# Scaleshell Mussel
# Draft Recovery Plan

(*Leptodea leptodon*)

August 2004

Department of the Interior
United States Fish and Wildlife Service
Great Lakes – Big Rivers Region (Region 3)
Fort Snelling, MN

# Scaleshell Mussel
# Draft Recovery Plan

(*Leptodea leptodon*)

August 2004

Prepared by

Andrew D. Roberts
U.S. Fish and Wildlife Service

**For**

Region 3
U.S. Fish and Wildlife Service
Fort Snelling, Minnesota

Approved: ____________________________

Robyn Thorson, Regional Director, Region 3
U. S. Fish and Wildlife Service

Date: ____________________

## Disclaimer

This is the scaleshell mussel (*Leptodea leptodon*) recovery plan. Recovery plans delineate reasonable actions believed required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service and 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 or the official positions or approval of any individuals or agencies involved in 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 being signed by the Regional Director. Approved recovery plans are subject to modifications as dictated by new findings, changes in species status, and the completion of recovery actions.

The plan will be revised as necessary, when more information on the species, its life history ecology, and management requirements are obtained.

Literature citation:

U.S. Fish and Wildlife Service. 2004. Scaleshell Mussel Draft Recovery Plan (*Leptodea leptodon*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 90 pp.

Recovery plans can be downloaded from the FWS website: http://endangered.fws.gov

Cover photo by Dr. M.C. Barnhart, female scaleshell (*Leptodea leptodon*)

# ACKNOWLEDGMENTS

The U.S. Fish and Wildlife Service gratefully acknowledge the commitment and efforts of the following individuals to the recovery of the scaleshell mussel. Without their assistance and valuable input this recovery plan would not have been possible.

**Dr. M.C. Barnhart**
Department of Biology
Southwest Missouri State University
901 South National Avenue
Springfield, Missouri 65804

**Sue Bruenderman**
Missouri Department of Conservation
1110 South College Avenue
Columbia, Missouri 65201

**Al Buchanan**
Missouri Department of Conservation
1110 South College Avenue
Columbia, Missouri 65201

**Scott Faiman**
Missouri Department of Conservation
1110 South College Avenue
Columbia, Missouri 65201

**Dr. John Harris**
Arkansas Highway Department
Environmental Division
P.O. Box 2261
Little Rock, Arkansas 72203

**Peggy Horner**
Missouri Department of Conservation
1110 South College Avenue
Columbia, Missouri 65201

**David Martinez**
U.S. Fish & Wildlife Service
222 S. Houston, Suite A
Tulsa, Oklahoma 74127

**Rob Pulliam**
Missouri Department of Conservation
P.O. Box 248
Sullivan, Missouri 63080

**Bill Posey**
Arkansas Game and Fish Commission
P.O. Box 6740
Perrytown, Arkansas 71801

**Susan Rogers**
U.S. Fish and Wildlife Service
4101 E. 80th Street
Bloomington, MN 55425-1665

**Charles M. Scott**
U.S. Fish and Wildlife Service
608 East Cherry Street, Room 200
Columbia, Missouri 65201

**Leslie TeWinkel**
U.S. Fish and Wildlife Service
Bishop Whipple Federal Building
1 Federal Dr.
Fort Snelling, MN 55111-4056

## EXECUTIVE SUMMARY

**Current Species Status**: The scaleshell mussel (*Leptodea leptod*on) is a federally endangered species that once occurred in 55 rivers in the Mississippi River Drainage including 13 states. The species has undergone a dramatic reduction in range and currently only 14 rivers support very small populations in Arkansas, Missouri, and Oklahoma. These rivers are included in the extant range of scaleshell based on the collection of a few or single specimen with the exception of the Meramec, Bourbeuse, and Gasconade rivers in Missouri where it is still rare. Of the 14 rivers with extant populations, 13 are believed to be declining.

**Habitat Requirements and Limiting Factors:** The scaleshell occurs in medium to large rivers with low to medium gradients. It primarily inhabits stable riffles and runs with gravel or mud substrate and moderate current velocity. Scaleshell requires good water quality, and is usually found where a diversity of other mussel species are concentrated. More specific habitat requirements of scaleshell are unknown, particularly of the juvenile stage. Water quality degradation, sedimentation, channel destabilization, and habitat destruction are contributing to the decline of the scaleshell throughout its range. The spread of the non-native zebra mussel (*Dreissena polymorpha*), may threaten scaleshell populations in the near future.

The scaleshell must complete a parasitic phase on freshwater drum (*Aplodinotus grunniens*) to complete its life cycle. This complex life cycle and extreme rarity of the species hinders its ability to reproduce. The sessile nature of the species and the low density of remaining populations exacerbate threats to its survival posed by the natural and manmade factors. Further, the shorter life span of the scaleshell may render it less able to tolerate periods of poor recruitment. The remaining populations are very susceptible to local extirpation with little chance of recolonization because of their scattered and isolated distribution.

**Recovery Strategy:** Augmenting existing populations through artificial propagation is considered necessary for the continued existence of scaleshell because remaining populations are in imminent danger of extirpation. The goal of a propagation program for scaleshell is to stabilize and create self-sustaining populations. Augmenting existing populations will help preserve genetic diversity of the species, ensure populations persist long enough to allow habitat improvements to take effect, and to permit further scientific study.

The decline of scaleshell is primarily due to threats that cause habitat loss and degradation from construction activities and intensive land use. Because only a small number of populations exist, it is essential that they all be protected, and recovery cannot be achieved without habitat restoration. Utilizing existing legislation, regulations, and programs to protect scaleshell and its habitat is a reasonable means to protect remaining scaleshell populations. A recovery implementation team will be formed to apply sound science to recovery and foster the diverse partnerships required to successfully implement the recovery actions outlined in this plan. The team will work with willing partners in each watershed occupied by the species, and eventually in parts of its historical range, to develop and implement habitat protection and restoration strategies to protect existing populations and habitat, eliminate threats, restore habitat, and improve surface land in watersheds while maintaining land in private ownership and preserving land ownership rights. Restoration efforts will be prioritized and focused on key areas within watersheds.

Other factors that potentially will affect scaleshell in the future include the introduction of non-native species, predation by small mammals, and mussel die-offs due to drought, contaminant spills, and disease. The scaleshell recovery implementation team will call on the nation's leading experts to devise methods to reduce the likelihood of zebra mussel or black carp invasions into streams occupied by scaleshell. Emergency response strategies will be developed, which will outline response protocols to effectively deal mussel kills and invasions of non-native species that do occur.

The successful recovery of the scaleshell mussel will depend on the extent of our knowledge of the species and the causes of its decline. Critical aspects of the biology, ecology, and genetics of the species needed to direct recovery actions and inform management decisions will be investigated. Water quality degradation has been a major factor in the decline of the scaleshell. Data will be collected on the tolerance of scaleshell to specific pollutants and the occurrence of these chemicals in watersheds in order to focus efforts to minimize or eliminate them. Lastly, various water quality and environmental changes associated with the operation of dams will be investigated to inform the conservation of populations located downstream of these operations.

An outreach and education program will be carried out to heighten awareness of scaleshell as an interesting and unique endangered species and to solicit outside help with recovery actions. Outreach material will be developed and produced to target the general public, schools, government agencies, congressionals, businesses, landowners, and other key partners needed to carry out recovery actions. The goal of this outreach program is to increase appreciation for scaleshell and provide information on how to become involved in recovery efforts. To increase the willingness of potential partners to participate in the recovery of scaleshell, materials will highlight the many benefits of scaleshell recovery actions to streams such as clean water and improved health of the ecosystem.

**Recovery Goals and Objectives**: The ultimate goal of the recovery actions outlined in this plan is to reclassify and eventually delist the scaleshell. The objectives are to ensure the long-term viability of the scaleshell by stabilizing and protecting existing populations and restoring its habitat and watersheds it depends on. Because of the extreme rarity of the species and the large-scale habitat restoration required to have a positive effect on populations, some recovery objectives may take a long time to achieve.

**Recovery Criteria:** The scaleshell will be considered for downlisting to threatened status when the likelihood of the species becoming extinct in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, four stream populations exist, each in a separate watershed and each made up of at least four local populations located in distinct portions of the stream. Each stream population must exist in a separate

watershed so that a single stochastic event, such as a toxic spill or disease outbreak, will not affect more than one stream population.

2. All local populations are persistent and viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.

3. Each local population and their habitat are sufficiently protected from any present and foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.

4. Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent and viable scaleshell populations if their densities have not changed for five consecutive years.

5. Tasks are completed to determine if water quality criteria should be included as a delisting criteria, and if so, water quality criteria for delisting will be developed.

The scaleshell will be considered for removal from the protection of the Endangered Species Act when the likelihood of the species becoming threatened in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of eight stream populations exist, each in a separate watershed and each made up of at least four local and geographically distinct populations. At a minimum, one stream population must be located in the Upper Mississippi River Basin, four in the Middle Mississippi River Basin (two of these must exist east of the Mississippi River), and three in the Lower Mississippi River Basin. Completion of action 3.4.2 or 3.4.3 may indicate more local populations, streams, or geographical regions are required.

2. All local populations are persistent and viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.

3. Each local population and their habitat are sufficiently protected from any present and foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.

4. Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent and viable scaleshell populations if their densities have not changed for five consecutive years.

5. Water quality criteria may be added to the recovery criteria for delisting upon completion of the tasks referred to under the recovery criteria for reclassification.

**Actions Needed:** Recovery actions needed for the scaleshell include: 1) Stabilize existing populations through artificial propagation to prevent their extirpation; 2) formation of partnerships and utilization of existing programs to protect remaining populations, restore habitat, and improve surface lands; 3) improve understanding of the biology and ecology of scaleshell; 4) further delineate the current status and distribution of scaleshell; 5) restore degraded habitat in areas of historical range; 6) reintroduce scaleshell into portions of its former range; 7) initiate various educational and public outreach actions to heighten awareness of the scaleshell as an endangered species and solicit help with recovery actions; and 8) track recovery and conduct periodic evaluations with respect to recovery criteria.

**Total Estimated Costs of Recovery:**

| **COST ESTIMATE (000's)** | | | | |
|---|---|---|---|---|
| **Year** | **Priority 1 Actions** | **Priority 2 Actions** | **Priority 3 Actions** | **Total** |
| **FY1** | 2517 | 79 | 2 | 2598 |
| **FY2** | 2528 | 71 | 3 | 2602 |
| **FY3** | 2526 | 0 | 15 | 2541 |
| **FY4** | 2490 | 0 | 15 | 2505 |
| **FY5 - 50** | 12855 | 1030 | 14482 | 28367 |
| **Total** | 22916 | 1180 | 14517 | **38613** |

**Date of Recovery:** If all funding requirements are met, the anticipated date of recovery is 2055. The threats affecting scaleshell populations are widespread in rivers occupied by the species and in many cases, the problems originate in the highest elevations of watersheds where the species does not occur. Because improvements need to take place throughout entire watersheds, a long period of time will be required for habitat improvements to begin having beneficial effects on populations and the habitat they depend on.

## TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

## PART 1. INTRODUCTION

### Status of the Species

The scaleshell mussel (*Leptodea leptodon*) was listed as endangered on October 9, 2001 (66 FR 51322). The species has a recovery priority number of two meaning that it is a species with a high degree of threat and is believed to have low recovery potential [see U.S. Fish and Wildlife Service (USFWS) 1990: 4 and Appendix IV].

### Taxonomy

| | |
|---|---|
| Phylum: | Mollusca; (Linne 1758, Cuvier 1797) |
| Class: | Bivalvia; (Linne 1758 after Bonnani 1681) |
| Order: | Unionoida; (Stoliczka 1871) |
| Family: | Unionidae; (Fleming 1828, Ortmann 1911) |
| Genus: | *Leptodea*; (Rafinesque, 1820) |
| Species: | *Leptodea leptodon*; (Rafinesque, 1820) |

The scaleshell is reported to have been first described by Rafinesque in 1820. However, there is some question whether his original description applies to scaleshell. Clarke (1996) argues that the original description of the shell and abundance of the species better fits the pink papershell (*Potamilus ohiensis*) or possibly the cracking pearlymussel (*Hemistena lata*). The following synonymy of scaleshell is from Parmalee and Bogan (1998).

*Unio* (*Leptodea*) *leptodon* Rafinesque, 1820; Rafinesque, 1820:295, pl. 80, figs. 5-7
*Unio leptodon* Rafinesque, 1820; Say, 1834:no pagination
*Symphynota leptodon* (Rafinesque, 1820); Férussac, 1835:25
*Alasmodonta leptodon* (Rafinesque, 1820); Lapham, 1852:370
*Leptodea leptodon* (Rafinesque, 1820); Conrad, 1853:262
*Lampsilis (Proptera) leptodon* (Rafinesque, 1820); Simpson, 1900:575
*Proptera leptodon* (Rafinesque, 1820); Sterki, 1907:393
*Lampsilis leptodon* (Rafinesque, 1820); Vanatta 1915:551
*Lasmonos leptodon* (Rafinesque, 1820); Utterback, 1916a:388
*Paraptera leptodon* (Rafinesque, 1820); Ortmann, 1918:571
*Lampsilis* (*Leptodea*) *leptodon* (Rafinesque, 1820); Frierson, 1927:82
*Anodon purpurascens* Swainson, 1823; Swainson, 1823a:pl. 160
*Symphynota tenuissima* Lea, 1829; Lea, 1829:453, pl. 11, fig. 21
*Margarita* (*Unio*) *tenuissimus* (Lea, 1829); Lea, 1836:38
*Unio tenuissimus* (Lea, 1829); Hanley, 1843:206, pl. 20, fig. 42
*Margaron* (*Unio*) *tenuissimus* (Lea, 1829); Lea, 1852c:38
*Unio velum* Say, 1829; Say, 1829:293
*Leptodea velum* (Say, 1829); Haas, 1969a:419
*Lampsilis blatchleyi* Daniels, 1902; Daniels, 1902:13, pl. 2
*Lampsilis* (*Proptera*) *blatchleyi* Daniels, 1902; Simpson, 1914:190
*Leptodea blatchleyi* (Daniels, 1902); Goodrich and van der Schalie 1944:316

## Description

The following description of scaleshell is summarized from Buchanan (1980), Cummings and Mayer (1992), Oesch (1995), Watters (1995), Parmalee and Bogan (1998), and Barnhart (2001). The shell reaches a length of approximately 10 centimeters (4 inches), although old individuals may reach 12 centimeters (4 ¾ inches). The periostracum is smooth, yellowish green or brown, with numerous faint green rays (Figure 1). The shells are elongate, very thin, compressed, and rhomboidal. The anterior end is rounded. The dorsal margin is straight, and the ventral margin is gently rounded. Beaks are small and low, and nearly even with the hinge line. The beak sculpture, which may not be visible in older individuals, is inconspicuously compressed and consists of four or five double-looped ridges. The pseudocardinal teeth are reduced to a small, thickened ridge. The lateral teeth are moderately long with two indistinct teeth occurring in the left valve and one fine tooth in the right valve. The beak cavity is very shallow. The nacre is pinkish white or light purple and highly iridescent.

The scaleshell exhibits marked sexual dimorphism (Figure 2). The most notable difference is the morphology of the posterior end. In males, the posterior end is bluntly pointed. In females, the periostracum forms a broad, ruffled extension of the posterior end of the shell (Buchanan 1980). Males and females also differ in overall size and shape. Females are usually smaller and less tall than males of similar age. Lastly, the beak of the female is located further anterior than that of the male (Barnhart 2001).

The anatomy of the soft tissues of scaleshell have not been described. Baker (1928) reported it to be similar to the fragile papershell (*Leptodea fragilis*). Utterback (1915) described the anatomy of the fragile papershell as follows: "Branchial opening round, with spreading, yellowish tentacles [papillae]; anal slightly crenulated, with thickened edges and normal diaphragm; supra-anal long, extending to dorsal ala, usually closed; mantles parallel at edges, dark colored and thickened on edges of siphonal openings, white patch at base of branchial papillae, crenulated along border in front of branchial opening, post-ventral region of mantle darker than that of female; palpi united only at base, very long in old specimens; foot large, powerful, very extensile; gills dark tan, pointed posteriorly, inner gills longer and broader than outer, inner laminae of inner gills entirely connected to visceral mass." The extent of which this description of the fragile papershell applies to scaleshell needs further investigation using living specimens. Based on recent photos of scaleshell from the Meramec Basin, Missouri (Figures 3 and 4), the above description does fit the species to some degree.

## Historical Distribution and Abundance

The scaleshell historically occurred in 55 rivers within the Mississippi River Drainage, which included 13 states (Table 1, Figure 5) (USFWS 2001). Williams *et al.* (1993) reported the historical range as Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Missouri, Ohio, Oklahoma, South Dakota, Tennessee, and Wisconsin. Historical records also exist in Minnesota (Clarke 1996).

While the scaleshell had a broad distribution historically, it apparently was not a common species locally (Call 1900, Baker 1928, Stansbery 1970, Gordon 1991, Oesch 1995, Clarke 1996). No quantitative data exists on the historic abundance of scaleshell, but early descriptions of its distribution indicate that scaleshell was rare. Call (1900) considered the species "fairly common but not an abundant species" in the Ohio and Wabash Rivers. Baker (1928) stated, "This is apparently a rare species in most places." In describing the status of scaleshell in the Mississippi River system, Stansbery (1970) wrote, "the expression 'widespread and everywhere rare' fits this species perfectly." Additionally, the small number of specimens in museum collections indicates that scaleshell was a rare species (Clarke 1996).

Several reports of scaleshell appear to be erroneous. Williams *et al.* (1993) listed Michigan and Mississippi as part of the scaleshell's range, but no valid records exist in these states. Therefore, its presence cannot be confirmed in Michigan and Mississippi (Szymanski 1998). Gordon (1991) included a portion of the St. Lawrence drainage in describing the distribution of scaleshell. However, the source specimens of the St. Lawrence River record were later identified as wingless examples of *Leptodea fragilis* (fragile papershell), a common species in New York (Strayer and Jirka 1997). Given this and that no other authentic specimens have been found, the historical occurrence of the species in the St. Lawrence Basin is doubtful (Szymanski 1998). Scammon (1906) reported scaleshell in Kansas, but this record is considered invalid (Murray and Leonard 1962). Lastly, Utterback (1915) mentioned the occurrence of scaleshell in the Neosho River, Missouri. However, no river exists in Missouri by that name. This is most likely a typo because Utterback was specifically discussing mussel collections from Missouri. However, the river name could have changed, or Utterback possibly was referring to the Neosho River in Kansas or Oklahoma.

See Appendix I for a more detailed discussion of scaleshell's historical distribution and abundance.

**Present Distribution and Abundance**

The scaleshell has been extirpated from all states in the northern and eastern portions of its range (Table 1). Most of this decline occurred before 1950 (USFWS). Within the last 20 years the scaleshell has become increasingly rare and its range greatly restricted. Currently, the species is found in only 14 of the 55 rivers where it historically occurred (USFWS 2001). These rivers include the Meramec, Bourbeuse, Big, Gasconade, and Osage rivers in Missouri; Frog Bayou and the St. Francis, Spring, South Fork Spring, South Fourche LaFave, and White rivers in Arkansas; and Little, Mountain Fork, and Kiamichi rivers in Oklahoma. The scaleshell may occur in an additional six rivers (Cossatot, Little Missouri, Saline, and Strawberry rivers, and Myatt and Gates creeks) in Arkansas and Oklahoma, but the existence of the species in these rivers is uncertain due to the lack of recent survey information (USFWS 2001).

With the exception of the Meramec, Bourbeuse, and Gasconade rivers in Missouri, all rivers listed as supporting the scaleshell are based on a few or a single specimen collected during one or more extensive mussel surveys of these rivers. In the Meramec, Bourbeuse, and Gasconade rivers, populations are extremely small and restricted to isolated patches of suitable habitat.

Based on dead and living specimens collected during a 1997 survey in the Meramec Basin, scaleshell occurs at isolated sites between river mile 18.5 and 60.2 of the Meramec and between river miles 1.4 and 76.9 in the Bourbeuse River. The species comprised 0.4 percent of the total number of living mussels found in the basin. This includes 34 living specimens in the Meramec from 9 sites and 10 living specimens from 5 sites in the Bourbeuse River (Roberts and Bruenderman 2000). Scaleshell has been reported in the Gasconade River between river mile 6 and 231. In a 1998/1999 survey, it comprised 0.2 percent of the total number of living mussels found between river miles 92 and 256.9. This included 12 living specimens from 9 sites (Bruenderman *et al*. 2001). In a 1994 survey of the lower 85 miles of the Gasconade River, 8 scaleshell were found at 8 sites and comprised 0.1% of the total number of mussels found (Buchanan 1994).

See Appendix I for a more detailed discussion of scaleshell's present distribution and abundance.

**Life History/Ecology**

General Biology

Relatively little is known about the life history of the scaleshell. Its general biology is believed to be similar to other bivalved mollusks belonging to the family Unionidae. Adults are filter feeders, using their gills to filter out suspended particles in the water column. While the diet of unionids is a subject of debate, it is believed to include detritus, phytoplankton, zooplankton, diatoms, bacteria, and other microorganisms (Fuller 1974). The extent of selectivity exhibited by mussels feeding on each of these food groups and species within these food groups is poorly understood and is likely to vary by species. Recent evidence suggests that detritus and bacteria may be an important food source (Silverman *et al*. 1997, Nichols and Garling 2000).

Even less is known about the feeding behaviors of juvenile mussels. Juvenile mussels are believed to employ foot (pedal) feeding to some degree for the first several months of their lives, feeding on depositional materials in interstitial water, including bacteria, algae, and detritus (Yeager *et al*. 1994). Pedal feeding in juveniles is accomplished by movements of microscopic cilia lining the foot that carry food particles into the mantle cavity and into the mouth. Juveniles also use the foot in a sweeping motion to draw particles toward the mantle cavity (Reid *et al*. 1992).

Adult unionids spend their entire lives partially or completely buried in the stream bottom (Murray and Leonard 1962). The depth to which they bury themselves may depend on the species, season, and environmental conditions (Parmalee and Bogan 1998). The posterior margin of the shell is usually partially spread, and the siphons extended to facilitate feeding and respiration. During periods of activity, movement is accomplished by extending and contracting a single muscular foot between the valves. Extension of the foot also enables the mussel to wedge itself into the river bottom. In the case of the scaleshell, it has frequently been observed living nearly or completely buried in the substrate to a depth of 13 centimeters (five inches) (Buchanan 1980, Oesch 1995, Roberts and Bruenderman 2000). In other circumstances it has been found residing on the surface (Roberts and Bruenderman 2000, Bruenderman *et al*. 2001).

The behavior of scaleshell with respect to the extent of its activity level, vertical migration in the substrate, and seasonal movements is not well understood.

Reproductive Biology

Unionids have an unusual and complex mode of reproduction, which includes a brief, obligatory parasitic stage on fish. Most species typically have separate sexes. Females lay eggs and brood them in specialized chambers in the gills (marsupia). Males release sperm into the water column in the spring, summer, or early fall (depending on the species). Sperm is drawn into the female through the incurrent siphon, and fertilization takes place internally. Within the marsupium, fertilized eggs develop into microscopic larvae (glochidia), which only have embryonic stages of a mouth, intestines, heart, and foot. Once the glochidia are mature, they are expelled into the water where they must quickly attach to the gills or the fins of an appropriate fish host to complete development. Glochidia that fail to attach to a suitable host will die. Host fish specificity varies among unionids. Some mussel species appear to require a single host species, while others can transform their glochidia into juvenile mussels on several fish species. Following proper host infestation, glochidia transform into juveniles and excyst (drop off). Juveniles must drop off into suitable habitat to survive. For further information on the life history of freshwater mussels, see Gordon and Layzer (1989), Watters (1995), and Parmalee and Bogan (1998).

Baker (1928) surmised that scaleshell is a long-term brooder. Recent observations support Baker's conclusion. Gordon (1991) reported observations of gravid scaleshell in September, October, November, and March (location unknown). In Missouri, gravid specimens have been observed in the Meramec and Gasconade rivers in August, September, October, April, and June (Barnhart 2001, data from Roberts and Bruenderman 2000). Additionally, Barnhart (1998) observed scaleshell in the Meramec River brooding undeveloped eggs in early August. The only known report of scaleshell collected in a non-gravid condition is July from the Big River, Missouri (Data from Roberts and Bruenderman 2000). Based on these observations, scaleshell spawns and begins brooding in early August and glochidia are released the following June in Missouri. Formal studies are needed to better define the breeding season of scaleshell. These studies should be based on water temperature, in addition to season, as a controlling factor of its reproductive cycle.

The glochidia of scaleshell are among the smallest in the family Unionidae. A specimen from the Meramec River, Missouri, produced glochidia with an average length and height of 0.0676 and 0.0810 millimeters respectively (Barnhart 1998). The glochidia are semi-elliptical, rounded in the ventral margin, and have a short hinge line, which is typical for the subfamily Lamsilinae (Figure 6). The fact that they are hookless suggests that they are more adapted to attach to the gill of its host. Some unionid species (mainly in the subfamily Anodontinae) have hooked glochidia, which is an adaptation to attach firmly and transform on the fins of hosts (Howard and Anson 1922, Hoggarth and Gaunt 1988). Scaleshell glochidia are brooded by the female in the outer gills (Figure 4). The marsupia occupies the posterior part of the outer pair of gills, and when gravid, extends beyond the original edge of the gills. This observation is similar to Utterback's (1915) description of *L. fragilis*.

Although the scaleshell is small, it has a high fecundity compared to many species. A small female collected from the Gasconade River with a length, width, and height of 44.1, 11.2, and 21.0 millimeters respectively produced an estimated 419,000 glochidia (Barnhart 2001). For comparison, a Plea's mussel (*Venustachoncha pleasii*) of similar size produced approximately 46,947 glochidia, and a giant floater (*Pyganodon grandis*) with a length, width, and height of 125.5, 81.1, and 56.5 millimeters respectively produced about 235,210 glochidia (Barnhart 2001). The small size of scaleshell's glochidia may contribute to its ability to produce large numbers of larvae (Barnhart 2001).

Unionids vary in their host specificity. Some mussel species can use a variety of fish species as hosts, but are usually limited to one or two families of fishes. A small number of mussels appear to be limited to a single fish host. The scaleshell appears to utilize the freshwater drum (*Aplodinotus grunniens*) exclusively as a host for its larvae. Barnhart (1998) tested 24 fish species and one amphibian, the mudpuppy (*Necturus maculosus maculosus*), as potential fish hosts in the laboratory. Glochidia only remained attached and transformed into juvenile mussels on the freshwater drum. Other species in the genus *Leptodea* and a closely related genus *Potamilus* are also known to use freshwater drum exclusively as a host (Watters 1994, Barnhart and Roberts 1997*a*, Roe *et al.* 1997, Barnhart 1998). While all available evidence suggests that drum is the host for scaleshell, it still is considered a potential host until drum with natural infections of scaleshell glochidia are observed in the wild.

