U.S. Fish & Wildlife Service

Ouachita Rock Pocketbook
(Arkansia wheeleri)

Recovery Plan

March 2004

OUACHITA ROCK POCKETBOOK
(*Arkansia wheeleri* Ortmann and Walker, 1912)

RECOVERY PLAN

Prepared by

A. David Martinez
U.S. Fish and Wildlife Service
Oklahoma Ecological Services Field Office
Tulsa, Oklahoma

for

Region 2
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

Approved: H Dale Hall
Regional Director, U.S. Fish and Wildlife Service, Region 2

Date: 3/30/04

Concurrence:
Executive Director, Texas Parks and Wildlife Department

Date: March 3, 2004

OKLAHOMA
BRAD HENRY, GOVERNOR
GREG D. DUFFY, DIRECTOR

DEPARTMENT OF WILDLIFE CONSERVATION

1801 N. LINCOLN   P.O. BOX 53465   OKLAHOMA CITY, OK 73105   PH. 521-3851

December 29, 2003

Dale Hall
Regional Director, USFWS Region 2
500 Gold Avenue S. W.
Albuquerque, NM 87102

Subject: Letter of Concurrence, Ouachita Rock Pocketbook Recovery Plan

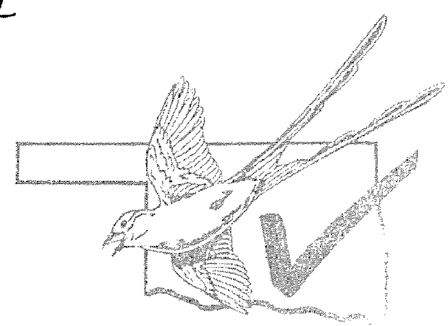
Dear Mr. Hall,

This letter responds to the final version of the Ouachita Rock Pocketbook Recovery Plan (Plan). The Department has reviewed the recovery plan and the recovery objectives. Based upon this review, we believe that the Plan contains a thorough assessment of the known historic and recent distributions of the Ouachita Rock Pocketbook and a complete summary of the data that have been collected with regard to this species' ecology and population biology. While data are limited for certain aspects of this species' biology, the recovery recommendations stated within the Plan appear to be biologically sound based upon our current knowledge and understanding of the Ouachita Rock Pocketbook. We trust that as new biological information is collected relative to this species, the Service will incorporate these data into future revisions of the Recovery Plan.

We concur with the U. S. Fish and Wildlife Service's findings and recommendations and will assist the Service in the implementation of the Ouachita Rock Pocketbook Recovery Plan within the constraints placed upon us by our funding and personnel limitations. If you have any questions regarding this letter, please direct them to Ron Suttles, Natural Resources Coordinator, at (405) 521-4616.

Sincerely,

Greg D. Duffy
Executive Director



DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available, subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

ACKNOWLEDGMENTS

Dr. Caryn Vaughn, Oklahoma Biological Survey, is acknowledged for her extensive and important contributions to recent knowledge of the Ouachita rock pocketbook and the ecosystems it inhabits. Dr. Vaughn's research has produced much information vital to conservation of this species, providing the U.S. Fish and Wildlife Service a greatly improved basis from which to prepare this recovery plan. Many other researchers have contributed additional findings of value, and are acknowledged in the plan by citation of their works. The following U.S. Fish and Wildlife Service employees reviewed preliminary versions of this plan and provided valuable comments: Gloria Bell, Jerry B. Brabander, Steve Chambers, Kenneth D. Collins, George Divine, Daniel B. Fenner, David P. Flemming, Kenneth D. Frazier, Stephen L. Hensley, Susan O. Rogers, Tracy A. Scheffler, Charles M. Scott, and Noreen E. Walsh.

LITERATURE CITATION

Literature citations should read as follows:

> U.S. Fish and Wildlife Service. 2004. Ouachita Rock Pocketbook (*Arkansia wheeleri* Ortmann and Walker, 1912) Recovery Plan. Albuquerque, New Mexico. vi + 83p. + A-1-85p.

Copies of the Recovery Plan are available from:

U.S. Fish and Wildlife Service
Oklahoma Ecological Services Field Office
222 S. Houston, Suite A
Tulsa, OK 74127
Tele. 918/581-7458

or from the U.S. Fish and Wildlife Service Web Site at:

www.fws.gov

EXECUTIVE SUMMARY

RECOVERY PLAN FOR THE OUACHITA ROCK POCKETBOOK (*ARKANSIA WHEELERI*)

Current Status: This freshwater mussel is listed as endangered. It is known to exist in approximately 252 kilometers (km) or 157 miles (mi) of the Red River system and 179 km (111 mi) of the Ouachita River system. The only known substantial population (fewer than 1,800 individuals) inhabits a 141-km (88-mi) section of the Kiamichi River, Oklahoma. A smaller, attenuated population (less than 100 individuals) inhabits approximately 111 km (69 mi) of the Little River in Oklahoma and Arkansas, although quality habitat for the species prevails in only a limited portion (24 km/15 mi) of that section above the Mountain Fork River. Recent observations of the species in the Ouachita River, Arkansas, are rare and widely separated. The only other recent evidence of the species consists of single shells recovered from Pine and Sanders creeks, Texas, which enter the Red River near the Kiamichi River.

Habitat Requirements and Limiting Factors: The Ouachita rock pocketbook inhabits pools, backwaters, and side channels of rivers and large creeks in or near the southern slope of the Ouachita Uplift. This species occupies stable substrates containing gravel, sand, and other materials. The Ouachita rock pocketbook always occurs within large mussel beds containing a diversity of mussel species. Impoundments and water quality degradation continue to adversely impact this species' survival. These factors, proposals for further water resource development, potential land use changes, and other secondary developments constitute primary future threats. Additional known threats include direct disturbance of river channels, possible invasion of inhabited waters by the exotic zebra mussel, natural factors (the species' restricted distribution, sensitivity to environmental conditions, and low abundance), and a lack of knowledge regarding the species' reproduction.

Recovery Objective: Delisting.

Recovery Criteria: The Ouachita rock pocketbook may be reclassified as threatened by protecting the Kiamichi River population, and by reestablishing and protecting distinct viable populations in two streams outside the Kiamichi River system. Protection involves elimination of present and foreseeable threats (e.g., deauthorizing Tuskahoma Reservoir), determining biological requirements, maintenance of suitable habitats and specific fish host(s), and verification of conditions through monitoring. The interim criterion for delisting requires establishment and protection of distinct viable populations in four stream systems historically inhabited. The delisting criterion may be revised as additional information becomes available.

Actions Needed:

1. Preserve existing population and habitat in the Kiamichi River.
2. Determine if other viable populations exist, preserve any population(s) found; restore degraded habitats.
3. Determine reproduction, habitat, genetics, and captive propagation requirements.
4. Establish, if necessary, and protect two populations outside the Kiamichi River (for reclassification as threatened).
5. Develop an outreach program.
6. Develop an enhanced management program.
7. Establish, if necessary, and permanently protect viable populations in four stream systems historically inhabited by the species (for delisting).

Estimated Recovery Costs ($1,000's):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Need 7	Total*
2003	149	226	245	40	25	218	0	903
2004	152	214	265	40	25	258	0	954
2005	142	190	190	40	2	235	0	799
2006	142	197	120	5	2	55	0	521
2007	127	182	110	15	2	115	0	551
2008	132	192	10	5	2	66	0	407
2009	147	207	0	0	2	66	40	462
2010	132	192	0	0	2	6	40	372
2011	132	192	0	0	2	6	40	372
2012	147	207	0	0	2	6	5	367
2013	107	142	0	0	2	6	15	272
2014	107	142	0	0	2	6	5	262
2015	122	157	0	0	2	6	0	287
2016	107	142	0	0	2	6	0	257
2017	107	142	0	0	2	6	0	257
2018	122	157	0	0	2	6	0	287
2019	107	142	0	0	2	6	0	257
2020	107	142	0	0	2	6	0	257
2021	122	157	0	0	2	6	0	287
2022	107	154	0	0	2	6	0	269
2023	107	142	0	0	2	6	0	257
Total*	2,624	3,618	940	145	88	1,097	145	8,657

Date of Reclassification: If criteria are met, the estimated date to reclassify to threatened is 2023.

Date of Delisting: A delisting date cannot be projected reasonably at this time.

* Total recovery costs, including habitat improvement costs needed for the species' recovery, will not be accurately known until the magnitude of specific threats is determined through research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART I: INTRODUCTION

Description

The Ouachita rock pocketbook, *Arkansia wheeleri*, is a freshwater mussel, one of a group of mollusks in the class Bivalvia, family Unionidae (Turgeon *et al.* 1998). The species was first described by Arnold E. Ortmann and Bryant Walker in 1912. The genus, *Arkansia*, was named for the state in which the species was first found, and the species, *wheeleri*, for the person, Harry Edgar Wheeler, who discovered the species. The genus is monotypic, containing a single known species. Clarke (1981) proposed subsuming the genus *Arkansia* within the older genus *Arcidens*; however, subsequent authorities (e.g., Turgeon *et al.* 1988, 1998, Williams *et al.* 1993) did not maintain such practice and retained the genus name *Arkansia*. Turgeon *et al.* (1998) comprise a committee set up to standardize common and scientific names of mollusks, and their findings are endorsed by the American Fisheries Society, the former Council of Systematic Malacologists, and the American Malacological Society. Nevertheless, some references use *Arcidens wheeleri* as the scientific name. The standardized common name for *A. wheeleri* is the Ouachita rock pocketbook. Other reported common names include Wheeler's pearly mussel, Wheeler's rock-pocketbook, the Arkansas rock-pocketbook, and a hyphenated form of the current standard name (Greenwalt 1974, Howells *et al.* 1996). The U.S. Fish and Wildlife Service (FWS) listed the Ouachita rock pocketbook as endangered in 1991 (Federal Register 56:54950-54957), without critical habitat.

Readily available references depict the shell of the Ouachita rock pocketbook in color photographs (Harris and Gordon 1990, Williams *et al.* 1993, Howells *et al.* 1996, Beacham *et al.* 2001), black-and-white photographs (Ortmann and Walker 1912, Webb 1942, Johnson 1980, Branson 1983, Howells *et al.* 1996), and drawings (Clench 1959, Burch 1975, Clarke 1981, Pennak 1989). This plan includes an image of the species (Figure 1), which also can be found within the FWS's endangered species website (http://endangered.fws.gov). The Ouachita rock pocketbook does not have a sexually dimorphic shell, both sexes appearing the same. The shell is subcircular to subovate to subquadrate in profile, truncated posteriorly, moderately inflated, up to 112 millimeters (mm) (4.4 inches) long, 87 mm (3.4 inches) high, and 60 mm (2.4 inches) wide, moderately heavy, somewhat thickened anteriorly, up to 6 mm (0.24 inches) thick, and half as thick posteriorly. The periostracum (outer shell layer) is chestnut-brown to black with a silky luster, and appears slightly iridescent when wet. The umbos are prominent, and project over a well-defined lunule depression. The posterior half of the shell is sculptured by irregular, oblique ridges that are sometimes crossed by smaller ridges or sometimes indistinct. Beak sculpturing, rarely intact, is very restricted and consists of weak double loops. The nacre (inner shell lining) is usually salmon-colored above the pallial line, white to light blue below, with a dark prismatic border. The shell has the so-called "complete" dentition for unionid bivalves, with all hinge teeth usually well-developed. The anterior left pseudocardinal and right pseudocardinal are both curved and parallel to the lunule; the posterior left pseudocardinal joins a conspicuous, flange-like, interdental projection that runs to the lower lateral. The lateral teeth are moderately short; the upper left lateral is sometimes reduced (Ortmann and Walker 1912, Johnson 1980, Clarke 1981, C.M. Mather, University of Science and Arts of Oklahoma, *in litt.* 2001).

Ortmann and Walker (1912) and Clarke (1981) described the soft anatomy of the Ouachita rock pocketbook, and Clarke (1981) included illustrations of a whole specimen and details of its gills. The soft parts agree in structure with anatomy characterized generally for the subfamily Anodontinae. Ortmann and

Figure 1. Ouachita rock pocketbook, *Arkansia wheeleri*. Photograph by Patricia Mehlhop.

Walker (1912) noted special agreement in the mantle edge and outer marsupial gill. In life, the incurrent opening is separated from the excurrent opening by appression of opposing mantle edges. The excurrent opening is separated from a supra-anal opening by a mantle connection. The incurrent opening is lined with three rows of small, flattened papillae; the excurrent opening is lined with one row of tiny, flattened papillae. The external membrane of the outer demibranch (gill) joins the mantle posteriorly to form a complete gill-diaphragm. The anterior end of the inner gills usually reaches between the posterior base of the labial palps and the anterior end of the outer gills. The inner lamina of the inner gills is free from the abdominal sac, except for a short distance at the anterior end. The labial palps are of medium size and subfalcate, with their posterior margins connected for about one-third of their length. The external membrane of the outer demibranch is openly porous, like a woven net. The gills have well-developed septa and water tubes. The septa are rather distant in the male and in the inner gill of the female. The outer gill alone is marsupial in the female, with very close septa. The edge of the marsupium is slightly thickened (Ortmann and Walker 1912, Clarke 1981).

Mussel identification is complex and relies on characters that may appear subtle to persons without specialized training. As a result, laypersons may confuse the Ouachita rock pocketbook with other freshwater mussels and may even question its validity as a separate species. However, *A. wheeleri* exhibits a number of characteristics that clearly distinguish it from other species. Furthermore, it shows no intergradation with other described mussel species and has been recognized by biologists as a distinct species from the time of its discovery. It is most likely to be mistaken for certain forms of two more widespread and common species, which it can resemble superficially: (1) the pimpleback, *Quadrula pustulosa* (I. Lea, 1831), and (2) the threeridge, *Amblema plicata* (Say, 1817). The Ouachita rock pocketbook can be differentiated from both species externally by its slightly iridescent periostracum and internally by its high interdental flange. In the pimpleback, the periostracum often remains a lighter shade of brown in adults and often includes greenish rays marking the umbos. The threeridge also exhibits oblique ridges but these tend to be more pronounced than those exhibited by the Ouachita rock pocketbook. The closest living relative to *A. wheeleri* is the rock pocketbook, *Arcidens confragosus* (Say, 1829). *A. wheeleri* can be distinguished from *A. confragosus* by the former species' heavier and more inflated shell; by its fuller, more anterior beaks; by its possession of a lunule; by its restriction of heavy sculpturing to the posterior half of the shell; by its much reduced beak sculpturing; and by its more greatly developed lateral teeth. Other subtle characteristics further differentiate the Ouachita rock pocketbook from other mussel species.

Ortmann and Walker (1912) designated the type locality for *A. wheeleri* as "Old River, Arkadelphia, Arkansas." Wheeler (1918) described the type locality as a series of oxbows connected to the Ouachita River, north of Arkadelphia, Clark County, Arkansas. The holotype of *A. wheeleri* was reported by Ortmann and Walker (1912) to be in the Walker collection. Paratypes were reported to have been placed in collections of the Carnegie Museum, the Philadelphia Academy of Science, the U.S. National Museum, and Reverend H.E. Wheeler. Johnson (1980) reported the holotype to be catalogued at the Museum of Zoology, University of Michigan (which acquired the Walker collection), and the Wheeler collection deposited at the Alabama Museum of Natural History (ALMNH), University of Alabama. Subsequently, however, much of the ALMNH mollusk collection, including the former Wheeler collection, was transferred to the Florida Museum of Natural History (FLMNH), University of Florida (Fred G. Thompson, FLMNH, pers. comm. 1999).

In accordance with the FWS's Species Recovery Priority System (Federal Register 48:43098-43105, 51985), the Ouachita rock pocketbook has been assigned a recovery priority of 4C.

Distribution and Abundance

To facilitate discussion of the Ouachita rock pocketbook's distribution, this plan reviews historical records separately from recent records. Historical records consist of those obtained prior to 1975, or that appear to represent occurrences of the species prior to 1975 (e.g., later discovery of pre-1975 shells). Recent records represent occurrences in 1975 or later. The term "natural range" denotes the total known range of the species, based on both historical and recent records (Figure 2).

Historical (prior to 1975)

Early records of *A. wheeleri* were published by Ortmann and Walker (1912), Wheeler (1918), Ortmann (1921), and Isely (1925). No additional discoveries of the species were reported until Stansbery (1970) and Valentine and Stansbery (1971), although some preceding reports (e.g., Brooks and Brooks 1931, Johnson 1956, and Parodiz 1967) accounted for specimens from early collections. Frierson (1927) erroneously reported *A. wheeleri* from the Arkansas River in Oklahoma. Records reported by Johnson (1977, 1979, 1980), Clarke (1981), and Bogan and Bogan (1983), while made after 1975, included specimens that represented historical populations. Published records reveal historical populations of the Ouachita rock pocketbook in three areas: the Ouachita River, southcentral Arkansas; the Kiamichi River, southeastern Oklahoma; and the Little River, southwestern Arkansas. Pre-1975 museum specimens of *A. wheeleri* for which data are available correspond fairly closely with the published records discussed (Table 1). Collection records indicate historical populations of the Ouachita rock pocketbook in the same general areas indicated by literature records (http://www.flmnh.ufl.edu; R. Hershler, National Museum of Natural History, *in litt.* 1993; R.I. Johnson, Museum of Comparative Zoology, *in litt.* 2001; M. Kitson, Academy of Natural Sciences of Philadelphia, *in litt.* 2001; C.A. Mayer and K.S. Cummings, Illinois Natural History Survey, *in litt.* 2001, N. McCartney, University of Arkansas, *in litt.* 2001, T.A. Pearce, Carnegie Museum of Natural History, *in litt.* 2002, and G.T. Watters, Ohio State University, *in litt.* 2001).

As stated above, the type locality for the Ouachita rock pocketbook was explained by Wheeler (1918) to be a set of oxbows of the Ouachita River north of Arkadelphia. Additional locality details were quoted from the holotype label by Clarke (1981). Wheeler gave the Ouachita River proper below Arkadelphia as another locality inhabited by *A. wheeleri* but stated that it rarely occurred there. Museum records show several lots of the species, some containing multiple specimens, collected from the Old River locality within a short span of years (even without counting cases where the collection date is unknown). A small number of lots seem to have originated from the Ouachita River (proper) locality, near or below Arkadelphia, during the same general time frame. Most of the early specimens from the Ouachita River system were likely collected by Wheeler.

Ortmann (1921) reported a single *A. wheeleri* shell collected in 1919 from the Kiamichi River at Antlers, Pushmataha County, Oklahoma. Isely (1925) reported a specimen collected in 1912 from the Kiamichi River at Tuskahoma, also in Pushmataha County. In 1968, Valentine and Stansbery (1971) found *A. wheeleri* in the Kiamichi River at Spencerville Crossing, Choctaw County, a site since flooded by Hugo Reservoir. Clarke (1981) reported data on three female specimens collected in 1971 by D.H. Stansbery, from the Kiamichi River southeast of Clayton, Pushmataha County. Bogan and Bogan (1983) reported a shell from an archaeological site on Jackfork Creek (a tributary of the Kiamichi River) in Pushmataha County,

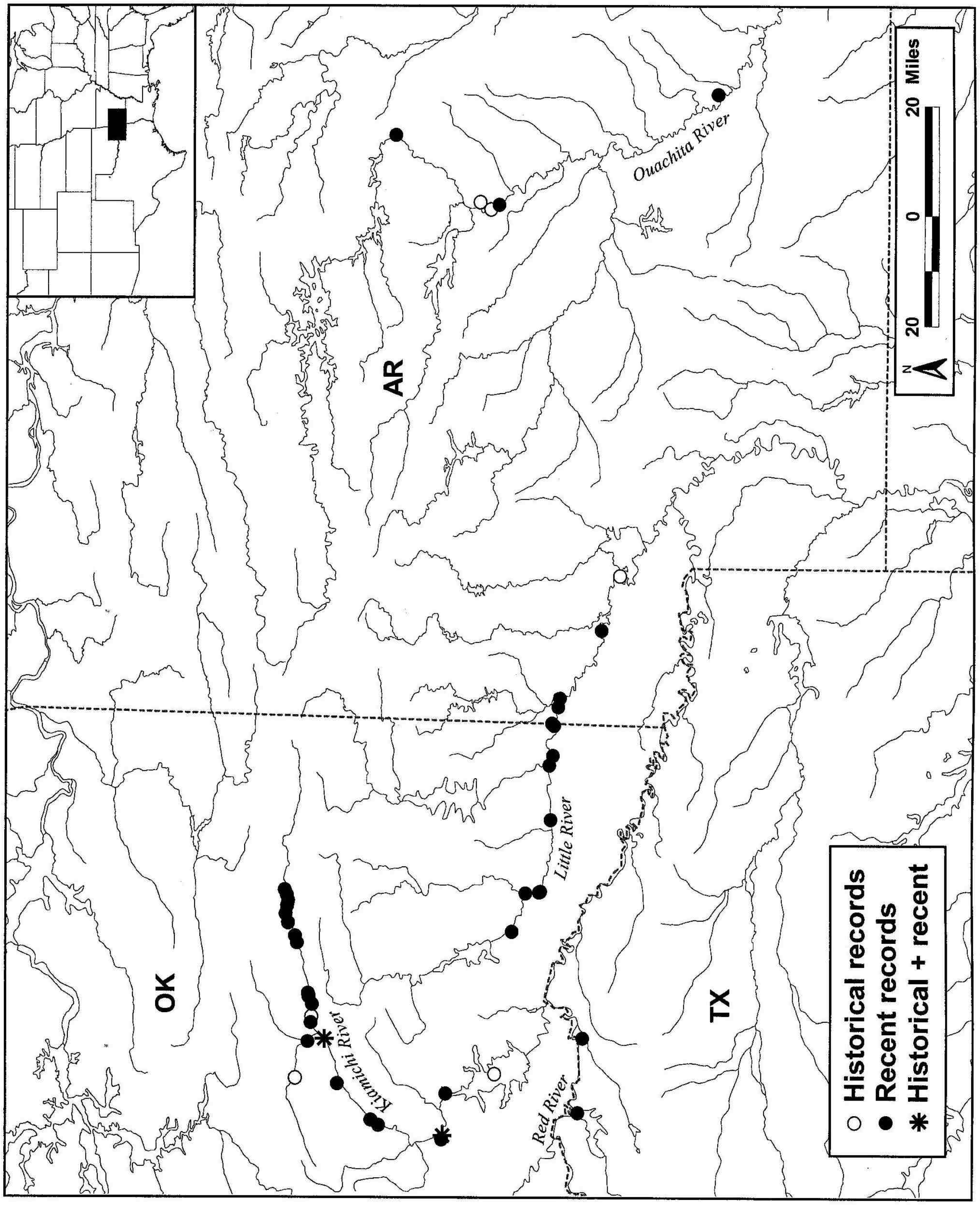


Figure 2. Distribution of Ouachita rock pocketbook, *Arkansia wheeleri.*

TABLE 1. SUMMARY OF AVAILABLE HISTORICAL RECORDS (PRE-1975) OF *ARKANSIA WHEELERI*.[1]
Entries are arranged chronologically by distinct localities. Bold type indicates the first record for the locality, normal type indicates subsequent records.

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Old River**, Arkadelphia / H.E. Wheeler	≤1911	ANSP 105546, CM 61.5357, CM 61.5358 (Brooks and Brooks 1931, Parodiz 1967, Johnson and Baker 1973, Kitson *in litt.* 2001, Pearce *in litt.* 2002)
Ouachita River	AR	Old River, Arkadelphia	≤1912	Ortmann and Walker (1912)
Ouachita River	AR	Old River, Arkadelphia; Ouachita Road, 3 mi. [4.8 km] above Arkadelphia	≤1912	UMMZ 105514 (Johnson and Baker1973, Johnson 1977, 1979, 1980, Clarke 1981)
Ouachita River	AR	Old River, Arkadelphia	1912	FLMNH 180629 (http://www.flmnh.ufl.edu)
Ouachita River	AR	Old River, Arkadelphia / H.E. Wheeler (CM 61.6162, FLMNH 64100)	1913	CM 61.6162, FLMNH 64100, FLMNH 180627, FLMNH 180628, INHS 20115 (http://www.flmnh.ufl.edu, Parodiz 1967, Mayer and Cummings *in litt.* 2001, Pearce *in litt.* 2002)
Ouachita River	AR	Old River, north of Arkadelphia	≤1918	Wheeler (1918)
Ouachita River	AR	Old River, Arkadelphia	1919[2]	ANSP 48318 (Kitson *in litt.* 2001)
Ouachita River	AR	Old River, Arkadelphia	≤1938	ARK 38-7-223 ex A.J. Brown (McCartney *in litt.*2001)
Ouachita River	AR	Old River, Arkadelphia / H.E. Wheeler (FLMNH 268996, all MCZ lots, USNM 218946)	[3]	FLMNH 180626, FLMNH 268996, MCZ 23319, MCZ 46759, MCZ 135712, USNM 218946, USNM 228905 (http://www.flmnh.ufl.edu, Clarke 1981, Hershler *in litt.* 1993, Johnson 1956, 1977, *in litt.* 2001)
Ouachita River	AR	**Arkadelphia**	1913	FLMNH 65593 (http://www.flmnh.ufl.edu)
Ouachita River	AR	Arkadelphia	1914	INHS 20113 (Mayer and Cummings *in litt.* 2001)
Ouachita River	AR	Below Arkadelphia	≤1918	Wheeler (1918)
Ouachita River	AR	Arkadelphia	1936	OSUM 43375, ex W.F. Webb (Watters *in litt.* 2001)
Ouachita River	AR	Arkadelphia		FLMNH 175092, FLMNH 225931, UMMZ (http://www.flmnh.ufl.edu, Johnson 1980)

TABLE 1. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Not specified**	≤1920	INHS 20114 (Mayer and Cummings *in litt.* 2001)
Kiamichi River	OK	**Tuskahoma**	1912	Isely (1925)
Kiamichi River	OK	**1.2 mi. SE of Clayton at U.S. Rt. 271** / D.H. Stansbery	1971	OSUM 32816 (Clarke 1981, Branson 1983, Watters *in litt.* (2001)
Kiamichi River	OK	**Antlers** / D.K. Gregor	1919	Ortmann (1921)
Kiamichi River	OK	Antlers / D.K. Greger	1919	CM 61.9830 (Johnson 1980, Pearce *in litt.* 2002)
Kiamichi River	OK	**Spencerville Crossing**, 1 mi. S of OK Rt. 93, 9 mi. NE of U.S. Rt. 70 / B. Valentine	1968	Valentine and Stansbery (1971), Clarke (1981)
Kiamichi River	OK	Spencerville Crossing, 8.5 mi. NE of Hugo / B. D. Valentine and class	1968	OSUM 20246, USNM uncat., ex OSUM (Hershler *in litt.* 1993, Watters *in litt.* 2001)
Jackfork Creek	OK	**Bug Hill**, 0.25 mi. NE of confluence of Jackfork and North Jackfork creeks	1981-1982	Bogan and Bogan (1983)
Little River	AR	**White Cliffs** / W.F. Webb	1933	ANSP 160466 (Clarke 1981, Kitson *in litt.* 2001)
Little River	AR	White Cliffs		UMMZ (Johnson 1980)

Notes

1. Includes duplicative records where an incomplete accounting exists between literature and museum records.
2. "Cotype" designation, label similarities, and original lot number (1897) shared with ANSP 105546 indicate that recorded date may be in error.
3. "Cotype"/paratype designation indicates at least some specimens likely collected ≤1912.

Key to acronyms used in Table 1

ANSP - Academy of Natural Sciences of Philadelphia
ARK - University of Arkansas, Fayetteville
CM - Carnegie Museum of Natural History
FLMNH - Florida Museum of Natural History
INHS - Illinois Natural History Survey
MCZ - Museum of Comparative Zoology
OSUM - Ohio State University, Museum of Biological Diversity
UMMZ -University of Michigan, Museum of Zoology
USNM - National Museum of Natural History
≤ - From specified year or earlier

indicating that the species might have inhabited the creek previously. The archaeological site and adjoining creek have since been flooded by Sardis Reservoir. Most historical reports of the Ouachita rock pocketbook from the Kiamichi River drainage match known museum specimens, and none of the latter indicate additional (unpublished) historical occurrences.

Johnson (1980) and Clarke (1981) reported *A. wheeleri* specimens collected from the Little River at White Cliffs, Little River County-Sevier County boundary, Arkansas. One of the museum specimens on which those reports were based is recorded as collected in 1933, and all those from White Cliffs appear to represent occurrences prior to 1975.

Recent (1975 to present)

Efforts to locate the Ouachita rock pocketbook increased during the 1980's and 1990's. Knowledge of the species' recent distribution (Table 2) derives largely from published records, and many specimens collected in recent years have yet to be deposited in museum collections or are among material waiting to be catalogued. Also, recent surveyors have more commonly returned live individuals of *A. wheeleri* to their habitats, after documenting occurrences with photography and other methods. Localities of recent occurrence are described here with only moderate precision, which is sufficient for most planning purposes without creating a significant risk of harm to individuals and habitats that might still exist at those localities. The following sources, unless noted otherwise, report observations during the year published.

Recent surveys indicate that the Ouachita rock pocketbook still occurs in the Ouachita River in Arkansas, but in very low abundance. Gordon and Harris (1983) and Harris and Gordon (1987) found relict shells in the Ouachita River at the mouth of Saline Bayou, Clark County, and at Malvern, Hot Spring County. Those authors did not attempt to date shells collected. Clarke (1987) found no evidence of the species in the Ouachita River. Posey *et al.* (1996) found, documented, and replaced a single live specimen of *A. wheeleri* in the Ouachita River southeast of Camden, Ouachita County-Calhoun County boundary, in 1995. That record extended the species' known range in the Ouachita River to a total of approximately 179 river kilometers (km) or 111 river miles (mi), although recent occurrences within that range are rare and widely separated. Among recent surveys of the Ouachita River, Gordon and Harris (1983) and Clarke (1987) reported extensive and considerable degradation of the localities historically inhabited by the Ouachita rock pocketbook.

The species continues to occur in the Kiamichi River. Mather (*in litt.* 2001) and Magrath found live individuals and shells between Clayton and Eubanks, Pushmataha County, during 1982-1986, and again during 1991-1995. Clarke (1987) reported a healthy but diffuse population within what he described as an 80-km (50-mi) reach of the Kiamichi River, from near Albion to near Antlers, all within Pushmataha County. The FWS believes 103 km (64 mi) is a more accurate estimate of that reach. Mehlhop and Miller (1989) subsequently documented that population to occupy an additional 22 km (13.6 mi) of the Kiamichi River, for an overall distribution in the river from near Whitesboro, LeFlore County, to near Antlers.

In a three-year (1990-1992) study of the Kiamichi River mainstem, Vaughn *et al.* (1993) found living Ouachita rock pocketbooks at six sites in the river, all within the range documented by Clarke (1987) and Mehlhop and Miller (1989). In 1993, Vaughn found *A. wheeleri* alive at an additional locality immediately upstream from Hugo Reservoir (C.C. Vaughn, Oklahoma Natural Heritage Inventory, *in litt.* 1994), extending

TABLE 2. SUMMARY OF AVAILABLE RECENT RECORDS (1975 AND LATER) OF *ARKANSIA WHEELERI*.[1]
Entries are arranged chronologically by distinct localities. Bold type indicates the first record for the locality, normal type indicates subsequent records.

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Near Malvern** / J.L. Harris		Harris and Gordon (1987)
Ouachita River	AR	**Near mouth of Saline Bayou** / M.E. Gordon, W.K. Welch and J.L. Harris	1983	Gordon and Harris (1983)
Ouachita River	AR	Below **[9 mi. SE of] Camden, river mile 334** / W.R. Posey, C. Davidson and V. Posey	1995	P. Hartfield, FWS *in litt.* (1995), Posey *et al.* (1996), Harris *et al.* (1997)
Kiamichi River	OK	**2+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**3+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**4+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[**5+ mi. WSW of Whitesboro**] Study site 1	1992	Vaughn *et al.* (1993)
Kiamichi River	OK	**6+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**5+ mi. ENE of Albion** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**2+ mi. E of Albion**, below bridge / A.H. Clarke	1987	Clarke (1987)
Kiamichi River	OK	2+ mi. ESE of Albion, below bridge / P. Mehlhop and E. Miller, ± C.M. Mather	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[2+ mi. ESE of Albion] Study site 2	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	**1+ mi. SE of Albion** / P. Mehlhop, C.M. Mather and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**1+ mi. above Dry Creek** / P. Mehlhop and E. Miller, ± C.M. Mather	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**4+ mi. E of Tuskahoma** / P. Mehlhop, C.M. Mather and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**3+ mi. E of Tuskahoma** / A.H. Clarke and C.M. Mather	1987	Clarke (1987)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Kiamichi River	OK	3+ mi. E of Tuskahoma / A.H. Clarke and C.M. Mather	1987	ANSP 369314 (Kitson *in litt.* 2001)
Kiamichi River	OK	**1+ mi. E of Tuskahoma** / A.H. Clarke, J.J. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	1+ mi. E of Tuskahoma / A.H. Clarke and C.M. Mather	1987	ANSP 369315 (Kitson *in litt.* 2001)
Kiamichi River	OK	[**1+ mi. W of Tuskahoma**] Study site 3	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	<1 mi. S **[1+ mi. SE] of Clayton** / C.M. Mather	1982	USAO 1786 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	1+ mi. SSE of Clayton / C.M. Mather	1986	USAO 3749 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	1+ mi. SSE of Clayton, below U.S. Rt. 271 bridge / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	<1 mi. S [1+ mi. SSE] of Clayton near U.S. Hwy 271 / C.M. Mather	1995	USAO 7821 (Mather *in litt.* 2001)
Kiamichi River	OK	**Near Stanley**, <1 mi. below ford / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	<1 mi. E of Stanley, <1 mi. below ford / P. Mehlhop	1988	Mehlhop and Miller (1989)
Kiamichi River	OK	<1 mi. E of Stanley, near and below ford / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[Near Stanley] Study site 5	1990, 1992	Vaughn *et al.* (1993)
Kiamichi River	OK	Near Stanley / C.M. Mather	1991	USAO 8108 (Mather *in litt.* 2001)
Kiamichi River	OK	Near Stanley / C.M. Mather	1992	USAO 6574 (Mather *in litt.*1992, 2001)
Kiamichi River	OK	**[S of Dunbar]** 16+ mi. SW of Clayton near State Hwy 2 / L.K. Magrath	1983	USAO 2415 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Near State Hwy 2 N of Antlers, N crossing / C.M. Mather	1984	USAO 2837 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	2+ mi. NNE of Eubanks / A.H. Clarke and C.M. Mather	1987	Clarke (1987)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Kiamichi River	OK	[S of Dunbar] Study site 6	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	[**N of Eubanks**] 14+ mi. NNE of Antlers near State Hwy 2 / C.M. Mather	1982	USAO 1771 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Near State Hwy 2 N of Antlers, S crossing / C.M. Mather	1984	USAO 2831 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Between Clayton and Antlers near State Hwy 2 (S crossing) / C.M. Mather	1986	USAO 4214 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	[N of Eubanks] Study site 7	1990, 1991	Vaughn *et al.* (1993)
Kiamichi River	OK	Near Eubanks crossing on State Hwy 2 / C.M. Mather	1995	USAO 7817 (Mather *in litt.* 2001)
Kiamichi River	OK	**1+ mi. N of Antlers**, <1 mi. above U.S. Rt. 271 / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	**1+ mi. NNE of Antlers**, above U.S. Rt. 271 / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	1 mi. N of Antlers / A.H. Clarke and C.M. Mather	1987	ANSP 369313 (Kitson *in litt.* 2001)
Kiamichi River	OK	**[Near mouth of Big Waterhole Creek,]** immediately above Lake Hugo / C.C. Vaughn	1993	Vaughn *in litt.* (1994)
Jackfork Creek	OK	**<1 mi. downstream from Sardis Dam** / A.D. Martinez	1997	A.D.M., unpublished data, Meier and Vaughn (1998)
Little River	OK	1+ **[2+] mi. SW of Wright City**, near railroad crossing / J.A.M. Bergmann and C.M. Mather	1991	Bergmann coll. (Mather pers. comm. 1993, *in litt.* 2001)
Little River	OK	2+ mi. W of Wright City, near railroad crossing / C.M. Mather and J.A.M. Bergmann	1993	USAO 7049 (Mather *in litt.* 2001)
Little River	OK	**Near Thompson Bend, below mouth of Glover River** / C.C. Vaughn, M. Pyron and M. Craig	1993	Vaughn (1994)
Little River	OK	**2+ mi. N of Garvin,** above Possum Ford Bend / C.C. Vaughn, M. Winston, E.K. Miller and C.M. Mather	1992	Mather *in litt.* (1992), Vaughn (1994)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Little River	OK	**1+ mi. N of Garvin** / C.M. Mather and J.A.M. Bergmann	1991	USAO 6293 (Mather pers. comm. 1993, *in litt.* 2001)
Little River	OK	**Near mouth of Yashoo Creek** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	OK	[Near mouth of Yashoo Creek] Sampling site 23		Vaughn and Taylor (1999)
Little River	OK	**<1 mi. above confluence with Mountain Fork River** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	OK	**Near mouth of Black Creek** / C.C. Vaughn, K.J. Eberhard, M.Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	AR	**<1 mi. E of OK/AR boundary** / A.H. Clarke and J.J. Clarke	1987	Clarke (1987)
Little River	AR	**<1 mi. NE of OK/AR boundary**, near mouth of Buck Creek / A.H. Clarke	1987	Clarke (1987)
Little River	AR	**<1 mi. upstream from LRCC boat ramp** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	AR	1+ [<1?] mi. **W of AR Hwy 41**[2] / M.E. Gordon and J.L. Harris	1983	Gordon and Harris (1983)
Little River	AR	<1 mi. W of AR Hwy 41, SW of Horatio / J. Harris and M. Gordon	1983	ANSP 358806 (Kitson *in litt.* 2001)
Little River	AR	**4+ mi. NW of U.S. Hwy 59/71 crossing** / M.E. Gordon and J.L. Harris	1983	Gordon and Harris (1983)
Sanders Creek	TX	**Below Pat Mayse Lake near TX Hwy 197 crossing** / C.M. Mather and J.A.M. Bergmann	1993	Howells *et al.* (1996, 1997) USAO 7052 (Mather *in litt.* 2001)
Pine Creek	TX	**TX Hwy 906 bridge near Faulkner** / J.A.M. Bergmann	1992	Mather pers. comm. (1993), Howells *et al.* (1996, 1997)

Notes

1. Includes duplicative records where an incomplete accounting exists between literature and museum records.
2. Later museum data (see following record) indicate possible locality error in original report (#53 for #54).

TABLE 2. (Continued)

Key to acronyms and symbols used in Table 2

ANSP - Academy of Natural Sciences of Philadelphia
FWS - U.S. Fish & Wildlife Service
USAO - University of Science and Arts of Oklahoma
< - Less than
+ - Unspecified fractional distance
± - Collector not present during all of multiple locality visits represented in record.

the portion of the Kiamichi River known to be inhabited by the species in recent times to 141 km (88 mi). In addition, it may be noted that between 1990 and the present, the FWS (unpublished data) salvaged a small number of empty shells of *A. wheeleri* and examined a few living individuals, all within the range identified by the researchers cited above, primarily at known sites on the Kiamichi River.

Meier and Vaughn (1998) surveyed for mussels and fish at 30 localities on 23 tributary streams of the Kiamichi River, using methods very similar to those employed by Vaughn *et al.* (1993). Their study resulted partly from recent public interest into whether such tributaries offered additional, as yet unknown habitat for the Ouachita rock pocketbook, in which case the river's overall population would be larger than estimated using habitat in the mainstem alone. They found no evidence of *A. wheeleri*, though they reported the FWS's 1997 discovery of an unweathered empty shell in Jackfork Creek downstream from Sardis Dam. Despite that latter discovery, the archaeological record reported by Bogan and Bogan (1983), and recovery of empty shells from Red River tributaries in Texas (see below), biologists have consistently concluded that the species is primarily adapted to large stream environments.

Clarke (1987) estimated the total Kiamichi River population as ranging from 100 to 1,000 individuals, based on his 50-mi figure, an estimate of 1,000 to 5,000 square meters (m^2) of habitat/river mile, and an average density of 0.002 to 0.004 individuals/m^2 in suitable habitat. Mehlhop and Miller (1989) estimated the Kiamichi River population to be just above 1,000 individuals (1,049), based on a documented range of 79.5 river mi, a measure of 88% (69.8 mi) of that as providing potential habitat, and an average density of 15 individuals/mi of potential habitat. Vaughn *et al.* (1993) calculated a mean density of *A. wheeleri* in occupied habitat as 0.27 individuals/m^2, but provided no new estimates of habitat availability or total size of the Kiamichi River population. The substantial difference between density estimates by Clarke (1987) and Vaughn *et al.* (1993) is due to differences between what those authors considered to be suitable and occupied habitat. Consequently, the two estimates should not be compared as indicating the temporal trend in a single parameter. The proportions of available habitat and individual density estimated by Clarke (1987) and Mehlhop and Miller (1989), if assumed still valid and applicable to the expanded range documented by Vaughn (*in litt.* 1994), would indicate a Kiamichi River population falling somewhere between 176 and 1,760 individuals.

Gordon and Harris (1983) collected relict shells of the Ouachita rock pocketbook from the Little River in Arkansas, just west of Arkansas Highway 41 and 6.4 km (4.0 mi) northwest of U.S. Highway 59/71, both sites located along the boundary between Little River County and Sevier County. Clarke (1987) found a small number of live individuals in a 1-km (0.7-mi) reach of the Little River running east from the Oklahoma-Arkansas state line, Little River-Sevier counties. He believed the species might exist through a defined section of about 8 river km (5 mi) extending east from the state line (a section the FWS estimates as closer to 7.25 km, or 4.5 mi). Clarke (1987) estimated the Little River population to be less than 100 individuals. In the Arkansas portion of their survey, Vaughn *et al.* (1995) found an *A. wheeleri* shell approximately 6.5 km (4 mi) east of the Oklahoma-Arkansas state line, Little River and Sevier counties, in 1994.

Clarke (1987) also surveyed the Little River in Oklahoma, but found no evidence of *A. wheeleri* there. Mather (pers. comm. 1993, *in litt.* 2001) and Bergmann found shells of the species in the Little River downstream of Pine Creek Reservoir, McCurtain County, Oklahoma, in 1991. Follow-up surveys in 1992 and 1993 produced additional shells from the same river section, from near Wright City to near Garvin, Oklahoma (Vaughn 1994, Mather *in litt.* 2001). Although most of the Oklahoma shells were weathered, one collected in each of 1991 and 1993 appeared to be from Ouachita rock pocketbooks that had died relatively recently. In 1994, Vaughn *et al.* (1995) discovered living *A. wheeleri* in the Little River section between U.S. Highway 70 and the Mountain Fork River confluence, in McCurtain County. They also found relict shells downstream of the Mountain Fork River, in both Oklahoma and Arkansas. An occurrence reported by Vaughn and Taylor (1999) likely represents one of the 1994 captures. For an inhabited Little River locality, Vaughn and Taylor (1999) calculated a standardized abundance measure for *A. wheeleri* of 0.7 individuals found/hour searching.

The recent occurrence of the Ouachita rock pocketbook in the Little River is less easily interpreted than in the Kiamichi River, because of the former river being affected to a greater extent by factors detrimental to stream fauna. No recent records exist for a 25-km (15.5-mi) section between Gordon and Harris's (1993) station west of U.S. 59 and White Cliffs. All recent records would suggest that the species exhibits a range of approximately 153 km (95 mi) in the Little River. However, significant parts of that range appear to be unsuitable for *A. wheeleri*, at least intermittently. In particular, the river segment between entry of the Rolling Fork River and the lowermost Little River locality has produced only fairly dated records of relict shells, and appears to be degraded by multiple, persistent factors (discussed later under Reasons for Listing/Threats). By excluding that segment, the overall recent range of *A. wheeleri* in the Little River may be estimated more accurately as approximately 111 km (69 mi). Portions of even that reduced distance lack suitable habitat due to degradation, and high quality conditions for the species may prevail in only a limited section (24 km/15mi) upstream of the Mountain Fork River confluence.

In 1992, Joseph Bergman found a Ouachita rock pocketbook shell in Pine Creek, a tributary entering the Red River near the mouth of the Kiamichi River, Lamar County, Texas (Mather pers. comm. 1993, Howells *et al.* 1996, 1997). In 1993, Mather and Bergmann found a second specimen in Sanders Creek, the next large Red River tributary in Texas upstream from Pine Creek, also in Lamar County (R.G. Howells, Texas Parks and Wildlife Department, *in litt.* 1994, Howells *et al.* 1996, 1997).

In a review of rare mollusks from Texas and Oklahoma, Landye (1980) listed the Ouachita rock pocketbook from the Kiamichi River of Oklahoma, plus the Little and Ouachita rivers of Arkansas. Landye (1980) did not find the species during limited field surveys performed as part of his survey. In a review of Oklahoma mussels, Branson (1983) reported the Ouachita rock pocketbook from the Kiamichi River in Oklahoma and Old River in Arkansas, based on previously published records and one specimen collected by Stansbery in 1971. In a review of Arkansas mussels, Harris and Gordon (1990) reported the Ouachita rock pocketbook from the Little River in Arkansas, the Kiamichi River in Oklahoma, and formerly from the Ouachita River. In the most recent assessment of Arkansas mussels, Harris *et al.* (1997) stated that *A. wheeleri* remains extremely rare.

Based on available data, the only known substantial population of Ouachita rock pocketbook mussels exists in the Kiamichi River of Oklahoma, upstream of Hugo Reservoir. A smaller, stressed population exists in the Little River between Wright City, Oklahoma, and the river's confluence with the Rolling Fork River in Arkansas. A diffuse, poorly known population continues to exist in the Ouachita River in Arkansas. Limited numbers of individuals appear to survive sporadically in tributary streams, such as Pine and Sanders creeks (Texas tributaries of the Red River) and Jackfork Creek. Many other localities in waters of the region have been surveyed without finding further evidence of *A. wheeleri* (e.g., see sources already cited, plus

Harris 1994, Mather and Bergmann 1994, Vaughn 1996a,b, 1997a, 2000, Vaughn *et al.* 1994a,b, Vaughn and Spooner 2000, Vidrine 1993, and White 1977). Nevertheless, continued survey work using current techniques is needed in less well-known systems to reveal whether the Ouachita rock pocketbook exists (or has existed) in additional populations, or occurs only sporadically outside the primary stream reaches where it is known to occur. Given the extent of past malacological surveys, any newly discovered populations are apt to be small, and the Kiamichi River population is likely to remain the sole viable population existing at this time.

Habitat/Ecosystem

Wheeler (1918) described the type locality of the Ouachita rock pocketbook as an oxbow lake, a former channel of the Ouachita River, still connected to the river by a small creek that did not appear to dry up in summer. From the mouth of the oxbow (located in a dense swamp) and for a mile or more upstream, the oxbow was described as, "deep and rather wide, with a very sluggish current." That habitat reportedly contained the largest Ouachita rock pocketbook individuals. Young individuals were found in shallow waters over sand bars and muddy bottoms; muddy river margins with little or no current were reportedly preferred. Approximately 41 other mussel taxa were indicated by Wheeler (1918) as also inhabiting the Old River locality, including very large specimens of the flat floater, *Anodonta suborbiculata*.

