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50 CFR Part 17
Endangered and Threatened Wildlife and Plants; Endangered Status for the Sheepnose and Spectaclecase Mussels; Proposed Rule

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

[Docket No. FWS–R3–ES–2010–0050; MO 92210–0–0008–B2]

RIN 1018–AV93

Endangered and Threatened Wildlife and Plants; Endangered Status for the Sheepnose and Spectaclecase Mussels

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Proposed rule.

SUMMARY: We, the U.S. Fish and Wildlife Service (Service), propose to list two freshwater mussels, the spectaclecase mussel (*Cumberlandia monodonta*) and sheepnose (*Plethobasus cyphyus*) as endangered under the Endangered Species Act of 1973, as amended (Act). If we finalize this rule as proposed, it would extend the Act's protections to these species throughout their ranges, including sheepnose in Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin, and spectaclecase in Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Kansas, Minnesota, Missouri, Nebraska, Ohio, Tennessee, Virginia, West Virginia, and Wisconsin. We determined that critical habitat for these species is prudent, but not determinable at this time. The Service seeks data and comments from the public on this proposed listing rule.

DATES: We will consider comments and information we receive from all interested parties by March 21, 2011. We must receive requests for public hearings, in writing, at the address shown in the **FOR FURTHER INFORMATION CONTACT** section by March 7, 2011.

ADDRESSES: You may submit comments by one of the following methods:

- *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the instructions for submitting comments on docket number FWS–R3–ES–2010–0050.
- *U.S. mail or hand-delivery:* Public Comments Processing, Attn: FWS–R3–2010–0050; Division of Policy and Directives Management; U.S. Fish and Wildlife Service; 4401 North Fairfax Drive, Suite 222; Arlington, VA 22203.

We will post all comments on *http://www.regulations.gov.* This generally means that we will post any personal information you provide us (*see* Public Comments section below for more information).

FOR FURTHER INFORMATION CONTACT: Richard Nelson, Field Supervisor, at the U.S. Fish and Wildlife Service, Rock Island, Illinois Ecological Services Field Office, 1511 47th Avenue, Moline, IL 61265 (telephone 309–757–5800).

SUPPLEMENTARY INFORMATION:

Public Comments

Our intent is to use the best available commercial and scientific data as the foundation for all endangered and threatened species classification decisions. We request comments or suggestions from other concerned governmental agencies, the scientific community, industry, or any other interested party concerning this proposed rule to list the spectaclecase and sheepnose mussels as endangered. We particularly seek comments concerning:

(1) Biological, commercial trade, or other relevant data concerning any threats (or lack thereof) to the species and regulations that may be addressing those threats.

(2) Additional information concerning the ranges, distributions, and population sizes of the species, including the locations of any additional populations of these species.

(3) Any additional information on the biological or ecological requirements of these species.

(4) Current or planned activities in the areas occupied by these species and possible impacts of these activities on the species and their habitats.

(5) Potential effects of climate change on these species and their habitats.

(6) The reasons why areas should or should not be designated as critical habitat as provided by section 4 of the Act (16 U.S.C. 1531 *et seq.*), including whether the benefits of designation would outweigh threats to the species that designation could cause (*e.g.,* exacerbation of existing threats, such as overcollection), such that the designation of critical habitat is prudent.

(7) Specific information on:

- What areas contain physical and biological features essential for the conservation of these species;
- What areas are essential to the conservation of these species and
- Special management considerations or protection that proposed critical habitat may require.

Please note that submissions merely stating support for or opposition to the action under consideration without providing supporting information, although noted, will not be considered in making a determination, as section 4(b)(1)(A) of the Act directs that determinations as to whether any species is an endangered or threatened species must be made "solely on the basis of the best scientific and commercial data available."

You may submit your comments and materials concerning this proposed rule by one of the methods listed in the **ADDRESSES** section. We will not accept comments sent by e-mail or fax or to an address not listed in the **ADDRESSES** section. Comments must be submitted to *http://www.regulations.gov* before 11:59 (Eastern Time) on the date specified in the **DATES** section. We will not consider hand-delivered comments that we do not receive, or mailed comments that are not postmarked, by the date specified in the **DATES** section.

We will post your entire comment—including your personal identifying information—on *http://www.regulations.gov.* If you provide personal identifying information in your comment, you may request at the top of your document that we withhold this information from public review. However, we cannot guarantee that we will be able to do so.

Comments and materials we receive, as well as supporting documentation we used in preparing this proposed rule, will be available for public inspection on *http://www.regulations.gov,* or by appointment, during normal business hours at the Rock Island, Illinois Ecological Services Field Office (*see* the **FOR FURTHER INFORMATION CONTACT** section).