The successful transfer of mature glochidia to a suitable host constitutes one of the critical events in the life cycle of freshwater mussels, and various adaptations to facilitate this process have evolved. The method of host infection greatly varies among species. While some species simply release glochidia into the water where they must haphazardly come into contact with the appropriate host, the process is more intricate and direct in other species. For example, females in the genus *Lampsilis* have an extension of the mantle tissue that strikingly resembles a small fish. This structure is displayed outside the shell from between the valves and is twitched repetitively to attract its predaceous fish host. The host is infected by the female mussel when the fish attempts to eat the lure (Kraemer 1970, Barnhart and Roberts 1997*b*). Other unionid species release conglutinates (small structures made up of gelatinous material that enclose large numbers of glochidia) freely into the water. These structures resemble prey items of the mussel's host fish; the host fish are infected when they attempt to eat them (Chamberlain 1934, Barnhart and Roberts 1997*b*).

How a scaleshell infects its host and the intricacy of this relationship is unknown. One interesting hypothesis is that the scaleshell infects drum via host predation of females (Barnhart 2001). The small size, sexual dimorphism, apparent rarity of females (see sex ratio section below), and the fact that freshwater drum are molluscivores support this hypothesis. Furthermore, scaleshell produce glochidia at a small size and young age, which may be another adaptation for consumption by drum (Barnhart 1998). Knowledge of how the scaleshell infects its host and what environmental conditions in the stream might facilitate this interaction might shed light on possible reasons for recruitment failure.

Once attached to its host fish, scaleshell will disperse with the fish for a period of weeks while they must successfully transform. This phase is another major bottleneck in the life cycle of unionids as not all glochidia that attach to a suitable host successfully transform into juveniles. Barnhart (2003) reported a transformation period for scaleshell glochidia of between two and three weeks on freshwater drum. In these laboratory infections, most developing glochidia remained encysted on drum for 16 to 20 days in water 25.5° C (77.9 °F). Transformation success of the glochidia varied widely on individual drum, ranging from 0 to 82%. This variation is unexplained and warrants further research. Genetics, age, and acquired immunity from previous parasitic infections are possible factors affecting the suitability of drum as a host for scaleshell.

Scaleshell is one of the few unionid species that grow during encystment on the host (Figure 7). Encysted juveniles grow more than four-fold in length before excysting. Bauer (1994) suggested that growth on the host fish and small glochidia size might be correlated with greater host specificity. Other species of *Leptodea* and species in the genus *Potamilus* also grow while encysted on host fish.

Growth and Longevity

Many freshwater mussel species are long-lived. Individuals of many species live more than 10 years, and some have been reported to live over 100 years (Cummings and Mayer 1992). Recent collections of scaleshell from Missouri indicate that it is relatively short-lived. A sample of 33 dead specimens and 2 living individuals collected in 2000 from a Gasconade River site did not contain any individuals exceeding approximately seven years old based on counts of external annuli (Barnhart 2001). Likewise, no individuals over approximately six years old were observed out of 44 living individuals collected in 1997 from the Meramec Basin (Roberts and Bruenderman 2000). Based on these collections, it appears that the life expectancy of the scaleshell is less than 10 years. However, these age estimates are speculative because the relationship between age and growth lines has not been validated for this species.

Sex Ratio

It appears that some scaleshell populations have skewed sex ratios. Barnhart (2001) reported collecting only 10 females out of 57 specimens in the Gasconade River and no females out of eight specimens in the Bourbeuse River (most of these specimens were fresh dead shells). Likewise, during a 1997 survey of the Meramec River Basin, only 15 females were collected out of 44 living individuals (Roberts and Bruenderman 2000). The sex ratio of the above collections is significantly different from a 50/50 ratio (Chi-Square Test, $P< 0.05$). The reason females appear to be less common than males in the Gasconade River and Meramec Basin is unknown and warrants further research.

**Habitat Characteristics/Ecosystem**

The scaleshell occurs in medium to large rivers with low to medium gradients. It inhabits a variety of substrate types, and primarily is found in stable riffles and runs with slow to moderate current velocity. Buchanan (1979, 1980, 1994) and Gordon (1991) reported it from riffle areas with substrate consisting of gravel, cobble, boulder, and occasionally mud or sand. Call (1900), Goodrich and Van der Schalie (1944), and Cummings and Mayer (1992) reported collections from muddy bottoms of medium-sized and large rivers. Oesch (1995) considered scaleshell a typical riffle species, occurring only in clear, unpolluted water with good current. Oesch also noted that it frequently buries itself in gravel to a depth of four to five inches. The scaleshell is also usually found in stable channels where a diversity of other mussel species are concentrated. Roberts and Bruenderman (2000) collected scaleshell primarily from mussel beds with stable, gravel substrates. These habitat observations are consistent with the current distribution of the scaleshell; the species is restricted to streams that have maintained relatively good water quality and to stream reaches with stable channels. More specific physical, chemical, and biological habitat requirements of scaleshell are unknown, particularly of the juvenile stage.

As discussed above, the scaleshell appears to be dependent solely upon freshwater drum to complete its life cycle. Drum are common in larger streams throughout the range of the scaleshell. Drum live most of their lives on or near the bottom, and are usually found in large pools (Pflieger 1997). Their diet consists primarily of fish, crayfish, and immature aquatic insects (Daiber 1953, Moen 1955, Priegel 1967). Additionally, drum are capable of crushing mollusk shells with their heavy pharyngeal teeth and are believed to feed on small freshwater mussels and other mollusks. Spawning of drum is believed to take place in open water and eggs float for one or two days until hatching (Daiber 1953). In Missouri, freshwater drum migrate out of large rivers and reservoirs into tributary streams to spawn in late April and May (Pflieger 1997). Knowledge on the distribution, abundance, habitat use, and behavior of freshwater drum is needed to manage scaleshell populations and determine suitable habitat for reintroduction of the species.

**Critical Habitat**

Critical habitat is not currently designated for the scaleshell. If following the completion of this plan the USFWS finds that it is prudent and determinable to designate critical habitat for this species, the USFWS will prepare a critical habitat proposal at such time as our available resources and other listing priorities under the Endangered Species Act (ESA) allow. This proposal will be based on essential habitat features needed to ensure the conservation and recovery of the species, many of which have been documented in the above Habitat Characteristics/Ecosystem section of this Recovery Plan.

**Reasons for Listing/Current Threats**

We followed procedures found in section 4 of the ESA (16 U.S.C. 1533) and regulations (50 CFR part 424) promulgated to implement the listing provisions of the ESA. The USFWS may determine a species to be endangered or threatened due to one or more of the five factors described in section 4(a)(1) of the ESA. These factors and their application to the scaleshell are as follows.

<u>Destruction, Modification, or Curtailment of its Habitat or Range</u>

The scaleshell has undergone a dramatic range reduction. The range of scaleshell was once expansive, spanning the Mississippi River Basin in at least 55 rivers in 13 states (Szymanski 1998). Today, the range is greatly reduced with extant populations in only 14 (potentially 20) rivers in three states. The scaleshell has been eliminated from all streams east of the Mississippi River and the entire upper Mississippi River drainage. Although much of the decline occurred before 1950, population declines continue in most portions of the species' range, and numerous threats are impacting the few remaining populations. Habitat destruction and degradation as a result of physical, chemical, and biological alterations, has and continues to threaten scaleshell populations. The major causes of such alteration are water pollution, sedimentation, channelization, sand and gravel mining, dredging, and impoundments. A general description of how these factors affect mussels is given below, followed by specific examples of how these threats are affecting scaleshell in its extant range. Refer to Szymanski (1998) and Watters (2000) for a more detailed discussion of threats to freshwater mussels.

Mussel biologists generally agree that contaminants are partially responsible for the decline of mussels [Havlik and Marking 1987, Williams *et al.* 1993, The National Native Mussel Conservation Committee (NNMCC) 1998]. Mussels are sedentary filter feeders and are vulnerable to contaminants that are dissolved in water, associated with suspended particles, or deposited in bottom sediments (Naimo *et al.* 1992). Mussels appear to be among the most sensitive organisms to heavy metals (i.e., cadmium, chromium, copper, mercury, zinc) some of which are lethal even at low levels (Havlik and Marking 1987). Mussels are also sensitive to ammonia associated with animal feedlots, nitrogenous fertilizers, and the effluents of municipal wastewater treatment plants (Goudreau *et al*. 1993).

Contaminants enter streams from point and nonpoint sources. Point source pollution is the entry of material from a discrete, identifiable source such as industrial effluents, sewage treatment plants, and solid waste disposal sites. Industrial and municipal effluents often contain heavy metals, ammonia, chlorine, phosphorus, and numerous organic compounds. Direct freshwater mussel mortality from toxic spills and polluted water is well documented (Ortmann 1909, Baker 1928, Cairns *et al.* 1971, Goudreau *et al.* 1988). Decline and elimination of populations may be due to acute and chronic toxic effects that result in direct mortality, reduced reproductive success, or compromised health of the animal or host fish.

Nonpoint source pollution is the entry of material into the environment from a diffuse source such as runoff from urban areas, cultivated fields, pastures, private wastewater effluents, agricultural feed lots and poultry houses, active and abandoned mines, construction, and highway and road drainage. Stream discharge from these sources may accelerate eutrophication (i.e., organic enrichment), decrease oxygen concentration, increase acidity and conductivity, and cause other changes in water chemistry that are detrimental to the survival of unionids and may impact host fishes (Fuller 1974, Dance 1981, Goudreau *et al.* 1988). Eutrophication generally occurs when nutrients are added in concentrations that cannot be assimilated as a result of runoff of organic wastewater contaminants from live stock farms and fertilizers used on row crops. Excessive growths of filamentous algae alter the surface of the stream bottom and may cause shifts in algal communities, disrupting food supplies for mussels. Juvenile mussels, utilizing interstitial habitats, are particularly affected by excessive levels of oxygen-consuming algae during nocturnal respiration (Sparks and Strayer 1998). Pesticides from row crops are a major source of agricultural contaminants, and are known to have direct affect on mussels (Havlik and Marking 1987).

Sediment is material that is suspended in the water, and is being transported, or has been moved, as the result of erosion [U.S. Soil and Conservation Service (USSCS) 1988]. Although sedimentation is a natural process, intensive agricultural practices, channelization, impoundments, timber harvesting within riparian zones, heavy recreational use, urbanization, and other land use activities can accelerate erosion (Chesters and Schierow 1985, Myers *et al.* 1985, Waters 1995, Watters 2000). The water quality impacts caused by sedimentation are numerous. Generally, it affects aquatic biota by altering the substratum and by altering the chemical and physical composition of the water (Ellis 1936, Myers *et al.* 1985, USSCS 1988). Heavy sediment loads can directly affect freshwater mussel survival by interfering with respiration and feeding. Due to their difficulty in escaping smothering conditions (Imlay 1972, Aldridge *et al.* 1987), either sudden or gradual blanketing of the stream bottom with sediment can suffocate freshwater mussels (Ellis 1936). Sediment particles may carry contaminants toxic to mussels (Naimo *et al.* 1992). Increased sediment levels may also reduce feeding efficiency (Ellis 1936), which can lead to decreased growth and survival (Bayne *et al.* 1981).

Channelization, sand and gravel mining, and dredging operations physically remove mussels from the water and may also bury or crush mussels (Watters 2000). More lasting effects of these activities involve the alteration or destruction of important unionid habitat that can extend upstream and downstream of the excavated area. Headcutting, the upstream progression of stream bed destabilization and accelerated bank erosion, can affect an area much larger than the dredging site (Hartfield 1993). In severe cases, this erosional process can extend for several miles upstream. As relatively immobile bottom-dwelling invertebrates, mussels are particularly vulnerable to channel degradation (Hartfield 1993). Accelerated erosion also releases sediment and pollutants, and in some instances, diminishes mussel diversity and habitat as documented in the Yellow and Kankakee Rivers in Indiana, the Big Vermillion River in Illinois, and the Ohio River (Fuller 1974).

Impoundments negatively affect mussels both upstream and downstream by inducing bank and channel scouring, altering water temperature regimes, and altering habitat, food, and fish host availability (Caryn Vaughn, in litt. 1997). Impoundments permanently flood stream channels and eliminate flowing water that is essential habitat for most unionids, including scaleshell (Fuller 1974, Oesch 1995). Scouring is a major cause of mussel mortality below dams (Layzer *et al.* 1993). Most detrimental, however, is the disruption of reproductive processes. Impoundments interfere with movement of host fishes, alter fish host assemblages, and isolate mussel beds from each other and from host fishes (Stansbery 1973, Fuller 1974, Vaughn 1993, Williams *et al.* 1993). The result is diminished recruitment (Layzer *et al.* 1993). Dams are effective barriers to fish host movement and migration that unionids depend on for dispersal. Mussels living upstream from the dam can become reproductively isolated from those living downstream, causing a decrease in genetic diversity locally. Even small, lowhead dams can hinder fish movement and isolate mussel beds from fish hosts and from each other. For example, Watters (1996) determined that the upstream distribution of two mussel species, the fragile papershell (*Leptodea fragilis*) and pink heelsplitter (*Potamilus alatus*), stopped at lowhead dams. These species, like the scaleshell, are believed to use the freshwater drum as a sole host.

The same threats that caused the extirpation of historical populations of scaleshell still exist and continue to threaten extant populations. This species appears to be susceptible to pollution and sedimentation. Historically, the species was widespread and occurred in diverse habitats. Today, scaleshell no longer occur at disturbed sites that still support other endangered unionids (Szymanski 1998). This suggests that scaleshell are sensitive to degraded water quality and habitat disturbance. Given the pervasiveness of the sources of pollution and sedimentation, it is apparent that these threats continue to be problematic for the remaining scaleshell populations. The following subsections describe threats to scaleshell within each watershed.

*Upper Mississippi River Basin*

The scaleshell formerly occurred in eight rivers and tributaries within the Upper Mississippi River Basin. However, this species has not been found in more than 50 years and is believed extirpated from this region (Kevin Cummings, in litt. 1994). It is believed that the same factors that have caused declines and extirpations of other mussel species including impoundments, pollution, sedimentation, and channelization and dredging activities, have caused the disappearance of scaleshell from the Upper Mississippi River Basin.

*Middle Mississippi River Basin*

Similar to the Upper Mississippi River Basin, impoundments, pollution, sedimentation, and channelization and dredging activities are believed to have led to the extirpation of the scaleshell from the entire Ohio River Basin. These same threats continue to adversely affect extant populations in the Middle Mississippi River Basin. Scaleshell habitat in the Meramec River Basin has been reduced in recent years. In 1979, Buchanan found living or dead scaleshell in the lower 180 km (112 mi) of the Meramec River (Buchanan 1979, 1980). In 1997, living or dead specimens were collected only in the lower 96 km (60 mi) of the river (Roberts and Bruenderman 2000). While portions of the lower reach continue to provide suitable habitat, mussel species diversity and abundance above mile 60 have declined noticeably in the last 20 years, and 9 mussel beds are no longer present between river mile 21.5 and 145.7. Roberts and Bruenderman (2000) attributed this decline primarily to the loss of channel stability. Water quality degradation is also a factor as the Meramec flows through the St. Louis Metropolitan area and a number of smaller towns.

Within the Meramec Basin, the Bourbeuse River has undergone the greatest change with respect to mussel populations. In particular, mussel populations have declined in the lower river. Whereas Buchanan (1979, 1980) found this section of the Bourbeuse River to have the greatest mussel diversity, this stretch was nearly devoid of mussels when resurveyed in 1997. Additionally, five mussel beds are no longer present between miles 0.4 and 137. Buchanan (in litt. 1997) and Roberts and Bruenderman (2000) attributed this decline to habitat loss from sedimentation, eutrophication, and substrate destabilization.

The Big River has the lowest species diversity and abundance in the Meramec River Basin. Buchanan (1979, 1980) attributed this to the effects of lead and barite mining. While most mining operations have ceased, 45 dams retaining mine waste and numerous waste piles remain in the Big River Basin. Most of those dams were improperly constructed or maintained. The U.S. Army Corps of Engineers (USACE) found that only one of the 45 dams was safe and 27 received the worst possible rating and could fail during a flood. The poor condition of the dams has led to large influxes of mine waste into the Big River from dam collapse [Missouri Department of Conservation (MDC) 1997]. For example, since 1978, a ruptured tailings dam has discharged 63,000 cubic meters (81,000 cubic yards) of mine tailings into the Big River covering 40 km (25 mi) of stream bottom and negatively impacting the lower 129 km (80 mi) of the river (Alan Buchanan, in litt. 1995), making it less suitable for mussels.

While no major impoundments exist in the Meramec River Basin, several old mill dams (low-head dams) affect the mainstem of the Big and Bourbeuse rivers. Five dams are still in place along the lower 48 km (30 mi) of the Big River, and two dams exist in the lower Bourbeuse River. These structures impound water for several miles upstream eliminating suitable mussel habitat. They are also effective barriers to host fish movement during normal flows (MDC 1997) and thus, continue to depress reproduction and dispersal of scaleshell and other mussels.

Gravel mining poses an imminent threat to scaleshell populations in the Meramec River Basin due to the high, and increasing, level of interest in gravel mining in the basin (Roberts and Bruenderman 2000). For example, between 1994 and 1998, the USACE issued permits for 230 sites. Additional sites were mined without a permit, but the number of these unauthorized operations is unknown. (Danny McClendon, USACE, St. Louis District, in litt. 1998).

The greatest threat to freshwater mussels reported in the Gasconade River is bank, channel, and substrate instability. This problem is particularly evident in tributaries to the Gasconade River. Other threats to mussels reported in the Gasconade River Basin include eutrophication, gravel dredging, municipal and industrial wastes, dense populations of the Asian clam, and cattle with unrestricted access to the stream (Bruenderman *et al*. 2001). In 1994, several areas of the lower Gasconade River channel were highly unstable, possibly a result of riparian vegetation removal in conjunction with the 1993 flood. These areas had high cut mud banks with trees fallen into the river, unstable substrate and contained very few mussels. Buchanan (1994) predicted that habitat degradation on this river would continue and postulated that the mussel fauna would be further impacted, with some species possibly disappearing. He noted that below river mile six, only one stable gravel bar contained a diverse mussel fauna. High silt deposition of the Missouri River prohibits the formation of mussel habitat below this area.

The majority of the Osage River system has been impounded and is no longer suitable for freshwater mussels. The majority of remaining mussel habitat occurs below Bagnell Dam in the lower 80 miles of the Osage River proper. This river reach is affected by the operation of Bagnell Dam, which alters flow and temperature regimes, lowers dissolved oxygen levels, and causes channel scouring and accelerated bank erosion. Several instream gravel mining operations, that physically remove mussels from the water and cause headcutting and siltation, currently exist in the Osage River.

*Lower Mississippi River Basin*

Channelization, levee construction, diversion ditches, control structures, and floodways have drastically altered much of the St. Francis River from the mouth above Helena, Arkansas, to Wappapello Dam, Missouri (Bates and Dennis 1983, Ahlstedt and Jenkinson 1987). Bates and Dennis (1983) determined that of the 54 sites sampled, 15 were productive, 10 were marginal, and 29 had either no shells or dead specimens only. They identified 77 km (48 mi) that may still provide suitable mussel habitat, but did not collect scaleshell. All the remaining river miles are unsuitable for mussels.

The White River between Beaver Reservoir and its headwaters is no longer suitable for mussels due to municipal pollution, gravel dredging, and dam construction (Gordon 1980). Navigational maintenance activities continue to destroy habitat from Newport to the confluence of the Mississippi River (Bates and Dennis 1983). This habitat destruction has relegated mussel species to a few refugial sites.

Species richness in the Spring River, Arkansas below river mile nine has declined markedly from past surveys, with the lower 5.0 km (3.0 mi) of river completely depleted of mussels and no longer providing suitable habitat (Gordon *et al.* 1984, Miller and Hartfield 1986). Sand and gravel dredging, destruction of stream banks, disturbance of mussel beds, deposition of wastes from livestock movement, siltation and surface run-off of pesticide and fertilizer appear to be contributing factors in the degradation of this river reach (Gordon *et al.* 1984).

Within Frog Bayou, potential habitat is restricted to the area between Rudy and the confluence of the Arkansas River. Within this area, streambank modifications and in-stream gravel mining are degrading scaleshell habitat. Two reservoirs, one near Maddux Spring and the other at Mountainburg, impact the river above Rudy. Below the confluence of the Arkansas River, Gordon (1980) did not find live mussels, likely due to dredging activities (Gordon 1980).

The proposed Tuskahoma Reservoir (located above Hugo Reservoir) is a potential threat to mussels in the Kiamichi River. Although the USACE has authorized construction, the lack of a local sponsor has rendered the project “inactive” (David Martinez, USFWS, Tulsa, pers. comm. 1997). If constructed, the adverse effects associated with reservoirs (including permanent flooding of the channel and disruption of reproduction) are likely to destroy the mussel fauna both above and below the proposed dam site.

Sewage pollution, gravel dredging, and reservoirs continue to impact the Little River. Pine Creek Reservoir impounds the mainstem of the river. Further downstream, Broken Bow Reservoir impounds a major tributary to the Little River, the Mountain Fork River. Below Pine Creek Lake, the mussel fauna is severely depleted but recovers with increasing distance from the impoundment (Caryn Vaughn, in litt. 1997). However, the discharge of reservoir water from

Pine Creek and periodic discharge of pollution from Rolling Fork Creek seriously impact any remaining scaleshell and prohibit any future recolonization (Clarke 1987).

Hydroelectric dams and artificial lakes have impacted the Ouachita River. The "Old River" (an oxbow system off the mainstem), is now essentially a series of muddy, stagnant pools, with water quality problems resulting from surrounding dumps (Clarke 1987).

In summary, many of the same threats that caused the extirpation of historical populations of scaleshell still exist and continue to threaten extant populations. Nonpoint and point source pollution is currently affecting the Spring River in Arkansas (Gordon *et al.* 1984, Miller and Hartfield 1986) and the Little River in Oklahoma (Clarke 1987, Vaughn 1994). Loss of stable substrates and sedimentation is causing deleterious effects in the Meramec and Bourbeuse rivers, Missouri (Bruenderman, pers. comm. 1998); Gasconade River, Missouri (Buchanan 1994); Frog Bayou, Arkansas (Gordon 1980); and Spring River, Arkansas (Gordon *et al.* 1984). Unregulated sand and gravel mining are eliminating important pool habitat (for both scaleshell and potential fish hosts) in the Meramec, Bourbeuse, Big, and Gasconade rivers in Missouri (Bruenderman, MDC, pers. comm. 1998). Impoundments, channelization, and other dredging activities (e.g., sand and gravel mining) are destroying mussel beds and impairing water quality in Frog Bayou, Arkansas (Gordon 1980); St. Francis River, Arkansas (Ahlstedt and Jenkinson 1987); White River, Arkansas (Bates and Dennis 1983); Spring River, Arkansas (Gordon *et al.* 1984); and Ouachita River, Arkansas (Clarke 1987). The proposed Kiamichi River Reservoir, if constructed, will have adverse impacts on any remaining populations in Oklahoma. Nearly all scaleshell populations are now restricted to small stretches of rivers with little, if any, potential for expansion or recolonization to other areas. For example, sewage pollution, gravel dredging, and reservoir construction have degraded the Little River in Oklahoma to the extent that only a few small stretches are able to support mussels.

Overuse for Commercial, Recreational, Scientific, or Educational Purposes

It is unlikely that commercial mussel collectors ever purposefully collected scaleshell because of their small size and thin shell. It is probable, however, that over-harvesting activities that removed entire mussel beds impacted scaleshell populations. For example, according to local fishermen, during a period of extended drought, mussel harvesters severely over-collected mussel beds in the Spring and Black Rivers and completely destroyed most beds (Gordon *et al.* 1984). Thus, scaleshell populations may have been impacted by habitat destruction (i.e., disturbance of stream bottom), trampling, and removal of individuals from the stream. Individuals dislodged from the stream bottom could be washed away into unsuitable habitat, particularly because scaleshell is a very light mussel in the water due to its small size and thin shell. Even for mussels returned to the stream, mortality can still occur (Williams *et al.* 1993). Today, intensive mussel collecting activity can have severe adverse affects on existing populations, because scaleshell now occur in very small, isolated areas. The destruction of only a few individuals could be a contributing factor in the extirpation of some populations.

As scaleshell become more uncommon, the interest of scientific and shell collectors will increase. Scaleshell occurrences are generally localized, easily accessible, and exposed during low flow periods, and, therefore, are also vulnerable to take for fish bait, curiosity, or vandalism. Prior to the listing of scaleshell as an endangered species, up to five freshwater mussels per day could be legally collected in Missouri and used for fishing bait (MDC 2003). While this provision does not include federally listed species or state species of conservation concern, scaleshell can easily be confused with other species, particularly by untrained collectors. However, the low density of scaleshell minimizes the likelihood of a scaleshell being collected.

Disease or Predation

Although natural predation is usually not a factor for stable, healthy mussel populations, small mammal predation could pose a problem for scaleshell populations (Gordon 1991). Small mammals, such as river otters, muskrats, and raccoons, are common predators of scaleshell throughout their range, particularly during periods of low water providing easy access to mussel beds. These mammals are so effective at finding and eating freshwater mussels that malacologists consider collecting dead shells from middens a good way to determine the presence of rare species. For example, freshly killed scaleshell were found among other species at several active raccoon middens during a freshwater mussel survey of the Meramec and Bourbeuse Rivers (Roberts and Bruenderman 2000). Muskrat predation has been shown to be potentially detrimental to the recovery of rare mussels (Neves and Odom 1989). While the large size or thick shells of some species afford protection from small mammal predators, the small size and fragile shell of the scaleshell makes it an easy and desirable prey species. Extant scaleshell populations in Arkansas and Oklahoma are small, isolated, and have very limited recolonization potential. Thus, the removal of even a small number of individuals could significantly affect these populations. Small populations are less resilient to these natural predators, and therefore, are much more threatened by them. Consequently, predation could exacerbate ongoing population declines of scaleshell.

Bacteria and protozoans persist at unnaturally high concentrations in streams with high sediment load or in water bodies affected by point source pollution, such as sewage treatment plants (Goudreau *et al.* 1988). At such concentrations, mussel ova and glochidia are more subject to infection (Ellis 1929). Disease and parasites may have caused major die-offs of freshwater mussels in the late 1970s throughout the eastern United States (Neves 1986). For example, significant die-offs of freshwater mussels occurred in 1977 and 1978 in the Meramec and Bourbeuse Rivers. Large numbers of mussels of all species, including scaleshell, were lost. Buchanan (1986) presumed an epizootic or other disease caused the die-off since no environmental impact was reported or could be found.

Little is known about predators of juvenile mussels. As microscopic inhabitants in the bottom of the stream, juvenile freshwater mussels probably fall prey to a variety of macroinvertebrate predators such as hydra, various aquatic insect larvae, and crayfish. Flatworms have been shown to be voracious predators of newly metamorphosed juvenile mussels (Barnhart 2002, Delp 2002, Zimmerman and Neves 2003). However, juvenile mussels grow rapidly and can exceed the size of these tiny predators (Barnhart 2002, Delp 2002).