Isely (1925) collected a single Ouachita rock pocketbook from the Kiamichi River. The habitat type was categorized as a side channel/river bend with mud bottom, water 2-3 feet deep, and no current. In another portion of his paper, he described collecting the *A. wheeleri* specimen from a mud bank. Isely (1925) reported 21 other mussel species from the Kiamichi River at the Tuskahoma locality, including 13 other species that shared the side channel/river bend habitat.

Clarke (1987) described typical Ouachita rock pocketbook habitat as muddy coves or backwaters adjacent to riffles, or at least close to areas of moderate to rapid current. Clarke (1987) found the species in such habitats in the Kiamichi and Little rivers, guided by an observation by C.M. Mather that the species inhabited such sites. Number of other mussel species found at localities inhabited by *A. wheeleri*, with/without including shell evidence, reached as high as 21/13 species in the Kiamichi River and 12/11 species in the Little River. As mentioned earlier, Clarke (1987) estimated the amount of suitable *A. wheeleri* habitat present in the Kiamichi River as ranging between 1,000 and 5,000 m^2/linear mi, for the section he surveyed.

Mehlhop and Miller (1989) suggested that early survey efforts were restricted to shallow water habitats that could be easily hand-searched by waders. More recently, scuba use has increased for studying freshwater mussels and allowed effective sampling of deeper water habitats. In studying the Kiamichi River population, Mehlhop and Miller (1989) employed scuba gear and found that Ouachita rock pocketbooks also inhabited deeper pools in the river. Deep pools provided more abundant habitat in the river than backwaters, side channels, or other shallow areas. Number of other mussel species found by Mehlhop and Miller (1989) at localities inhabited by *A. wheeleri* reached as high as 16/14, depending on whether shell evidence was included/excluded. As mentioned earlier, Mehlhop and Miller (1989) estimated that 88% of the documented range in the Kiamichi River, or 69.8 river mi (112 km), constituted potential habitat for the species.

Studies of the Kiamichi River population by Vaughn and coworkers (Vaughn *et al.* 1993, Vaughn and Pyron 1995) included greater efforts than previously made to measure and analyze relationships between occurrence/abundance of *A. wheeleri*, associated mussel species, and various habitat parameters. Those studies found that Ouachita rock pocketbooks showed no preference between riverine pools and backwaters, but inhabited certain of these sharing five characteristics: (1) an abundant and diverse assemblage of mussels; (2) stable bottom substrata containing adequate amounts of fine gravel/coarse sand; (3) low (but not stagnant) summer-to-fall current velocities; (4) low siltation; and (5) proximity to tributaries, emergent vegetation, riffles, and gravel bars. Other measured parameters (water temperature, conductivity, dissolved oxygen, and pH) did not vary significantly among sites. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) further described large mussel beds or shoals as key to the distribution of *A. wheeleri* in the Kiamichi River. Such shoals provided an optimal habitat in which many mussel species thrived. These shoals usually contained both pool and backwater areas, had significant gravel bar development with accompanying vegetation, were adjacent to major riffles, and were close (<0.25 mi) to tributary inflows. Those workers concluded that Ouachita rock pocketbooks cannot survive in less than optimal habitat for stream mussels.

Vaughn and Pyron (1995) developed a discriminant function model for predicting *A. wheeleri* occurrence, based on mussel species richness, depth, presence/absence of emergent vegetation, and habitat type. In that analysis, mussel species richness proved to be the best single predictor of *A. wheeleri* occurrence in the Kiamichi River.

In Vaughn's studies, localities inhabited by the Ouachita rock pocketbook were found to be inhabited by 11-19 other mussel species, as indicated by living individuals. Those sites exhibited a significantly greater number of mussel species, on average, than did sites lacking *A. wheeleri*. Based on abundance correlations, the species most positively associated with *A. wheeleri* was a mapleleaf, *Quadrula quadrula/apiculata*, followed by the washboard, *Megalonaias nervosa*, and the butterfly, *Ellipsaria lineolata*. Though absent or undetected at many sites, at confirmed sites the Ouachita rock pocketbook occurred at relative abundances of 0.2% to 0.7% (Vaughn *et al.* 1993, Vaughn and Pyron 1995). This and a density measurement of 0.27 individuals/m^2 indicated quantitatively the limited abundance attained by the species where it manages to survive.

Most recently, Posey *et al.* (1996) found a single live *A. wheeleri* mid-channel in a 2,600-m^2 Ouachita River mussel bed exhibiting gravel, gravel/sand, and sand substrates; 5- to 7-meter (m) water depths; and a 50-m mean river width. Posey *et al.* (1996) identified 21 other mussel species in the bed with *A. wheeleri*.

Vaughn *et al.* (1993) did not associate Ouachita rock pocketbooks with muddy or silty substrates, an observation that differs from the historical characterizations of Wheeler (1918), Isely (1925), and Clarke (1987). There are multiple possible explanations for this. As has been noted, some backwaters are relatively easy habitats to search and may have been sampled preferentially by early surveyors (Mehlhop and Miller 1989, Vaughn and Pyron 1995). However, it is apparent that the preceding workers recognized and surveyed habitats beyond backwaters. Different interpretations of substrate classes are possible, although discussions by the earlier authors indicate clear distinctions among sand, silt, and clay types. Different methods could be partly responsible, e.g., Vaughn's procedure used excavated, sieved substrate samples, while preceding workers might have used a visual approach, which could have favored superficial deposits. During low flow conditions associated with most stream surveys, substrates of diverse compositions can become coated with seasonal and proportionally minor silt layers. Still, some associated species reported in historical accounts (e.g., *Anodonta suborbiculata*) are considered adapted to muddy habitats (Oesch 1984, Harris and Gordon 1990). This suggests additional possibilities, such as changes in riverine conditions over time (e.g., as in Gammon and Reidy 1981, Turner and Rabalais 1991), and an incomplete understanding of the habitat relations of *A. wheeleri* across its range.

Degrees and aspects of habitat stability most vital to the Ouachita rock pocketbook also remain insufficiently understood, given their probable importance. Relative stability of substrates seems linked to the occurrence of mussel species in general (Vannote and Minshall 1982, Stern 1983, Young and Williams 1983, Strayer and Ralley 1993, Di Maio and Corkum 1995, Johnson and Brown 2000) and *A. wheeleri* specifically (Vaughn *et al.* 1993). Yet, there must be limits to this effect because streams are naturally dynamic systems in which there are frequent movements of substrate materials and longer-term changes in channel form, even with minimal human disturbance (Leopold *et al.* 1964, Allan 1995). Mehlhop and Miller (1989) observed that many Kiamichi River backwater areas visible in aerial photographs $\leq$10 years old shifted in location or disappeared through seasonal flooding. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) also reported shifting of sediments between a backwater and pool inhabited by *A. wheeleri*. Certain low to intermediate levels and forms of stability may be most conducive to occurrence of many species, including rare forms (Death and Winterbourne 1995).

Closely related to stability are aspects of flow, considering that most movements of substrate materials appear associated with flood flows and abrupt changes in flow. Flows also can affect other processes such as delivery of oxygen and food items to mussels, removal of wastes, transport and concentration of sperm cells, sustained immersion of juveniles and adults, protection from heat stress, and formation of stream habitats. In the case of some mussel species and environments, such relationships have even been studied to varying degrees (Vannote and Minshall 1982, Salmon and Green 1983, Hartfield and Ebert 1986, Payne and Miller 1987, Di Maio and Corkum 1995, Layzer and Madison 1995, Tippit *et al.* 1997, U.S. Fish and Wildlife Service 1997b, Strayer 1999b, Payne and Miller 2000, Gore *et al.* 2001, Hardison and Layzer 2001). Several of these studies have led to indications that complex hydraulic variables and relationships offer significant potential for explaining local distributions of mussels and mussel habitats. In the case of the Ouachita rock pocketbook, however, the complexities involved are not known to an extent that is useful to many flow management decisions. In addition, native stream fish communities have shown adaptations to flooding and other elements of natural flow regimes (Ross and Baker 1983, Wootton *et al.* 1996, Poff *et al.* 1997), raising the possibility that the host fish for *A. wheeleri* might be affected by flow modifications. Consequently, significant relationships between stream flows and survival of the Ouachita rock pocketbook need further study and definition for specific waterbodies inhabited by the species. Abilities to reduce flood flows with impoundments, in an interest of increasing habitat stability (as has been suggested by some agencies), might not produce a net benefit when all effects are considered.

Additional study is needed of habitat requirements of the Ouachita rock pocketbook. One limitation of the studies by Vaughn *et al.* (1993) is that all sites used were known recent localities of *A. wheeleri*; thus, their evaluations examined fine distinctions among these rather than a broader contrast between suitable and unsuitable sites. Furthermore, even those workers faced inevitable constraints in regards to range of parameters examined, study intensity, and scale, and recognized that certain habitat dynamics were beyond the scope of their investigation. The characteristic rarity of the species adds to the difficulty of determining its habitat relationships. There remain apparently significant but inadequately understood factors affecting the restricted distribution of the Ouachita rock pocketbook, such as ones limiting occurrence outside certain sized streams. The Little River above Pine Creek Reservoir appears to be too small to support *A. wheeleri* (Clarke 1987, Vaughn *et al.* 1994a), as are many tributary streams, whereas the largest (most downstream) locality found thus far is that of Posey *et al.* (1996). Incompletely deciphered influences include drainage restrictions and other geographic, biological, environmental, and historical processes (Johnson 1980, Watters 1992, 1996, Strayer 1993, Vaughn 1997c, Haag and Warren 1998, Vaughn and Taylor 2000, Vaughn and Hakenkamp 2001). From a recovery standpoint, knowledge is needed of the most significant factors, sufficient to guide key management decisions.

Life History/Ecology

The Ouachita rock pocketbook's life cycle is unknown; however, it is most likely similar to that of other unionid mussels. Reproductive anatomy is likely similar to other members of the subfamily Anodontinae, as discussed by Ortmann (1912). Facultative hermaphroditism (ability of individual mussels to develop both male and female reproductive organs) has been suggested, along with other mechanisms, as a potential reproductive adaptation in *A. wheeleri* (Vaughn 1997b) but remains speculative.

Johnson (1980) designated the species as bradytictic (a winter breeder or long-term breeder), based on Wheeler's (1918) description of the breeding season as winter. Wheeler's conclusion is likely to have been based on unsuccessful efforts to find gravid females at inhabited localities, visited outside of winter, rather than any positive evidence. Clarke (1987) and Vaughn (1997b) predicted the Ouachita rock pocketbook to be a long-term breeder based on the condition seen in *Arcidens confragosus*, and other members of the mussel tribe Alasmidontini. *A. confragosus* is recorded as becoming gravid in September and exhibiting active glochidia (larvae) from January into March (Baker 1928, Clarke 1981). Vaughn *et al.* (1993) examined some *A. wheeleri* on-site (field work conducted between June and October) and retained in an artificial stream four individuals captured in September, one for nearly six months. None of these individuals were found to be gravid. No data are known that demonstrate the actual timing or duration of reproductive phases in the Ouachita rock pocketbook.

Nothing has been published describing the Ouachita rock pocketbook's glochidium. Based on related species, Clarke (1987) predicted that Ouachita rock pocketbook glochidia would possess stylets (hooks) used to attach to fish fins, tails, or scales. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) noted that the stylets would likely be covered by microstylets and the glochidial shell should be asymmetrical in profile. Vaughn *et al.* (1993) collected general glochidial samples using drift nets and by dissecting the gills of fish from the Kiamichi River; their preserved samples were not processed to the point of identifying constituent species.

The natural fish host(s) of the Ouachita rock pocketbook remain(s) unknown. Nearly all unionid mussel species must parasitize fish to transform from glochidium to juvenile, and many can successfully parasitize only one to a few fish species (Lefevre and Curtis 1912, Coker *et al.* 1922). This narrow dependency on specific host fish is one of the main factors contributing to the high sensitivity of unionid mussels to environmental disturbance (Bogan 1993, Neves *et al.* 1997). Fish species that share the same natural distribution and habitat preference as the Ouachita rock pocketbook, and fish hosts for closely related species, likely include the host(s) for *A. wheeleri*. For the closest living relative, *A. confragosus*, known fish hosts include the American eel *Anguilla rostrata*, gizzard shad *Dorosoma cepedianum*, rock bass *Ambloplites* *rupestris*, white crappie *Pomoxis annularis*, and freshwater drum *Aplodinotus grunniens* (Surber 1913, Wilson 1916). In an attempt to identify strong candidates for host species, Vaughn *et al.* (1993) analyzed fish-mussel associations, and found positive correlations between *A. wheeleri* and nine species, led by the redfin shiner *Lythrurus umbratilis,* the channel darter *Percina copelandi,* and the rocky shiner *Notropis suttkusi* (at the time referred to as *N. rubellus* or *N. sp.*).

Vaughn (1997b) examined techniques used to study mussel reproduction and recommended particular approaches for investigating the reproductive biology of the Ouachita rock pocketbook. Her recommendations included additional fish species warranting evaluation as potential hosts and mussel species most appropriate as surrogates for *A. wheeleri* in reproductive research.

Mehlhop and Miller (1989) and Vaughn *et al.* (1993) were the first workers to analyze size/age distributions among a population of Ouachita rock pocketbooks using data from a significant number of individuals. Both research teams found the population dominated by adults well past juvenile stages, e.g., at least 15 years old. Similar findings are not uncommon among studies of other mussel species, produced by both natural characteristics of mussel populations and relatively low detection rates of juveniles. However, concerns have been expressed that many such cases reflect aging populations of adults in which adequate reproduction and recruitment of young are no longer occurring, due to environmental modifications (McMahon 1991).

Reasons for Listing/Threats

Impoundment, channelization, and water quality degradation have been identified as principal factors causing the decline of the Ouachita rock pocketbook (Clarke 1987, Mehlhop and Miller 1989, Martinez and Jahrsdoerfer 1991). Those same factors have been associated with declines of many freshwater mussel species and communities (e.g., Coker 1914, Ellis 1936, Stansbery 1970, Starnes and Bogan 1988, Bogan 1993, Williams *et al.* 1993). Most reports of mussel declines and responsible factors have been based on observation and inference, with little cause and effect data. This is partly because most environmental modifications are made without detailed assessments of impacts, and partly because diagnostic analyses usually were not available or appropriate to the scale and intent of standard studies performed on mussels. It also can be attributed to the typically complex nature of most environmental and biological impacts (Allan and Flecker 1993, Watters 2000). The following paragraph illustrates some of the complexities involved.

When impounded, stream environments undergo many changes, such as decreased water velocities, temperatures, and dissolved oxygen levels; and increased levels of carbon dioxide, nutrients, and sediment deposition, including a greater proportion of compounds in chemically reduced form. Many of these changes can contribute to reductions in mussel diversity and productivity, although the relative contribution of each may be difficult to distinguish (or considered unimportant, as long as the sum of changes proves significant). Limnological studies strongly indicate that adverse effects of impoundment (and channelization) on aquatic life occur partly from changes in water quality produced by those modifications. Thus, the two factors of impoundment/channelization and water quality are not strictly separable. In addition, certain types of pollution produce water quality changes that resemble, and may augment, changes produced by impoundment and channelization. Furthermore, although some forms of pollution are potent enough to singularly impact mussel communities, actual instances of pollution more commonly involve multiple sources and processes that are complex, interrelated, and difficult to separate.

In spite of complexities, significant progress has been made in clarifying the influence of natural and anthropogenic factors on freshwater environments, and the effects of various physical and chemical conditions on mussels, including some of the underlying physiological mechanisms (Fuller 1974, McMahon 1991). Experimental studies have produced evidence generally supporting incompletely documented reports of mussel declines and their implied causes (e.g., see references cited below in separate discussions of threats). As highly influential factors, impoundment, channelization, and water quality degradation are recognized as major modifications that embrace many smaller modifications and reactions. Few native freshwater mussels are adapted to live in environmental conditions produced by such major modifications. Commonly observed evidence of effects in actual environments include reduced communities of only tolerant species, dead mussels or shells positioned naturally in the substrate, or populations containing no or reduced numbers of juvenile mussels.

Continued growth and activity of human populations portend that these major factors, at least impoundment construction and water quality degradation, will continue and expand in influence. Thus, they pose significant threats for further declines of native mussels such as the Ouachita rock pocketbook. Within portions of this species' range, recent proposals to withdraw and transport large quantities of water for human consumption have raised an additional threat, related essentially to reservoir development, and with similar bearings on stream organisms. Moreover, various other factors, mostly secondary in significance, have been identified as potential future threats to *A. wheeleri*.

Efforts to analyze impacts and identify conditions needed by the Ouachita rock pocketbook benefit from a number of information sources and technical abilities presently available. The U.S. Geological Survey, U.S. Army Corps of Engineers, and other agencies monitor flow rates and a range of water quality parameters for all stream systems comprising the natural range of *A. wheeleri*. That information allows comparison of conditions between areas still inhabited by the Ouachita rock pocketbook and areas in which the species has declined or perished. A limited historical record and sophisticated models currently available also allow comparison between historical and present conditions in impacted areas. As with the hydrologic and water quality data, various agencies periodically record land features using aerial photography and satellite sensing. Such records provide another means of comparing conditions between times or areas of suitable habitat. Some studies have already been performed of recent land use patterns within the Kiamichi River, Little River, and upper Ouachita River basins. One further example involves researchers at the Oklahoma Natural Heritage Inventory, University of Oklahoma, which have maintained a significant track of research since the late 1980s into status and ecology of *A. wheeleri* and the mussel communities of Ouachita streams.

Impoundment, channelization, and flow modification

Some of the greatest impact on Ouachita rock pocketbook habitat throughout its natural range has been from construction and operation of impoundments for multiple purposes, i.e, flood control, water supply, water quality, hydroelectric power generation, navigation, recreation, and fish and wildlife management. Construction of impoundments can be deleterious to most native mussels in a number of ways, many of which are related to the siltation that accompanies impoundment (Coker 1914, Scruggs 1960, Bates 1962, Isom 1969, Neves *et al.* 1997, Watters 2000). The stream sections flooded directly are subject to many physical and chemical changes, among them (at the level of benthic habitats) increased depth, sediment deposition, and carbon dioxide concentrations; decreased flow velocities, illumination levels, average temperatures, dissolved oxygen concentrations, and pH; and lags in seasonal temperature changes (Neel 1963, Oesch 1984). Although some mussel species are tolerant and establish successful populations in impoundments (White and White 1977, Mather 1989, Howells *et al.* 2000), the large majority of species are not adapted to live in such conditions (Parmalee *et al.* 1982, Williams *et al.* 1992, Parmalee and Hughes 1993, Blalock and Sickel 1996).

In addition to affecting the impounded section, reservoirs modify river habitats downstream, typically altering flow and temperature regimes, erosion and deposition of sediments, and composition/transport of plankton and other organic materials (Baxter 1977, Williams and Wolman 1984, Ligon *et al.* 1995, Collier *et al.* 1996, Poff *et al.* 1997, Hadley and Emmett 1998). While wide ranges in these conditions may be normal for unimpounded streams, the variation produced downstream of dams frequently differs from natural variation in some critical respects, thus affecting suitability of the tailwater habitats for native species. The altered conditions tend to approach more natural states with increasing distance from the dams (Voelz and Ward 1991, Vaughn and Taylor 1999); however, within the altered zone, aquatic communities are invariably modified and depressed, and sensitive species may be eradicated (Fisher and LaVoy 1972, Suloway *et al.* 1981, Miller *et al.* 1984, Williams *et al.* 1992, Layzer *et al.* 1993, Heinricher and Layzer 1999, McMurray *et al.* 1999, Vaughn and Taylor 1999). Flow velocities and stream stages, for example, may be modified frequently or abruptly below dams. This can injure or strand many mussels, which generally have limited mobility (Vaughn *et al.* 1993, Layzer and Madison 1995). Where death is avoided by reimmersion, mussels exposed by stranding to frequent or prolonged temperature extremes still can experience excessive physiological stress and reduced reproductive potential (McMahon 1991).

In some cases, suitable conditions for stream mussel species have been maintained in downstream stream sections (Isom 1969, Dennis 1984), indicating that it is possible to mitigate adverse effects on tailwaters by implementing appropriate structural and operational measures. Available evidence shows, however, that the Ouachita rock pocketbook survives only in optimum stream mussel habitat (Vaughn *et al.* 1993, Vaughn and Pyron 1995, Vaughn and Taylor 1999). The extent to which such habitat can be restored below impoundments in its range is unknown. Finally, it should be recognized that impoundments exert negative effects on mussels surviving in upstream waters (and surviving populations in general), because the isolation produced by dams reduces their resilience to local declines and prevents genetic exchange with other populations.

Just as reservoirs can affect mussels directly within the reach of impoundment, in tailwaters and headwaters, in each of these areas they may affect distribution or behavior patterns of fish species that are required hosts for larvae of freshwater mussels (Hubbs and Pigg 1976, Swink and Jacobs 1983, Bain *et al.* 1988, Kinsolving and Bain 1993). Such effects could reduce or eliminate reproductive success of mussel populations dependent upon those fish.

Where channel modifications are made to provide for navigability by commercial watercraft, riverine habitats are degraded in additional ways (Clark 1976, Coon *et al.* 1977, Harris and Gordon 1987, Neves *et al.* 1997, Watters 2000). The channelization and dredging involved in creating and maintaining navigable channels are especially deleterious to native mussels. The most obvious means is from the actual removal of mussels and their habitat by the cutter head of the dredge. In addition, dredging and channelization directly disturb and destabilize large quantities of sediments not removed, but left within the affected systems. For long periods afterwards, such sediments may remain largely in suspended states or as unstable substrate deposits. This effect is increased by other aspects of these projects, e.g., the bypassing of meanders with shortened channel segments; the removal of normal, established variations in width, depth, and slope of the stream channels; the removal of riparian vegetation; the creation of dredged spoil piles; and barge traffic. Periodic maintenance dredging ensures that channelized streams remain disturbed over time. Few freshwater mussels are adapted to live in such habitat. Like impoundment, channelization may affect distribution or behavior patterns of fish species that act as required hosts for larvae of freshwater mussels.

Withdrawals of large quantities of surface water often are combined with impoundments, generally because those structures provide places of storage until use of the water occurs. Withdrawals obviously reduce flows and quantity of aquatic habitat downstream of points of diversion, and may increase flows elsewhere, by wastewater returned to streams near points of use. Those reductions and increases in flow produce physical, chemical, and biological changes, essentially like those produced with stream flow alterations below dams. Where portions of stream channels are incorporated into the means for delivering flows for human use (e.g., rather than total reliance on pipelines or artificial canals), associated effects become less related to overall quantities of flow and more related to timing of discharge and water quality issues. Water diversions that reach a scale of transferring flows between unrelated basins exhibit an additional potential to introduce species outside of their native ranges.

Numerous large impoundments have been constructed within the natural range of the Ouachita rock pocketbook, or are close enough to the range to potentially affect habitat sites used by the species (Oklahoma Water Resources Board 1990, U.S. Army Corps of Engineers 1989). On the Kiamichi River, Hugo Reservoir was impounded on the mainstem in 1974, and Sardis Reservoir on Jackfork Creek, a main tributary of the river, in 1983. Another impoundment, Tuskahoma Reservoir, is authorized for construction on the mainstem of the Kiamichi River near Albion, Pushmataha County, but has not been built. On the Little River mainstem, Pine Creek Reservoir and Millwood Reservoir were impounded in 1969 and 1966, respectively. Reservoirs on larger tributaries of the Little River (and years of first impoundment) include Broken Bow Reservoir on the Mountain Fork River (1968), DeQueen Reservoir on the Rolling Fork River (1977), Gillham Reservoir on the Cossatot River (1975), and Dierks Reservoir on the Saline River (1975). The Ouachita River mainstem has been impounded in Arkansas to form Lake Ouachita (1953), Lake Hamilton (1932), and Lake Catherine (1924), and by H.K. Thatcher Lock and Dam (1984) and Felsenthal Lock and Dam (1984). The Caddo River and Little Missouri River (large tributaries of the upper Ouachita River) have been impounded to form Degray Lake (1972) and Lake Greeson (1950).

Many of these impoundments include facilities for hydroelectric generation, which usually increase reservoir-related impacts, because of sharper fluctuations in water levels and preferences to draw water from deeper depths. In addition, following early experiments with establishing a trout fishery in Broken Bow Reservoir, a put-and-take trout fishery was established in the Mountain Fork River downstream of the dam beginning in 1989. Reservoir releases from that dam, tailored largely to serve hydroelectric generation, are modified further in attempts to support the trout fishery by producing cool tailwater temperatures. Interest exists to achieve even lower tailwater temperatures extended over a greater length of stream (conditions needed for more successful development of the fishery), by modifying the dam and its operations in additional ways.

Development of the Ouachita River for navigation was first authorized more than 100 years ago and consisted of channel clearing and snagging from Arkadelphia to the mouth of the Black River. Lock and dam developments in 1926 provided a 6.5-foot-deep navigable channel from the mouth of the Black River to Camden, Arkansas. The project was modified to provide a 9-foot navigable channel to Camden by construction of four new locks and dams, including the two in Arkansas mentioned above. The project includes 11 cutoffs and 14 bend widenings that have not yet been performed.

Environmental changes related to impoundment and channelization have been reported for the river sections historically inhabited by Ouachita rock pocketbooks. Survey results indicate that *A. wheeleri* is sensitive to those changes. Clarke (1987) noted that he and other workers had recently failed to find living Ouachita rock pocketbooks in the Ouachita River, and that the river was now impacted by several hydroelectric dams and artificial lakes.

Clarke (1987) reported the Little River to be strongly influenced by cold hypolimnetic discharges from Pine Creek Reservoir, for about 30 mi downstream from the dam (all within Oklahoma). Extensive former beds containing old shells of many mussel species, and very few live individuals, occurred in that segment. Vaughn (1994) reported very similar conditions in the Little River, from just downstream of Pine Creek Reservoir to Garvin, Oklahoma. Shells immediately downstream from the reservoir were highly corroded and coated with an orange rust-like substance. Vaughn (1994) noted cold water releases from the reservoir as one of several disturbances present in the affected section. Following further investigation, Vaughn and Taylor (1999) reported a severe, extended depression of mussel populations downstream of Pine Creek Dam. No live mussels were found at three locales closest below the dam. Mussel species richness and abundance did not recover significantly until 20 km downstream and did not peak until 53 km downstream. Vaughn and Taylor (1999) identified coldwater releases from Pine Creek Reservoir as undoubtedly affecting mussel populations of the Little River, possibly in conjunction with flow modifications. Although they identified other disturbances as well, only the impoundment-related alterations corresponded closely with the predominant trend and scale of impacts observed on the mussel community.

Clarke (1987) observed no clear deleterious effects that he could attribute to releases from Broken Bow Reservoir, and measured an improvement in mussel diversity in the Little River near its confluence with the Mountain Fork River. However, he noted unexpectedly cold water in the Mountain Fork River, and limited effects (dead mussel beds mid-stream, live mussels concentrated near tributary inflows, and ≥20 years' reduced growth in threeridge specimens) in the Little River below the two streams' confluence. Furthermore, Clarke (1987) stated that a potential exists for very serious damage to mussels from Broken Bow Reservoir, even to the point of eliminating the Little River Ouachita rock pocketbook population. The "favorable" conditions he saw near the Mountain Fork River continued downstream for several miles, whereupon mussel diversity dropped again (attributed to pollution carried by the Rolling Fork River). Diversity began to recover a second time, only to reach Millwood Reservoir, where conditions were deemed unsuitable for the Ouachita rock pocketbook and other riverine mussels (Clarke 1987). In more recent years, Vaughn and Taylor (1999) found mussel species richness and abundance declined dramatically downstream of the Mountain Fork River confluence, and showed only meager returns of species (not abundance) in the 15-km section surveyed. They judged summer water releases from Broken Bow Reservoir as being colder than the receiving waters, to the point of undoubtedly affecting mussel populations downstream. Despite current degradation, the discovery of empty Ouachita rock pocketbook shells at several Little River sites and the small living population in Oklahoma and Arkansas demonstrate that the river once provided suitable habitat for the species.

The lower Kiamichi River includes a portion flooded by Hugo Reservoir and an affected section between the reservoir and the Red River, neither of which now support the Ouachita rock pocketbook (Clarke 1987). One historical record (Valentine and Stansbery 1971) indicates that *A. wheeleri* inhabited at least one river site subsequently flooded by the reservoir. Upstream of Hugo Reservoir, Clarke (1987) observed no negative effects on the mainstem population from releases out of Sardis Reservoir through Jackfork Creek. Mehlhop and Miller (1989) believed, however, that Sardis Reservoir releases had altered water quality in the river downstream of Jackfork Creek, specifically by reducing temperatures and altering flows. Mehlhop and Miller (1989) suggested that altered conditions could affect Ouachita rock pocketbooks in a number of ways, including reduced metabolic rate and growth, decreased nutrient supply, and altered availability of fish hosts for glochidia. The FWS (unpublished data) collected temperature data from Jackfork Creek and the Kiamichi River in 1997, and confirmed that releases from Sardis Reservoir significantly reduced summer temperatures downstream, at least within the creek.

In a comparison of former localities upstream and downstream of Jackfork Creek, Vaughn *et al.* (1993) and Vaughn and Pyron (1995) found *A. wheeleri* absent from some of the downstream localities and less abundant on average at the downstream sites. In view of many difficulties of directly evaluating reproduction by *A. wheeleri,* Vaughn *et al.* (1993) also examined drift densities of general mussel glochidia and size distributions of a surrogate species, *Amblema plicata*. They found lowest glochidial densities at the first two sites downstream of Jackfork Creek, though ample adults were present, and significantly greater numbers of young *A. plicata* upstream from Sardis versus downstream. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) judged all of the live Ouachita rock pocketbooks they encountered in the Kiamichi River to have been produced prior to the filling of Sardis Reservoir in 1983. In their analysis of land use in the Kiamichi River watershed, Vaughn *et al.* (1993) concluded that Hugo and Sardis reservoirs constituted the most significant recent land use change to date.

Vaughn *et al.* (1993) directly observed large differences in water level and flow fluctuations between stations in the Kiamichi River immediately upstream and downstream of Sardis Reservoir. One visit to a downstream site appeared to coincide with a drastic drop in water levels, stranding >100 mussels and many fish in small warm pools (>35° C), where many were perishing. In September 2000, researchers encountered very low flows at a Kiamichi River locality downstream from Sardis Reservoir (C.C. Vaughn, pers.comm. 2000, Spooner and Vaughn 2000). Flows had declined to a point that many mussels had died or were distressed, resulting from high water temperatures and desiccation. *A. wheeleri* and the scaleshell mussel, *Leptodea leptodon* (at the time a proposed endangered species, final endangered status published October 9, 2001) were among the species represented in the kill. While an extended drought partly produced the low flow conditions, a lack of reservoir releases into Jackfork Creek (which contributes, on average, nearly 30% of the river flows at the point of confluence) unquestionably played a part as well. Upon a request from the FWS, the U.S. Army Corps of Engineers (CE) began special releases (5 cubic feet/second) from Sardis Reservoir, which relieved conditions in the mussel beds until later rains revived river flows. Thus, given normal operations, mussel habitats downstream from Sardis Reservoir may experience both excessive fluctuations in flows and prolonged flow reductions during critical periods.

Incidental to other work in the area from 1997 into 1999, the FWS (unpublished data) observed that the Kiamichi River channel immediately downstream of Jackfork Creek was greatly disturbed, exhibiting extensive bank erosion, an abrupt decrease in depth, and widespread burying of the former substratum under a thick layer of unstable sediments. Site conditions suggested that the channel modifications resulted largely from reservoir operations, i.e., frequent, sudden, and/or marked changes in flow, rather than from other factors (e.g., clearing of riparian forest) more widely dispersed along the river corridor. Finally, aside from any effects on the river mainstem, Sardis Reservoir has displaced and affected habitat in Jackfork Creek that might have been suitable for the Ouachita rock pocketbook.

Tuskahoma Reservoir, if constructed, would flood a large, likely critical portion of the extent of Kiamichi River now inhabited by the Ouachita rock pocketbook. Authorities have readily predicted that addition of the reservoir would eliminate the species from the flooded section (Clarke 1987, Mehlhop and Miller 1989). It is reasonable to presume that headwater and tailwater effects would extend impacts to the species beyond the flooded section, especially downstream, with a potential to negatively affect all or nearly all of the remaining Kiamichi River population. Because of its foreseeable impact on the only healthy population of the Ouachita rock pocketbook, Tuskahoma Reservoir constitutes a very serious threat to the species. The reservoir project is congressionally authorized, but no funds have been appropriated and the CE has suspended further planning at this time.

Numerous other potential water resource development projects, other than Tuskahoma Reservoir, have been proposed within the range of the Ouachita rock pocketbook. However, such projects have been discussed largely on a conceptual basis. None have had detailed information submitted for formal consideration by the FWS (at the time of this writing). An example of a project concept drawing significant recent attention centers around releasing water from Sardis Reservoir (in the realm of 150,000 acre-ft/year), passing it down the Kiamichi River channel to Hugo Reservoir, where it would be pumped via pipeline into the Trinity River basin of north Texas. Variations of that basic project include withdrawals of a comparable quantity of water from the Little River and Mountain Fork River, which would be piped and added to the Kiamichi River withdrawals. Impacts posed by the conceived water development projects vary greatly in relation to their size, location, and specific project features.

Impoundment, channelization, and flow modification may pose hazards to the Ouachita rock pocketbook beyond those already identified. Without knowing more of the life history and habitat requirements of the Ouachita rock pocketbook, the impact of these developments on the species cannot be fully determined. Because of the predominantly negative nature of known impacts, steps should be taken to answer additional key questions about *A. wheeleri* in the course of evaluating water development proposals within the species' range.

Water quality degradation

A variety of activities can degrade water quality, including point and nonpoint source pollution discharges, changes in the amount of stream shading, and other watershed alterations. Water quality degradation can be deleterious to native mussels in a number of ways (Isom 1969, Fuller 1974, Bates and Dennis 1978, Foster and Bates 1978, Horne and McIntosh 1979, Dennis 1981, Havlik and Marking 1987, McMahon 1991, Neves *et al.* 1997). Water quality is most obviously degraded for mussels by pollutants that are toxic or otherwise injurious to these organisms (e.g., Keller and Zam 1991, Jacobson *et al.* 1993). Water quality also is degraded by conditions that directly or indirectly deprive mussels of their normal biological needs, such as acceptable ranges of dissolved oxygen, nutrients, water temperatures, substrate consistency, and suitable hosts (Coker *et al.* 1922, Dimrock and Wright 1993, Sparks and Strayer 1998).

Although effects of pollution on freshwater mussels have been documented, relatively little data are available on tolerance limits of freshwater mussels to specific pollutants. Most work in this area, such as that by Foster and Bates (1978), has dealt with heavy metal concentrations. Havlik and Marking (1987) reviewed the effects of contaminants on naiad mollusks, including a large number of metals, pesticides, and other pollutants. They compiled toxic concentrations reported in other studies, and concluded that contaminants had reduced mussel density, range, and diversity. Silt is suggested to interfere with respiration, feeding, and/or reproduction due to irritation and clogging of mussel gills and siphons (Ellis 1936, Dennis 1984, Aldridge *et al.* 1987, Brim Box and Mossa 1999).

Extreme water quality conditions measured in mussel habitats can be misleading, because many mussels are able to detect certain adverse conditions, and may exclude them temporarily by retreating within their shells until conditions improve. However, exposure to such conditions on a frequent or prolonged basis can significantly interfere with feeding. Abilities to detect and exclude adverse conditions are incomplete, so that limited exposures often impact at least some members of any given mussel population. It is clear that most freshwater mussel species are not adapted to live in the degraded water quality conditions caused by unmitigated human activities. As in the case of impoundment and channelization, it is necessary also to consider the effect water quality may have on fish species that serve as hosts for mussel glochidia.

Considerable progress has been made assessing pollution sources and developing water quality management programs in states where the Ouachita rock pocketbook occurs. That progress, overseen by the U.S. Environmental Protection Agency and the states involved, has taken place largely through substantial funds made available under Section 208 and other sections of the Clean Water Act. Programs in place provide the means necessary to monitor instream quality, regulate point sources, and reduce nonpoint sources affecting the health and distribution of *A. wheeleri* populations. The upper Ouachita River in Arkansas has recently been described as having generally good and improving water quality, with elevated nutrients from a municipal source constituting the principal known source of continuing impairment. In Oklahoma, the Little River is considered to have water quality supportive of its beneficial uses, but threatened by silvicultural pesticides, atmospheric nutrients, acidity, high suspended solids, and siltation from unspecified sources. In Arkansas, water quality in the Little River continues to be impaired by several chronic problems, including three that degrade the Rolling Fork River: agricultural nonpoint sources, a Weyerhaeuser Superfund site, and the City of DeQueen. The Kiamichi River is considered to have water quality supportive of its beneficial uses, but threatened by acidity from the atmosphere and pastureland, nutrients from crop production, siltation from rangeland, and suspended solids from silviculture (Arkansas Department of Pollution Control and Ecology 1992, Oklahoma Department of Pollution Control 1992).

Habitat changes characteristic of water quality degradation have been reported for river reaches historically inhabited by the Ouachita rock pocketbook. Survey results indicate that *A. wheeleri* is a species sensitive to those changes. Gordon and Harris (1983) reported degraded conditions in both the Ouachita River and Little River in Arkansas, with organic eutrophication suggested as the probable cause. Water quality degradation appeared to be extensive in the main channel of the Ouachita River, where few live mussels were seen and shells of recently dead mussels were not frequently encountered. Evidence of Ouachita rock pocketbook inhabitation was limited to relict shell material at a single site. Clarke (1987) reported the Old River oxbow (the type locality) to be severely polluted and found no evidence of it being inhabited by any mussel species. He specifically noted the water exhibiting an oily surface film and other degradation attributed to a large trash dump extending into the oxbow.

In the section of Little River between Pine Creek Reservoir and U.S. Highway 70, Vaughn (1994) observed evidence of mussel kills, in-stream sedimentation, and surface films, and noted a mill discharge, a chicken processing plant discharge, other point source discharges, chicken farms, logging, gravel mining, cattle, and feral swine as non-reservoir related water quality disturbances present. Vaughn and Taylor (1999) elaborated on the effect of the "paper mill" [in reality a sawmill], attributing it with small-scale reductions in abundance and diversity that dissipated within 2 km. They also described sedimentation as patchy and occurring within all sections of the Little River that they sampled. In the Little River section between U.S. 70 and the Rolling Fork River confluence, Vaughn *et al.* (1995) observed evidence of mussel kills and in-stream sedimentation, and noted gravel mining, riparian clearing, and feral swine as potential sources of degradation. Clarke (1987) identified an inadequately treated sewage discharge by the City of Idabel in McCurtain County, Oklahoma, as a source of possible harm to a surviving population of the Ouachita rock pocketbook in the Little River. He also identified a gravel dredging operation in the Little River north of Goodwater, McCurtain County, as another source of potential harm to that population, presumably by water quality effects. In the Little River in Arkansas, Gordon and Harris (1983) found evidence of a recent catastrophic die-off of mussels, with many thousands of mussel shells found at most of the nine sites sampled. A thriving mussel fauna had been observed in 1979. Live mussels were encountered only in backwaters away from the main channel and in the river just upstream of Millwood Reservoir. Evidence of the Ouachita rock pocketbook was limited to relict shells at two sites, as previously stated. Clarke (1987) reported that mussel diversity dropped dramatically in the Little River in Arkansas, approximately five miles downstream from where the mussel community had largely recovered from effects caused by releases from Pine Creek Reservoir. He attributed the decline to pollution periodically entering the Little River from the Rolling Fork River. Vaughn *et al.* (1995) found no live mussels downstream from the Little River's confluence with the Rolling Fork River, and empty shells of only the Asian clam, *Corbicula fluminea*.

In regard to the Kiamichi River, Clarke (1987) stated that no significant municipal pollution was evident from Clayton, Oklahoma. Mehlhop and Miller (1989) described point source pollution affecting the Kiamichi River as low, and indefinite contributions from nonpoint sources. However, they identified a gravel mining site, a bridge construction site, and a proposed pipeline crossing as activities likely to impact nearby Ouachita rock pocketbooks by degrading water quality. In addition to existing activities, it has been predicted that any development of hydropower facilities at Sardis Reservoir would degrade conditions in the Kiamichi River.

Water quality degradation likely poses hazards to the Ouachita rock pocketbook beyond those that are already known. Without knowing more of the life history and habitat requirements of the Ouachita rock pocketbook, the impact of water quality degradation on the species cannot be fully determined for all parts of its range.

<u>Other factors</u>

Gravel excavation, construction of road and utility crossings, and vehicle/livestock activities within stream channels can impact mussels and mussel habitats directly, in addition to degrading water quality downstream (Brown and Curole 1997, Meador and Layher 1998, Jennings 2000, Watters 2000). Valentine and Stansbery (1971) reported a gravel dredging operation on the Kiamichi River in which many mussels were buried or crushed, at a site inhabited by the Ouachita rock pocketbook. Several local roadways cross the Kiamichi River at fords, used by vehicles ranging from all-terrain vehicles to logging trucks. Evidence indicates that some mussels are negatively impacted by large vehicles driven across the streambed or used to maintain the fords.

Beyond the channels, surrounding landscapes significantly influence stream environments, exerting effects on water quality, hydrology, and organic production. Changes in landscape condition and introduction of unmitigated human activities can dramatically degrade aquatic communities and habitats (Vaughn 1997a, Watters 2000). Although all portions of a watershed relate to the stream environment, in general, the greatest influence is produced by riparian zones that border stream channels. Because riparian zones can be affected by flow alterations and other stream modifications, potential exists for a compounding of effects between these environments. Indeed, many ecological interactions occur between streams and riparian zones (Morris and Corkum 1996), making the latter natural areas of focus in stream and mussel conservation. Vaughn *et al.* (1993) found the Kiamichi River watershed to maintain significant coverage by mature forest, but believed much of the forest was likely to differ from its original state. In addition, they observed many cut forest stands in various stages of regrowth and human developments concentrated along and near the river channel. Certain and Vaughn (1994) found very similar conditions in the Little River and Ouachita River watersheds.

Mehlhop and Miller (1989) identified the introduced Asian clam, *C. fluminea*, as a potential threat to the Ouachita rock pocketbook. *Corbicula* became established in the region in the mid-1970's (Britton and Murphy 1977, White and White 1977). Since then, it has become widely dispersed throughout area surface waters and is often abundant. To date, however, biologists working within the region have not reported evidence of Asian clams competing directly with native mussels or otherwise affecting them adversely. Studies elsewhere have produced mixed results, some indicating adverse effects on native mussels but others indicating none (Belanger *et al.* 1990, Leff *et al.* 1990, McMahon 1991, Strayer 1999a). However, the exotic zebra mussel, *Dreissena polymorpha*, may pose a serious biological threat to the Ouachita rock pocketbook. This small bivalve is environmentally adaptive and prolific, producing immense populations within most freshwater environments to which it is introduced. The zebra mussel has high dispersal capabilities, and has spread extensively within the U.S. since its introduction here in 1985 or 1986, including up the Arkansas River system into Arkansas and Oklahoma. However, it has not been reported from the Red River or Ouachita River systems, where *A. wheeleri* occurs. Zebra mussels secrete threads by which they attach to most firm underwater surfaces, including shells of native mussels. Although the ultimate biological impact cannot be predicted, evidence indicates these mussels will eventually infest most major North American drainages south of central Canada and will interfere with normal feeding and movements of native mussels, sufficient to seriously reduce native mussel populations (Strayer 1991 and 1999a, Neves *et al.* 1997, Ricciardi *et al.* 1998). Contaminated watercraft facilitate dispersal of zebra mussels; thus, existing and future impoundments and navigation pools (where most watercraft activity occurs) constitute the most likely centers from which zebra mussels might infest the range of the Ouachita rock pocketbook.

Wheeler (1918) reported that *A. wheeleri* was sometimes harvested by persons mistaking the species for *Quadrula pustulosa*. Vaughn *et al.* (1993) noted that commercial harvest of mussels was currently prohibited in the Kiamichi River, but felt such activity, if allowed, could pose a grave threat to *A. wheeleri*. Finally, over-collection for scientific or hobby purposes may have constituted a threat to the Ouachita rock pocketbook at one time. This possibility is suggested by the large number of *A. wheeleri* specimens collected from the Old River locality within a short span of years, and the subsequent lack of specimens from that locality (although the relative effect of over-collection versus pollution and other factors cannot be determined at this point). Current prohibitions against take of *A. wheeleri* and a greater appreciation of its endangered status should largely eliminate over-collection as a significant threat to the species.

Reduction and/or elimination of significant threats to the species and its habitat are necessary to achieve recovery. Three sections in this recovery plan, the *Narrative Outline for Recovery Actions*, *Recovery Actions Specifically Addressing Endangered Species Listing Factors* (Table 3), and the *Implementation Schedule*, detail a variety of actions (e.g., monitoring of threats, upgrading of water quality standards, and public outreach) that if implemented, will address the threats discussed above.

Conservation Measures

Since listing, a number of efforts have been made to help conserve the Ouachita rock pocketbook. A three-year study, funded through Section 6 of the Endangered Species Act, was completed regarding habitat use in the Kiamichi River. That study contributed much information regarding *A. wheeleri* occurrence in different river microhabitats. Movement, growth, survival, population fluctuations, and relative influence of water pollution and impoundment on mussel populations also were examined. Subsequent studies, funded primarily by the FWS, updated occurrence of the Ouachita rock pocketbook and threats to its existence within the Little River. Results of these various studies were reported by Vaughn (1994), Vaughn *et al.* (1993, 1994, 1995), Vaughn and Pyron (1995), and Vaughn and Taylor (1999), and are summarized in this plan in the preceding sections on distribution, habitat/ecosystem, life history/ecology, and reasons for listing/threats. As a part of these studies and through supplemental funds (Certain and Vaughn 1994), land uses were assessed within portions of the Kiamichi River, Little River, and Ouachita River basins. Other post-listing studies funded through Section 6 or discretionary FWS funds include a survey of Kiamichi River tributaries (Meier and Vaughn 1998) and planning for studies of reproduction in *A. wheeleri* (Vaughn 1997b). Most recently, Region 4 and the Arkansas Field Office of the FWS have funded a research project to investigate suitable host fish species for the Ouachita rock pocketbook and collect other new information on reproduction, habitat, and populations of the species in Arkansas and Oklahoma (Susan Rogers, FWS, *in litt.* 2001). That project is being performed by Arkansas State University.

The U.S. Forest Service (FS) has funded a number of surveys to ascertain the possible occurrence of the Ouachita rock pocketbook on and near FS lands (Vaughn *et al.* 1994b, Vaughn 1996a, Vaughn and Spooner 2000). Although those surveys did not discover additional localities of the species, they answered questions of possible occurrence in several streams targeted for survey work in the draft recovery plan. The FS also conducted a substantial assessment of aquatic resource information applicable to the Ozark and Ouachita Highlands (Bell *et al.* 1999). Mussel species comprised one representative resource used in that assessment, which presents analyses useful to continuing research and management in the region.

As part of a memorandum of understanding with the FWS, the Oklahoma Department of Environmental Quality (ODEQ) agreed to recognize a FWS list of Aquatic Resources of Concern in Oklahoma. The list includes the Kiamichi River and Little River drainages in southeast Oklahoma, based on their inhabitation by the Ouachita rock pocketbook and other federally-listed species. The memorandum provides for the FWS to receive special notification of proposed discharge permit actions pending before the ODEQ, where those actions involve waters listed as Aquatic Resources of Concern.

