | 0.65                   | 0.27                       | 0.56                     |              |
| Diversity   | 0.78                  | 0.98                   | 0.67                       | 0.90                     |              |
| Evenness  | 0.42                  | 0.51                   | 0.61                       | 0.49                     |              |
| % Individuals < 30 mm                             | 0.00                  | 0.00                   | 0.00                       | 0.16                     |              |
| % Species < 30 mm                                 | 0.00                  | 0.00                   | 0.00                       | 7.14                     |              |

| Table 5<br>Frequency of O<br>Quiver River Sa | ccurrence<br>mpled Usi | of Freshwa<br>ng Qualitativ | ter Mussels<br>ve Methods | s at All Sit<br>s, August | es on the<br>1995 |
|--|------------------------|-----------------------------|---------------------------|---------------------------|-------------------|
| Species                                      | RM 6.4                 | RM 12.4                     | RM 19.7                   | RM 27.0                   | Total             |
| A. p. plicata                                | 14.00                  | 40.00                       | 68.33                     | 60.00                     | 46.96             |
| P. dombeyanus                                | 10.00                  | 25.00                       | 60.00                     | 33.33                     | 33.04             |
| M. nervosa                                   | 2.00                   | 5.00                        | 20.00                     | 13.33                     | 10.43             |
| Q. pustulosa                                 | 2.00                   | 16.67                       | 3.33                      | 5.00                      | 6.96              |
| P. purpuratus                                | 0.00                   | 1.67                        | 6.67                      | 8.33                      | 4.35              |
| F. flava                                     | 0.00                   | 0.00                        | 1.67                      | 13.33                     | 3.91              |
| Q. quadrula                                  | 0.00                   | 0.00                        | 6.67                      | 8.33                      | 3.91              |
| L. fragilis                                  | 2.00                   | 1.67                        | 5.00                      | 5.00                      | 3.48              |
| P. grandis                                   | 2.00                   | 3.33                        | 0.00                      | 0.00                      | 1.30              |
| O. reflexa                                   | 0.00                   | 0.00                        | 3.33                      | 1.67                      | 1.30              |
| T. truncata                                  | 2.00                   | 0.00                        | 0.00                      | 1.67                      | 0.87              |
| P. pyramidatum                               | 2.00                   | 0.00                        | 0.00                      | 0.00                      | 0.43              |
| E. crassidens                                | 0.00                   | 0.00                        | 0.00                      | 1.67                      | 0.43              |
| L. teres                                     | 0.00                   | 0.00                        | 0.00                      | 1.67                      | 0.43              |
| G. rotundata                                 | 0.00                   | 1.67                        | 0.00                      | 0.00                      | 0.43              |
| A. confragosus                               | 2.00                   | 0.00                        | 0.00                      | 0.00                      | 0.43              |
| E. lineolata                                 | 0.00                   | 0.00                        | 0.00                      | 1.67                      | 0.43              |
| T. verrucosa                                 | 0.00                   | 0.00                        | 1.67                      | 0.00                      | 0.43              |
| U. declivus                                  | 0.00                   | 0.00                        | 0.00                      | 1.67                      | 0.43              |
| Total sites                                  | 5                      | 12                          | 6                         | 6                         | 29                |
| Total quadrats                               | 50                     | 60                          | 60                        | 60                        | 230               |

## Location of valuable mussel resources in the project area

As illustrated in Table 6, high-density populations of mussels in the Quiver River were found at RMs 27.0 and 19.7. Although the river was thoroughly surveyed and 26 sites were critically examined, there is always the possibility that other beds could be found. Regardless, in comparison with other rivers, both the Quiver River and Bogue Phalia have relatively uniform conditions of habitat throughout. With the exception of weirs, most areas had low flow, fine-grained substratum, and fairly steep banks. Mussel habitat was relatively similar throughout both rivers. Although high-density areas exist, it is accurate to state that much of the shallow areas along the shore of both rivers provided fair to good mussel habitat.

| Table 6<br>Mean Densit | ty and S   | tandard E      | irror of t  | he Mean     | for Mus    | sels Coll   | lected a    | t Four L    | ocations    | in the ( | Quiver R | iver, 1 | 995           |
|------------------------|------------|----------------|-------------|-------------|------------|-------------|-------------|-------------|-------------|----------|----------|---------|---------------|
|                        |            |                |             |             |            | Site Numl   | Ders        |             |             |          |          |         |               |
| River Mile             | 1          | 2              | e           | 4           | ß          | 9           | 7           | 8           | ი           | 10       | 11       | 12      | Overall Mean  |
|                        |            |                |             |             |            | Mean V      | alues       |             |             |          |          |         |               |
| 6.4                    | 42.8       | 0.4            | 0.0         | 0.0         |            |             |             |             |             |          |          |         | 8.6           |
| 12.4                   | 1.6        | 9.6            | 6.4         | 6.4         | 0.8        | 0.0         | 12.0        | 6.4         | 5.6         | 0.0      | 16.0     | 58.8    | 10.1          |
| 19.7                   | 24.8       | 276.8          | 47.6        | 46.8        | 153.6      | 4.0         |             |             |             |          |          |         | 92.3          |
| 27.0                   | 112.4      | 57.6           | 0.4         | 4.8         | 62.8       | 8.4         |             |             |             |          |          |         | 41.1          |
|                        |            |                |             |             |            | Site Num    | bers        |             |             |          |          |         |               |
| River Mile             | -          | 2              | e           | 4           | വ          | 9           | 7           | 8           | 6           | 10       | 11       | 12      | Overall Value |
|                        |            |                |             |             | Stai       | ndard Error | of the Me   | u           |             |          |          |         |               |
| 6.4                    | 17.5       | 0.4            | 0.0         | 0.0         | 0.0        |             |             |             |             |          |          |         | 4.2           |
| 12.4                   | 1.1        | 2.1            | 1.7         | 2.5         | 0.6        | 0.0         | 3.9         | 2.1         | 3.3         | 0.0      | 3.2      | 6.2     | 2.2           |
| 19.7                   | 12.5       | 27.8           | 23.3        | 20.0        | 43.8       | 1.6         |             |             |             |          |          | ,       | 15.8          |
| 27.0                   | 21.7       | 13.6           | 0.4         | 1.6         | 9'0        | 2.6         |             |             |             |          |          |         | 6.8           |
| Note: Five quac        | drats were | collected at e | ach site at | RM 12.4; te | n quadrats | were takei  | n at each o | f the other | three river | miles.   |          |         |               |

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| Table 7                       |                  |          |          |           |            |            |           |          |            |           |             |           |
|-------------------------------|------------------|----------|----------|-----------|------------|------------|-----------|----------|------------|-----------|-------------|-----------|
| Percent Sper<br>15 August 1   | cies Abur<br>995 | ndance o | f Freshw | ater Biva | lives Usin | g Qualitat | ive Metho | ds at 11 | Sites on B | ogue Phal | lia, Missis | sippi,    |
|                               | Site 1           | Site 2   | Site 3   | Site 4    | Site 5     | Site 6     | Site 7    | Site 8   | Site 9     | Sita 10   | Site 11     |           |
| Species                       | RM 33.7          | RM 25.6  | RM 27.4  | RM 28.2   | RM 32.2    | RM 35.8    | RM 39.8   | RM 47.5  | RM 59.5    | RM 60 8   | DAI GO D    | F         |
| A. p. plicata                 | 33.33            | 22.22    | 0.00     | 81.63     | 40.00      | 00.0       |           | 76.40    |            |           | 6.00 MM     |           |
| P. dombeyanus                 | 33.33            | 66.66    | 0.00     | 14.29     | 0.00       | 0.0        |           |          | 10.02      | 05.68     | 91.07       | 78.14     |
| P. grandis                    | 16.67            | 0.00     | 0.00     | 0.00      | 0.00       | 0.00       | 00.0      | 11 76    |            | 0.00      | 3.57        | 10.70     |
| Q. quadrula                   | 0.00             | 5.56     | 0.00     | 0.00      | 20.00      | 0.00       | 0.00      | 5 88     |            | 0.02      | 0.00        | 2.79      |
| P. purpuratus                 | 0.00             | 5.56     | 0.00     | 2.04      | 20.00      | 0.00       | 00.0      | E BB     |            | 0.00      | 76.5        | 2.33      |
| L. fragilis                   | 0.00             | 0.00     | 0.00     | 0.00      | 0.00       | 0.00       |           |          |            | 0.00      | 0.00        | 1.86      |
| L. teres                      | 0.00             | 00.0     |          | 20.0      |            |            |           | 0.0      | 3.33       | 0.00      | 1.79        | 0.93      |
|                               |                  |          | 2010     | +0.3      | 00.02      | 00.0       | 0.00      | 0.00     | 0.00       | 0.00      | 0.00        | 0.93      |
| L. Subrostrata                | 0.00             | 0.00     | 0.00     | 0.00      | 0.00       | 0.00       | 0.00      | 0.00     | 0.00       | 5.88      | 0.00        | 0.93      |
| Q. nodulata                   | 16.67            | 0.00     | 0.00     | 0.00      | 0.00       | 0.00       | 0.00      | 0.00     | 3.33       | 000       | 000         | 000       |
| U. imbecillis                 | 0.00             | 0.00     | 0.00     | 0.00      | 0.00       | 0.00       | 0.00      |          | 3 22       |           | 0,00        | 0.20      |
| Total individuals             | 9                | 18       | 0        | 49        | 5          | 0          | c         | 17       | 00.0       | 0.00      | 0.00        | 0.46      |
| Total species                 | 4                | 4        | 0        | 4         | 4          | c          |           |          |            | 45        | 96          | 215       |
| Total collection<br>time, min | 20               | 20       | 20       | 20        | 20         | 20         | 20        | 20       | 20         | 20        | 20          | 10<br>220 |
| Mussels/min                   | 0.30             | 0.90     | 0.00     | 2.45      | 0.25       | 0.00       | 0.00      | 0.85     | 1.50       | 1 70      | 00 0        |           |
|                               |                  |          |          |           |            |            |           |          |            | - ^ / · · | 2.00        | 0.98      |