Public Hearing

The Act provides for one or more public hearings on this proposal, if requested. Requests must be received by March 7, 2011. Such requests must be made in writing and be addressed to the Field Supervisor at the address provided in the **FOR FURTHER INFORMATION CONTACT** section. We will schedule public hearings on this proposal, if any are requested, and announce the dates, times, and places of those hearings, as well as how to obtain reasonable accommodations, in the **Federal Register** and local newspapers at least 15 days before the hearing.

Persons needing reasonable accommodations to attend and participate in a public hearing should contact the Rock Island, Illinois Ecological Services Field Office by telephone at 309–757–5800, as soon as possible. To allow sufficient time to process requests, please call no later than one week before the hearing date. Information regarding this proposed rule is available in alternative formats upon request.

Background

Species Descriptions

The spectaclecase (*Cumberlandia monodonta*) is a member of the mussel family Margaritiferidae and was originally described as *Unio monodonta* Say, 1829. The type locality is the Falls of the Ohio (on the Ohio River in the vicinity of Louisville, Kentucky, and adjacent Indiana), and the Wabash River (probably the lower portion in Illinois and Indiana) (Parmalee and Bogan 1998, p. 49). Parmalee and Bogan (1998, p. 49) summarized the synonymy of the spectaclecase. The species has been placed in the genera *Unio, Margaritana, Alasmidonta, Margarita, Margaron,* and *Margaritifera* at various times in history. Ortmann (1912, p. 13) placed it in the monotypic (a taxonomic group with only one biological type) genus *Cumberlandia* in the family Margaritiferidae. Currently recognized synonymy includes *Unio soleniformis* (Lea). Smith (2001, p. 43) reassigned the spectaclecase to the Holarctic genus *Margaritinopsis* based on shell and gill characters. However, the Service will defer to the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union (Turgeon *et al.* 1998), on whether the genus *Margaritinopsis* is accepted as valid for the spectaclecase. Until an official decision is made, the Service will use the commonly accepted *Cumberlandia* for the genus of this species. Spectaclecase is the accepted common name for *Cumberlandia monodonta* (Turgeon *et al.* 1998, p. 32).

The spectaclecase is a large mussel that reaches at least 9.25 inches (23.5 centimeters (cm)) in length (Havlik 1994, p. 19). The shape of the shell is greatly elongated, sometimes arcuate (curved), and moderately inflated, with the valves being solid and moderately thick, especially in older individuals (Parmalee & Bogan 1998, p. 49). Both anterior and posterior ends of the shell are rounded with a shallow depression near the center of shell (Baird 2000, p. 6; Parmalee & Bogan 1998, p. 49). The anterior end is higher than the posterior end (Baird 2000, p. 6). The posterior ridge is low and broadly rounded (Parmalee & Bogan 1998, p. 50). Year-one specimens have heavy ridges running parallel with the growth arrests, which are shell lines that indicate slower periods of growth, thought to be laid down annually (Baird 2000, p. 6). The periostracum (external shell surface) is somewhat smooth, rayless, and light yellow, greenish-tan, or brown in young specimens, becoming rough and dark brown to black in old shells (Parmalee & Bogan 1998, p. 50). The shell commonly will crack posteriorly when dried (Oesch 1984, p. 31).

Internally, the single pseudocardinal tooth (a triangular tooth-like structure along the hinge line of the internal portion of the shell) is simple and peg-like in the right valve, fitting into a depression in the left (Parmalee & Bogan 1998, p. 50). The lateral teeth are straight and single in the right valve, and double in the left valve but become fused with age into an indistinct raised hinge line (Parmalee & Bogan 1998, p. 50). The soft anatomy was described by Williams *et al.* (2008, pp. 497–498). The color of the nacre (interior covering of the shell) is white, occasionally granular and pitted, mostly iridescent in young specimens, but becoming iridescent posteriorly in older shells (Parmalee & Bogan 1998, p. 50). There are no differences between the sexes in the shells of this species (Baird 2000, p. 19). Key characters for distinguishing the spectaclecase from other mussels are its large size, elongate shape, arcuate ventral margin, dark coloration, roughened periostracum, poorly developed teeth, and white nacre (Oesch 1984, pp. 31–32). No other North American mussel species has this suite of characters.