The Oklahoma Department of Wildlife Conservation amended its regulations to designate the Kiamichi River a mussel sanctuary (9 OK Reg. 1909, effective January 1, 1993). As such, the river is closed to all commercial mussel harvest. Although the Ouachita rock pocketbook already receives some protection under Oklahoma law as a state and federal endangered species, designation of the Kiamichi River as a sanctuary provides additional protection by prohibiting activities that might disrupt the species' habitats. Without prohibiting harvest activities, musselers might be required only to separate and return Ouachita rock pocketbooks back to the stream unharmed.

In 1992-1993, The Texas Parks and Wildlife Department designated both Pine and Sanders creeks as mussel sanctuaries, in which no harvest is permitted (Howells *et al.* 1997). As described for the Kiamichi River, the designation of sanctuaries in Texas provides additional protection to *A. wheeleri* populations that may continue to inhabit these waters.

In 1997 and 2000, the Arkansas Game and Fish Commission designated the Ouachita River upstream from U.S. Highway 79B at Camden as a mussel sanctuary, in which no harvest is permitted. As described for Oklahoma and Texas, the designation of this sanctuary in Arkansas provides additional protection to the *A. wheeleri* population that may continue to inhabit these waters.

The U.S. Fish and Wildlife Service (1994a,b) prepared and distributed a draft of this recovery plan in July 1994, providing preliminary information about the species and its recovery needs to other agencies and the general public. Several subsequent surveys and studies discussed in this approved plan were performed to address key information needs identified in the draft plan. From a more general standpoint, a broad group of representatives from federal agencies, state agencies, academia, commercial interests, and private entities produced a national strategy for native mussel conservation (National Native Mussel Conservation Committee 1998), outlining a range of needs and tasks and highlighting their subject as a problem worthy of national attention. Other mussel conservation strategies, more focused in scope, also have been published (e.g., U.S. Fish and Wildlife Service 1994c, 1996, 1997a,b, Jennings 2000, Obermeyer 2000). These, plus formation of a freshwater mollusk conservation association, and evidence of a renewed recent interest in freshwater mussel research (Jenkinson and Todd 1997), indicate an increasing body of knowledge, experience, and appreciation of these organisms that can be applied to their conservation, including recovery of *A. wheeleri*.

The FWS has reviewed a number of federal actions within the range of the Ouachita rock pocketbook and consulted further with other agencies in cases where it appeared those actions might adversely affect the species. The most significant of these consultations to date occurred in regard to replacements of bridges across the Kiamichi River near Tuskahoma and Clayton, both in Pushmataha County, Oklahoma. Through the FWS's work with the Federal Highway Administration and other entities, those projects were modified to avoid significant effects on *A. wheeleri*. Similar planning has occurred in relation to construction of new water treatment facilities and other recent/proposed developments affecting waters inhabited by the Ouachita rock pocketbook. The FWS has begun informal consultation with the CE regarding operation of Sardis Reservoir. The FWS also has provided general comments to State of Oklahoma officials regarding conceptual proposals for water resource development in southeast Oklahoma.

The Nature Conservancy, a private organization, has shown pertinent interest by initiating its own conservation planning for the Ouachita Mountains region (Doug Zollner, TNC, *in litt.* 1994), and by exploring local interest in river conservation specifically within the Kiamichi River watershed (Wilson 1999).

Strategy of Recovery

Many scientific investigations and conservation assessments, historical to recent, have identified the Kiamichi River as an exceptional stream resource, exhibiting a high diversity of native species and an unusual maintenance of that diversity to current times, including rare species (Isely 1925, Clarke 1987, Vaughn *et al.* 1993, 1996, Pyron and Vaughn 1994, Master *et al.* 1998, Bell *et al.* 1999). The Kiamichi River basin is a desirable location to emphasize in initial recovery efforts, because of its natural values and because of the relative ease of maintaining existing high quality conditions versus trying to restore them in more degraded environments. Timely efforts to protect and recover the Ouachita rock pocketbook and its associated ecosystem in the Kiamichi River can in many cases help maintain other valued ecological characteristics of that river, and assist development interests in identifying compatible approaches for human activity.

The Kiamichi River presently supports the only known substantial population of the Ouachita rock pocketbook. Protection of that population, including the conditions that provide for its natural growth and reproduction, is essential to the continued existence of the Ouachita rock pocketbook. Reservoir construction and water quality degradation have caused declines of *A. wheeleri* populations, and remain principal threats to the Kiamichi River population. Measures to achieve protection of the Kiamichi River population are identified as the most important tasks (Priority 1) in this recovery plan.

Existing statutes provide considerable protection, especially the Endangered Species Act, the Clean Water Act, and corresponding state laws and regulations. Additional protection will be required to ensure survival of the Kiamichi River population. Deauthorization of the proposed Tuskahoma Reservoir project is believed necessary to recover the species. Survival and recovery of the Ouachita rock pocketbook cannot be accomplished as long as that threat exists.

Additional life history and ecological investigations are needed to determine the full range of conditions that must be protected. Those studies would determine the host species required by larval Ouachita rock pocketbooks, other critical aspects of reproduction, juvenile habitat requirements, and environmental tolerances. In addition, permanent monitoring of the population and habitat should be conducted to confirm the effectiveness of present and future protection measures. Without determining key aspects/requirements and monitoring for effectiveness, the vital Kiamichi River population could decline further or disappear.

Protection of the Kiamichi River population is believed essential to survival and to provide for the eventual recovery of the Ouachita rock pocketbook. By itself, however, such action would not return the species to a secure status as provided historically by the existence of multiple distinct populations. The existence of multiple, separate populations greatly reduces vulnerability of a species to adverse events impacting a single population, such as spill of a toxic material into an inhabited drainage. Consequently, restoration of Ouachita rock pocketbook populations and habitats outside of the Kiamichi River would benefit survival of the species under conceivable but unintended circumstances (e.g., toxic spills).

Restoration of those populations and habitats also offers the greatest potential for species recovery, because of their presently degraded condition.

Enhancement of the Kiamichi River population, updated assessments of other populations that may still exist, plus restoration and protection of degraded populations and habitat are tasks designed to recover the Ouachita rock pocketbook. Restoration of decimated populations may require translocation of mussels from healthy populations, if techniques can be developed to perform this operation successfully. Additional research will be needed on habitats in other inhabited waters, genetic composition of extant populations, and population viability.

Available information indicates the natural range of the Ouachita rock pocketbook to be portions of the Ouachita River, Kiamichi River, Little River, and two or more small tributaries of the Red River. The small, closely situated Red River tributary portions likely are incompletely isolated from each other (in terms of larval dispersal between mussel populations), and are regarded here as parts of a single area of occurrence, i.e., inhabited by a single metapopulation. Restoration and protection of habitat and viable populations in the four indicated areas or systems would return the species to its total known range. Such reestablishment is identified as necessary before delisting can be considered. Restoration and protection of habitat and viable populations in three areas, including the Kiamichi River, form the basis for considering a reclassification to threatened. The recovery criteria may be revised as the results of additional research, outlined in this recovery plan, become available.

Shared understanding of important facts and concerns, and meaningful involvement of the public, will significantly influence the success of any recovery effort. Tasks have been incorporated into this plan that are designed to enhance communication and public participation. These tasks will contribute to the success of other recovery tasks.

The Ouachita rock pocketbook has always been reported as rare, even in its most favorable habitats, making its natural propagation especially vulnerable to loss of individuals. Survey, monitoring, and research efforts, although crucial elements of recovery, must be carefully designed and conducted to minimize impacts on wild populations. Management efforts must likewise avoid impacting wild populations while treating threats adequately.

Use of existing statutes to protect the Kiamichi River system; deauthorization of Tuskahoma Reservoir; monitoring of the Kiamichi River population, its habitat, and threats; determination of the host species and other reproductive details; and determination of environmental sensitivities are all priority one tasks identified by this plan. Priority one tasks are actions that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future. Restoration, protection, and monitoring of degraded populations and habitats; certain ecological investigations; and conducting a public outreach program are the most important priority two tasks.

Any recovery task proposed to be carried out by a federal agency is subject to the provisions of the National Environmental Policy Act (NEPA) if that task constitutes a major federal action. Such actions will only be implemented in compliance with NEPA and would undergo complete public review and comment prior to implementation. Recovery plans do not obligate an agency, entity, or persons to implement the various tasks listed in the plan.

PART II: RECOVERY

A. Objectives and Criteria:

The ultimate goal of this recovery plan is to restore the Ouachita rock pocketbook, *Arkansia wheeleri*, to a point where protection under the Endangered Species Act is no longer needed. This would be accomplished by conserving the remaining populations and reestablishing viable[1] populations within the species' natural geographic range. Achievement of this goal would allow removal of the species from the Federal List of Endangered and Threatened Wildlife and Plants.

Reclassification to Threatened Criteria

The initial objective is to reclassify the Ouachita rock pocketbook from endangered status to threatened status when:

(1) The existing population in the Kiamichi River is protected[2] from further decline and degradation of its habitat; and

(2) At least two viable populations are successfully reestablished (or found) and protected in two additional stream systems within the natural range of the Ouachita rock pocketbook.

These criteria will be fulfilled by the successful completion of Tasks 1 through 8 and 9.6 outlined in the following pages. It is believed that accomplishment of these tasks will eliminate the likelihood of the species becoming extinct in the foreseeable future. The estimated date for reclassifying the species to threatened is 2023.

---

[1] For purposes of this plan, a viable population is defined as a naturally reproducing population large enough to maintain sufficient genetic variation to provide for its continued evolution and response to natural environmental changes. A minimum viable population has not been designated for the Ouachita rock pocketbook, although the Kiamichi River population, estimated as between 1,000 and 2,000 individuals, is regarded as viable, while the Little River population, estimated at less than 100 individuals, is not. The minimum population size needed for long-term viability will be determined through studies prescribed in the recovery plan.

[2] For purposes of this plan, protection is defined as preserving populations of the species, its life history requirements and habitats, sufficient to maintain the species and its habitat in their baseline condition or an improved state, as reflected in population levels, year-class composition, distribution, and other primary indicators of biological health and environmental quality. Complete protection includes prevention, elimination or exclusion of present and foreseeable threats, determination of essential biological requirements, verification of condition through monitoring, and the performance of additional measures as may be needed to ensure continued maintenance of the species and its habitat. The effectiveness and reasonable permanence of protection programs shall be judged by success throughout a minimum of fifteen consecutive years, and an assessment of the adequacy of protective measures established for the species, in light of current information.

Interim Delisting Criterion

The long-term objective of this recovery plan is to delist the Ouachita rock pocketbook. The delisting criterion that follows is considered interim because the opportunity and potential locations for reestablishment are uncertain. Recovery Action 7.2 addresses this uncertainty and calls attention to several important aspects of site selection, including proximity to known populations, and water and habitat quality. In addition, several significant uncertainties pertaining to life history and habitat selection need to be answered; completion of recovery actions 1.22, 4, 4.1., 4.2, 5, 5.1, 5.2, 5.3, 6, 6.1, 6.2, and 7.1 should provide data needed to affirm or revise the recovery criterion. A date to delist the Ouachita rock pocketbook cannot be accurately determined at this time. After the species has been reclassified to threatened, it may be possible to delist it when:

> Viable populations are successfully reestablished (or found) and protected in four major stream systems naturally inhabited by the Ouachita rock pocketbook, including the Ouachita River, Kiamichi River, Little River, and one or more additional tributaries of the Red River basin.

This criterion will be fulfilled by completion of Task 9.7 outlined in the following pages. It is believed that this action will eliminate the likelihood of the species becoming endangered in the foreseeable future.

Tasks 9.1 through 9.5 are not considered essential to the fulfillment of either the criteria for reclassifying to threatened or the criterion for delisting. However, these tasks are considered means for more efficiently and effectively pursuing fulfillment of recovery criteria.

The downlisting and delisting criteria above are preliminary and may be revised on the basis of new information.

This recovery plan is a guide to be used by the FWS and individuals, organizations, and other agencies working to recover the Ouachita rock pocketbook. As the plan is implemented, revision will likely be necessary. Sound management of the species and close coordination among management entities should provide more stable habitat and population structure for the Ouachita rock pocketbook and restore it to a less endangered status.

B. Narrative Outline for Recovery Actions:

1. Preserve existing Ouachita rock pocketbook population and habitat in the Kiamichi River in Oklahoma. The only known population of this species considered to have long-term viability occurs in the mainstem of the Kiamichi River from near the upper reaches of Hugo Reservoir, Oklahoma, upstream to Whitesboro, Oklahoma. That population contains a large majority of the known living Ouachita rock pocketbooks, and is essential to the survival and recovery of the species. Habitat of the Kiamichi River population has been impacted by reservoir construction and water quality degradation. Potential future threats include construction of the authorized Tuskahoma Reservoir, conceivable operations of Sardis Reservoir and smaller impoundments, large water withdrawals from the river upstream of Hugo Reservoir, and further degradation of water quality. Without the

protection of the Kiamichi River population and its habitat encompassed by these tasks, the Ouachita rock pocketbook is almost certain to become extinct.

1.1 Use existing statutes to protect the Kiamichi River system where the Ouachita rock pocketbook occurs. The Endangered Species Act, the Fish and Wildlife Coordination Act, and other environmental statutes provide a measure of protection for this species. Activities governed by existing statutes and with potential to adversely affect the inhabited extent of the Kiamichi River must be carefully designed and implemented to prevent adverse impacts to the Ouachita rock pocketbook and its habitat. All entities that may adversely affect the species should consider it in project planning, construction, and operation, and provide adequate protection from the effects of actions taken. Species protection and achievement of other objectives are most likely to be successful where interested parties cooperate in these efforts and consider environmental issues from the outset of project planning.

This task will consist largely of continued consultation by federal agencies with the FWS in accordance with Section 7(a)(2) of the Endangered Species Act. That section requires federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered species such as the Ouachita rock pocketbook. The full range of federal agencies and activities involved in consultation cannot be anticipated, but will likely include U.S. Army Corps of Engineers (CE) multipurpose reservoir activities; CE permit programs regulating placement of fill and structures in waters of the United States; U.S. Environmental Protection Agency (EPA) programs overseeing state water quality standards, point source and nonpoint source controls, solid waste disposal, and pesticide registration; U.S. Forest Service (FS) management activities on the Ouachita National Forest; Federal Highway Administration (FHWA) bridge and highway construction projects; Farm Service Agency (FSA) inventory transfers, other U.S. Department of Agriculture (USDA) agriculture assistance programs, and Federal Energy Regulatory Commission (FERC) programs regulating pipelines and non-federal hydroelectric projects. Consultations regarding the Kiamichi River population of the Ouachita rock pocketbook may involve, as applicants or non-federal representatives, various representatives of the State of Oklahoma, local authorities, and private parties. The FWS must keep pertinent parties aware of the need for consultation and fulfill its responsibilities in a constructive, timely, and biologically sound manner.

This task also will involve actions under Sections 9 and 10 of the Endangered Species Act. Those sections set forth prohibitions and exceptions that, in part, make it illegal to take (includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt any of these), import or export, ship in interstate commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It is illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to agents of the FWS and state conservation agencies. Permits may be issued to carry out otherwise prohibited activities involving endangered species under certain circumstances. Such permits are available for scientific purposes, to enhance the propagation or survival of the species, and/or for incidental take in connection with otherwise lawful activities.

The Kiamichi River is covered by existing requirements that provide for protection of a basic level of water quality. Water quality protection is administered primarily by the states (although the EPA maintains an oversight authority, which can be reviewed under the Section 7 consultation procedures mentioned above). In Oklahoma, most program responsibilities are placed with the Oklahoma Department of Environmental Quality and the Oklahoma Water Resources Board, although others are distributed among additional agencies. Although existing water quality standards for the Kiamichi River are not based on specific needs of the Ouachita rock pocketbook, their enforcement can maintain water quality that is generally supportive of aquatic life. Existing water quality standards and other water quality requirements (e.g., point source discharge permit limitations) presently receive incomplete enforcement due to factors such as limited program resources that produce, for example, a near total reliance on self-monitoring data reported by dischargers. Existing programs also include tolerance for a certain number and degree of violations and generally allow dischargers to approach full compliance over extended periods. Existing standards and associated water quality requirements should be stringently enforced for the Kiamichi River and its tributaries. Information on all potential violations of these standards or requirements should be immediately reported to appropriate officials, investigated, and corrected. Dischargers should invest adequate funds into construction and operation of treatment facilities (using assistance programs, where appropriate) and enforcement programs should receive adequate funding, to eliminate funding deficiencies as factors limiting compliance.

Oklahoma Department of Wildlife Conservation (ODWC) statutes prohibit collection of the Ouachita rock pocketbook in the course of commercial mussel harvest, and also prohibit attempts to possess, hunt, chase, harass, capture, shoot, wound, kill, take, or trap endangered species such as *A. wheeleri*. ODWC regulations designate the Kiamichi River as a mussel sanctuary, in which no commercial mussel harvest is allowed, and prohibit the collection or sale of threatened or endangered species of mussels. In addition, ODWC regulations designate the Kiamichi River upstream from Highway 271, and its tributaries, as areas closed to seining by commercial minnow dealers. Those restrictions add protection for the Ouachita rock pocketbook, and should be strictly enforced.

1.2 <u>Provide additional measures needed to achieve basic protection of the Kiamichi River population</u>. Adequate protection of the Ouachita rock pocketbook in the Kiamichi River will require additional measures that are not fully provided for by existing authorizations and requirements. For some protective measures, proper authorization does not yet exist. In other cases, limited authorizations may exist, but their use to protect the Ouachita rock pocketbook may be inadequate. Such use may be more discretionary or less specifically prescribed, requiring creative application and implementation. While requirements of the Endangered Species Act provide protection for *A. wheeleri* and its habitat, other programs and measures may provide alternate protection that landowners find preferable to regulatory approaches (e.g., eventual development of a habitat conservation plan).

1.21 <u>Deauthorize Tuskahoma Reservoir</u>. This reservoir is presently authorized for construction by the CE and poses a serious threat to the Ouachita rock pocketbook's continued existence and recovery. Impoundments have already caused much of the decline experienced by this species. While any project significantly affecting *A. wheeleri* is a source of concern, the Tuskahoma project is of special concern because it would (1) displace by the dam and conservation pool approximately 19% of the 88-mi river section inhabited by the sole viable population, (2) likely reduce the inhabited section further, by headwater and tailwater effects, and (3) effectively block genetic exchange among any portions of the population left upstream and downstream of the reservoir. Numbers and distribution of the Ouachita rock pocketbook would both be significantly reduced. Although Tuskahoma Reservoir can be evaluated further through Section 7 consultation (Task 1.1), the project appears to pose inherent impacts that would severely interfere with the species' survival and efforts for its recovery. Alternatives likely exist that would meet needs to be served by the reservoir with less adverse or even beneficial effects on the mussel and its habitat. Therefore, the Tuskahoma Reservoir project should be deauthorized. Until deauthorization is accomplished, *A wheeleri* should not be delisted. Authority to deauthorize a project such as Tuskahoma Reservoir lies with the U.S. Congress. Removal of this threat is essential to prevent extinction.

1.22 <u>Determine value of major tributaries as habitat for the Kiamichi River population</u>. The Ouachita rock pocketbook has been characterized as inhabiting certain habitats within the mainstems of rivers. However, both archaeological and recent evidence indicate possible occurrence of the species in Jackfork Creek, a major tributary of the Kiamichi River (Bogan and Bogan 1983, A.D. Martinez, unpublished data). Report of *A. wheeleri* shells from Pine and Sanders creeks in Texas (Howells *et al.* 1996, 1997) also indicate the possibility of the species inhabiting large tributaries of rivers. Discovery of significant Ouachita rock pocketbook numbers in tributaries of the Kiamichi River would increase the recognized size of the river population and the area of habitat requiring protection. Main tributaries, including Jackfork Creek, Pine Creek, Buck Creek, Tenmile Creek, and Cedar Creek, should be surveyed further for *A. wheeleri* at selected, inadequately surveyed sites, using scuba when mussels are found and the water depth is more than 100 centimeters (cm). Habitat conditions and apparent threats should be assessed concurrently.

1.23 <u>Perform cooperative projects to increase protection of Ouachita rock pocketbook habitat in the Kiamichi River</u>. Section 7(a)(1) authorizes federal agencies to carry out programs to conserve listed species such as *A. wheeleri*. The FWS will assist other federal agencies in developing and carrying out such programs, as well as undertake its own programs, to conserve this species. Section 6 of the Endangered Species Act provides for the FWS to grant funds to states for management actions aiding the protection and recovery of listed species. Section 6 funds should continue to be made available to the State of Oklahoma for Ouachita rock pocketbook recovery. Other programs (e.g., FWS Partners for Fish and Wildlife Program; EPA Nonpoint Source Program; and USDA Conservation Reserve Program, Environmental Quality Incentives Program, Forestry Incentives Program, Stewardship Incentive Program, and Wetlands Reserve Program) provide additional means of developing cooperative projects that could be used to protect the river environment, while retaining lands in private ownership. These programs differ somewhat in the objectives and practices they support; consequently, development of individual projects to benefit *A. wheeleri* will require consideration of program differences as well as environmental objectives. Participants in cooperative programs may include a broad variety of public and private parties. The total cost of task completion will be determined by the amount of private and governmental participation.

1.24 Upgrade protection provided to the Kiamichi River through water quality standards and water quality management programs. In addition to enforcing existing water quality requirements, it is important to seek improvements where those requirements offer incomplete protection to the Ouachita rock pocketbook and its habitat. A special beneficial use category should be defined for waters containing *A. wheeleri* habitat, and criteria developed that more accurately reflect the species' environmental needs (e.g, as determined through Task 5). Once determined, such a category and criteria should be included in the Oklahoma Water Quality Standards and applied to the Kiamichi River. To protect existing water quality while specific standards are developed, the river and its tributaries should receive the highest level of protection under the state's anti-degradation policy.

Best management practices (BMPs) have been developed to control nonpoint sources of pollution, but application of those practices in Oklahoma, presently on a volunteer basis, has been limited. The limited extent of treating nonpoint sources should be remedied, and the adequacy of implemented BMPs verified. Other elements of Oklahoma's water quality management program should be upgraded to increase protection of the Kiamichi River (e.g., evaluations of the effectiveness of point source discharge requirements to remove biological toxicity).

1.25 Develop and implement a strategic habitat protection plan for the Kiamichi River. Protection of the Kiamichi River Ouachita rock pocketbook population can be most effectively accomplished by developing a strategic or systematic protection plan. The plan would identify and place a priority on protective measures benefitting the most important habitat sites, treating the most important or most readily alleviated threats, or presenting other key opportunities to benefit the species. At the same time, such a plan could promote consistency among properties regarding conditions needed to protect habitat quality. One valuable component of such a plan would be development of a computerized database containing relevant information in a form suitable for query and analysis, e.g., within a geographic information system (GIS). This effort should consider enlisting the assistance of Oklahoma's Natural Areas Registry Program (administered by the Oklahoma Natural Heritage Inventory).

1.251 Inventory property ownerships on and along the Kiamichi River and water rights appropriations. To support other recovery tasks, an ownership map should be prepared for all properties having a potential to affect portions of the Kiamichi River inhabited by the Ouachita rock pocketbook. Appropriated rights to river flows also should be inventoried.

1.252 Ensure public landowner notification. Pursuit of Tasks 1.1 and 1.23 will identify many federal, state, county, and municipal landowners along the Kiamichi River, but perhaps not all. Efforts should be made to ensure that all governmental entities holding properties along the river are aware of the Ouachita rock pocketbook's status, recovery efforts being made, entity responsibilities to protect the species, and opportunities to assist in its recovery. Efforts should be made to ensure that governmental entities incorporate consideration for *A. wheeleri* into their respective management plans to the greatest extent possible.

1.253 Ensure private landowner notification. Most lands within the Kiamichi River basin are privately owned. Efforts should be made to ensure that private owners (at least those owning lands that are most significant to the Ouachita rock pocketbook) are aware of the species' status, need for protection of the species and its habitat, recovery efforts being made, and the role of private landowners in species protection and recovery.

1.254 Manage response to identified threats. Site-specific threats to the Kiamichi River population will continue to be identified through a variety of avenues, including by responsible parties, by other interested parties, by monitoring programs (Task 1.3), by new research studies, and by other means. Appropriate responses to such threats, including the involvement of pertinent authorities, will be largely determined by the nature of specific threats, as well as their potential significance. Information, program commitments, and administrative relationships should be developed that facilitate response to individual threats, including objective assessments of basis and magnitude, determination of proper jurisdiction, notification of appropriate parties, adequate investigation and treatment, and follow-up.

1.255 Develop protection approaches for specific areas. This task will add to the specific public and private areas protected along the Kiamichi River under Tasks 1.1, 1.23, and 1.254. Options for protection by various parties will be explored, including cooperative agreements; technical and financial assistance; easement or fee title purchase, transfer, or donation; leases; regulation; enrollment in ONHI's Natural Areas Registry Program; identification of specific river reaches as essential habitat; and any need to reconsider critical habitat designation for the species. A model easement conveyance should be drafted incorporating specific rights needed to protect the Ouachita rock pocketbook. The FWS would work with willing property owners to convey landholdings and water rights into public ownership if this would benefit species protection. Prior to development of all elements needed for a strategic protection plan (Task 1.256), recovery participants will pursue protection of specific areas using a professional judgement of resource needs and opportunities.

1.256 Integrate initial protections into a systematic habitat protection plan. Specific habitat protection efforts would be most effectively pursued and tracked within a systematic protection plan. Under this task such a plan would be prepared, including development of a database containing information referenced in Tasks 1.251-1.255, as well as information on known locations, quality, and quantity of mussel habitat. The plan would provide a means of integrating pertinent information and systematically identifying protection priorities based on criteria such as aquatic targets (Higgins *et al.* 1999), other location-specific resource values, threat characteristics, landowner interest, and alternative management strategies (Saunders *et al.* 2002). As part of this task, recovery participants also will determine how each will use the plan. Actual selection of protection projects may deviate at times from the plan according to specific participant interests, funding levels and sources, and other considerations.

1.3 Institute a monitoring program to ensure continued viability of the Kiamichi River population. A comprehensive trend monitoring program should be developed and implemented at selected sites in the Kiamichi River basin to track population trends, habitat quality and quantity, and threats; to evaluate recovery efforts; and to ensure the population does not decline nor habitat degrade from preventable impacts. The monitoring program must include assessments performed specifically for these purposes, but also may make use of data collected for other purposes (e.g., state water quality assessment monitoring, point source compliance monitoring). Design of the monitoring program (including specific stations, timing, parameters, and methodologies) should consider preceding studies (as evaluating particular study designs and establishing records of potential comparative value), but also should have benefit of a 3-year developmental period during which an expanded suite of parameters is evaluated. Long-term monitoring would incorporate the best, low-impact indicators of the most important conditions. Without periodic monitoring, this species could become extinct.

1.31 Develop and implement monitoring of the Kiamichi River population and its habitat. Parameters that reflect key aspects of biological condition should be monitored at selected sites. Monitored parameters should include number of Ouachita rock pocketbooks present, individual shell dimensions and ages, plus numbers and shell lengths of associated mussel species. Ouachita rock pocketbooks found should be marked (using a noninjurious method) and recaptures recorded. Biological and habitat monitoring must be performed by knowledgeable biologists who can readily identify the species, obtain the necessary data, and carefully return the mussels alive to their habitats with a minimum of disturbance. Biological monitoring should occur at not more than 3-year intervals at any one locality. Initially, habitat monitoring should at least include water depth, velocity, temperature, dissolved oxygen, ammonia, nitrates, phosphates, pH, specific conductance, turbidity, suspended sediments, substrate composition, aquatic vegetation, canopy vegetation, suitable habitat available, adjacent land use, upstream land use, plus riparian thickness and health.

1.32 Develop and implement monitoring of current and potential threats to the Kiamichi River population. Parameters indicative of active or potential threats to the Ouachita rock pocketbook should be monitored, including water discharge (flow) modifications, channel modifications, point source and nonpoint source contributions, land use, and contamination of the river environment. Threat monitoring should collect information from a variety of sources, including broad assessments (e.g., basinwide aerial photography, satellite imagery), more specific appraisals (e.g., habitat monitoring, point source compliance data, records of agricultural chemical applications, inventories of permitted gravel mining operations), and investigations of specific activities (e.g., citizen reports, applications for Section 404 permits).

2. Determine viability of populations outside the Kiamichi River system. A relatively complete knowledge of the Ouachita rock pocketbook's current distribution (as can be determined in the short-term) is essential to ensure against further decline in the species' status and provide for the soundest possible conservation and recovery efforts. Live *A. wheeleri* individuals were found in the lower Little River, Arkansas, in 1987 (Clarke 1987) and in Oklahoma in 1994 (Vaughn *et al.* 1995). Empty Ouachita rock pocketbook shells were collected over a longer section of the Little River, Oklahoma, as recent as 1991-1994 (C.M. Mather, pers. comm. 1993, Vaughn 1994, Vaughn *et al.* 1995). *A. wheeleri* has been collected over a considerable portion of the Ouachita River, Arkansas, and the species' continued existence in the river was verified from a single live individual encountered in 1995 (Posey *et al.* 1996). Empty Ouachita rock pocketbook shells were collected from Pine and Sanders creeks, two Red River tributaries in Texas, in 1992 and 1993 (C.M. Mather, pers. comm. 1993, Howells *et al.* 1996, 1997). Selected sites in those streams, and possibly others, should be surveyed further to determine the presence or absence of living *A. wheeleri*. If present, determinations should be made of whether or not each population found is viable and the extent of existing or needed relationships with other populations (Vaughn 1993). General habitat quality and quantity and vulnerability to threats should be assessed as a part of each survey. The surveys must be performed by knowledgeable biologists who can readily identify the species, obtain the necessary data, and carefully return the mussels alive to their habitats with minimum disturbance.

2.1 Conduct a survey of the Little River in Arkansas and Oklahoma for existing populations. A small population is believed to persist within portions of an approximately 69-mi section of the Little River between Wright City, Oklahoma, and the river's confluence with the Rolling Fork River in Arkansas. A survey of the Little River in 1987 found a small number of live Ouachita rock pocketbook specimens, all in Arkansas between the state line and the river's confluence with the Rolling Fork River (Clarke 1987). Later (1994) surveys of the Little River found live *A. wheeleri* in the short section in Oklahoma between U.S. Highway 70 and the river's confluence with the Mountain Fork River, but empty shells also were found at additional points, upstream and downstream, during 1991-1994 (C.M. Mather, pers. comm. 1993; Vaughn 1994, Vaughn *et al.* 1995). Most of the shells found in Oklahoma were relatively weathered; however, two sets of valves (shell halves) were in good condition and appeared to represent relatively recent Ouachita rock pocketbook deaths. It is usually difficult to judge how long specimens found in such cases have been dead, and no estimates are given for the shells found in the Little River. The species persists in the Little River in Oklahoma and possibly Arkansas; however, the total distance currently inhabited remains uncertain. Habitat in the Little River has been impacted by reservoir construction and degraded water quality, and further water quality degradation is an identified threat. Surveys for *A. wheeleri* should be continued on that stream at selected, inadequately surveyed sites, using scuba when mussels are found and the water depth is more than 100 cm. Habitat conditions and apparent threats should be assessed concurrently.

2.2 Conduct surveys of the Ouachita River in Arkansas for existing populations. This species seems to persist within the Ouachita River in Arkansas. Although most recent surveys have found no live Ouachita rock pocketbooks and some researchers have reported degraded habitat conditions, one live individual was documented recently and portions of the river continue to support diverse mussel assemblages (Posey *et al.* 1996). Habitat in the Ouachita River has been impacted by construction of impoundments, channelization, and water quality degradation, and further channelization and impoundment in the basin constitute future threats. However, continued search of the Ouachita River is warranted, including efforts to locate and examine large mussel beds in mainstem shoals, side channels, and backwaters, between Lake Catherine and Lake Jack Lee, Arkansas. The use of scuba is recommended to search mussel beds where water depth is more than 100 cm. Information on habitat conditions and threats should be updated during these surveys.

2.3 Conduct surveys of other Red River tributaries in Oklahoma, Texas, and Arkansas for existing populations. Single empty *A. wheeleri* shells were collected in 1992 from Pine Creek and in 1993 from Sanders Creek, both in Lamar County, Texas (C.M. Mather, pers. comm. 1993, Howells *et al.* 1996, 1997). Although it is difficult to judge precisely how long such specimens have been dead, the Texas shells appeared to represent recently expired Ouachita rock pocketbooks. The species may inhabit these creeks or other tributaries of the Red River beyond those from which it is known historically. Factors that might have impacted habitat for the mussel in those tributaries or might constitute future threats have not yet been assessed. Certain Red River tributaries near the Kiamichi River and Little River may have offered suitable habitat for the Ouachita rock pocketbook. Inadequately surveyed streams should be examined for *A. wheeleri* at selected sites, using scuba where water depth exceeds 100 cm. Habitat conditions and threats should be assessed concurrently.

2.4 Determine if any populations found in Tasks 2.1, 2.2, or 2.3 are viable. When Ouachita rock pocketbooks are encountered in the previously-described surveys, all individuals should be measured and their ages estimated in order to assess recruitment, growth, and longevity trends. Estimates of *A. wheeleri* density and available habitat are desirable to provide for future population trend determinations. Follow-up monitoring at not more than 3-year intervals to establish trends over a minimum of a 15-year period will be used to determine population viability. Relationships with other populations or sub-populations of *A. wheeleri* in connected drainages should be evaluated.

3. Preserve any additional population of the Ouachita rock pocketbook found in Tasks 2.1, 2.2, and 2.3, its associated habitat, and restore degraded habitat in the Ouachita River, Little River, and other areas producing evidence of extirpated or depressed populations of the Ouachita rock pocketbook.

3.1 Use existing statutes to restore and protect habitat for the Ouachita rock pocketbook. The Endangered Species Act, the Fish and Wildlife Coordination Act, and other environmental statutes provide some means to restore and protect habitats and impacted populations of this species. The Endangered Species Act is most easily applied to areas where the species still exists (such as in a portion of the Little River in Oklahoma), but other regulatory measures exist that can be used to restore and protect areas that are not currently suitable for the species. This task will consist of efforts to protect *A. wheeleri* populations and restore degraded habitat outside of the Kiamichi River, using actions similar to those performed under Task 1.1. Federal agencies must ensure activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered species such as the Ouachita rock pocketbook. Consultations may involve, as applicants or non-federal representatives, various representatives of the states of Arkansas, Oklahoma, and Texas, local authorities, and private parties. This task also will involve actions under Sections 9 and 10 of the Endangered Species Act.

All waters in which *A. wheeleri* may occur are covered by existing requirements that provide for basic water quality protection. Water quality protection is administered primarily by the states, although agency responsibility for program elements and the activities that affect water quality varies from state to state. Although existing water quality standards for degraded habitats of the Ouachita rock pocketbook are not based on specific needs of the species, their enforcement can maintain water quality that is generally supportive of aquatic life. Existing water quality standards and associated water quality requirements should be strictly enforced for those areas containing *A. wheeleri*. Information on all potential violations of these standards or requirements should be immediately reported to appropriate officials, investigated, and corrected.

Arkansas Game and Fish Commission (AGFC) regulations make it illegal to import, transport, sell, purchase, take or possess any endangered species of wildlife or parts of such wildlife. ODWC statutes prohibit attempts to hunt, chase, harass, capture, shoot, wound, kill, take, or trap endangered species such as the Ouachita rock pocketbook. ODWC statutes and regulations governing commercial mussel harvest also prohibit the collection or sale of threatened or endangered species of mussels. Texas Parks and Wildlife Department (TPWD) statutes and regulations make it illegal to possess, take, or transport endangered fish or wildlife for zoological gardens, scientific purposes, or commercial propagation without special permit. AGFC and TPWD designate certain waters inhabited by the Ouachita rock pocketbook as mussel sanctuaries. All of these existing restrictions that relate to *A. wheeleri* should be strictly enforced.

3.2 Provide additional measures needed to achieve restoration and protection of degraded habitats and populations. Restoration and protection of degraded habitats and populations of the Ouachita rock pocketbook will require additional measures that are not fully provided for by existing authorizations and requirements. For some conservation measures, proper authorization does not yet exist. In other cases, limited authorizations may exist, but their use to recover *A. wheeleri* may not be adequate. Such use may be more discretionary or less specifically prescribed, requiring creative application and implementation. While requirements of the Endangered Species Act provide for the recovery of the Ouachita rock pocketbook, other programs and measures may provide means of recovering the species that are preferable to alternative regulatory protection (e.g., eventual development of a habitat conservation plan).

3.21 Deauthorize unimplemented channel modifications of the Ouachita River. Early water resource planning for the Ouachita River basin led to the 1950 authorization of many development projects, most of which were eventually constructed. A number of low priority projects were not completed, including 11 cutoffs and 14 bend widenings on the Ouachita River, and Murfreesboro Lake on the Muddy Fork of the Little Missouri River. Those projects would cause additional modification of the natural characteristics of the Ouachita River, and could be contrary to the interest of restoring suitable habitat for the Ouachita rock pocketbook in that river system. The projects mentioned are presently inactive. Their deauthorization could support efforts to recover the Ouachita rock pocketbook. Authority to deauthorize such projects lies with the U.S. Congress.

3.22 Develop and implement cooperative projects to increase restoration and protection of degraded habitat and populations of the Ouachita rock pocketbook. Section 7(a)(1) of the Endangered Species Act authorizes federal agencies to carry out programs to conserve listed species. The FWS will assist other federal agencies in developing and carrying out such programs, as well as undertake its own programs, to conserve *A. wheeleri*. Section 6 of the Endangered Species Act provides for the FWS to grant funds to states for management actions aiding the protection and recovery of listed species. Section 6 funds should continue to be made available to the states of Arkansas, Oklahoma, and Texas for Ouachita rock pocketbook recovery. Other programs (e.g., FWS Partners for Fish and Wildlife Program, Private Stewardship Grants Program, and Landowner Incentive Program; EPA Nonpoint Source Program; and USDA Stewardship Incentive Program, Water Quality Incentive Program, Conservation Reserve Program, and Wetlands Reserve Program) provide additional means of developing cooperative projects that could be used to restore this species' habitat, while retaining lands in private ownership. These programs differ somewhat in objectives and practices they support; consequently, development of individual projects to benefit *A. wheeleri* will require consideration of program differences as well as environmental objectives. Participants in cooperative programs may include a broad variety of public and private parties.

3.23 Upgrade protection provided to degraded areas of habitat for the Ouachita rock pocketbook through water quality standards and water quality management programs. In addition to enforcing existing water quality requirements, it is important to seek improvements where those requirements offer incomplete protection to the Ouachita rock pocketbook and its habitat. A special beneficial use category should be defined for waters containing *A. wheeleri* habitat, and criteria developed that more accurately reflect the species' environmental needs. Once determined, such category and criteria should be included in Arkansas, Oklahoma, and Texas water quality standards and applied to waters that historically or recently contained the species. Special high quality water designations also should be applied to such waters to help protect natural water quality levels. Other elements of the states' water quality management programs also should be upgraded to increase restoration and protection (e.g., accelerated treatment of nonpoint pollution sources).

3.3 Institute a monitoring program to verify preservation of any additional populations found, augmentation of initially depressed populations, and restoration of initially degraded habitat. A comprehensive trend monitoring program should be developed and implemented at selected sites of the Ouachita River, Little River, and other appropriate waters to track population trends, habitat quality and quantity, and threats; to evaluate recovery efforts; and to ensure against further population declines and habitat degradation from preventable impacts. The monitoring program must include assessments performed specifically for these purposes, but also may use data collected for other purposes. Design of the monitoring program should consider preceding surveys and studies, and include the features specified under Tasks 1.31 and 1.32 for the Kiamichi River. The monitoring program also should have benefit of a 3-year developmental period during which an expanded suite of parameters is evaluated. Long-term monitoring would incorporate the best, low-impact indicators of the most important conditions. Without periodic monitoring, important populations of this species could become extirpated due to a lack of current information on adverse conditions and the populations' status.

4. Conduct reproductive studies of the Ouachita rock pocketbook. For this species, survival cannot be ensured nor recovery accomplished until details of reproduction are known, including the natural fish host(s) and timing of reproduction. Techniques that minimize sacrifice of individuals from natural populations must be used, to the extent possible. (Examples include nonlethal examination of individuals (with/without anesthetization), salvage and examination of individuals killed incidentally; use of DNA fingerprinting to identify glochidia and successful infestations on hosts; nonlethal methods of sexing individuals from small, excised tissue samples; production of an experimental, cultured population; and development of such techniques using more common surrogate species). Once determined, essential aspects of reproduction must be protected as a part of management for the species.

4.1 Determine and protect the fish host(s) and its(their) required habitat. Protection of the fish host(s) and its/their required habitat is essential to the survival and recovery of the Ouachita rock pocketbook. Identification of the one or more fish species that serve as host for *A.*

wheeleri glochidia must be performed before specific host protection can be pursued. Fish species that serve as hosts for closely related mussels and fish species that share the same natural distribution and habitat preference as the Ouachita rock pocketbook should be selected as likely candidates. Following selection of likely host species, it will be necessary to artificially infest them with glochidia and determine if the glochidia encyst and develop into juvenile mussels. Successful replicate experiments should be achieved to ensure that host identification is accurate. Once the fish host(s) is identified, its habitat requirements must be determined. Then, host species' habitat requirements and access to populations of the mussel must be integrated into habitat management programs to ensure continued *A. wheeleri* survival.

4.2 <u>Determine sex ratio among Ouachita rock pocketbooks, age at which they achieve sexual maturity, number of years they continue gamete production, and seasonal timing of reproductive events</u>. The sex ratio of Ouachita rock pocketbooks, normal ages during which the species is capable of reproduction and seasonal timing of reproductive events (e.g., fertilization, gravidity, glochidial release) are critical factors in assessing potential impacts to the species and its rate of recovery. Studies to determine these aspects will be performed under this task. To minimize impacts to extant populations, normal values for these parameters will initially be estimated from a small number of individuals, but will be refined over time as techniques improve to study reproduction without sacrificing individuals from wild populations.

5. <u>Conduct further studies of habitat requirements and preferences of the Ouachita rock pocketbook</u>. Detailed studies of habitat used by this species have been performed for the Kiamichi River population, but should be supplemented by study of other populations and conditions. Additional study also is needed of habitat requirements for juvenile forms and sensitivities of all life stages. These studies are necessary to provide effective management of the species' habitat. The studies must use techniques that minimize sacrifice of individuals from wild (natural) populations. (Examples include modeling of natural conditions; extended study of individuals *in situ;* production of an experimental, cultured population; study of tissue glycogen levels, shell closing/gaping, filtration rates, growth, density, population structure, and other evident, repeatable indicators of disturbance; and study of sensitivities in more common associated species). Once determined, additional habitat requirements must be integrated into efforts to recover the species.

5.1 <u>Determine habitat use patterns of Ouachita rock pocketbook populations outside of the Kiamichi River</u>. Detailed studies of habitat occupied by this species have been performed for the Kiamichi River population. Although those studies establish a basic understanding of habitat utilization, the various waterbodies from which the species is known differ enough in environmental characteristics to warrant study of habitat use by populations outside of the Kiamichi River. Results of such studies will be used to refine management actions to restore and protect suitable habitat for *A. wheeleri* throughout its natural range.

5.2 <u>Determine habitat requirements and early life history characteristics of juvenile Ouachita rock pocketbook mussels</u>. Within individual mussel species, juveniles can be adapted to different habitats than adults. Moreover, adult mussels are frequently capable of withstanding environmental disturbances that result in the death of juveniles. Additional study is needed to define the habitat requirements and sensitivities of juvenile Ouachita rock pocketbooks. Once determined, the habitat requirements of juveniles must be protected to ensure continued survival of *A. wheeleri*.

5.3 Determine environmental sensitivities of the Ouachita rock pocketbook. The Ouachita rock pocketbook appears to be sensitive to habitat degradation. Habitat studies to date have partially characterized the predominant nature of sites inhabited by members of the largest remaining *A. wheeleri*. Knowledge is still incomplete regarding the full range and dynamics of conditions in suitable habitats, and critical differences between suitable and unsuitable habitats. This is particularly true of high-flow conditions and human-induced modifications. For example, the Ouachita rock pocketbook may continue to inhabit many localities downstream from Sardis Reservoir, but recent conditions there may not represent optimum ones for growth and reproduction (Vaughn *et al.* 1993, Vaughn and Pyron 1995). Additional study is needed of physical, chemical, and biological conditions (including macrohabitat variables, additional flow variables, and food items) in habitats throughout the species' range, of further conditions that would accompany conceivable developments, and responses of *A. wheeleri* to each of these factors. Results of such study will enhance the ability to restore and protect suitable habitat for the Ouachita rock pocketbook. Unknown habitat requirements and sensitivities (i.e., tolerances) are likely critical to survival and recovery of *A. wheeleri*.

6. Evaluate genetic and population characteristics of existing populations of the Ouachita rock pocketbook. Timely reestablishment of Ouachita rock pocketbooks in restored habitats is likely to require artificial translocation of individuals from existing populations. If multiple populations still exist, it is important to know the genetic composition of each population before using them as stock to reestablish or augment populations. In addition, long-term management of the species will require an understanding of each population's characteristics and factors that affect its viability. Such studies should develop and use techniques that minimize sacrifice of individuals from natural populations. (Examples include salvage and analysis of individuals killed incidentally; nonlethal analysis of individuals using small, excised tissue samples; production of an experimental, cultured population; and development of such techniques using more common surrogate species).

6.1 Determine comparative genetic composition of extant populations. This task will analyze the genetic composition and variability of the Kiamichi River population, as well as any other population(s) found. In addition, studies will evaluate the genetic similarity of different populations, the value of different populations as sources from which to reestablish or augment populations, and the potential for unaided genetic exchange among populations.

6.2 Determine factors that limit population growth, and refine characterization of population viability for the species. This task will evaluate results from distributional surveys; habitat, reproductive, and genetic studies (e.g., population size, density, longevity, recruitment, sex ratio, reproductive timing, fecundity, glochidial host(s), habitat specificity, and habitat availability); and assess other factors indicated to be important (e.g., geographic constraints, physiological condition of mussels, causes of mortality). Factors that limit population growth, as well as those most easily treated to enhance population growth, will be determined. Investigations will be designed to develop improved characterizations of population viability for the species, and determine the optimum number, arrangement, and interaction of populations. These studies are needed to refine recovery objectives and criteria as well as specific management actions, and may indicate a need to perform additional actions.

7. Establish two viable populations outside the Kiamichi River system, if these populations do not already exist, and protect. Reestablishment of the Ouachita rock pocketbook outside of the Kiamichi River system would reduce susceptibility of the species to catastrophic threats (such as a large spill of toxic material). Reestablishment in areas from which the species has been extirpated also would return the species to a broader ecological setting for its continued evolution and adaptation. Artificial barriers or other factors may prevent natural repopulation of areas in which suitable habitat conditions are restored. In other cases, small populations may exist but contain insufficient numbers or densities of individuals to achieve long-term viability. *A. wheeleri* individuals should be relocated from the healthy Kiamichi River population (or other justifiable sources) to other sites within the species' natural range, as necessary to meet recovery objectives. Transplants will be accomplished as capabilities and suitable site conditions are obtained, unless the existence of other viable populations, or populations approaching viability, has been documented within the natural range. These tasks should use techniques that minimize sacrifice of individuals from natural populations. (Examples include production of an experimental, cultured population; and development of techniques using more common surrogate species).