| Table 8<br>Quantitative Data on   | Freshwater I       | Viussels From       | Three Sites      | on Bogue Ph        | alia River Mil | e 41.72, Mis       | sissippi, 199 | 10        |
|---|--------------------|---------------------|------------------|--------------------|----------------|--------------------|---------------|-----------|
|   | Site 1             | , LDB <sup>1</sup>  | Site 2,          | Channel            | Site 3,        | , RDB <sup>2</sup> | Tot           | al        |
| Species   | Abundance          | Frequency           | Abundance        | Frequency          | Abundance      | Frequency          | Abundance     | Frequency |
| A. p. plicata   | 00.00              | 0.00                | 75.00            | 20.00              | 50.00          | 10.00              | 70.00         | 10.00     |
| Q. quadrula   | 0.00               | 0.00                | 12.50            | 10.00              | 0.00           | 0.00               | 10.00         | 3.33      |
| P. purpuratus   | 0.00               | 0.00                | 0.00             | 0.00               | 50.00          | 10.00              | 10.00         | 3.33      |
| A. confragosus  | 0.00               | 00.0                | 12.50            | 10.00              | 0.00           | 0.00               | 10.00         | 3.33      |
| Total individuals   | 0                  |                     | 8                |                    | 2              |                    | 10            |           |
| Total quadrat samples   | 10                 |                     | 10               |                    | 10             |                    | 30            |           |
| Mean density  |                    | 0.0                 |                  | 3.2                |                | 0.8                | 1.33          |           |
| % individual <30 mm   |                    |                     |                  |                    |                |                    | 0.00          |           |
| % species < 30 mm   |                    |                     |                  |                    |                |                    | 0.00          |           |
| Menhinik's Index  |                    |                     |                  |                    |                |                    | 1.26          |           |
| Species diversity (H')  |                    |                     |                  |                    |                |                    | 0.94          |           |
| Equitability  |                    |                     |                  |                    |                |                    | 0.73          |           |
| Note: Sites were immediate<br><sup>1</sup> Left-descending bank.<br><sup>2</sup> Richt-descending bank. | ly upriver of a we | ir at Station 6. Th | here was no wate | r downriver of the | s weir.        |                    |               |           |

Chapter 3 The Bivalve Community

## Size Demography of Dominant Populations

Only mussels from the quantitative samples in the Quiver River were used for demographic analysis. The size demography of these species was similar at all locations; therefore individuals from all sites were grouped for analysis (Figure 2). Only populations with at least 15 individuals were analyzed.



Figure 2. Size demography of dominant mussels in the Quiver River, 1995

### Amblema plicata plicata

With the exception of one mussel 51.5 mm long, A. p. plicata individuals ranged from 69.2 to 129.5 mm total SL (Figure 2). This population clearly consists of several closely spaced cohorts, although overlap obscured age class separations. The modal length of this population ranged from 90 to 98 mm.

Evidence of recent recruitment for this species, as with all mussels listed in Table 4, was extremely poor.

#### Megalonaias nervosa

Mean SL of *M. nervosa* population ranged from 74.7 to 88.7 mm. This was a medium- to older aged population with no evidence of recent recruitment. Clearly several age classes were present, although since few individuals were collected, it is difficult to discern cohorts.

#### Plectomerus dombeyanus

With the exception of one individual less than 80 mm long, total SL of P. *dombeyanus* ranged between 83.4 and 131.7 mm. As with the other two thick-shelled species, several cohorts are present although not easily discerned from these data.

### Fusconaia flava

A single individual of F. *flava* was less than 4 mm long; the remainder of the population was between 74.4 and 88.7 mm total SL. It is likely that at least three cohorts of F. *ebena* were present, one represented by the single small individual, one less than 80 mm total SL, and one greater than 80 mm total SL.

## Economic Value of Mussels in the Project Area

#### Background

The commercial shell industry typically purchases only thick-shelled species to make inserts for oysters to culture pearls. In addition to having a thick shell, shell nacre should be white and free of blemishes. Although many species are potentially marketable (i.e., *Quadrula* spp., *Fusconaia* spp., and *Pleurobema* spp.), usually the threeridge (A. p. plicata) and washboard (M. nervosa) comprise the majority of the market. In the Big Sunflower River, these two species will certainly dominate commercial sales. The bank climber (*Plectomerus dombeyanus*) is abundant although not marketable.

Size limits for freshwater mussels are based on minimum shell height. If a live specimen cannot pass through a metal ring of a given diameter, then it is considered legal. In scientific surveys, total SL is usually measured and used to determine length-weight or length-age relationships. In this survey, SL of each specimen collected using quantitative methods was measured. Shell height measures were calculated from length-height relationships obtained from specimens collected in the Big Sunflower River (Miller and Payne 1995).

## Estimate of the commercial value of mussels in the project area

In February 1994, the Mississippi Department of Wildlife, Fisheries and Parks tentatively established minimum sizes for marketable shells in the Big Sunflower River. The minimum marketable size of A. p. plicata was set at 2 5/8 (66.7 mm) in. high. The minimum size of M. nervosa (washboard) was set at 3.25 in. (82.6 mm) high for the first year of commercial harvest and 4.0 in. high (101.6 mm) for 1995 and beyond. There is an obvious shortterm advantage for harvesters to have shell sizes set small. However, a small-sized shell will be less marketable than larger shells. The larger shells potentially provide more inserts for pearl production than smaller ones.

Shell height (SH) to SL ratios for these two marketable species, based upon data collected in the Sunflower River (Miller and Payne 1995), are as follows:

A. p. plicata SL = 0.57 \* SH + 12.46 (r = 0.86)M. nervosa SL = 0.65 \* SL + 6.57 (r = 0.95)

Based on these relationships, all A. p. plicata greater than 95 mm (3.7 in.) long, and all M. nervosa greater than 146 mm long (5.7 in.) are marketable.

| Maximum and Minimu<br>able Mussels, Quiver R     | n Shell Lengths of<br>liver, 1995 | Two Species of Market- |
|--|-----------------------------------|------------------------|
| Parameter  | A. p. plicata                     | M. nervosa             |
| Total Number Analyzed                            | 1,720                             | 33                     |
| Minimum SL                                       | 51.55                             | 74.71                  |
| Maximum SL                                       | 129.51                            | 156.78                 |
| Range  | 77.96                             | 82.07                  |
| Minimum Marketable SL                            | 95                                | 116.9                  |
| % of the population > mini-<br>mum marketable SL | 41.69                             | 78.79                  |

Average total organism wet weight was estimated based on these sizes. Approximately 42 percent of all *A. p. plicata* were greater than 66.67 mm SH and potentially marketable. Average mass of all *A. p. plicata* greater than 66.67 mm high (SL = 95 mm) was 168.07 g. The percent marketable *M. nervosa* was estimated at 78.79 percent, and the average mass of this species greater than 82.55 mm high (SL = 116.9 mm) was 438.81 g. Based upon information provided by the Mississippi Department of Wildlife, Fisheries and Parks, the price per pound (total live weight) was estimated to be \$1.00.