The sheepnose (*Plethobasus cyphyus*) is a member of the mussel family Unionidae and was originally described as *Obliquaria cyphya* Rafinesque, 1820. The type locality is the Falls of the Ohio (Parmalee & Bogan 1998, p. 175) on the Ohio River in the vicinity of Louisville, Kentucky, and adjacent Indiana. Parmalee and Bogan (1998, p. 175) summarized the synonymy of the species. Over the years, the name of this species has been variably spelled *cyphya, scyphius, cyphius, cyphia, cyphyum,* and ultimately *cyphyus.* Over the years the species has been placed in the genera *Obliquaria, Unio, Pleurobema, Margarita,* and *Margaron.* It was ultimately placed in the genus *Plethobasus* by Ortmann (1919, pp. 65–66) where it remains today (Turgeon *et al.* 1998, p. 35). The Service recognizes *Unio aesopus* and *U. compertus* as synonyms of *Plethobasus cyphyus.* Sheepnose is the accepted common name for *Plethobasus cyphyus* as established by the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union (Turgeon *et al.* 1998, p. 35). The Service also recognizes “bullhead” and “clear profit” as older common names for the sheepnose.

Key characters useful for distinguishing the sheepnose from other mussels are its color, the occurrence of central tubercles, and its general shape. Oesch (1984, p. 120) and Parmalee and Bogan (1998, p. 176), describe the sheepnose as a medium-sized mussel that reaches nearly 5 inches (13 cm) in length. The shell is elongate ovate in shape, moderately inflated, and with thick, solid valves. The anterior end of the shell is rounded, but the posterior end is somewhat bluntly pointed to truncate. The dorsal margin of the shell is nearly straight, while the ventral margin is uniformly rounded or slightly convex. The posterior ridge is gently rounded, becoming flattened ventrally and somewhat biangular. There is a row of large, broad tubercular swellings on the center of the shell extending from the beak to the ventral margin. A broad, shallow sulcus (depression on furrow on the outside surface of shell) lies between the posterior ridge and central row. Beaks are elevated, high, and placed near the anterior margin. Juvenile beak sculpture consists of a few concentric ridges at the tip of the beaks. The periostracum is generally smooth, shiny, rayless, and light yellow to a dull yellowish brown. Concentric ridges resulting from growth arrests are usually darker.

Oesch (1984, p. 120) describes the internal anatomy of the sheepnose as the left valve having two heavy, erect, roughened, somewhat triangular, and divergent pseudocardinal teeth. The right valve has a large, triangular, roughened pseudocardinal tooth. The lateral teeth are heavy, long, slightly curved, and serrated. The beak cavity is shallow to moderately deep. The soft anatomy was described by Williams *et al.* (2008, p. 94). The color of the nacre is generally white, but may be pinkish to cream-colored and iridescent posteriorly. There are no differences between the sexes in the shells of this species. The shell of the sheepnose is extremely hard and was given the name “clear profit” by early commercial shellers, being too hard to cut into buttons (Wilson & Clark 1914, p. 57). The species also preserves well in archaeological material (Morrison 1942, p. 357).

Life History

The general biology of the spectaclecase and sheepnose are similar to other bivalve mollusks belonging to the families Margaritiferidae and Unionidae, order Unioniformes or Unionoida. Adult mussels suspension-feed, spending their entire lives partially or completely buried within the substrate (Murray and Leonard 1962, p. 27). Adults feed on algae, bacteria, detritus, microscopic animals, and dissolved organic material (Christian *et* *al.* 2004, pp. 108–109; Nichols & Garling 2000, p. 873; Silverman *et al.* 1997, p. 1859; Strayer *et al.* 2004, pp. 430–431). Recent evidence suggests that adult mussels may also deposit feed on particles in the sediment (Raikow & Hamilton 2001, p. 520). For their first several months, juvenile mussels employ foot (pedal) feeding, consuming bacteria, algae, and detritus (Yeager *et al.* 1994, p. 221).

As a group, mussel longevity varies tremendously with some species living only about 4 years (Haag & Rypel 2010, p. 5) but possibly up to 100 to 200 years in other species (Ziuganov *et al.* 2000, p. 102). However, the vast majority of species live a few decades (Haag & Rypel 2010, pp. 4–6). Baird (2000, pp. 54, 59, 67) aged 278 specimens of the spectaclecase in Missouri by sectioning the hinge ligament, as most margaritiferids are aged. The maximum age determined was 56 years, but he surmised that some large individuals may have been older. A very large specimen (9.25 inches (23.5 cm)) from the St. Croix River, Minnesota and Wisconsin, was estimated (based on external growth ring counts) to be approximately 70 years old (Havlik 1994, p. 19). Sheepnose longevity has been reported as being nearly 30 years (Watters *et al.* 2009, p. 221). Thick shelled mussels from large rivers, like sheepnose, are thought to live longer than other species (Stansbery 1961, p. 16).

Mussels tend to grow relatively rapidly for the first few years, and then slow appreciably at sexual maturity, when energy presumably is being diverted from growth to reproductive activities (Baird 2000, pp. 66–67). In spectaclecase, the biggest change in growth rate appears to occur at 10 to15 years of age, which suggests that significant reproductive investment does not occur until they reach 10 years of age (Baird 2000, pp. 66–67).