7.1 Develop technique(s) for successfully reestablishing or augmenting populations by transplantation. Techniques for transplanting mussels are incompletely developed, and attempts to relocate individuals of sensitive species have often produced significant mortalities. Therefore, this task will develop at least one effective technique for transplanting Ouachita rock pocketbooks. Use of individuals from the Kiamichi River population should be carefully controlled to maintain the health of that population. If accomplished, captive mussel propagation could provide a preferred source for stocking efforts to enhance recovery. Following technique development, the feasibility of using it on a scale sufficient to reestablish populations or population viability should be evaluated.

7.2 Select stream sites for introduction. Transplantation efforts should be directed toward sites that offer suitable conditions and where future protection can be provided. Streams and specific stream sites for introduction will be selected based on need of existing populations to be supplemented, location within the species' natural range, geographic relationship to other populations, plus present and expected future habitat and water quality. The occurrence of small populations or of fresh empty shells of the Ouachita rock pocketbook will be used as one indication that minimum requirements for the survival of the species may be present. The process of identifying candidate sites will involve a number of federal and state agencies, local governments, and other interested parties.

7.3 Translocate Ouachita rock pocketbooks into two populations outside of the Kiamichi River system. The species should be translocated into selected sites, contingent upon conditions still indicating that such introduction is needed and appropriate. Donor populations will be selected using information on population levels and genetic characteristics.

7.4 Protect transplanted populations and evaluate success. Restoration and protective measures should be continued for the areas into which Ouachita rock pocketbooks are transplanted (in all or most cases, these measures will have begun under Task 3). The success of all translocations should be monitored and evaluated, and used to influence decisions on subsequent attempts.

8. Develop an outreach program. Recovery of the species will require support and assistance from governmental entities, commercial interests, agricultural interests, conservation interests, and private citizens. For the Kiamichi River basin and other places where the Ouachita rock pocketbook may exist, a program should be developed and implemented to communicate with interested parties. Information should be produced describing the plight of this endangered species, its ecological needs and their relationship to human activities, its protection and recovery under the Endangered Species Act, the variety of avenues available for benefitting the species and its habitat, the importance of maintaining genetic diversity, the value of mussels in ecosystem functioning and as indicators of environmental health, and the mussel's representation of the region's unique natural heritage. Public and private parties will be encouraged to assist in implementing the outreach program.

9. Enhance management by increased technical knowledge, improved coordination of monitoring/research and management, and attention to special management needs. Continued improvements will be sought in programs that enhance survival and recovery of the Ouachita rock pocketbook. For example, prompt and thorough distribution of monitoring and research findings to management agencies can broaden awareness of studied conditions and stimulate informed responses. Likewise, for scientists involved in monitoring, notification of proposed or known activities in monitored areas can support more complete investigations and interpretations of monitoring results. Additional research will be necessary to address new or long-term information needs. Management planning and actions will continue to evolve as progress occurs in recovering *A. wheeleri*.

9.1 Improve coordination of monitoring and research activities with management activities. This task will provide for prompt and thorough distribution of relevant monitoring and research findings to management agencies and other interested parties. It also will provide for scientists involved in monitoring and field research to be notified of inventoried activities and proposed developments. Appropriate access to information will be provided where full dissemination is not desirable.

9.2 Refine ability to correlate basin conditions and human activities with habitat conditions. Determining the relationships between various basin conditions and instream habitat conditions will enhance Ouachita rock pocketbook recovery. This task will clarify such relationships, by evaluating information from other tasks (e.g., as exchanged in Task 9.1) and conducting additional investigations, as needed.

9.3 Refine ability to identify and implement appropriate treatments and responses for identified threats/sources of degradation. Species recovery would benefit by ensuring that effective treatment measures are prescribed expeditiously to counteract unavoidable and accidental disturbances, and that capabilities exist for their implementation. This task will promote familiarity with effective treatments for a variety of likely environmental disturbances, and also will promote advance provision for treatment implementation.

9.4 Develop and implement an expanded habitat restoration-protection plan for all areas inhabited by the Ouachita rock pocketbook. Experience developing Task 1.25, information obtained from other tasks, and progress in habitat restoration will allow expansion of strategic planning to all areas of important habitat for *A. wheeleri*. Subtasks essentially similar to those performed for the Kiamichi River will be performed, including inventory of property ownerships and water rights, landowner notification, managed response to identified threats, protection of specific properties, and integration of initial protections into a systematic protection plan.

9.5 Develop enhanced notification and consultation procedures. FWS assistance in consultations can be facilitated by having accurate information on current and proposed activities provided as early as possible. Federal and state agencies having management responsibility within the range of the Ouachita rock pocketbook should keep the FWS informed of activities potentially affecting the species, from the time such activities are first given serious consideration. Based on agency contacts and other sources, the FWS should compile a list of ongoing, authorized, or proposed projects and activities. The FWS also should improve its capabilities to evaluate projects for potential threats to *A. wheeleri*, considering direct, indirect, and cumulative effects. Upon evaluation, the agencies involved should be informed of the nature and extent of potential threat to the Ouachita rock pocketbook posed by their projects or activities. Early efforts should be made to ensure that threats are avoided.

9.6 Develop strategy and capabilities for preservation of the Ouachita rock pocketbook against potentially drastic threats, such as future invasion of native habitats by the zebra mussel, *Dreissena polymorpha*. Since its introduction to the U.S. in 1986, the zebra mussel has spread up the Arkansas River system into Oklahoma, but has not yet invaded the Red River system where *A. wheeleri* occurs. Zebra mussels are prolific and tolerant to a variety of environmental conditions. They also attach themselves to a variety of underwater surfaces, including mussel shells. Where zebra mussels have become established, native mussels often decline dramatically. Zebra mussels may soon reach waters inhabited historically by the Ouachita rock pocketbook. If zebra mussels become established, *A. wheeleri* and other native mussels may be adversely impacted. Possible effects of the zebra mussel on the Ouachita rock pocketbook should be predicted, based on effects seen on other native species, and measures taken to counteract such effects. In addition to the threat of the zebra mussel, *A. wheeleri* remains vulnerable to other catastrophic threats, especially so long as only one healthy population exists. Although artificial propogation is not a primary recovery strategy, development of captive propagation facilities and techniques and cryopreservation of reproductive products are contingency measures that should be taken in response to the possibility of a catastrophic event.

9.61 Develop necessary resources for captive propagation of the Ouachita rock pocketbook. Preceding tasks (e.g., 4-7) may develop procedures for propagation of *A. wheeleri* but in most cases will establish only small experimental populations. This task would develop the necessary facilities and culture techniques to maintain a captive, reproducing population. Such measures are necessary to provide animals for reintroduction in the event of disastrous losses or to supplement depleted populations.

9.62 Perform cryogenic preservation for the Ouachita rock pocketbook. Cryogenic preservation could maintain genetic material from all extant populations of the species. If a population were lost to a catastrophic event, cryogenic preservation could allow for eventual reestablishment using the genetic material preserved from that population.

9.7 Determine and provide continued protection and restoration needs for delisting of the Ouachita rock pocketbook. The tentative delisting criterion requires establishment and permanent protection of viable populations in four stream systems historically inhabited by *A. wheeleri*. Information does not exist indicating that the long-term survival of the Ouachita rock pocketbook could be ensured by restoration within a smaller area, or would require a greater area. The delisting criterion and the management actions needed to achieve recovery will evolve as additional information is obtained. If the species is to be removed from the Federal List of Endangered and Threatened Animals and Plants and the protection afforded by the Endangered Species Act, then alternative programs must be in place that ensure adequate protection of habitat and populations in perpetuity.

9.71 Establish and permanently protect viable populations in all four stream systems historically inhabited by the species, if those populations do not already exist. Ouachita rock pocketbooks should be relocated from suitable sources to other sites within its natural range, if necessary to meet the recovery objective. Transplants should continue until populations are found to be successfully reestablished. Measures must be put in place to provide permanent protection to reestablished populations and their habitat, and must be effective enough to restore the populations to viable levels.

9.72 Refine delisting criterion, and provide any corresponding measures needed to support delisting of the Ouachita rock pocketbook. Knowledge obtained from completion of the preceding tasks will allow an improved assessment of the species' status and natural characteristics, including population size and density, habitat suitability, life history aspects, and those factors that limit the species' distribution and abundance. From that knowledge, recovery criteria can be defined that more specifically and comprehensively reflect the species' needs and sensitivities. The refined criteria will indicate any additional measures needed to achieve full recovery of *A. wheeleri.*

C. Recovery Actions Specifically Addressing Endangered Species Act Listing Factors

When the Ouachita rock pocketbook was listed as an endangered species under the Endangered Species Act of 1973 (Act), four of the five factors necessary to list a species under the Act threatened the species' continued survival. The Ouachita rock pocketbook recovery plan addresses these threats by recommending a variety of recovery actions that, if implemented, will lead to the species' reclassification and delisting (Table 3).

TABLE 3. RECOVERY ACTIONS AND RELATED LISTING FACTORS FOR *ARKANSIA WHEELERI*

Listing Factor	Specific Threat to Ouachita Rock Pocketbook	Related Recovery Actions[1]
(A) the present or threatened destruction, modification, or curtailment of its habitat or range;	impoundment, channelization, flow modification, water quality degradation, stream channel disturbance	1.1, 1.2, 1.21, 1.22, 1.23, 1.24, 1.25, 1.3, 1.31, 1.32, 2.1, 2.2, 2.3, 3.1, 3.2, 3.21, 3.22, 3.23, 3.3, 4.1, 5.1, 5.2, 5.3, 7.2, 9.2, 9.4.
(B) overutilization for commercial, recreational, scientific, or educational purposes;	commercial harvest, scientific and/or recreational harvest	*Other mechanisms address this factor, such as the designation by Texas Parks and Wildlife, Oklahoma Department of Wildlife Conservation, and Arkansas Game and Fish Commission of several rivers as mussel sanctuaries (see pgs. 30 and 31).*
(C) disease or predation;	---	*Not considered a significant threat.*
(D) the inadequacy of existing regulatory mechanisms;	inadequate habitat protection and/or protection of Ouachita rock pocketbook populations	1.2, 1.24, 3.23, 7.4, 9.7.
(E) other natural or manmade factors affecting its continued existence.	exotic species invasion (Asian clam, zebra mussel)	9.6.

[1]Recovery Actions are detailed in the previous section, Narrative Outline for Recovery Actions.

D. Literature Cited

Ahlstedt, S.A. and J.D. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell rivers, Tennessee and Virginia. pp. 72-97 *In:* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo (eds.) Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. vi + 293 p.

Aldridge, D.W., B.S. Payne, and A.C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution (Series B) 45(1):17-28.

Allan, J.D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, London, UK. xii + 388 p.

Allan, J.D. and A.S. Flecker. 1993. Biodiversity conservation in running waters. BioScience 43(1):32-43.

Arkansas Department of Pollution Control and Ecology. 1992. Water quality inventory report, 1992. ADPCE, Little Rock, AR. vi + 80 p. + appendices.

Bain, M.B., J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69(2):382-392.

Baker, F.C. 1928. The fresh water Mollusca of Wisconsin, Part 2: Pelecypoda. Bull. Univ. Wisconsin 1527 (1301):vi + 495 p. + 77 pl.

Bates, J.M. 1962. The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River. Amer. Midl. Nat. 68(1):232-236.

Bates, J.M. and S.D. Dennis. 1978. The mussel fauna of the Clinch River, Tennessee and Virginia. Sterkiana Nos. 69-70:3-23.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Ann. Rev. Ecology & Systematics 8:255-283.

Beacham, W., F.V. Castronova, and S. Sessine (eds.) 2001. Ouachita Rock-pocketbook. pp. 1182-1183 *In:* Beacham's guide to the endangered species of North America. Vol. 2. Gale Group, Inc., Farmington Hills, MI. viii + 677-1356.

Belanger, T.V., C.G. Annis Jr., and D.D. VanEpps. 1990. Growth rates of the Asiatic clam, *Corbicula fluminea,* in the upper and middle St. Johns River, Florida. Nautilus 104(1):4-9.

Bell, R.W., T.C. Brown, J.A. Clingenpeel, B.G. Crump, D.A. Freiwald, J.L. Harris, P.D. Hays, W.E. Heilman, J. Hill, L. Hlass, T.W. Holland, J.C. Nichols, H.W. Robison, R.W. Standage, K. Tinkle, M.L. Warren Jr., and L. Weeks. 1999. Ozark-Ouachita Highlands Assessment: aquatic conditions.

Report 3 of 5. USDA Forest Service, Southern Research Station, Asheville, NC. Gen. Tech. Rept. SRS-33. xxiv + 318 p.

Blalock, H. and J.B. Sickel. 1996. Changes in the mussel (Bivalvia: Unionidae) fauna within the Kentucky portion of Lake Barkley since impoundment of the lower Cumberland River. Amer. Malacological Bull. 13(1-2):111-116.

Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. Amer. Zool. 33(6):599-609.

Bogan, A.E. and C.M. Bogan. 1983. Molluscan remains from the Bug Hill site (34PU116), Pushmataha County, Oklahoma. pp. 233-240 *In:* J.H. Altschul (ed.) Bug Hill: excavation of a multicomponent midden mound in the Jackfork Valley, southeast Oklahoma. New World Research Inc., Report of Investigation No. 81-1. prepared for U.S. Army Corps of Engineers, Tulsa District. xvi + 425 p.

Branson, B.A. 1983. The mussels (Unionacea: Bivalvia) of Oklahoma - Part 2: The Unioninae, Pleurobemini and Anodontini. Proc. Oklahoma Acad. Sci. 63:49-59.

Brim Box, J. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. J. N. Amer. Benthol. Soc. 18(1):99-117.

Britton, J.C. and C.E. Murphy. 1977. New records and ecological notes for *Corbicula manilensis* in Texas. Nautilus 91(1):20-23.

Brooks, S.T. and B.W. Brooks. 1931. List of types of Pelecypoda in the Carnegie Museum on January 1, 1931. Annals Carnegie Museum 20:171-177.

Brown, K.M. and J.P. Curole. 1997. Longitudinal changes in the mussels of the Amite River: endangered species, effects of gravel mining, and shell morphology. pp. 236-246 *In:* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo (eds.) Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. vi + 293 p.

Burch, J.B. 1975. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America. Second edition. Malacological Publications, Hamburg, MI. xviii + 204 p.

Certain, D.L. and C.C. Vaughn. 1994. Landuse classification of the Little River and Ouachita River watersheds in Oklahoma and Arkansas. Oklahoma Natural Heritage Inventory, final report to the U.S. Fish & Wildlife Service, Tulsa, OK. Project No. 20181-2-5125. ii + 23 p.

Clark, C.F. 1976. The freshwater naiades of the lower end of the Wabash River, Mt. Carmel, Illinois, to the south. Sterkiana No. 61:1-14.

Clarke, A.H. 1981. The tribe Alasmidontini (Unionidae: Anodontinae), Part I: *Pegias, Alasmidonta*, and *Arcidens*. Smithsonian Contributions to Zoology, No. 326, Smithsonian Institution Press, Washington, D.C. iv + 101 p.

Clarke, A.H. 1987. Status survey of *Lampsilis streckeri* Frierson (1927) and *Arcidens wheeleri* (Ortmann & Walker, 1912). Ecosearch, Inc., final report to the U.S. Fish and Wildlife Service, Jackson, MS. Contract No. 14-16-0004-86-057. i(ii) + 24 p. + 66 p. appendix.

Clench, W.J. 1959. Mollusca. pp. 1117-1160 *In:* W.T. Edmondson (rev. ed.), H.B. Ward and G.C. Whipple (eds.) Fresh-water biology. Second edition. John Wiley & Sons, Inc., New York, NY. xxii + 1248 p.

Coker, R.E. 1914. Water-power development in relation to fishes and mussels of the Mississippi. U.S. Dept. of Commerce, Bur. Fish. Doc. No. 805, 28 p. + 6 pl.

Coker, R.E., A.F. Shira, H.W. Clark, and A.D. Howard. 1922. Natural history and propagation of freshwater mussels. Bull. U.S. Bur. Fish. 37:75-181.

Collier, M. R.H. Webb, and J.C. Schmidt. 1996. Dams and rivers: a primer on the downstream effects of dams. Circular 1126. U.S. Geological Survey, Tucson, AZ. vi (xiv) + 94 p.

Coon, T.G., J.W. Eckblad, and P.M. Trygstad. 1977. Relative abundance and growth of mussels (Mollusca: Eulamellibranchia) in pools 8, 9, and 10 of the Mississippi River. Freshwater Biology 7:279-285.

Death, R.G. and M.J. Winterbourne. 1995. Diversity patterns in stream benthic invertebrate communities: the influence of habitat stability. Ecology 76(5):1446-1460.

Dennis, S.D. 1981. Mussel fauna of the Powell River, Tennessee and Virginia. Sterkiana No. 71:1-7.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. Ph.D. Dissertation, Virginia Polytechnic Institute and State University. Blacksburg, VA. 171 p.

Di Maio, J. and L.D. Corkum. 1995. Relationship between the spatial distribution of freshwater mussels (Bivalvia: Unionidae) and the hydrological variability of rivers. Canadian J. Zool. 73(4):663-671.

Dimrock, R.V. Jr. and A.H. Wright. 1993. Sensitivity of juvenile freshwater mussels to hypoxic, thermal and acid stress. J. Elisha Mitchell Sci. Soc. 109:183-192.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1):29-42.

Fisher, S.G. and A. LaVoy 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. J. Fisheries Res. Board Canada 29:1472-1476.

Foster, R.B. and J.M. Bates. 1978. Use of freshwater mussels to monitor point source industrial discharges. Environ. Sci. Technol. 12(8):958-962.

Frierson, L.S. 1927. A classified and annotated check list of the North American naiades. Baylor Univ. Press, Waco, TX. 111 p.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). pp. 215-273 *In:* C.W. Hart, Jr., and S.L.H. Fuller (eds.) Pollution ecology of freshwater invertebrates. Academic Press, New York, NY. xvi + 389 p.

Gammon, J.R. and J.M. Reidy. 1981. The role of tributaries during an episode of low dissolved oxygen in the Wabash River, Indiana. pp. 396-407 *In:* L.A. Krumholz (ed.) The warmwater streams symposium. Proceedings of a symposium, 9-11 March 1980, Knoxville, TN. Southern Division, American Fisheries Society, Lawrence, KS. x + 422 p.

Gordon, M.E. and J.L. Harris. 1983. Distribution and status of fourteen species of freshwater mussels considered rare or endangered in Arkansas. Univ. of Arkansas report to the Arkansas Natural Heritage Commission, Little Rock, AR. Contract G6301. 35 p.

Gore, J.A., J.B. Layzer, and J. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream management and restoration. Regul. Rivers: Research & Mgmt. 17(4-5):527-542.

Greenwalt, L.A. 1974. Fish and Wildlife Service; snails, mussels and crustaceans; endangered species. Federal Register 39(202):37078-37079.

Haag, W.R. and M.L. Warren. 1998. The role of ecological factors and reproductive strategies in structuring freshwater mussel communities. Canadian J. Fisheries & Aquatic Sciences 55(2):297-306.

Hadley, R.F. and W.W. Emmett. 1998. Channel changes downstream from a dam. J. Amer. Water Resources Assoc. 34(3):629-637.

Hardison, B.S. and J.B. Layzer. 2001. Relations between complex hydraulics and the localized distribution of mussels in three regulated rivers. Regul. Rivers: Research & Mgmt. 17(1):77-84.

Harris, J.L. Survey of the freshwater mussels (Mollusca: Unionidae) of the Poteau River drainage in Arkansas. Final report to the USDA Forest Service, Ouachita National Forest, Hot Springs, AR. i + 23 p. + 79 p. appendix.

Harris, J.L. and M.E. Gordon. 1987. Distribution and status of rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Proc. Arkansas Acad. Sci. 41:49-56.

Harris, J.L. and M.E. Gordon. 1990. Arkansas mussels. Arkansas Game and Fish Commission. Little Rock, AR. i + 32 p.

Harris, J.L., P.J. Rust, A.C. Christian, W.R. Posey II, C.L. Davidson, and G.L. Harp. 1997. Revised status of rare and endangered Unionacea (Mollusca: Margaritiferidae, Unionidae) in Arkansas. J. Arkansas Acad. Sci. 51:66-89.

Hartfield, P.D. and D. Ebert. 1986. The mussels of southwest Mississippi streams. Amer. Malacological Bull. 4(1):2-23.

Havlik, M.E. and L.L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U.S. Dept. Interior, Fish and Wildlife Service, Resource Publication 164. Washington, D.C. ii + 20 p.

Heinricher, J.R. and J.B. Layzer. 1999. Reproduction by individuals of a non-reproducing population of *Megalonaias nervosa* (Mollusca: Unionidae) following translocation. Amer. Midl. Nat. 141(1):140-148.

Higgins, J., M. Lammert, and M. Bryer. 1999. Including aquatic targets in ecoregional portfolios: guidance for ecoregional planning teams. Designing a geography of hope update #6. The Nature Conservancy, Freshwater Initiative. Internet document, http://www.freshwaters.org/pub_docs/guidance.pdf (19 Mar. 1999 version).

Horne, F.R. and S. McIntosh. 1979. Factors influencing distribution of mussels in the Blanco River of central Texas. Nautilus 94(4):119-133.

Howells, R.G., C.M. Mather, and J.A.M. Bergmann. 1997. Conservation status of selected freshwater mussels in Texas. pp. 117-128 *In:* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo (eds.). Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. vi + 293 p.

Howells, R.G., C.M. Mather, and J.A.M. Bergmann. 2000. Impacts of dewatering and cold on freshwater mussels (Unionidae) in B.A. Steinhagen Reservoir, Texas. Texas J. Sci. 52(4) Supplement:93-104.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater mussels of Texas. Texas Parks and Wildlife Department, Inland Fisheries Division, Austin, TX. iv (vii) + 218 p.

Hubbs, C. and J. Pigg. 1976. The effects of impoundments on threatened fishes of Oklahoma. Annals Oklahoma Acad. Sci. No. 5:113-117.

Isely, F.B. 1925. The fresh-water mussel fauna of eastern Oklahoma. Proc. Oklahoma Acad. Sci. (1924) 4:43-118 + 2 tables.

Isom, V.G. 1969. The mussel resource of the Tennessee River. Malacologia 7(2-3):397-425.

Jacobson, P.J., J.L. Farris, D.S. Cherry, and R.J. Neves. 1993. Juvenile freshwater mussel (Bivalvia: Unionidae) responses to acute toxicity testing with copper. Env. Toxicol. & Chem. 12(5):879-883.

Jenkinson, J.J. and R.M. Todd. 1997. Management of native mollusk resources. pp.283-306 *In*: G.W. Benz and D.E. Collins (eds.) Aquatic fauna in peril: the southeastern perspective. Southeast Aquatic Research Institute, Spec. Publ. 1, Lenz Design & Communications, Decatur, GA. xviii + 553 p.

Jennings, S. 2000. Needs in the management of native freshwater mussels in the National Park System. National Park System, Water Resources Division. Internet document, http://www.nature.nps.gov/wrd/mussels/mussels5.htm (11 Jan. 2000 version).

Johnson, P.D. and K.M. Brown. 2000. The importance of microhabitat factors and habitat stability to the threatened Louisiana pearl shell, *Margaritifera hembeli* (Conrad). Canadian J. Zool. 78(2):271-277.

Johnson, R.I. 1956. The types of naiades (Mollusca: Unionidae) in the Museum of Comparative Zoology. Bull. Mus. Comp. Zool. 115(4):102-142.

Johnson, R.I. 1977. Arnold Edward Ortmann, a bibliography of his work on mollusks, with a catalog of his recent molluscan taxa. Occas. Papers on Mollusks, Mus. Comp. Zool. 4(58):229-241.

Johnson, R.I. 1979. The types of Unionacea (Mollusca: Bivalvia) in the Museum of Zoology, the University of Michigan. Malacological Review 12(1-2):29-36.

Johnson, R.I. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. Bull. Mus. Comp. Zool. 149(2):77-189.

Johnson, R.I. and H.B. Baker. 1973. The types of Unionacea (Mollusca: Bivalvia) in the Academy of Natural Sciences of Philadelphia. Proc. Acad. Nat. Sci. Phil. 125(9):145-186.

Keller, A.E. and S.G. Zam. 1991. The acute toxicity of selected metals to the freshwater mussel, *Anodonta imbecillis*. Env. Toxicol. & Chem. 10(4):539-546.

Kinsolving, A.D. and M.B. Bain. 1993. Fish assemblage recovery along a riverine disturbance gradient. Ecological Applications 3(3):531-544.

Landye, J.J. 1980. Status of rare, endangered, and/or threatened molluscan species of Texas and Oklahoma. Bio-Geo Southwest, Inc., report to the U.S. Dept. of the Interior, U.S. Fish and Wildlife Service, Region II, Albuquerque, NM. Project No. 14-16-0002-79-202. 15 p.

Layzer, J.B. and L.M. Madison. 1995. Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs. Regul. Rivers: Research & Mgmt. 10(2-4):329-345.

Layzer, J.B., M.E. Gordon, and R.M. Anderson. 1993. Mussels: the forgotten fauna of regulated rivers. A case study of the Caney Fork River. Regul. Rivers: Research & Mgmt. 8(1):63-71.

Lefevre, G. and W.C. Curtis. 1912. Studies on the reproduction and artificial propagation of freshwater mussels. Bull. U.S. Bur. Fish. 30:105-201 + 12 pl.

Leff, L.G., J.L. Burch, and J.V. MacArthur. 1990. Spatial distribution, seston removal, and potential competitive interactions of the bivalves *Corbicula fluminea* and *Elliptio complanata*, in a coastal plain stream. Freshwater Biology 24(2):409-416.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial processes in geomorphology. W.H. Freeman & Co., San Francisco, CA. xiv + 522 p.

Ligon, F.K., W.E. Dietrich, and W.J. Trush. 1995. Downstream ecological effects of dams. BioScience 45(3):183-192.

Martinez, A.D. and S.E. Jahrsdoerfer. 1991. Endangered and threatened wildlife and plants; final rule to list the Ouachita rock-pocketbook (mussel) as an endangered species. Federal Register 56(205):54950-54957.

Master, L.L., S.R. Flack, and B.A. Stein (eds.) 1998. Rivers of life: critical watersheds for protecting freshwater biodiversity. The Nature Conservancy, Arlington, VA. iv + 71 p.

Mather, C.M. 1989. New bivalve records from Lake Texoma, Oklahoma-Texas. Southwest. Nat. 34(4):563-564.

Mather, C.M. and J.A.M. Bergmann. 1994. Freshwater mussels of the Cypress Bayou system, northeast Texas. Malacology Data Net 33(5/6):139-145.

McMahon, R.F. 1991. Mollusca: Bivalvia. pp. 315-399 *In:* J.H. Thorp and A.P. Covich (eds.) Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., San Diego, CA. xii + 911 p.

McMurray, S.E., G.A. Schuster, and B.A. Ramey. 1999. Recruitment in a freshwater unionid (Mollusca: Bivalvia) community downstream of Cave Run Lake in the Licking River, Kentucky. Amer. Malacological Bull. 15(1):57-63.

Meador, M.R. and A.O. Layher. 1998. Instream sand and gravel mining: environmental issues and regulatory process in the United States. Fisheries 23(11):6-13.

Mehlhop, P. and E.K. Miller. 1989. Status and distribution of *Arkansia wheeleri* Ortmann & Walker, 1912 (syn. *Arcidens wheeleri*) in the Kiamichi River, Oklahoma. Oklahoma Natural Heritage Inventory, report to the U.S. Fish and Wildlife Service, Tulsa, OK. Order No. 21440-88-00142. iv + 19 p. + 84 p. appendices.

Meier, C.K. and C.C. Vaughn. 1998. Ouachita rock-pocketbook surveys in major tributaries of the Kiamichi River. Oklahoma Natural Heritage Inventory, final report to the Oklahoma Department of Wildlife Conservation, Oklahoma City, OK. Federal Aid Project E-46. 6 p. + 67 p. appendices.

Miller, A.C., L. Rhodes, and R. Tippet. 1984. Changes in the naiad fauna of the Cumberland River below Lake Cumberland in central Kentucky. Nautilus 98(3):107-110.

Morris, T.J. and L.D. Corkum. 1996. Assemblage structure of freshwater mussels (Bivalvia: Unionidae) in rivers with grassy and forested riparian zones. J. N. Amer. Benthol. Soc. 15(4):576-586.

Naimo, T.J. and E.M. Monroe. 1999. Variation in glycogen concentrations within mantle and foot tissue in *Amblema plicata plicata*: implications of tissue biopsy sampling. Amer. Malacological Bull. 15(1):51-56.

Naimo, T.J., E.D. Damschen, R.G. Rada, and E.M. Monroe. 1998. Nonlethal evaluation of the physiological health of unionid mussels: methods for biopsy and glycogen analysis. J. N. Amer. Benthol. Soc. 17(1):121-128.

National Native Mussel Conservation Committee. 1998. National strategy for the conservation of native freshwater mussels. J. Shellfish Research 17(5):1419-1428.

Neel, J.K. 1963. Impact of reservoirs. pp. 575-593 *In:* D.G. Frey (ed.) Limnology in North America. Univ. Wisconsin Press, Madison, WI. xviii + 734 p.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southern United States: a downward spiral of diversity. pp. 43-86 *In*: G.W. Benz and D.E. Collins (eds.) Aquatic fauna in peril: the southeastern perspective. Southeast Aquatic Research Institute, Spec. Publ. 1, Lenz Design & Communications, Decatur, GA. xviii + 553 p.

Obermeyer, B.K. 2000. Recovery plan for four freshwater mussels in southeast Kansas: Neosho mucket *Lampsilis rafinesqueana,* Ouachita kidneyshell *Ptychobranchus occidentalis,* rabbitsfoot *Quadrula cylindrica cylindrica,* western fanshell *Cyprogenia aberti*. Kansas Department of Wildlife and Parks, Pratt, KS. vi + 53 p.

Oesch, R.D. 1984. Missouri naiades: a guide to the mussels of Missouri. Missouri Dept. of Conservation, Jefferson City, MO. vii + 271 p.

Oklahoma Department of Pollution Control. 1992. The State of Oklahoma water quality assessment report, 1992 ed. ODPC, Oklahoma City, OK. xxviii + 697 p.

Oklahoma Water Resources Board. 1990. Oklahoma water atlas. Publication 135, OWRB, Oklahoma City, OK. vi + 360 p.

Ortmann, A.E. 1912. Notes upon the families and genera of the najades. Annals Carnegie Museum 8(2):222-365 + 3 pl.

Ortmann, A.E. 1921. A new locality for *Arkansia wheeleri* Ortmann & Walker. Nautilus 34(4):141.

Ortmann, A.E. and B. Walker. 1912. A new North American naiad. Nautilus 25(9):97-100 + 1 pl.

Parmalee, P.W. and M.H. Hughes. 1993. Freshwater mussels (Mollusca: Pelecypoda: Unionidae) of Tellico Lake: twelve years after impoundment of the Little Tennessee River. Annals Carnegie Museum 62(1):81-93.

Parmalee, P.W., W.E. Klippel, and A.E. Bogan. 1982. Aboriginal and modern freshwater mussel assemblages (Pelecypoda: Unionidae) from the Chickamunga Reservoir, Tennessee. Brimleyana 8:75-90.

Parodiz, J.J. 1967. Types of North American Unionidae in the collection of the Carnegie Museum. Sterkiana No. 28:21-30.

Payne, B.S. and A.C. Miller. 1987. Effects of current velocity on the freshwater bivalve *Fusconaia ebena*. Amer. Malacological Bull. 5(2):177-179.

Payne, B.S. and A.C. Miller. 2000. Recruitment of *Fusconaia ebena* (Bivalvia: Unionidae) in relation to discharge of the lower Ohio River. Amer. Midl. Nat. 144(2):328-341.

Pennak, R.W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca. Third edition. John Wiley & Sons, Inc., New York, NY. xviii + 628 p.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47(11):769-784.

Posey, W.R. II, J.L. Harris, and G.L. Harp. 1996. New distributional records for freshwater mussels in the Ouachita River, Arkansas. Proc. Arkansas Acad. Sci. 50:96-98.

Pyron, M. and C.C. Vaughn. 1994. Ecological characteristics of the Kiamichi River, Oklahoma. Oklahoma Natural Heritage Inventory, unpublished report to the U.S. Fish and Wildlife Service, Tulsa, OK. Project No. 20181-2-5126. 78 p. + 2 appendices (8 maps).

Ricciardi, A., R.J. Neves, and J.B. Rasmussen. 1998. Impending extinctions of North American freshwater mussels (Unionida) following the zebra mussel (*Dreissena polymorpha*) invasion. J. Animal Ecology 67(4):613-619.

Richter, B.D., J.V. Baumgartner, R. Wigington, and D.P. Braun. 1997. How much water does a river need? Freshwater Biology 37(1):231-249.

Ross, S.T. and J.A. Baker. 1983. The response of fishes to periodic spring floods in a southeastern stream. Amer. Midl. Nat. 109(1):1-14.

Salmon, A. and R.H. Green. 1983. Environmental determinants of unionid clam distribution in the Middle Thames River, Ontario. Canadian J. Zool. 61(4):832-838.

Saunders, D.L., J.J. Meeuwig, and A.C.J. Vincent. 2002. Freshwater protected areas: strategies for conservation. Conservation Biology 16(1):30-41.

Scruggs, G.D., Jr. 1960. Status of fresh-water mussel stocks in the Tennessee River. U.S. Fish and Wildlife Service, Spec. Sci. Rept., Fisheries, No. 370:iv + 41 p.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile *Elliptio complanata* (Bivalvia: Unionidae). J. N. Amer. Benthol. Soc. 17(1):129-134.

Spooner, D.E. and C.C. Vaughn. 2000. Impact of drought conditions on a mussel bed in the Kiamichi River, southeastern Oklahoma. Ellipsaria 2(3):10-11.

Stansbery, D.H. 1970. American Malacological Union symposium: rare and endangered mollusks. 2. Eastern freshwater mollusks (I). The Mississippi and St. Lawrence river systems. Malacologia 10(1):9-21.

Starnes, L.B. and A.E. Bogan. 1988. The mussels (Mollusca: Bivalvia: Unionidae) of Tennessee. Amer. Malacological Bull. 6(1):19-37.

Stern, E.M. 1983. Depth distribution and density of freshwater mussels (Unionidae) collected with scuba from the lower Wisconsin and St. Croix Rivers. Nautilus 97(1):36-42.

Strayer, D.L. 1991. Projected distribution of the zebra mussel, *Dreissena polymorpha*, in North America. Canadian J. Fisheries & Aquatic Sciences 48(8):1389-1395.

Strayer, D.L. 1993. Macrohabitats of freshwater mussels (Bivalvia: Unionacea) in streams of the northern Atlantic Slope. J. N. Amer. Benthol. Soc. 12(3):236-246.

Strayer, D.L. 1999a. Effects of alien species on freshwater mollusks in North America. J. N. Amer. Benthol. Soc. 18(1):74-98.

Strayer, D.L. 1999b. Use of flow refuges by unionid mussels in rivers. J. N. Amer. Benthol. Soc. 18(4):468-476.

Strayer, D.L. and J. Ralley. 1993. Microhabitat use by an assemblage of stream-dwelling unionaceans (Bivalvia), including two rare species of *Alasmidonta*. J. N. Amer. Benthol. Soc. 12(3):247-258.

Suloway, L., J.J. Suloway, and E.E. Herricks. 1981. Changes in the freshwater mussel (Pelecypoda: Unionidae) fauna of the Kaskaskia River, Illinois, with emphasis on the effects of impoundment. Trans. Illinois Acad. Sci. 74:79-90.

Surber, T. 1913. Notes on the natural hosts of fresh-water mussels. Bull. U.S. Bur. Fish. 32:101-116 + 3 pl.

Swink, W.D. and K.E. Jacobs. 1983. Influence of a Kentucky flood-control reservoir on the tailwater and headwater fish populations. N. Amer. J. Fisheries Mgmt. 3:197-203.

Tippit, R.N., J.K. Brown, J.F. Sharber, and A.C. Miller. 1997. Modifying Cumberland River system reservoir operations to improve mussel habitat. pp. 229-235 *In:* K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo (eds.). Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. vi + 293 p.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson, and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union. American Fisheries Society Special Publication 16. American Fisheries Society, Bethesda, MD. viii + 277 p. + pl.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. Second edition. Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union. American Fisheries Society Special Publication 26. American Fisheries Society, Bethesda, MD. x + 526 p.

Turner, R.E. and N.N. Rabalais. 1991. Changes in Mississippi River water quality this century. BioScience 41(3):140-147.

U.S. Army Corps of Engineers. 1989. Water resource development in Arkansas 1989. U.S. Army Corps of Engineers, Southwestern Division, Dallas, TX. x + 76 p.

U.S. Fish and Wildlife Service. 1994a. Notice of availability of a draft recovery plan for the Ouachita rock-pocketbook for review and comment. Federal Register 59(134):35948-35949.

U.S. Fish and Wildlife Service. 1994b. Ouachita rock-pocketbook, *Arkansia wheeleri* Ortmann and Walker, 1912, draft recovery plan. USFWS, Region 2, Albuquerque, NM. 90 p.

U.S. Fish and Wildlife Service. 1994c. Clubshell (*Pleurobema clava*) and northern riffleshell (*Epioblasma torulosa rangiana*) recovery plan. Hadley, MA. iv + 63 p.

U.S. Fish and Wildlife Service. 1996. Recovery plan for the Appalachian elktoe (*Alasmidonta raveneliana*) Lea. Atlanta, GA. vi + 31 p.

U.S. Fish and Wildlife Service. 1997a. Recovery plan for the Carolina heelsplitter (*Lasmigona decorata*) Lea. Atlanta, GA. v + 30 p.

U.S. Fish and Wildlife Service. 1997b. Winged mapleleaf mussel (*Quadrula fragosa*) recovery plan. Ft. Snelling, MN. vii + 69 p. + 281 p. appendices.

Valentine, B.D. and D.H. Stansbery. 1971. An introduction to the naiads of the Lake Texoma region, Oklahoma, with notes on the Red River fauna (Mollusca: Unionidae). Sterkiana No. 42:1-40.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proc. Natl. Acad. Sci. USA 79(13):4103-4107.

Vaughn, C.C. 1993. Can biogeographic models be used to predict the persistence of mussel populations in rivers? pp. 117-122 *In:* K.S. Cummings, A.C. Buchanan, and L.M. Koch (eds.). Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, MO. Upper Mississippi River Conservation Committee, Rock Island, IL. v + 189 p.

Vaughn, C.C. 1994. Survey for *Arkansia wheeleri* in the Little River. Oklahoma Natural Heritage Inventory, final report to the U.S. Fish & Wildlife Service, Tulsa, OK. Project No. 20181-1-1352. i + 23 p. + 170 p. appendix + map.

Vaughn, C.C. 1996a. Glover River mussel survey. Oklahoma Natural Heritage Inventory, final report to the USDA Forest Service, Ouachita National Forest, Hot Springs, AR. i + 7 p. + 45 p. appendix.

Vaughn, C.C. 1996b. Survey of mussel assemblages in the Glover River. Oklahoma Natural Heritage Inventory, final report to The Nature Conservancy, Oklahoma Field Office, Tulsa, OK. i + 7 p. + 45 p. appendix.

Vaughn, C.C. 1997a. Catastrophic decline of the mussel fauna of the Blue River, Oklahoma. Southwest. Nat. 42(3):333-336.

Vaughn, C.C. 1997b. Pre-planning for studies of reproduction by rare mussel species in Oklahoma. Oklahoma Natural Heritage Inventory, final report to the U.S. Fish & Wildlife Service, Tulsa, OK. Project No. 20181-5-8055. 28 p.

Vaughn, C.C. 1997c. Regional patterns of mussel species distributions in North American rivers. Ecography 20(2):107-115.

Vaughn, C.C. 2000. Changes in the mussel fauna of the middle Red River drainage: 1910-present. pp. 225-232 *In:* R.A. Tankersley, D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (eds.). Freshwater Mollusk Symposia Proceedings. Ohio Biological Survey, Columbus, OH. xiii + 274 p.

Vaughn, C.C. and C.C. Hakenkamp. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46:1-16.

Vaughn, C.C. and M. Pyron. 1992. Habitat use and reproductive biology of *Arkansia wheeleri* (Mollusca: Unionidae) in the Kiamichi River, Oklahoma. Oklahoma Natural Heritage Inventory, performance report to the Oklahoma Department of Wildlife Conservation, Oklahoma City, OK. Federal Aid Project No. E-12-2. 12 p. + 18 p. appendices.

Vaughn, C.C. and M. Pyron. 1995. Population ecology of the endangered Ouachita rock- pocketbook mussel, *Arkansia wheeleri* (Bivalvia: Unionidae), in the Kiamichi River, Oklahoma. Amer. Malacolcogical Bull. 11(2):145-151.

Vaughn,C.C. and D. Spooner. 2000. Mussel survey of the Mountain Fork River. Oklahoma Biological Survey, final report to the USDA Forest Service, Ouachita National Forest, Hot Springs, AR. 11 p. + 51 p. appendix.

Vaughn, C.C. and C.M. Taylor. 1999. Impoundments and the decline of freshwater mussels: a case study of an extinction gradient. Conserv. Biol. 13(4):912-920.

Vaughn, C.C. and C.M. Taylor. 2000. Macroecology of a host-parasite relationship. Ecography 23:11-20.

Vaughn, C.C., C.M. Mather, M. Pyron, P. Mehlhop, and E.K. Miller. 1996. The current and historical mussel fauna of the Kiamichi River, Oklahoma. Southwest. Nat. 41(3):325-328.

Vaughn, C.C., M. Pyron, and D.L. Certain. 1993. Habitat use and reproductive biology of *Arkansia wheeleri* (Mollusca: Unionidae) in the Kiamichi River, Oklahoma. Oklahoma Natural Heritage Inventory, final report to the Oklahoma Department of Wildlife Conservation, Oklahoma City, OK. Federal Aid Project E-12. 51 p. + 13 tables + 28 figs. + 16 p. appendix.

Vaughn, C.C., C.M. Taylor, K.J. Eberhard, and M. Craig. 1994a. Mussel biodiversity inventory of the upper Little River. Oklahoma Natural Heritage Inventory, final report to the U.S. Fish & Wildlife Service, Tulsa, OK. National Fish and Wildlife Foundation Grant No. 93-131, Project BIP-1. i + 13 p. + 5 maps.

Vaughn, C.C., C.M. Taylor, K.J. Eberhard, and M. Craig. 1994b. Survey for *Arkansia wheeleri* and other rare unionids in the Tiak District. Oklahoma Natural Heritage Inventory, final report to the USDA Forest Service, Ouachita National Forest, Hot Springs, AR. ii + 30 p.

Vaughn, C.C., C.M. Taylor, K.J. Eberhard, and M. Craig. 1995. Survey for *Arkansia wheeleri* in the Little River in eastern Oklahoma and western Arkansas. Oklahoma Natural Heritage Inventory, final report to the U.S. Fish & Wildlife Service, Tulsa, OK. Project No. 20181-4-8047. ii + 53 p. + map.

Voelz, N.J. and J.V. Ward. 1991. Biotic responses along the recovery gradient of a regulated stream. Canadian J. Fisheries & Aquatic Sciences 48(12):2477-2490.

Vidrine, M.F. 1993. The historical distributions of freshwater mussels in Louisiana. Gail Q. Vidrine Collectables, Eunice, LA. xii (xiv) + 225 p. + 20 pl.

Watters, G.T. 1992. Unionids, fishes, and the species-area curve. J. Biogeography 19(5):481-490.

Watters, G.T. 1996. Small dams as barriers to freshwater mussels (Bivalvia, Unionoidea) and their hosts. Biological Conservation 75(1):79-85.

Watters, G.T. 2000. Freshwater mussels and water quality: a review of the effects of hydrologic and instream habitat alterations. pp. 261-274 *In:* R.A. Tankersley, D.I. Warmolts, G.T. Watters, B.J. Armitage, P.D. Johnson, and R.S. Butler (eds.). Freshwater Mollusk Symposia Proceedings. Ohio Biological Survey, Columbus, OH. xiii + 274 p.

Webb, W.F. 1942. United States Mollusca. Bookcraft, New York, NY. 220 p.

Wheeler, H.E. 1918. The Mollusca of Clark County, Arkansas. Nautilus 31(4):109-125.

White, D.S. 1977. Changes in the freshwater mussel populations of the Poteau River system, Le Flore County, Oklahoma. Proc. Oklahoma Acad. Sci. 57:103-105.

White, D.S. and S.J. White. 1977. Observations on the pelecypod fauna of Lake Texoma, Texas and Oklahoma, after more than 30 years impoundment. Southwest. Nat. 22(2):235-254.

Williams, G.P. and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. Geological Survey Professional Paper 1286. U.S. Geological Survey, Government Printing Office, Washington, D.C. v + 83 p.

Williams, J.D., S.L.H. Fuller, and R. Grace. 1992. Effects of impoundment on freshwater mussels (Mollusca: Bivalvia: Unionidae) in the main channel of the Black Warrior and Tombigbee rivers in western Alabama. Bull. Alabama Museum Nat. Hist. 13:1-10.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation and status of freshwater mussels of the United States and Canada. Fisheries 18(9):6-22.

Wilson, C. 1999. Conservation initiative launched on Kiamichi River. Oklahoma Conservator No. 40:6.

Wilson, C.B. 1916. Copepod parasites of fresh-water fishes and their economic relations to mussel glochidia. Bull. U.S. Bur. Fish. 34:331-374.

Wootton, J.T., M.S. Parker, and M.E. Power. 1996. Effects of disturbance on river food webs. Science 273(5281):1558-1561.

Young, M.R. and J. Williams. 1983. Redistribution and local recolonisation by the freshwater pearl mussel *Margaritifera margaritifera* (L.). J. Conchology 31(4):225-234.

PART III: IMPLEMENTATION SCHEDULE

The following table is a summary of actions and estimated costs for implementing the Ouachita rock pocketbook recovery plan. It is a guide for meeting the objectives discussed in Part II of this plan. This table indicates task priorities, task numbers, task descriptions, duration of tasks, responsible parties, and lastly, estimated costs. These tasks, when accomplished, should bring about the recovery of the species and protect its habitat. The estimated monetary needs for all parties involved in recovery are identified and, therefore, Part III reflects the total estimated financial requirements for the recovery of this species.

Key to priorities assigned in the Implementation Schedule (column 1)

1. Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2. Priority 2 - An action that must be taken to prevent a significant decline in species population, habitat quality, or some other significant negative impact short of extinction.