The Inadequacy of Existing Regulatory Mechanisms

The passage of the Clean Water Act (CWA) resulted in many positive consequences for freshwater ecosystems (including a decrease in lead and fecal coliform bacteria), and set the stage for the regulations and the water standards that exist today. Goals of the CWA include the protection and enhancement of fish, shellfish, and wildlife providing conditions suitable for recreation in surface waters and eliminating the discharge of pollutants into U.S. waters. However, despite the implementation of the CWA, degraded water quality still presents problems for sensitive aquatic organisms such as freshwater mussels. Specifically, nationwide stream and lake sampling has indicated continuing increases in nitrate, chloride, arsenic, and cadmium concentrations (Neves 1993). Nonpoint pollution sources appear to be the cause of increases in nitrogen. Many of the impacts discussed above occurred in the past as unintended consequences of human development. Improved understanding of these consequences has led to regulatory (e.g., CWA) and voluntary measures (e.g., best management practices for agriculture and silviculture) and improved land use practices that are generally compatible with the continued existence of the scaleshell. Nonetheless, the scaleshell is highly restricted in numbers and distribution and shows little evidence of recovering from historical habitat degradation and losses.

In 1997, gravel mining became a more serious threat for scaleshell range-wide when a court ruling (American Mining Congress versus USACE) changed the interpretation of the CWA as it applies to the regulation of gravel mining (Roell 1999). Previously, gravel mining was more strictly regulated because “incidental fallback” (the incidental soil movement from excavation, such as the soil that is disturbed when dirt is shoveled, or back-spill that comes off a bucket and falls into the same place from which it was removed) was considered fill in surface waters, thus triggering the permitting process of the USACE under Section 404 of the CWA. Prior to the 1997 ruling, gravel mining operators were required to obtain a USACE Section 404 permit and follow several conditions outlined on the permit. Except in very small tributaries, the USACE required all operators to establish a streamside and riparian buffer and prohibited removing gravel from flowing water (i.e., no in-stream mining) or from below the water table (Danny McClendon, USACE, St. Louis District, pers. comm. 1998). These requirements avoided most adverse effects to mussels including headcutting, channel modification, and the physical crushing or removal of mussels. Furthermore, the USACE’s permit process included consultation with the USFWS concerning the presence of federally listed species at each proposed mining site. However, the 1997 ruling eliminated the USACE’ authority to regulate most instream gravel mining activities, thereby eliminating the section 404 permit and the conditions that protected mussel beds. Therefore, the scaleshell has lost much of its protection from gravel mining. The USACE will still retain oversight authority and require a permit for gravel mining activities that deposit fill into streams greater than incidental fallback under Section 404 of the CWA (i.e. instream gravel stockpiling, stream crossings, and select removal methods). A USACE permit would also be required under Section 10 of the Rivers and Harbors Act for navigable waterways. However, many gravel mining operations do not fall under these two categories.

The Missouri Department of Natural Resources (MDNR) is currently responsible for regulating gravel mining in Missouri, but has limited regulatory authority. City, county, and state operators using their own equipment and private operations are not required to obtain a MDNR permit for instream gravel mining. In Arkansas, instream gravel mining will still be controlled by the Arkansas Open-Cut Mining and Land Reclamation Code, which contains required conditions to reduce impacts (Roell 1999). Additionally, since MDNR is not a Federal agency, Section 7 of the ESA, which required the USACE to consult with the USFWS regarding the presence of federally listed species at proposed gravel mining sites, is no longer applicable. Without the section 7 consultation process, mussel beds containing federally listed species could be adversely affected by gravel mining operations.

Although recognized by species experts as threatened in the state of Arkansas, the scaleshell has not been afforded state protection prior to becoming federally listed as an endangered species. Missouri and Oklahoma previously listed it a species of conservation concern (Sue Bruenderman, in litt. 1998; Caryn Vaughn, pers. comm. 1995). However, these designations were primarily used for planning and communication purposes and did not afford any significant state protection from direct take and habitat destruction (David Martinez, pers. comm. 1997; Paul McKenzie, USFWS, Columbia, MO, pers. comm. 1997).

Other Natural or Manmade Factors Affecting Its Continued Existence

Biological traits: The inherent biological traits of freshwater mussels increase their vulnerability to extinction (Neves 1993). Their complex life cycle offers many opportunities for reproduction to fail including incomplete fertilization due to low density upstream populations, failure to attach to the appropriate fish host, and unsuccessful transformation on the fish host. If a larva successfully transforms on a host, it is further challenged with dropping off into suitable habitat. Estimated chances of successful glochidial transformation and excystment (detachment) range between 0.0001 percent (Jansen and Hanson 1991) and 0.000001 percent (Young and Williams 1984). As a result of fish host-specificity and the difficulty of locating suitable habitat, even under optimal conditions, freshwater mussel population growth occurs very slowly. Furthermore, the sedentary nature of mussels limits their dispersal capability. This trait, coupled with low recruitment success, translates into the need for decades of immigration and recruitment for re-establishment of self-sustaining populations.

Population size and habitat fragmentation: The small number and low density of the remaining scaleshell populations exacerbate threats to its survival posed by the natural and manmade factors discussed above. Although the scaleshell was always locally rare though broadly distributed, the widespread loss of populations and the limited number of collections in recent years indicates that the current population densities are much lower (due to the previously identified threats) than historical levels. Despite any evolutionary adaptations for rarity, habitat loss and degradation increase a species' vulnerability to extinction (Noss and Cooperrider 1994). Similarly, as the number of occupied sites decreases, and the likelihood of extinction increases (Vaughn 1993). This increased vulnerability is the result of chance events. Environmental variation, random or predictable, naturally causes fluctuations in populations. However, small and low density populations are more likely to fluctuate below the minimum viable population (i.e., the minimum number of individuals needed in a population to persist) (Szymanski 1998). If population levels stay below this minimum size, an inevitable and often irreversible slide toward extinction will occur. Further, the shorter life span of the scaleshell may render it less able to tolerate periods of poor recruitment or increased mortality than longer-lived mussel species (Barnhart 2001).

Small populations are also more susceptible to inbreeding depression and genetic drift. Populations subjected to either of these problems usually have low genetic diversity, which reduces fertility, survivorship, and the ability to adapt to environmental changes. Also, chance variation in age and sex ratios can affect birth and death rates. Skewing of these ratios may lead to death rates exceeding the birth rates, and when this occurs in small populations there is a higher risk of extinction (Szymanski 1998).

Similarly, the fertilization success of females may be related to population density, with a threshold density required for any reproductive success to occur (Downing *et al.* 1993). Many of the remaining scaleshell populations may be at or below this threshold density. Because females must siphon sperm released by males into the water column, successful spawning events depend on upstream males. Therefore, a low density or lack of upstream males can result in incomplete fertilization of females. In 2002, a gravid female scaleshell collected from the Meramec River Basin, Missouri was observed to be only partially fertilized (Dr. M.C. Barnhart, pers. comm. 2003). This individual is one of only a few females in which the gill contents were examined under a microscope to determine the developmental condition of the eggs. The incomplete fertilization of this female may be an indication that spawning failures may be occurring in scaleshell populations because small populations may have individuals too scattered to reproduce effectively. These populations will be, if the aforementioned threats go unabated, forced below or forced to remain below the minimum threshold. As a result, reproduction is diminished or ceases, and the current decline to extinction will be accelerated.

Species that occur in low numbers must rely on dispersal and immigration for long-term persistence. In order to retain genetic viability and guard against chance extinction, movement between populations must occur. Although the scaleshell naturally occurs in patches within a river and necessarily possesses mechanisms to adapt to such a discontinuous distribution, anthropogenic (man-made) influences have fragmented and further lengthened the distance between patches. Empirical studies have shown that with increasing isolation, immigration and colonization rates decrease. Also, as previously explained, natural recolonization of mussels occurs at a very low rate (Vaughn 1993). Therefore, preservation of a population (including all partially isolated patches in a river) structure is imperative for long-term freshwater mussel survival. Unfortunately, many of the extant scaleshell populations now occur as single, isolated sites. These highly isolated populations are very susceptible to natural stochastic events and human-induced environmental change.

<u>Drought</u>: Severe drought is a natural event that can have devastating effects on freshwater mussels because of their inability to escape adverse environmental conditions. Because scaleshell is primarily a riffle species, many extant scaleshell sites are in relatively shallow water. This makes some local populations susceptible to exposure during drought conditions.

For example, unusually low water in 2000 caused the partial exposure of several mussel beds containing scaleshell in the Gasconade and Meramec River basins (Bruenderman, pers. comm. 2000). Concentrations of mussels, particularly around the peripheral edges of mussel beds, were exposed for long periods. Based on fresh dead shells collected from these areas, a number of scaleshell and many other species died from desiccation. While some thick-shelled mussel species can survive emersion for extended periods, the thin shell of scaleshell and its inability to close its valves completely makes it especially vulnerable to emersion (Dr. M.C. Barnhart, pers. comm. 2004). Low water also allows raccoons and other small mammals that prey on mussels to gain easy access to mussel beds.

Non-native species: The introduction of non-native freshwater bivalves into the United States has contributed to the decline of the native mussel fauna. The recent invasion of the exotic zebra mussel (*Dreissena polymorpha*) poses a substantial threat to native unionids (Herbert *et al.* 1989). The introduction of *Dreissena* into North America probably resulted from an ocean-crossing vessel that discharged freshwater ballast from Europe containing free-swimming larvae of the zebra mussel (Griffiths *et al.* 1991). Since its discovery in North America in Lake St. Clair of the Laurentain Great Lakes in 1988, this prolific species has spread throughout the Mississippi River and many of its tributaries including the Illinois and Ohio basins and the Arkansas (into Oklahoma and Kansas) and Tennessee rivers (Figure 8).

Zebra mussels have effective dispersal mechanisms, which has facilitated their spread in the United States. Because zebra mussels attach themselves to hard surfaces, they can spread by attaching and living on commercial and recreational vessels. The free swimming, microscopic larva spread naturally downstream of reproducing populations. The larva are also transported from infected waters via bait buckets and live wells of recreational boats and introduced into new areas (Figure 8). Zebra mussels starve and suffocate native mussels by attaching to their shells and the surrounding habitat in large numbers. The spread of this prolific species has caused severe declines of native freshwater mussel species in many areas (Tucker *et al.* 1993, Kent Kroonemeyer, USFWS in litt. 1994, Illinois Natural History Survey, in litt. 1995, USACE, in litt. 2000).

Zebra mussels have spread throughout much of the Mississippi River Basin, but at this time, no established populations are known to occur in streams occupied by scaleshell. However, they are likely to invade these streams based on the proliferation and spread that has already occurred. Many rivers within scaleshell's extant range are similar in most ways to other tributaries of the Mississippi River with established zebra mussel populations.

The threat posed by zebra mussels appears to be imminent for the largest remaining populations of scaleshell. In 1999, a live zebra mussel was collected at river mile 6.9 in the lower Meramec River (Dr. M.C. Barnhart, in litt. 1999). Veligers have been found in Missouri River in Nebraska, indicating the existence of a reproducing population. If zebra mussels successfully colonize the Missouri River, it is likely that they will eventually spread into the Gasconade River (a tributary of the Missouri), which has perhaps the largest population of scaleshell next to those in the Meramec Basin. Further, scaleshell populations in navigable rivers and downstream from reservoirs (e.g., White and Osage Rivers) are particularly vulnerable due to commercial and recreational vessels that utilize these water bodies, which will hasten the invasion. For example, in 2003, an established zebra mussel population was discovered in Oologah Lake on the Virdigris River in Oklahoma (David Martinez, FWS, in litt. 2003). This population was likely introduced by boats.

The Asian clam (*Corbicula fluminea*) is another freshwater bivalve that has been introduced into North America. It was first discovered in the United States in the late 1930's (Oesch 1995). Its prolific reproductive capability has allowed it to quickly spread its range across the continent, and the species is now almost ubiquitous throughout the range of scaleshell. The Asian clam can become the dominant benthic species as densities of several hundred to $10{,}000/m^2$ have been reported in some rivers (Neves 1986, Sickel 1986). The species is believed to compete with native mussels for resources such as food, nutrients, and space (Kraemer 1979, Clark 1986). High densities of Asian clams have been found to negatively affect the survival and growth of juvenile native mussels by disturbance and displacement of young juveniles and possibly through incidental ingestion of newly metamorphosed individuals (Yeager *et al*. 2000). Further, *Corbicula* populations can grow rapidly and are prone to rapid die-offs (MacMahon and Williams 1986), which can affect native mussels by depleting the oxygen supply and by producing high levels of ammonia (Strayer 1997).

The black carp (*Mylopharyngodon piceus*) poses a new and significant threat to scaleshell in the near future. The species is native to Eastern Asia. Adults feed on freshwater mollusks extensively. A four year old black carp was shown to eat an average of 3-4 pounds of mussels per day (USFWS 2002*a*). Sterile forms of the species are currently proposed for widespread use in fish farm ponds to control snail populations that provide the intermediate host for a parasitic trematode affecting hatchery stocks. It is currently being maintained in research and production facilities in six states (Nico and Williams 1996). Because adult black carp feed heavily on mollusks, it poses a major threat to scaleshell and other native mussel and snail species if allowed to escape into the wild and establish reproducing populations. Escape is inevitable if the species is used outside of closely controlled and monitored hatchery facilities. In fact, a sterile black carp specimen was found in March 2003 in an oxbow of the Mississippi River near the mouth of the Ohio River (Mississippi Interstate Cooperative Resource Association 2003). This confirms that the black carp can escape and survive in the wild. Farm fish ponds are not closely controlled and monitored and are often located in bottomlands that are subject to flooding. Thus, a single event could permit their escape. If wild populations are established, the black carp is likely to proliferate in North America as other related, non-native carp have such as the grass carp (*Ctenopharyngodon idella*) (Nico and Williams 1996). Currently, the black carp is proposed as an injurious wildlife species. If it becomes listed as injurious wildlife, it will come under jurisdiction of the Lacey Act. This will allow federal agencies to control black carp use and monitor commercial hatcheries and pond facilities.

Summary of reasons for listing/current threats

Significant habitat loss and degradation, range reduction, population fragmentation, and small population size has made the scaleshell vulnerable to extinction. The scaleshell has disappeared from the entire upper and most of the middle Mississippi River drainages. Of the 55 known historical populations, 14 (possibly 20) remain. Although much of the decline occurred before 1950, population declines continue in most of the species' range, and numerous threats, including water quality degradation, loss of stable substrates, sedimentation, channelization, gravel mining, dredging, and impoundments, are negatively affecting the few remaining viable extant populations. The small number and low density of the remaining scaleshell populations exacerbate the threats and adverse effects of chance events to scaleshell. Additionally, the threat of the non-native zebra mussel and possibly the black carp is impending.

Data Gaps in Available Information

The successful recovery of the scaleshell mussel will depend on the extent of our knowledge of the species and the causes of its decline. More information is needed to successfully recover and conserve this species. Critical aspects of the biology, ecology, and genetics of the species remain unknown and are needed to direct recovery actions and inform management decisions. At the present time, only general aspects of the habitat requirements are known for scaleshell. The protection of scalehell populations will require the identification of full set of physical, chemical, and biological habitat features essential for its survival.

While threats affecting scaleshell have been described, little is known of the distribution and intensity of these threats in specific watersheds. This information will allow threats to be prioritized before taking action to alleviate them and focus efforts to restore habitat in key areas within watersheds. Water quality degradation has been a major factor in the decline of the scaleshell. Data on the tolerance of scaleshell to specific pollutants and the occurrence of these pollutants in watersheds is needed in order to focus efforts to minimize or eliminate them. Lastly, the recovery of habitat and populations located downstream of dams will be dependent on knowledge of how various water quality and environmental changes associated with the operation of these dams affect scaleshell.

**Conservation Measures**

The precipitous decline of freshwater mussels in the U.S. has resulted in a renewed interest in research and conservation of this fauna nation-wide. The Freshwater Mollusk Conservation Society (FMCS) was formed to help conserve this highly imperiled fauna in North America. This organization promotes the conservation of freshwater mussels by exchanging scientific information among researchers and resource agencies and informing the public on mussel biology and conservation issues. In 1998, a broad group of representatives from federal agencies, state agencies, academia, commercial interests, and private entities published a national strategy for the conservation of native freshwater mussels (NNMCC 1998). The goals outlined in this document are to conserve native mussel species, ensure their continued survival, and maintain their ecological, economic, and scientific values to our society. This document outlines critical measures that are necessary to conserve this resource and highlights the subject as a problem worthy of national attention. Other mussel conservation strategies, more focused in scope, also have been published (e.g., USFWS 1994, 1996, 1997*a*, 1997b, 2002b, 2004, Obermeyer 2000). These efforts indicate an increasing body of knowledge, experience, and appreciation of freshwater mussels that can be applied to their conservation, including scaleshell.

Prior to becoming listed as a federally endangered species, scaleshell was considered threatened in the state of Arkansas. However, this designation did not afford any legal protection for the species. Missouri and Oklahoma previously listed it as species of conservation concern. However, these designations were primarily used for planning and communication purposes and did not afford any significant state protection from direct take and habitat destruction.

The federal ESA of 1973, as amended contains protection and recovery provisions for federally listed threatened and endangered species. Conservation measures provided to the scaleshell as an endangered species include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing results in public awareness and conservation actions by Federal, State, and local agencies, private organizations, groups, and individuals. The ESA provides for possible land acquisition and cooperation with the State and requires that recovery actions be carried out for all listed species. The protection required of Federal agencies and the prohibitions against certain activities involving listed species are discussed, in part, below.

Section 6 of the ESA allows the USFWS to provide money to States for the conservation of species. The USFWS also has the latitude to provide funding to private landowners and researchers interested in the conservation of the scaleshell mussel through discretionary monies and other sources as available. The USFWS's Partners for Fish and Wildlife (PFW) Program can provide funding for habitat restoration or enhancement. Other funding sources are available through other Federal agency programs such as the Farm Service Administration's (FSA), Conservation Reserve Program (CRP), and the National Resources Conservation Service's (NRCS) Forestry Incentives Program (FIP),Wetlands Reserve Program (WRP), Environmental Quality Incentives Program (EQIP), and Wildlife Habitat Incentives Program (WHIP) programs.

Private landowners can also benefit from Safe Harbor Agreements which are voluntary arrangements between the USFWS and cooperating non-Federal landowners. These agreements benefit endangered or threatened species while giving landowners assurances from additional restrictions. Following development of an agreement, the USFWS will issue an "enhancement of survival" permit, to authorize any necessary future incidental take to provide participating landowners with assurances that no additional restrictions will be imposed as a result of their conservation actions.

Under sections 2(c)(1) and 7(a)(1) of the ESA[1]"Sec. 7. (a) Federal Agency Actions and Consultations.- (1) The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this ESA. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this ESA by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this ESA.", all Federal agencies within the range of scaleshell, and in consultation with the USFWS, have a responsibility to develop and carry out programs for the conservation of this species.

Section 7(a)(2) of the ESA, as amended, requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as endangered or threatened. Regulations implementing the section 7 interagency cooperation provisions of the ESA are codified at 50 CFR Part 402. Section 7(a)(2) requires Federal agencies to ensure activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the scaleshell mussel. If a Federal agency's action is likely to adversely affect the scaleshell mussel, the responsible Federal agency must initiate formal consultation with the USFWS. Federal agencies that may have jurisdictional responsibilities within the range of scaleshell include, but is not limited to, the U.S. Forest Service, USACE, Federal Energy Regulatory Commission (FERC), Natural Resources Conservation Service (NRCS), U.S. Environmental Protection Agency (USEPA), Farm Services Administration, and Federal Highway Administration.

Sections 9 and 10 of the ESA and their implementing regulations found at 50 CFR 17.21 set forth a series of general prohibitions and exceptions that apply to all endangered wildlife. These prohibitions, in part, make it illegal for any person subject to the jurisdiction of the United States to take (including harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect; or attempt any such conduct), import or export, ship in interstate or foreign commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It also is illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to USFWS agents and those of State conservation agencies.

Section 10 of the ESA and its implementing regulations codified at 50 CFR 17.22 and 17.23 provide for the issuance of permits to carry out otherwise prohibited activities involving endangered wildlife under certain circumstances. For endangered species, such permits are available for scientific purposes, to enhance the propagation or survival of the species, and for incidental take in connection with otherwise lawful activities.

---

2 "(c) Policy- (1)- It is further declared to be the policy of Congress that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act." "Sec. 7. (a) Federal Agency Actions and Consultations.- (1) The Secretary shall review other programs administered by him and utilize such programs in furtherance of the purposes of this Act. All other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act."

The CWA was passed in 1972, and has greatly reduced the point-source discharge of pollutants into streams (Neves *et al*. 1997). Municipalities and industries have improved wastewater treatment facilities with grants and aid from the USEPA and State environmental protection departments. Nonpoint-source pollution is dealt with in a number of ways under the CWA, including providing funds through Section 319 nonpoint-source pollution program to improve water quality and reduce nutrient loading, sedimentation, and the likelihood of other pollutants entering streams. In addition, the States, USEPA, and U.S. Geological Survey (USGS) have assessed and monitored water quality in streams throughout much of the range of scaleshell.

Federal government involvement also includes the Fish and Wildlife Coordination Act (FWCA), which is intended to protect fish and wildlife resources and their habitats by coordinating with natural resource agencies on their projects. Programs under the U.S. Department of Agriculture (USDA), particularly those administered by the NRCS [e.g., Conservation Reserve Enhancement Program (CREP), EQIP, WRP, Fish and Wildlife Habitat Improvement Program], are increasingly addressing restoration of impaired streams with imperiled species. The NRCS is routinely adopting animal waste management plans to reduce nutrient and sediment input into streams throughout the country.

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) authorizes the USFWS and the National Oceanic and Atmospheric Administration to issue regulations preventing the unintentional introductions of aquatic nuisance species. On February 2, 1999, the President issued Executive Order (EO) 13112 on invasive species. The EO places increased emphasis on efforts to prevent the introduction of invasive species; to provide for their control; and to minimize the economic, ecological, and human health impacts that invasive species cause. Regulations under the NANPCA and the EO will help prevent the incidental importation of other mollusks that are harmful to native species. The USFWS has developed four priorities under the title “Director’s Priorities FY 1999-2000.” One of the priorities is to develop and implement an aggressive program to enhance the USFWS’s capability and leadership role to respond effectively to present and future invasive species problems and issues. All USFWS offices will focus efforts via three goal statements—enhance leadership, take direct action, and raise public awareness.

As part of a memorandum of understanding with the USFWS, the Oklahoma Department of Environmental Quality (ODEQ) agreed to recognize a USFWS 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 federally listed species. The memorandum provides for the USFWS 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 and Conservation amended its regulations to designate the Kiamichi River as a mussel sanctuary (9 Oklahoma Regulations 1909, effective January 1, 1993). Likewise, in 1997 and 2000, the Arkansas Game and Fish Commission designated the Ouachita River upstream of Camden as a mussel sanctuary. With this designation, these rivers are closed to all commercial harvest. It also provides additional protection to scaleshell and other federally listed species by prohibiting activities that might disrupt the species' habitats.

Since the scaleshell was listed as an endangered species, several efforts have been made specifically to help conserve the species and improve its habitat. USFWS monies (i.e., discretionary and Section 6) and state funds have also been used to fund survey work in various portions of its range, ongoing monitoring of the species' population numbers, and conducting searches for additional populations. A six-year project, funded through Section 6 of the ESA, has been underway since 1998 at Southwest Missouri State University and select MDC state hatcheries to produce and release artificially propagated juveniles into the wild in Missouri. The goal of the project is to develop propagation methods and stabilize the most significant remaining populations of scaleshell and other species through augmentation of existing populations. Unfortunately, propagation efforts have been limited by the availability of gravid females. Release sites include extant sites in the Meramec, Bourbeuse, and Gasconade rivers. Other release sites will depend on the collection location and availability of gravid females. This effort is intended to help stabilize populations while habitat improvements are implemented in these watersheds.

Several habitat improvement projects have been completed within the Bourbeuse River Basin through the USFWS's Partners for Fish and Wildlife and the MDC's Private Lands Program in cooperation with volunteer private landowners. These actions involve the following land management actions that have made habitat and watershed improvements benefiting scaleshell: 1) establishment of planned grazing systems to address overgrazing, 2) providing alternative watering sources away from streams and drainages to address cattle watering in streams, 3) reestablishing a protective riparian corridor to reduce erosion and sedimentation of streams and drainages, and 4) bank stabilization to reduce bank erosion, and 5) improving and reinforcing low water stream crossings to reduce stream bed erosion and improve fish passage. These efforts are just now getting underway at specific sites in the Bourbeuse River Basin.

The USGS's Columbia Environmental Research Center is conducting a large-scale research project funded by the USFWS and USEPA to develop and apply methods to conduct toxicity tests for freshwater mussels (including scaleshell). This study will 1) develop methods for conducting acute and chronic toxicity tests with glochidia and juvenile life stages of mussels, 2) evaluate the acute or chronic effects of ammonia, chlorine, and copper on glochidia and juvenile mussels (surrogates and listed species), and 3) develop American Society for Testing and Materials standards for conducting toxicity tests with freshwater mussels. The main focus of this study is to determine if USEPA's national water quality standards are protective of freshwater mussels to apply to the monitoring of point-source discharges of pollutants into streams.

**Biological Constraints and Needs**

Several biologically inherent factors of the scaleshell mussel must be considered for planning and management of the species. While the scaleshell once had a broad distribution, it appears to have been naturally uncommon where it was found. What may limit its natural abundance is unknown. Its current distribution is also limited within a river by available habitat. Many of the extant populations now occur as single, isolated sites. These highly isolated populations are very susceptible to stochastic events and local extirpation with little chance of recolonization. Scaleshell requires stable riffles and runs with moderate current velocity and is usually found in mussel beds. This habitat is naturally patchy in distribution. The survival and eventual recovery of the scaleshell is dependent on stable stream channels and maintenance of good water quality. The sessile nature of the species makes it especially vulnerable to environmental disturbances because it cannot move to avoid threats. Any activities within watersheds that contribute to a deterioration of the water quality or destroy occupied habitat would adversely affect the scaleshell and hinder recovery efforts

The complex life cycle, skewed sex ratio, and extreme rarity of scaleshell offers several opportunities for reproduction to fail. As with most freshwater mussels, there are two major annual events during its life cycle, and most of the time will be found in some stage of its reproduction. Scaleshell is a long-term brooder that spawns in August and infects its host the following June. It appears to rely solely on the freshwater drum (*Aplodinotus grunniens*) to reproduce. Therefore, the maintenance of drum populations and habitat is also necessary for the continued existence of scaleshell. The fertilization of females depends on the density of upstream males, and therefore, a low density or lack of males can lead to incomplete fertilization of eggs brooded by the females. Likewise, a lack of females due to a skewed sex ratio further hinders reproduction. After females are fertilized they must come into contact with and successfully infect the appropriate fish host. The glochidia must then successfully attach to the host, transform, and drop off into suitable habitat, which is naturally patchy in distribution in rivers. Transformed juveniles that reach suitable habitat must then survive, as a very thin-shelled microscopic organism, a plethora of invertebrate predators in the benthic ecosystem until it grows to a larger size. Undoubtedly, natural mortality is high during all of these critical life stages.