The number of river miles to be affected by dredging in the Quiver River and Bogue Phalia are 56 and 43, respectively (Table 9). Based on the assumption on the amount of available shoreline habitat (4 m in the

| Table 9<br>Estimated Commercial Value of<br>sels in the Quiver River and Bog<br>Data Collected in 1995 (Values | Two Species of F<br>ue Phalia, Mississ<br>Rounded to Whole | reshwater Mus-<br>ippi, Based Upon<br>e Numbers) |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|--|
| Parameter  | Quiver River   | Bogue Phalia                                     |  |  |  |  |  |  |
| River miles  | 56   | 43   |  |  |  |  |  |  |
| Length, m  | 90,104   | 69,509   |  |  |  |  |  |  |
| Width of channel available for mussels, m  | 4  | 2  |  |  |  |  |  |  |
| Total area, sq m   | 360,416  | 139,018  |  |  |  |  |  |  |
| Available, habitat, %  | 0.5  | 0.25   |  |  |  |  |  |  |
| Available area   | 180,208  | 34,754   |  |  |  |  |  |  |
| Mean mussel density  | 39.3   | 1.3  |  |  |  |  |  |  |
| % At   | oundance   |  |  |  |  |  |  |  |
| A. p. plicata  | 76.1   | 78.1   |  |  |  |  |  |  |
| M. nervosa   | 1.5  | 0.0  |  |  |  |  |  |  |
| Density, I   | Number/sq m  |  |  |  |  |  |  |  |
| A. p. plicata  | 29.9   | 1.0  |  |  |  |  |  |  |
| M. nervosa   | 0.6  | 0.0  |  |  |  |  |  |  |
| Total Nur  | nber Present   |  |  |  |  |  |  |  |
| A. p. plicata  | 5,390,243  | 36,119   |  |  |  |  |  |  |
| M. nervosa   | 103,400  | 0  |  |  |  |  |  |  |
| % Ma   | arketable  |  |  |  |  |  |  |  |
| A. p. plicata 41.7 41.7  |  |  |  |  |  |  |  |  |
| M. nervosa   | 78.8   | 1.0  |  |  |  |  |  |  |
| Number of Marketa  | ble Individuals Present                                    |  |  |  |  |  |  |  |
| A. p. plicata  | 2,247,192  | 15,058   |  |  |  |  |  |  |
| M. nervosa   | 81,469   | 0  |  |  |  |  |  |  |
| Mean we  | et weight, g   |  |  |  |  |  |  |  |
| A. p. plicata  | 168.1  | 168.1  |  |  |  |  |  |  |
| M. nervosa   | 438.8  | 438.8  |  |  |  |  |  |  |
| Total Mas  | s Present, Ib  |  |  |  |  |  |  |  |
| A. p. plicata  | 830,991.4  | 5,568.3  |  |  |  |  |  |  |
| M. nervosa   | 78,656.2   | 0.0  |  |  |  |  |  |  |
| Price/lb   | \$1.00   | \$1.00   |  |  |  |  |  |  |
| Tota   | al value   |  |  |  |  |  |  |  |
| A. p. plicata  | \$830,991  | \$5,568  |  |  |  |  |  |  |
| M. nervosa   | \$78,656   | \$0  |  |  |  |  |  |  |
| Total in river   | \$909,648  | \$5,568  |  |  |  |  |  |  |
| Grand total  |  | \$915,216  |  |  |  |  |  |  |

Quiver River and 2 m in Bogue Phalia), an estimate of the total possible mussel habitat was made. It was assumed that 50 percent of the Quiver River and 25 percent of the Bogue Phalia was suitable for mussels; therefore, approximately 180,000 and 35,000 sq m of mussel habitat could be affected by dredging. Although the dredge typically only works in the center of the river, both of these streams are so narrow that it was assumed that dredging in the channel would affect all mussel habitat.

An estimate of the total number of A. p. plicata and M. nervosa in the affected reaches was made, and this value was converted to total biomass in pounds. If mussels sell at \$1 per pound from the project area, the total value would be approximately \$910,000 in the Quiver River and \$5,000 in Bogue Phalia for a grand total of \$915,000 (Table 9). These estimates are based on population structure and density determined in the fall of 1995. Recent recruits will become marketable each year, and they will have commercial value.

# 4 Discussion

## The Bivalve Community

Certain sections of the Quiver River are characterized by high density and often extreme dominance by a single species (A. p. plicata). However, in most reaches mussels are scattered and densities are less than  $5/m^2$ . Mussel densities were also low in Bogue Phalia, mainly because of reduced water levels. During the summer, many reaches have extremely shallow water (several inches deep), with little or no flow. Such conditions will be extremely stressful for mussels. There was little or no evidence of recent recruitment in either river. Lack of small specimens was noted in high-density as well as low-density areas; it is unlikely that high-density populations inhibit recruitment.

It is difficult to determine why mussels reach extremely high densities in the river, yet exhibit so little evidence of recent recruitment. In comparison with northern habitats in northern latitudes, these mussels could be stressed by elevated temperatures in the summer, low-calcium-content water, and highsediment deposits. Although these effects are obviously negative, they do not appear to have affected the ability of these areas to support high-density populations.

In comparison with the Sunflower River, which is within the same drainage, these two rivers support fewer individuals and species. A total of 26 species of native mussels were collected in the Sunflower River, as compared with 22 in the Quiver and 10 in Bogue Phalia. It is difficult to make meaningful density comparisons among rivers, although clearly high-density sites exist in both the Big Sunflower and Quiver rivers. At a site at RM 19.7 in the Quiver River, total density was estimated at 276 individuals/square meter. Immediately downriver of abandoned Lock and Dam 1 in the Big Sunflower River, mean density of 10 quadrats was 235 individuals/square meter.

The total value of A. p. plicata and M. nervosa in the Big Sunflower River was estimated at \$2.7 million dollars for 1994 (Miller and Payne 1995). This estimate included four mussel beds as well as nearly 50 river miles. Although total miles in Bogue Phalia and Quiver River were slightly greater, the density and amount of habitat were less than in the Sunflower River. It was estimated that the commercial value of A. p. plicata and M. nervosa in the project area was approximately \$915,216 in Bogue Phalia and Quiver River.

## Impacts of Dredging

Removal of mussels from the river bottom, using either a hydraulic dredge or dragline, and transporting them to an upland disposal site would result in 100-percent mortality. If dredged material is deposited in the water, an unknown percentage of mussels would survive. Most mussels have the ability to extricate themselves after being buried, as long as sediments are not more than a few centimeters deep. However, there is the likelihood that high mortality will result as a result of the dredge. Mussels can be negatively affected by the effects of elevated suspended solids immediately downriver of a dredge. However, the molluscan gill and feeding palps are designed to separate nutritious particles from inorganic particles without food value. In addition, mussels in the project area have adapted to a naturally high suspended sediment regimen. Because of the uncertainty of these estimates, the effects of elevated suspended sediments immediately downriver of the dredge on mussels were not determined.

## Effects of Commercial Shell Harvest

A commercial shell harvester using scuba or surface-supplied air has the potential for removing virtually all mussels in a bed. A brail misses many mussels and can be less detrimental to valuable beds. However, an experienced shell diver should take only commercially valuable species. Uncommon or rare species with no commercial value should be left in the river and not dumped on shore. In addition, when size limits are placed on the population, not all specimens will be collected. Commercial shell harvest has the potential to be detrimental to mussel resources. However, if carefully regulated, existing populations could be maintained.

## Recommendations

With careful planning, mussels in the Quiver River and Bogue Phalia could survive selective commercial harvest. In addition, some will survive the effects of dredging. In order to protect as many mussels as possible, the following recommendations are made:

a. The effects of dredging and commercial harvest should be monitored. Quantitative and qualitative methods should be used to collect mussels in the areas where commercial harvesting is permitted and where dredging took place. Information should also be obtained from nondredged areas. Information on density, community composition, evidence of recent recruitment, population structure, and shell morphometrics should be obtained. These findings will be used to assist with regulating the commercial harvest and can be used to assess the environmental effects of maintenance dredging.

b. Selected areas should be set aside as a sanctuary where no harvesting would be permitted. This would provide an undisturbed community for future reproduction as well as a control area with no commercial impact.