3. Priority 3 - All other actions necessary to meet recovery objectives.

Key to acronyms used in the Implementation Schedule

FWS Regions: 2 - Albuquerque (Southwest), 4 - Atlanta (Southeast)

Federal Agencies

CE - U.S. Army Corps of Engineers
EPA - U.S. Environmental Protection Agency
FERC - Federal Energy Regulatory Commission
FHWA - Federal Highway Administration
FS - U.S. Forest Service
FWS - U.S. Fish and Wildlife Service
EA - FWS External Affairs
ES - FWS Ecological Services
LE - FWS Law Enforcement
RE - FWS Realty
RS - FWS Refuges
WR - FWS Water Resources
USDA - U.S. Department of Agriculture

State Agencies

ADE - Arkansas Department of Ecology
ADPT - Arkansas Department of Parks and Tourism
AGFC - Arkansas Game and Fish Commission
AHTD - Arkansas Highway and Transportation Department
OCONS - Oklahoma Conservation Commission
ODEQ - Oklahoma Department of Environmental Quality
ODM - Oklahoma Department of Mines

ODT - Oklahoma Department of Transportation
ODWC - Oklahoma Department of Wildlife Conservation
ONHI - Oklahoma Natural Heritage Inventory
OSDA - Oklahoma State Department of Agriculture
OTRD - Oklahoma Tourism and Recreation Department
OWRB - Oklahoma Water Resources Board
TCEQ - Texas Commission on Environmental Quality
TPWD - Texas Parks and Wildlife Department
TxDOT - Texas Department of Transportation

Private Entities

AZAA - American Zoo and Aquarium Association
Contr - Contractor (unspecified)
HTRG - Hancock Timber Resource Group
TNC - The Nature Conservancy
WEYCO - Weyerhaeuser Company

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
1	1.1	Use existing statutes to protect the Kiamichi River system where the Ouachita rock pocketbook occurs	Continuous	2	ES LE	 CE EPA FERC FHWA FS USDA ODWC ODEQ ODM OSDA	3 1 3 2 1 2 2 2 1 1 1 1	3 1 3 2 1 2 2 2 1 1 1 1	3 1 3 2 1 2 2 2 1 1 1 1	
1	1.21	Deauthorize Tuskahoma Reservoir	10 years	2	ES	CE	TBD	TBD	TBD	Requires Congressional action
1	1.31	Develop and implement monitoring of the Kiamichi River population and its habitat	3-year intervals	2	ES	 ODWC ONHI	10 5 5	0 0 0	0 0 0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
1	1.32	Develop and implement monitoring of current and potential threats to the Kiamichi River population	Continuous	2	ES	 CE EPA FS OCONS ODEQ ODM ODWC OSDA	4 4 4 3 3 3 3 3 3	4 4 4 2 3 3 1 2 2	4 4 4 2 3 3 1 2 2	
1	4.1	Determine and protect the fish host(s) and its (their)habitat	3 years	2,4	ES	 AGFC ODWC Contr	30 5 5	30 5 5	30 5 5	Dependent upon determining timing of glochidial release
1	4.2	Determine sex ratio among Ouachita rock pocketbook, ages at which they produce gametes, and seasonal timing of reproduction	2 years	2,4	ES	 AGFC ODWC Contr	44 8 8	44 8 8	0 0 0	Initial estimates supplemented by data collected through continuing tasks
1	5.2	Determine habitat and early life history of juvenile Ouachita rock pocketbooks	3 years	2	ES	 ODWC ONHI	20 5 5	20 5 5	20 5 5	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
1	5.3	Determine environmental sensitivities of the Ouachita rock pocketbook	5 years	2	ES WR	 CE EPA FS ODWC Contr	15 10 30 30 10 5	15 10 30 30 10 5	15 10 30 30 10 5	
2	1.22	Determine value of major tributaries as habitat for the Kiamichi River population	1 year	2	ES	 ODWC ONHI HTRG	2 2 2 2	0 0 0 0	0 0 0 0	
2	1.23	Perform cooperative projects to increase habitat protection in the Kiamichi River	Continuous	2	ES	 CE EPA FHWA FS USDA OCONS ODT ODWC OSDA	0 0 0 0 0 0 0 0 0 0	5 2 4 2 2 4 1 1 2 2	5 2 4 2 2 4 1 1 2 2	
2	1.24	Upgrade protection of Kiamichi River through water quality standards and water quality management programs	10 years	2	ES	 EPA FS OCONS ODEQ ODWC ODSA OWRB	2 2 1 1 1 1 1 1	4 4 2 2 2 2 2 2	4 4 2 2 2 2 2 2	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
2	2.1	Conduct a survey of the Little River in Arkansas and Oklahoma for existing populations	1 year	2,4	ES RS	 CE FS AGFC ODWC Contr	3 1 2 2 2 2	0 0 0 0 0 0	0 0 0 0 0 0	
2	2.2	Conduct surveys of the Ouachita River in Arkansas for existing populations	2 years	2,4	ES	 CE FS AGFC Contr	4 3 2 3	4 3 2 3	0 0 0 0	
2	2.3	Conduct surveys of other Red River tributaries in Oklahoma, Texas and Arkansas for existing populations	1 year	2,4	ES	 AGFC ODWC TPWD Contr	4 2 2 2	0 0 0 0	0 0 0 0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
2	3.1	Use existing statutes to restore and protect habitat for the Ouachita rock pocketbook outside of the Kiamichi River	Continuous	2,4	ES		6	6	6	
					LE		2	2	2	
					RS		2	2	2	
						CE	6	6	6	
						EPA	4	4	4	
						FERC	2	2	2	
						FHWA	4	4	4	
						FS	4	4	4	
						USDA	4	4	4	
						ADE	2	2	2	
						AGFC	2	2	2	
						ODEQ	2	2	2	
						ODM	2	2	2	
						ODWC	2	2	2	
						OSDA	2	2	2	
						TCEQ	2	2	2	
						TPWD	2	2	2	
2	3.21	Deauthorize unimplemented channel modifications of the Ouachita River	10 years	2,4	ES	CE	TBD	TBD	TBD	Deauthorization requires Congressional action

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
2	3.22	Develop and implement cooperative projects to increase restoration and protection of degraded habitat and populations outside of the Kiamichi River	Continuous	2,4	ES		6	6	6	
					RS		4	4	4	
						CE	4	4	4	
						EPA	8	8	8	
						FHWA	4	4	4	
						FS	4	4	4	
						USDA	8	8	8	
						AGFC	4	4	4	
						AHTD	2	2	2	
						OCONS	2	2	2	
						OGT	2	2	2	
						ODWC	4	4	4	
						OSDA	2	2	2	
						TPWD	4	4	4	
						TxDOT	2	2	2	
2	3.23	Upgrade protection of degraded habitat areas outside of the Kiamichi River through water quality standards and water quality management programs	10 years	2,4	ES		5	10	10	Coordinate with Tasks 1.24 and 5
						EPA	4	8	8	
						FS	2	4	4	
						ADE	1	2	2	
						AGFC	1	2	2	
						OCONS	1	2	2	
						ODEQ	1	2	2	
						ODWC	1	2	2	
						OSDA	1	2	2	
						OWRB	1	2	2	
						TCEQ	1	2	2	
						TPWD	1	2	2	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
2	3.3	Institute a monitoring program for degraded populations and habitat outside of the Kiamichi River	Continuous	2,4	ES RS	 CE EPA FS ADE AGFC OCONS ODEQ ODM ODWC ONHI OSDA TCEQ TPWD	7 2 4 4 3 3 3 3 3 3 3 3 3 3 3	7 2 4 4 3 2 2 2 2 2 2 2 2 2 2	7 2 4 4 3 2 2 2 2 2 2 2 2 2 2	Biological monitoring at 3-year intervals
2	5.1	Determine habitat use of populations outside of the Kiamichi River	3 years	2,4	ES	 AGFC ODWC ONHI TPWD	0 0 0 0 0	8 4 2 2 4	8 4 2 2 4	
3	1.251	Inventory property ownerships and water rights appropriations along the Kiamichi River	2 years	2	ES RE	 ODWC ONHI HTRG	2 1 1 1 1	2 1 1 1 1	0 0 0 0 0	
3	1.252	Ensure public landowner notification	1 year	2	ES	 ODWC	0 0	1 0	0 0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	1.253	Ensure private landowner notification	1 year	2	ES	 ODWC	0 0	2 1	0 0	
3	1.254	Manage response to identified threats to the Kiamichi River population	Continuous	2	ES	 CE FS OCONS ODEQ ODM ODWC OSDA	1 1 1 1 1 0 0 0	1 0 0 0 1 0 0 0	1 0 0 0 1 0 0 0	
3	1.255	Develop protection approaches for specific Kiamichi River properties	Continuous	2	ES LE RE RS	 CE FHWA FS USDA OCONS ODWC ONHI HTRG	12 1 1 1 4 3 3 3 2 5 3 2	12 1 1 1 4 3 3 3 2 5 3 2	12 1 1 1 4 3 3 3 2 5 3 2	
3	1.256	Integrate initial protections into a habitat protection plan for the Kiamichi River population	3 years	2	ES	 ODWC	5 5	5 5	5 5	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	2.4	Determine if any populations outside of the Kiamichi River are viable	2 years	2,4	ES	 AGFC ODWC TPWD Contr	6 2 2 2	6 2 2 2	0 0 0 0	Initial assessment to be revised, based on completion of Task 6.2 and cumulative monitoring data
3	6.1	Determine comparative genetic composition of extant populations	2 years	2,4	ES	 AGFC ODWC TPWD Contr	9 2 2 2	9 2 2 2	0 0 0 0	
3	6.2	Determine factors limiting population growth, and refine characterization of population viability for the species	2 years	2,4	ES	 AGFC ODWC TPWD Contr	0 0 0 0	0 0 0 0	0 0 0 0	Dependent upon results from Tasks 2,4,5 and 6.1; start estimated in year 5 of recovery program
3	7.1	Develop techniques for successful transplantation	3 years	2,4	ES	 AGFC ODWC TPWD Contr	16 8 8 8	16 8 8 8	16 8 8 8	Prerequisite to Tasks 7.2, 7.3, 7.4

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	7.2	Select stream sites for introduction	1 year	2,4	ES		0	0	0	Start estimated in year 4
						AGFC	0	0	0	
						ODWC	0	0	0	
						TPWD	0	0	0	
3	7.3	Translocate Ouachita rock pocketbooks into two populations outside of the Kiamichi River population	1 year	2,4	ES		0	0	0	Start estimated in year 5
						AGFC	0	0	0	
						ODWC	0	0	0	
						TPWD	0	0	0	
3	7.4	Protect transplanted populations and evaluate success	Continuous	2,4	ES		0	0	0	Start estimated in year 5. With success in second year, incorporate continued protection into Task 3
					LE		0	0	0	
						CE	0	0	0	
						EPA	0	0	0	
						FHWA	0	0	0	
						FS	0	0	0	
						USDA	0	0	0	
						ADE	0	0	0	
						AGFC	0	0	0	
						ODEQ	0	0	0	
						ODWC	0	0	0	
						TCEQ	0	0	0	
						TPWD	0	0	0	
3	8	Develop an outreach program	2 years to develop, then continuous	2,4	ES		4	4	1	
					EA		4	4	1	
						AGFC	3	3	0	
						ADPT	3	3	0	
						ODWC	3	3	0	
						OTRD	3	3	0	
						TPWD	5	5	0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	9.1	Improve coodination of monitoring and research activities with management activities	Continuous	2,4	ES		4	4	4	
						CE	0	0	0	
						EPA	0	0	0	
						FS	0	0	0	
						ADE	0	0	0	
						AGFC	0	0	0	
						OCONS	0	0	0	
						ODEQ	0	0	0	
						ODWC	0	0	0	
						ONHI	0	0	0	
						TCEQ	0	0	0	
						TPWD	0	0	0	
3	9.2	Better correlate basin conditions and human activities with habitat conditions	5 years	2,4	ES		3	6	6	
					WR		1	2	2	
						CE	1	2	2	
						EPA	1	2	2	
						FS	1	2	2	
						ADE	1	2	2	
						AGFC	1	2	2	
						OCONS	1	2	2	
						ODEQ	1	2	2	
						ODWC	1	2	2	
						OSDA	1	2	2	
						TCEQ	1	2	2	
						TPWD	1	2	2	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	9.3	Better indicate and implement appropriate treatments and responses for identified threats/sources of degradation	5 years	2,4	ES		1	1	1	
						CE	1	1	1	
						EPA	1	1	1	
						FHWA	1	1	1	
						FS	1	1	1	
						ADE	1	1	1	
						AGFC	1	1	1	
						OCONS	1	1	1	
						ODEQ	1	1	1	
						ODM	1	1	1	
						ODWC	1	1	1	
						OSDA	1	1	1	
						TCEQ	1	1	1	
						TPWD	1	1	1	
						WEYCO	1	1	1	
3	9.4	Develop expanded habitat restoration-protection plan for all areas inhabited by the Ouachita rock pocketbook	3 years	2,4	ES LE RE RS		0	0	0	Start estimated in year 5
						CE	0	0	0	
						FHWA	0	0	0	
						FS	0	0	0	
						USDA	0	0	0	
						AGFC	0	0	0	
						OCONS	0	0	0	
						ODEQ	0	0	0	
						ODM	0	0	0	
						ODWC	0	0	0	
						OSDA	0	0	0	
						TPWD	0	0	0	
						ONHI	0	0	0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	9.5	Develop enhanced notification and consultation procedures	5 years	2,4	ES	 CE EPA FERC FHWA FS USDA	4 0 0 0 0 0 0	4 0 0 0 0 0 0	4 0 0 0 0 0 0	
3	9.61	Develop necessary resources for captive propogation of the Ouachita rock pocketbook	3 years to develop, then indefinite	2,4	ES	 AGFC ODWC TPWD AZAA Contr	80 25 25 25 25	80 25 25 25 25	80 25 25 25 25	
3	9.62	Perform cryogenic preservation for the Ouachita rock pocketbook	1 year to establish, then continuous	2,4	ES	 AGFC ODWC TPWD AZAA Contr	0 0 0 0	10 5 5 5	2 0 0 0	

IMPLEMENTATION SCHEDULE

Priority Number	Recovery Action Number	Action Description	Action Duration	FWS		Other	Cost Estimates ($1000s)			Comments
				Region	Program		FY1	FY2	FY3	
3	9.71	Establish and permanently protect viable populations in all four stream systems historically inhabited by the Ouachita rock pocketbook	3 years to establish, then continuous	2,4	ES	CE EPA FHWA FS USDA ADE AGFC ODEQ ODWC TCEQ TPWD	TBD	TBD	TBD	Timing and cost to be determined
3	9.72	Refine delisting criterion, and provide any corresponding measures needed to support delisting of the Ouachita rock pocketbook	Continuous	2,4	ES	AGFC ODWC TPWD	TBD	TBD	TBD	Timing and cost to be determined

APPENDIX A: PUBLIC COMMENTS ON THE FIRST DRAFT PLAN FOR THE OUACHITA ROCK POCKETBOOK

FWS published notice of an opportunity to review and comment on a Ouachita Rock Pocketbook Draft Recovery Plan in the Federal Register on July 14, 1994 (Vol. 59, No. 134, pp. 35948-35949). FWS also distributed a news release inviting public review and comment to six newspapers within the range of the Ouachita rock pocketbook. FWS placed copies of the draft plan in five public libraries within the affected region, and directly distributed approximately 115 copies to various federal agency offices, state agency offices, private interests, and congressional members in the states of Oklahoma, Arkansas, and Texas. Since publication of the draft Ouachita Rock Pocketbook Recovery Plan in 1994, further information gathering on population status, tributary surveys, and related issues was completed; however, no substantive changes were made to the overall recovery strategy for the species in the final Recovery Plan.

Thirteen comment letters were received in response to the first draft plan, copies of which are included in this appendix. FWS appreciates the interest expressed by the commenting parties, and has attempted to evaluate the submitted comments in a thorough and considerate manner. FWS responses to individual comments appear both as changes in the body of the recovery plan and in a summary following the comment letters. Numbers placed in the margins of comment letters refer to specific responses appearing in the FWS's summary.

Assistant
Adornato
Aldrich
Brubeck
Collins
Frazier
Langer
Martin
Martinez
Off. Asst.
Reading
Files

8-10-94

To: Mr. Jerry Brabander
Mr. David Martinez

I direct my comments to you because yours were the names mentioned in article, 'Bring' em Back Alive' campaign launched for mussels, in the Broken Bow News August 17, 1994.

After consultation with a number of friends who Remember, as I do, tragedies of the past, which we believe might continue to have an effect on many creatures of the Little River Basin. Even though these were happening of many years ago, considering the slow movement of a creature like a mussel we believe the self re-introduction would take many years, The on site observation and the extent of the two tragedies will rest in our memories forever. The disgust we experienced when we asked for help of what we thought to be proper authorities, will also be remembered. Our efforts were quickly mingled with politics and we we were rediculed by the perpitrators for what they termed as obsticles to progress. We certainly didn't bend or break and believe our efforts did some good because the guilty parties knew we were watching.

When the Craig Fiber board Plant four miles East of Broken Bow opened during the mid 50's the first experment with waste dumping was to release it into a pin oak flat south of the plant the property belonging to the plant owner. Within sixty days it was obser-

1

ved the waste wasn't only killing all living creatures of the soil envolved but also the timber where it stood puddled up for any length of time. ~~Two~~ One or two settling pond were built that were filled in a short time. A relieve was made into a natural drain that entered Mountain Fork River about a quarter mile away. A friend was on the scene and took pictures which I believe he still has. Every aquatic creature was killed. The way he described it to me at the time, "Even the turtles broke their necks climbing up on rocks or running out on the bank." He came to me on that morning advising I should go see. I was buisy and told him I had already seen enough. Thad Mc Farland, Eagletown, 74734 has the pictures he took that morning and I am shure he would let anyone intrested to see them.

It is about three miles from the site of this kill to where Mountain Fork enters Little River. I know this effected this part of Mountain Fork. I am not shure of the effect on Little River. I know some of the mussels on lower Mountain Fork have made a recovery. Especially the little white "Odie" mussel, the primary diet of sucker fish and drum. The fish themselves have also made a recovery.

About a half mile up river from the mouth of Mt. Fork is the lower end of what is know as the Nine Mile eddy. I do not recall ever seeing the mussul described further up Little River than this point. If they are, they would be in the long

2

Sholey stretch above the mouth of Yonubee Creek. If I was physically able I would like to look. I would also like to look in the stretch of Mountain Fork from the site of the poison release, through the Doc Sherrill eddy and on up through the Huffman eddy. I believe if they were ever there they would still be there.

Thad McFarland is the owner of property at the up river end of this stretch of river from White Oak Bend, the site of the poisoning, to the U.S. highway 70 bridge on Mountain Fork. A distance by river of about three miles. The bridge crosses at the upper end of Huffman eddy. He has had a gravel removal operation that has gone on for many year. The fishing along the river is wonderful, fishing in some of the dug out ponds where gravel has been removed is also very good. He welcoms friends and reasonable people to fish. Some of the fanatics of E.P.A. have given him a hard time over the years but he believes they have come to realize they were wrong. His property and the stretch of river up to the Re-regulation dam is a classic example where the belief by some that gravel removal and dam construction is detremental to the aquatic creatures of the area is a farce. It just does-n't work that way in the little River Basin. The creatures simply move near by and adjust. They are as capable of adjusting as humans.

3

4

The other Memorable tragedy OF the Little River basin was the poison spill, cresoat and penta and maybe others that entered the Rolling Fork river in 1968. This came from a post treating operation at the south west edge of De Queen Arkansas. This spill even killed vegetation along the river bank. All species of dead fish floated into the upper part of Millwood lake. A friend walked the bank of Little River from the Highway U.S. 71 Bridge up to the mouth of the Cossotot River to observe the dead fish in drifts. Some one had retrieved and layed side by side on the bank, three flat head cat fish with a note, combined weight 117 lbs., There were many other species in evidence at this spot, possably by a study group of Arkansas Game and Fish. There was concern only by fishermen. The politics of the day handeled the situation.

I spent many days walking the bank and fishing Little River. I even sampeled a stew a group of Indins living near the river south of Eagletown use to make on the river bank. I dont believe there was ever many of the mussels described, along lower little River down to Line Ford. I know the Indians called the ones I saw, (sand mussels) they didnt use them in their stew because of the sand content. The Indians name was, or is Ashalintubbi, some of the older one might shed some light on the mussel mystery.

Hope this is an assist to the mussel issue
Maybe the presentation of past history which
was so impressive and disappointing will help.

Sincerely
Eugene C. Gregory
2410 S Park Drive
Broken Bow Okla.
74728

P.S. I will gladly assist in any way.

405-584-6335

'ne McGazette Broken Bow News

AUG 3

Letters to the Editor 1994

We Need Your help. This is simply An Unfinished Job. The Unique Nature of the Little River Basin Begs For the Project

To the Editor:

The Farm and Forestry section of the *McCurtain Gazette and Broken Bow News* July 17 presents an excellent map of the 2.7 million acre Little River Basin. This is an area unique in many ways. It is protected from the cold blasts of winter by the Kiamichi and Ouachita mountains to the north. The relative humidity of our summers during times of excessive rainfall is a tolerable blessing.

During a lifetime of hunting, fishing and just exploring, there is no end to the amazement of the biodiversity of the region. I must follow a branch or creek to the beginning to discover many, or most start with a cool spring made eternal by the hand of God.

I urge every citizen of the area who has appreciation of a thing of beauty and interest in the environment in which we live to study this map with a feeling of imagination of the hills, valleys, flora and fauna that combine to tie it together.

Take note, there are six rivers in the Little River watershed. Glover is tagged a creek on the map, but as far as I know, since the beginning of time, for those who know, it is a river not be be belittled by some I have in mind who wish to downplay its importance in the over scheme of water resources development for the Little River Basin.

There are also many beautiful creeks — Rock Creek, one of the largest, co-owned by Arkansas and Oklahoma, and one-third the size of Rolling Fork and Glover, being one of many.

Because of their vital importance to the well being of all creatures inhabiting this area, these, along with the mother, Little River itself is our golden lifeline. The upstream series of flood control dams make up the golden chain. The missing link of the golden chain to the hook at the top end of the chain is missing due to default. This hook at the end of the chain being Pine Creek on upper Little River.

When the late John Burwell arrived as one of the first forestry experts in the early '50s, he kept Mac McCartney busy for months getting acquainted with what he recognized as a fragile environment to be handled with care. He appreciated the vision of Sen. Robert S. Kerr for the vital incorporation of land, wood and water resources.

Years of honest effort, time and resources were unselfishly spent by Harold Norris, Jewel Callaham, Louie Johnson, Mayo Holman and many others working as members of the Red River Valley Association, with the cooperation of Sen. Robert S. Kerr, to make a complete golden chain of upstream dams designed for flood control and recreation a reality in the Little River Basin.

Long ago, I asked the chief or Corps of Engineers officer in charge during the planning stage for the upstream dams,and it became likely the construction of the Glover Dam would be delayed. What part would the Glover Dam play in the overall scheme of flood control dams? He presented a map and explained to the best of my memory: "During flood stage on the rivers of the area, Glover would contribute about 15 percent of flood waters to be controlled. This would be from 8 to 15 feet of flood water on the upper Little River system.

The lack of control on Glover would greatly affect bank stabilization on Little River below where it enters the river and the sedimentation would also be a negative factor.

I, along with all who have observed have watched the deterioration of the bank and sedimentation as predicted come to pass. Some of the old camping spots, especially in river beds, have caved into the river. This is an ongoing tragedy. Many of the floods on Glover are very quick to materialize and very swift. This has the effect of a cutting torch on the river banks.

The default and delay in construction of Glover Dam and the reality of a permanent pool of water where the river free flow is controlled only during flood stage was caused by dater mania by a small group of fanatics who imported a copy cat lie from the Tennessee River Valley where the small darter had been declared to be endangered. They didn't know the leopard darter existed until they were introduced by those who had used them for live bait for bass fishing for many years.

The snail darter was declared to be prospering and well where they had always been last year. They had never been endangered and were removed from the list.

The leopard darter is alive and prospering in its chosen habitat and has never been endangered. It's time to demand this obstacle to progress be removed.

At least one candidate for governor knows the true story of the issue and has promised help in the past. We need the commitment of others. I will assure our congressional delegation is listening.

The congressional approval of the dam on Glover River must not be removed as some selfish groups seek. A progressive future of those who call southeastern Oklahoma home should be the primary consideration in the development of our God given natural resources. Planning must have the needs of the future in mind.

If further impact study is required, all that need to be done is to look to the benefits the permanent pool on Rolling Fork River near DeQueen, Ark., has afforded since completion about 20 years ago.

Those responsible for the default in the construction of the congressionally approved dam on Glover are liable. An outfit who claims to have 14,000 members around the state of Oklahoma should have liability insurance enough to cover the cost of construction. If not, their resources should be pooled for political clout, as it has been used in the past. We will cooperate.

The people of McCurtain County should demand the final link to the golden chain. We should let it all hang out during this election year.

The 15 percent help that would be afforded by Glover Dam is needed by Larry Pratt and many others who are watching as the bank of Little River cave in. This is their soil that is causing the siltation and gradual filling of holes of water along the river.

We need help to make McCurtain County the garden spot of Oklahoma. I promise to continue to do my part.

Sincerely yours,
E.C. "Cotton" Gregory

P.S. I will answer any question anyone wished to present in writing with a self-addressed stamped envelope.

Texas Department of Transportation

DEWITT C. GREER STATE HIGHWAY BLDG. • 125 E. 11TH STREET • AUSTIN, TEXAS 78701-2483 • (512) 463-8585

Supervisor	
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

August 31, 1994

Mr. Jerry J. Brabander
Field Supervisor
U.S. Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

Thank you for the opportunity to review and comment on the Draft Ouachita Rock-pocketbook Recovery Plan (Plan). We have these comments:

> Please use the abbreviation TxDOT to refer to the Texas Department of Transportation in the plan. 5

> TSDH (TxDOT) is scheduled for an estimated $2000 contribution in each of three years for cooperative projects to increase restoration and protection of degraded habitat and populations (Page 79, Implementation Schedule, Task number 3.22 under responsible party). How was this contribution determined? 6

We have asked our Paris, TX, district to compile a list of all projects planned within the drainages potentially occupied by this mussel (Howells 1993) so that we may plan appropriate actions. We will consult with the Arlington, TX office of USFWS for this species, unless otherwise instructed. 7

We look forward to constructive planning to ensure that our actions are not detrimental to any of the stream fauna.

Sincerely,

For Dianna F. Noble, P.E.
Director of Environmental Affairs

An Equal Opportunity Employer

Supervisor	
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

Heart of the Hills Research Station
HC07, Box 62
Ingram, TX 78025
1 September 1994

Jerry J. Brabander
U.S. Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Sir:

I recently received and read the draft Recovery Plan for Ouachita rock-pocketbook (Arkansia wheeleri). I find it well put together and have few comments. Martinez did an excellent job. Several points worth mentioning include:

(1) Page 8; collections of Arkansia in Texas:

- Aside from the specimen taken by J.A.M. Bergman in Pine Creek, Lamar Co., TX, a second specimen was found by C.M. Mather and J.A.M. Bergman on 8 August 1993 in adjacent Sanders Creek some distance below Pat Mayse Reservoir (USACE reservoir), Lamar Co., TX. The second individual was also relatively-recently dead. 8
- On 8 and 9 August 1993, C.M. Mather (University of Science and Arts of Oklahoma), J.A.M. Bergman (Boerne, TX), along with myself, Vernon Hodges, and Jarret Marquart (TPWD, HOH, Ingram, TX) surveyed areas on both Pine and Sanders creeks, Lamar Co., TX, and Crook Lake on Pine Creek. No additional Arkansia specimens were found.
- On 13 June 1994, Tony Castillo and Jarret Marquart (TPWD, HOH) surveyed areas on Pat Mayse Reservoir and Crook Lake primarily seeking local mapleleafs (Quadrula spp.) and pink papershell (Potamilus ohiensis) for electrophoretic analysis here. High water conditions prevented sampling Sanders and Pine creeks and confounded efficient sampling of the impoundments. No Arkansia were found.
- During the week of 8 August 1994, Caryn Vaughn (Oklahoma Natural Heritage Inventory) and her staff along with Mather and Bergman again attempted to sample Pine and Sanders creek as well as Bois de Arc Creek to the west. However, again high water thwarted successful sampling. Neither Vaughn (pers. comm.) nor Bergman and Mather (pers. comm.) found Arkanisa.

(2) Page 15; Impoundments and Channelization:

Pat Mayse Reservoir was constructed long before Arkansia was found in Sanders Creek; the reservoir occupies much of that short system. During the 8 August 1993 survey of Sanders Creek below Pat Mayse Reservoir, virtually all discharge from the dam had been stopped leaving the creek with little or no flow. Heavy rock rubble has been placed below the dam, presumably to protect from scouring discharges that likely occur at other times. Survival of the benthic community downstream can likely be enhanced by suggesting minimum and maximum water releases. Because 9 the reservoir is fairly large and the creek below small and short, low-volume minimum releases could prevent water stagnation and could likely be easily accomplished with little disruption to general reservoir operation. Our general mussel survey work in rivers below reservoirs in Texas typically indicated most impoundment operators are completely oblivious to environmental impact of discharged (or non-discharged) waters.

Hopefully the above comments will be useful in completing your recovery plan. If I can help in any way, please do not hesitate to ask.

Sincerely,

Bob Howells

Bob Howells

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

Supervisor	9-8
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

September 6, 1994

Mr. Alan David Martinez
U.S. Fish and Wildlife Service
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Martinez:

I have reviewed the draft recovery plan for the Ouachita rock-pocketbook, Arkansia wheeleri, that you recently prepared. Overall, I thought the draft recovery plan to be well written, and I haven't any substantive comments on the bulk of the text. However, you may be 10
interested to know that in addition to Bergman's collection from Pine Creek (pg. 8), a recently dead shell of Arkansia wheeleri recently was found in nearby Sander's Creek. This small stream also is in Lamar County, Texas and is a tributary of the Red River. This information was given to me by Bob Howells of our Department who is responsible for mussel research in our state. Bob can be reached at: Texas Parks and Wildlife Dept., Heart of the Hills Research Station, HC-7, Box 62, Ingram, TX 78025, (210) 866-3356. Both Pine and Sanders creeks 11
subsequently have been designated as no-harvest mussel sanctuaries by our Department which will afford some protection for any existing populations. You may wish to reflect these changes in your draft plan where appropriate. If I can provide you further assitance on this matter, please don't hesitate to ask.

Sincerely,

Dr. David E. Bowles
Endangered Species Biologist

Supervisor	
Assistant	✓
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	✓
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

United States Department of Agriculture **Forest Service** **Ouachita National Forest** **P. O. Box 1270 Hot Springs, AR 71902**

Reply to: 2670

Date: September 8, 1994

Mr. Jerry J. Brabander, Field Supervisor
U.S. Fish and Wildlife Service
Ecological Services
222 South Houston, Suite A
Tulsa, Oklahoma 74127-8909

Dear Mr. Brabander:

We have reviewed the draft Ouachita Rock-pocketbook Recovery Plan and find it to be a thorough plan. We stand ready to assist where we can and as funding permits.

As you probably are aware we have worked with your office and Dr. Caryn Vaughn, 12
of the Oklahoma Natural Heritage Inventory to finance a Challenge Cost Share project to complete mussel surveys on the Tiak Ranger District covering major tributaries to both the Red and Little Rivers. The final report of that project is not due until December 31, 1994. Your office will be provided a copy upon our receipt of the report. It is our understanding that no Ouachita rock-pocketbook mussels were found in the tributaries. This probably completes our responsibility for task 2.3.

We are also interested in cooperating in life history/genetic or other similar 13
type studies utilizing our Challenge Cost Share Program for funding of small short-term projects as the opportunities arise and our funding allows. Please forward us any such proposals that you may be unable to fund for our consideration.

Thank you for the opportunity to review this draft. We look forward to working with you in implementing these actions.

Sincerely,

RICHARD W. STANDAGE
for
LARRY D. HEDRICK
Staff Officer, Fisheries, Wildlife, T&E and Range

cc: M. Bosch, R8
District Rangers, Tiak, Kiamichi, & Choctaw w/ Draft Recovery Plan

Supervisor
Assistant
Adornato
Aldrich
Brubeck
Collins
Frazier
Hensley
Langer
Martin
Martinez
Off. Asst.
Clk Typist
Reading
File/Toss

Oklahoma Biological Survey

Oklahoma Natural Heritage Inventory

OKLAHOMA BIOLOGICAL SURVEY
111 E. Chesapeake Street
Norman, Oklahoma 73019-0575, USA
(405) 325-1985
FAX: (405) 325-7702

8 September 1994

Jerry L. Brabander, Field Supervisor
U.S. Fish and Wildlife Service
222 S. Houston, Suite A
Tulsa, Oklahoma 74127-8909

Dear Mr. Brabander:

I have reviewed the draft Ouachita Rock Pocketbook Recovery Plan. The plan is well-written and designed. When implemented it should aid in the recovery of *Arkansia wheeleri*. Specific comments are listed below. These comments are submitted on behalf of myself and the Oklahoma Natural Heritage Inventory.

1. Executive Summary, under Current Status. Need to add that we now know of an existing small population in the Little River in Oklahoma. 14

2. Page 3, 2nd paragraph. In the Little River *A. wheeleri* is more easily confused with *Amblema plicata* than with *Quadrula pustulosa*. 15

3. Page 7, 3rd paragraph. An additional location for *A. wheeleri* in the Kiamichi River was found by myself in August 1993. Two live individuals were found in a large mussel bed immediately above where the Kiamichi River becomes Lake Hugo. 16

4. Page 8, 2nd paragraph. In 1994 myself and assistants surveyed the Little River from I-70 to the mouth of the Mountain Fork River. Single live *A. wheeleri* were found at two sites. Survey efforts on the Little River are not complete. Weather permitting, we will survey from the mouth of the Mountain Fork to the Rolling Fork River in Arkansas during mid to late September, 1994. 14

5. Page 11, top of page. The habitat associations listed here are from a preliminary report from 1992. A more accurate habitat description, extracted from Vaughn et al. (1993) is given below: 17

"*Arkansia wheeleri* occurs in both pools and backwaters in the Kiamichi River, not just backwaters as was previously believed. However, while pool and backwater habitats are common in the Kiamichi River, *A. wheeleri* only occurs in a select few of them. Pools and backwaters where *A. wheeleri* occur have in common an (1) abundant and diverse assemblage of mussels, (2) bottom substrata that are stable and contain adequate amounts of fine gravel/coarse sand, (3) low current (but not stagnant), (4) low siltation, and (5) proximity to tributaries, emergent vegetation, riffles and gravel bars.

Although pools and backwaters were considered different habitat types in this study, in most cases they are tightly interconnected and share many characteristics in common. Backwater areas tend to be shallower and have finer substrata. As backwaters merge into the main river channel they turn into deeper pools with coarser substrata and slightly higher current velocity. As stated before, at our sites *A. wheeleri* occurred in both of these microhabitats. In addition we believe *A. wheeleri* moves back and forth between these habitats either voluntarily or through physical displacement of shifting sediments. As described in the Results section, individuals at site three that were repeatedly recaptured had not moved. However, at another site (site five) we found unmarked individuals in the backwater area only for two years (1990 and 1991), and then in the pool area alone in 1992. At this site the backwater and pool were interconnected. This site had undergone a great deal of sediment deposition during the high flow of spring 1992 and a great deal of the original backwater sediment was shifted to the pool area.

Recent studies addressing the substratum preferences of unionids have reached different conclusions and substratum preferences among unionids remain poorly understood. However, mussels are generally believed to be most successful in stable, sand-gravel mixtures and are generally absent from substrata with heavy silt loads (Cooper 1984, Salmon and Green 1983, Stern 1983, Way et al. 1990). Most unionid species can be found on a number of different substrata, but growth rates of individuals in each microhabitat can be quite different (Kat 1982, Hinch et al. 1989). Furthermore, many mussel species can occupy a wide range of habitats as a result of extensive larval dispersal over a heterogenous stream environment (Strayer 1981), but growth and reproduction may be optimized only under the habitat conditions described above. As an example consider *Amblema plicata*, the clearly dominant mussel species in the Kiamichi River. This species occurred in every microhabitat we examined (pool, backwater, riffle, run) and at every site we examined. Its density, however, was not the same in all of these habitats. The greatest numbers of individuals were found in the large, diverse mussel beds where *A. wheeleri* also occurred. It is clearly able to "survive" in a large number of habitats, but its survival and growth is only optimized in "good" habitat (Strayer 1981).

The key to the distribution of *A. wheeleri* in the Kiamichi River is the presence of the large mussel beds where other mussel species thrive. These shoals represent optimal habitat for most mussel species, as evidenced by the large number of species and their high abundance. These shoals usually contain both pool and backwater areas,

Oklahoma Natural Heritage Inventory comments

have significant gravel bar development with accompanying vegetation (dominated by *Justicia americana*), and are close to a tributary (usually within one quarter mile). Shoals are usually adjacent to a major riffle area, although they can be either up or downstream of the riffle.

While other mussel species may survive in less than optimum habitat, *A. wheeleri* clearly cannot. They only survive in the best available habitat. Other studies have shown that these mainstream river shoals in shallower areas with slow, steady current and vegetation and coarse substrate are optimal habitat for lotic unionids because of minimal turbulence, low silt and steady food supply (Salmon and Green 1982).

In summary, *A. wheeleri* does not show a habitat preferences that is unique from other unionids in the Kiamichi River. However, *A. wheeleri* only occurs in the best available habitat for mussels."

In addition, I have recently completed some additional analyses of A. wheeleri ecological associations. These are detailed in the following manuscript: Vaughn, Caryn C. and Mark Pyron. Population Ecology of the Ouachita Rock Pocketbook Mussel, *Arkansia wheeleri* (Bivalvia: Unionacea), in the Kiamichi River, Oklahoma. this manuscript is currently in review for the *American Malacological Bulletin*. I have enclosed a copy.

6. Page 11, bottom of first paragraph. The fact that Vaughn and Pyron (1992) did not find *A. wheeleri* in "muddy or silty" substrates like other surveys has to do with how one defines a substrate type. We actually measured substrate particle sizes using standard USGS techniques. Using this methodology, the finest substrate that *A. wheeleri* occurred in would have been sand, and we report this habitat association in Vaughn and Pyron (1992) and Vaughn et al. (1993). This sandy substrate type is the prevalent one in shallow backwaters where Wheeler (1918), Isely (1925) and Clarke (1987) did their sampling. They refer to this sand as "muddy and silty" but they did not measure particle sizes, and according to USGS standards it would be sand. I found no areas in the Kiamichi River that geologically could be defined as silt that contained mussels. 18

7. Page 12, 2nd and 3rd paragraphs. The following material from Vaughn et al. (1993) should be incorporated: 19

"Because of its rarity, the reproductive biology of *A. wheeleri* remains unknown. Like other anodontines, it is probably bradytictic. The closest relative of *A. wheeleri*, *Arcidens confragosus*, becomes gravid in the fall and releases glochidia in the spring (Clarke 1981). We were unable to obtain any gravid *A. wheeleri* and thus obtained no glochidia. *A. wheeleri* glochidia are probably similar to other alasmidontine

3

Oklahoma Natural Heritage Inventory comments

glochidia. Alasmidontine glochidia are asymmetrical and have a stylet covered with microstylets which facilitate attachment to the fish host. Glochidial releases are probably tied to natural water temperature changes in the spring and fall (Jirka and Neves 1992).

The fish host or hosts of *A. wheeleri* remain unknown. However, we have identified strong possibilities for the fish host species. *A. wheeleri* was positively associated with several cyprinid species which were found to harbor glochidia. *Notropis (=Lythrurus) umbratilis*, the redfin shiner, inhabits "sluggish pools lined with water willows (*Justicia americana*) over gravel or sand substrates" (Robison and Buchanan 1988). This is the same habitat occupied by *A. wheeleri*. *N. umbratilis* is widespread in the Mississippi and Ohio valleys and in the southern Great Lakes tributaries as far north as western New York, southern Ontario, southern Michigan and Wisconsin, and southeastern Minnesota. It occurs south in the Mississippi valley to the Red River drainage but is uncommon in tributaries east of the Mississippi River. It occurs west to central Kansas and Oklahoma in the Missouri, Arkansas and Red River drainages."

Notropis suttkusi, a new species of cyprinid from the Ouachita uplands of Oklahoma and Arkansas, was recently described by Drs. Julian Humphries at Cornell University and Robert C. Cashner at the University of New Orleans (Humphries and Cashner 1994). The range of *N. suttkusi* is from the Blue River throughout the Little River drainage, and includes the Kiamichi River (R.C. Cashner, pers. comm.). The taxonomy of the species in the Ouachita River is unresolved (R.C. Cashner, pers. comm.).

8. Page 14, first paragraph. Please see the discussion of factors affecting mussels in: Mehlhop, Patricia and Caryn C. Vaughn. 1994. Threats to and sustainability of ecosystems for freshwater mollusks. Pp. 68-77 in Covington, W. and L.F. Dehand (eds)., Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management. General Technical Report Rm-247 for Rocky Mountain Range and Forest Experimental Station. U.S. Forest Service, U.S. Department of Agriculture, Fort Collins, CO. 363 pp. A copy of this paper is attached.

9. Page 16, second paragraph. The current data from the Little River back up this 20
statement. While relict shells of *A. wheeleri* occur throughout the lower reaches of the river, live specimens have only been found in the mussel beds that are the furthest away from Pine Creek Reservoir.

10. Page 17, 2nd paragraph. Like Clarke (1987), in our surveys this summer we 21
also found that mussel diversity improves dramatically the closer one gets to the confluence with the Mountain Fork River (above Broken Bow) and away from Pine Creek Reservoir. We have also found that the mussel beds near the confluence with

Oklahoma Natural Heritage Inventory comments

the Mountain Fork are healthier; that is, they contain fewer dead specimens than those near Pine Creek Reservoir. We are presently in the process of quantifying this by counting the number of dead versus live shells in each quadrat that we sample in the Little River. Mussel populations below Pine Creek Reservoir are not doing well and cold water from Pine Creek Reservoir is certainly part of the problem. Effluent from the paper mill at Wright City is also a factor.

We have not yet sampled in the Little River below the confluence with the Mountain Fork River. These data will be collected shortly and will be made available to the U.S. Fish and Wildlife Service as soon as they are collected. We will be looking at shell size distributions to see if there have been any effects of the cold water discharge from Broken Bow Reservoir on mussel size distributions. This will allow us to make inferences about recruitment. Mussels are long-lived organisms and one cannot tell if a population is doing well by simply looking at diversity and abundance. You could have a diverse, old population that is managing to hang on but is not reproducing. Such a population will eventually go extinct.

11. Page 19, top of page. Please add the following material from Vaughn et al. (1993): 22

"It appears that historically *A. wheeleri* did equally well above and below Jackfork Creek (Clarke 1987). Historically, *A. wheeleri* occurred at least seven sites between Clayton and Antlers. However, in five years of combined sampling effort by Mehlhop and Miller, 1988-1989, and ourselves,1990-1992, we have only found three subpopulations of *A. wheeleri* below Jackfork Creek. Therefore, only three out of seven or 43% of the known subpopulations of *A. wheeleri* survive below Jackfork Creek. In contrast, three out of four or 75% of the historical locations of *A. wheeleri* above Jackfork Creek have been confirmed and five new locations have been discovered (Mehlhop and Miller 1989, Vaughn 1991). The fourth historical location above Jackfork Creek has not been adequately surveyed and may well contain a subpopulation of *A. wheeleri*. This site cannot be surveyed because of threats from a landowner along the river. One new location was discovered directly above the top of Hugo Reservoir in August, 1993. In addition, the relative abundance of *A. wheeleri* is slightly higher above Jackfork Creek than below. Unfortunately, we have no historical abundance data for *A. wheeleri* in the Kiamichi River.

Overall mussel densities vary both above and below Sardis Reservoir and relative abundances of most mussel species are not significantly different above and below the reservoir. However, in any mussel survey it is easier to find large adults than small, secretive juveniles. As shown above with the *A. wheeleri* data, most adult mussels were probably produced before the reservoir was filled. Therefore, a finding of no differences in relative abundances of adult mussels above and below the

5

Oklahoma Natural Heritage Inventory comments

reservoir may actually be a reflection of habitat conditions before reservoir construction. To determine the effects of Sardis Reservoir on the recruitment of mussels in the Kiamichi River we examined the size distribution of *Amblema plicata*. *A. plicata* is a generalist mussel species that is extremely abundant in the Kiamichi River and occurred at all of our sites. Many juvenile mussels are extremely difficult to identify to species, but juvenile *A. plicata* are readily identifiable. Shell lengths of live *A. plicata* from above Sardis reservoir were significantly different than shell lengths of live *A. plicata* from below the reservoir. These data indicate that recruitment of *A. plicata* is reduced below Sardis Reservoir. Smaller *A. plicata* were much more common above Sardis Reservoir than below. Because *A. plicata* is a common, tolerant species, any reductions in its recruitment may signify similar problems with most mussel species in the community.

Recently malacologists have voiced concerns that many North American unionid 23
populations are composed of slowly dwindling numbers of long-lived adults destined
for extirpation as pollution and other disturbances prevent juvenile recruitment to aging
populations (McMahon 1991). The lowest average number of glochidia found in the
drift occurred at sites 4 and 5, the two sites below and closest to the confluence with
Jackfork Creek.

To date we have found no water chemistry differences at sites above and below
Sardis Reservoir. However, this study was designed to gather broad information on
river habitats used by *A. wheeleri* and is not an intensive investigation of water quality
dynamics in proximity to Jackfork Creek. Nevertheless, we have observed large 24
physical differences in water level and flow regime fluctuations above and below
Sardis Reservoir. For example, site 4 (Clayton) is almost directly below the
confluence with Jackfork Creek. The measured summer flow rates at this site are
typically much higher than the other sites because of water being released from the
reservoir. Periodic scouring of substrata exposed to high flow velocities can remove
both substrata and mussels and prevent their successful resettlement (Young and
Williams, 1983; McMahon, 1991). When we visited site 7 during the summer of 1991
water levels had obviously just dropped drastically. Our evidence for this was the
large number of small pools on gravel bars that harbored live but rapidly perishing fish
and mussels. We counted over 100 stranded mussels at this site. Water level
variation can have significant effects on mussel survival and may pose a significant
threat to *A. wheeleri* at sites below the confluence of Jackfork Creek. Declining water
levels expose relatively immotile mussels for weeks or months to air. It is doubtful
that *A. wheeleri* can withstand such long air exposure, especially during the hot
southeastern Oklahoma summer. Water temperature in some of the pools of stranded
animals exceeded 35^{0}C. Adult mussels are fairly sedentary in habit. While most
species are adapted to seasonal changes in water levels and flow rates, they cannot

move fast enough to respond to unpredictable and rapid changes in water level and flow rate.

Rivers regulated by dams differ from free-flowing rivers in many ways and alteration in volume of flow and timing of discharge can seriously impact riverine fauna. Stream organisms, including mussels, have evolved in rivers that experience seasonal low-flow and high-flow periods (Meador and Matthews 1992). Fluctuating flows, especially if there will be lower flows for long periods to time, will result in the stranding of many mussels. Unlike fish species which can move rapidly in and out of microhabitats with changes in water levels, mussels move very slowly and are unable to respond to sudden drawdowns. Even if stranding doesn't actually kill a mussel, desiccation and thermal extremes will cause physiological stress and may reduce reproductive potential (McMahon 1991). We have already observed significant stranding of mussel individuals in the Kiamichi River below Sardis Reservoir (Vaughn and Pyron 1992).

Fluctuating flows also mean that transport of particulates will vary. Depending on the 25
flow schedule and the materials normally transported in the water column, there is the potential for loss of organics which are the food base for mussels.