Even as adults, scaleshell is more susceptible to natural and manmade threats to its survival than most other mussel species. Its small size and fragile shell makes it vulnerable to predation and physical disturbance such as trampling. Its thin shell and inability to close completely makes it vulnerable to emersion from drought. Further, the shorter life span of the scaleshell may render it less able to tolerate periods of poor recruitment or increased mortality than longer-lived mussel species. (see additional discussion in *Destruction, Modification, or Curtailment of Habitat or Range* above).

## PART II: RECOVERY

### Recovery Strategy

The decline of scaleshell is primarily due to threats that cause habitat loss and degradation from construction activities and intensive land use. Because only a small number of populations exist, it is essential that they all be protected. Utilizing existing legislation, regulations, and programs (i.e., ESA, CWA, FWCA, wetland and water quality regulations, stream alteration regulations, FERC relicensing, etc.) to protect scaleshell and its habitat is a reasonable means to protect remaining scaleshell populations.

The recovery of scaleshell will not be possible without soliciting outside help to restore habitat and improve surface lands. The threats causing habitat degradation are numerous in streams throughout its range. In many cases, these threats are the result of wide-spread problems that originate on land at the highest elevations of watersheds where the species does not occur. Habitat restoration will require that improvements take place on a large scale in watersheds. The assistance of federal and state agencies, conservation groups, local governments, private landowners, industries, businesses, and farming communities will be essential in implementing the recovery of scaleshell to meet recovery goals. The role of private landowners and businesses cannot be emphasized enough as land in watersheds occupied by scaleshell are primarily privately owned.

To solicit outside help and foster the many partnerships needed to restore habitat and improve surface lands with existing programs, a recovery implementation team will be formed. This team will be made up of species experts and representatives from federal and state wildlife agencies, other federal and state agencies, non-government organizations, academia, and other concerned groups with a diversity of expertise on conservation science and public relations in extant, and eventually historical, watersheds of scaleshell. This team will take a step-by-step watershed approach to recovery by first identifying specific threats for each watershed occupied by scaleshell and developing a threat database. Then, using the threat database as a guide, a habitat protection and restoration strategy will be tailored for each watershed to prioritize and focus restoration efforts on key areas within the watershed. This strategy will be a living document as it will include important future protection strategies with willing partners. Last, the teams will work with willing partners to carry out appropriate recovery actions to alleviate threats and restore habitat. Some actions will require the teams to assemble local working groups of partners to gain the necessary expertise to develop protection strategies and land management options.

Watershed improvements will be aimed at addressing the various causes of habitat degradation including sedimentation; point and non-point pollution sources; substrate destabilization; land, bank, and channel erosion; and eutrophication. Examples of watershed improvements to alleviate these threats include, but are not limited to the following: reestablishing protective riparian corridors to reduce sedimentation; stabilizing stream banks; using no-till agricultural methods; controlling nutrient enrichment by carefully planning heavy livestock use areas; excluding cattle from streams by erecting fences and providing alternative water supplies; development of gravel mining guidelines; and implementing voluntary best management practices to control run-off for a variety of agricultural, silvicultural, and construction activities.

Achieving the recovery goals and criteria outlined in this plan will also be dependent upon the application of sound science to make informed management decisions. Because the recovery implementation team will include species experts and experts in conservation science, it will serve in this capacity as well. The recovery implementation team will coordinate and oversee the implementation of the recovery objectives outlined in this plan. Other roles of the team include, but are not limited to the following: 1) determine the effectiveness of recovery actions and adapt management measures accordingly, 2) determine ongoing research needs, 3) interpret and apply scientific information and consult with appropriate experts to make sound and scientifically-based management decisions, 4) assist FWS in determining when reclassification/delisting is appropriate, and 5) assist FWS in conducting reviews.

The remaining populations of scaleshell are also in imminent danger of extirpation because of their extremely small size and isolated distribution. The small number and low density of remaining populations exacerbate threats to its survival posed by natural and manmade factors. Recruitment failures could lead to their extirpation, with little chance of recolonization, in a relatively short period of time because of the short life-span of the species. Therefore, augmenting existing populations through artificial propagation is considered necessary for the continued existence of scaleshell. This is the most urgent recovery action at this time. The goal of a propagation program for scaleshell is to stabilize and create self-sustaining populations. Augmenting existing populations will help ensure populations persist long enough to allow habitat improvements to take effect and to permit further scientific study. Preventing further loss of populations may also preserve genetic diversity of the species.

Other factors that potentially will affect scaleshell in the future include the introduction of non-native species, predation by small mammals, and mussel die-offs due to drought, contaminant spills, and disease. The scaleshell recovery implementation team will call on the nation's leading experts to devise methods to reduce the likelihood of zebra mussel or black carp invasions into streams occupied by scaleshell. Emergency response strategies will be developed that will outline response protocols to effectively deal with mussel kills and invasions of non-native species that do occur. Measures will also be taken to control predators at select sites where it is identified as a significant factor contributing to scaleshell's decline.

The successful recovery of the scaleshell mussel will depend on the extent of our knowledge of the species and the causes of its decline. Critical aspects of the biology, ecology, and genetics of the species will be investigated, the results of which will direct recovery actions and inform management decisions. Data will be collected on the tolerance of scaleshell to specific pollutants and the occurrence of these chemicals in watersheds in order to focus efforts to minimize or eliminate them. Lastly, how various water quality and environmental changes associated with the operation of dams will be investigated to inform the conservation of populations located downstream of these operations.

Initial recovery efforts will focus in watersheds where extant populations exist in order protect and stabilize populations. Once the recovery requirements are met to downlist the species to threatened, restoration efforts will be expanded to areas of scaleshell's historical range to meet the recovery objectives to delist the species. Because improvements need to take place throughout entire watersheds, a long period of time will be required for habitat improvements to begin to have beneficial effects on populations and the habitat they depend on.

An outreach and education program will be carried out to heighten awareness of scaleshell as an interesting and unique endangered species and to solicit outside help with recovery actions. Outreach material will be developed and produced to target the general public, schools, government agencies, congressionals, businesses, landowners, and other key partners needed to carry out the recovery actions. The goal of this outreach program is to increase appreciation for scaleshell and provide information on how to become involved in recovery efforts. To increase the willingness of potential partners to participate in the recovery of scaleshell, materials will highlight the many benefits of scaleshell recovery actions such as cleaner water and improved health of the stream ecosystem overall.

**Recovery Goals and Objectives**

The ultimate goal of the actions outlined in this plan are to reclassify and eventually delist the scaleshell. The objectives are to ensure the long-term viability of the scaleshell by stabilizing and protecting existing populations and restoring habitat and watersheds it depends on and preventing the spread of zebra mussels and other non-natives when and where possible. Recovery of the scaleshell in the near future is not likely because of the extreme rarity of the species, the extent of the decline that has occurred, and the large-scale the habitat restoration required to have a positive effect on populations.

**Recovery Criteria**

In the criteria for downlisting and delisting the scaleshell, populations are either referred to as a local population or stream population. A local population is an assemblage of individuals that more or less interact with each other in the course of their routine feeding and breeding activities (e.g. mussel bed) (Vaughn 1993). A "stream population" is a term used in a geographical sense and is defined as all individuals living in one river or stream. By using this term it is not implied that a mussel population is currently reproducing or that it is a distinct genetic unit. This term was created to divide scaleshell populations into manageable, geographical units so that which measurable recovery criteria could be created and applied to downlist and delist the species.

The scaleshell will be considered for downlisting to threatened status when the likelihood of the species becoming extinct in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, four stream populations exist, each in a separate watershed and each made up of at least four local populations located in distinct portions of the stream. Each stream population must exist in a separate watershed so that a single stochastic event, such as a toxic spill or disease outbreak, will not affect more than one stream population.

2. All local populations are persistent and viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.

3. Each local population and their habitat are sufficiently protected from any present and

foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.

4. Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent and viable scaleshell populations if their densities have not changed for five consecutive years.

5. Tasks are completed to determine if water quality criteria should be included as a delisting criteria, and if so, water quality criteria for delisting will be developed.

The scaleshell will be considered for removal from the protection of the Endangered Species Act when the likelihood of the species becoming threatened in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of eight stream populations exist, each in a separate watershed and each made up of at least four local and geographically distinct populations. At a minimum, one stream population must be located in the Upper Mississippi River Basin, four in the Middle Mississippi River Basin (two of these must exist east of the Mississippi River), and three in the Lower Mississippi River Basin. Completion of action 3.4.2 or 3.4.3 may indicate more local populations, streams, or geographical regions are required.

2. All local populations are persistent and viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.

3. Each local population and their habitat are sufficiently protected from any present and foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.

4. Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent

and viable scaleshell populations if their densities have not changed for five consecutive years.

5. Water quality criteria may be added to the recovery criteria for delisting upon completion of the tasks referred to under the recovery criteria for reclassification.

**Step-down Outline**

**Action 1. Establish a working group to implement the recovery actions outlined in this plan.**

1.1 Assemble a scaleshell recovery implementation team.

**Action 2. Protect, restore, and maintain existing populations and habitat.**

2.1 Further delineate the current status and distribution of scaleshell.

2.1.1 Conduct surveys in rivers in which the status of scaleshell is unknown.

2.1.2 Conduct searches for additional populations within historic range where the species may potentially occur.

2.2 Develop and maintain a Geographic Information System (GIS) database to map threats, habitat conditions, land use, and existing conservation efforts with respect to the location and status of scaleshell populations within each watershed.

2.3 Develop a habitat protection and restoration strategy for each watershed occupied by scaleshell.

2.4 Carry out cooperative projects using existing programs to protect the species and its habitat, restore degraded habitat, and improve surface lands in occupied watersheds.

2.5 Stabilize and establish self-sustaining populations by artificial propagation.

2.5.1 Develop and implement a propagation plan.

2.5.2 Improve methodologies for artificial propagation, rearing and maintenance of brood stock, and monitoring techniques of release sites.

2.6 Conduct water quality studies.

2.6.1 Determine tolerance to various contaminants suspected to have adverse affects to scaleshell (e.g. ammonia, chlorine, and heavy metals).

2.6.2 Conduct field studies to determine seasonal ambient exposure conditions of contaminants evaluated in Action 2.6.1.

2.6.3 Determine tolerance to increasing siltation, turbidity, and stream flow.

2.6.4 Determine tolerance to low dissolved oxygen and extremes in pH.

2.7 Develop an emergency response strategy for mussel kills and major drought conditions for extant populations.

2.8 Develop management options to reduce or eliminate the threat of non-native introduced aquatic species.

2.8.1 Create and distribute education materials to help prevent the spread of zebra mussels and black carp.

2.8.2 Identify and investigate methods to prevent the spread of zebra mussels and black carp.
2.8.3 Track the spread of zebra mussels and black carp within the range of scaleshell.
2.8.4 Create an emergency response plan to protect scaleshell populations from zebra mussel and black carp invasion.
2.8.5 Determine densities and track population trends of the Asian clam at historical and extant scaleshell sites.

2.9 Determine the impact of predator populations on local populations, and, if necessary, implement local predator control measures.

2.10 Preserve genetic material via cryogenic preservation.

**<u>Action 3.</u> Improve understanding of the biology and ecology of scaleshell.**

3.1 Life history.
3.1.1 Conduct research on reproductive biology.
3.1.2 Investigate age and growth characteristics of populations including male/female life spans.
3.1.3 Investigate the biology of the symbiotic relationship between scaleshell and its confirmed host(s).

3.2 Ecology.
3.2.1 Investigate the biology, habitat use, and ecology of the juvenile stage.
3.2.2 Investigate burrowing behaviors and seasonal movements.
3.2.3 Further define habitat use and requirements of adults.

3.3 Summarize abundance, distribution, and habitat requirements of host(s) within the historical and extant range of scaleshell.

3.4 Research population biology.
3.4.1 Determine genetic differentiation among and within populations.
3.4.2 Define what constitutes a viable population of scaleshell.
3.4.3 Estimate the number of local and stream populations to maintain the species and the optimal geographic distribution for those populations.

**<u>Action 4</u>. Identify suitable reintroduction sites and develop and implement habitat restoration strategies for those areas.**

4.1 Identify suitable sites for future reintroductions within the historical range.

4.2 Map existing threats, habitat conditions, land use, and existing conservation efforts with respect to the location suitable habitat within each target historical watershed.

4.3 Develop a habitat protection and restoration strategy for each target historical watershed.

4.4 Carry out cooperative projects to protect, improve, or restore unoccupied scaleshell habitat in target historical watersheds.

**Action 5. Reintroduce scaleshell into portions of its former range.**

5.1 Develop and implement a reintroduction plan.

**Action 6. Initiate educational and public outreach actions to heighten awareness of the scaleshell as an endangered species and solicit help with recovery actions.**

6.1 Develop outreach materials (e.g. brochures, web pages, videos, posters) on the scaleshell for general distribution.

6.2 Develop and distribute a handout on all available land owner cost share incentive programs that could be applied to scaleshell in critical watersheds.

6.3 Develop and implement outreach programs that will request assistance in the recovery of scaleshell from land owners, businesses, and government agencies.

6.4 Develop and give presentations to targeted local schools, stream teams, and other interested groups.

6.5 Publish articles on the scaleshell, and the ecosystem it depends on, in state conservation magazines, local and regional newspapers, magazines, and local business newsletters.

**Action 7. Conduct periodic reviews and track recovery.**

7.1 Evaluate status of species, in terms of recovery criteria.
- 7.1.1 Conduct surveys to determine persistence and viability of local populations.
- 7.1.2 Demonstrate that local populations are protected from threats.

7.2 Maintain a database of completed recovery actions.

7.3 Revise or update recovery plan as needed.

7.4 Develop a post-delisting monitoring plan.

**Recovery Narrative**

**<u>Action 1</u>. Establish a working group to implement the recovery actions outlined in this plan.**

**1.1 Assemble a scaleshell recovery implementation team.** This team will be made up of species experts and representatives from federal and state wildlife agencies, other federal and state agencies, non-government organizations, academia, and other concerned groups with a diversity of expertise on conservation science and public relations in extant (and eventually historical) watersheds of scaleshell. This group will meet periodically (not usually as a whole depending on meeting objectives) to coordinate and oversee the implementation of the recovery objectives outlined in this plan by using good science. The team will be instrumental in identifying and fostering the diverse partnerships needed to successfully complete recovery objectives for scaleshell. Other roles of the team include, but are not limited to the following: 1) assisting with development of GIS threat database and habitat protection and restoration strategies for individual watersheds (see Actions 2.2, 2.3, 4.2, 4.3), 2) identify and pursue funding sources, 3) determine the effectiveness of recovery actions and adapt management measures accordingly, 4) determine ongoing research needs, 5) interpret and apply scientific information and consult with appropriate experts to make sound and scientifically based management decisions, 6) provide guidance to FWS in determining when reclassification/delisting is appropriate, and 7) assist FWS in conducting periodic status reviews of the species (see Action 7.1).

**<u>Action 2.</u> Protect, restore, and maintain existing populations and habitat.**

**2.1 Further delineate the current status and distribution of scaleshell.** A relatively complete knowledge of the status and distribution of scaleshell is necessary to protect extant sites and focus recovery efforts.

**2.1.1 Conduct surveys in rivers in which the status of scaleshell is unknown.** These rivers include the Cossatot, Little Missouri, Saline, and Strawberry rivers, and Myatt and Gates creeks. If new extant populations are discovered, actions can be taken to protect them and ensure they persist.

**2.1.2 Conduct searches for additional populations within historic range where the species may potentially occur.** Locating additional populations may play an important role in meeting recovery criteria and preserving genetically distinct populations.

**2.2 Develop and maintain a Geographic Information System (GIS) database to map threats, habitat conditions, land use, and existing conservation efforts with respect to the location of populations of scaleshell within each watershed.** The creation of this database will include studies to determine the distribution of threats in watersheds relative to existing populations. This database is required for Action 2.3 and will allow the scaleshell recovery implementation teams to prioritize threats before coordinating actions to alleviate them and focus efforts to restore habitat in key areas within watersheds. This database will be combined with the database developed to track recovery actions (see Action 7.2).

**2.3 Develop a habitat protection and restoration strategy for each watershed occupied by scaleshell.** Because threats to stream populations vary widely among watersheds, the focus of recovery efforts must be tailored to each watershed in order to effectively implement the recovery actions outlined in this plan. This activity will be carried out by the scaleshell recovery implementation team and utilize the GIS database discussed in Action 2.2 to ensure all aspects of habitat protection and restoration are addressed. Existing programs will be utilized as discussed in Action 2.4 to implement this strategy. These strategies will be living documents to include future voluntary agreements with willing partners to achieve habitat protection as required by Recovery Criteria 3.

**2.4 Carry out cooperative projects using existing programs to protect the species and habitat, restore degraded habitat, and improve surface lands in occupied watersheds.** Because only a small number of populations exist, it is essential that they all be protected. Continue to use existing legislation, regulations, and programs (the ESA, CWA, FWCA, wetland and water quality regulations, stream alteration regulations, FERC relicensing, etc.) to protect scaleshell and its habitat.

The recovery of scaleshell will not be possible without soliciting outside help. The assistance of Federal and State agencies, conservation groups, and local governments will be essential in implementing the recovery of scaleshell. Of equal importance is the assistance of private landowners, local industries, businesses, and farming communities to meet recovery goals. The role played by scaleshell recovery implementation team will be vital in fostering diverse partnerships needed to restore habitat and improve surface lands, through the existing programs outlined below, to the extent that scaleshell will benefit. The role of private landowners and businesses cannot be emphasized enough as most of the land in watersheds occupied by scaleshell are privately owned.

Section 7 (a) (1) of the ESA authorizes federal agencies to carry out programs to conserve listed species such as scaleshell. 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 ESA provides for the FWS to grant funds to states for management actions aiding the protection and recovery of listed species including the acquisition of land. Section 6 funds should continue to be made available to Arkansas, Missouri, and Oklahoma for scaleshell recovery.

Other programs (e.g., FWS Partners for Fish and Wildlife Program; USEPA Non point Source Program; and USDA's CRP, EQIP, FIP, Stewardship Incentive Program, and WRP) 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 scaleshell 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 action completion will be determined by the amount of private and governmental participation. These activities will be done in conjunction with outreach described under Action 6.

**2.5 Stabilize and establish self-sustaining populations by artificial propagation.** The remaining populations of scaleshell are in imminent danger of extirpation because of their extremely small size and the short life span of this species. Augmenting existing populations will help ensure populations persist long enough to allow habitat improvements to take effect and to permit further scientific study. Preventing further loss of populations may also preserve genetic diversity of the species. Additionally, propagation work increases our knowledge of the species and offers opportunities to conduct research including toxicity, life history, ecology, and physiological studies on glochidia and juveniles.

**2.5.1 Develop and implement a propagation plan.** The success of a propagation program depends on careful planning and consideration of issues such as genetics and site selection criteria. This plan will include monitoring protocol as it is necessary to determine the survival rate of released juveniles and assess the effectiveness of current propagation methods.

**2.5.2 Improve methodologies for artificial propagation, rearing and maintenance of brood stock, and monitoring techniques of release sites.** Despite the high fecundity of scaleshell, propagation efforts have been limited. Several problems have been identified with production including low transformation success on freshwater drum and destruction of juveniles by macroinvertebrate predators. More efficient juvenile production will allow more measurable results of releases and allow small numbers to be used for research. Currently, there is no way to determine if captured specimens in the field have been artificially propagated. However, new genetic techniques are now available that can be developed for scaleshell that will allow recaptured juveniles to be genetically traced back to brood stock.

**2.6 Conduct water quality studies.** Water quality degradation is believed to be a major threat to scaleshell. Managers need information on the effects of specific pollutants to scaleshell and the occurrence of these pollutants in watersheds in order to focus efforts to minimize or eliminate them. Likewise, specific information is needed to determine if EPA's current national water quality criteria or state standards are protective of all life stages of scaleshell. Last, the recovery of habitat and populations located downstream of dams will be dependent on knowledge of how various water quality and environmental changes associated with the operation of dams affect scaleshell.

**2.6.1 Determine tolerance to various contaminants suspected to have adverse affects to scaleshell (e.g. ammonia, chlorine, and heavy metals).** These studies will include an analysis of acute and chronic effects to all life stages including glochidia, artificially propagated juveniles, and adults (or adult surrogate species). The results from these studies may be utilized to develop water quality standards for recovery criterion five.

**2.6.2 Conduct field studies to determine seasonal ambient exposure conditions of contaminants evaluated in Action 2.6.1.** These studies will be conducted within stream reaches currently occupied by scaleshell. Results will be entered into the GIS database discussed in Action 2.2 and used to map sources of contaminants within specific watersheds.

**2.6.3 Determine tolerance to increasing siltation, turbidity, and stream flow.** These studies will include an analysis of short-term, long-term, and indirect effects of these stressors on reproduction and all life stages.

**2.6.4 Determine tolerance to low dissolved oxygen and extremes in pH.** These studies will include an analysis of long-term, short-term, and indirect effects of these stressors and all life stages. The results from these studies may be utilized to develop water quality standards for recovery criterion five.

**2.7 Develop an emergency response strategy for mussel kills and major drought conditions for extant populations.** Mussel kills have been reported periodically throughout the range of scaleshell due to natural causes and spills of contaminants. The development of an emergency response strategy is important not only to prevent spills, but establish a protocol for the quick response needed to contain spills and possibly remove surviving scaleshell from affected areas. The strategy will also call for the investigation of kills where the cause is unknown, which may allow these events to be prevented in the future. Some local populations of scaleshell are susceptible to emersion during drought periods. Local populations that might be susceptible to drought will be identified in the plan. Additionally, water levels that begin to expose scaleshell sites will be identified for specific sites identified in the GIS database described in Action 2.2. The emergency response protocol to protect populations from zebra mussel and black carp invasions as described in Action 2.8.4 could also be included in this strategy. This emergency response strategy can be developed by the recovery implementation team (see Action 1).

**2.8 Develop management options to reduce or eliminate the threat of non-native introduced aquatic species.** The introduction of non-native aquatic species including zebra mussels, Asian clam, and black carp pose a significant risk to the scaleshell. The technology does not currently exist to eliminate the effect of these species once they are established. However, the development of certain management options will help reduce the likelihood of these species spreading and can help prevent the extirpation of scaleshell populations from this threat.

**2.8.1 Create and distribute education materials to help prevent the spread of zebra mussels and black carp.** The spread of zebra mussels and black carp can be prevented or delayed through education of the public because they are introduced and dispersed through the activities of humans. Many of these educational materials and efforts already exist and need to be applied to portions of scaleshell's range.

**2.8.2 Identify and investigate methods to prevent the spread of zebra mussels and black carp.** The zebra mussel is likely to invade portions of scaleshell's range in the near future. It may be possible to prevent the colonization of some streams such as implementing breaks in boat traffic. Stream reaches where this might be possible would be recorded in the GIS database developed in Action 2.2.

**2.8.3 Track the spread of zebra mussels and the black carp within the range of scaleshell.** The early detection of zebra mussels and black carp will allow the implementation of the emergency response plan developed in Action 2.8.3.

**2.8.4 Create an emergency response strategy to protect scaleshell populations from zebra mussel and black carp.** Zebra mussel populations tend to die off after the initial population explosion following colonization of new areas. This offers an opportunity to conserve scaleshell through relocation efforts or protect populations by the development of temporary holding facilities. This strategy and the emergency response strategies described in Action 2.7 can be combined into one document.

**2.8.5 Determine densities and track population trends of the Asian clam at historical and extant scaleshell sites.** The Asian clam already occurs throughout the range of scaleshell, but its co-occurrence with scaleshell varies among specific sites. Knowing current densities and population trends of the Asian clam at specific sites will help determine suitable augmentation and reintroduction sites. This action can be accomplished through existing monitoring efforts of scaleshell populations and information can be managed in the GIS database described in Action 2.2.

**2.9 Determine the impact of predator populations on local populations and, if necessary, implement local predator control measures.** The small size and thin, fragile shell of scaleshell makes them easy prey for raccoons, muskrats, river otters, and other predators. Scaleshell, despite its rarity, has often been observed in shell piles that have been produced by feeding mammals, particularly during low water conditions. Although natural predation is usually not a factor for stable, healthy mussel populations, it could pose a problem for scaleshell populations because of their small size. Local populations may vary in their susceptibility to predation. For example, some scaleshell sites can become extremely shallow during dry periods making the habitat accessible to raccoons. A report will be produced that assesses the potential of various forms of predation for each local population, will allow managers to focus control efforts on areas where this threat is significantly affecting the species.

**2.10 Preserve genetic material via cryogenic preservation**. The remaining populations of scaleshell are extremely small, and most appear to be declining. Therefore, the species is believed to be at high risk of extinction. Cryogenic preservation could maintain genetic material (much like seeds banks for plants) from extant populations. If the species or a population is lost, this preservation technique may allow for eventual establishment using the preserved genetic material.

**Action 3. Improve understanding of the biology and ecology of scaleshell.** Critical aspects regarding the biology and life history remain unknown. The following actions will provide information critical to devising actions to recover and manage scaleshell.

**3.1 Life history.**

**3.1.1 Conduct research on reproductive biology.** An improved knowledge of the reproductive biology of scaleshell is required to make sound management decisions and to determine additional recovery actions needed in the future. These studies will include additional host work and defining the reproductive season, age at sexual maturity, life-time fecundity, and sex ratio of sample populations.

**3.1.2 Investigate age and growth characteristics of populations including male/female life spans.** Current information on age and growth of scaleshell is based on observations in the field and has not been validated. More formal studies are needed to understand the population dynamics of the species.

**3.1.3 Investigate the biology of the symbiotic relationship between scaleshell and its confirmed host(s).** The successful transfer of mature glochidia to a suitable host constitutes one of the critical events of the life cycle of freshwater mussels. A major bottleneck in recruitment occurs during the parasitic phase, which offers many opportunities for reproduction to fail. Investigating the intricacy of the initial parasite/host interaction that results in glochidial attachment on the host may shed light on what seasonal environmental factors may limit recruitment and management actions needed for scaleshell and its host. These studies will also include investigating factors that affect the suitability of drum to serve as hosts.

**3.2 Ecology.**

**3.2.1 Investigate the biology, habitat use, and ecology of the juvenile stage.** Virtually nothing is known about the juvenile phase of scaleshell including habitat requirements. These studies will include investigation of natural factors that limit recruitment of juveniles in the wild such as macroinvertebrate predators.

**3.2.2 Investigate burrowing behaviors and seasonal movements.** Scaleshell has frequently been observed completely buried. In other circumstances it has been seen actively moving on the surface of the substrate. An improved understanding of their seasonal burrowing behaviors will increase effectiveness of surveys, allow more accurate estimates of population size, and increase chances of locating gravid females for propagation efforts.