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| Table A1<br>Percent Spe<br>26 Location: | cies Abu<br>s at the | ındance f<br>Quiver Ri | or Freshv<br>ver, Miss | water Biv<br>sissippi, { | valves Us<br>3 August | sing Qua<br>1995 | litative N | lethods a | at         |
|---|----------------------|------------------------|------------------------|--------------------------|-----------------------|------------------|------------|-----------|------------|
|   | Site 1               | Site 2                 | Site 3                 | Site 4                   | Site 5                | Site 6           | Site 7     | Site 8    | Site 9     |
| Species                                 | RM 5.1               | RM 6.1                 | RM 6.4                 | RM 12.4                  | RM 13.2               | RM 15            | RM 16.1    | RM 18     | RM 19.4    |
| A. p. plicata                           | 39.29                | 80.21                  | 60.70                  | 77.60                    | 4.88                  | 94.19            | 54.21      | 66.67     | 27.59      |
| P. dombeyanus                           | 7.14                 | 11.46                  | 30.85                  | 12.00                    | 60.98                 | 0.00             | 39.25      | 18.39     | 65.52      |
| Q. quadrula                             | 0.00                 | 1.56                   | 2.49                   | 0.00                     | 2.44                  | 0.00             | 0.00       | 0.00      | 0.00       |
| M. nervosa                              | 21.43                | 1.04                   | 1.00                   | 4.80                     | 0.00                  | 0.00             | 0.93       | 4.60      | 1.15       |
| G. rotunda                              | 0.00                 | 0.00                   | 0.00                   | 2.40                     | 0.00                  | 0.00             | 0.00       | 0.00      | 0.00       |
| P. purpuratus                           | 7.14                 | 0.52                   | 0.50                   | 1.60                     | 12.20                 | 1.16             | 0.93       | 5.75      | 0.00       |
| Q. p. pustulosa                         | 7.14                 | 2.08                   | 1.49                   | 0.00                     | 0.00                  | 0.00             | 0.93       | 2.30      | 1.15       |
| C. pyramidatum                          | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 0.00      | 2.30       |
| F. flava                                | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 2.44                  | 2.33             | 2.80       | 1.15      | 2.30       |
| L. fragilis                             | 0.00                 | 0.52                   | 1.99                   | 0.80                     | 4.88                  | 0.00             | 0.93       | 0.00      | 0.00       |
| A. confragosus                          | 7.14                 | 0.52                   | 0.00                   | 0.00                     | 4.88                  | 0.00             | 0.00       | 0.00      | 0.00       |
| Q. nodulata                             | 7.14                 | 1.56                   | 0.50                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 0.00      | 0.00       |
| P. grandis                              | 3.57                 | 0.00                   | 0.00                   | 0.80                     | 4.88                  | 0.00             | 0.00       | 0.00      | 0.00       |
| O. reflexa                              | 0.00                 | 0.52                   | 0.50                   | 0.00                     | 2.44                  | 1.16             | 0.00       | 0.00      | 0.00       |
| L. complanata                           | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 0.00      | 0.00       |
| U. tetralasmus                          | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 1.16             | 0.00       | 0.00      | 0.00       |
| L. teres                                | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 0.00      | 0.00       |
| T. verrucosa .                          | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 1.15      | 0.00       |
| A. suborbiculata                        | 0.00                 | 0.00                   | 0.00                   | 0.00                     | 0.00                  | 0.00             | 0.00       | 0.00      | 0.00       |
| Total individuals                       | 28                   | 192                    | 201                    | 125                      | 41                    | 86               | 107        | 87        | 87         |
| Total species                           | 8                    | 10                     | 9                      | 7                        | 9                     | 5                | 7          | 7         | 6          |
| Total search<br>time                    | 31                   | 42                     | 119                    | 20                       | 20                    | 20               | 20         | 20        | 20         |
| Mussels/min                             | 0.90                 | 4.57                   | 1.69                   | 6.25                     | 2.05                  | 4.30             | 5.35       | 4.35      | 4.35       |
|   |                      |                        |                        |                          |                       |                  |            | (She      | et 1 of 3) |

| Table A1 (Co         | ontinued | )       |         |         |         |         |         |         |             |
|----------------------|----------|---------|---------|---------|---------|---------|---------|---------|-------------|
|                      | Site 10  | Site 11 | Site 12 | Site 13 | Site 14 | Site 15 | Site 16 | Site 17 | Site 18     |
| Species              | RM 19.7  | RM 19.9 | RM 21.6 | RM 22.7 | RM 26.9 | RM 26.9 | RM 27.2 | RM 27.6 | RM 28.7     |
| A. p. plicata        | 89.11    | 82.73   | 52.58   | 73.86   | 69.86   | 76.00   | 76.83   | 69.49   | 60.00       |
| P. dombeyanus        | 10.89    | 10.91   | 44.33   | 21.59   | 24.66   | 18.67   | 10.98   | 27.12   | 25.71       |
| Q. quadrula          | 0.00     | 0.91    | 0.00    | 0.00    | 0.00    | 1.33    | 2.44    | 1.69    | 0.00        |
| M. nervosa           | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 4.88    | 1.69    | 8.57        |
| G. rotunda           | 0.00     | 3.64    | 2.06    | 2.27    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| P. purpuratus        | 0.00     | 0.00    | 0.00    | 0.00    | 2.74    | 0.00    | 1.22    | 6:00    | 5.71        |
| Q. p. pustulosa      | 0.00     | 1.82    | 1.03    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| C. pyramidatum       | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| F. flava             | 0.00     | 0.00    | 0.00    | 1.14    | 2.74    | 4.00    | 0.00    | 0.00    | 0.00        |
| L. fragilis          | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| A. confragosus       | 0.00     | 0.00    | 0.00    | 1.14    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| Q. nodulata          | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| P. grandis           | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| O. reflexa           | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| L. complanata        | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 2.44    | 0.00    | 0.00        |
| U. tetralasmus       | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| L. teres             | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 1.22    | 0.00    | 0.00        |
| T. verrucosa         | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| A. suborbiculata     | 0.00     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00    | 0.00        |
| Total individuals    | 101      | 110     | 97      | 88      | 73      | 150     | 82      | 59      | 35          |
| Total species        | 2        | 5       | 4       | 5       | 4       | 4       | 7       | 4       | 4           |
| Total search<br>time | 20       | 20      | 20      | 20      | 20      | 20      | 20      | 20      | 20          |
| Mussels/min          | 5.05     | 5.5     | 4.85    | 4.4     | 3.65    | 7.5     | 4.1     | 2.95    | 1.75        |
|                      |          |         |         |         |         |         |         | (Sh     | eet 2 of 3) |

|                      | Site 19 | Site 20 | Site 21 | Site 22 | Site 23  | Site 24 | Site 25 | Site 26 |                        |
|----------------------|---------|---------|---------|---------|----------|---------|---------|---------|------------------------|
| Species              | RM 31.2 | RM 31.6 | RM 32   | RM 33.5 | RM 34.36 | RM 34.6 | RM 35.4 | RM 36.5 | Total for<br>all sites |
| A. p. plicata        | 91.18   | 93.33   | 28.26   | 40.74   | 41.30    | 79.00   | 56.38   | 0.00    | 67.34                  |
| P. dombeyanus        | 3.92    | 6.67    | 19.57   | 11.11   | 28.26    | 13.00   | 3.36    | 0.00    | 20.29                  |
| Q. quadrula          | 0.00    | 0.00    | 4.35    | 11.11   | 0.00     | 0.00    | 20.81   | 0.00    | 2.28                   |
| M. nervosa           | 1.96    | 0.00    | 13.04   | 14.81   | 0.00     | 4.00    | 1.34    | 0.00    | 2.14                   |
| G. rotunda           | 0.00    | 0.00    | 30.43   | 11.11   | 23.91    | 0.00    | 1.34    | 25.00   | 1.88                   |
| P. purpuratus        | 2.94    | 0.00    | 2.17    | 3.70    | 2.17     | 1.00    | 2.68    | 25.00   | 1.56                   |
| Q. p. pustulosa      | 0.00    | 0.00    | 2.17    | 0.00    | 0.00     | 1.00    | 2.01    | 0.00    | 0.94                   |
| C. pyramidatum       | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 11.41   | 0.00    | 0.85                   |
| F. flava             | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.80                   |
| L. fragilis          | 0.00    | 0.00    | 0.00    | 3.70    | 0.00     | 0.00    | 0.67    | 25.00   | 0.54                   |
| A. confragosus       | 0.00    | 0.00    | 0.00    | 0.00    | 2.17     | 1.00    | 0.00    | 0.00    | 0.36                   |
| Q. nodulata          | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.27                   |
| P. grandis           | 0.00    | 0.00    | 0.00    | 3.70    | 0.00     | 0.00    | 0.00    | 0.00    | 0.22                   |
| O. reflexa           | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.18                   |
| L. complanata        | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.09                   |
| U. tetralasmus       | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 1.00    | 0.00    | 0.00    | 0.09                   |
| L. teres             | 0.00    | 0.00    | 0.00    | 0.00    | 2.17     | 0.00    | 0.00    | 0.00    | 0.09                   |
| T. verrucosa         | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.04                   |
| A. suborbiculata     | 0.00    | 0.00    | 0.00    | 0.00    | 0.00     | 0.00    | 0.00    | 25.00   | 0.04                   |
| Total individuals    | 102     | 15      | 46      | 27      | 46       | 100     | 149     | 4       | 2,238                  |
| Total species        | 4       | 2       | 7       | 8       | 6        | 7       | 9       | 4       | 19                     |
| Total search<br>time | 20      | 20      | 30      | 30      | 30       | 30      | 30      | 30      | 712                    |
| Mussels/min          | 5.1     | 0.75    | 1.53    | 0.90    | 1.53     | 3.33    | 4.97    | 0.13    | 3.14                   |