Increased flows associated with river regulation have the potential to alter the 26
distribution of sediment through scour, flushing, and deposition of newly eroded materials from the banks. Increased flows have the potential to activate the bed (i.e. actually cause the bottom of the river to move). Bedload movement will wreak havoc on the survival of many mussels, particularly juveniles (Young and Williams 1983). Erosion caused by increased flows at one location results in deposition of this material further downstream. This "zone of aggradation" results in an increased width/depth ration of that portion of the channel. As width/depth ratios increase the potential for bedload transport also increases. Thus, increased flows cause habitat loss through both sediment deposition and increased bed mobility.

Sediment deposition not only removes habitat, but also clogs mussel siphons (i.e. smothers them) and interferes with feeding and reproduction (Aldridge et al. 1987).

In the long term, higher base flow levels and shorter periods between peak flood 27
periods will decrease habitat complexity by preventing the formation of islands, establishment of macrophyte beds etc... (Frissell 1986). Stabilized sediments, sand bars, and low flow areas, are all preferred unionid habitats (Hartfield and Ebert 1986, Payne and Miller 1989, Stern 1983, Way et al. 1990). It is around these "complex" areas that most mussel beds in the Kiamichi River, and indeed the highest diversity of stream fauna, are found.

Oklahoma Natural Heritage Inventory comments

Flow regulation not only has the potential to profoundly effect the stream fauna, but 28
riparian fauna as well. Flood waters that normally recharge soils and aquifers may be rapidly exported downriver. Lowered water tables may cause shrinkage of the riparian corridor and shifts in terrestrial species composition (Allan and Flecker 1993, Smith et al. 1991).

Because of their dependence on the appropriate substrate and flow conditions, 29
freshwater mussels, including *A. wheeleri*, are already naturally patchily distributed in rivers. Any further fragmentation, such as the construction of a reservoir, will act to increase patchiness and to increase the distance between patches. These effects may have major consequences for the metapopulation (i.e. local or subpopulations connected by infrequent dispersal) structure of *A. wheeleri* (Vaughn 1993b). As some subpopulations are eliminated and dispersal distances are increased between other subpopulations, demographic and genetic constraints will diminish the ability of this species to respond to even natural stochastic events much less human-induced environmental change (Wilcox 1986, Murphy et al. 1990).

Timber harvesting operations can have significant effects on both stream water 30
quantity and quality. The influence of catchment vegetation on stream discharge is dependent on a large number of variables, many of which are site-specific. However, in general, removal of forest vegetation increases stream runoff (Campbell and Doeg 1989) and leads to many of the effects of increased flows discussed above.

Road-building activities and low water crossings associated with logging can lead to 31
the development of "headcuts", or migrating knickpoints in the channel remote from areas of actual modification. Headcuts result in severe bank erosion, channel widening, and depth reduction and can have devastating effects on the mollusc fauna (Hartfield 1993).

12. Page 20. The following is also from Vaughn et al. (1993):

"Their sedentary life style and filter-feeding habits make mussels especially 32
vulnerable to chemical pollution events. Contaminants can destroy mussel populations directly by exerting toxic effects or indirectly by causing or contributing to the elimination of essential food organisms or host fish (Havlik and Marking 1987). To date, the Kiamichi River has remained relatively unpolluted, and this is one reason it maintains a generally healthy mussel fauna. Rivers near the Kiamichi, which have experienced more development, are rapidly losing their mussel faunas. For example, below the point where the Little River receives effluent from a paper mill, there have been massive mussel die offs.

Oklahoma Natural Heritage Inventory comments

Natural predation does not appear to be a threat to *A. wheeleri* in the Kiamichi River. Fresh shells found opened along the shore are predominately *Corbicula* (Vaughn and Pyron, pers. obs.). *Corbicula* have been shown to be the dominant prey of muskrats in other systems in which it has invaded (Neves and Odum 1989). 33

Zebra mussels (*Dreissena polymorpha*) are now found in the Arkansas River system in Oklahoma. The high dispersal capabilities of this species make it highly probable that it will invade the Red River system in the near future (French 1990). Invasion of the Kiamichi would most likely be from the two existing reservoirs, Sardis and Hugo, because this is where boats (with encrusted adults or water containing larvae) would be launched. The zebra mussel could then spread downstream from both reservoirs. Construction of the authorized Tuskahoma Reservoir would provide an additional entryway for zebra mussels into the Kiamichi. The exotic bivalve *Corbicula fluminea* may also pose a threat to *A. wheeleri* (Mehlhop and Miller 1989)." 34

13. Page 35. At the present time releases from Sardis Reservoir are from the surface and are warm. If cold, hypolimnetic releases were initiated these would threaten the *A. wheeleri* population downstream of Jackfork Creek. 35

14. Page 44, task 1.31. On-site population monitoring should include an assessment of current landuse immediately adjacent to and upstream of the site and a measure of riparian thickness and health. 36

15. Page 54, task 4.1.

Identification of the fish host might best be done by a molecular genetic approach (DNA fingerprinting). Such analyses are being used by other researchers to identify fish hosts of mussels (White 1993). The technique compares DNA obtained from glochidia found attached to fish to a battery of DNA's from adult mussels in the community. Even this approach would not guarantee identification of the fish host. Identification is contingent upon *A. wheeleri* still reproducing (unknown), fish being collected during the spawning season of *A. wheeleri* (unknown), and collection of the correct fish host (unknown). We have tissue of three *A. wheeleri* from the Kiamichi River stored in an ultracool freezer at the University of Oklahoma. This material could be made available to researchers for DNA fingerprinting once they work out the techniques on more common species. We also have preserved glochidia samples available for analysis. 37

16. Page 56, task 5.2. How will juveniles for such a study be obtained? Juveniles of most species of mussels, probably including *A. wheeleri*, are extremely difficult to tell apart. Juvenile *A. wheeleri* in the Kiamichi River are probably indistinguishable from 38

Oklahoma Natural Heritage Inventory comments

juvenile *Quadrula pustulosa* until they reach a certain size. In order to be able to carry out this task you will have to have a successful culture program.

17. Page 57, task 5.3. As written, I am not sure exactly what this means. I have already done a great deal of work comparing areas with and without *A. wheeleri* (see Vaughn et al. (1993) and attached manuscript by Vaughn and Pyron). Comparing areas with mussels to areas with no mussels at all would not yield much usable information. Please see recent articles by Strayer (1993), Strayer et al. (1994) and Strayer and Ralley (1993). 39

18. Page 62, task 9.1, last sentence. How will this be achieved under the confines of the Freedom of Information Act? 40

LITERATURE CITED

References not listed below are cited in Vaughn et al. (1993).

Humphries, J. M., and R. C. Cashner. 1994. *Notropis suttkusi*, a new cyprinid from the Ouachita uplands of Oklahoma and Arkansas, with comments on the status of Ozarkian populations of *N. rubellus*. Copeia 1994: 82-90.

Mehlhop, P. and C. C. Vaughn. Threats to and sustainability of ecosystems for freshwater mollusks. Pp. 68-77 in Covington, W. and L.F. Dehand (eds)., Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management. General Technical Report Rm-247 for Rocky Mountain Range and Forest Experimental Station. U.S. Forest Service, U.S. Department of Agriculture, Fort Collins, CO. 363 pp.

Pyron, M. and C.C. Vaughn. 1994. Ecological characteristics of the Kiamichi River. Report to the U.S. Fish and Wildlife Service, Tulsa, Oklahoma.

Strayer, D.L. 1993. Macrohabitats of freshwater mussels (Bivalvia: Unionacea) in streams of the northern Atlantic slope. Journal of the North American Benthological Society 12:236-246.

Strayer, D.L. and J. Ralley. 1993. Microhabitat use by an assemblage of stream-dwelling unionaceans (Bivalvia), including two rare species of *Alasmidonta*. Journal of the North American Benthological Society 12:247-258.

Strayer, D.L., D.C. Hunter, L.C. Smith, and C.K. Borg. 1994. Distribution, abundance, and roles of freshwater clams (Bivalvia, Unionidae) in the freshwater tidal Hudson River. Freshwater Biology 31: 239-248.

Oklahoma Natural Heritage Inventory comments

Vaughn, C.C., M. Pyron, and D.L. Certain. 1993. Habitat Use and Reproductive Biology of *Arkansia wheeleri* in the Kiamichi River, Oklahoma -Final Report. Oklahoma Department of Wildlife Conservation.

Vaughn, C.C. 1994. Survey for *Arkansia wheeleri* in the Little River. Final Report. U.S. Fish and Wildlife Service, Tulsa, Oklahoma.

Vaughn, C.C. and M. Pyron. Population ecology of the endangered Ouachita Rock Pocketbook Mussel, *Arkansia wheeleri* (Bivalvia: Unionacea), in the Kiamichi River, Oklahoma.

Thank you for allowing me to review the plan.

Sincerely,

Caryn C. Vaughn

Caryn C. Vaughn, Ph.D.

Submitted to American Malacological Bulletin 25 July 1994

Population Ecology of the

Endangered Ouachita Rock Pocketbook Mussel,

Arkansia wheeleri (Bivalvia: Unionacea),

in the Kiamichi River, Oklahoma

Caryn C. Vaughn and Mark Pyron[1]

Oklahoma Biological Survey and Department of Zoology

University of Oklahoma

Norman, OK 73019

Phone: (405) 325-2753 Fax: (405) 325-7702

E-mail: CVAUGHN@UOKNOR.EDU

Running head: Ouachita Rock Pocketbook Mussel in the Kiamichi River

Keywords: Unionacea, ecology, endangered species, Arkansia wheeleri

[1]Present address: El Verde Field Station, P.O. Box 1690, Luquillo, PR 00773

ABSTRACT

The only known remaining viable population of Arkansia wheeleri in the world occurs within a 128 km stretch of the Kiamichi River in Pushmataha County, Oklahoma. Within this river A. wheeleri occurs only within the most species-rich mussel beds. In its optimal habitat, A. wheeleri is always rare: mean relative abundance varies from 0.2 to 0.7% and the average density is 0.27 individuals/m^2. The youngest individual A. wheeleri encountered was approximately 12 years of age. Forty-three percent of the historically known subpopulations of A. wheeleri below where inflow from an impounded tributary enters the Kiamichi River have apparently been extirpated, and no new subpopulations have been located. A. wheeleri survive at 75% of the historically known locations above the impounded tributary and five new subpopulations have been located.

INTRODUCTION

Arkansia (syn. Arcidens) wheeleri (Bivalvia: Unionacea), the Ouachita Rock Pocketbook Mussel, is a federal endangered species (Federal Register 56(205):54950-54957). Originally named Arkansia wheeleri by Ortmann and Walker (1912), Clarke (1981, 1985) recognized Arkansia as a subgenus of Arcidens. The species is considered by Clarke to be distinct. However, Turgeon et al. (1988) have continued to use the binomial Arkansia wheeleri.

The historical distribution of Arkansia wheeleri was in the Ouachita and Little Rivers in Arkansas and the Kiamichi River in Oklahoma, all south-flowing rivers out of the Ouachita Mountains (Figure 1). A survey by Clarke (1987) indicated that the species is probably extirpated from the Ouachita River and severely depleted in the Little River in Arkansas. In 1992 and 1993, relict shells of A. wheeleri were found in the Little River in Oklahoma below Pine Creek Reservoir (Vaughn, 1993a).

Arkansia wheeleri was first reported from the Kiamichi River by Isely (1924) who conducted a survey of the river in 1911. Clarke (1987) and Mehlhop and Miller (1989) both conducted recent status surveys for A. wheeleri in the Kiamichi River. They found that A. wheeleri was patchily distributed and rare in the Kiamichi River from above Hugo Reservoir to Whitesboro (Figure 2). Since the construction of a dam and reservoir in the lower reaches of the Kiamichi in the 1970s, some of the backwater areas where it was known to occur have been destroyed (Valentine and Stansbery, 1971), and connection with potential habitats on the Red River and other tributaries to it has been blocked. Based on the above information A. wheeleri was listed as endangered in October, 1991 (Federal Register 56:54950-54957)

The objectives of this study were to determine the distribution and abundance of Arkansia wheeleri in the Kiamichi River, characterize the species' microhabitat, and determine movement, growth, and survivorship of individuals. We also examined the impact of a reservoir on the A. wheeleri population.

STUDY SITE

The Kiamichi River is a major tributary of the Red River. It flows for a total of 180 km through a 4,800 km^2 drainage area across the Ridge and Valley Belt of the Ouachita Mountain geologic province and the Dissected Coastal Plain province (Curtis and Han, 1972). The average gradient of the river is 0.47 m/km. Two reservoirs influence the river: Sardis Reservoir is an impoundment of Jackfork Creek, a tributary of the Kiamichi River. Hugo Reservoir is an impoundment of the lower Kiamichi River. The vegetation cover in the watershed can be described as a patchwork of forest made up of short-leaf and loblolly pine, mesic oak forests, and diverse bottomland habitats in various stages of maturity. Another large component of the watershed coverage is made up of pasture and other agricultural lands (Vaughn et al., 1993).

The Kiamichi River is located near the western edge of mussel diversity in the United States (Williams et al., 1992; Warren and Burr, 1994). Therefore, because of historical biogeographic factors, one would not expect diversity in the Kiamichi River to be as high as rivers in more eastern states. Nevertheless, the Kiamichi River has high mussel diversity for its size and geographic location. Fifty-five species of mussels are known from Oklahoma (Williams et al., 1992), and twenty-nine of these currently occur in the Kiamichi River (Vaughn et al., 1993). Only two species that were known historically from the Kiamichi River (Isley, 1924) no longer occur there. Several species of mussels from the Kiamichi River are endemic to rivers in the Ouachita Mountains, including Arkansia wheeleri, Ptychobranchus occidentalis (Conrad) and Villosa arkansasensis (Lea) (Pyron and Vaughn, 1994). P. occidentalis, the Ouachita kidney shell, is a C2 candidate for federal listing.

METHODS

Our quantitative survey efforts were restricted to areas that contained concentrations of mussels and thus could be defined as "beds". Mussel relative abundance and habitat data for 22 sites in the Kiamichi River were collected during July - August 1990. These sites included 11 areas defined as "pools", 6 areas defined as "backwaters", and 5 areas defined as "runs" (see discussion). Mussel surveys (timed to standardize sampling effort) (Kovalak et al., 1986; Green et al., 1985) were conducted by hand searching with the aid of SCUBA in deeper areas and by hand searches in shallow areas in the following manner: (1) a shoal was identified for surveying; (2) the entire area was searched by at least two people for one hour; (3) all mussels encountered were removed to shore; (4) all mussels were immediately identified; (5) mussels were put back in the water as close to where they were removed as possible.

At each of the 22 sites we measured water depth, water temperature, current velocity, conductivity, dissolved oxygen, and pH. Five measures of water depth and current velocity were taken across the mussel bed and averaged. Current velocity was measured 10 cm above the stream bottom with a Marsh-McBirney model 201 portable flow meter. Conductivity and dissolved oxygen were measured with YSI meters. pH was measured with a Fisher Accumet portable pH meter.

At each site we recorded proximity of the site to entering tributaries, islands, and macrophyte cover. Three replicate substratum samples were collected at each site. These were brought back to the laboratory and allowed to dry. Samples were dry sieved, weighed, and individual proportions of samples assigned to the appropriate substrate size class (in mm) following Hynes (1970, p. 24). Standard sieving techniques do not segregate particles greater than about 2 mm in diameter (i.e. gravel from pebble from cobble). To determine the proportion of fine gravel, coarse gravel, pebble, and cobble in samples we took the proportion of the sample greater than 2 mm in diameter and randomly measured the diameter of 100 particles in that subsample (Dunne and Leopold, 1978).

In 1991 we selected ten of the 22 sites as long-term population monitoring sites for Arkansia wheeleri (Figure 2). The ten sites were chosen to be as evenly distributed as possible along the Kiamichi River above Hugo Reservoir, but still be reasonably accessible and included sites where A. wheeleri had been located by us in 1990 and sites where it had been found historically (Mehlhop and Miller 1989, Clarke 1987) and sites above and below the impoundment on Jackfork Creek. Density and relative abundance data for mussel species at the ten monitoring sites were collected during July - August 1991. Densities were calculated from quadrat samples and relative abundances were estimated from timed searches, as described above. Quadrat sampling was done with quarter meter square PVC pipe quadrats. Fifteen random quadrats were sampled for each site. Quadrats were searched by hand, with the aid of SCUBA in deeper areas, until all mussels had been recovered to a depth of 15 cm. Individual mussels were returned to the mussel bed as in timed searches. All A. wheeleri found were measured using digital calipers (height, width, and length), and individually marked using numbered, laminated plastic fish tags. A. wheeleri were returned to the precise location from which they were captured.

To obtain additional information on Arkansia wheeleri size and age distribution we measured relict shells of A. wheeleri that had been deposited in the Oklahoma Museum of Natural History (OMNH) or that we found on the Kiamichi River between 1990 - 1992. We counted external annuli on the shells we had collected and those in the OMNH (Neves and Moyer, 1988; McMahon, 1991). We used the above data to calculate shell length, width and height vs. number of annuli regression lines. Shell height vs. number of annuli produced the best fit, and the resulting equation was used to predict the number of annuli for live mussels that had been measured in the field. We used Replicated Goodness of Fit tests (G_H) (Sokal and Rohlf, 1981) to compare size distributions of relict shells and live mussels, and to compare predicted age distributions of mussels above and below the impounded tributary.

We used several statistical techniques to explore relationships between Arkansia wheeleri distribution and abundance and measured habitat parameters. For all of these analyses we used the data collected from the 22 sites in 1990. Associations between A. wheeleri and other species of mussels were calculated using Spearman Rank correlations on relative abundance data (Ludwig and Reynolds, 1988). We used discriminant function analysis (SYSTAT, 1992) to predict the presence or absence of A. wheeleri at a site based on the habitat characteristics of that site. We used an independent sample t-test (one-tail) (Sokal and Rohlf, 1981) to compare species richness at sites with and without A. wheeleri.

RESULTS

Arkansia wheeleri were found in 10 of the 22 mussel beds that were sampled. Six of these 10 sites were classified as pools and four were classified as backwaters. A. wheeleri did not occur in any of the run areas sampled. A multivariate analysis of variance using all of the habitat variables to predict the presence or absence of A. wheeleri at a site was not significant ($F_{(12,9)} = 1.22$, $P = 0.39$). A significant discriminant model was produced using four habitat variables: depth, habitat type (pool, backwater, or run), presence or absence of emergent vegetation at the site, and mussel species richness (Table 1). This model successfully predicted the presence or absence of A. wheeleri 17 out of 22 times ($G_{(1)} = 7.72$, $P = 0.005$). Mussel species richness at a site was the best individual predictor of A. wheeleri occurrence (Table 1). Mussel sites where A. wheeleri occurred were more species-rich than other mussel sites that we sampled in the Kiamichi River (Figure 5, $t_{(15)} = 3.18$, P=0.006).

Spearman rank correlations of relative abundance data revealed three significant associations between Arkansia wheeleri and other mussel species. A. wheeleri was positively correlated with the relative abundance of Quadrula c.f.appiculata (r_s=0.437, P < .05) and Megalonaias nervosa (r_s = 0.423, P < .05), and negatively correlated with Lampsilis teres (r_s = -0.368, P < .05).

In most cases Arkansia wheeleri were located only through timed searches and did not occur in quadrat samples. Mean relative abundance of A. wheeleri at monitoring sites in 1990-92 is shown in Figure 3 and varied from 0.2% to 0.7%. In 1991, A. wheeleri was found in quadrat samples at two sites, 6 and 7. This allowed us to calculate the density of A. wheeleri at these two sites. The density of A. wheeleri was 0.27 individuals per square meter at both of these sites.

In both 1990 and 1991 we marked and released at the point of capture nine Arkansia wheeleri. In 1991 we recaptured only two marked individuals, although we found nine live individuals. Both recaptured A. wheeleri were found at site 3 (Figure 2). Both of these individuals were found within one meter of where they were released in 1990. No other live A. wheeleri were found at site 3. In 1992 we recaptured the same two A. wheeleri at site 3 that we had recaptured in 1991. The individuals were within a few meters of where they had been released in 1991. The recaptured individuals had not grown discernably (i.e. more than 1 mm, within the margin of error of our calipers). No other marked A. wheeleri were recaptured in 1992. The size distribution (means for 1990 - 92) for A. wheeleri in the Kiamichi River is shown in Figure 4.

The overall size distribution of relict shells in the OMNH (n = 50) was significantly different than the size distribution of live Arkansia wheeleri in the Kiamichi River (n = 43) (Figure 4, $G_{H(5)} = 23.1$, $P < .001$). The resulting regression equation for number of annuli on shell height was $Y = (-.483)X + 49.62$ ($n=24$, $R^2=0.467$, $P < 0.05$). Predicted ages based on number of annuli for live A. wheeleri from the Kiamichi River are shown in Figure 5. Predicted age distributions of spent shells vs. live A. wheeleri were also significantly different ($G_{H(12)} = 57.43$, $P < .001$). Using this technique, the youngest predicted age for a live A. wheeleri was 12 years. If this estimate is accurate, none of the A. wheeleri we encountered on the Kiamichi River during our study were produced after Sardis Reservoir was filled in 1983.

Arkansia wheeleri occurs both above and below the inflow to the Kiamichi River from Sardis Reservoir via Jackfork Creek. Of our ten monitoring sites, three were located above Sardis Reservoir and seven below (Figure 2). All of these sites historically harbored A. wheeleri. A. wheeleri was found during this study at all three sites (100%) above Sardis Reservoir. A. wheeleri was found at three of seven (43%) of the sites below the reservoir inflow. The relative abundance of A. wheeleri at sites above Sardis reservoir was on average greater than the relative abundance of A. wheeleri at sites below the reservoir (Figure 3), although these differences were not statistically significant.

DISCUSSION

Prior to this study, the habitat of Arkansia wheeleri was reported to be backwater reaches of rivers where current is slow and where there are relatively non-shifting deposits of silt/mud and sand (Wheeler, 1918; Isely, 1924; Clarke, 1987). We found that A. wheeleri occurs in both pools and backwaters in the Kiamichi River, not just backwaters as was previously believed. The distribution of A. wheeleri may have been underestimated in past surveys because backwaters are relatively easy to survey, whereas pools often require SCUBA techniques.

Although pools and backwaters were considered different habitat types in this study, in reality they are tightly interconnected and share many characteristics in common. Backwater areas tend to be shallower and have finer substrata. As backwaters merge into the main river channel they turn into deeper pools with coarser substrata and slightly higher current velocities. In the Kiamichi River Arkansia wheeleri occurs in both of these habitats. In addition we believe A. wheeleri moves back and forth between these habitats either voluntarily or through physical displacement of shifting sediments. Locomotory tendencies differ among different mussel species. For example, Anodonta grandis (Say) migrate up and down with changes in water level (White, 1979) and in this way avoid stranding at low water. Other species such as Uniomerus tetralasmus (Say) and the introduced Corbicula fluminea (Muller) remain in position and suffer prolonged exposure to air (McMahon, 1991). Marked individual A. wheeleri in a backwater area (site 3) did not move significantly from July 1990 to July 1992. However, at another site (site 5) unmarked individuals moved from a backwater area into the adjacent pool area. This movement was probably the result of physical displacement of these individuals through sediment scour and redeposition.

Unlike previous surveys (Wheeler, 1918; Isely, 1924; Clarke, 1987), we did not find Arkansia wheeleri to be restricted to areas where the substratum was predominantly mud or fine sand. In the Kiamichi River A. wheeleri is just as prevalent in gravel/cobble/coarse sand substrata (which predominates in pools) as in finer substrata. Recent studies addressing the substratum preferences of unionids have reached different conclusions, and substratum preferences among unionids remain poorly understood. However, mussels are generally believed to be most successful in stable, sand-gravel mixtures and are generally absent from substrata with heavy silt loads (Cooper 1984, Salmon and Green 1983, Stern 1983, Way et al. 1990). Most unionid species can be found on a number of different substrata, but growth rates of individuals in each microhabitat can be quite different (Kat 1982, Hinch et al. 1989). Furthermore, many mussel species can occupy a wide range of habitats as a result of extensive larval dispersal over a heterogenous stream environment (Strayer 1981), but growth and reproduction may be optimized only under the habitat conditions described above.

Arkansia wheeleri only occurred at the most species-rich sites in the Kiamichi River. These shoals represent optimal habitat for most mussel species, as evidenced by the large number of species and their high abundance. These shoals usually contain both pool and backwater areas, have significant gravel bar development with accompanying vegetation (dominated by Justicia americana), and are close to a tributary (usually within one quarter mile). Shoals are usually adjacent to a major riffle area, although they can be either up or downstream of the riffle. Other studies have shown that these mainstream river shoals in shallower areas with slow, steady current and vegetation and coarse substrate are optimal habitat for lotic unionids because of minimal turbulence, low silt and steady food supply (Salmon and Green, 1982).

In the majority of mussel species the greatest amount of growth occurs in the first few years of life. Shell growth rate then declines exponentially with age, although the rate of tissue biomass accumulation usually remains constant (McMahon, 1991). Our examination of live Arkansia wheeleri in the Kiamichi River and of relict A. wheeleri shells in the museum collections indicate that this growth pattern is also followed by A. wheeleri. Early annuli (those near the umbo) are much wider than later annuli near the edge of the shell.

Recruitment, growth and survival of mussels is often assessed by monitoring changes in density and size demography of natural populations (Payne and Miller, 1989). We have no quantitative historical data on densities of Arkansia wheeleri in the Kiamichi River or anywhere else. Past size distribution, however, can be assessed by examining the size distribution of relict shells. The size distribution of live A. wheeleri in the Kiamichi River is skewed to the left (Sokal and Rohlf, 1981) (Figure 4) with more large individuals and fewer small individuals than one would expect from a statistically normal distribution. The size distribution of relict shells (Figure 4) follows a more normal distribution, with a greater proportion of smaller individuals than in the live population. Looking at these shell length data alone one would conclude that the size distribution of A. wheeleri in the Kiamichi River has changed over time and recruitment has decreased.

External annular rings have long been used to determine mussel age and growth rates. Recently this technique has been criticized as being replete with problems (Neves and Moyer, 1988; Downing et al., 1992). Natural erosion and corrosion of shells makes it difficult to distinguish true from false annuli. For example, false annuli can be formed by the incorporation of small substrate particles into mussel shells. It is difficult to count closely deposited growth lines near the margins of old shells. This produces an underestimate of shell age that becomes more erroneous with shell age. Downing et al. (1992) studied populations of Lampsilis radiata (Gmelin) and Anondonta grandis (Say) in an oligotrophic lake. In these populations, many mussels showed no new external annuli at all, even several years after individual animals had been marked. They concluded that estimates of growth based on shell annuli consistently overestimated real shell growth. In addition, shell size and growth rates are linked to environmental conditions. For example, some species form narrower shells in coarser substrates (Hinch et al., 1989) or grow faster in sand than in mud (Hinch et al., 1986). However, taking into account the large margin of error in using this method, most Arkansia wheeleri encountered in the Kiamichi River are old. Using this method, the youngest live A. wheeleri we encountered was approximately 12 years in age. No juveniles were encountered. Both types of data, shell-size distributions and ages predicted from external annuli, demonstrated that most A.

wheeleri encountered in the Kiamichi River are old.

Because of its rarity, the reproductive biology of Arkansia wheeleri remains unknown. Like other anodontines, it is probably bradytictic. The closest relative of A. wheeleri, Arcidens confragosus (Say), becomes gravid in the fall and releases glochidia in the spring (Clarke, 1981). We were unable to obtain any gravid A. wheeleri and thus obtained no glochidia. A. wheeleri glochidia are probably similar to other alasmidontine glochidia. Alasmidontine glochidia are asymmetrical and have a stylet covered with microstylets which facilitate attachment to the fish host. Glochidial releases are probably tied to natural water temperature changes in the spring and fall (Jirka and Neves, 1992).

It appears that historically Arkansia wheeleri did equally well above and below the impounded tributary to the Kiamichi River (Clarke, 1987). Historically, A. wheeleri occurred in at least seven sites below the tributary. However, in five years of combined sampling effort by Mehlhop and Miller (1989), 1988-1989, and ourselves, 1990-1992, only three subpopulations of A. wheeleri have been found below Jackfork Creek. Therefore, only three out of seven or 43% of the known subpopulations of A. wheeleri survive below Jackfork Creek. In contrast, three out of four or 75% of the historical locations of A. wheeleri above Jackfork Creek have been confirmed and five new locations have been discovered. No new locations have been discovered below Jackfork Creek despite intensive survey efforts. In addition, the relative abundance of A. wheeleri is slightly higher above Jackfork Creek than below. Unfortunately, we have no historical abundance data for A. wheeleri in the Kiamichi

River.

The greatest threats to the continued existence of Arkansia wheeleri in the Kiamichi River are land use changes, including further impoundment of the river, water transfers, timber harvesting, and pollution from agricultural and industrial development (Neves 1993, Mehlhop and Vaughn 1994). A. wheeleri is also threatened by the invasion of exotic bivalve species, particularly the zebra mussel, Dreissena polymopha. D. polymorpha are now found in the Arkansas River system in Oklahoma. The high dispersal capabilities of this species make it highly probable that it will invade the Red River system, including the Kiamichi River, in the near future (French 1990).

ACKNOWLEDGEMENTS

We thank John Alderman, Tambra Browning, David Certain, Julian Hilliard, David Martinez, Estelle Miller, David Partridge, and Matthew Winston for help with field work at various times. Matthew Craig performed the annuli counts on Arkansia wheeleri and Christopher Taylor commented on the manuscript. This study was funded by the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation through Endangered Species Act funding (project E-12).

LITERATURE CITED

Clarke, A. H. 1981. The tribe Alasmidontini (Unionidae: Anodontinae), Part I: Pegias, Alasmidonta and Arcidens. Smithsonian Contributions to Zoology 326:85-89.

Clarke, A.H. 1985. The tribe Alasmidontini (Unionidae: Anodontinae), Part II: Lasmigona and Simpsonaias. Smithsonian Contrib. to Zoology no. 399. 75 pp.

Clarke, A.H. 1987. Status survey of Lampsilis streckeri Frierson (1927) and Arcidens wheeleri (Ortmann & Walker, 1912). Unpubl. Report no 14-16-0004-86-057 to U.S. Fish and Wildlife Service, Jackson, Mississippi.

Cooper, C.M. 1984. The freshwater bivalves of Lake Chicot, an oxbow of the Mississippi in Arkansas. Nautilus 98:142-145.

Curtis, N.M. and W.E. Han. 1972. Geomorphic Provinces in Oklahoma in Geology and Earth Resources of Oklahoma. Oklahoma Geological Survey, Educational Publication 1. Page 3.

Downing, W.L., J. Shostell and J.A. Downing. 1992. Non-annual external annuli in the freshwater mussels Anodonta grandis grandis and Lampsilis radiata siliquoidea. Freshwater Biology 28:309-317.

Dunne, T. and L.B. Leonard. 1978. Water in Environmental Planning. W.H. Freeman and Co., New York.

French, J. R. P. 1990. The exotic zebra mussel - a new threat to endangered freshwater mussels. Endangered Species Technical Bulletin 15:3-4.

Green, R. H., S. M. Singh, and R. C. Bailey. 1985. Bivalve Molluscs as Response Systems for Modelling Spatial and Temporal Environmental Patterns. The

Science of the Total Environment 46:147-169.

Hinch, S. G., R. C. Bailey, and R. H. Green. 1986. Growth of Lampsilis radiata (Bivalvia: Unionidae) in sand and mud: a reciprocal transplant experiment. Canadian Journal Fisheries and Aquatic Sciences 43:548-552.

Hinch, S. G., L. J. Kelly, and R. H. Green. 1989. Morphological variation of Elliptio complanata (Bivalvia: Unionidae) in differing sediments of soft-water lakes exposed to acidic deposition. Canadian Journal of Zoology 67:1895-1899.

Hynes, H.B.N. 1970. The Ecology of Running Water. University of Toronto Press. 555 pp.

Isely, F.B. 1924. The freshwater mussel fauna of eastern Oklahoma. Proceedings of the Oklahoma Academy of Science 4:43-118.

Jirka, K.J. and R.J. Neves. 1992. Reproductive biology of four species of freshwater mussels (Mollusca: Unionidae) in the New River, Virginia and West Virginia. Journal of Freshwater Ecology 7:35-44.

Kat, P. W. 1982. Effects of population density and substratum type on growth and migration of Elliptio complanata (Bivalvia: Unionidae). Malacological Review 15:119-127.

Kovalak, W.P., S.D. Dennis, and J.M. Bates. 1986. Sampling effort required to find rare species of freshwater mussels. Pp 46-59 in, B.G. Isom (ed), Rationale for Sampling and Interpretation of Ecological Data in the Assessment of Freshwater Ecosystems. American Society for Testing and Material, Special Technical Publication No. 894.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical Ecology. John Wiley & Sons. 337 pp.

McMahon, R.F. 1991. Mollusca: Bivalvia. Pp. 315-390 in, J.H. Thorp and A.P. Covich, eds., Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. New York.

Mehlhop, P., and E.K. Miller. 1989. Status and distribution of Arkansia wheeleri Ortmann & Walker, 1912 (syn. Arcidens wheeleri) in the Kiamichi River, Oklahoma. Unpublished report no. 21440-88-00142 to U.S. Fish and Wildlife Service, Tulsa, Oklahoma.

Mehlhop, P. and C.C. Vaughn. Threats to and sustainability of ecosystems for freshwater mollusks. Pp __ to __ in General Technical Report No. __ for Rocky Mountain Range and Forest Experimental Station. U.S. Forest Service, U.S. Department of Agriculture. In press.

Neves, R. J. 1992. A state-of-the-unionids address. Pp. 1-10 in, Cummings, K.S., A.C. Buchanan and L. M. Koch (eds)., Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.

Neves, R.J. and J.C. Widlak. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Bulletin 5:1-7.

Neves, R.J. and S.N. Moyer. 1988. Evaluation of techniques for age determination of freshwater mussels (Unionidae). American Malacological Bulletin 6:179-188.

Ortmann, A.E. and B. Walker. 1912. A new North American naiad. The Nautilus 25:97-100.

Payne, B. S., and A. C. Miller. 1989. Growth and survival of recent recruits to a population of Fusconaia ebena (Bivalvia: Mollusca) in the lower Ohio River. American Midland Naturalist 121:99-104.

Pyron, M. and C.C. Vaughn. 1994. Ecological characteristics of the Kiamichi River, Oklahoma. Unpublished report submitted to the U.S. Fish and Wildlife Service, Tulsa, Oklahoma.

Salmon, A., and R. H. Green. 1983. Environmental determinants of unionid clam distribution in the Middle Thames River, Ontario. Canadian Journal of Zoology 61:832-838.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, second ed. W.H. Freeman and Co., San Francisco.

Stern, E.M. 1983. Depth distribution and density of freshwater mussels (Unionidae) collected with scuba from the lower Wisconsin and St. Croix Rivers. Nautilus 97:36-42.

Strayer, D. L. 1981. Notes on the microhabitats of unionid mussels in some Michigan streams. American Midland Naturalist 106:411-415.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson, and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United State and Canada: mollusks. Amer. Fisheries Soc. Special Publ. 16.

Valentine, B. D., and D. H. Stansbery. 1971. An introduction to the naiads of the Lake Texoma region, Oklahoma, with notes on the Red River fauna (Mollusca: Unionidae). Sterkiana 42:1-40.

Vaughn, C. C. 1993a. Survey for Arkansia wheeleri in the Little River, Oklahoma. Unpublished report submitted to the U.S. Fish and Wildlife Service, Tulsa, Oklahoma. 24 pp.

Vaughn, C.C. 1993b. Can biogeographic models be used to predict the persistence of mussel populations in rivers? Pp. 117-122 in, Cummings, K.S., A.C. Buchanan and L. M. Koch (eds.), Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.

Vaughn, C.C., M. Pyron and D. Certain. 1993. Habitat Use and Reproductive Biology of Arkansia wheeleri in the Kiamichi River, Oklahoma -Final Report. Unpublished report submitted to the Oklahoma Department of Wildlife Conservation, Oklahoma City, Oklahoma. 104 pp.

Warren, M.L. and B.M. Burr. 1994. Status of the freshwater fishes of the United states: overview of an imperiled fauna. Fisheries 19:6-18.

Way, C.M., A.C. Miller and B.S. Payne. 1990. The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionacea) in the lower Tennessee River. Nautilus 103:96-98.

White, D.S. 1979. The effect of lake-level fluctuations on Corbicula and other pelecypods in Lake Texoma, Texas and Oklahoma. Pages 82-88 in, J.C. Britton, ed. Proceedings, First International Corbicula Symposium. Texas Christian University.

Wheeler, H.E. 1918. The Mollusca of Clark County, Arkansas. Nautilus 31:109-125.

Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris and R.J. Neves. 1992. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

:

Table 1. Results of univariate F-tests of the presence or absence of Arkansia wheeleri at a site using four habitat variables. The multivariate model is significant ($F_{(1,20)}$ = 0.54, P = 0.03).

Variable	$F_{(4,17)}$	P
Depth	6.87	0.016
Habitat type (pool, backwater, or run)	0.95	0.342
Emergent vegetation (presence/absence)	5.45	0.030
Mussel species richness	10.72	0.004

FIGURE CAPTIONS

Figure 1. Rivers in which Arkansia wheeleri historically occurred.

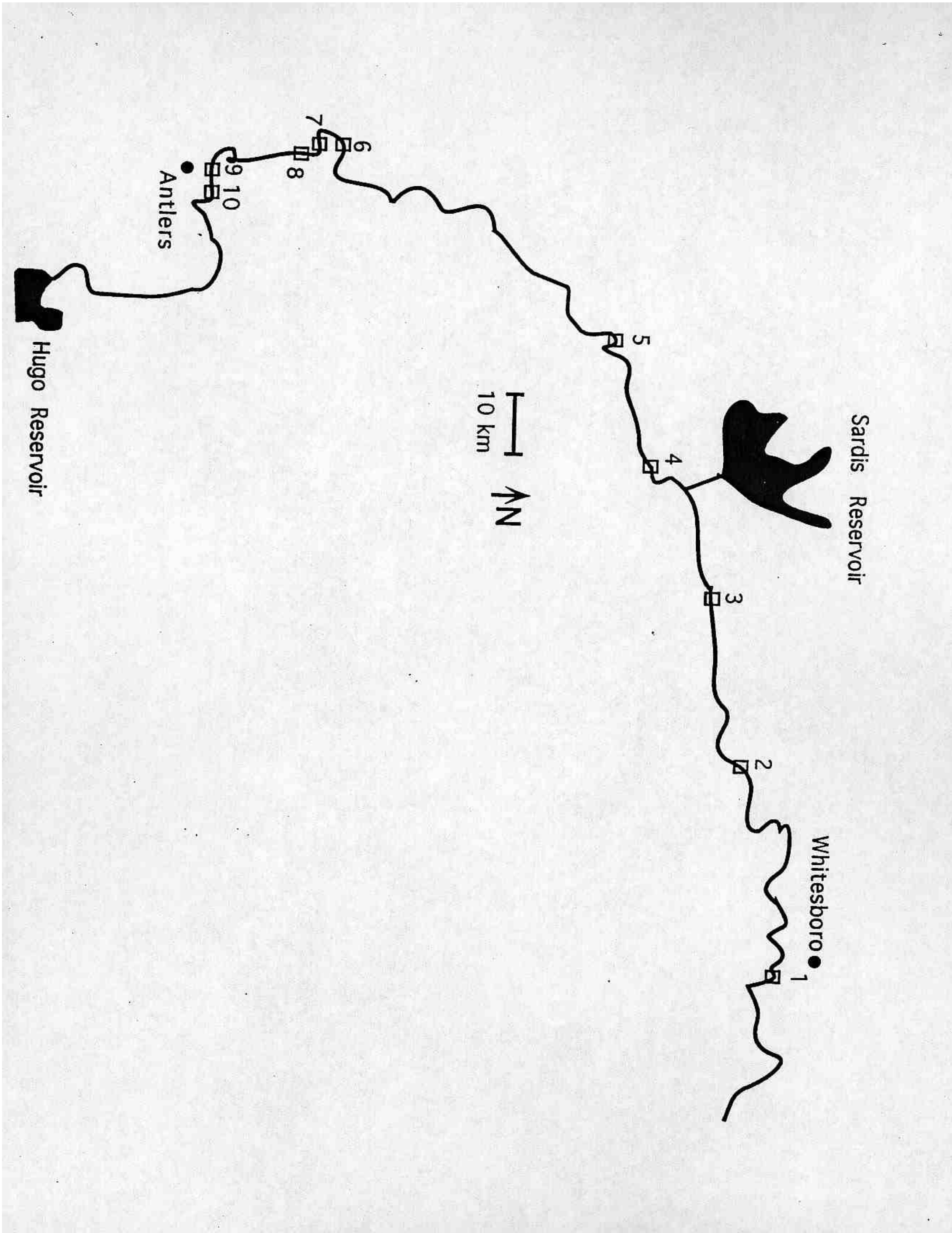
Figure 2. Population monitoring sites for Arkansia wheeleri on the Kiamichi River.

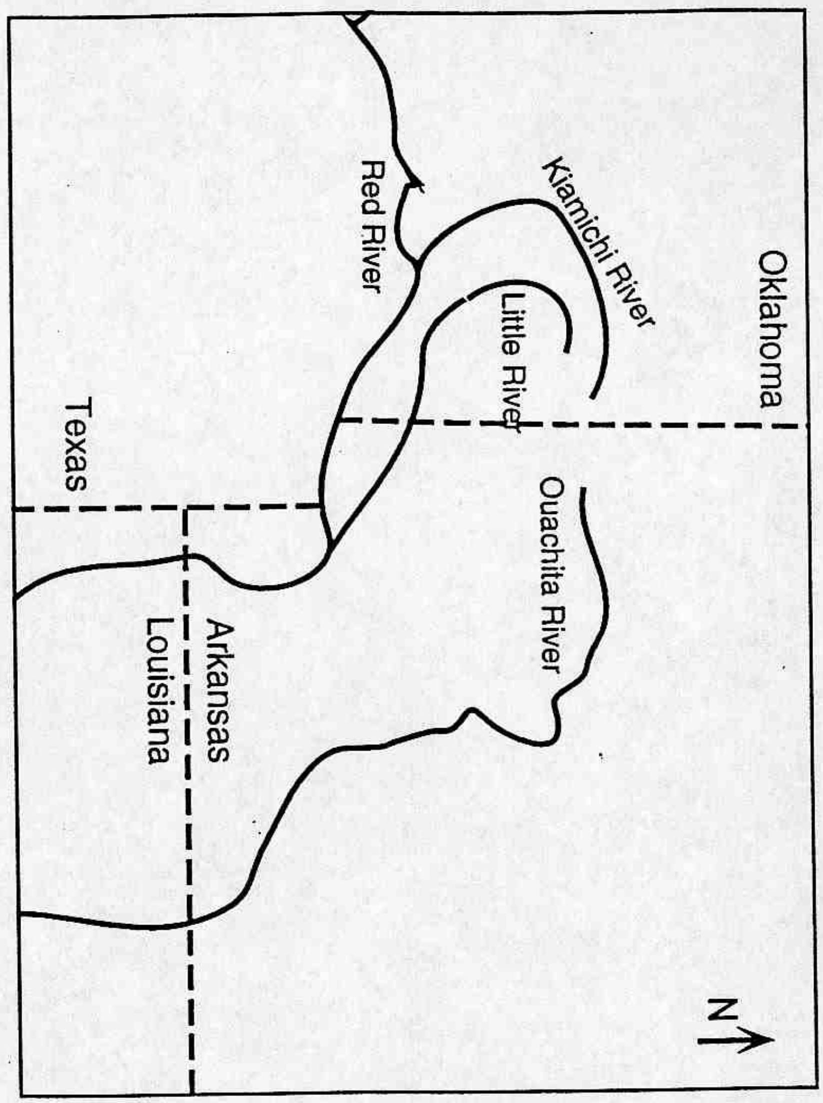
Figure 3. Mean relative abundance of Arkansia wheeleri at the 10 monitoring sites in 1990 - 1992.

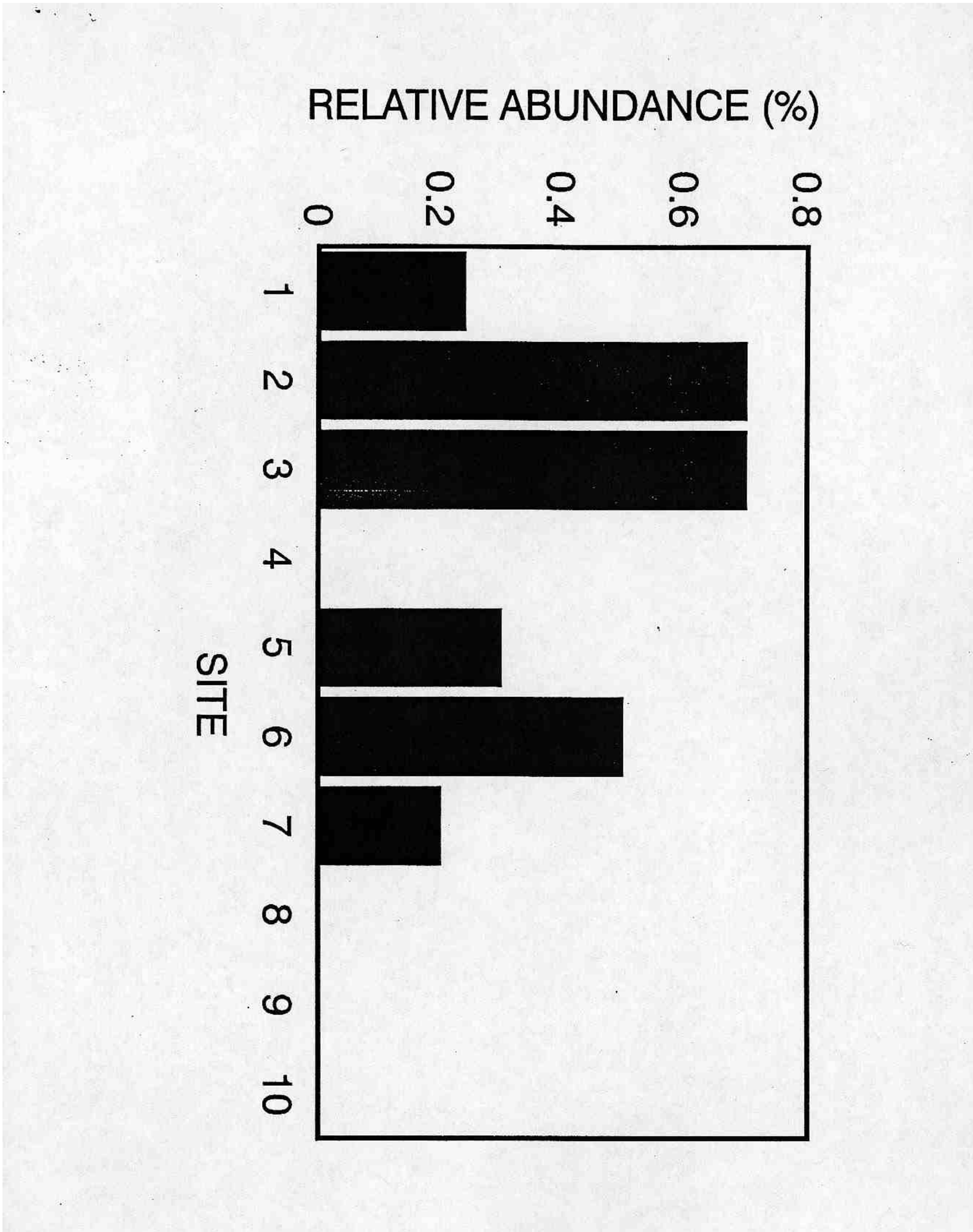
Figure 4. Total lengths of live Arkansia wheeleri compared to relict shells from the Kiamichi River.