Margaritiferids and unionids have an unusual mode of reproduction. With very few exceptions, their life cycle includes a brief, obligatory parasitic stage on a host organism, typically fish. Eggs develop into microscopic larvae (glochidia) within special gill chambers of the female. The female expels the mature glochidia, which must attach to an appropriate host species (generally a fish) to complete development. Host specificity varies among margaritiferids and unionids. Some species appear to use a single host, while others can transform on several host species. Following successful infestation, glochidia encyst (enclose in a cyst-like structure), remain attached to the host for several weeks, and then drop off as newly transformed juveniles. For further information on the life history of freshwater mussels, see Williams *et al.* 2008.

Mussel biologists know relatively little about the specific life-history requirements of the spectaclecase and sheepnose. Most mussels, including the spectaclecase and sheepnose, have separate sexes. Age at sexual maturity of the spectaclecase was estimated to be 4 to 5 years for males and 5 to 7 years for females, with sex ratios approximating 50:50 (Baird 2000, p. 24). The spectaclecase life cycle includes a parasitic phase; however, despite extensive investigation, the host species is not yet known. The spectaclecase is thought to release glochidia from early April to late May in the Meramec and Gasconade Rivers, Missouri (Baird 2000, p. 26). Gordon and Smith (1990, p. 409) reported the species as producing two broods, one in spring or early summer and the other in the fall, also based on Meramec River specimens. In the Meramec and Gasconade Rivers, however, Baird (2000, pp. 26–27) found no evidence of two spawns in a given year.

Age at sexual maturity for the sheepnose is unknown, but given its estimated longevity, probably occurs after a few years. The sheepnose is thought to be a short-term brooder, with egg fertilization taking place in early summer (Parmalee & Bogan 1998, p. 177; Williams *et al.* 1998, p. 498), and glochidial release presumably occurring later in the summer. Hermaphroditism occurs in many mussel species (van der Schalie 1966, p. 77), but is not known for the sheepnose. If hermaphroditism does occur in the sheepnose, it may explain the occurrence of small, but persistent populations over long periods of time.

Glochidia of spectaclecase and sheepnose are released in conglutinates (gelatinous structures containing numerous glochidia and analogous to cold capsules). Spectaclecase glochidia lack hooks (teeth-like structures that presumably function to pierce through skin tissue of the host) and are the smallest glochidia known of any North American freshwater mussel; they measure approximately 0.0024 inches (0.06 mm) in both length and height (Baird 2000, p. 22). Tens to hundreds of thousands of glochidia may occur in each conglutinate. Based on eight Missouri spectaclecase specimens, the number of conglutinates released per female varied from 53 to 88, with a mean of 64.5 (Baird 2000, p. 23). Total fecundity (reproductive potential, including glochidia and ova) in Baird's (2000, p. 27) Missouri study varied from 1.93 to 9.57 million per female. In mussels, fecundity is related positively to body size and inversely related to glochidia size (Bauer 1994, pp. 940–941). The reproductive potential of the spectaclecase is therefore phenomenal. However, the fact that extant populations are generally skewed towards larger adults strongly indicates that survival rates to the adult stage must be extraordinarily low.

Researchers in Wisconsin observed female spectaclecase under boulders in the St. Croix River simultaneously releasing their conglutinates (Heath 2008, pers. comm.). The spectaclecase conglutinates are entrained along a transparent, sticky mucous strand up to several feet in length (Lee & Hove 1997, p. 9). Baird (2000, p. 29) observed the release of loose glochidia and small fragments of conglutinates. Based on his observations, he hypothesized that conglutinates sometimes contain mostly immature glochidia, and that conglutinates containing mostly immature glochidia may be aborted when disturbed.

Sheepnose conglutinates are narrow and lanceolate in outline, solid and red or pink in color, and discharged in unbroken form (Oesch 1984, pp. 118–119). Discharge of sheepnose conglutinates have been observed in late July (Ortmann 1911, p. 306) and August (Williams *et al.* 2008, p. 498). Ortmann (1911, p. 306) described them as being pink and "lying behind the posterior end of the shell, which were greedily devoured by a number of minnows." Sheepnose glochidia are semicircular in outline, with the ventral margin obliquely rounded, hinge line long, and medium in size. The length (0.009 inches (0.23 mm)) is slightly greater than the height (0.008 inches (0.20 mm)) (Oesch 1984, p. 119). Several hundred glochidia probably occur in each conglutinate. Judging from the size of the glochidia, total fecundity (including glochidia and ova) per female sheepnose is probably in the tens of thousands.