| River Mile 6.4, August | 1995     |          |          |          | ; ~~     |       |
|------------------------|----------|----------|----------|----------|----------|-------|
| Species                | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Total |
| A. p. plicata          | 82.24    | 0.00     | 0.00     | 0.00     | 0.00     | 81.48 |
| P. dombeyanus          | 8.41     | 0.00     | 0.00     | 0.00     | 0.00     | 8.33  |
| P. pyramidatum         | 4.67     | 0.00     | 0.00     | 0.00     | 0.00     | 4.63  |
| L. fragilis            | 0.93     | 0.00     | 0.00     | 0.00     | 0.00     | 0.93  |
| Q. pustulosa           | 0.93     | 0.00     | 0.00     | 0.00     | 0.00     | 0.93  |
| T. truncata            | 0.93     | 0.00     | 0.00     | 0.00     | 0.00     | 0.93  |
| M. nervosa             | 0.00     | 100.00   | 0.00     | 0.00     | 0.00     | 0.93  |
| P. grandis             | 0.93     | 0.00     | 0.00     | 0.00     | 0.00     | 0.93  |
| A. confragosus         | 0.93     | 0.00     | 0.00     | 0.00     | 0.00     | 0.93  |
| Total individuals      | 107      | 1        | 0        | 0        | 0        | 108   |
| Total species          | 9        | 1        | 0        | 0        | 0        | 9     |
| Menhinik's Index       | 0.78     | -        | 0        | 0        | 0        | 0.87  |
| Diversity (H')         | 0.73     | -        | 0        | 0        | 0        | 0.78  |
| Evenness               | 0.43     | -        | 0        | 0        | 0        | 0.42  |
| % Individuals < 30 mm  | 0.00     |          | 0        | 0        | 0        | 0.00  |
| % Species < 30 mm      | 0.00     | -        | 0        | 0        | 0        | 0.00  |

# Table A2Percent Abundance of Freshwater Rivers, Based on Quantitative Sampling, at QuiverRiver Mile 6.4, August 1995

## Table A3

# Frequency of Occurrence of Freshwater Rivers, Based on Quantitative Sampling, at Quiver River Mile 6.4, August 1995

| Species        | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Total |
|----------------|----------|----------|----------|----------|----------|-------|
| A. p. plicata  | 70.00    | 0.00     | 0.00     | 0.00     | 0.00     | 14.00 |
| P. dombeyanus  | 50.00    | 0.00     | 0.00     | 0.00     | 0.00     | 10.00 |
| L. fragilis    | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| P. pyramidatum | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| M. nervosa     | 0.00     | 10.00    | 0.00     | 0.00     | 0.00     | 2.00  |
| T. truncata    | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| Q. quadrula    | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| P. grandis     | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| A. confragosus | 10.00    | 0.00     | 0.00     | 0.00     | 0.00     | 2.00  |
| Total samples  | 10       | 10       | 10       | 10       | 10       | 50    |

| Table A4<br>Percent Abun | idance o | f Freshw | /ater Riv | ers, Bas | ed on Q  | uantitati | ive Sam  | olina, at | Ouiver I   | Ziver Mile  | 10 A M    | 1001      |       |
|--------------------------|----------|----------|-----------|----------|----------|-----------|----------|-----------|------------|-------------|-----------|-----------|-------|
| Species                  | Sample 1 | Sample 2 | Sample 3  | Sample 4 | Samnla 5 | Samula 6  | Samula 7 | Campo o   |            |             |           | and tool  |       |
|                          |          |          |           |          |          |           |          |           | C Aldillac | oditiple 10 | sample 11 | Sample 12 | Total |
| A. p. plicata            | 50.00    | 41.67    | 62.50     | 50.00    | 0.00     | 0.00      | 80.00    | 25.00     | 28.57      | 0.00        | 70.00     | 90.14     | 71.71 |
| P. dombeyanus            | 0.00     | 33.33    | 37.50     | 25.00    | 0.00     | 0.00      | 13.33    | 12.50     | 57.14      | 0.00        | 15.00     | 2.82      | 13.82 |
| Q. quadrula              | 0.00     | 16.67    | 0.00      | 0.00     | 100.00   | 0.00      | 0.00     | 0.00      | 14.29      | 0.00        | 15.00     | 5.63      | 7.24  |
| M. nervosa               | 50.00    | 0.00     | 0.00      | 0.00     | 0.00     | 0.00      | 0.00     | 50.00     | 0.00       | 0.00        | 0.00      | 1.41      | 3.95  |
| P. grandis               | 0.00     | 8.33     | 0.00      | 12.50    | 0.00     | 0.00      | 0.00     | 0.00      | 0.00       | 0.00        | 0.00      | 0.00      | 1.32  |
| L. fragilis              | 0.00     | 0.00     | 0.00      | 12.50    | 0.00     | 0.00      | 0.00     | 0.00      | 0.00       | 0.00        | 0.00      | 0.00      | 0.66  |
| P. purpuratus            | 0.00     | 0.00     | 0.00      | 0.00     | 0.00     | 0.00      | 6.67     | 0.00      | 0.00       | 0.00        | 0.00      | 0.00      | 0.66  |
| G. rotundata             | 0.00     | 0.00     | 0.00      | 0.00     | 0.00     | 0.00      | 0.00     | 12.50     | 0.00       | 0.00        | 0.00      | 0.00      | 0.66  |
| Total individuals        | 2        | 12       | 8         | 8        | -        | 0         | 15       | 8         | 7          | 0           | 20        | 71        | 152   |
| Total species            | 2        | 5        | 2         | 4        | -        | 0         | 3        | 4         | e          | 0           | 3         | 4         | 8     |
| Menhinik's Index         | 1.40     | 1.10     | 0.71      | 1.41     | '        | 0.00      | 0.77     | 1.41      | 1.13       | 0.00        | 0.67      | 0.47      | 0.65  |
| Species diversity        | 0.69     | 1.24     | 0.66      | 1.21     | ,        | 0.00      | 0.63     | 1.21      | 0.96       | 0.00        | 0.82      | 0.42      | 0.98  |
| Evenness                 | 0.00     | 1.18     | 1.23      | 1.27     | 1        | 0.00      | 0.65     | 1.27      | 1.25       | 0.00        | 0.76      | 0.51      | 0.51  |
| % Individuals<br>< 30 mm | 0.00     | 0.00     | 0.00      | 0.00     | 4        | 0.00      | 0.00     | 0.00      | 0.00       | 0.00        | 0.00      | 0.00      | 0.00  |
| % Species<br>< 30 mm     | 0.00     | 0.00     | 0.00      | 0.00     |          | 0.00      | 0.00     | 0.00      | 0.00       | 0.00        | 0.00      | 0.00      | 0.00  |