**3.2.3 Further define habitat use and requirements of adults.** This information is vital for Section 7 consultations, Habitat Protection Plans, and other management programs.

**3.3 Summarize abundance, distribution, and habitat requirements of host(s) within the historical and extant range of scaleshell.** The life cycle of scaleshell includes a brief, obligatory parasitic stage on freshwater drum. Therefore, the host fish is considered an essential part of scaleshell's habitat. Knowledge of the abundance, distribution, and habitat requirements of drum is necessary for management of the species and habitat restoration. Much of this data already exists, but needs to be summarized for the range of scaleshell.

**3.4 Research population biology.** An improved knowledge of the population biology of scaleshell is necessary to further define recovery criteria in this plan and to make informed management decisions.

**3.4.1 Determine genetic differentiation among and within populations.** It is important to characterize the genetic structure and diversity of scaleshell as a basis for conservation and management. Augmentation and reestablishment of populations in restored habitats will require artificial propagation of individuals from existing populations. It will be important to know the genetic composition of each population before using them as stock. This action will analyze the genetic composition and diversity of extant populations. In addition, studies will evaluate the value of different populations as sources from which to reestablish or augment populations, and the potential for unaided genetic exchange among populations.

**3.4.2 Define what constitutes a viable population of scaleshell.** Conduct a Population Viability Analysis (PVA) to determine the Minimum Viable Population (MVP) for scaleshell.

**3.4.3 Estimate the number of local and stream populations needed to maintain the species and the optimal geographic distribution for those populations.** The recovery criteria outlined in this plan requires that eight stream populations exist to delist the species. This number is based on the best professional judgment of species experts. However, more genetic information is needed to better determine the most appropriate number of stream populations required for the recovery of scaleshell.

Action 4. **Identify suitable reintroduction sites and develop and implement habitat restoration strategies for those areas.** The recovery criteria require that scaleshell become established into portions of its former range. Some of these areas may need additional habitat restoration to allow the natural or artificial colonization of the species.

**4.1 Identify suitable sites for future reintroductions within the historical range.** This action will include habitat studies to assess the suitability of sites considered for reintroductions and rely on criteria for suitable release sites developed in the propagation plan (see action 2.5.1). Historical sites considered for the reintroduction of scaleshell are likely to be in rivers where habitat conditions have improved since the extirpation of scaleshell or high quality rivers that have a high potential for restoration. The status of existing zebra mussel populations and the potential for colonization will also be a major consideration for reintroduction areas. Rivers supporting existing populations of federally listed species will be favored to take advantage of watershed and habitat restoration efforts that have already been implemented for those species.

**4.2 Map existing threats habitat conditions, land use, and existing conservation efforts with respect to the location of suitable habitat within each target historical watershed.** This action will add to the GIS database developed in Action 2.2 and will include studies to determine the distribution of threats in watersheds relative to suitable habitat. This data will be used when assessing the suitability of specific reintroduction sites (see Action 5) and allow the scaleshell recovery implementation teams to prioritize threats before taking action to alleviate them and focus efforts to restore habitat in key areas within historical watersheds.

**4.3 Develop and implement a habitat protection and restoration strategy for each target historical watershed.** This activity will be carried out by the scaleshell recovery implementation team and utilize the GIS database discussed in Action 2.2 to ensure that the appropriate threats are addressed and all aspects of habitat protection are addressed. The habitat protection and restoration plans will include agreements to protect certain essential populations and habitat as indicated in the recovery criteria.

**4.4 Perform cooperative projects to protect, improve, or restore unoccupied scaleshell habitat in target historical watersheds.** See discussion of Action 2.4.

Action 5. **Reintroduce scaleshell into portions of its former range.** Given the current range of scaleshell, it is unlikely that the species will naturally colonize many portions of its historical range within a reasonable amount of time, particularly east of the Mississippi River and the Upper Mississippi River region as required by the recovery criteria. This program will review and apply all information generated by genetic studies described in Action 3 in assessing the location of source populations and appropriate numbers of brood stock. Artificially propagated juveniles will most likely be used for reintroductions due to the small size of scaleshell populations.

**5.1 Develop and implement a reintroduction plan.** The reestablishment of scaleshell can be accomplished by several different methods including the relocation of adults from a source population, release of propagated juveniles, or release of propagated juveniles that have been reared in captivity for a period of time. This plan will include an analysis to determine the most appropriate method to use for establishing populations and development of the most appropriate monitoring techniques and protocols. When the reintroduction plan is developed, the USFWS will weigh the costs and benefits of reintroducing this species as an experimental population, under Secion 10(j) of the ESA.

**Action 6. Initiate educational and public outreach actions to heighten awareness of the scaleshell as an endangered species and solicit help with recovery actions.** Outreach to government agencies, federal and state congressionals, businesses, landowners, stream teams, schools, and other interested parties within the range of scaleshell will facilitate the development of partnerships and recovery actions needed for recovery. The development of outreach materials will be coordinated among the scaleshell recovery implementation team and appropriate federal and state outreach specialists.

**6.1 Develop outreach materials (e.g. brochures, web pages, videos, posters) on the scaleshell for general distribution.** These materials will include information on the species, best management practices that benefit the species, and what people can do to help recover scaleshell.

**6.2 Develop and distribute a handout on all available land owner cost share incentive programs that could be applied to scaleshell in critical watersheds.** Numerous landowner incentive programs are available to private landowners through such programs as the USFWS's Partners for Fish and Wildlife and Private Land Owner Incentive programs; NRCS's CRP, WRP, FIP, EQIP, and WHIP programs, and the Recovery Land Acquisition Program. A short handout should be developed that outlines responsibilities of each program, funding availability, application procedures, and possible examples of successful agreements in place.

**6.3 Develop and implement outreach programs that will request assistance in the recovery of scaleshell from landowners, businesses, and government agencies.** These programs will be tailored for each watershed in the range of scaleshell and may focus on stakeholders key to the recovery of the species to help foster these partnerships. The programs will ensure that stakeholders are aware of scaleshell's status, need for protection of the species and its habitat, recovery efforts underway and proposed, the role of stakeholders in the species protection and recovery, available incentive programs that would benefit scaleshell, and examples of cooperative programs underway in their watershed. Additionally, these outreach efforts will inform stakeholders of how the ESA protects and recovers species and how it applies to them.

**6.4 Develop and give presentations to targeted local schools, stream teams, and other interested groups.** A power point presentation will be developed that includes information on the scaleshell and other mussel species, reasons for federal listing, threats to the species, best management practices that benefit the species (and other aquatic species), and its link to the overall health of streams. This presentation would be made available to individuals asked to give talks to various interested parties.

**6.5 Publish articles on the scaleshell, and the ecosystem it depends on, in state conservation magazines, local and regional newspapers, magazines, and local business newsletters.** These articles will highlight the unique and interesting life history of scaleshell, reasons for its decline, current recovery projects and how they benefit the overall health of streams, and what people can do to contribute to its conservation. Reprints of articles will be made available for general distribution.

**Action 7. Conduct periodic evaluations and track recovery.** Under Sections 4 (c)(2)(A) & (B) of the ESA, the USFWS is required to conduct periodic reviews of all federally listed species to determine if such species should: 1) be removed from the list, 2) be changed in status form an endangered to a threatened species, or 3) be changed in status from a threatened to an endangered species.

**7.1 Evaluate status of species, in terms of recovery criteria.** The recovery criteria for scaleshell require that local populations are persistent and viable in terms of size, recruitment, and age structure to count toward recovery goals. A population may be counted toward reclassification or delisting only after the following actions are performed to demonstrate its viability and persistence. The USFWS will, in consultation with species experts of the scaleshell recovery implementation team, regularly evaluate the status of scaleshell. This examination will include an assessment on the overall distribution and population trends, an appraisal of the threats within occupied watersheds, and an evaluation of population health. The recovery criteria will be assessed to determine if the species warrants reclassification. A summary will be provided that outlines what percentage of recovery objectives outlined in the recovery plan have been accomplished.

**7.1 Conduct surveys to determine persistence and viability of local populations.** Three consecutive surveys conducted at five-year intervals must demonstrate: 1) population size exceeds the MVP determination in Action 3.4.2, 2) age structure is consistent with the MVP determination in Action 3.4.2, and 3) population contains representatives in the 1-3 age class

**7.1.2 Demonstrate that local populations are protected from threats.** Each habitat protection and improvement strategy developed in Action 2.3 or 4.3 should include agreements that will protect scaleshell populations from habitat loss after it is downlisted.

**7.2 Maintain a database of completed recovery actions.** In order to meet recovery goals of this plan and evaluate the success of recovery actions, it is necessary to maintain a recovery implementation database. This database will track completed recovery actions and the location of habitat improvements in conjunction with threats within each watershed. This database will be developed as recovery actions are completed and incorporated into the GIS threat database described in Action 2.2. It will also include results of monitoring efforts.

**7.3 Revise or update recovery plan as needed.** As new information becomes available on the species, recovery objectives will be revised accordingly. Minor changes to the recovery plan would necessitate an update to the document while any major changes would require a revision (USFWS 1990). A revision to the recovery plan may address: 1) any new data collected in the next five years on scaleshell, 2) any necessary refinement to the recovery criteria, and 3) the status of the scaleshell Recovery Implementation Plans (Action 2.3 or 4.3).

**7.**4 **Develop a post-delisting monitoring plan.** Once a species is removed from the list of threatened and endangered species, Section 4(g)(1) of the ESA requires the USFWS to monitor the status of the species for a minimum of 5 years. A plan shall be developed to describe how the status of the scaleshell will be monitored once the species has been delisted.

## PART III. IMPLEMENTATION SCHEDULE

The Implementation Schedule lists the actions and estimated costs for the recovery program for the scaleshell mussel. It is a guide for meeting the recovery goals outlined in this plan. This schedule indicates action priorities, action numbers, action descriptions, duration of actions, and estimated costs to fulfill the recovery objective outlined in part II of this plan. These actions, when accomplished, should bring about the recovery of the scaleshell and protect its essential habitat. The estimated funding needs for all parties anticipated to be involved in recovery are identified. The estimate recovery cost for the 50 year program is $31,044,000. The costs presented are the estimates of the contributors and the USFWS, based on experience with costs of similar work. They are not based on budgets prepared for individual sub-actions. Actual costs may be higher or lower than costs indicated in the implementation schedule.

Potential partners with authority, responsibility, or expressed interest to implement a specific recovery action are also identified in the Implementation Schedule. The listing of a potential partner in the Implementation Schedule does not require, nor imply a requirement, that the identified party has agreed to implement the action(s) or to secure funding for implementing the action(s). However, parties willing to participate may benefit by being able to show in their own budgets that their funding request is for a recovery action identified in an approved recovery plan and is therefore considered a necessary action for the overall coordinated effort to recover the scaleshell. Also, Section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

Recovery actions for the scaleshell are outlined in multiple priority levels defined as follows:

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

**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.

**Priority 3**. All other actions necessary to meet the recovery objectives.
Action numbers are taken from the recovery step-down outline and narrative.

**Key to acronyms used in implementation schedule**

| | |
|---|---|
| FA | Other Federal Agencies – (e.g., U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Environmental Protection Agency, Office of Surface Mining, U.S. Geological Survey, U.S. Department of Transportation, Tennessee Valley Authority) |
| USFWS | U.S. Fish and Wildlife Service |

| | |
|---|---|
| SCA | State Conservation Agencies (e.g., Arkansas Fish and Game Commission; Oklahoma Department of Wildlife Conservation; Missouri Department of Conservation; Missouri Department of Natural Resources; Illinois Department of Natural Resources; Iowa Department of Natural Resources; Indiana Department of Natural Resources; Ohio Department of Natural Resources; Minnesota Department of Natural Resources; Kentucky State Nature Preserves Commission; Tennessee Wildlife Resources Agency; Tennessee Department of Environment and Conservation; Alabama Division of Wildlife and Freshwater Fisheries; Dakota Department of Game, Fish, and Parks; Wisconsin Department of Natural Resources) |
| RSU | Research and State University Institutions |
| PL | Private Landowners |
| CCG | County and City Governments |
| BI | Businesses and Industries |
| SDOT | State Transportation Departments |
| NGO | Non-governmental Organizations (e.g., Freshwater Mollusk Conservation Society, The Nature Conservancy, Fish and Wildlife Foundation, World Wildlife Fund) |
| SRIT | Scaleshell Recovery Implementation Team |

**Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan**

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 1 | 1.1 | Establish a scaleshell recovery implementation team | Continuous | USFWS, FA, SCA, RSU, PL, NGO | 900 | 36 | - | 36 | - | 828 | Team meets biennially |
| 1 | 2.2 | Develop and maintain a GIS database | Continuous | USFWS, SCA | 687 | 50 | 13 | 13 | 13 | 598 | |
| 1 | 2.3 | Develop a habitat protection and restoration strategy for each occupied watershed | 2 | SRIT | 100 | - | - | 50 | 50 | - | Starts 3rd year to allow SRITs to become established |
| 1 | 2.4 | Carry out cooperative projects to protect the species and its habitat, restore degraded habitat, and improve surface lands | Continuous | SRIT, USFWS, FA, SCA, RSU, PL, CCG, BI, SDOT, NGO | 13000 | 2240 | 2400 | 2400 | 2400 | 11960 | |
| 1 | 2.5.1 | Develop and implement a propagation plan | 15 | USFWS, SRIT, RSU, SCA | 418 | 40 | 27 | 27 | 27 | 297 | |
| 1 | 2.5.2 | Improve methodologies for artificial propagation, rearing and maintenance of brood stock, and monitoring techniques | 2 | USFWS, SRIT, SCA, RSU | 26 | 13 | 13 | - | - | - | |
| 1 | 2.7 | Develop an emergency response strategy for mussel kills and major drought conditions for extant populations | 1 | SRIT | 13 | 13 | - | - | - | - | |

## Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 1 | 2.8.2 | Identify and investigate methods to prevent the spread of zebra mussels and black carp. | 2 | USFWS, RSU, SRIT, NGO, SCA, FA | 100 | 50 | 50 | - | - | - | |
| 1 | 3.1.1 | Conduct research on reproductive biology | 1 | USFWS, SCA, RSU | 25 | 25 | - | - | - | - | |
| 1 | 3.1.3 | Investigate the biology of the symbiotic relationship between scaleshell and its confirmed host(s) | 2 | USFWS, SCA, RSU | 50 | 25 | 25 | - | - | - | |
| 1 | 3.2.3 | Further define habitat use and requirements of adults | 1 | USFWS, SCA, RSU | 25 | 25 | - | - | - | - | |
| 2 | 2.6.1 | Determine tolerance to various contaminants | 2 | USFWS, SCA, RSU, BI | 400 | - | - | - | - | 400 | |
| 2 | 2.6.2 | Conduct field studies to determine seasonal ambient exposure conditions of contaminants tested in Action 2.5.1.1 | 2 | USFWS, SCA, RSU, BI | 130 | - | - | - | - | 130 | |
| 2 | 2.6.3 | Determine tolerance to increasing siltation, turbidity, and stream flow | 1 | USFWS, SCA, RSU, BI | 85 | - | - | - | - | 85 | |
| 2 | 2.6.4 | Determine tolerance to low dissolved oxygen and extremes in pH | 1 | USFWS, SCA, RSU, BI | 57 | - | - | - | - | 57 | |
| 2 | 2.8.1 | Create and distribute education materials to help prevent the spread of zebra mussels and black carp | 1 | USFWS, SCA, SRIT | 75 | - | - | - | - | 75 | |

## Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 2 | 2.8.3 | Track the spread of zebra mussels and black carp in the range of scaleshell | Continuous | USFWS, SCA | - | - | - | - | - | - | Cost is included with existing scaleshell population monitoring |
| 2 | 2.8.4 | Create an emergency response plan to protect scaleshell populations from zebra mussel and black carp invasion | 1 | SRIT, SCA | 3 | 3 | - | - | - | - | |
| 2 | 2.9 | Determine the impact of predator populations on local populations, and, if necessary, implement local predator control measures | 1 | USFWS, SCA, SRIT | 21 | - | 21 | - | - | - | |
| 2 | 2.10 | Preserve genetic material via cryogenic preservation | 2 | USFWS, SCA, RSU | 100 | - | - | - | - | 100 | |
| 2 | 3.1.2 | Investigate age and growth characteristics of populations | 3 | USFWS, SCA, RSU | 75 | - | - | - | - | 75 | |
| 2 | 3.2.1 | Investigate the biology, habitat use, and ecology of the juvenile stage | 2 | USFWS, SCA, RSU | 50 | 25 | 25 | - | - | - | |
| 2 | 3.2.2 | Investigate burrowing behaviors and seasonal movements | 2 | USFWS, SCA, RSU | 50 | 25 | 25 | - | - | - | |
| 2 | 3.3 | Summarize abundance and distribution of host(s) within the historical and extant range | 1 | USFWS, SCA, RSU | 13 | - | - | - | - | 13 | |

## Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 2 | 3.4.2 | Define what constitutes a viable population | 1 | USFWS, SCA, RSU | 15 | - | - | - | - | 15 | |
| 2 | 6.1 | Develop outreach materials on the scaleshell for general distribution | 1 | USFWS, SCA, SRIT | 100 | 15 | - | - | - | 80 | |
| 2 | 6.2 | Develop and distribute a handout on all available land owner cost share incentive programs | 1 | USFWS, SCA, SRIT | 1 | 1 | - | - | - | - | |
| 2 | 6.3 | Develop and implement outreach programs that will request land owner assistance in the recovery of scaleshell | 1 | USFWS, SCA, SRIT | 10 | 10 | - | - | - | - | |
| 3 | 2.1.1 | Conduct surveys in rivers in which the status of scaleshell is unknown | 2 | USFWS, SCA, RSU, SRIT | 60 | - | - | - | - | 60 | |
| 3 | 2.1.2 | Conduct searches for additional populations within historic range where the species may potentially occur | 1 | USFWS, SCA, RSU, SRIT | 60 | - | - | - | - | 60 | |
| 3 | 2.8.5 | Determine densities and track population trends of the Asian clam at historical and extant scaleshell sites | Continuous | USFWS, SCA | - | - | - | - | - | - | Cost is included in existing scaleshell population monitoring efforts |
| 3 | 3.4.1 | Determine genetic differentiation among and within populations | 2 | USFWS, SCA, RSU | 26 | - | - | 13 | 13 | - | |

## Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 3 | 3.4.3 | Estimate the number of local and stream populations needed to maintain the species and the optimal geographic distribution for those populations | 1 | USFWS, SCA, RSU | 15 | - | - | - | - | 15 | |
| 3 | 4.1 | Identify suitable sites for future reintroductions within the historical range | 1 | FA, USFWS, SCA, RSU, PL, CCG, BI, SDOT, NGO, SRIT | 40 | - | - | - | - | 40 | |
| 3 | 4.2 | Map existing threats, habitat conditions, land use, and existing conservation efforts with respect to the location of suitable habitat within each target historical watershed | 1 | USFWS, SCA | 92 | - | - | - | - | 92 | |
| 3 | 4.3 | Develop a habitat protection and restoration strategy for each target historical watershed | 2 | FA, USFWS, SCA, RSU, PL, CCG, BI, SDOT, NGO, SRIT | 6 | - | - | - | - | 6 | |
| 3 | 4.4 | Carry out cooperative projects to protect, improve, or restore unoccupied scaleshell habitat in target historical watersheds | Continuous | FA, USFWS, SCA, RSU, PL, CCG, BI, SDOT, NGO, SSAT, SRIT | 13,500 | - | - | - | - | 13,500 | |

## Implementation schedule for the scaleshell mussel (*Leptodea leptodon*) recovery plan

| Priority Number | Action Number | Action Description | Action Duration (Years) | Potential Partners | Total Cost ($1000's) | Cost Estimates ($1000's) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 – 50 | |
| 3 | 5.1 | Develop and implement a reintroduction plan | 1 | USFWS, SCA, RSU, SRIT | 143 | - | - | - | - | 143 | |
| 3 | 6.4 | Develop and give presentations to targeted local schools, stream teams, and other interested groups | Continuous | USFWS, SCA, SRIT | 50 | 1 | 1 | 1 | 1 | 46 | |
| 3 | 6.5 | Publish articles on the scaleshell mussel and the ecosystem it depends on | Continuous | USFWS, SCA, SRIT | 10 | - | 1 | - | - | 9 | |
| 3 | 7.1.1 | Conduct surveys to determine persistence and viability of local populations | 10 | USFWS, SCA, RSU, SRIT | 440 | - | - | - | - | 440 | |
| 3 | 7.1.2 | Demonstrate that local populations are protected from threats | 1 | USFWS, SCA, RSU, SRIT | 1 | - | - | - | - | 1 | |
| 3 | 7.2 | Maintain database of recovery actions | Continuous | USFWS | 50 | 1 | 1 | 1 | 1 | 50 | |
| 3 | 7.3 | Revise or update the recovery plan as needed | As needed | USFWS, SCA, SRIT | 20 | - | - | - | - | 20 | |
| 3 | 7.4 | Develop a post monitoring plan | 1 | USFWS, SCA, SRIT | 2 | - | - | - | - | - | |

## LITERATURE CITED


Ahlstedt, S.A. and J.J. Jenkinson. 1987. Distribution and abundance of *Potamilus capax* and other freshwater mussels in the St. Francis River System, Arkansas and Missouri. Unpublished Report prepared for U.S. Army Corps of Engineers, Memphis District, Contract No. PD-86-C052.

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 45(1):17-28.

Arkansas State Highway & Transportation Department (ASHTD). 1984. Relocation of the Pink Mucket Pearly Mussel (*Lampsilis orbiculata*) in the Spring River near Ravenden, Lawrence County, Arkansas. 9 pp.

Baker, F.C. 1928. The fresh-water Mollusca of Wisconsin. Part II: Pelecypoda. University of Wisconsin, Bulletin No. 70. 495 pp.

Barnhart, M.C. 1998. Fish hosts and culture of mussel species of special concern: Annual report for 1998. Report to Missouri Department of Conservation. 45 pp.

Barnhart, M.C. 2001. Fish hosts and culture of mussel species of special concern: Annual report for 2000. Report to Missouri Department of Conservation. 41 pp.

Barnhart, M.C. 2003. Fish hosts and culture of mussel species of special concern: Annual report for 2002. Report to Missouri Department of Conservation.

Barnhart M.C. and A.D. Roberts. 1997*a*. Reproduction and fish hosts of the fat pocketbook mussel, *Potamilus capax*. Triannual Unionid Report 11:24. Available from: U.S. Fish and Wildlife Service, Ashville, North Carolina.

Barnhart, M. C. and A.D. Roberts. 1997*b*. Reproduction and fish hosts of unionids from the Ozark Uplifts. *In*: K. S. Cummings, A. C. Buchanan and L. M. Koch, eds. Conservation and management of freshwater mussels II. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Bates, J.M. and S.D. Dennis. 1983. Mussel (naiad) survey--St. Francis, White, and Cache rivers Arkansas and Missouri. Final Report prepared for U.S. Army Corps of Engineers, Memphis District, Contract No. DACW66-78-C-0147. 89 pp + appendices.

Bauer, G. 1994. The adaptive value of offspring size among freshwater mussels (Bivalvia; Unionidae). Journal of Animal Ecology. 63:933-944.

Bayne, B.L., K.R. Clarke, and M.N. Moore. 1981. Some practical considerations in the measurement of pollution effects on bivalve molluscs, and some possible ecological consequences. Aquatic Toxicology. 1:159-174.

Branson, B.A. 1984. The mussels (Unionaceae:Bivalvia) of Oklahoma- Part 3: Lampsilini. Proceedings Oklahoma Academy of Science 64:20-36.

Bruenderman, S.A., J.S. Faiman, and A.C. Buchanan. 2001 Survey for endangered and other unionid species in the upper Gasconade River Basin, Missouri. Report prepared for the U.S. Fish and Wildlife Service, Whipple Federal Building, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056. 97 pp.

Buchanan, A.C. 1979. Mussels (Naiades) of the Meramec River Basin, Missouri. Final report prepared for U. S. Army Corps of Engineers, St. Louis District.

Buchanan, A.C. 1980. Mussels (Naiades) of the Meramec River basin. Missouri Department of Conservation. Aquatic Series 17. 76p.

Buchanan, A.C. 1994. A survey of the freshwater mussels of the lower Gasconade River. Report for U.S. Army of Corps of Engineers, Kansas City District, 700 Federal Building, Kansas City, MO 64106.

Buchanan, A.C. 1986. Die-off impacts on the mussel fauna of selected reaches of the Bourbeuse and Meramec Rivers, Missouri. Pages 44-54 *in* R.J. Neves (ed.), Die-offs of freshwater mussels in the United States. Proceedings of a workshop, 23-25 June 1986, Davenport, Iowa. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Cairns, J., J.S. Crossman, K.L. Dickson, and E.E. Herricks. 1971. The recovery of damaged streams. Association of Southeastern Biologists Bulletin 18:79-106.

Call, R.E. 1900. A descriptive illustrated catalogue of the Mollusca of Indiana. Indiana Department of Geology and Natural Resources Annual Report 24:335-535.

Chamberlain, T.K. 1934. The glochidial conglutinates of the Arkansas fanshell, *Cyprogenia aberti* (Conrad). Biological Bulletin 66:55-61.

Chesters, G. and L. Schierow. 1985. A primer on nonpoint pollution. Journal of Soil and Water Conservation 40(1):9-13.

Clarke, A.H. 1985. Mussel (naiad) study: St. Francis and White rivers Arkansas. Unpublished Report submitted to U.S. Army of Corps of Engineers, Memphis District, Contract No. 84M 1666R. 28p.

Clarke, A.H. 1987. Status survey of *Lampsilis streckeri* and *Arcidens wheeleri*. Final Report to U.S. Fish and Wildlife Service, Jackson Mississippi Field Office. 24p.

Clarke, A.H. 1996. Results of a biological survey for *Leptodea leptodon* (Rafinesque, 1820) in the Missouri River in Southeastern South Dakota. Unpublished Report prepared for U.S. Fish and Wildlife Service, South Dakota Field Office. 13 pp + appendices.

Cummings, K.S., and C.A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manual 5. 194p.

Daiber, F.C. 1953. The life history and ecology of the sheepshead, *Aplodinotus grunniens* Rafinesque, in western Lake Erie Dissertation Abstracts., 64:131-136.

Dance, K.W. 1981. Seasonal aspects of organic and inorganic matter in streams. Pages 69-95 in Perspectives in Running Water Ecology. Williams, D.D. and M.A. Lock, eds. Plenum Press, New York.

Downing, J.A., Rochon, Y. and M. Perusse. 1993. Spatial aggregation, body size, and reproductive success in the freshwater mussel *Elliptio complanata*. Journal of the North American Benthological Society 12:148-156.

Ellis, M.M. 1929. The artificial propagation of freshwater mussels. Transactions of the American Fisheries Society. American Fisheries Society 59:217-223.

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

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pages 215-273 *in* C.W. Hart and S.L.H. Fuller, eds. Pollution ecology of freshwater invertebrates. Academic Press, Inc., New York.