Like many freshwater mussels, the complex life histories of the spectaclecase and sheepnose have many vulnerable components that may prevent successful reproduction or recruitment of juveniles into existing populations. Glochidia must come into contact with a specific host species for their survival to be ensured. Without the proper host, the glochidia will perish. The host(s) for the spectaclecase is unknown, although over 60 species of fish, amphibians, and crayfish have been tested in the lab during host suitability studies (Baird 2000, pp. 23–24; Henley & Neves 2006, p. 3; Hove *et al.* 2009b, pp. 22–23; Hove *et al.* 1998, pp. 13–14; Hove *et al.* 2008, p. 4; Knudsen & Hove 1997, p. 2; Lee & Hove 1997, pp. 9–10). Two of 690 wild-collected fish checked by Baird (2000, p. 24) had spectaclecase glochidia attached to their gills; these fish were the bigeye chub (*Hybopsis amblops*) and pealip redhorse (*Moxostoma pisolabrum*). However, these fish are not confirmed as hosts, because the encysted glochidia had not grown measurably and glochidial transformation was not observed (Baird 2000, p. 24). Spectaclecase populations are oftentimes highly aggregated (*see Habitat*) with many apparently even-aged individuals, suggesting that glochidia may excyst simultaneously from a host (Gordon & Layzer 1989, p. 19). Additional host work is underway to test the wild-collected fish species that were found with encysted spectaclecase glochidia (pealip redhorse and bigeye chub), as well as to test additional species of fish and other aquatic organisms for suitability. Host information is needed so that existing populations can be artificially cultured for potential population augmentation and reintroduction efforts.

Little is known regarding host fish of the sheepnose. Until recently the only cited host for this species came from a 1914 report that found glochidia naturally attached to sauger (*Sander canadense*) in the wild. No confirmation of successful transformation was recorded in this early report (Surber 1912, p. 110; Wilson 1914, pp. 338–340). However, recent laboratory studies at the Genoa National Fish Hatchery, the University of Minnesota, and Ohio State University have successfully transformed sheepnose glochidia on fathead minnow (*Pimephales promelas*), creek chub (*Semotilus atrromaculatus*), central stoneroller (*Campostoma anomalum*), and brook stickleback (*Culaea inconstans*) (Watters *et al.* 2005, pp. 11–12; Brady 2008, pers. comm.; Watters 2008, pers. comm.). Although these are identified as suitable hosts in laboratory studies, natural interactions between the aforementioned fishes and the sheepnose seem rare and infrequent due to habitat preferences. Fish that frequent medium to large rivers near mussel beds, like the sauger, may act as hosts in the natural environment.

Habitat

The spectaclecase generally inhabits large rivers, and is found in microhabitats sheltered from the main force of current. It occurs in substrates from mud and sand to gravel, cobble, and boulders in relatively shallow riffles and shoals with a slow to swift current (Baird 2000, pp. 5–6; Buchanan 1980, p. 13; Parmalee & Bogan 1998, p. 50). According to Stansbery (1967, pp. 29–30), this species is usually found in firm mud between large rocks in quiet water very near the interface with swift currents. Specimens have also been reported in tree stumps, in root masses, and in beds of rooted vegetation (Oesch 1984, p. 33). Similar to other margaritiferids, spectaclecase occurrences throughout much of its range tend to be aggregated (Gordon & Layzer 1989, p. 19), particularly under slab boulders or bedrock shelves (Baird 2000, p. 6; Buchanan 1980, p. 13; Parmalee & Bogan 1998, p. 50), where they are protected from the current. Up to 200 specimens have been reported from under a single large slab in the Tennessee River at Muscle Shoals, Alabama (Hinkley 1906, p. 54). Unlike most species that move about to some degree, the spectaclecase may seldom if ever move except to burrow deeper and may die from stranding during droughts (Oesch 1984, p. 17).

The sheepnose is primarily a larger-stream species occurring primarily in shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984, p. 121). Habitats with sheepnose may also have mud, cobble, and boulders. Sheepnose in larger rivers may occur at depths exceeding 6 m (Williams *et al.* 2008, p. 498).

Genetics

A recent genetic study (Monroe *et al.* 2007, pp. 7–13) indicates that much of the remaining genetic variability in the spectaclecase is represented in each of the remaining large populations, and that these populations do not appear to differ significantly from one another. Genetics studies of sheepnose are currently under investigation; however, no conclusions were available at the time of publication (Roe 2010, pers. comm.).

Species Distribution

We use the term "population" here in a geographical and not genetic sense, defining it as all individuals of the spectaclecase or sheepnose living in one stream. Using the term in this way allows the status, trends, and threats to be discussed comparatively across streams where the species occur. In using this term we do not imply that their populations are currently reproducing and recruiting or that they are distinct genetic units. We considered populations of the spectaclecase and sheepnose as extant if live or fresh-dead specimens have been observed or collected since 1990. A "population cluster" refers to where two or more adjacent stream populations of a species occur without a barrier (for example, a dam and impoundment) between them.