| Table A5<br>Frequency of<br>1995 | Occurre     | nce of Fi   | reshwati    | er Rivers   | , Based     | on Quan     | titative §  | Sampling    | l, at Quiv  | /er River    | Mile 12      | .4, Augu     | st    |
|----------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|--------------|--------------|-------|
| Species                          | Sample<br>1 | Sample<br>2 | Sample<br>3 | Sample<br>4 | Sample<br>5 | Sample<br>6 | Sample<br>7 | Sample<br>8 | Sample<br>9 | Sample<br>10 | Sample<br>11 | Sample<br>12 | Total |
| A. p. plicata                    | 20.00       | 40.00       | 60.00       | 60.00       | 0.00        | 0.00        | 60.00       | 40.00       | 20.00       | 0.00         | 80.00        | 100.00       | 40.00 |
| P. dombeyanus                    | 0.00        | 60.00       | 60.00       | 20.00       | 0.00        | 0.00        | 40.00       | 20.00       | 20.00       | 0.00         | 40.00        | 40.00        | 25.00 |
| Q. quadrula                      | 0.00        | 40.00       | 0.00        | 0.00        | 20.00       | 0.00        | 0.00        | 0.00        | 20.00       | 0.00         | 60.00        | 60.00        | 16.67 |
| M. nervosa                       | 20.00       | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 20.00       | 0.00        | 0.00         | 0.00         | 20.00        | 5.00  |
| P. grandis                       | 0.00        | 20.00       | 0.00        | 20.00       | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00         | 0.00         | 0.00         | 3.33  |
| L. fragilis                      | 0.00        | 0.00        | 0.00        | 20.00       | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00         | 0.00         | 00.0         | 1.67  |
| P. purpuratus                    | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 20.00       | 0.00        | 0.00        | 0.00         | 0.00         | 0.00         | 1.67  |
| G. rotundata                     | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 0.00        | 20.00       | 0.00        | 0.00         | 0.00         | 0.00         | 1.67  |
| Total samples                    | 5           | 5           | 5           | 5           | 5           | 5           | 5           | 2           | 5           | 2            | 5            | 5            | 60    |

| Table A6<br>Percent Abundance<br>River Mile 19.7, Au | e of Freshv<br>Igust 199 | water Mus<br>5 | sels, Base | d on Quan | ititative Sa | ampling, a | t Quiver |  |  |  |
|--|--------------------------|----------------|------------|-----------|--------------|------------|----------|--|--|--|
| Species  | Sample 1                 | Sample 2       | Sample 3   | Sample 4  | Sample 5     | Sample 6   | Total    |  |  |  |
| A. p. plicata  | 82.26                    | 83.38          | 77.31      | 52.14     | 72.92        | 50.00      | 77.02    |  |  |  |
| P. dombeyanus  | 8.06                     | 15.17          | 19.33      | 46.15     | 24.22        | 10.00      | 20.30    |  |  |  |
| M. nervosa   | 0.00                     | 0.58           | 0.84       | 0.85      | 2.08         | 20.00      | 1.16     |  |  |  |
| Q. q. quadrula                                       | 3.23                     | 0.14           | 0.00       | 0.85      | 0.26         | 0.00       | 0.36     |  |  |  |
| P. purpuratus  | 0.00                     | 0.14           | 0.00       | 0.00      | 0.26         | 20.00      | 0.29     |  |  |  |
| Q. pustulosa   | 0.00                     | 0.14           | 2.52       | 0.00      | 0.00         | 0.00       | 0.29     |  |  |  |
| O. reflexa   | 1.61                     | 0.29           | 0.00       | 0.00      | 0.00         | 0.00       | 0.22     |  |  |  |
| L. fragilis 4.84 0.00 0.00 0.00 0.00 0.00 0.22       |                          |                |            |           |              |            |          |  |  |  |
| T. verrucosa   | 0.00                     | 0.00           | 0.00       | 0.00      | 0.26         | 0.00       | 0.07     |  |  |  |
| F. flava   | 0.00                     | 0.14           | 0.00       | 0.00      | 0.00         | 0.00       | 0.07     |  |  |  |
| Total individuals                                    | 62                       | 692            | 119        | 117       | 384          | 10         | 1,384    |  |  |  |
| Total species  | 5                        | 8              | 4          | 4         | 6            | 4          | 10       |  |  |  |
| Menhinik's Index                                     | 0.63                     | 0.30           | 0.37       | 0.37      | 0.31         | 1.26       | 0.27     |  |  |  |
| Species diversity (H')                               | 0.69                     | 0.52           | 0.65       | 0.78      | 0.71         | 1.22       | 0.67     |  |  |  |
| Equitability   | 0.47                     | 0.57           | 0.63       | 0.92      | 0.68         | 1.15       | 0.61     |  |  |  |
| % Individuals < 30 mm                                | 0.00                     | 0.00           | 0.00       | 0.00      | 0.00         | 0.00       | 0.00     |  |  |  |
| % Species < 30 mm                                    | 0.00                     | 0.00           | 0.00       | 0.00      | 0.00         | 0.00       | 0.00     |  |  |  |

| Table A7<br>Frequency of (<br>Quiver River N | Occurrence<br>lile 19.7, / | e of Freshw<br>August 199 | vater Muss<br>95 | els, Based | on Quantita | tive Samp | ling, at |
|--|----------------------------|---------------------------|------------------|------------|-------------|-----------|----------|
| Species                                      | Sample 1                   | Sample 2                  | Sample 3         | Sample 4   | Sample 5    | Sample 6  | Total    |
| A. p. plicata                                | 50.00                      | 100.00                    | 70.00            | 70.00      | 90.00       | 30.00     | 68.33    |
| P. dombeyanus                                | 40.00                      | 100.00                    | 40.00            | 80.00      | 90.00       | 10.00     | 60.00    |
| M. nervosa                                   | 0.00                       | 30.00                     | 10.00            | 10.00      | 50.00       | 20.00     | 20.00    |
| Q. q. quadrula                               | 10.00                      | 10.00                     | 0.00             | 10.00      | 10.00       | 0.00      | 6.67     |
| P. purpuratus                                | 0.00                       | 10.00                     | 0.00             | 0.00       | 10.00       | 20.00     | 6.67     |
| L. fragilis                                  | 30.00                      | 0.00                      | 0.00             | 0.00       | 0.00        | 0.00      | 5.00     |
| O. reflexa                                   | 10.00                      | 10.00                     | 0.00             | 0.00       | 0.00        | 0.00      | 3.33     |
| Q. pustulosa                                 | 0.00                       | 10.00                     | 10.00            | 0.00       | 0.00        | 0.00      | 3.33     |
| T. verrucosa                                 | 0.00                       | 0.00                      | 0.00             | 0.00       | 10.00       | 0.00      | 1.67     |
| F. flava                                     | 0.00                       | 10.00                     | 0.00             | 0.00       | 0.00        | 0.00      | 1.67     |
| Total samples                                | 10                         | 10                        | 10               | 10         | 10          | 10        | 60       |

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| Percent Abundance<br>River Mile 27.0, A | ce of Fresh<br>August 199 | water Mus<br>95 | sels, Base | d on Quar | ntitative Sa | ampling, a | t Quiver |
|---|---------------------------|-----------------|------------|-----------|--------------|------------|----------|
| Species                                 | Sample 1                  | Sample 2        | Sample 3   | Sample 4  | Sample 5     | Sample 6   | Total    |
| A. p. plicata                           | 62.63                     | 81.25           | 0.00       | 91.67     | 91.72        | 42.86      | 74.19    |
| P. dombeyanus                           | 29.18                     | 13.89           | 0.00       | 8.33      | 1.91         | 9.52       | 17.53    |
| F. flava                                | 4.27                      | 2.08            | 0.00       | 0.00      | 0.00         | 0.00       | 2.44     |
| M. nervosa                              | 0.00                      | 0.69            | 0.00       | 0.00      | 3.82         | 14.29      | 1.62     |
| Q. quadrula                             | 1.42                      | 2.08            | 0.00       | 0.00      | 0.00         | 0.00       | 1.14     |
| Q. pustulosa                            | 0.36                      | 0.00            | 100.00     | 0.00      | 0.00         | 14.29      | 0.81     |
| P. purpuratus                           | 0.71                      | 0.00            | 0.00       | 0.00      | 1.27         | 4.76       | 0.81     |
| L. fragilis                             | 0.71                      | 0.00            | 0.00       | 0.00      | 0.00         | 4.76       | 0.49     |
| E. lineolata                            | 0.00                      | 0.00            | 0.00       | 0.00      | 0.00         | 4.76       | 0.16     |
| E. crassidens                           | 0.36                      | 0.00            | 0.00       | 0.00      | 0.00         | 0.00       | 0.16     |
| U. declivus                             | 0.00                      | 0.00            | 0.00       | 0.00      | 0.64         | 0.00       | 0.16     |
| L. teres                                | 0.36                      | 0.00            | 0.00       | 0.00      | 0.00         | 0.00       | 0.16     |
| T. truncata                             | 0.00                      | 0.00            | 0.00       | 0.00      | 0.64         | 0.00       | 0.16     |
| O. reflexa                              | 0.00                      | 0.00            | 0.00       | 0.00      | 0.00         | 4.76       | 0.16     |
| Total individuals                       | 281                       | 144             | 1          | 12        | 157          | 21         | 616      |
| Total species                           | 9                         | 5               | 1          | 2         | 6            | 9          | 14       |
| Menhinik's Index                        | 0.54                      | 0.42            | -          | 0.58      | 0.48         | 1.75       | 0.56     |
| Species diversity                       | 0.98                      | 0.64            | -          | 0.29      | 0.40         | 1.72       | 0.90     |
| Evenness                                | 0.66                      | 0.53            | -          | 0.60      | 0.38         | 0.84       | 0.49     |
| % Individuals < 30 mm                   | 0.36                      | 0.00            | -          | 0.00      | 0.00         | 0.00       | 0.16     |
| % Species < 30 mm                       | 11.11                     | 0.00            | -          | 0.00      | 0.00         | 0.00       | 7.14     |