Goodrich, C. and H. Van Der Schalie. 1944. A revision of the Mollusca of Indiana. American Midland Naturalist. 32:257-326.

Gordon, M.E. 1980. Recent Mollusca of Arkansas with annotations to systematics and zoogeography. Proceedings Arkansas Academy of Science 34:58-62.

Gordon, M.E. 1991. Species account for scaleshell (*Leptodea leptodon*). Unpublished report to The Nature Conservancy. 5p.

Gordon, M.E. and J.B. Layzer. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River: review of life histories and ecological relationships. U.S. Fish Wildlife Service Biological Report 89(15). 99p.

Gordon, M.E., P.A. Durkee, H.M. Runke, and H.J. Zimmerman. 1984. Mussel fauna of the Black and Spring Rivers in northeastern Arkansas. Unpublished report prepared for Army Corps of Engineers, Little Rock District. 27p.

Goudreau, S.E., R.J. Neves, and R.J. Sheehan. 1988. Effects of sewage treatment plant effluents on mollusks and fish of the Clinch River in Tazewell County, Virginia. Final Report prepared for U.S. Fish and Wildlife Service, Asheville, North Carolina. 127p.

Goudreau, S.E., R.J. Neves, and R.J. Sheehan. 1993. Effects of sewage treatment plant effluents on mollusks and fish of the Clinch River, Virginia, U.S.A. Hydrobiologia 252(3):211-230.

Grace, T.B. and A.C. Buchanan. 1981. Naiads (mussels) of the lower Osage River, Tavern Creek, and Maries River, Missouri. Final Report. Prepared for the U.S. Army Corps of Engineers. Missouri Department of Conservation. 147p.

Griffiths, R.W., D.W. Schloesser, J.H. Leach, and W.P. Kovalak. 1991. Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes region. Canadian Journal of Fisheries and Aquatic Sciences 48:1381-1388.

Harris, J.L. 1992. Survey of the freshwater mussels (Mollusca: Unionidae) of the South Fourche LaFave River and major tributaries. Unpublished manuscript. 19 pp + appendices.

Harris, J.L. 1994. Survey of the freshwater mussels (Mollusca: Unionidae) of the Poteau River drainage in Arkansas. Unpublished manuscript. 23 pp + appendices.

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

Hartfield, P. 1993. Headcuts and their effect on freshwater mussels. Pages 131-141 *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, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Havlik, M. and L.L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): A review. U.S. Fish and Wildlife Series, Research Publication 164:1-20.

Herbert, P.D.N., B.W. Muncaster, and G.L. Mackie. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 46: 1587-1589.

Hoggarth, M.A. and A.S. Gaunt. 1988. Mechanics of glochidial attachment (Mollusca: Bivalvia: Unionidae). Journal of Morphology 198:71-81.

Hoke, Ellet. 1983. Unionid mollusks of the Missouri River on the Nebraska border. Am. Mal. Bull., Vol. 1(1983):71-74.

Hoke, Ellet. 2000. The scaleshell *Leptodea leptodon* (Rafinesque, 1820) in the Missouri River. Triannual Unionid Report 9:9. Available from: U.S. Fish and Wildlife Service, Asheville, North Carolina.

Howard, A. D., and B. J. Anson. 1922. Phases in the parasitism of the Unionidae. Journal of Parasitology 9: 70-84.

Imlay, M.J. 1972. Greater adaptability of freshwater mussels to natural rather than to artificial displacement. The Nautilus 86(2-4):76-79.

Imlay, M.J. and Paige, M.J. 1972. Laboratory growth of freshwater sponges, unionid mussels, and sphaeriid clams. The Progressive Fish-Culturist 34(4):210-216.

Isley, F. B. 1925. The fresh-water mussel fauna of eastern Oklahoma. Proceedings of the Oklahoma Academy of Science 4:43-118.

Jansen, W.A. and J.M. Hanson. 1991. Estimates of the number of glochidia produced by clams (*Anodonta grandis simpsonianus* Lea), attaching to yellow perch (*Perca flavescens*), and surviving to various ages in Narrow Lake, Alberta. Canadian Journal of Zoology 69:973-977.

Kraemer, L.R. 1970. The mantle flap in three species of *Lampsilis* (Pelecypoda: Unionidae). Malacologia 10(1):225-282.

Kraemer, L.R. 1979. *Corbicula* (Bivalvia: Sphaeriacea) vs. indigenous mussels (Bivalvia: Unionacea) in U.S. rivers: a hard case for interspecific competition? American Zoologist 19:1085-1096.

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. Research & Management 8:63-71.

McMahon, R.F. and C.J. Williams. 1986. A reassessment of growth rate, life span, life cycles and population dynamics in a natural population and field caged individuals of *Corbicula fluminea* (Muller) (Bivalvia:Corbiculacea). American Malacological Bulletin Special Edition 2:151-166.

Miller, A.C. and P.D. Hartfield. 1986. A survey for live mussels in the Black and Spring rivers, Arkansas, 1985. Prepared for U.S. Army Engineer, Little Rock District. 13 pp + appendices.

Mississippi Interstate Cooperative Resource Association. 2003. Black carp escapes to the wild. River Crossings (newsletter) 12(2):4-5.

Missouri Department of Conservation. 1997. Big River Basin inventory and management plan. Missouri Department of Conservation, Jefferson City Missouri. 106 pp.

Missouri Department of Conservation. 2003. Wildlife code of Missouri-rules of the Conservation Commission. Missouri Department of Conservation, Jefferson City. 188 pp.

Moen, T. 1955. Food of the freshwater drum, *Aplodinotus grunniens* Rafinesque, in four Dickinson County, Iowa, lakes. Proceedings of the Iowa Academy of Science, 62:589-598.

Murray, H.D. and A.B. Leonard. 1962. Handbook of unionid mussels in Kansas. University of Kansas. Museum of Natural History Misc. Publications 28:1-184.

Myers, C.F., J. Meek, S. Tuller, and A. Weinberg. 1985. Nonpoint sources of water pollution. Journal of Soil and Water Conservation 40(1):14-18.

Naimo, T.J., G.J. Atchison, and L.E. Holland-Bartels. 1992. Sublethal effects of cadmium on physiological responses in the pocketbook mussel, *Lampsilis ventricosa*. Environmental Toxicology and Chemistry 11:1013-1021.

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

Neves, R.J. 1986. Recent die-offs of freshwater mussels in the United States: an overview. Pages 7-20 in R.J. Neves (ed.), Die-offs of freshwater mussels in the United States. Proceedings of a workshop, 23-25 June 1986, Davenport, Iowa. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J. 1993. A state-of-the-unionids address. Pages 1-10 *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, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pp. 43-85 *in*: G.W. Benz nad D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective. Special Publication 1, Southern Aquatic Research Institute, Chattanooga, Tennessee.

Nichols, S.J. and D. Garling. 2000. Food-web dynamics and trophic-level interactions in a multispecies community of freshwater unionids. Canadian Journal of Zoology. 78:871-882.

Neves, R.J. and M.C. Odom. 1989. Muskrat predation on endangered freshwater mussels in Virginia. Journal of Wildlife Management 53(4):934-941.

Nico, L.D. and J.D. Williams. 1996. Risk assessment on black carp (Pisces: Cyprinidae). Report to: The Risk Assessment and Management Committee of the Aquatic Nuisance Species Task Force. 61 pp.

Noss, F.R. and A.Y. Cooperrider. 1994. Savings nature's legacy: Protecting and restoring biodiversity. Island Press, Washington D.C. 416p.

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

Oesch, R.D. 1995. Missouri naiades: A guide to the mussels of Missouri. Missouri Department of Conservation, Jefferson City, Missouri. 271p.

Ortmann, A.E. 1909. The destruction of the freshwater fauna in western Pennsylvania. Proceedings of the American Philosophical Society 48(1):90-110.

Parmalee P.W. and A.E. Bogan. 1998. The freshwater mussels of Tennessee. 1st edition. University of Tennessee Press/Knoxville. 328 pp.

Perkins III, K.P. and D.C. Backlund. 2000. Freshwater mussels of the Missouri National Recreational River below Gavins Point Dam, South Dakota and Nebraska. SD GFP Report 2000-1, 23 pp.

Pflieger, W.L. 1997. Fishes of Missouri. Missouri Department of Conservation, Jefferson City, 372 pp.

Priegel, G.R. 1967. Food of the freshwater drum, *Aplodinotus grunniens*, in Lake Winnebago, Wisconsin. Transactions of the American Fisheries Society. 96(2): 218-220.

Reid, R.G.B., R.F. McMahon, D.O. Foighil, and R. Finnigan. 1992. Anterior inhalant currents and pedal feeding in bivalves. The Veliger 35:93-104.

Roberts, A.D. and S. Bruenderman. 2000. A reassessment of the status of freshwater mussels in the Meramec River Basin, Missouri. Report prepared for the U.S. Fish and Wildlife Service, Whipple Federal Building, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056. 141 pp.

Roe, K.J., A.W. Simons, and P. Hartfield. 1997. Identification of a fish host of the inflated heelsplitter, *Potamilus inflatus* (Bivalvia: Unionida), with a description of its glochidium. American Midland Naturalist 138:48-54.

Roell, M.J. 1999. Sand and gravel mining in Missouri stream systems: aquatic resource effects and management alternatives. Missouri Department of Conservation, Conservation Research Center, Columbia, Missouri. 34 pp.

Scammon R.E. 1906. The Unionidae of Kansas, part I. University of Kansas Science Bulletin, vol 3, pp. 279-373 pls. 52-86.

Sickel, J.B. 1986. *Corbicula* population mortalities: factors influencing population control. American Malacological Bulletin Special Edition 2:89-94.

Silverman, H., S.J. Nichols, J.S. Cherry, E. Achberger, J.W. Lynn, and T.H. Dietz. 1997. Clearance of laboratory-cultured bacteria by freshwater bivalves: differences between lentic and lotic unionids. Canadian Journal of Zoology. 75:1857-1866.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile *Elliptio complanata* (Bilvalvia: Unionidae). Journal of the North American Benthological Society 17(1):129-134.

Stansbery, D. 1970. Eastern freshwater mollusks (I) the Mississippi and St. Lawrence River Systems. Malacologia. 10(1):9-22.

Stansbery, D. 1973. Dams and extinction of aquatic life. The Garden Club of America Bulletin, 61(1):43-46.

Strayer, D.L. 1997. Effects of exotic species on freshwater mollusks in North America. Draft (3 February 1997) report written for the National Native Mussel Conservation Committee. Institute of Ecosystem Studies, Box AB, Milolbrook, New York, 12545. 67p.

Strayer, D.L. and K.J. Jirka. 1997. The pearly mussels of New York State. The New York State Education Department. 113 pp. + 27 plates.

Stoeckel, J.N., L. Lewis, and S. Shook. 1995. Mulberry River Freshwater mussel survey. Unpublished manuscript. 6 pp.

Stoeckel J. and K. Moles. 2002. Status survey for the scaleshell mussel (*Leptodea leptodon*), with a summary of baseline data on other freshwater mussel species, of the South Fourche LaFave River, Arkansas. Report prepared for the Ouachita National Forest, Hot Springs Arkansas. 26 pp.

Szymanski, J. 1998. *Leptodea leptodon* (Scaleshell Mussel) Rangewide Status Assessment. Unpublished report for U.S. Fish and Wildlife Service, Region 3, Fort Snelling, MN.

Tucker, K.T., C.H Theiling, K.D. Blodgett, and P.A. Theil. 1993. Initial occurrences of zebra mussels (*Dreissena polymorphia*) on freshwater mussels (family Unionidae) in the Upper Mississippi River System. Journal of Freshwater Ecology. 8(3):245-251.

U.S. Fish and Wildlife Service (USFWS). 1990. Policy and guidelines for planning and coordinating recovery of endangered and threatened species. U.S. Department of the Interior, U.S. Fish and Wildlife Service unpublished report. 14 pp. + 4 appendices.

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

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

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

U.S. Fish and Wildlife Service (USFWS). 1997*b*. Winged mapleleaf mussel (*Quadrula fragosa*) recovery plan. Fort Snelling, Minnesota. Vii + 69 p. + 281 p. appendicies.

U.S. Fish and Wildlife Service (USFWS). 2001. Endangered and threatened wildlife and plants; final rule to list the scaleshell mussel as endangered. Federal Register 66(195) 51322-51339, October 2001.

U.S. Fish and Wildlife Service (USFWS). 2002*a*. Proposed rule to list the black carp (*Mylopharyngodon piceus*) as an injurious wildlife species. Federal Register 67(146) 49280-49284.

U.S. Fish and Wildlife Service (USFWS). 2002*b*. Ouachita Rock Pocketbook (*Arkansia wheeleri* Ortman and Walker, 1912) Recovery Plan. Albuquerque, New Mexico. vii + 84p. + A-1-85p.

U.S. Fish and Wildlife Service (USFWS). 2004. Recovery plan for Cumberland elktoe, Oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot. Atlanta, Georgia. 168 pp.

U.S. Soil Conservation Service (USSCS). 1988. Water quality field guide. United States Department of Agriculture. 63 pp.

Utterback, W.I. 1915. The naiades of Missouri. American Midland Naturalist. 4(3-8). 200 pp.

Vaughn, C.C. 1993. Can biogeographic models be used to predict the persistence of mussel populations in rivers? Pages 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, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Vaughn, C.C. 1994. Survey for *Arkansia wheeleri* in the Little River. Final report submitted to U.S. Fish and Wildlife Service, Tulsa, Oklahoma. 23 pp + map.

Waters, T.F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society Monograph 7.

Watters, T.G. 1994. An annotated bibliography of the reproduction and propagation of the Unionoidia (Primarily in North America). Ohio Biological Survey Miscellaneous Contributions No. 1. 158 pp.

Watters, T.G. 1995. A guide to the freshwater mussels of Ohio, third ed. Published by the Ohio Division of Wildlife, Columbus, Ohio. 122p.

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

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. Part II. Proceedings of the First Freshwater Mollusk Conservation Society Symposium. Ohio Biological Survey Special Publication, Columbus. 274 pp.

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

Yeager, M.M., D.S. Cherry, and R.J. Neves. 1994. Feeding and burrowing behaviors of juvenile rainbow mussels, *Villosa iris* (Bivalvia: Unionidae). Journal of the North American Benthological Society 13(2):217-222.

Yeager, M.M., R.J. Neves, and D.S. Cherry. 2000. Competative interactions between early life stages of *Villosa iris* (Bivalvia: Unionidae) and adult Asian clams (*Corbicula fluminea*). pp. 253-259 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. Part II. Proceedings of the First Freshwater Mollusk Conservation Society Symposium. Ohio Biological Survey Special Publication, Columbus. 274 pp.

Young, M. and J. Williams. 1984. The reproductive biology of the freshwater pearl mussel *Margaritifera margaritifiera* (Linn.) in Scotland. I. Field studies. Archiv fur Hydrobiologie 99:405-422.

Zimmerman, L.L., and R.J. Neves. 2003. Control of predaceous flatworms *Macrostomum* sp. in culturing juvenile freshwater mussels (Bilvalvia: Unionidae). American Malacological Bulletin 17:31-35.

**Table 1**. Distribution and status of the scaleshell (*Leptodea leptodon*) organized by drainage region and watershed*.

| Drainage Region | Major Watersheds | Stream Populations (tributaries indented) | State | Counties of Occurrences | Last Date Found | Status** |
|---|---|---|---|---|---|---|
| **Upper Mississippi River** (above Missouri River) | Upper Mississippi River | Mississippi River mainstem | Illinois, Iowa | Carroll, Hancock, Mercer (IL); Lee, Clayton, Scott (IA) | Pre-1958 | Extirpated |
| | | Burdett's Slough | Iowa | Muscatine | 1890 | Extirpated |
| | Minnesota River | Minnesota River | Minnesota | Dakota | 1800's | Extirpated |
| | Iowa River Basin | Iowa River mainstem | Iowa | Johnson | Pre-1944 | Extirpated |
| | | Cedar River | Iowa | Linn | 1882 | Extirpated |
| | Illinois River Basin | Illinois River mainstem | Illinois | Peoria | Pre-1887 | Extirpated |
| | | Sanagamon River | Illinois | Menard | Pre-1944 | Extirpated |
| | | Pecatonica River | Illinois | Stephenson | Pre-1944 | Extirpated |
| **Middle Mississippi River** (between Missouri River and Ohio River) | Kaskaskia River Basin | Kaskaskia River mainstem | Illinois | Washington | 1921 | Extirpated |
| | Ohio River Basin | Ohio River mainstem | Kentucky, Ohio | Boone, Kenton (KY); Hamilton, Washington (OH) | 1897 | Extirpated |
| | | Wabash River | Illinois, Indiana | White (IL); Carroll, Posey, Tippecanoe, Vigo (IN) | Pre-1919 | Extirpated |
| | | White River | Indiana | Marion | Pre-1919 | Extirpated |
| | | Sugar Creek | Indiana | Parke | 1925 | Extirpated |
| | | Green River | Kentucky | Hart | 1964 | Extirpated |
| | | Licking River | Kentucky | unknown | Pre-1950 | Extirpated |
| | | Scioto River | Ohio | unknown | 1838 | Extirpated |
| | | St. Mary's River | Ohio | unknown | 1930 | Extirpated |
| | | East Fork Little Miami River | Ohio | unknown | ~1900 | Extirpated |
| | | Cumberland River | Alabama, Kentucky, Tennessee | Colbert (AL); Cumberland, Russell (KY); Clay (TN) | 1964 | Extirpated |
| | | Beaver Creek | Kentucky | Russell | 1948 | Extirpated |
| | | Caney Fork | Tennessee | Smith | Pre-1950 | Extirpated |
| | | Tennessee River | Alabama, Tennessee | Colbert (AL), Knox (TN) | Pre-1950 | Extirpated |
| | | Clinch River | Tennessee | Anderson | Pre-1950 | Extirpated |
| | | Holston River | Tennessee | Knox | Pre-1950 | Extirpated |

| Drainage Region | Major Watersheds | Stream Populations (tributaries indented) | State | Counties of Occurrences | Last Date Found | Status** |
|---|---|---|---|---|---|---|
| **Middle Mississippi River** (con't) | | Duck River | Tennessee | unknown | Pre-1950 | Extirpated |
| | Meramec River Basin | Meramec River mainstem | Missouri | Crawford, Jefferson, St. Louis | 2002 | Extant |
| | | Big River | Missouri | Jefferson | 1997 | Extant |
| | | Bourbeuse River | Missouri | Franklin, Jefferson, St. Louis | 2002 | Extant |
| | Missouri River Basin | Missouri River mainstem | South Dakota | Yankton | 1990 | Extirpated |
| | | Gasconade River | Missouri | Gasconade, Laclede, Maries, Osage, Pulaski, Wright | 1994 | Extant |
| | | Big Piney River | Missouri | Pulaski | 1981 | Extirpated |
| | | Osage River | Missouri | Osage | 2001 | Extant |
| | | South Grand River | Missouri | Benton | Early 1970's | Extirpated |
| | | Auxvasse Creek | Missouri | Callaway | Late 1960's | Extirpated |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Lower Mississippi River** (below Ohio River) | St. Francis River Basin | St. Francis River mainstem | Arkansas | Cross, Lee, St. Francis | 1985 | Extirpated |
| | White River Basin | White River mainstem | Arkansas | Benton, Jackson | 1999 | Extant |
| | | James River | Missouri | Stone | Pre-1950 | Extirpated |
| | | Spring River | Arkansas | Lawrence, Randolph, Sharpe | 1991 | Extant |
| | | South Fork Spring River | Arkansas | Fulton | 1990 | Extant |
| | | Myatt Creek | Arkansas | Fulton | 1996 | Extant |
| | | Strawberry River | Arkansas | Lawrence | 1996 | Extant |
| | | Middle Fork Little Red River | Arkansas | Van Buren | 1967 | Extant |
| | Arkansas River Basin | Mulberry River | Arkansas | unknown | Unknown | Extirpated |
| | | Frog Bayou | Arkansas | Sevier | 1979 | Extant |
| | | Poteau River | Oklahoma | LeFlore | Pre-1980 | Extirpated |
| | | South Fourche LaFave River | Arkansas | Perry | 1991 | Extant |
| | Red River Basin | Kiamichi River | Oklahoma | Choctaw, Pushmataha | 1987 | Extant |
| | | Gates Creek | Oklahoma | Pushmataha | Pre-1971 | Unknown |
| | | Little River | Oklahoma | McCurtain | 1960 | Extant |
| | | Mountain Fork | Oklahoma | McCurtain | Pre-1971 | Extant |
| | | Casatot River | Arkansas | Sevier | 1983 | Unknown |

| Drainage Region | Major Watersheds | Stream Populations (tributaries indented) | State | Counties of Occurrences | Last Date Found | Status** |
|---|---|---|---|---|---|---|
| **Lower Mississippi River** (below Ohio River) con't | Red River Basin (con't) | Saline River | Arkansas | Howard, Sevier | 1987 | Unknown |
| | | Ouachita River | Arkansas | Clark | Old museum specimen | Extirpated |
| | | Little Missouri River | Arkansas | Clark | 1995 | Unknown |
| | | Saline River | Arkansas | Cleveland | 1946 | Unknown |

* Data from Szymanski (1998) and USFWS (2001)

** The status as determined in the final rule to list the scaleshell as an endangered species (USFWS 2001). Criteria used for these determinations are as follows. The population is considered extant there has been post-1980 collection of live or fresh dead mussels and, if surveys were thorough, evidence of recruitment was found. The population is considered "extirpated" if 1) despite one or more thorough post-1980 surveys, no scaleshell mussels, or only old dead shells, have been found, <u>or</u> 2) all known suitable habitat has been destroyed. The status of populations is considered "unknown" if the available information is inadequate to place the population in one of the above categories. In a few cases, additional biological information not listed above was used to categorize a population that otherwise would have been called "unknown" or which appeared to fit into multiple categories.

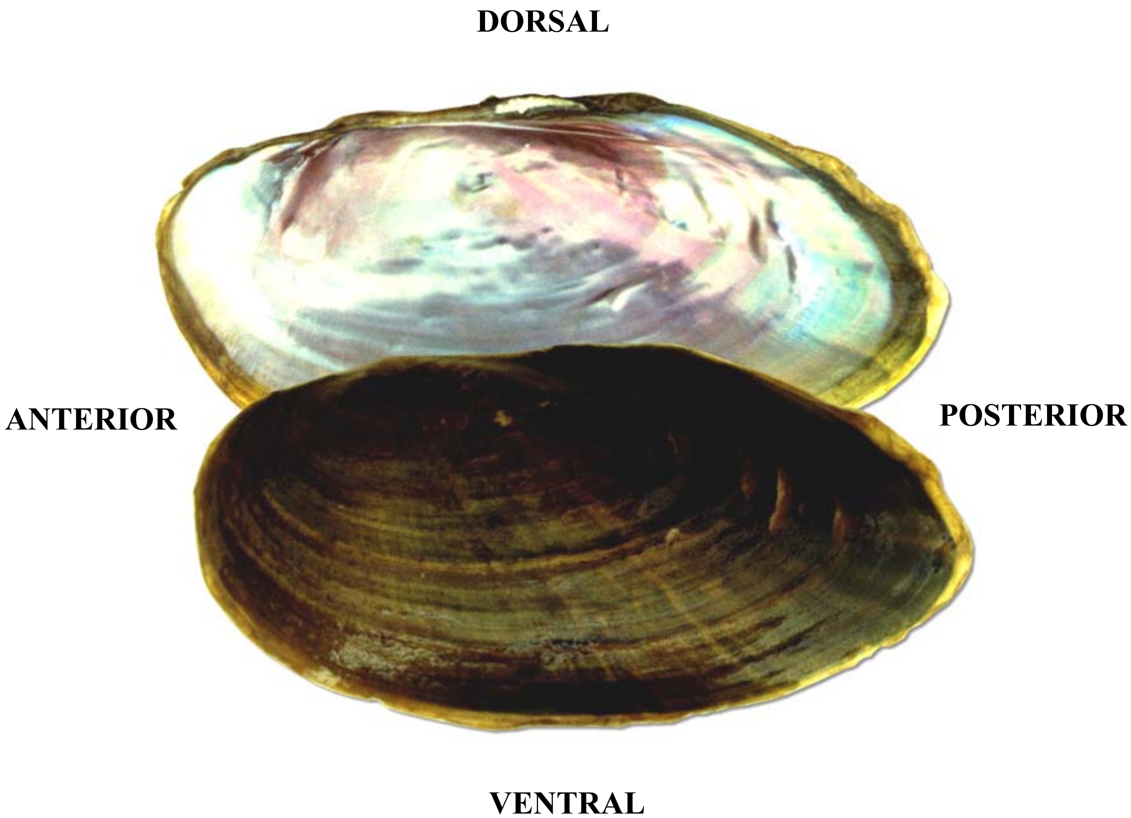



**Figure 1.** Shell of a male scaleshell (*Leptodea leptodon*). Photo taken by Dr. M.C. Barnhart, Southwest Missouri State University.

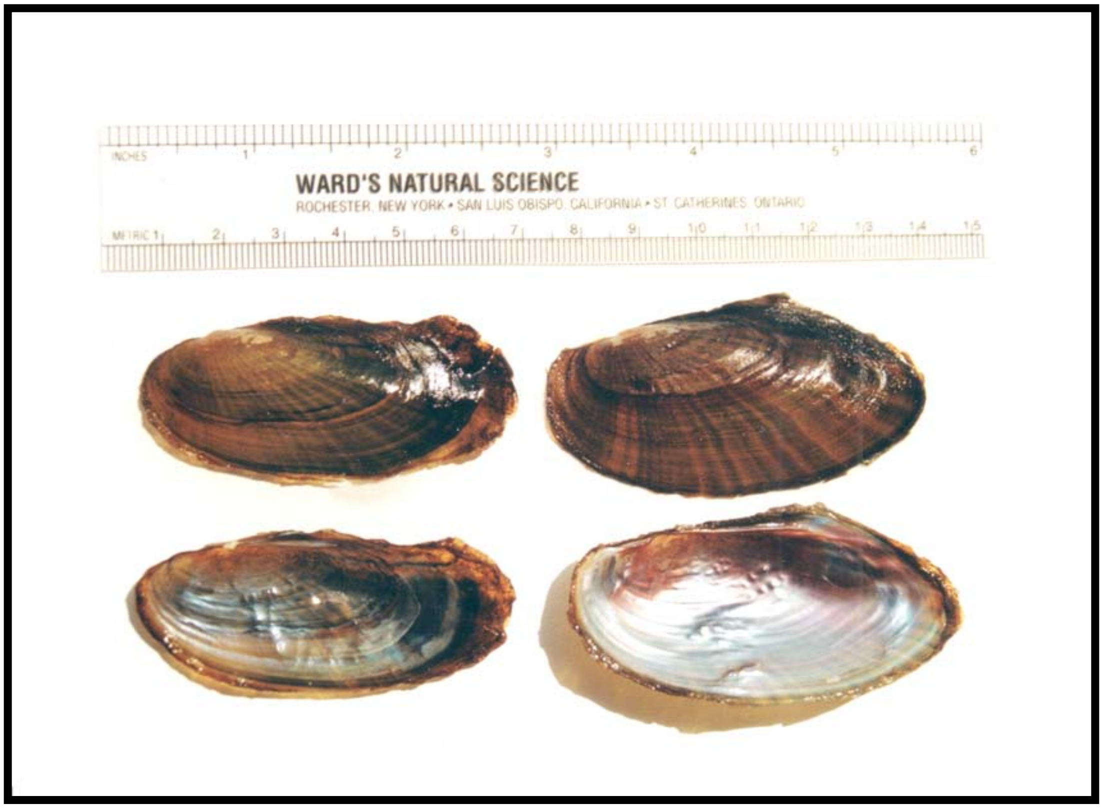



**Figure 2.** Female (left) and male scaleshell (*Leptodea leptodon*). Photo taken by Dr. M.C. Barnhart, Southwest Missouri State University.