Following are generalized sets of criteria that were used to categorize the relative status of populations of spectaclecase and sheepnose. The status of a population is considered "improving" if: (1) There is evidence that habitat degradation appears insignificant, (2) live or fresh dead mussel abundance has improved during post-1990 surveys, or (3) ample evidence of recent recruitment has been documented during post-1990 surveys. The status of a population is considered "stable" if: (1) There is little evidence of significant habitat loss or degradation, (2) live or fresh dead mussel abundance has been fairly consistent during post-1990 surveys, or (3) evidence of relatively recent recruitment has been documented during post-1990 surveys. The status of a population is considered "declining" if: (1) There is ample evidence of significant habitat loss or degradation, (2) live or fresh dead mussel numbers have declined during recent surveys, or (3) no evidence of relatively recent recruitment has been documented during recent surveys. The status of a population is considered "extirpated" if: (1) All known suitable habitat has been destroyed, or (2) no live or fresh dead mussels of any age have been located during recent surveys. The status of a population is considered "unknown" if the available information is inadequate to place the population in one of the above four categories. In a few cases, additional information not listed above may have been used to categorize a population.

Spectaclecase Historical Range and Distribution

The spectaclecase occurred historically in at least 44 streams in the Mississippi, Ohio, and Missouri River basins (Butler 2002a, p. 6, Heath 2008, pers. comm.). Its distribution comprised portions of 15 States (Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Minnesota, Missouri, Nebraska, Ohio, Tennessee, Virginia, West Virginia, and Wisconsin). Historical occurrence by stream system (with tributaries) include the: upper Mississippi River system (Mississippi River (St. Croix, Chippewa, Rock, Salt, Illinois (Des Plaines, Kankakee Rivers), Meramec (Bourbeuse, Big Rivers), Kaskaskia Rivers; Joachim Creek)); lower Missouri River system (Missouri River (Platte, River Aux Vases, Osage (Sac, Marais des Cygnes Rivers), Gasconade (Osage Fork, Big Piney River) Rivers)); Ohio River system (Ohio River

(Muskingum, Kanawha, Green, Wabash Rivers)); Cumberland River system (Cumberland River (Big South, Caney Fork; Stones, Red Rivers)); Tennessee River system (Tennessee River (Holston, Nolichucky, Little, Little Tennessee, Clinch (Powell River), Sequatchie, Elk, Duck Rivers)); lower Mississippi River system (Mulberry, Ouachita Rivers).

Spectaclecase Current Range and Distribution

Extant populations of the spectaclecase are known from 19 streams in 11 States (Butler 2002b, p. 7). These include the following stream systems (with tributaries):

- Upper Mississippi River system (Mississippi River (St. Croix, Meramec (Bourbeuse, Big Rivers) Rivers));
- Lower Missouri River system (Sac and Gasconade (Osage Fork, Big Piney River) Rivers);
- Lower Ohio River system (lowermost Ohio River (Kanawha, Green Rivers));
- Cumberland River system (Cumberland River);
- Tennessee River system (Tennessee River (Nolichucky, Clinch, Duck Rivers)); and
- Lower Mississippi River system (Mulberry, Ouachita Rivers).

The 19 extant spectaclecase populations occur in the following 11 States (with streams):

- Alabama (Tennessee River),
- Arkansas (Mulberry, Ouachita Rivers),
- Illinois (Mississippi, Ohio Rivers),
- Iowa (Mississippi River),
- Kentucky (Ohio, Green Rivers),
- Minnesota (Mississippi, St. Croix Rivers),
- Missouri (Mississippi, Meramec, Bourbeuse, Big, Gasconade, Sac, Big Piney Rivers; Osage Fork),
- Tennessee (Tennessee, Clinch, Nolichucky, Duck Rivers; Caney Fork),
- Virginia (Cumberland, Clinch Rivers),
- West Virginia (Kanawha River), and
- Wisconsin (Mississippi, St. Croix Rivers).

Spectaclecase Population Estimates and Status

Based on historical and current data, the spectaclecase has declined significantly rangewide and is now known from only 19 of 44 streams (Table 1), representing a 57 percent decline. The species is presumed extirpated from thousands of river miles and from numerous reaches of habitat in which it occurred historically, including long reaches of upper Mississippi, Ohio, Cumberland, and Tennessee Rivers and many other streams and stream reaches. Of the 19 extant populations, 6 are represented by only one or two recent specimens each and are likely declining and some may be extirpated. Populations in Mississippi and Clinch Rivers have recently experienced significant population declines. Most surviving populations face significant threats and with few exceptions are highly fragmented and restricted to short stream reaches. The spectaclecase is considered extirpated from Indiana, Kansas, Nebraska, and Ohio. The only relatively strong populations remaining are in the Meramec and Gasconade Rivers in Missouri and in the St. Croix River in Minnesota and Wisconsin.