# Table A8

| Table A9<br>Frequency of<br>Quiver River | Occurrenc<br>Mile 27.0, | e of Freshv<br>August 19 | vater Muss<br>95 | sels, Based | on Quantit | ative Samp | lling, at |
|--|-------------------------|--------------------------|------------------|-------------|------------|------------|-----------|
| Species                                  | Sample 1                | Sample 2                 | Sample 3         | Sample 4    | Sample 5   | Sample 6   | Total     |
| A. p. plicata                            | 90.00                   | 80.00                    | 0.00             | 60.00       | 100.00     | 30.00      | 60.00     |
| P. dombeyanus                            | 90.00                   | 70.00                    | 0.00             | 10.00       | 10.00      | 20.00      | 33.33     |
| M. nervosa                               | 0.00                    | 10.00                    | 0.00             | 0.00        | 40.00      | 30.00      | 13.33     |
| F. flava                                 | 70.00                   | 10.00                    | 0.00             | 0.00        | 0.00       | 0.00       | 13.33     |
| Q. quadrula                              | 30.00                   | 20.00                    | 0.00             | 0.00        | 0.00       | 0.00       | 8.33      |
| P. purpuratus                            | 20.00                   | 0.00                     | 0.00             | 0.00        | 20.00      | 10.00      | 8.33      |
| L. fragilis                              | 20.00                   | 0.00                     | 0.00             | 0.00        | 0.00       | 10.00      | 5.00      |
| Q. pustulosa                             | 10.00                   | 0.00                     | 10.00            | 0.00        | 0.00       | 10.00      | 5.00      |
| E. lineolata                             | 0.00                    | 0.00                     | 0.00             | 0.00        | 0.00       | 10.00      | 1.67      |
| E. crassidens                            | 10.00                   | 0.00                     | 0.00             | 0.00        | 0.00       | 0.00       | 1.67      |
| U. declivus                              | 0.00                    | 0.00                     | 0.00             | 0.00        | 10.00      | 0.00       | 1.67      |
| L. teres                                 | 10.00                   | 0.00                     | 0.00             | 0.00        | 0.00       | 0.00       | 1.67      |
| T. truncata                              | 0.00                    | 0.00                     | 0.00             | 0.00        | 10.00      | 0.00       | 1.67      |
| O. reflexa                               | 0.00                    | 0.00                     | 0.00             | 0.00        | 0.00       | 10.00      | 1.67      |
| Total samples                            | 10                      | 10                       | 10               | 10          | 10         | 10         | 60        |

Appendix A Results of Sampling in Quiver River

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| Table A10         Percent Abundance of Freshwater Rivers at All Sites on the Quiver         River Mile Sampled Using Quantitative Methods, August 1995 |        |         |         |         |       |  |  |
|--|--------|---------|---------|---------|-------|--|--|
| Species  | RM 6.4 | RM 12.4 | RM 19.7 | RM 27.0 | Total |  |  |
| A. p. plicata  | 81.48  | 71.71   | 77.02   | 74.19   | 76.11 |  |  |
| P. dombeyanus  | 8.33   | 13.82   | 20.30   | 17.53   | 18.54 |  |  |
| M. nervosa   | 0.93   | 3.95    | 1.16    | 1.62    | 1.46  |  |  |
| Q. pustulosa   | 0.93   | 7.24    | 0.29    | 0.81    | 0.93  |  |  |
| F. flava   | 0.00   | 0.00    | 0.07    | 2.44    | 0.71  |  |  |
| Q. quadrula  | 0.00   | 0.00    | 0.36    | 1.14    | 0.53  |  |  |
| P. purpuratus  | 0.00   | 0.66    | 0.29    | 0.81    | 0.44  |  |  |
| L. fragilis  | 0.93   | 0.66    | 0.22    | 0.49    | 0.35  |  |  |
| P. pyramidatum   | 4.63   | 0.00    | 0.00    | 0.00    | 0.22  |  |  |
| P. grandis   | . 0.93 | 1.32    | 0.00    | 0.00    | 0.13  |  |  |
| T. truncata  | 0.93   | 0.00    | 0.00    | 0.16    | 0.09  |  |  |
| E. lineolata   | 0.00   | 0.00    | 0.00    | 0.16    | 0.04  |  |  |
| A. confragosus   | 0.93   | 0.00    | 0.00    | 0.00    | 0.04  |  |  |
| G. rotundata   | 0.00   | 0.66    | 0.00    | 0.00    | 0.04  |  |  |
| O. reflexa   | 0.00   | 0.00    | 0.22    | 0.16    | 0.18  |  |  |
| E. crassidens  | 0.00   | 0.00    | 0.00    | 0.16    | 0.04  |  |  |
| L. teres   | 0.00   | 0.00    | 0.00    | 0.16    | 0.04  |  |  |
| T. verrucosa   | 0.00   | 0.00    | 0.07    | 0.00    | 0.04  |  |  |
| U. declivus  | 0.00   | 0.00    | 0.00    | 0.16    | 0.04  |  |  |
| Total individuals  | 108    | 152     | 1,384   | 616     | 2,260 |  |  |
| Total species  | 9      | 8       | 10      | 14      | 19    |  |  |

| Table A11Frequency of Occurrence of Freshwater Rivers at All Sites on the<br>Quiver River Sampled Using Qualitative Methods, August 1995 |        |         |         |         |       |  |  |
|--|--------|---------|---------|---------|-------|--|--|
| Species  | RM 6.4 | RM 12.4 | RM 19.7 | RM 27.0 | Total |  |  |
| A. p. plicata  | 14.00  | 40.00   | 68.33   | 60.00   | 46.96 |  |  |
| P. dombeyanus  | 10.00  | 25.00   | 60.00   | 33.33   | 33.04 |  |  |
| M. nervosa   | 2.00   | 5.00    | 20.00   | 13.33   | 10.43 |  |  |
| Q. pustulosa   | 2.00   | 16.67   | 3.33    | 5.00    | 6.96  |  |  |
| P. purpuratus  | 0.00   | 1.67    | 6.67    | 8.33    | 4.35  |  |  |
| F. flava   | 0.00   | 0.00    | 1.67    | 13.33   | 3.91  |  |  |
| Q. quadrula  | 0.00   | 0.00    | 6.67    | 8.33    | 3.91  |  |  |
| L. fragilis  | 2.00   | 1.67    | 5.00    | 5.00    | 3.48  |  |  |
| P. grandis   | 2.00   | 3.33    | 0.00    | 0.00    | 1.30  |  |  |
| O. reflexa   | 0.00   | 0.00    | 3.33    | 1.67    | 1.30  |  |  |
| T. truncata  | 2.00   | 0.00    | 0.00    | 1.67    | 0.87  |  |  |
| P. pyramidatum   | 2.00   | 0.00    | 0.00    | 0.00    | 0.43  |  |  |
| E. crassidens  | 0.00   | 0.00    | 0.00    | 1.67    | 0.43  |  |  |
| L. teres   | 0.00   | 0.00    | 0.00    | 1.67    | 0.43  |  |  |
| G. rotundata   | 0.00   | 1.67    | 0.00    | 0.00    | 0.43  |  |  |
| A. confragosus   | 2.00   | 0.00    | 0.00    | 0.00    | 0.43  |  |  |
| E. lineolata   | 0.00   | 0.00    | 0.00    | 1.67    | 0.43  |  |  |
| T. verrucosa   | 0.00   | 0.00    | 1.67    | 0.00    | 0.43  |  |  |
| U. declivus  | 0.00   | 0.00    | 0.00    | 1.67    | 0.43  |  |  |
| Total sites  | 5      | 12      | 6       | 6       | 29    |  |  |
| Total quadrats   | 50     | 60      | 60      | 60      | 230   |  |  |