**Figure 3**. Dorsal view of female (left) and side view of male scaleshell (*Leptodea leptodon*) actively siphoning water and showing external portions of the nutritive anatomy. Photo by Dr. M.C. Barnhart.

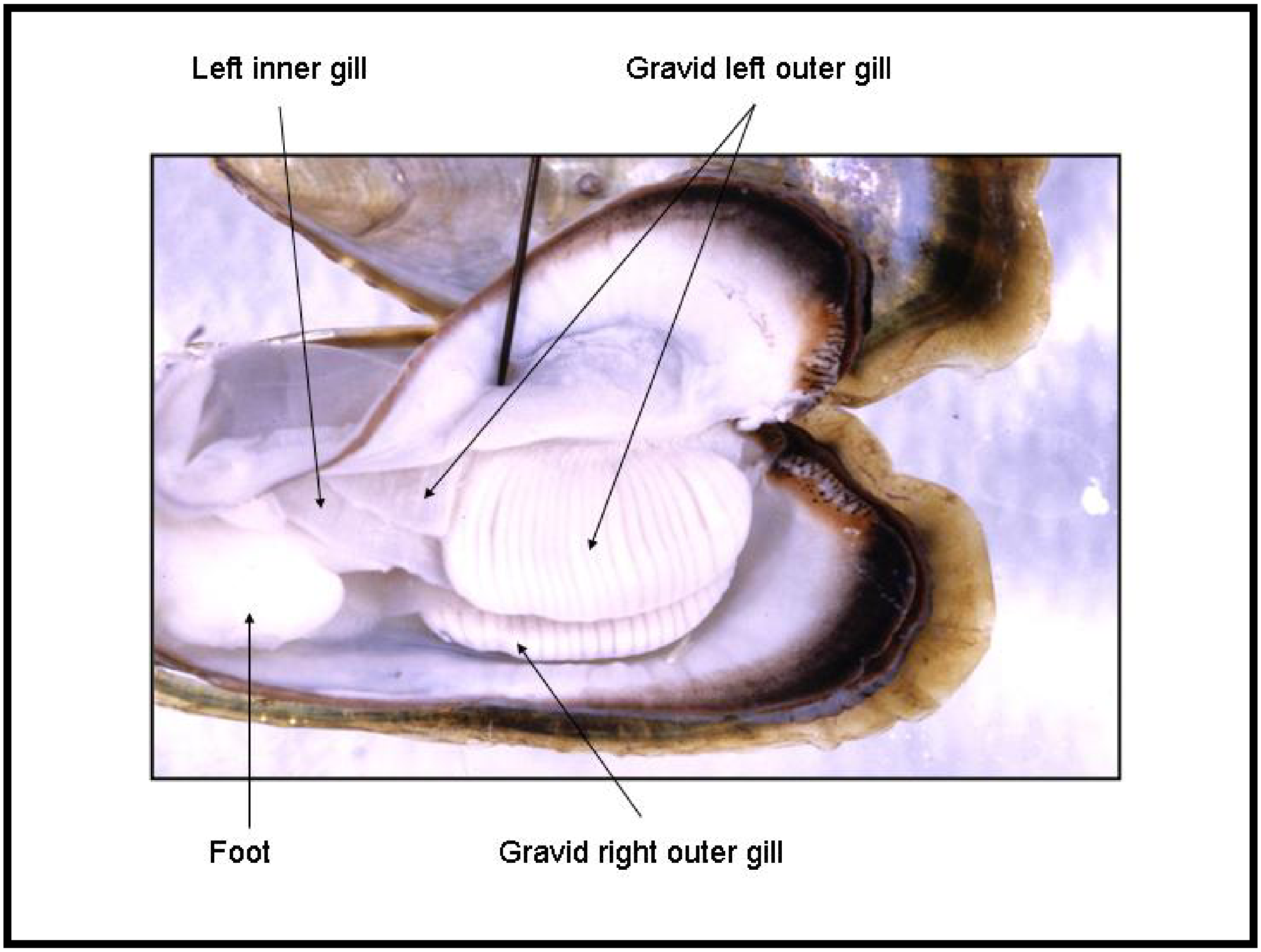
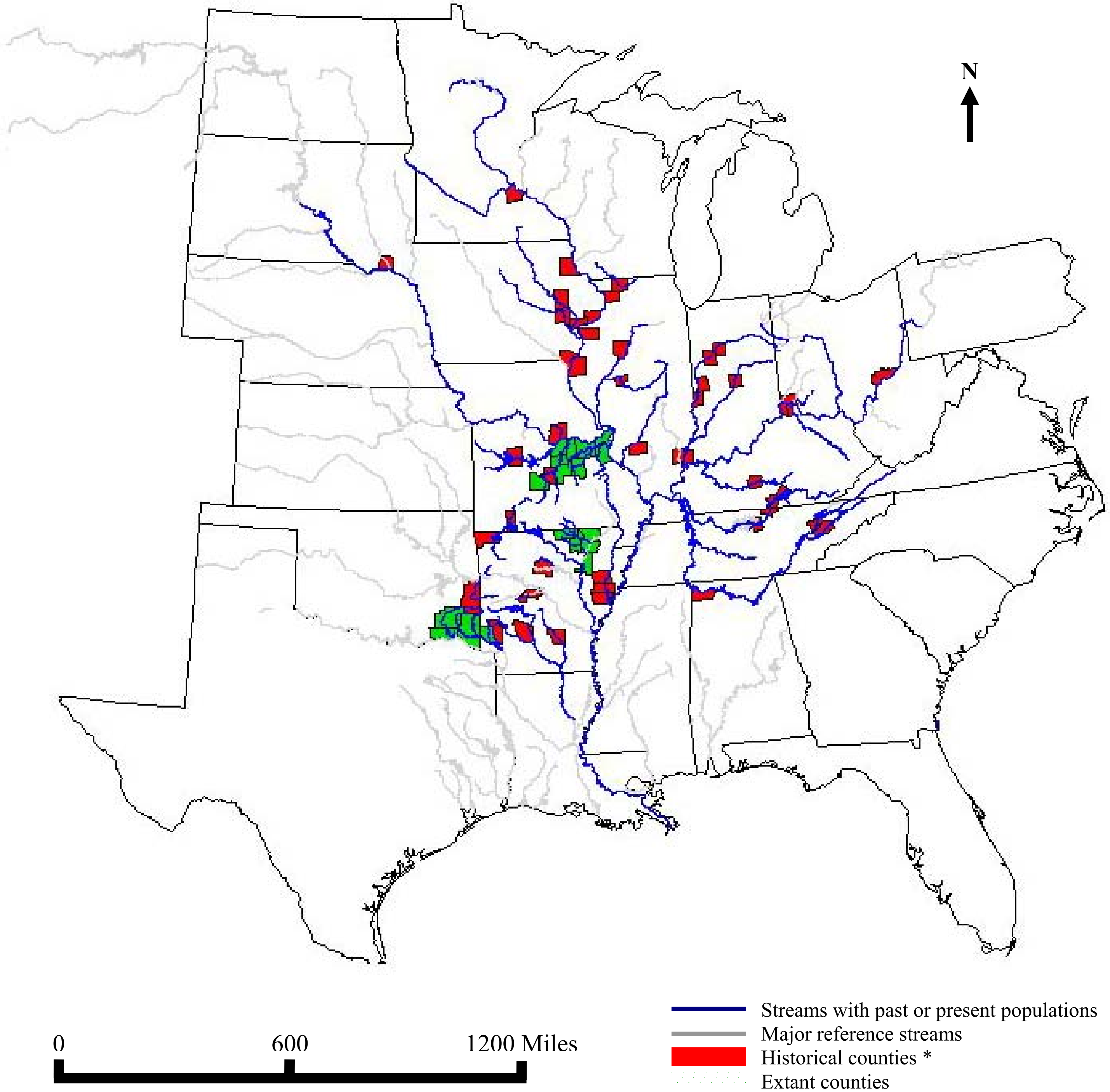



**Figure 4.** Gravid gill of scaleshell (*Leptodea leptodon*). Photo taken by Dr. M.C. Barnhart, Southwest Missouri State University.




* In some cases, the county is not known for historical streams occupied by scaleshell and only the stream could be shown. These streams include the Licking River in Kentucky; Scioto, St. Mary's, and East Fork Little Miami rivers in Ohio; Duck River in Tennessee; and Mulberry River in Arkansas.

**Figure 5.** Historical and current distribution of scaleshell (*Leptodea leptodon*).

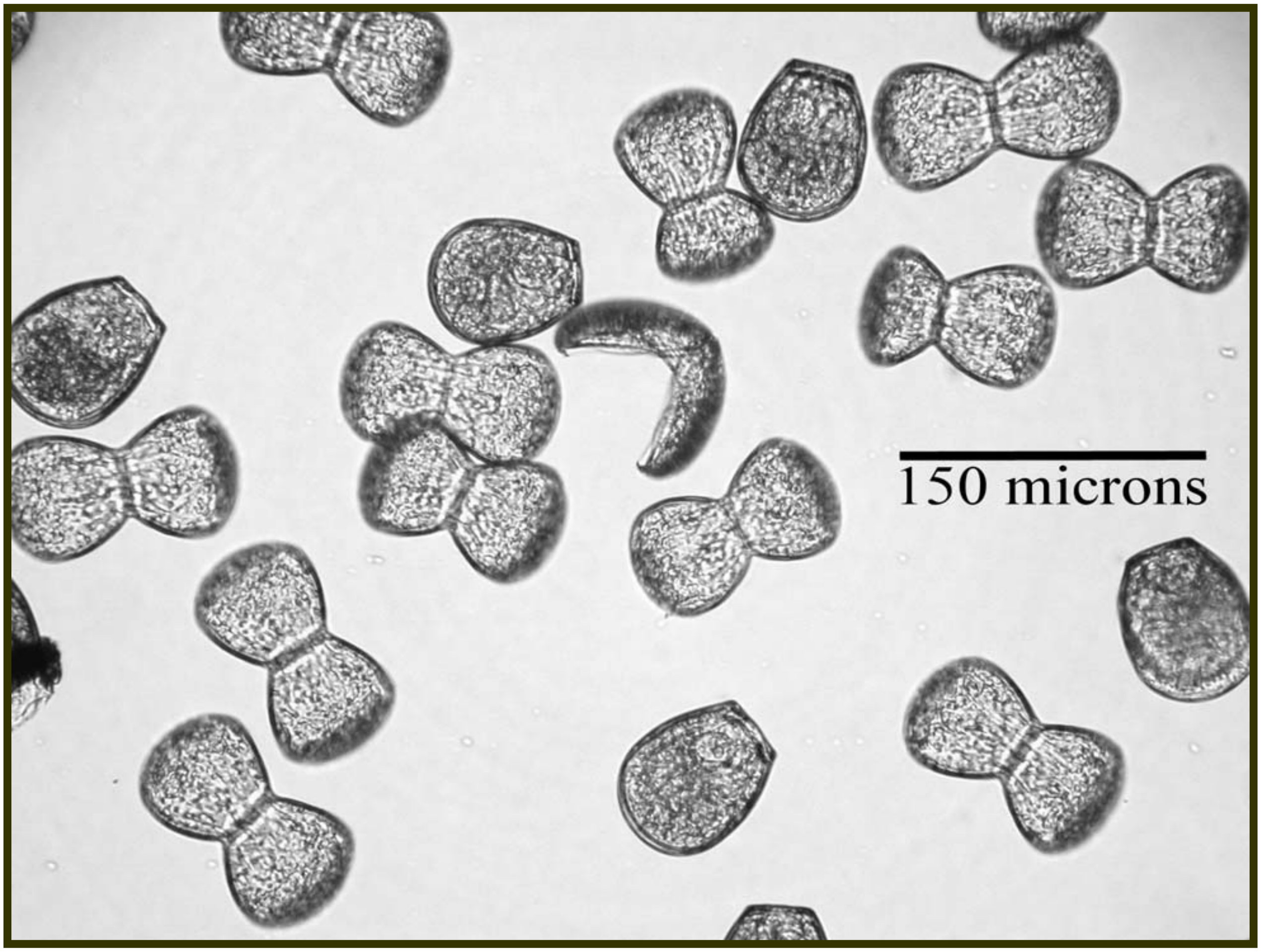



**Figure 6.** Live glochidia of scaleshell (*Leptodea leptodon*). Photo taken by Dr. M.C. Barnhart, Southwest Missouri State University.

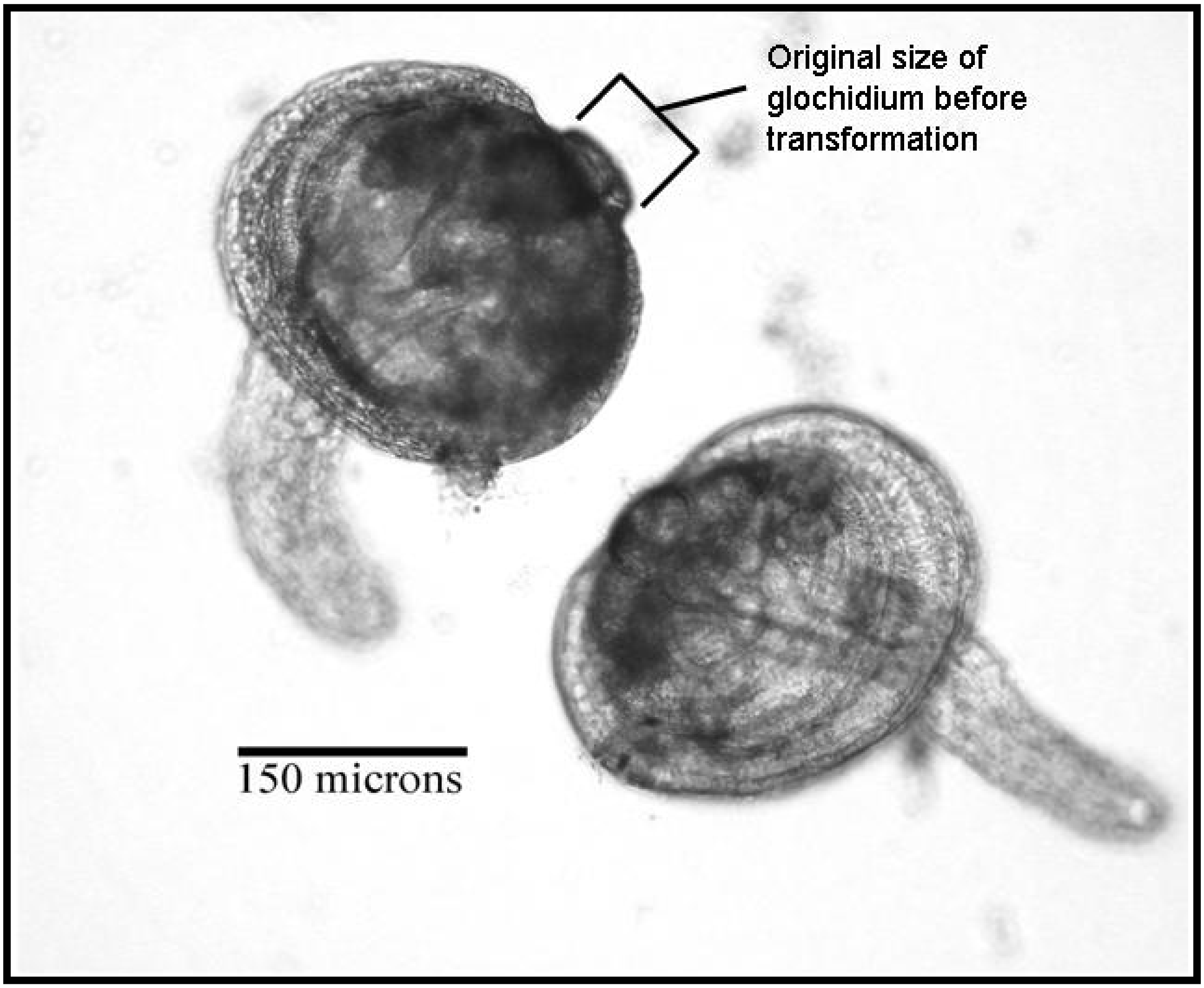



**Figure 7.** Freshly transformed juveniles of scaleshell (*Leptodea leptodon*) showing growth that occurred during encystment on freshwater drum (*Aplodinotus grunniens*). Photo taken by Dr. M.C. Barnhart, Southwest Missouri State University.

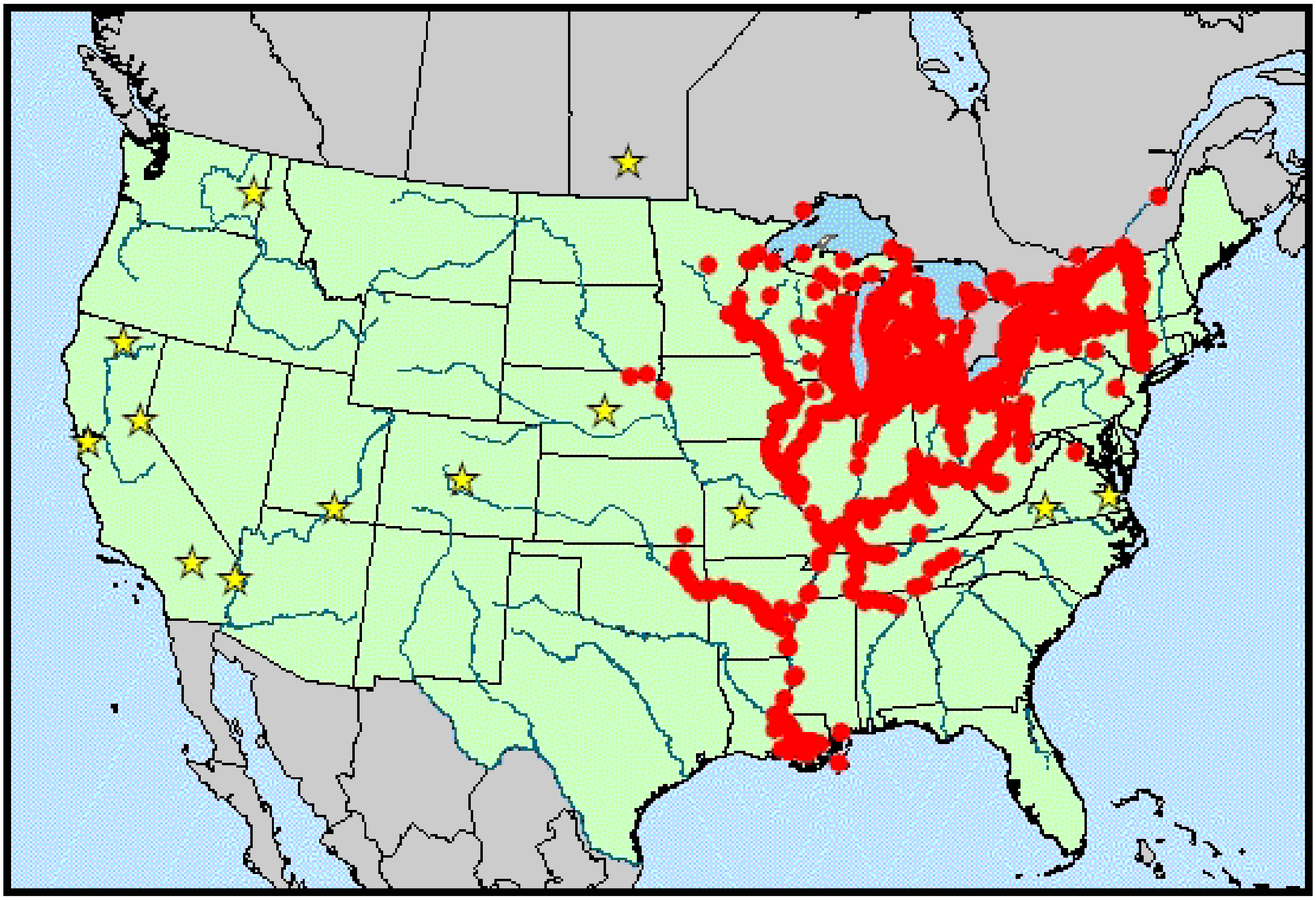


**Figure 8**. Distribution and sightings of the zebra mussel (*Dreissena polymorpha*) as of 2003 (Taken from U.S. Geological Survey web site: "Zebra Mussel Information" http://nas.er.usgs.gov/zebra.mussel/). Red dots represent confirmed collections or observations of adults, juveniles, or veligers, but not always established populations. Yellow stars represent the discovery of the overland transport of zebra mussels on trailered boats.

**APPENDIX I: Detailed Historical and Current Distribution of Scaleshell (*Leptodea leptodon*)**

The following discussion is a more detailed discussion of the distribution and abundance of scaleshell organized by region and river basin.

Upper Mississippi River Basin

The scaleshell formerly occurred in eight rivers and tributaries within the upper Mississippi River Basin, including the Mississippi River in Illinois, Iowa, and Wisconsin; the Minnesota River in Minnesota; Burdett's Slough in Iowa; the Iowa and Cedar Rivers in Iowa; and the Illinois, Sangamon, and Pecatonica Rivers in Illinois. However, it has not been found for more than 50 years in the upper Mississippi River Basin and is believed extirpated from that region (Kevin Cummings, Illinois Natural History Survey, in litt. 1994).

Middle Mississippi River Basin

Historically, the scaleshell occurred in 26 rivers and tributaries within the middle Mississippi River Basin including the Kaskaskia River in Illinois; the mainstem Ohio River in Kentucky and Ohio; the Wabash River in Illinois and Indiana; the White River and Sugar Creek in Indiana; the Green and Licking rivers in Kentucky; the Scioto, St. Mary's, and East Fork Little Miami rivers in Ohio; the Cumberland River in Kentucky and Tennessee; Beaver Creek in Kentucky; Caney Fork in Tennessee; the Tennessee River in Alabama and Tennessee; the Clinch, Holston, and Duck rivers in Tennessee; Auxvasse Creek in Missouri; the Meramec, Bourbeuse, South Grand, Gasconade, Big, Osage, and Big Piney rivers in Missouri; and the mainstem Missouri River in South Dakota and Missouri. The scaleshell has been extirpated from most of the middle Mississippi River Basin. Currently, the species is extant in five streams within the Meramec River Basin and tributaries of the Missouri River in Missouri. Its current and historical distribution is discussed below by drainage.

*Ohio River Drainage*–The scaleshell has been extirpated from the entire Ohio River system. The most recent collection from the Ohio River Basin was in 1964 from the Green River (Wayne Davis, Kentucky Department of Fish and Wildlife, in litt. 1994). All other records are pre-1950 (Kevin Cummings, in litt. 1994; Catherine Gremillion-Smith, Indiana Department of Natural Resources, in litt. 1994; Ron Cicerello, Kentucky Department of Fish and Wildlife, in litt., 1994; Paul Parmalee, University of Tennessee, pers. comm. 1995).

*Meramec River Basin* (Missouri)–In 1979, Buchanan surveyed mussels at 198 sites within the Meramec River Basin (Buchanan 1979, 1980). Of these sites, 14 had evidence of live or dead scaleshell. Seven of the 14 sites were in the lower 180 kilometers (km) (112 miles (mi)) of the Meramec River, five in the lower 87 km (54 mi) of the Bourbeuse River, and two in the lower 16 km (10 mi) of the Big River. Buchanan found that the species comprised less than 0.1 percent of the 20,589 living mussels he examined in the basin. He collected live scaleshell at only four sites, three in the Meramec and one in the Bourbeuse. Although the lower 174 km (108 mi) of the Meramec River had suitable habitat for many rare species, live scaleshell were found only in the lower 64 km (40 mi) (Buchanan 1980). Both the Bourbeuse and Big rivers had lower species diversity and less suitable habitat than the Meramec River. In 1979, suitable habitat occurred in only the lower 87 km (54 mi) of the Bourbeuse River and lower 16 km (10 mi) of the Big River (Buchanan 1980).

The Missouri Department of Conservation (MDC) sampled 78 sites in an intensive resurvey of the Meramec River Basin in 1997 (Roberts and Bruenderman 2000). Similar to Buchanan's (1979, 1980) findings, scaleshell represented only 0.4 percent of all living mussels collected. Live specimens were collected from the mainstem Meramec River (34 specimens from 9 sites), Bourbeuse River (10 specimens from 5 sites), and Big River (2 specimens from 1 site). In addition to the nine sites surveyed by Buchanan (1979, 1980), new sites were included in the 1997 survey. Living or dead scaleshell were found at four of five new sites in the Meramec River and two of four new sites in the Bourbeuse River. The three sites where the presence of scaleshell was not reconfirmed no longer support mussels due to stream bed degradation. Other species that were found in mussel beds at those sites in the earlier surveys were no longer present in 1997. Although portions of the Meramec River basin continue to provide suitable habitat, mussel species diversity and abundance have declined noticeably since 1980 and significant losses of mussel habitat have occurred (Roberts and Bruenderman 2000).

The number of scaleshell specimens MDC collected in 1997 in the Meramec Basin is greater than that reported by Buchanan (1980). The small number of specimens collected however, especially from the Bourbeuse and Big rivers, indicates that the long-term viability of these populations is tenuous. Moreover, the long-term persistence of populations in the Meramec Basin is in question because of the limited availability of mussel habitat and the loss of mussel beds since 1980 from bank and channel degradation, sedimentation, and eutrophication (Roberts and Bruenderman 2000; Alan Buchanan, MDC, in litt. 1997; Sue Bruenderman, MDC, pers. comm. 1998).

*Missouri River Drainage* (South Dakota and Missouri)–Within the Missouri River Drainage, Buchanan (1980, 1994) and Oesch (1995) reported the occurrence of scaleshell from the Missouri, Gasconade, Big Piney, South Grand, Osage rivers, and Auxvasse Creek. The last collection of scaleshell in Auxvasse Creek was in the late 1960s (Alan Buchanan, in litt. 1997). Similarly, the last known scaleshell collection in the South Grand was in the early 1970s, at a site now inundated by Truman Lake and unsuitable for scaleshell (Alan Buchanan, in litt. 1997). A single, fresh dead specimen was collected from Big Piney River in 1981 (Sue Bruenderman, in litt. 1998). However, the scaleshell has not been found in recent surveys of this river. Between 1994 and 1996, 70 sites were sampled in the Big Piney River from the mouth to the headwaters. While 3,331 mussels of 26 species were collected, no evidence of scaleshell was found (Janet Sternberg, MDC, pers. comm. 2000). Another survey was conducted in 1998 in which 10 sites were sampled between river miles 53.6 and 96.0. Over 1,000 living mussels were collected representing 15 species, but no living or dead scaleshell was found (Bruenderman *et al*. 2001).