TABLE 1—SPECTACLECASE STATUS IN ALL STREAMS OF HISTORICAL OR CURRENT OCCURRENCE

River Basin	Stream	Current Status	Date of Last Live Observation	Comments
Upper Mississippi River	Mississippi River	declining	2009	
	St. Croix River	stable	2008	
	Chippewa River	extirpated	1989	
	Rock River	extirpated	~1970	
	Salt River	extirpated	1980	
	Illinois River	extirpated	~1914	
	Des Plaines River	extirpated	~1921	
	Kankakee River	extirpated	1906	
	Meramec River	stable	2003	
	Bourbeuse River	stable	1997	
	Big River	stable	2002	
	Kaskaskia River	extirpated	~1970	
	Joachim Creek	extirpated	~1965	
Lower Missouri River	Missouri River	extirpated	~1914	
	Platte River	extirpated	~1917	
	River Aux Vases	extirpated	~1974	
	Osage River	extirpated	1980	
	Sac River	declining	2001	
	Marais des Cygnes River	extirpated	unknown	relic shell observed in 1998.
	Gasconade River	stable	2007	
	Big Piney River	unknown	2004	
	Osage Fork	unknown	1999	
Ohio River	Ohio River	declining	1994	single individual observed.
	Muskingum River	extirpated	unknown	relic shell observed in 1995.
	Kanawha River	unknown	2005	two live individuals observed.
	Green River	unknown	2006	
	Wabash River	extirpated	1970	
Cumberland River	Cumberland River	unknown	2008	single individual observed.
	Big South Fork	extirpated	1911	
	Caney Fork	extirpated	1988	
	Stones River	extirpated	1968	
	Red River	extirpated	1966	
Tennessee River	Tennessee River	unknown	2001	
	Holston River	extirpated	1981	
	Nolichucky River	unknown	1991	

TABLE 1—SPECTACLECASE STATUS IN ALL STREAMS OF HISTORICAL OR CURRENT OCCURRENCE—Continued

River Basin	Stream	Current Status	Date of Last Live Observation	Comments
	Little River	extirpated	~1911	
	Little Tennessee River	extirpated	unknown	relic shell observed in 1980, previous record archaeological.
	Clinch River	declining	2005	
	Powell River	extirpated	~1978	
	Sequatchie River	extirpated	~1925	
	Elk River	extirpated	unknown	relic shell observed in 1998.
	Duck River	declining	1999	single individual observed.
Lower Mississippi River	Mulberry River	unknown	~1995	single individual observed.
	Ouachita River	declining	2000	two individuals observed.

Based on collections made over 100 years ago, the spectaclecase was historically widespread and locally common in many streams rangewide. The spectaclecase is often absent from archaeological shell middens (Morrison 1942, p. 353) and is generally difficult to find due to its habit of occurring under rocks or ledges and burrowing deep into the substrate (Parmalee 1967, p. 25). Therefore, the chance of casually finding the species where population numbers are low is remote.

The spectaclecase was considered a rare species by mussel experts as early as 1970 (Stansbery 1970, p. 13), when the first attempt was made to compile a list of imperiled mussels. The spectaclecase is considered widely distributed but absent from many areas where it formerly occurred (Cummings & Mayer 1992, p. 22). The American Malacological Union and American Fisheries Society consider the spectaclecase to be threatened (Williams *et al.* 1993, p.10). Six of the 19 streams (or big river reaches) considered to harbor extant populations of the spectaclecase are represented by one or two recent specimens (for example, Ohio, Kanawha, Cumberland, Duck, Ouatchita, and Mulberry Rivers), exemplifying the species' imperiled status rangewide.

In some streams, the last reported records for the spectaclecase occurred decades ago (for example, Rock, Des Plaines, Kaskaskia, Platte, Wabash, Stones, Red, and Little Rivers; River Aux Vases; Big South Fork). Parmalee (1967, p. 25) considered the spectaclecase to be "rare and of local occurrence" in Illinois in the 1960s, but that it had "[a]pparently already been extirpated from the Illinois and Kankakee Rivers." The only records known from some streams are relic specimens collected around 1975 (for example, Marais des Cygnes, Muskingum, and Elk Rivers).

Although quantitative historical abundance data for the spectaclecase is rare, generalized relative abundance (the percent abundance of a species, divided by the total abundance of all mussel species combined) was sometimes noted in the historical literature and can be inferred from museum lots. The following is a summary of what is known about the relative abundance and trends of presumably extant spectaclecase populations by stream system.