Appendix B Results of Qualitative and Quantitative Sampling for Freshwater Mussels in Bogue Phalia, Mississippi, 1995

| Table B1<br>Percent Species Ab<br>Mississippi, 15 Aug | undance<br>lust 199 | of Frest<br>5 | ıwater E | livalves | Using Q | lualitativ | e Metho | ds at 11 | Sites o | n Bogue | Phalia, |       |
|---|---------------------|---------------|----------|----------|---------|------------|---------|----------|---------|---------|---------|-------|
|   | Site 1              | Site 2        | Site 3   | Site 4   | Site 5  | Site 6     | Site 7  | Site 8   | Site 9  | Site 10 | Site 11 |       |
| Species   | RM 33.7             | RM 25.6       | RM 27.4  | RM 28.2  | RM 32.2 | RM 35.8    | RM 39.8 | RM 47.5  | RM 59.5 | RM 60.8 | RM 66.9 | Total |
| A. p. plicata   | 33.33               | 22.22         | 0.00     | 81.63    | 40.00   | 0.00       | 0.00    | 76.48    | 90.01   | 85.30   | 91.07   | 78.14 |
| P. dombeyanus   | 33.33               | 66.66         | 0.00     | 14.29    | 0.00    | 0.00       | 0.00    | 0.00     | 0.00    | 0.00    | 3.57    | 10.70 |
| P. grandis  | 16.67               | 0.00          | 0.00     | 0.00     | 0.00    | 0.00       | 0.00    | 11.76    | 0.00    | 8.82    | 0.00    | 2.79  |
| Q. quadrula   | 0.00                | 5.56          | 0.00     | 00'0     | 20.00   | 0.00       | 0.00    | 5.88     | 0.00    | 0.00    | 3.57    | 2.33  |
| P. purpuratus   | 0.00                | 5.56          | 0.00     | 2.04     | 20.00   | 0.00       | 0.00    | 5,88     | 0.00    | 0.00    | 0.00    | 1.86  |
| L. fragilis   | 0.00                | 0.00          | 0.00     | 0.00     | 0.00    | 0.00       | 0.00    | 0.00     | 3.33    | 0.00    | 1.79    | 0.93  |
| L. teres  | 0.00                | 0.00          | 0.00     | 2.04     | 20.00   | 0.00       | 0.00    | 0.00     | 0.00    | 0.00    | 0.00    | 0.93  |
| L. subrostrata  | 0.00                | 0.00          | 0.00     | 0.00     | 0.00    | 0.00       | 0.00    | 0.00     | 0.00    | 5.88    | 0.00    | 0.93  |
| Q. nodulata   | 16.67               | 0.00          | 0.00     | 0.00     | 0.00    | 0.00       | 0.00    | 0.00     | 3.33    | 0.00    | 0.00    | 0.93  |
| P. imbecillis   | 0.00                | 0.00          | 0.00     | 0.00     | 0.00    | 0.00       | 0.00    | 0.00     | 3.33    | 0.00    | 0.00    | 0.46  |
| Total individuals                                     | 9                   | 18            | 0        | 49       | 5       | 0          | 0       | 17       | 30      | 34      | 56 4    | 215   |
| Total species   | 4                   | 4             | 0        | 4        | 4       | 0          | 0       | 4        | 4       | e       | 4       | 10    |
| Total collection time, min                            | 20                  | 20            | 20       | 20       | 20      | 20         | 20      | 20       | 20      | 20      | 20      | 220   |
| Mussels/min   | 0.30                | 0.90          | 0.00     | 2.45     | 0.25    | 0.00       | 0.00    | 0.85     | 1.50    | 1.70    | 2.80    | 0.98  |
|   |                     |               |          |          |         |            |         |          |         |         | -       |       |

| Table B2<br>Quantitative Data o<br>1995 | n Freshwate | or Mussels Fi | rom Three Si | ites on Bogu | e Phalia Rive | r Mile 41.72 | 2, Mississipp | i, October |
|---|-------------|---------------|--------------|--------------|---------------|--------------|---------------|------------|
|   | Site 1      | Site 1        | Site 2       | Site 2       | Site 3        | Site 3       | Total         | Total      |
| Species                                 | Abun        | Freq          | Abun         | Freq         | Abun          | Freq         | Abun          | Freq       |
| A. p. plicata                           | 0.00        | 0.00          | 75.00        | 20.00        | 50.00         | 10.00        | 70.00         | 10.00      |
| Q. quadrula                             | 0.00        | 0.00          | 12.50        | 10.00        | 0.00          | 0.00         | 10.00         | 3.33       |
| P. purpuratus                           | 0.00        | 0.00          | 0.00         | 0.00         | 50.00         | 10.00        | 10.00         | 3.33       |
| A. confragosus                          | 0.00        | 0.00          | 12.50        | 10.00        | 0.00          | 0.00         | 10.00         | 3.33       |
| Total individuals                       | 0           |               | 8            |              | 2             |              | 10            |            |
| Total samples                           |             | 10            |              | 10           |               | 10           |               | 30         |
| % Individuals < 30 mm                   |             |               |              |              |               |              | 0.00          |            |
| % Species < 30 mm                       |             |               |              |              |               |              | 0.00          |            |
| Menhinik's Index                        |             |               |              |              |               |              | 1.26          |            |
| Species diversity (H')                  |             |               |              |              |               |              | 0.94          |            |
| Equitability                            |             |               |              |              |               |              | 0.73          |            |

Appendix B Results of Sampling in Bogue Phalia

| Path model, and under the This additional to availing 1 for permanents, building the share model and available to acched of the share model as and the share of the | REPORT DOC   | UMENTATION F   | PAGE  | Form Approved<br>OMB No. 0704-0188   |  |  |  |
|--|--|--|---|--|--|--|--|
| 1. AGENCY USE ONLY (Lowe blank)       2. PEPORT DATE<br>September 1997       3. PEPORT TYPE AND DATES COVERED<br>Final report         4. TITLE AND SUBTITLE<br>Analysis of Freshwater Mussels (Unionidae) in the Quiver River and<br>Bogue Phalia, Mississippi, 1994-95       5. FUNDING NUMBERS         6. AUTHOR(s)<br>Andrew C. Miller, Barry S. Payne       5.       FUNDING NUMBERS         7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>U.S. Army Engineer Witerways Experiment Station<br>3909 Halls Ferry Road, Vicksburg, MS 39180-6199       8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br>Technical Report EL-97-19         9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>U.S. Army Engineer District, Vicksburg<br>4155 Clay Street<br>Vicksburg, MS 39180-3435       10. SPONSORING/MONITORING<br>AGENCY NEPORT NUMBER<br>AGENCY REPORT NUMBER         11. SUPPLEMENTARY NOTES<br>Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.       12. DISTRIBUTION CODE         13. ABSTRACT (Maximu 200 works)<br>A survey to assess community characteristics, density, population demography of dominant species, and the presence of rare or<br>endangered species of mussels (Emaily: Unionidae) was conducted in selected reaches of the Quiver River and Bogue Phalia,<br>Mississipi, in 1994 and 1995 for the U.S. Army Engineer District, Vicksburg, Results are being used to assess the economic<br>value of mussels in the project-Talibatchic comptine. In the Bogue Phalia, mississipi, in 1994 and 1995 for the U.S. Army Engineer District, Vicksburg, Results are being used to assess the economic<br>value of mussels in the project-Talibatchic comptine in the Quiver River immediately north of<br>Highway 82 and Rosedale, west-central Bolivar County.<br>Twenty-two species of native freshwater mussels were collecte  | Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503. |  |   |  |  |  |  |
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#### 13. (Concluded).

Qualitative collections for mussels were made at 11 sites on Bogue Phalia. This river exhibited low density (overall mean was 1.3 individuals/square meter) with low species richness (only 10 species were found). At four sites on Bogue Phalia, total mean density ranged from 0.0 to 3.2 individuals/square meter; the overall mean was 1.33 individuals/square meter. The fauna was dominated by *A. p. plicata*, which comprised 70 percent of the collection. If mussels sell at \$1 per pound from the project area, the total value would be approximately \$910,000 in the Quiver River and \$5,000 in Bogue Phalia.

Maintenance dredging and commercial shell harvest could negatively affect common and uncommon species in both rivers. The lack of recent recruitment, dominance of a single species, and low species richness make these mussels vulnerable. Commercial harvest should be carefully regulated and monitored, and selected reaches should be set aside as sanctuaries. The long-term survival of this resource could be ensured by regular monitoring and careful adherence to a well-designed dredging and commercial harvest plan.