Only two records (both dead shells) of scaleshell exist for the mainstem of the Missouri River. In 1981 and 1982, the Missouri River was surveyed from Santee to Omaha, Nebraska (Hoke 1983). One fresh dead shell specimen was found during this study just below Gavin's Point

Dam, South Dakota. This occurrence represents the westernmost record of the scaleshell in North America. This species has not been found, however, in subsequent surveys in the same area. In 1995, Clarke (1996) found no evidence of the scaleshell in a survey conducted from Gavin's Point Dam to 48 river km (30 mi) downstream. High water conditions limited Clark's search efforts, and only 10 individual mussels were found. In 1999, the Omaha District of the U.S. Army Corps of Engineers (Corps) funded a mussel survey between Gavin's Point Dam and Ponca, Nebraska, a distance of 96 river km (60 mi). In all, 355 live and 1,709 dead individual mussels were collected representing 16 species, but no living or dead scaleshells were found (Perkins and Backlund 2000). The second scaleshell record from the mainstem of the Missouri River is a single fresh dead individual that was collected in 1990 from Gasconade County, Missouri. This specimen was found during an extensive survey conducted from Gavin's Point Dam to St. Louis (Hoke 2000). However, the site of this collection was subsequently destroyed by development.

Because no living scaleshell have been found in the Missouri River, its habitat cannot be determined. However, both dead shells were collected from areas shielded from the main flow of the river in relatively stable, sandy bottoms with moderate current (Hoke 2000). Hoke (2000) described scaleshell as "extremely rare" and its habitat "very uncommon . . . and existing in only widely separated locales" in the Missouri River. This population is currently considered extirpated (USFWS 2001). Of the two known Missouri River records for scaleshell, one locality has been destroyed and recent surveys have not found any evidence of this species at or in the vicinity of the other site. Additionally, no other scaleshell specimens were found during Hoke's survey from Gavin's Point Dam to St. Louis. More information is needed on the existence of the scaleshell and its habitat in the Missouri River.

Buchanan (1994) surveyed the lower 137 km (85 mi) of the Gasconade River, and documented 36 species of freshwater mussels. He collected scaleshell at eight sites between river miles 6.0 and 57.7. Buchanan found only dead shells at two sites and eight live specimens from the remaining six sites. Overall, scaleshell comprised less than 0.1 percent of all mussels collected. In 1998-1999, the Gasconade River was surveyed at 46 sites from mile 92 to 256. A total of 15 living scaleshell were found at 9 sites, and dead shells were found at an additional 10 sites between river miles 92 and 231. At sites where scaleshell were collected, living individuals represented less than 0.5 percent of the total number of mussels found. Catch per unit effort of scaleshell was 0.1 individuals per hour of sampling (Sue Bruenderman *et al.* 2001).

The scaleshell has recently been discovered in the lower Osage River in Osage County, Missouri. On July 16, 2001, one live male specimen was found at river mile 20 (Heidi Dunn, pers. comm.). This individual was found during an intensive mussel survey in the lower 80 miles of the Osage River and several tributaries. In this survey, 34 sites were surveyed including 25 in the mainstem Osage River. A total of 8,000 living mussels were collected representing 28 living species. No other evidence of scaleshell was found during the survey.

Until the recent discovery of the scaleshell in the Osage River, it had never been reported from the Osage system in past surveys. Utterback (1917) found 34 species in the basin. No other information is available because his notes and collections have since been lost. Oesch (1995) collected mussels in the 1970s at a number of sites in the basin and reported 39 species. In 1980, a detailed study of mussel distribution was conducted by Grace and Buchanan (1981) in the lower 129 km (80 miles) of the Osage River and two tributaries below Bagnell Dam. A total of 43 sites were surveyed and 21,593 living mussels were found representing 36 species. No evidence of scaleshell was found in any of these surveys.

*Middle Mississippi River Basin summary*--Of the 26 rivers and tributaries in the middle Mississippi River Basin that historically supported scaleshell, the species is still present in five including the Meramec, Bourbeuse, Big, Osage, and Gasconade rivers in Missouri. The Meramec, Bourbeuse, and Gasconade rivers support the largest known populations.

<u>Lower Mississippi River Basin</u>

The scaleshell historically occupied 21 rivers and tributaries in the lower Mississippi River Basin. These include the St. Francis, White, James, Spring, Little Missouri, Middle Fork Little Red, Saline (of the Ouachita River), Ouachita, Cossatot, Saline (of the Little River), South Fourche LaFave, Mulberry, and Strawberry rivers in Arkansas; South Fork Spring, Frog Bayou, and Myatt Creek in Arkansas; Poteau, Little, and Kiamichi rivers in Oklahoma; and Gates Creek and Mountain Fork in Oklahoma. These rivers are discussed below according to drainage (St. Francis, White, Arkansas, and Red River drainages).

*St. Francis River Drainage* (Arkansas )--Bates and Dennis (1983), Clarke (1985), and Ahlstedt and Jenkinson (1987) conducted mussel surveys on the St. Francis River in Arkansas and Missouri. In these surveys, the scaleshell was only documented from two sites, both of which are single-specimen records (Clarke 1985). Records of dead shells of various species indicate that at one time freshwater mussels occurred throughout the river (Bates and Dennis 1983). Bates and Dennis (1983) determined that of the 54 sites sampled, 15 were productive, 10 marginal, and 29 had either no shells or dead specimens only; scaleshell was not documented at any of the 54 sites. They identified 77 km (48 mi.) of habitat generally suitable for mussels: Wappapello Dam to Mingo Ditch, Missouri; Parkin to Madison, Arkansas; and Marianna to the confluence with the Mississippi River at Helena, Arkansas. They indicated that the remaining portions of the river were no longer suitable for mussels. If the scaleshell is extant in the St. Francis River, it is restricted to the few remaining patches of suitable habitat.

*White River Drainage* (Arkansas)–-Clarke (1996) noted a 1902 collection of a single specimen from the White River near Garfield, Arkansas. A late 1970s survey of the White River between Beaver Reservoir and its headwaters failed to relocate live or dead scaleshell. In 1999, however, a single live specimen was collected from the White River near Newport by John Harris (Arkansas Department of Transportation, pers. comm. 2000). Navigation maintenance activities have relegated the mussel fauna to a few refugial sites (Bates and Dennis 1983). Specimens have not been collected from the James River, a tributary of the White River, since before 1950 (Clarke 1996).

An eight-mile section of the Spring River in Arkansas supports a diverse assemblage of freshwater mussels (Gordon *et al.* 1984, Arkansas Highway and Transportation Department

1984, Miller and Hartfield 1986). The collections from this river total eight scaleshell specimens [Kevin Cummings in litt. 1994; Clarke 1996, Arkansas State Highway and Transportation Department 1984]. Gordon *et al.* (1984) surveyed the river and reported suitable mussel habitat between river miles 3.2 and 11.0, although species richness below river mile 9 had declined markedly compared to past surveys. Gordon *et al.* (1984), as well as Miller and Hartfield (1986), reported that the lower 5.0 km (3.0 mi) of the river were completely depleted of mussels and contained no suitable habitat. Harris did not find scaleshell in a 1993 survey of the Spring River (John Harris, in litt. 1997).

The scaleshell was collected from the South Fork of the Spring River in 1983 and 1990. During the 1983 survey, Harris (in litt. 1997) collected four dead male specimens near Saddle, Arkansas, and one dead male specimen and a single male valve north of Hunt, Arkansas. During a subsequent visit in 1990, Harris collected shells of young adults (Harris, pers. comm. 1995). Although juveniles were not found, the presence of young adults suggested that reproduction had recently occurred.

Records of scaleshell from the Strawberry River and the Myatt Creek are based on single specimen collections, both made in 1996 (John Harris, in litt. 1997). Harris collected a live specimen from the Strawberry River near the confluence with Clayton Creek in Lawrence County. He also collected a single dead specimen from Myatt Creek in Fulton County (John Harris, in litt. 1997). Comprehensive surveys have not been conducted in these rivers since 1996.

The historical locality (near Shirley, Van Buren County, Arkansas) where a single scaleshell specimen was collected from the Middle Fork of the Little Red River no longer provides mussel habitat. Clarke (1987) stated that suitable mussel habitat was restricted to a 9.6 km (6.0 mi) stretch from the confluence of Tick Creek upstream to the mouth of Meadow Creek.

*Arkansas River Drainage* (Oklahoma and Arkansas)–The scaleshell has been collected in the following streams from the Arkansas River drainage: Poteau River in Oklahoma (Gordon 1991), Frog Bayou in Arkansas (Harris and Gordon 1987), and the South Fourche LaFave and Mulberry rivers in Arkansas (Gordon 1991; Harris 1992). A single scaleshell specimen was collected in the Poteau River (Gordon 1980). However, it has not been documented in subsequent surveys of this river (Branson 1984; Harris 1994). The existence of scaleshell in Poteau River is doubtful.

Gordon (1980) collected two scaleshell specimens from Frog Bayou. Beaver Reservoir now inundates one of the Frog Bayou collection sites. The most recent record was a fresh dead individual collected during a 1979 survey (Gordon 1980). Gordon noted that stream bank bulldozing upstream recently disturbed this site and other nearby sites. He also reported in-stream gravel mining activities at several sites. Within Frog Bayou, potential habitat is restricted to the area between Rudy and the confluence of the Arkansas River. Above Rudy, two reservoirs impact the river; one near Maddux Spring and the other at Mountainburg. Live mussels have not been found at the confluence of the Arkansas River, likely due to dredging activities (Gordon 1980). Although the current status of the scaleshell in Frog Bayou is uncertain, any remaining individuals are in potential jeopardy due to limited habitat and in-stream mining activities.

The only record of scaleshell from the South Fourche LaFave River is based on a single live specimen found in 1991 (Harris 1992). No evidence of scaleshell was found in an intensive, subsequent mussel survey of this stream, which indicates that the species is extremely rare or extirpated from this stream (Stoeckel and Moles 2002). An 86-acre reservoir is approved for construction on Bear Creek approximately six miles upstream from this site. The effect of this impoundment on scaleshell is uncertain. The potential for discovering additional scaleshell sites in this river is unlikely due to the limited availability of suitable substrate. Similarly, other major tributaries of the South Fourche LaFave River provide little mussel habitat. Like Frog Bayou, the persistence of scaleshell in this river is in doubt.

Although Gordon (1991) reported scaleshell from the Mulberry River, documentation is lacking. In recent mussel surveys of this river, the species was not found (Craig Hilborne, U.S. Forest Service, pers. comm. 1995; Stoeckel *et al.* 1995). The existence of scaleshell in the Mulberry River is unlikely.

*Red River drainage* (Oklahoma and Arkansas)–The scaleshell has been documented from the following streams in the Red River drainage: the Kiamichi River, Gates Creek, Little River, Mountain Fork; and the Cossatot, Ouachita, Little Missouri, and Saline Rivers. Isley (1925) first collected scaleshell from the Kiamichi River in 1925. Based on his account, the Kiamichi River historically supported a diverse and abundant mussel fauna. He collected 36 scaleshell specimens at one of 22 stations visited. A single specimen was also collected from Gates Creek, a tributary of the Kiamichi River, by Valentine and Stansbery (1971). As recently as 1987, Clarke described the Kiamichi River as "in remarkably good condition" and a "faunal treasure" (Clarke 1987). However, despite extensive searches of the Kiamichi River over the last 11 years, only a single fresh dead shell of scaleshell (in 1987) has been collected (Caryn Vaughn, Oklahoma Biological Survey, pers. comm. 1997; Charles Mather, University of Science and Arts of Oklahoma, in litt. 1984 and 1995). Vaughn (pers. comm. 1997) failed to find even a dead shell during three years (1993-1996) of surveys in the Red River Basin. However, the mussel habitat in the Kiamichi River is in relatively good condition above the Hugo Reservoir (Clarke 1987) and may still support a remnant population of scaleshell.

Although there is no evidence of scaleshell persisting in the Little River, healthy mussel beds exist above the Pine Creek Reservoir (Caryn Vaughn, in litt. 1997). Below Pine Creek Reservoir, the mussel fauna is severely depleted but recovers with increasing distance from the impoundment (Caryn Vaughn, in litt. 1997). Although scaleshell has not been documented during extensive surveys throughout the length of the Little River, suitable habitat remains and the species may persist (Caryn Vaughn, in litt. 1997). However, the discharge of reservoir water from Pine Creek and periodic discharge of pollution from Rolling Fork Creek may seriously impact any remaining viable scaleshell population and prohibit any future recolonization (Clarke 1987). Valentine and Stansbery (1971) reported a single specimen from Mountain Fork. Clarke (1987) hypothesized that, based on the presence of mussels at the confluence of Mountain Fork and beyond the Arkansas border, damage to Mountain Fork from the Broken Bow Reservoir has not occurred. Vaughn (in litt. 1997), however, indicated that these areas have been severely depleted, with most no longer supporting live mussels.

If the scaleshell still occurs in the Red River drainage in Oklahoma, extant populations are probably small and are likely restricted to isolated areas of suitable habitat in the Kiamichi and Mountain Fork Rivers. Given the extensive survey effort over the last decade, long-term survival of the scaleshell in Oklahoma is doubtful.

Harris collected single scaleshell specimens from the Cossatot and Saline Rivers in Arkansas in 1983 (John Harris, in litt. 1997) and 1987 (John Harris, pers. comm. 1995), respectively. No other information is available for either river.

The existence of scaleshell in the Ouachita River and its two tributaries, the Saline River and Little Missouri River, is questionable as well. Both the Little Missouri and Saline Rivers records are based on single specimens. The Saline River specimen was collected in 1964 (Clarke 1996), and the Little Missouri River collection record is from 1995 (John Harris, in litt. 1997). Four undated museum specimens of scaleshell from the Ouachita River in Arkadelphia, Clark County, Arkansas are listed in Clarke (1996), but details are unavailable. Based on the few collections and the limited available habitat, the long-term persistence of scaleshell in Cossatot, Saline, Little Missouri, and Ouachita rivers appears precarious.

*Lower Mississippi River Basin Summary*--Of these 21 rivers and tributaries in the lower Mississippi River Basin that historically supported scaleshell, nine, and possibly an additional six, support the species today. The nine rivers where scaleshell is extant include the South Fork Spring, St. Francis, Kiamichi, Little, Spring, South Fourche LaFave, and White rivers; Mountain Fork; and Frog Bayou. The status of scaleshell in the Myatt and Gates Creeks and the Strawberry, Cossatot, Saline, and Little Missouri rivers is unknown.

**APPENDIX II: Summary of Threats and Recommended Recovery Actions for Scaleshell (*Leptodea leptodon*)**

| Listing Factor | Threat | Recovery Criteria | Task Numbers |
|---|---|---|---|
| A | Significant range reduction | 1, 2, 3, 4, 5 | Utilize: recovery implementation team, GIS database; Further delineate current status and distribution, identify suitable reintroduction sites and develop and implement habitat restoration strategies, develop and implement a reintroduction plan, initiate educational and public outreach actions (see tasks 1.1, 2.1, 4.1, 4.2, 4.3, 4.4, 5.1, 6.1, 6.2, 6.3, 6.4, 6.5) |
| A | Water quality degradation, point source | 1, 2, 3, 5 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| A | Water quality degradation, nonpoint source | 1, 2, 3, 5 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| A | Contaminant spills | 1, 3 | Utilize: recovery implementation team; develop emergency response strategy, initiate educational and public outreach actions (see tasks 1.1, 2.7, 6.1, 6.2, 6.3, 6.4, 6.5) |
| A | Sedimentation and eutrophication | 1, 2, 3 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| A | Loss of stable substrates, channel degradation, excessive bank erosion | 1, 2, 3 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |

| Listing Factor | Threat | Recovery Criteria | Task Numbers |
|---|---|---|---|
| A | Habitat loss and degradation due to channelization, sand and gravel mining, dredging operations, construction and operation of reservoirs, and other construction activities | 3 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| B | Possible disturbance of habitat and trampling from commercial harvesting | 3 | Utilize existing programs (i.e. ESA) to protect the species, initiate educational and public outreach actions (see task 2.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| B | Specimens potentially taken for shell collections, bait, curiosity, or vandalism | 3 | Utilize existing programs (i.e. ESA) to protect the species, initiate educational and public outreach actions, (see task 2.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| C | Mussels kills due to disease | 1, 3 | Utilize: recovery implementation team; develop emergency response strategy, initiate educational and public outreach actions (see tasks 1.1, 2.7, 6.1, 6.2, 6.3, 6.4, 6.5) |
| C | Predation by mammals | 1, 3 | Utilize: recovery implementation teeam (see tasks 1.1, 2.9) |
| D | Habitat loss and degradation continues despite existing regulatory mechanisms | 1, 2, 3 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies, initiate educational and public outreach actions (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4, 6.1, 6.2, 6.3, 6.4, 6.5) |
| E | Reduced recruitment due to bottlenecks in life cycle | 2 | Utilize recovery implementation team; stabilize and establish self-sustaining populations by artificial propagation, which bypasses bottlenecks (see tasks 1.1, 2.5.1, 2.5.2) |
| E | Reduced reproduction due to habitat fragmentation | 1, 2, 3 | Utilize: recovery implementation team, GIS database, and habitat protection and restoration strategies; carry out cooperative projects using existing programs, conduct water quality studies (see tasks: 1.1, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.4, 4.2, 4.3, 4.4) |

| Listing Factor | Threat | Recovery Criteria | Task Numbers |
|---|---|---|---|
| E | Extant populations with greater chance of extirpation due to small, isolated populations | 1, 2, 3 | Utilize recovery implementation team; stabilize and establish self-sustaining populations by artificial propagation (see tasks 1.1, 2.5.1, 2.5.2) |
| E | Reduction of populations due to drought | 1, 3 | Utilize recovery implementation team, develop emergency response strategy (see tasks 1.1, 2.7) |
| E | Threats from non-native species | 3, 4 | Utilize recovery implementation team, develop management options to reduce or eliminate the threat of non-native species, initiate educational and public outreach actions (See tasks 1.1, 2.8.1, 2.8.2, 2.8.3, 2.8.4, 2.8.5, 6.1, 6.2, 6.3, 6.4, 6.5) |

**Listing Factors:**
A. The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes (not a factor)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence

**Recovery Criteria:**
The scaleshell will be considered for downlisting to threatened status when the likelihood of the species becoming extinct in the foreseeable future has been eliminated by the achievement of the following criteria:
**1.** Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, four stream populations exist, each made up of at least four local populations. Each stream population must exist in a distinct geographical region so that a single stochastic event, such as a toxic spill or disease outbreak, will not affect more than one stream population.
**2.** All local populations are persistent and are viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.
**3.** Each local population and their habitat are sufficiently protected from any present and foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.
**4.** Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent and viable scaleshell populations if their densities have not changed for five consecutive years.

**5.** Tasks are completed to determine if water quality criteria should be included as a delisting criteria, and if so, water quality criteria for delisting will be developed.

The scaleshell will be considered for removal from the ESA protection when the likelihood of the species becoming threatened in the foreseeable future has been eliminated by the achievement of the following criteria:
**1.** Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of eight stream populations exist, each made up of at least four local populations, unless Action 3.4.2 or 3.4.3 indicates more local populations, streams, or geographical regions are required. Each stream population must exist in a distinct geographical region. At a minimum, one stream population must be located in the Upper Mississippi River Basin, four in the Middle Mississippi River Basin (two of these must exist east of the Mississippi River), and three in the Lower Mississippi River Basin.
**2.** All local populations are persistent and viable in terms of population size, age structure, and recruitment. Adequate population size and age structure for each local population will be determined through Minimum Viable Population analysis (see Action 3.4.2). A stream population will be considered persistent and viable if three consecutive surveys conducted at five-year intervals demonstrate that population size and age structure are adequate and populations contain representatives in the 1-3 age class.
**3.** Each local population and their habitat are sufficiently protected from any present and foreseeable threats that would jeopardize their continued existence. Protection will be accomplished by establishing habitat protection agreements as discussed in Action 2.3 and 5.3, developing cooperative agreements with involved states, and initiating measures that provide for review of federally funded, permitted, or planned activities in or near scaleshell habitat pursuant to the FWCA and CWA.
**4.** Measures are in place to prevent the spread of zebra mussels into habitat occupied scaleshell where zebra mussels have not become established. In streams that might have established zebra mussel populations, they will not be considered a threat to persistent and viable scaleshell populations if their densities have not changed for five consecutive years.
**5.** Water quality criteria may be added to the recovery criteria for delisting upon completion of the tasks referred to under the recovery criteria for reclassification.

## APPENDIX III: Glossary of Terms

**Adaptive management -** habitat management techniques that are updated to incorporate new information.

**Ala** – wing-like structure on the shell of unionids, usually on the dorsal side.

**Anal opening** – an opening above the *branchial* opening; waste material from the digestive tract and water leave through this opening.

**Anterior** – toward the head or front end of an animal.

**Anthropogenic** – activities involving the impact of man on nature.

**Augmentation** - moving eggs, larvae, juveniles or adults to a site with an existing *local population*.

**Beak** - the raised, or inflated portion of a bivalve shell, centrally or *anteriorly* placed along the dorsal margin of the shell.

**Beak cavity** - a cavity located inside the shell that extends into the *beak*.

**Beak sculpture** – lines, corrugations or other surface relief seen on the disk in some unionids.

**Benthic** – refers to the bottom of surface water bodies and the organisms that live there.

**Branchial** – the lower or ventral siphon.

**Conglutinates** - small structures made up of gelatinous material that enclose large numbers of glochidia.

**Crenulate** – having a roughened or scalloped border.

**Cryogenic preservation** – the solidification of a biological specimen by rapid cooling, while maintaining structural integrity.

**Dorsal** – toward the back or top of an animal.

**Eutrophication** - excessive fertilization caused by pollution of plant nutrients.

**Extant** – currently existing population of a species.

**Extirpation** – the local disappearance of a species that does not lead to the range-wide extinction of that species.

**Fresh dead** – dead mussel specimens that still have soft tissue attached to the shell.

**Genetic drift** – Random changes in gene frequencies in a population.

**Glochidia** – The bivalve microscopic larvae of freshwater mussels in the superfamily Unionoidea, which are generally parasitic upon vertebrates, usually fish.

**Gravid** – refers to unionids brooding eggs or glochidia in the gills.

**Headcutting** - the upstream progression of stream bed destabilization and accelerated bank erosion.

**Inbreeding depression –** The reduction of population fitness due to inbreeding.

**Interstitial water** – water found in small spaces beneath the surface of substrate.

**Laminae** – thin plate or layer.

**Lateral teeth** - the elongated, raised, and interlocking structures located dorsally along the hing line of the inside of the valves if freshwater mussels.

**Local population** - assemblage of individuals that more or less interact with each other in the course of their routine feeding and breeding activities (e.g. mussel bed).

**Long-term brooder** – unionids that spawn in the fall months, and females brood glochidia until the following spring.  Short-term brooders spawn and release glochidia in the spring.

**Mantle** – outermost part of the soft tissue of unionids; secretes shell at the edges and produces the periostracum.

**Mantle cavity** – empty space inside the shell between the shell and soft tissues of bivalved mollusks.

**Marsupia** – The portion of the gills of a female freshwater mussel that are used in brood glochidia.

**Midden** – pile of discarded mussel shells resulting from feeding activities of small mammals.

**Macroinvertebrate** – an animal without a backbone large enough to been seen without magnification.

**Mussel beds** - areas containing a high concentration and diversity of mussels.

**Nacre** – the interior layer of the shell, made up of crystalline carbonate.

**Papillae** – small, finger-like projections seen around the siphons of unionids.

**Periostracum** - the thin, uncalcified outer layer or covering of the shell.

**Posterior** – toward the tail-end of an animal.

**Pseudocardinal teeth -** the triangular, often serrated, teeth-like structures located on the upper part of the shell in freshwater mussels.

**Reintroduction**—moving eggs, larvae, juveniles, or adults from one or more existing populations to help create another population at a separate geographic area within the historic range of the species where there are no existing populations.

**Rhomboid -** a parallelogram with opposite sides equal.

**Sexual dimorphism** – exhibiting external morphological characteristics that allow the separation of male from female.

**Silviculture** – the cultivation of woods or forests.

**Siphon** – aperture through which water is drawn in or out of a bivalved mollusc.

**Status** - an assessment of the current existence of a population

**Stochastic event** – unpredictable, random catastrophic event such as an oil spill, flood, or drought.

**Stream population** – all individuals living in one river or stream. This is a geographical term that does not imply that a population is currently reproducing or that it is a distinct genetic unit.

**Stream team** – Stream teams are working partnerships of citizens who are concerned about streams and become involved in steam conservation including education, habitat restoration projects, and stream advocacy.

**Supra-anal** – an opening above the anal opening.

**Sympatric** – pertaining to populations of two or more species which occupy identical or broadly overlapping geographical areas.

**Trend** - an assessment of change in a population's numbers and its probable future condition.

**Unionid** – a freshwater bivalve belonging to the family Unionidae. The larval form is usually parasitic upon a fish; adults do not have proteinaceous threads with which to attach themselves to the substrate. Also called freshwater mussel, freshwater clam, or naiad.

**Valve** – The left or right half of a bivalve shell such as a freshwater mussel.

**Ventral** – toward the underside or bottom of an animal

## APPENDIX IV: List of Abbreviations

| | |
|---|---|
| CWA | Clean Water Act |
| CRP | Conservation Reserve Program |
| EQIP | Environmental Quality Incentives Program |
| EO | Executive Order |
| ESA | Endangered Species Act |
| FERC | Federal Energy Regulatory Commission |
| FIP | Forestry Incentives Program |
| FMCS | Freshwater Mollusk Conservation Society |
| FSA | Farm Service Administration |
| FWCA | Fish and Wildlife Coordination Act |
| GIS | Global Information System |
| MDC | Missouri Department of Conservation |
| MDNR | Missouri Department of Natural Resources |
| MVP | Minimum Viable Population |
| NANPCA | Nonindigenous Aquatic Nuisance Prevention and Control Act |
| NNMCC | National Native Mussel Conservation Committee |
| NRCS | National Resources Conservation Service |
| ODEQ | Oklahoma Department of Environmental Quality |
| PVA | Population Viability Analysis |
| RBP | Rapid Bioassessment Protocol |
| USEPA | United States Environmental Protection Agency |
| USACE | United States Army Corps of Engineers |
| USDA | United States Department of Agriculture |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| WHIP | Wildlife Habitat Incentives Program |
| WRP | Wetlands Reserve Program |

–