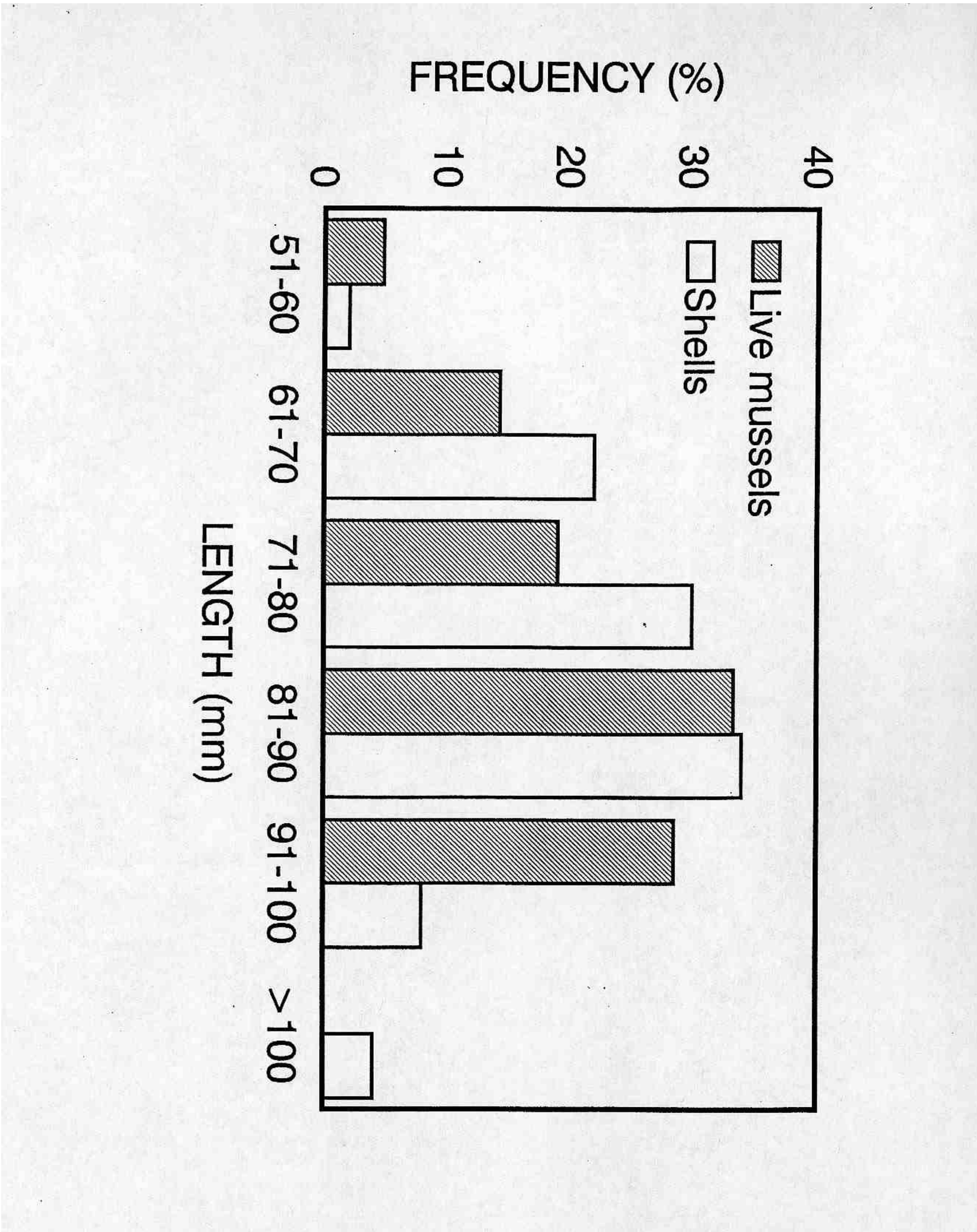
Figure 5. Predicted number of annuli for live Arkansia wheeleri versus relict shells from the Kiamichi River.

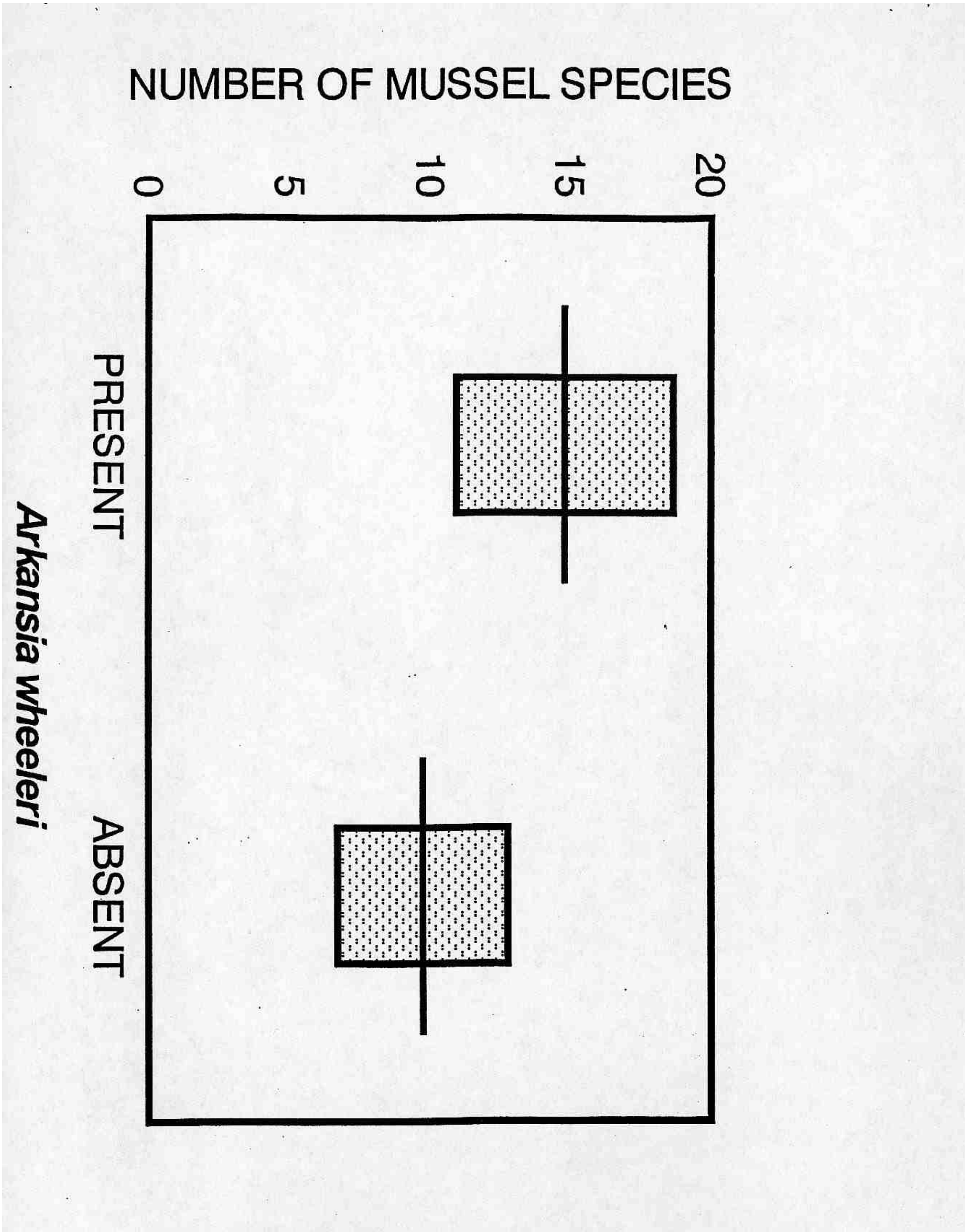
Figure 6. Mussel species richness (mean and standard deviation) at sites with and without Arkansia wheeleri. Data are from the 22 sites sampled in 1990.

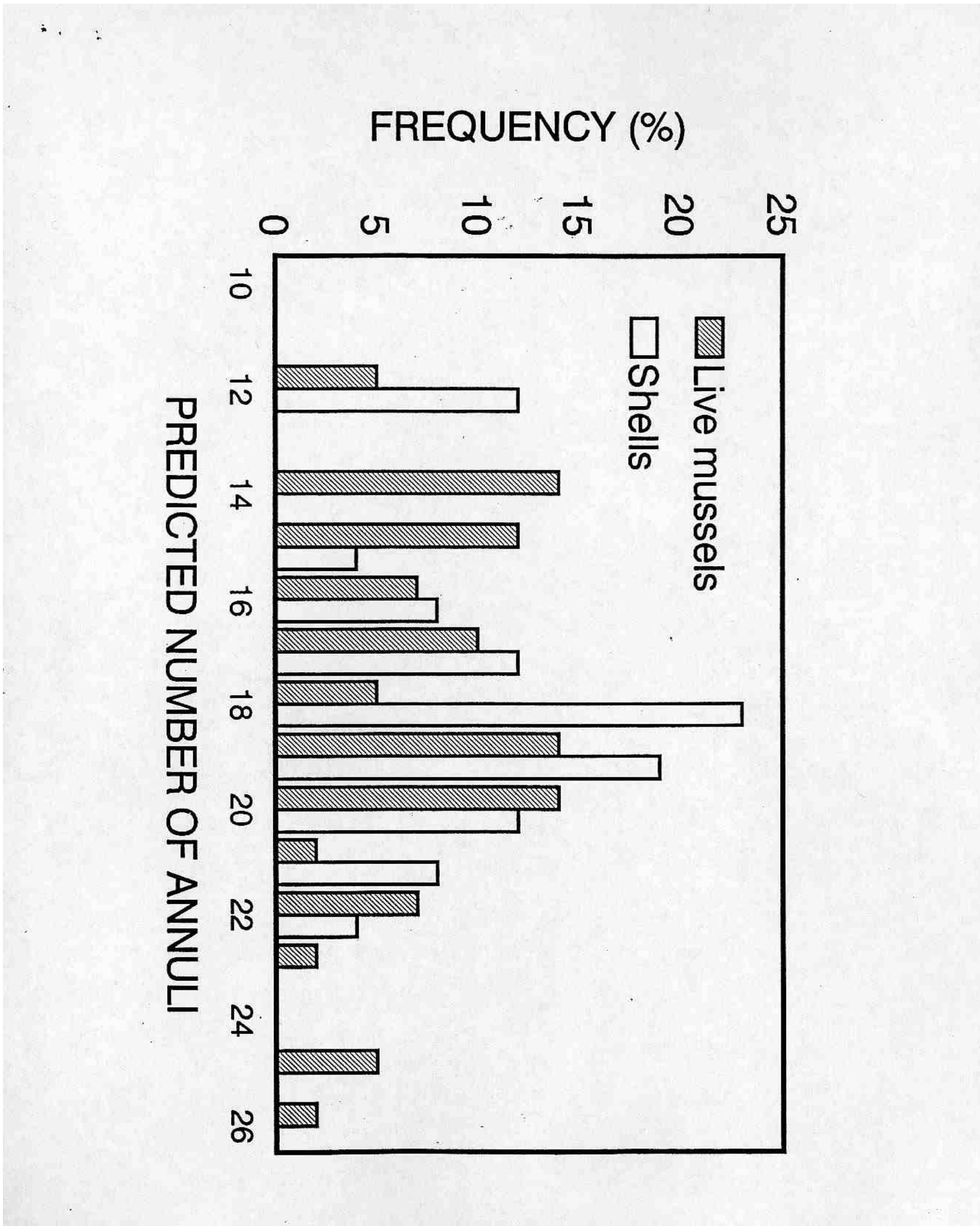

Sardis Reservoir
Whitesboro
Antlers
Hugo Reservoir
10 km
N
1
2
3
4
5
6
7
8
9
10


Oklahoma
Kiamichi River
Little River
Red River
Texas
Ouachita River
Arkansas
Louisiana
N


RELATIVE ABUNDANCE (%)
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
SITE


FREQUENCY (%)
0
10
20
30
40
Live mussels
Shells
51-60
61-70
71-80
81-90
91-100
>100
LENGTH (mm)


NUMBER OF MUSSEL SPECIES
0
5
10
15
20
PRESENT
ABSENT
Arkansia wheeleri


FREQUENCY (%)
0
5
10
15
20
25
Live mussels
Shells
10
12
14
16
18
20
22
24
26
PREDICTED NUMBER OF ANNULI

Threats to and Sustainability of Ecosystems for Freshwater Mollusks

Patricia Mehlhop[1] and Caryn C. Vaughn[2]

Abstract — In North America, two groups of freshwater molluscs are most threatened by human activities and require ecosystem approaches to their sustainability. Prosobranch snails in the family Hydrobiidae are restricted to small spring systems and are limited by their relative immobility, dependence on highly oxygenated waters and use of gills. Many are narrow endemics of localized springs, which are altered by ground water depletion and surface water diversion and by changes in water quality such as nutrification and chemical pollution from non-point sources. Spring alteration can result in direct species extirpation. Conservation through threat assessment and abatement is recommended. Most rare and declining native mussels are Unionidae in riverine ecosystems. Their relative immobility, long lifespan, filter-feeding habits, and parasitic larval stage make them highly vulnerable to habitat disturbance. The major cause of their declines has been the fragmentation of river ecosystems through impoundments, channelization and other activities such as timber harvesting, which alter flow and sedimentation patterns. Fragmentation acts to increase the distance between mussel subpopulations and may have major consequences of the metapopulation structure of species, particularly rare species and those with narrow fish host requirements. As some populations are eliminated and dispersal distances are increased, demographic and genetic constraints will diminish the ability of local populations to respond to natural environmental disturbance as well as human-induced changes. Sustainable ecosystem management in river systems will require devising strategies to conserve mussel metapopulations.

INTRODUCTION

Lotic systems harbor a diverse array of species, including some of the most threatened (Allan and Flecker 1993). Those in the United States have been altered by humans in ways that often are detrimental to their native inhabitants. One consequence of this is that the native molluscan fauna in those systems has declined. We examine here ecological and life history characteristics of two groups of molluscs, prosobranch snails in the family Hydrobiidae and riverine bivalves in the family Unionidae, that have suffered declines due to human activities or appear to be threatened with declines in the future. Their distribution and life history characteristics render them vulnerable to human alteration of their habitats.

[1] *Research Zoologist and Director, New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, New Mexico USA.*

[2] *Aquatic Ecologist, Oklahoma Natural Heritage Inventory, Oklahoma Biological Survey, University of Oklahoma, Norman, Oklahoma USA.*

HYDROBIIDAE

The aquatic snail family Hydrobiidae is species rich and ranges worldwide. Many of the North American species occur as narrow endemics in one or a few small spring systems as living "fossils" that flourished during the Pleistocene (Deixis 1992, Taylor 1987). The systematic relationships of most North American species have only recently been addressed (Hershler 1984, 1985, 1989; Hershler and Landye 1988; Hershler and Longley 1986; Hershler and Sada 1987; Hershler and Thompson 1987; Taylor 1987; Thompson 1968, 1969), and many species remain undiscovered and undescribed (T. Frest, personal communication, R. Hershler, personal communication). Currently, 5 species have been listed as endangered (Federal Register 1991a, 1992), 10 are considered to merit listing as endangered or threatened, and 84 are under review for listing (Federal Register 1991b) (fig. 1).

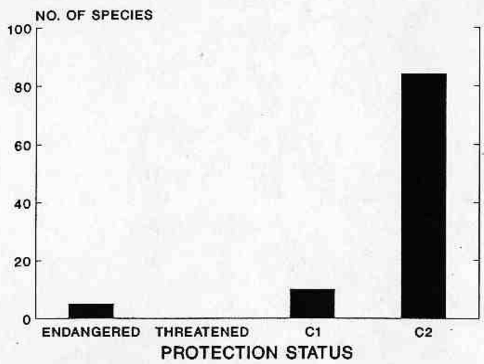


Figure 1.—Federal status toward listing of rare or declining snails of the family Hydrobiidae in the United States. Histogram shows number of species listed as endangered or threatened, number of candidate 1 species (species that merit listing) and number of candidate 2 species (species requiring further study to determine status).

Freshwater hydrobiids are indicators of artesian spring ecosystems with permanent, flowing, highly oxygenated waters (Ponder et al 1989). The waters may be highly mineralized, but must be relatively unpolluted. When hydrobiids occupy a significant portion of a spring system, it is an indication that the system is functioning and intact.

Life History and Ecological Characteristics

Hydrobiids are gill breathing and thus intolerant of drying or anaerobic conditions. Reproduction occurs annually or more often depending on water temperature (Deixis 1992, Hershler 1984, Mladenka 1992, Taylor 1987), and survivorship is estimated to be approximately one year (Mladenka 1992, T. Frest personal communication). They are found in flowing waters, often in thermal springs. The ecology of these snails in North America has received little study until recently (eg., Deixis 1992, Hershler 1984, Mladenka 1992, Reiter 1992). Here we examine ecological data for 59 species in the subfamilies Hydrobiinae and Littoridininae that have been reported as rare or threatened, or which occur in a narrow range in springs and their associated outflows. The sources of information consulted for each species are given in Appendix 1.

Of 59 species, most occur at only a single site and most of the remaining occur at only two or three sites (fig. 2). Occurrences represent single springs with no surface connection to other inhabited springs or parts of spring systems separated by more than 500 m of uninhabited waters. Because studies have not been conducted on gene flow among occurrences, it is not known whether an occurrence is the equivalent of a population.

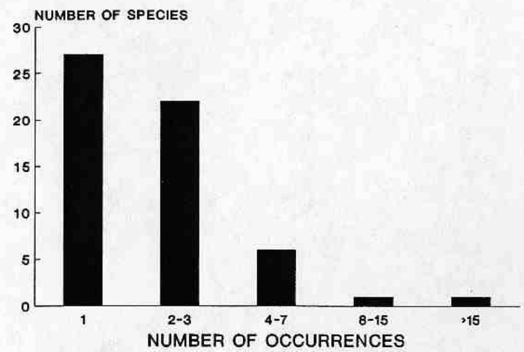


Figure 2.—Number of known occurrences per species of hydrobiid snails that are rare or threatened or have a narrow range of distribution.

Maximum occupied range was estimated in miles for 58 species as the greatest linear distance between two occupied points. Of those, 43% are known to occupy a range less than 0.1 mile, and less than 9% have a range greater than 10 linear miles (fig. 3).

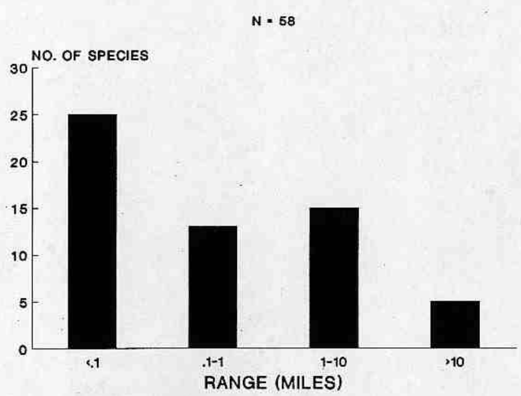


Figure 3.—Maximum occupied range per species (linear miles) of hydrobiids in the subfamilies Hydrobiinae and Littoridininae that are rare, threatened or have a narrow range of distribution.

69

Substrates occupied by each of 50 species were grouped into seven substrate types. Species in the Littoridininae were most often reported on vegetation, including algal mats and on soft substrates, such as mud and flocculent, but they were reported also on fine substrates such as silt and sand and on tufa (fig. 4). Species in the Hydrobiinae were reported from the same substrates as Littoridininae and also from wood, from stones, including pebbles and cobble, and from boulders and bedrock. It is not clear whether substrate associations reflect particular substrate preferences or hydrologic regimes of the occupied springs and spring runs, which in turn influence substrate availability. Mladenka (1992) showed experimentally that *Pyrgulopsis bruneauensis* (subfamily Hydrobiinae) preferred gravel and sand to silt.

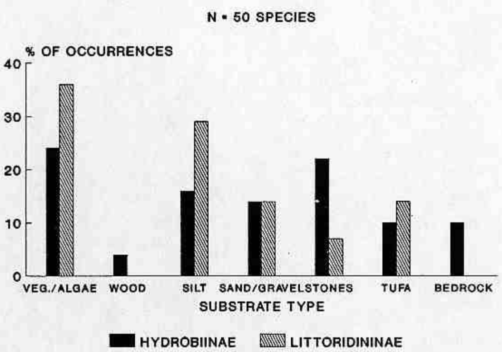


Figure 4.—Reported substrates at occurrences of hydrobiid snails in the subfamilies Hydrobiinae (N = 60 occurrences) and Littoridininae (N = 27 occurrences).

The extreme endemism of the species surveyed, as measured by the number of occurrences and occupied range, suggests that they may be extremely vulnerable to human disturbance. Threats to viability were assessed or identified for 53 species (fig. 5). When more than one threat was identified for a species, the two most prominent threats were tabulated. Decrease in water quantity, due to aquifer depletion or surface water diversion, was identified as a threat for 33 species, with many of those species threatened by both aquifer depletion and surface water diversion. Declines in water quality, due to habitat destruction (from impoundment, dredging or cattle trampling), or pollution (nutrient or chemical), was identified as a threat for 21 species. Recreation, such as swimming or hot spring bathing, was identified as a threat for 10 species. A study by Reiter (1992) suggests that recreation may not be as severe a threat as a change in water quantity or quality. He found that swimmers at a spring in Florida displaced *Aphaostracon monas* from a small area favored by both swimmers and snails, but the snails repopulated the area following the swimming season. For 2 species, no threats were identified in threat assessment procedures.

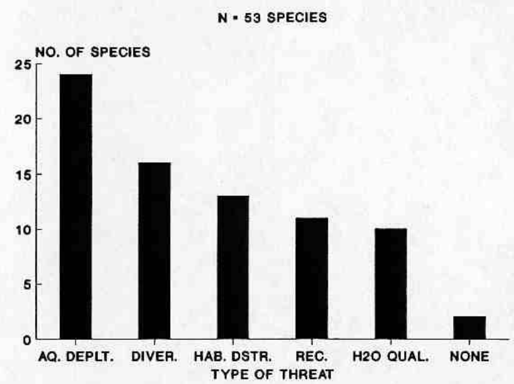


Figure 5.—Reported threats to snails in the family Hydrobiidae. AQ DEPLT = aquifer depletion, DIVER = water diversion, HAB DSTR = habitat destruction, REC = recreation, H2O QUAL = water quality, NONE = no threats found.

Ecosystem Sustainability

Species on public land and on private land designated for conservation offer some degree of long-term protection of ecosystems (Crumpacker et al. 1988). The number of occurrences for 59 hydrobiids was tallied by land ownership (fig. 6), multiple owners of any single occurrence were each counted as an owner. The greatest number of occurrences were on federal lands managed by the Bureau of Land Management (BLM) with private owners having the second greatest number. However, most of the occurrences on BLM lands were attributed to over 100 occurrences of *Pyrgulopsis bruneauensis* in springs along less than 10 miles of a water course (Mladenka 1992), a concentration of occurrences that has not been reported for other North American hydrobiids. If these are clustered as a single occurrence, 85 of the reported occurrences, or 65%, are on public lands or private conservation lands, 44 (33%) are on private lands other than those with a conservation interest and 3 (2%) are on tribal lands. Springs in western states are frequently in private ownership, often as inholdings or adjacent to large tracts of public land, while in Florida many are in the State Park system (Florida Natural Areas Inventory 1992).

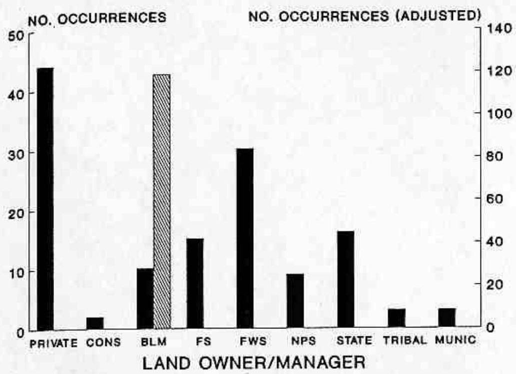


Figure 6.—Land owner or management agency of sites where hydrobiid snails in this study occur. When more than one owner was reported for a species occurrence, each owner was counted. The hatched bar shows the number of occurrences on BLM land without adjustment for the close clustering of over 100 occurrences of a single species. PRIVATE = private land with no formal protection status, CONS = private land with protection status, BLM = Bureau of Land Management; FS = USDA Forest Service, FWS = Fish & Wildlife Service, NPS = National Park Service, MUNIC = municipal ownership or control.

Recommendations for Ecosystem Sustainability

Most freshwater hydrobiids that have been reported as rare or threatened, or which occupy a narrow range, occur in one or a few artesian springs and their associated outflows (figs. 2 and 3). The aquifer source and hydrology of most of the spring systems is not well understood and because of this, hydrobiid ecosystems tend to be defined in reference to the surface waters of the host springs and outflows. When several springs are in close proximity to one another and have one or more hydrobiid species in common, they tend to be treated as a single system for management purposes (Deixis 1992; Federal Register 1991, 1992; Mladenka 1992). Hydrobiid-occupied springs are spatially small ecosystems, which is an advantage for management toward sustainability.

However, conservation and management planning needs to begin at a level higher than single spring ecosystems. For instance, a few spring systems, such as the Ash Meadows system in Nevada (Hershler and Sada 1987) and the Cuatro Cienegas system in Coahuila, Mexico (Hershler 1984, 1985) are quite large with several endemic species in various subsets of springs within the large system. In such cases, management needs to begin with the entire spring system. Artesian springs, especially those in arid environments, are analogous to islands in a sea of dry land that is inhospitable to aquatic species (Ponder et al. 1989). Striking regional species radiations have been demonstrated for both fishes (Soltz and Naiman 1978) and hydrobiids (Ponder et al. 1989, Thompson 1968). This argues for management perspectives that are at regional or large ecosystem levels rather than at the level of single isolated springs.

In many instances, springs are components of larger riverine ecosystems, though hydrologically distinct from them. Two examples of this are the Gila River ecosystem in southwestern New Mexico, which is a riverine ecosystem with eight known spring ecosystems occupied by hydrobiids (Mehlhop 1992 and unpublished data, Taylor 1987), and the middle Snake River with numerous associated springs (Deixis 1992, Federal Register 1992). In those situations, spring management must be a special target of management plans for larger ecosystems.

Most spring ecosystems examined in this survey are best sustained through threat analysis and control. Systems that are highly degraded with marginal hydrobiid populations probably cannot be restored without large financial expenditure and may not be worthy of investment if other, more naturally functioning spring ecosystems can be protected. Systems such as Torreon Spring in New Mexico, which has been impounded to an extent that the hydrobiid *Pyrgulopsis neomexicana* occupies less than 1 m^2 of its former range, is an example of an ecosystem that is no longer functional in its natural state (personal observation). The following recommendations for sustaining spring ecosystems for hydrobiids use a threat assessment and control approach.

1) Identify all springs in the landscape with hydrobiid snails and prioritize them for conservation.
2) Monitor and maintain water quantity in priority spring ecosystems.
3) Monitor and maintain water quality in priority spring ecosystems.
4) Identify and assess the need to abate other threats to ecosystem sustainability.
5) Quantitatively monitor occupied hydrobiid habitats within the targeted springs. In spring ecosystems with co-occurring hydrobiids, monitor relative numbers.

Monitoring will be the most time consuming action in sustaining many spring ecosystems. In most instances, it need not be elaborate, but it must be repeatable and occur at a frequency that will indicate decline in the parameters being monitored.

Hydrobiids are minute and easily overlooked by an untrained observer. To avoid investing in spring ecosystem management in lower priority spring systems, it is important to survey all springs and seeps in a large landscape (e.g., a National Forest and adjacent lands with similar landscape features). Primary threats to hydrobiid-occupied springs should then be identified and management actions prioritized based on assessments of species rarity, population size, degree of threat and amenability of threats to control measures.

Surface water diversion is readily detected and easily monitored. However, protection of surface waters alone is insufficient for many of the spring ecosystems. There are a large number of species for which ground water depletion has been identified as a major threat (fig. 5). Monitoring and protection of ground water flows for those systems is probably the single most important management need. This requires assessing the uses and regulation of the spring aquifer, for which depth and size are most often unknown. A long term monitoring program that roughly estimates water quantity at a spring may be an inexpensive, but adequate means of detecting ground water depletion.

For spring ecosystems that are a high priority for conservation, water quality should be measured initially to obtain baseline water quality data. The subsequent frequency of monitoring will vary with degree of threat. Results of this survey suggest that recreation is a threat to spring ecosystems only if spring outflows are altered substantially or if chemicals are added to the system. For instance, a hot spring in New Mexico is used for recreational bathing upstream from one of only two populations of a hydrobiid, and the population is maintained by flows of 0.3 cm and less over the snail substrate. While the probability of diversion or chemical pollution appears low, the consequences of such threats could be great.

Monitoring the snails themselves provides both a measure of the impacts of identified threats and a means of detecting unanticipated threats. Hydrobiid snail populations are difficult and costly to estimate, and methods used at one spring system may not be applicable to others (personal observation, T. Frest, personal communication). However, population stability can be estimated by monitoring the surface area occupied or the boundary of occupation. This needs to be done at approximately the same time of year due to seasonal population fluctuations generally associated with birth and death events. When hydrobiids co-occur in a spring, they usually cannot be distinguished with certainty without some disturbance to the population. However, some minimal monitoring is desirable to confirm that species proportions remain relatively stable.

UNIONIDAE

The unionid mussel fauna of North American freshwater is the most diverse in the world but is highly threatened. There have been major declines of mussel populations and species diversity in North American over the last century. Of the 283 species of native North American mussels, 131 species, or approximately 40%, are threatened with extinction: 17 species are presumed extinct, 44 species are actually listed as threatened or endangered, and 70 species are federal candidates for listing (Neves 1993, Master 1993) (fig. 7). Furthermore, all federally listed unionids are declining. There are no listed species with populations that are being maintained or increasing (Neves 1993).

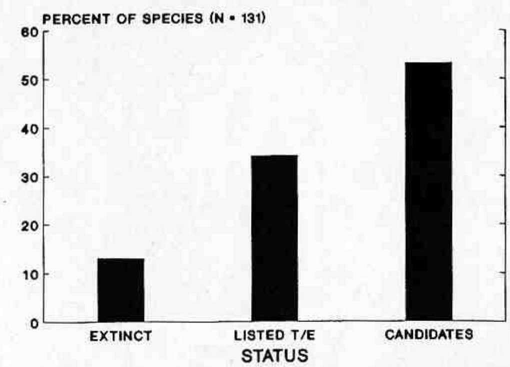


Figure 7.—Status of unionid mussels in the United States. N = 131. LISTED T/E = listed by the federal government as threatened or endangered, CANDIDATES = candidates for federal listing.

Unionid Characteristics

Freshwater mussels possess a suite of traits that make them highly vulnerable to habitat disturbance (table 1). Mussels have a complicated life history. The larval stage of freshwater mussels (glochidia) are temporary, obligate parasites on the gills or fins of fish. Many mussel glochidia can survive only on a narrow range of fish species hosts (Way 1988). Contact with an appropriate fish host and the location where young mussels are shed from the host is largely due to chance and only juveniles that reach a favorable habitat survive (Neves & Widlak 1987). Because only larvae can move between patches and juvenile survival is low, the potential rates of colonization are low. Reproductive maturity is not reached until age 6, most species live greater than 10 years, and some species live as long as 90 years (Haskin 1954, Imlay 1982, McMahon 1991). Once mature, adult mussels exhibit high survivorship (>80%) (McMahon 1991). However, adult mussels are sedentary; movements are

Table 1. — Life history characteristics of the Unionidae. Modified from McMahon (1991).

Life span	< 6 > - 100 yr
Age at maturity	6 - 12 yr
Strategy	Iteroparous
Fecundity	200,000-17,000,000
Reprod. efforts/year	1
Juvenile size	50 - 400 um
Rel. juvenile survivorship	Very low
Rel. adult survivorship	High
Larval habitat	Obligate parasite on fish

seasonal and on a scale of a few to an estimated maximum of 100 meters (Green et al. 1985). Therefore, unlike many stream organisms such as fish and aquatic insects (Townsend 1989), adult mussels have no refugia from disturbance events in streams. In addition, their filter-feeding habits make them especially vulnerable to sedimentation and chemical pollution events.

Threats and Causes of Decline

Species associations, species richness, metapopulation structure, and densities and population size structure of individual species are all potentially impacted by forest management practices. In addition, any effects on fish communities may ultimately affect mussels as well. Watters (1992) recently found high correlation between fish distribution and diversity and mussel distribution and diversity.

One major cause of mussel declines has been the fragmentation of river drainages through impoundments, channelization and other activities, such as timber-harvesting, which alter flow and sedimentation patterns. Declines in mussel species for various river drainages and the disturbance factor associated with these declines are shown in Table 2.

Timber harvesting operations can have significant effects on both stream water quantity and quality. The influence of catchment vegetation on stream discharge is dependent on a large number of variables, many of which are site-specific. However, in general, removal of forest vegetation increases stream runoff (Campbell and Doeg 1989). Increased flows have the potential to alter the distribution of sediment through scour, flushing, and deposition of newly eroded materials from the banks. Increased flows also have the potential to activate the bed. Bedload movement will wreak havoc on the survival of many mussels, particularly juveniles (Young and Williams 1983). Erosion caused by increased flows at one location results in deposition of this material further downstream. This "zone of aggradation" results in an increased width/depth ratio of that portion of the channel. As width/depth ratios increase the potential for bedload transport also increases. Thus, increased flows cause habitat loss through both sediment deposition and increased bed mobility. In the long term, higher base flow levels and shorter periods between peak flood periods will decrease habitat complexity by preventing the formation of islands, establishment of macrophyte beds, etc. (Frissell 1986). Stabilized sediments, sand bars, and low flow areas, are all preferred unionid habitats (Hartfield and Ebert 1986, Payne and Miller 1989, Stern 1983, Way et al. 1990). It is around these "complex" areas that most mussel beds, and indeed the highest diversity of stream fauna, are found.

Road-building activities and low water crossings associated with logging can lead to the development of "headcuts", or migrating knickpoints in the channel remote from areas of actual modification. Headcuts result in severe bank erosion, channel widening, and depth reduction and can have devastating effects on the mollusc fauna (Hart 1993).

Stream organisms, including mussels, have evolved in rivers that experience seasonal low-flow and high-flow periods (Meador and Matthews 1992). Fluctuating flows, especially if there will be lower flows for long periods of time, will result in the stranding of many mussels. Unlike fish species which can move rapidly in and out of microhabitats with changes in water levels, mussels move very slowly and are unable to respond to sudden drawdowns. Even if stranding doesn't actually kill a mussel, desiccation and thermal extremes will cause physiological stress and may reduce reproductive potential (McMahon 1991).

Fluctuating flows also mean that transport of particulates will vary. Depending on the flow schedule and the materials normally transported in the water column, there is the potential for loss of organics which are the food base for mussels.

Flow alteration not only has the potential to profoundly affect the stream fauna, but riparian fauna as well. Flood waters that normally recharge soils and aquifers may be rapidly exported

Table 2. — Reported loss of unionid mussel species from rivers and factors contributing to the losses.

Drainage	% Species Lost	Major Factor in Decline	Source
Upper Tennessee River	36%	Impoundments, sedimentation	Starnes and Bogan (1988)
Middle and Lower Tennessee R.	13%	Impoundments, channelization, sedimentation	Starnes and Bogan (1988)
Tombigbee River at Epes, AL	68%	Impoundment	Williams et al. (1992)
Stones River, TN	40%	Impoundment	Schmidt et al. (1989)
Upper Stones River, TN	25%	Gravel dredging, water quality	Schmidt et al. (1989)
Sugar Creek, IN	20%		Harmon (1992)
Illinois River, IL	51%	Impoundments, channelization, sedimentation	Starret (1971)
Kankakee River, IL	25%	Siltation	Suloway (1981)
Kaskaskia River, IL	38%	Siltation (80% reduction in numbers of individuals)	Suloway et al. (1981)
Vermillion River, IL	40%		Cummings (1991)
Embarras River, IL	39%		Cummings (1991)
Little Wabash River, IL	24%		Cummings (1991)

downriver. Lowered water tables may cause shrinkage of the riparian corridor and shifts in terrestrial species composition (Allan and Flecker 1993, Smith et al. 1991).

Mussels are most successful where water velocities are low enough to allow sediment stability but high enough to prevent excessive siltation (Salmon and Green 1983, Way et al. 1990). Thus, well-oxygenated, coarse-sand and sand-gravel beds comprise optimal habitat (McMahon 1991). Sediment deposition not only removes or moves habitat, but also clogs mussel siphons (i.e. smothers them) and interferes with feeding and reproduction (Dennis 1984, Aldridge et al. 1987). In addition, because mussels are sedentary filter-feeders, they are particularly sensitive to changes in water quality (Havlik and Marking 1987).

Demographic Consequences

Because of this dependence on the appropriate substrate and flow conditions, freshwater mussels are already naturally patchily distributed in rivers. Fragmentation acts to increase patchiness and to increase the distance between patches. These effects may have major consequences for the metapopulation (i.e. local or subpopulations connected by infrequent dispersal) structure of mussel species, particularly rare species and those with narrow fish-host requirements (Vaughn 1993). As some subpopulations are eliminated and dispersal distances are increased between other subpopulations, demographic and genetic constraints will diminish the ability of mussels to respond to even natural stochastic events much less human-induced environmental change (Wilcox 1986, Murphy et al. 1990).

Forest Management Strategies

Managing forests to maintain fully functional riverine ecosystems is the best way to protect unionid populations in National Forests. Best land-use practices should strive to maintain an uncut riparian corridor at least as wide as the predicted 100 year channel meander (Boon et al. 1992). Forest managers should seek to minimize the use of biocides and encourage selective logging rather than clear-cutting whenever possible. Disturbances such as low-water crossing which were thought to have temporary effects are now known to have long-term detrimental effects on mussel populations through the formation of migrating headcuts. Managing forests from an ecosystem perspective must include long-term monitoring of unionid populations.

LITERATURE CITED

Aldridge, D.W.; Payne, B.S; and Miller, A.C. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 45:17-28.

Allan, J.D. and Flecker, A.S. 1993. Biodiversity conservation in running waters. BioScience 43:32-43.

Arizona Heritage Data Management System. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Arizona Game and Fish Department, Phoenix, AZ.

Boon, P.J.; Calow, P.; and Petts, G.E. 1992. River Conservation and Management. John Wiley and Sons Ltd.

California Natural Heritage Division. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. California Department of Fish and Game, Sacramento, CA.

Campbell, I.C. and Doeg, T.J. 1989. Impact of timber harvesting and production on streams: a review. Australian Journal of Marine and Freshwater Research 40: 519-539.

Clarke, A.H. 1987. Status survey of *Lampsilis streckeri* Frierson (1927) and *Arcidens wheeleri* (Ortmann & Walker, 1912). Unpublished report no. 14-16-0004-86-057 to the U.S. Fish and Wildlife Service, Jackson, Mississippi.

Crumpacker, D.W.; Hodge, S.W.; Friedley, D.; and Gregg, W.P. 1988. A preliminary assessment of the status of major terrestrial and wetland ecosystems on federal and indian lands in the united states. Conservation Biology 2:101-115.

Cummings, K.S. 1991. The aquatic mollusca of Illinois. Illinois Natural History Survey Bulletin 34:428-438.

Deixis 1992. Distribution and ecology of the endemic and relict mollusc fauna of Idaho TNC's thousand springs preserve. Unpublished report to The Nature Conservancy of Idaho. pp. 70.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. PhD. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Federal Register. 1991a. Endangered and threatened wildlife and plants; final rule to list the Alamosa springsnail and the Socorro springsnail as endangered. Federal Register 56:49646-49649.

Federal Register. 1991b. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species. Federal Register 56:58804-58836.

Federal Register. 1992. Endangered and threatened wildlife and plants; determination of endangered or threatened status for five aquatic snails in south central Idaho. Federal Register 57:59244-59256.

Florida Natural Areas Inventory. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Florida Natural Areas Inventory, Tallahassee, FL.

Frissell, C.A. 1986. A hierarchial framework for stream classification. Environmental Management 10:199-214.

Green, R.H.; Singh, S.M.; and Bailey, R.M. 1985. Bivalve mollusks as response systems for modelling spatial and temporal environmental patterns. The Science of the Total Environment 46:147-169.

Hart, P. 1993. Headcuts and their effect on the mussel fauna of the Lower Mississippi alluvial plain. Symposium on the Conservation and Management of freshwater mussels. Illinois Natural History Survey. *In press.*

Hartfield, P.; and Ebert, D. 1986. The mussels of southwest Mississippi streams. American Malacological Bulletin 4:21-23.

Haskin, H.H. 1954. Age determination in mollusks. Transactions of the New York Academy of Science 16:300-304.

Havlik, M.E.; and Marking, L.L. 1987. Effects of contaminants on an naiad mollusks (Unionidae): a review. U.S. Fish and Wildlife Service. 20 pp.

Hershler, R. 1984. The Hydrobiid snails (Gastropoda: Rissoacea) of the Cuatro Cienegas Basin: systematic relationships and ecology of a unique fauna. Journal of the Arizona-Nevada Academy of Science 19:61-76.

Hershler, R. 1985. Systematic revision of the Hydrobiidae (Gastropoda: Rissoacea) of the Cuatro Cienegas Basin, Coahuila, Mexico. Malacologia 26:31-123.

Hershler, R. 1989. Springsnails (Gastropoda: Hydrobiidae) of Owens and Amargosa River (exclusive of Ash Meadows) drainages, Death Valley System, California-Nevada. Proc. Biol. Soc. Wash. 102: 176-248.

Hershler, R.; and Landye, J.J. 1988. Arizona Hydrobiidae (Prosobranchia: Rissoacea). Smithsonian Institution Press, Washington, D.C. pp. 63.

Hershler, R.; and Longley, G. 1986. Phreatic hydrobiids (Gastropoda: Prosobranchia) from the Edwards (Balcones fault zone) aquifer region, south central Texas. Malacologia 27:127-172.

Hershler, R.; and Sada, D.W. 1987. Springsnails (Gastropoda: Hydrobiidae) of Ash Meadows, Amargosa Basin, California-Nevada. Proc. Biol. Soc. Wash. 100:776-843.

Hershler, R.; and Thompson, F.G. 1987. North American Hydrobiidae (Gastropoda: Rissoacea): redescription and systematic relationships of *Tryonia* Stimpson, 1865 and *Pyrgulopsis* Call and Pilsbry, 1886. The Nautilus. 101:25-32.

Idaho Conservation Data Center. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Idaho Department of Game and Fish, Boise, ID.

Imlay, M.J. 1982. Use of shells of freshwater mussels in monitoring heavy metals and environmental stresses: a review. Malacological Review 15:1-14.

Kat, P. W. 1982. Effects of population density and substratum type on growth and migration of *Elliptio complanata* (Bivalvia: Unionidae). Malacological Review 15:119-127.

Kovalak, W.P.; Dennis, S.D.; and Bates, J.M. 1986. Sampling effort required to find rare species of freshwater mussels. Pp 46-59 in, B.G. Isom (ed), Rationale for Sampling and Interpretation of Ecological Data in the Assessment of Freshwater Ecosystems. American Society for Testing and Material. Special Technical Publication No. 894.

Landye, J.J. 1973. Status of the inland aquatic and semi-aquatic mollusks of the american southwest. Unpublished report to the U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife, Office of Rare and Endangered Species, Washington, D.C.

Lord, J.M.; and Norton, D.A. 1990. Scale and the spatial concept of fragmentation. Conservation Biology 4: 197-202.

Master, L.L. 1993. Information networking and the conservation of freshwater mussels. Symposium on the Conservation and Management of Freshwater Mussels. *In press.*

McMahon, R.F. 1991. Mollusca: Bivalvia. Pp. 315-400 in, J.H. Thorp and A.P. Covich eds)., Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc., New York.

Meador, M.R. 1992. Inter-basin water transfer: ecological concerns. Fisheries 17:17-22.

Meador, M.R.; and Matthews, W.J. 1992. Spatial and temporal patterns in fish assemblage structure of an intermittent Texas stream. American Midland Naturalist 127:106-114.

Mehlhop, P. 1992. Establishment of a rare mollusk inventory and monitoring program for New Mexico. Unpublished report for the New Mexico Department of Game and Fish. Santa Fe, NM. Contract No. 80-519-52.

Miller, A.C.; and Payne, B.S. 1988. The need for quantitative sampling to characterize size demography and density of freshwater mussel communities. American Malacological Bulletin 5: 1-7.

Mladenka, G.C. 1992. The ecological life history of the Bruneau hot springs snail (*Pyrgulopsis bruneauensis*). Unpublished report, Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho. pp. 116.

Murphy, D.D.; Freas, K.E.; and Welss, S.B. 1990. An environmental-metapopulation approach to population viability analysis for a threatened Invertebrate. Conservation Biology 4:41-51.

Nevada Natural Heritage Program. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Nevada Department of Conservation and Natural Resources, Carson City, NV.

Neves, R.J. 1993a. Freshwater mussels of North America: an impending spasm of extinctions? Bulletin of the North American Benthological Society 10:125 (Abstract).

Neves, R.J. 1993b. A state-of-the-unionids address. Symposium on the Conservation and Management of Freshwater Mussels. In press.

Neves, R.J.; and Widlak, J.C. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Bulletin 5: 1-7.

New Mexico Natural Heritage Program. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. University of New Mexico, Albuquerque, NM.

Payne, B.S.; and Miller, A.C. 1989. Growth and survival of recent recruits to a population of *Fusconala ebena* (Bivalvia: Mollusca) in the lower Ohio River. American Midland Naturalist 121:99-104.

Ponder, W.F.; Hershler, R.; and Jenkins, B. 1989. An endemic radiation of hydrobiid snails from artesian springs in northern south Australia: their taxonomy, physiology, distribution and anatomy. Malacologia 31: 1-140.

Reiter, M.A. 1992. The distribution of the blue spring *Aphaostracon* in blue spring run, Florida: final report. Unpublished report to The Nature Conservancy from Department of Biology, Seminole Community College, Sanford, Florida. pp. 19.

Rutherford, D.A.; Echelle, A.A.; and Maughan, O.E. 1992. Drainage-wide effects of timber harvesting on the structure of stream fish assemblages in southeastern Oklahoma. Transactions of the American Fisheries Society 121: 716-728.

Salmon, A.; and Green, R.H. 1983. Environmental determinants of unionid clam distribution in the Middle Thames River, Ontario. Canadian Journal of Zoology 61: 832-838.

Schmidt, J.E.; Estes, R.D.; and Gordon, M.E. 1989. Historical changes in the mussel fauna (Bivalvia: Unionacea) of the Stones River, Tennessee. Malacological Review 22:55-60.

Smith, S.D.; Wellington, A.B.; Nachlinger, J.L.; and Fox, C.A. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. Ecological Applications 1:89-97.

Soltz, D.L. and Naiman, R.J. 1978. The natural history of native fishes in the Death Valley system. Natural History Museum of Los Angeles County, Science Series No. 30.

Starrett, W.C. 1971. A survey of the mussels (Unionacea) of the Illinois river: a polluted stream. Illinois Natural History Survey Bulletin 30(5): 267-403.

Stern, E.M. 1983. Depth distribution and density of freshwater mussels collected with scuba from the lower Wisconsin and St. Croix rivers. Nautilus 97:36-42.

Suloway, L. 1981. The unionid (Mollusca: Bivalvia) fauna of the Kankakee River in Illinois. American Midland Naturalist 105:233-239.

Suloway, L.; Suloway, J.J.; and Herricks, E.E. 1981. Changes in the freshwater mussel (Pelecypoda: Unionidae) fauna of the Kaskaskia River, Illinois, with emphasis on the effects of impoundment. Transactions of the Illinois Academy of Science 74:79-90.

Taylor, D.W. 1987. Fresh-water mollusks from New Mexico and vicinity. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM. pp. 50.

Texas Parks and Wildlife Department. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Texas Parks and Wildlife Department, Endangered Resources Branch, Austin, TX.

Thompson, F.G. 1968. The aquatic snails of the Family Hydrobiidae of peninsular Florida. Univ. Florida Press, Gainseville.

Thompson, F.G. 1969. Some hydrobiid snails from Georgia and Florida. Quart. J. Acad. Sci., 32:241-265.

Thompson, F.G. 1984. Freshwater snails of Florida; a manual for identification. University of Florida Press, Gainesville. pp. 94.

Townsend, C.R. 1989. The patch dynamic concept of stream community ecology. Journal of the North American Benthological Society 8:36-50.

Utah Natural Heritage Program. 1992. Unpublished records of rare mollusks from the Biological Conservation Database. Utah Natural Heritage Program, Salt Lake City, UT.

Vaughn, Caryn C. 1993. Can biogeographic models be used to predict the persistence of mussel populations in rivers? Symposium on the Conservation and Management of Freshwater Mussels. Illinois Natural History Survey. *In press.*

Watters, G.T. 1992. Unionids, fishes, and the species-area curve. Journal of Biogeography 19: 481-490.

Way, C.M. 1988. An analysis of life histories in freshwater bivalves (Mollusca: Pisidiidae). Canadian Journal of Zoology 66:1179-1183.

Way, C.M.; Miller, A.C.; and Payne, B.S. 1990. The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River. Nautilus 103: 96-98.

Wilcox, B.A. 1986. Extinction models and conservation. Trends in Ecology and Evolution 1:46-48.

Young, M.R. and Williams, J. 1983. Redistribution and local recolonization by the freshwater pearl mussel *Margaritifera margaritifera* (L). Journal of Conchology 31:225-234.

Appendix 1. Species of snails in the family Hydrobiinae included in this study and the sources of information used.

Apachecoccus arizonae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973, Taylor 1987
Aphaostracon asthenes	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon monas	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon pycnus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon theiocrenetus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Aphaostracon xynoelictus	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia helicogyra	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia mica	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia monroensis	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia parva	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia ponderosa	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia vanhyningi	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Cincinnatia wekiwae	FL	Florida Natural Areas Inventory 1993, Thompson 1984
Pyrgulopsis aardahli	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis bacchus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis bruneauensis	ID	Idaho Conservation Data Center 1993, Mladanka 1992
Pyrgulopsis chupaderae	NM	National Museum Natural History collections, Mehlhop (personal observation), Taylor 1987
Pyrgulopsis conicus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis crystalis	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis davisi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Pyrgulopsis deserta	AZ, UT	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Utah Natural Heritage Program 1993
Pyrgulopsis erythopoma	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis fairbanksensis	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis gilae	NM	Mehlhop (1992, personal observation), Taylor 1987
Pyrgulopsis glandulosus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis isolatus	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis merriami	NV	Nevada Natural Heritage Program 1993
Pyrgulopsis metcalfi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Pyrgulopsis montezumensis	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis morrisoni	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis nanus	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis neomexicanus	NM	Federal Register 1991a, Taylor 1987
Pyrgulopsis nevadensis	NV	Nevada Natural Heritage Program 1993
Pyrgulopsis n. sp.	NM	Mehlhop (1992, personal observation)
Pyrgulopsis owenensis	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis pecosensis	NM	Mehlhop (1992), Landye 1973, Taylor 1987
Pyrgulopsis pisteri	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Pyrgulopsis perturbata	CA	California Natural Heritage Division 1993, Hershler 1989
Pyrgulopsis roswellensis	NM	Mehlhop (1992), Landye 1973, Taylor 1987
Pyrgulopsis simplex	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis solus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Pyrgulopsis thermalis	NM	Mehlhop (1992), Taylor 1987
Pyrgulopsis thompsoni	AZ, MX	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Pyrgulopsis trivialis	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973
Tryonia adamantina	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia alamosae	NM	Landye 1973; Mehlhop, P. personal observation, New Mexico Natural Heritage Program 1993, Taylor 1987
Tryonia angulata	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia brunei	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia cheatumi	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Tryonia elata	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia ericae	NV	Hershler and Sada 1987, Nevada Natural Heritage Program 1993
Tryonia gilae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Landye 1973, Taylor 1987
Tryonia kosteri	NM	Landye 1973, Mehlhop, P. 1992, New Mexico Natural Heritage Program 1993, Taylor 1987
Tryonia margae	CA	Hershler 1989
Tryonia quitobaquitae	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988
Tryonia rowlandsi	CA	Hershler 1989
Tryonia salina	CA	Hershler 1989
Tryonia stocktonensis	TX	Taylor 1987, Texas Parks & Wildlife Department 1993
Yaquicoccus bernardinus	AZ	Arizona Heritage Data Management System 1993, Hershler and Landye 1988, Taylor 1987

Supervisor
Assistant
Adornato
Aldrich
Brubeck
Collins
Frazier
Hensley
Langer
Martin
Martinez
Off. Asst.
Clk Typist
Reading
File/Toss

THE Nature Conservancy
ARKANSAS FIELD OFFICE

9 September 1994

Jerry Brabander/Field Supervisor
Fish and Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

Thank you for the opportunity to review the draft Ouachita Rock-pocketbook Recovery Plan. The plan as written is reasonable and doable and appears to have a good chance of leading to the recovery of the Ouachita Rock-pocketbook. The Conservancy fully supports its implementation and offers its services to the recovery effort. Specific comments follow:

1. The Corps of Engineers' regulation of water releases from the Sardis Dam appear to be negatively impacting reproduction of downstream mussel populations. Firm scientific evidence is lacking but it should be possible to work with the Corps to achieve a more "natural" flow regime while simultaneously researching the life history and habitat requirements of the Ouachita Rock-pocketbook. 41

2. Task 1.25, the development of a strategic habitat protection plan for the Kiamichi should also be a number one priority. Biologically the Kiamichi River is one of the most diverse in the United States. High numbers of resident fish and mussel species, many of which are declining throughout their ranges, as well as consistent water quality make the Kiamichi a river system of high protection priority. An ecosystem approach to maintaining this biologically rich system is appropriate. 42

3. Will there be an attempt to delineate critical habitat areas? 43

4. While the negative impacts of gravel mining are mentioned in the plan it may deserve more emphasis. Much of the mining seems to be carried out by local and state agencies which should need permits for these activities. 44

Sincerely,

Douglas Zollner/Project Manager
Ouachita Mountains Conservation Initiative

The Nature Conservancy 601 North University Avenue / Little Rock, Arkansas 72205 / (501) 663-6699 FAX (501) 663-8332
International Headquarters / 1815 Lynn Street / Arlington, Virginia 22209

Recycled Paper

Little River Conservation District

Federal Building, Rm. 124 - 201 N. Central - Idabel, OK 74745 - Phone (405) 286-SOIL (7645)

~~Supervisor~~	
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	ADM
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

Sept. 9, 1994

Jerry J. Brabander
U. S. Fish & Wildlife
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Brabander,

On behalf of the Board of Directors of the Little River Conservation District, I would like to make the following request of the U. S. Fish and Wildlife Service, concerning the Ouachita Rock-Pocketbook Recovery Plan.

45

Since the Little River Basin contains all of the alleged Ouachita Rock-Pocketbook Mussel habitat; and since a large portion of this area lies within the boundaries of the Little River Conservation District. The Board of Directors in accordance with the Endangered Species Act; request that you hold a public meeting within the boundaries of said District for the purpose of reviewing historical records on the Ouachita Rock-Pocketbook and answering any questions that local citizens may have. 46

Sincerely,

Frank Acker, Manager
Little River Conservation District

Supervisor	9-15
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	ADM
Off. Asst.	
Clk Typist	
Reading	
File/Toss	

PATRICIA P. EATON
EXECUTIVE DIRECTOR

DAVID WALTERS
GOVERNOR

STATE OF OKLAHOMA
WATER RESOURCES BOARD

September 12, 1994

Jerry J. Brabander
Field Supervisor
U.S. Fish & Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

We have reviewed your draft recovery plan for the Ouachita Rock-pocketbook Mussel and are currently developing formal comments which should be completed later this week. I ask that you allow us this short extension of time so that our position on this plan may be considered for inclusion in the final document. 47

As you know, the continued viability of the Ouachita Rock-pocketbook Mussel in Oklahoma is important to the Water Resources Board. We appreciate your efforts to ensure the survival of this species.

Sincerely,

Mike Mathis, Chief
Planning Division

600 N. HARVEY AVE. • P.O. BOX 150 • OKLAHOMA CITY, OKLAHOMA 73101-0150 • TELEPHONE (405) 231-2500 • FAX (405) 231-2600

PATRICIA P. EATON
EXECUTIVE DIRECTOR

DAVID WALTERS
GOVERNOR

STATE OF OKLAHOMA
WATER RESOURCES BOARD

Supervisor 9-21
Assistant
Adornato
Aldrich
Brubeck
Collins
Frazier
Hensley
Langer
Martin
Martinez
Off. Asst.
Clk Typist
Reading
File/Toss

September 19, 1994

Jerry J. Brabander
Field Supervisor
U.S. Fish & Wildlife Service
Ecological Services
222 S. Houston, Suite A
Tulsa, OK 74127

Dear Mr. Brabander:

RE: Ouachita Rock-Pocketbook Draft Recovery Plan

As you know, the continued viability of the Ouachita Rock-pocketbook Mussel in Oklahoma is important to the Oklahoma Water Resources Board. We sincerely appreciate your efforts to ensure the survival of this species.

Thank you for granting us a short extension of time to formally comment. We have reviewed the Draft Recovery Plan, submitted to the OWRB on August 10, 1994. After review, we have identified several concerns regarding the Draft Recovery Plan and these are enclosed in Attachment A.

If you have any questions concerning our comments, please feel free to write or call me at (405)231-2551.

Sincerely,

Duane A. Smith

Duane A. Smith, Assistant Director
Oklahoma Water Resources Board

Attachment

600 N. HARVEY AVE. • P.O. BOX 150 • OKLAHOMA CITY, OKLAHOMA 73101-0150 • TELEPHONE (405) 231-2500 • FAX (405) 231-2600

Attachment A
Comments regarding the Ouachita Rock-Pocketbook Draft Recovery Plan

by
Oklahoma Water Resources Board
September 19, 1994

In short, the Oklahoma Water Resources Board has several concerns regarding the Draft Recovery 48
Plan for the Ouachita Rock-Pocket Book Mussel. The OWRB believes that reservoir control has the potential of being beneficial to the survival of the mussel. Additionally, we believe that reservoir control would help stabilize flows, prevent scouring of the river bed and reduce sediment levels within the stream system below the reservoir. Although reservoir control has a potential to create problems (such as isolation between populations above and below the reservoir), the OWRB feels that the advantages of reservoir control may prove to out weigh the disadvantages associated with reservoir control.

Additionally, it is obvious from the contents of the document, further detailed studies of the mussel 49
(including its reproduction patterns, susceptibility to change within its environment, life cycle and habitat requirements) should be conducted prior to the finalization of any recovery plan and expenditure of literally hundreds of thousands of dollars toward implementation of such a plan.

Specific Comments:

1. Page 10. The OWRB believes that reservoir control has the potential to help stabilize the 50
fluctuating flows of the Kiamichi. We also believe that reservoir control will help prevent scouring to the river bed during periods of high flow (i.e. flooding) and would also help reduce sediment levels. Flow for the Kiamichi River is known to range from multi-thousand CFS to near zero, during low flow months.

2. Page 12. The OWRB is concerned with the notion of determining reproduction without the 51
process somehow affecting existing populations.

3. Page 13. According to the text on the preceding page 13, stable flows are important to mussel 50
survival. It should be noted that reservoirs will help stabilize flows through controlled releases. Therefore, reservoir control has the potential to be beneficial to the existence of the mussel.

4. Page 15. Impoundments do have the potential to disrupt fish species acting as hosts for the 52
mussel larvae, but in what manner does siltation/sedimentation damage the species? Is it true that impoundments actually trap and hold sediment, rather than allow its passage downstream (into the mussel habitat) as could be caused by activity in the stream/river?

5. Page 16. In reference to all available evidence indicating that the Ouachita rock-pocketbook 53
does not tolerate certain changes, it may be helpful to know what the available evidence is or where to find it.

6. Page 17. More information is needed to back up the comment concerning the potential existing 54
for very serious damage to mussels from Broken Bow reservoir, even to the point of eliminating the Little River Ouachita Rock-pocketbook population.

7. Page 18. Here, a somewhat positive study is dismissed due to insufficient data. If this is 55
accepted, then the other data throughout this report also appears pretty thin/insufficient to support the proposed conclusions/recommendations.

8. Page 19. The document now suggests that impacts are predictable even though previous pages 56
indicate there is not enough information available.

9. Page 20. Have there been any studies regarding exposure time and frequency? It would be 57
interesting to see some numbers.

10. Page 23. There seems to be some disagreement as to whether or not development of 58
hydropower facilities at Sardis Reservoir would degrade conditions within the Kiamichi River. Could a low-level hydropower project operate in a manner that would not degrade current conditions or influence the Ouachita Rock-Pocketbook mussel?

11. Page 24. The OWRB is concerned with the following statement: "Although the ultimate 59
biological impact cannot be predicted, evidence indicates these mussels will eventually infest most North American drainage south of central Canada and will interfere with normal feeding and movements of native mussels, sufficient to seriously reduce native mussel populations." We believe this scenario is highly unlikely and our reasons are as follows: water in Southeast Oklahoma is too warm; 2) conductivity/hardness is too low and; 3) salinity in the Red River Basin is too high.

12. Page 26. Additional explanation is needed to expand upon the informal "Service" consultation 60
with the U.S. Army Corps of Engineers regarding the operation of Sardis Reservoir.

13. Page 56. The questions that must be asked is how can any species receive additional protection 61
until one knows it's habitat requirements and limiting factors (i.e. if mussels are limited by sedimentation, augmenting larval host populations or limiting discharges would have no effect).

UNITED STATES GOVERNMENT
memorandum

DATE: September 26, 1994

REPLY TO ATTN OF: Chief, Division of Endangered Species, FWS, Atlanta, Georgia (AES/TE)

SUBJECT: Ouachita Rock-pocketbook Draft Recovery Plan

TO: Field Supervisor, FWS, Tulsa, Oklahoma (Attn: Alan David Martinez)

Supervisor	0ES
Assistant	
Adornato	
Aldrich	
Brubeck	
Collins	
Frazier	
Hensley	
Langer	
Martin	
Martinez	ADM

We have reviewed the subject draft plan as requested. We only have a few comments to offer and these are provided below.

Executive Summary

Recovery Criteria - We suggest using the term "reclassification" to threatened status instead of "upgrading" throughout the recovery plan. How feasible is deauthorizing the Tuskahoma Reservoir? 62

Part I. Introduction

Page 24, second paragraph - Suggest restructuring the third sentence to "That study is designed to determine Ouachita rock-pocketbook occurrence in different river microhabitats. Movement, growth, survival, population fluctuations, and relative influence of water pollution and impoundment on mussel populations are also being examined." 63

Page 26, second paragraph - Would deauthorization of the proposed Tuskahoma Reservoir be a reasonable and prudent alternative? 64

Page 27, first paragraph - What do you mean by "unintended circumstances" in the fourth sentence? 65

Part II. Recovery

Page 31, third paragraph - Recommend rewording the last sentence to "The estimated date for reclassifying the species to threatened is 2015, if recovery criteria are met." 62

Page 32, fourth paragraph - Change "between" to "among" in the third sentence. 66

Page 36, second paragraph - What are some examples of the "additional measures" needed to achieve basic protection of the Kiamichi River population? What are 67

OPTIONAL FORM NO. 10
(REV. 1-80)
GSA FPMR (41 CFR) 101-11.6
5010-114

*U.S. GPO: 1993-342-199/60133

the limited authorizations that may exist? Development of a habitat conservation plan for an incidental take permit is still a requirement of the Endangered Species Act.

Page 37, first paragraph - We recommend changing this task to "Evaluate the feasibility of deauthorizing the Tuskahoma Reservoir" and suggest working with the Corps of Engineers (Corps) in finding a reasonable and prudent solution. 68

Page 51, first paragraph - Again, we recommend renaming and changing this task to show that the Fish and Wildlife Service will work with the Corps to implement feasible recovery actions.

Page 64, second paragraph - This task can also be implemented through partnerships with universities, private contractors, or the American Zoo and Aquarium Association. We suggest adding these to the list of responsible parties in the Implementation Schedule for this task and task 9.62. 69

Page 65, second paragraph - Suggest adding "in perpetuity" at the end of the last sentence. 70

We appreciate the opportunity to review this recovery plan. If you have any questions regarding our comments, please contact Gloria Lee of my staff at 404/679-7100.

OKLAHOMA

DAVID WALTERS, GOVERNOR
GREG D. DUFFY, DIRECTOR

DEPARTMENT OF WILDLIFE CONSERVATION

1801 N. Lincoln P.O. Box 53465 Oklahoma City, OK 73152 PH. 521-3851

September 29, 1994

Mr. David Martinez
U.S. Fish and Wildlife Service
222 South Houston, Suite A
Tulsa, OK 74127-8909

Dear Mr. Martinez,

This responds to the draft Ouachita Rock-pocketbook Recovery Plan prepared by your office and distributed for review on August 8, 1994. The ~~draft~~ recovery plan has been reviewed by the Natural Resources Section and Fisheries Division of the Oklahoma Department of Wildlife Conservation; however, no coordinated response has been prepared. This letter reflects the comments of the Natural Resources Section. If you do not receive a response from ODWC's Fisheries Division, please assume they have no additional comments.

We have reviewed the draft recovery plans and have no objections to its findings or approach. We concur with the need for each of the stated recovery tasks and will cooperate with the Service to accomplish these tasks to the best of our capability. 71

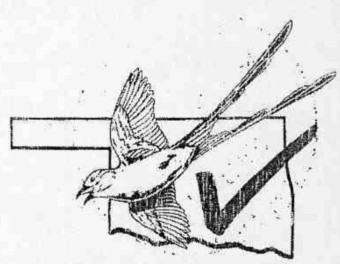
We appreciate the opportunity to review and provide comments on this draft. If you have any questions, please feel free to contact the Natural Resources Office at (405) 521-4616.

Sincerely,

Mark D. Howery

Mark D. Howery
Natural Resources Biologist

Supervisor	1073
Assistant	
Adornato	
Aldrich	
Bruheck	
Collins	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
Martin	
Martinez	ADM
Off. Asst.	
Clk Typist	
Reading	
File/Toss	



Search for the Scissortail on Your State Tax Form

An Equal Opportunity Employer

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

End. Sp. R-2
MacMullin
Brown
Byles
Chambers
Divine
Halvorson
Harp
Helfert
Lewis
McDonald
Parsons
Spangle

OCT 3 1994

RECEIVED
USFWS REG 2
OCT 11 '94
EWE

U.S. Fish and Wildlife Service
Division of Endangered Species
Recovery Coordinator
P.O. Box 1306
Albuquerque, NM 87103

Dear Sir:

Thank You for sending us a copy of the Ouachita Rock-pocketbook *Arkansia wheeleri* Ortmann and Walker, 1912 Draft Recovery Plan for review and comment.

Ecological Effects Branch has reviewed the draft document. It appears to be a conscientiously developed recovery plan for this endangered mollusk. We have no specific comments or questions at this time. 72

Sincerely,

Douglas Urban, Deputy
for
Antony F. Maciorowski, Chief
Ecological Effects Branch
Environmental Fate and Effects Division (7507C)

Printed on Recycled Paper

SUMMARY OF FWS RESPONSES TO COMMENTS ON THE FIRST DRAFT RECOVERY PLAN FOR THE OUACHITA ROCK POCKETBOOK

Eugene C. Gregory

1. The commenter expressed concern for possible persisting effects on organisms (such as the Ouachita rock pocketbook) inhabiting the Little River basin, from past activities at a former fiberboard plant. It is possible for such effects to occur, either from residual pollutants continuing to exert adverse effects (Ahlstedt and Tuberville 1997), or from biological factors (e.g., limited mobility, delayed maturation, low recruitment of offspring, and high juvenile mortalities) constraining mussels or other species so that many years are required to reestablish and rebuild damaged populations (McMahon 1991, Vaughn and Taylor 1999).

   Although it is difficult at this point to evaluate events described by the commenter, the facility in question is known to have operated for many years under relatively lax (by today's standards) waste management requirements, was sold in 1969 by the owners who would have been responsible for the alleged practices, and drew attention from jurisdictional agencies on multiple occasions for attributed environmental effects and/or apparent violations of applicable requirements. The U.S. Environmental Protection Agency (EPA) evaluated the facility under CERCLA (the Comprehensive Environmental Response, Compensation and Liability Act, aka Superfund) in the early 1980's, but found that persisting risks did not warrant further action under that program (Jhana Enders, EPA, *in litt.* 2001). Production operations at the facility ceased in 1990, and the current owner (Weyerhaeuser Co.) has continued working with the Oklahoma Department of Environmental Quality (ODEQ) to address waste management needs on the subject property. A former landfill at the site has been capped; continuing activities include use of monitoring wells to identify possible leaks from the landfill, eventual closure of former waste treatment lagoons on the property, and interim compliance with an NPDES (National Pollutant Discharge Elimination System) permit issued for the lagoons (Kelly Dixon, ODEQ, *in litt.* 2001, Mike Wood, Weyerhaeuser Co., pers. comm. 2002). Biological data from localities downstream from the facility indicate degraded conditions, but other local influences (e.g., cold, irregular reservoir releases) appear more severe than any residual pollution likely issuing from the former fiberboard plant. As recovery of the Ouachita rock pocketbook is pursued, future research and management efforts (e.g., under Tasks 3.1, 3.2, 3.3, and 5) may include more detailed assessments of factors affecting the lower Mountain Fork River, possibly better discerning effects attributable to reservoir operations, area pollution sources, and other causes. These tasks also call for treatment of factors found to interfere with the recovery of *Arkansia wheeleri*.

2. Recent surveys of the Little River system have included localities in the Little River shortly above the Mountain Fork River confluence, in the reach above Yanubbee [Crooked] Creek, and elsewhere (see references discussed under Distribution and Abundance). These have verified the Ouachita rock pocketbook's recent occurrence in the Little River as far west as Wright City, and as far east as near Millwood Reservoir, although the species' occurrence through most of that river section is limited and sporadic, due to habitat degradation.

3. The commenter's opinions notwithstanding, many scientific studies have documented potentials for gravel excavation and dam construction to harm aquatic life and modify native aquatic communities, including mussels and fish (see references discussed under Reasons for Listing/Threats). Because tolerant species can exploit many such disturbances, effects can be subtle and remain undetected without scientific investigation. At the same time, gravel excavation can be performed in ways that minimize effects on stream life, and small, low-head dams do not produce the full range and scale of effects produced by large dams. If the gravel mine mentioned truly has not been detrimental to aquatic life, it is most likely due to its operation in an environmentally conscientious manner.

4. The described pollution of the Rolling Fork River is discussed in the recovery plan as a known threat (see Water quality degradation) and has been noted, in fact, by multiple survey crews. Treatment of residual contamination from the spill, and of other pollution affecting the stream, has been initiated. Tasks 3.1, 3.23, and 9.3, among others, call for adequate treatment of pollution sources potentially affecting the Ouachita rock pocketbook and its existing/former habitats.

Dianna F. Noble, Texas Department of Transportation

5. Agency references in the plan have been changed to use the requested abbreviation.

6. The cost shown for the agency was an FWS estimate of average annual expenses. Like other cost estimates appearing in the plan, the level was developed using a variety of considerations, such as portion of the species' range within the state, relevant facilities and activities, task priority and total duration (extending, as in most cases, beyond the three years shown), and findings of others planning or implementing similar recovery tasks for other species. Because of considerable uncertainties regarding recovery of *A. wheeleri* and prevailing economic conditions at the time of specific actions, actual costs will likely differ from those listed, which were intended as general approximations only. Task costs listed in the recovery plan neither commit nor limit recovery participants to actual expenditures, which will be more accurately estimated as specific tasks are pursued.

7. It is appropriate for the Texas Department of Transportation to consult with the Arlington Ecological Services Field Office in matters regarding the Ouachita rock pocketbook. In occasional instances (e.g., involving formal consultations or take permits), the Arlington office may seek assistance from other FWS offices or suggest the Department contact such offices directly.

Bob Howells, Texas Parks and Wildlife Department

8. The plan has been revised to reflect the additional record.

9. The FWS agrees that survival of *A. wheeleri* and associated organisms in Sanders Creek could be enhanced by managing reservoir releases to maintain favorable conditions for the species. As indicated, Pat Mayse Reservoir was built and is operated by the U.S. Army Corps of Engineers (CE). The Endangered Species Act requires federal agencies such as the CE to ensure that they

do not jeopardize the continued existence of listed species, and further authorizes them to actively conserve such species. These considerations will be applied to Pat Mayse Reservoir under tasks 3.1 and 3.22 of the recovery plan, with input from tasks 4.1 and 5. As release recommendations are developed and revised, the relevant (Tulsa) CE district will ensure that project personnel receive information and approval by which to implement those recommendations.

David E. Bowles, Texas Parks and Wildlife Department

10. The plan has been revised to reflect the additional record.

11. The plan has been revised to reflect designation of the Texas streams as mussel sanctuaries.

Richard W. Standage and Larry D. Hedrick, Ouachita National Forest

12. The FWS subsequently received a copy of the project report, which did indeed report no evidence of the Ouachita rock pocketbook from tributaries on the Tiak Ranger District. Task 2.3 has been revised within the plan and implementation schedule to reflect completion of this responsibility by the Ouachita National Forest.

13. The FWS appreciates the interest of the Ouachita National Forest in supporting projects to benefit recovery of the Ouachita rock pocketbook. The FWS will notify the Forest of further opportunities to participate in such efforts, as these are submitted by cooperators for our consideration.

Caryn C. Vaughn, Oklahoma Natural Heritage Inventory

14. The plan has been updated as suggested to reflect more recent records from the Little River, including surveys completed later in 1994.

15. The introduction has been revised to include possible confusion with the threeridge, *Amblema plicata*, and basic means of distinguishing typical specimens.

16. The plan has been revised to reflect this additional record from the Kiamichi River.

17. The plan's discussion of habitat has been revised to reflect both the extracted description and the manuscript analyses, later published as Vaughn and Pyron (1995).

18. The habitat discussion has been revised to include the possibility that early habitat descriptions mischaracterized substrates in which specimens of *A. wheeleri* were found, in the context of current standards for sampling and classification.

19. Some of this information was covered in the paragraphs preceding the two specified. The plan has been revised to reflect other information provided, such as efforts to identify probable fish hosts.

20. The discussion of effects related to impoundment and channelization has been revised, and includes reference to available studies on the Little River. Those studies help substantiate the apparent sensitivity of the Ouachita rock pocketbook to stream modifications produced downstream from dams.

21. The discussions of effects observed downstream from Pine Creek Reservoir have been revised to incorporate later surveys, and include effects attributed to coldwater releases and the sawmill near Wright City (actually a timber/plywood mill, the company's local paper mill being located at Valliant and discharging into Garland Creek).

22. The plan has been revised to incorporate (in paraphrased form) this later comparison of localities upstream and downstream from Sardis Reservoir, using numbers of inhabited localities; abundances of *A. wheeleri*; recruitment by a more common, surrogate species; and glochidial densities.

23. While this concern has been expressed, many mussel populations seeming to exhibit such characteristics may face better than expected chances for survival. Many species appear to be relatively long-lived, and some of those examined do not exhibit senescence, showing a continued increase in reproductive output with age. Failure to recruit significant numbers of juveniles during certain years may be normal among some populations, and surviving juveniles are typically difficult to detect for the first few years. Nevertheless, the Ouachita rock pocketbook is not known to possess such traits, and any potential loss of reproduction is a point of concern, given the species' endangered status.

24. The stranding episode described was summarized in the draft plan, based on the account of Vaughn and Pyron (1992). Additional information pertaining to effects from flow modifications has been incorporated into the approved plan, including further observations in the Kiamichi River below Jackfork Creek.

25. Post-impoundment changes in the quantity and composition of particles transported by streams (including items used as food by mussels) has been documented for some drainages, and hypothesized as a possible effect on the Kiamichi River (Mehlhop and Miller 1989). A general potential for such change is mentioned in the recovery plan. Specific changes are not known to have been evaluated for streams within the natural range of *A. wheeleri*, but can be reasonably assumed to have occurred. The significance of such changes to the species is unknown.

26. Increased flows can indeed cause the indicated conditions, and like other flow modifications potentially associated with dams and diversions, can change aquatic communities dramatically by affecting species sensitive to the change in conditions. Substrate qualities are among the most significant factors determining freshwater mussel distribution, and loss of channel stability/increased sedimentation are probably detrimental to most mussel species. The plan's discussion of such effects has been expanded, including a description of channel changes detected below the confluence of Jackfork Creek and the Kiamichi River.

27. The plan has been revised to note the role of natural flows in formation and maintenance of complex habitats important to the occurrence of many mussels and other stream species.

28. The plan has been revised to note the important ecological relationships existing between streams and riparian zones, the corresponding importance of riparian zones to stream conservation (and vice versa), and the inordinate susceptibility of those zones to disturbance.

29. The isolation effect of reservoirs is considered in the plan, although not described at the level of detail provided by the commenter. While the plan is meant to be comprehensive, it is necessary to briefly treat most subject matter covered, while providing references to further information. In this case, and some others, it was felt that the recovery plan adequately covered commenters' issues or technical points, without discussion at the length requested. While not always requested by a given commenter, raised issues or points often receive additional consideration in the development of individual recovery tasks, such as 6.1 and 6.2, which include analysis of population isolation. Regardless, the full comments of commenters remain available in this appendix.

30. The plan has been revised to note important ecological relationships existing between streams and surrounding landscapes. The modification of natural cover can produce a wide range in stream effects, dependent on many variables (as stated).

31. "Headcuts" are a legitimate concern in conserving aquatic mollusks, and can be caused by activities other than construction of roads and crossings. Other activities commonly initiating headcuts include gravel mining, channelization projects, and smaller cuts to bypass stream meanders. One of the most significant effects from headcutting on the benthic fauna results from essentially a total disruption of the stream bottom at the moving point of the cut.

32. The plan is felt to cover this material adequately.

33. Likewise, predation was not identified as a threat during listing of *A. wheeleri* as an endangered species (Martinez and Jahrsdoerfer 1991).

34. The FWS considers the zebra mussel to be a serious threat to the Ouachita rock pocketbook, though not an immediate one. The plan's discussion of this threat has been expanded to highlight likely invasion routes into the range of *A. wheeleri*, as priority points for applying preventive measures.

35. Sardis Dam includes capabilities for both surface and subsurface releases, and both are used. The FWS has conducted preliminary evaluations of releases from Sardis Reservoir, and found that these are sometimes significantly cooler than acclimated water in the downstream channel. Such releases can abruptly and markedly reduce temperatures in the creek, although extent of effect in the Kiamichi River has not been determined. Degree of threat to *A. wheeleri* from existing or hypothetical releases is currently unknown, but warrants research and management attention under Tasks 5.3and 1.1.

36. The recommended parameters have been added to Task 1.31.

37. DNA fingerprinting has been added as a technique specifically listed under Task 4. While the

FWS agrees with the distinct utility of that technology, certain obstacles exist to its potential application to *A. wheeleri*, several of which the commenter mentions. To the list could be added the normal rarity of *A. wheeleri*, by which its glochidia would be expected to comprise a very small fraction of combined glochidial populations. The FWS appreciates the offer of adult tissue and glochidia samples for genetic analysis.

38. It would be necessary to obtain juveniles from infested fish known to be free of infestation from other indistinguishable species. While culture of the fish would be necessary, it might be possible to bring gravid *A. wheeleri* into the lab for only the period necessary to release active glochidia. Similarly, transformed juveniles might be returned to the wild in very fine-mesh enclosures where their success in different microhabitats could be monitored. Alternatively, successful development of culture techniques would allow more of this work to be performed in the lab. Clearly, there are many pre-requisite steps to either approach, and the task would probably follow other priority 1 tasks.

39. Work to date has produced much useful information about microhabitats successfully occupied by the Ouachita rock pocketbook. While these have been contrasted with other microhabitats available nearby in the same system, and affinities exhibited by other species, studies have not examined broad-scale variables that might potentially correspond with *A. wheeleri* incidence among streams or stream segments (e.g., as in Strayer 1993, Strayer *et al.* 1994, Di Maio and Corkum 1995). In addition, studies have not yet defined actual environmental sensitivities (i.e., responses and tolerances) of the Ouachita rock pocketbook to variable conditions. Environmental factors (e.g., temperatures) varying to extreme levels can produce stress in mussels and other organisms prior to reaching lethal levels. Relatively non-injurious techniques exist (e.g., tissue glycogen analysis) that indicate degrees of stress (Naimo *et al.* 1998, Naimo and Monroe 1999). Knowledge of stress levels produced under varied conditions would be valuable to management decisions dealing with water quality standards development, reservoir operations, instream and nearstream construction, for example. The task has been partly rewritten to better explain its value.

40. The Freedom of Information Act (FOIA) allows certain information (e.g., data divulging precise locations of threatened or endangered species occurrences) to be exempted from FOIA requests, as sensitive information. This is in recognition of the fact that full release of such information might subject listed species to increased harm.

<u>Doug Zollner, The Nature Conservancy Arkansas Field Office</u>

41. The CE has shown an interest in modifying releases from Sardis Reservoir to accommodate needs of the Ouachita rock pocketbook, while meeting other project purposes. This is perhaps most clearly indicated by the CEs' agreement to begin special releases in September 2000 to relieve extreme drying and heating of downstream mussel beds (discussed in the body of this plan). Through further analysis, the FWS hopes to recommend and arrange for automatic releases to meet minimum flow needs, should similar conditions recur. In addition, the CE has undertaken hydrologic studies to better characterize pre- and post- impoundment flow conditions in Jackfork Creek and the Kiamichi River. When completed, these should give an improved picture of the natural flow regime (Poff *et al.* 1997, Richter *et al.* 1997), and could be used as an

initial basis for restoring key elements of flow.

42. The FWS agrees that development of such a plan for the Kiamichi River is important but believes it should remain a number 2 priority. Current priority 1 tasks include such things as protection of the river under existing law; monitoring of *A. wheeleri*, its habitat and threats; and determination of the species' reproductive biology. Recovery of the Ouachita rock pocketbook would be virtually impossible without pursuing these tasks. While expected to be valuable and effective, development of a strategic habitat protection plan for the Kiamichi River is not equally essential. Advantages might exist to developing such a plan after starting certain other tasks. In the interim, the species' recovery plan can serve as a partial protection plan for the Kiamichi River.

43. Designation of critical habitat was determined to be not prudent at the time *A. wheeleri* was listed as an endangered species (Martinez and Jahrsdoerfer 1991). However, the overall value and prudence of designating critical habitat are issues that can be revisited over time, as circumstances change. At present, the FWS has no particular plans to reconsider critical habitat designation for the Ouachita rock pocketbook.

44. Multiple mussel surveyors have noted gravel mining as an actual or potential threat to *A. wheeleri* and associated species. While not affecting these resources to the degree of some other factors (especially impoundments), the harm produced by gravel mining practices must be addressed to accomplish recovery of the Ouachita rock pocketbook. Opportunities to do this exist within tasks 1.1, 1.24, 1.254, 1.32, 3.1, 3.23, 3.3, 8, and 9.3, among others. Additional information related to gravel mining effects has been added to the recovery plan. The FWS will strive to ensure that implementation efforts include adequate attention to these activities as significant impact sources.

<u>Frank Acker, Little River Conservation District</u>

45. The Ouachita rock pocketbook is known from the Little River basin, but also from the Kiamichi River, Ouachita River, Pine Creek, and Sanders Creek, all separate basins from the Little River watershed. Known localities appear to be shared by the Kiamichi, Little River, Pushmataha, Talihina, and Valliant conservation districts (Oklahoma); the Calhoun County, Clark County, Cossatot, Hot Spring County, Little River County, and Ouachita County conservation districts (Arkansas); and the Lamar Soil and Water Conservation District (Texas).

46. The FWS chose not to hold the requested public meeting, finding it more important at the time to deal with pressing research and management needs, to examine emerging proposals for new water resource development, and to work toward completion of the recovery plan, given limited program resources. Historical records of *A. wheeleri* were reviewed individually in the draft plan and are reviewed again in the approved plan, with the addition of previously unavailable information. The recovery plan calls for development of an outreach program to more effectively communicate with the public regarding the Ouachita rock pocketbook. That program will include opportunities for groups and citizens to meet with FWS specialists.

<u>Mike Mathis, Oklahoma Water Resources Board</u>

47. The requested extension was granted. The comments under development were later received, and follow this letter.

Duane A. Smith, Oklahoma Water Resources Board

48. The FWS agrees that reservoirs can be operated to produce conditions that are compatible with, and sometimes enhance, the survival of native mussels, other riverine organisms, and their habitats downstream from the reservoir structures. However, achieving such benefit can be impeded by (1) operational limitations of a reservoir, e.g., an inability to draw releases from multiple levels within the reservoir and loss of discretionary capacity over time, (2) conflicts between such operation and operation to serve other reservoir management objectives, (3) a lack of sufficient knowledge regarding actions needed to best benefit downstream resources, and (4) a failure to complete the necessary coordination among parties that would translate best available knowledge of biological needs into operational actions at reservoirs. Furthermore, some impacts associated with reservoirs (e.g., environmental changes throughout most of the pool, loss of genetic exchange between upstream and downstream populations) cannot be feasibly mitigated for the full native community by modifying operations. Given the general situation seen in North American freshwater systems today, an instance in which the sum of downstream benefits produced with a reservoir outweighs the associated impacts seems very unlikely, in relation to conserving the native diversity of species and especially sensitive species. In any case, the relative balance of benefits and impacts would vary case-by-case, and would depend on such factors as the extent of favorable actions actually realized, an avoidance of unfavorable actions, and location and reach of reservoir impacts within the ranges of affected species.

49. A need for research to fill information gaps is not a valid reason for postponing finalization of a recovery plan. In fact, identification of a research need within an approved recovery plan typically improves chances of funding a proposal to address that need through the primary funding sources used in listed species conservation. In addition, the term “final” can be misinterpreted here, since approved recovery plans (sometimes referred to as final plans) that normally follow draft plans can be revised or supplemented. The FWS reviews approved recovery plans periodically and may prepare updates or revisions, as tasks are completed, new information collected, and new needs identified. In regards to the Ouachita rock pocketbook, the FWS is issuing an approved plan to promote conservation of the species, but anticipates that periodic revisions will be warranted as knowledge of the species increases and investments are made in its recovery.

50. The FWS agrees that Sardis Reservoir could be operated to partly reduce flow fluctuations, riverbed scouring, sediment suspension, and other conditions generally detrimental to the native mussel fauna. However, difficulties are seen in achieving that potential, amply and soundly, for reasons listed above. Without adequate weighing of resource impacts, reservoir operations often produce new flow fluctuations and channel erosion, typically at unnatural times and places. In addition, certain extreme conditions (flood flows) and forms of instability are probably important in the formation and maintenance of stream habitats, and the occurrence of rare species such as the Ouachita rock pocketbook. Furthermore, consideration must be given to other adverse reservoir effects on stream organisms, which are not addressed by treating flow and sediment issues. These topics are discussed in more detail in revisions to the recovery plan and in some of

the following responses. Regardless, the recovery plan calls for improved management of existing reservoirs to produce the best practicable conditions for *A. wheeleri* (e.g., see Tasks 1.1 and 3.1).

51. Determination of details of reproduction in the Ouachita rock pocketbook is necessary because impaired reproduction may be one of the primary effects expressed under adverse conditions. It is necessary also in case population declines continue to a point where it becomes necessary to apply artificial propagation. However, in studying these aspects, it will be crucial to take steps that absolutely minimize effects on existing populations. Several such steps are identified under Task 4, including non-injurious examinations of individuals, minimal retention of individuals in laboratory facilities, and use of surrogate species to develop techniques, among others. While some stages of this research may involve intended or unintended deaths of *A. wheeleri* individuals, the FWS believes failure to obtain this information would ultimately lead to greater impacts on existing populations.

52. Excess siltation and sedimentation are detrimental to mussels in numerous ways, the more direct avenues including interference with respiration, feeding, and reproduction, processes that all depend upon unimpeded circulation of water through the animals and a proper condition and functioning of the gills. This is discussed in the recovery plan under Water quality degradation, including references to detailed sources. Impoundments do create deep deposits of fine sediments, which relatively few mussel species inhabit, and releases from impoundments generally exhibit a much reduced sediment load. However, sediment loads tend to reduce the energy characteristics of streams, and load reductions correspondingly allow faster flows within a given channel and gradient. As a result, clarified waters released from dams tend to be faster and more erosive until restoring a natural balance between transported load and flow characteristics. Dams can increase downstream erosion and sedimentation in other ways as well. For example, frequent fluctuations in released flows alternately saturate and expose bank soils, promoting sloughing.

53. Evidence indicating *A. wheeleri*'s low tolerance to changes produced downstream from reservoirs is discussed in the recovery plan and includes poor survival/possible elimination within an extended stream section below Pine Creek Dam, a similar status below Little River's confluence with the Mountain Fork River, elimination from the Kiamichi River below Hugo Dam, and reduced frequency and abundance in the Kiamichi River downstream from Jackfork Creek. Discussion in the recovery plan includes reference to detailed sources.

54. Clarke's (1987) statement was probably based on the small size of the Little River population (considered too small for long-term viability), limited effects he observed but failed to emphasize, and a known potential of other impoundments to eliminate sensitive species. Subsequent studies (Vaughn and Taylor 1999) help to back up Clarke's statement. The recovery plan has been revised to mention more of the conditions noted by Clarke and the later investigation by Vaughn and Taylor.

55. The recovery plan attempts to summarize available information, which is sometimes limited, but rarely contradictory. Regarding the section of Kiamichi River downstream from Jackfork Creek, Clarke's assessment, while authoritative, lacked the intensity and specificity of later studies.

Perhaps worth noting is the fact that Clarke's survey occurred close in time to the impoundment of Sardis Reservoir (1983), and certain effects may not have been as evident as in later years.

56. It is possible to predict predominant impacts resulting from water resource development projects, but certainly not the full range and extent of impacts. Because Tuskahoma Reservoir would be located in the heart of the healthiest sub-population of *A. wheeleri* (in the Kiamichi River upstream from Jackfork Creek), and would likely produce downstream effects, the FWS feels confident in predicting its impacts as severe and far-reaching.

57. Numerous studies have controlled exposure time and frequency. The review by Havlik and Marking (1987) includes examples of these.

58. While it is difficult to speak in generalities, addition of a low-level hydropower facility would add another management objective at Sardis Reservoir to be considered while trying to provide for the Ouachita rock pocketbook. Ability to meet both objectives would typically be determined during Section 7 consultation with the FWS.

59. The FWS disagrees. The range projected by Strayer (1991) using mean annual temperatures includes all but a fraction of southeastern Oklahoma. Conductivity and hardness in southeast Oklahoma are sufficient for mussels and gastropods to thrive across the area. The most likely routes of invasion involve placement of contaminated watercraft into reservoirs; for these and many of the tributary streams, salinity is not excessive.

60. The Endangered Species Act, specifically Section 7(a)(2), requires federal agencies to consult with the FWS whenever actions they perform may affect a listed species. Because operation of Sardis Reservoir has a recognized potential to affect the Ouachita rock pocketbook, the CE and FWS have initiated informal consultation regarding that operation. This consultation is being performed under standard procedures for interagency consultation detailed in 50 CFR 402.

61. Past and present research activities have provided a progressive increase in knowledge regarding the Ouachita rock pocketbook's habitat requirements and potential limiting factors. Future research will extend that knowledge. While knowledge remains incomplete, protection efforts can focus on known problems (e.g., mussel strandings below dams, specific sources observed as degrading water quality) and researched subjects (e.g., habitat associations in the Kiamichi River). As knowledge increases, it may modify initial priorities, or concepts of what constitutes sufficient protection for the species.

<u>David P. Flemming, FWS, Region 4</u>

62. Previous references to "upgrading" the species to threatened status have been replaced by "reclassification of," as requested. The FWS office primarily responsible for the plan preferred the former term at the time the draft was prepared, to express the positive nature of potentially improving a species' status from endangered to threatened. Currently that office agrees with use of the term reclassification, particularly for reasons of promoting a single, uniform terminology throughout the FWS recovery program. In addition, the lead office believes a relatively good chance exists to see Tuskahoma Reservoir deauthorized.

63. The suggested changes were made, along with an updating of the information.

64. Identification of deauthorization as a reasonable and prudent alternative (i.e., a protective action possible under existing law) might be difficult, because alone it would fail to serve the purposes of the reservoir project.

65. This refers basically to events such as accidental spills of deleterious materials. The sentence has been clarified.

66. The suggested change has been made.

67. Examples of additional measures include actions identified in the subordinate subtasks, i.e., 1.21 through 1.25. Examples of limited authorizations are identified in the same subtasks, or should be fairly apparent. While development of a habitat conservation plan is required in an instance of take, implementation of conservation measures that avoid take can be done voluntarily. The latter also have greater flexibility in their specific form and in participating parties.

68. The FWS office primarily responsible for the recovery plan prefers to retain the original language. While deauthorization of the project would represent a tangible benefit to the species, evaluating the feasibility of deauthorizing the project would not necessarily produce a benefit of similar importance.

69. The AZAA and Contractor (unspecified) have been added to the lists for these tasks. The FWS considers universities to qualify for the latter category.

70. The suggested change has been made.

<u>Mark D. Howery, Oklahoma Department of Wildlife Conservation</u>

71. No summary response needed.

<u>Anthony F. Maciorowski, U.S. Environmental Protection Agency</u>

72. No summary response needed.

U.S. Fish & Wildlife Service
Oklahoma Ecological Services Field Office
222 South Houston, Suite A
Tulsa, Oklahoma 74127
918/581-7458
918/581-7467 Fax

U.S. Fish & Wildlife Service
Office of Endangered Species
P.O. Box 1306
Albuquerque, New Mexico 87103
505/248-6920
505/248-6788 Fax

http://www.fws.gov

March 2004