Upper Mississippi River System

The spectaclecase was historically known from 13 streams in the upper Mississippi River system. Currently, only four streams in the system are thought to have extant spectaclecase populations.

Mississippi River mainstem: In 1907, Bartsch found spectaclecase at approximately nine of the 140 sampled sites from what are now Mississippi River Pools (MRP) 9 to 22 (Havlik 2001b, p. 10). Grier (1922, p. 11) did not find spectaclecase in sampled portions of MRP 4 to 6. Van der Schalie and van der Schalie (1950, p. 456), reporting on studies from the upper Mississippi River to the Missouri River mouth, stated that no live spectaclecase were found in their study of 254 sites during 1930–31. Havlik and Stansbery (1977, p. 12) thought the spectaclecase had disappeared from MRP 8 by the 1920s. Thiel (1981, p. 10) found only shell material in MRP 11 in a survey that spanned MRP 3 to 11 conducted during 1977 to 1980. Whitney *et al.* (1997, p. 12) recorded a single individual during 1994–1995 in MRP 15, for a density of 0.004 per square foot (sq. ft) (0.04 per square meter (sq. m)). Helms (2008, p. 8) found eight live individuals and numerous shells during a recent search of MRP 19, representing the most recent and numerous collection of the species in the Mississippi River.

The spectaclecase is thought to be extant in at least four pools of the Mississippi River mainstem, albeit in very low numbers. Records include MRP 15 (Quad Cities area, Illinois and Iowa; in 1998), MRP 16 (Muscatine area, Iowa and Illinois in 1997), MRP 19 (Burlington area, Illinois and Iowa in 2009), and MRP 22 (Quincy, Illinois and Hannibal, Missouri, area in 1996). Populations may still persist in MRP 9 and 10 where specimens were found in the 1980s (Heath 2010a, pers. comm.). Only a relic spectaclecase shell was found in MRP 3 above the St. Croix River confluence in 2001, and none were found in subsequent surveys (Kelner 2008, pers. comm.). In general, spectaclecase population levels in the upper Mississippi River appear to have always been fairly small and difficult to locate, and are now of questionable long-term persistence.

St. Croix River: The northernmost and one of the three most significant extant populations of the spectaclecase occurs in the St. Croix River, Minnesota and Wisconsin. The population is primarily found in the middle reaches of the river in Chisago and Washington Counties, Minnesota, and Polk and St. Croix Counties, Wisconsin (river miles (RM) 17 to 118). Havlik (1994, p. 19) reported spectaclecase in the St. Croix Wild River State Park portion of the river (approximately RM 62 to 65) and the reproducing population below the St. Croix Falls Dam at St. Croix Falls, Wisconsin (dam located at approximately RM 52). Additional survey work in the lower river at Afton State Park (approximately RM 7 to 9) failed to find the spectaclecase (Havlik 1994, p. 19).

Hornbach (2001, p. 218) reported 68 live specimens from 4 of 16 river reaches. Relative abundance for the spectaclecase varied from 0.67 percent from RM 78 to 92 (20 live spectaclecase among 17 species collected), 0.008 percent from RM 63 to 78 (41 live, 24 species), 0.0006 percent from RM 42 to 52 (6 live, 33 species), and 0.003 percent from RM 40 to 42 (1 live, 21 species). Reaches where the spectaclecase is extant are fragmented by the pool formed from the power dam at St. Croix Falls.

Baird (2000, p. 70) presented a length-frequency histogram for the spectaclecase in the St. Croix River using data from an unpublished 1989 study. The 962 specimens were fairly evenly distributed over the length scale, indicating multiple age classes including healthy numbers of young spectaclecase recruiting into the population. Baird (2000, p. 70) used growth curves determined from his Missouri study of the species to estimate the ages of spectaclecase of known size in the St. Croix River. The percentage of newly recruited individuals (less than or equal to 10 years of age) in the St. Croix was 40 percent— considerably higher than that noted from the Gasconade (10.4 percent) and Meramec (2.8 percent) Rivers in Missouri, two other streams with abundant spectaclecase populations that he studied. The St. Croix spectaclecase population, while among the largest known, may also be the healthiest based on this metric. The spectaclecase is currently distributed from RM 17 to 118 and appears to be recruiting from RM 17 to 54 (downstream of the St. Croix Falls Dam) (Heath 2008, pers. comm.).

The long-term health of mussel populations in the St. Croix may be in jeopardy, however. Hornbach *et al.* (2001, pp. 12–13) determined that juvenile mussel density had suffered a statistically significant decline at three of four lower St. Croix sites sampled in the 1990s and in 2000. Zebra mussels also threaten the spectaclecase and other mussel populations in the lower St. Croix River. A 2000 survey at 20 sites on the lowermost 24 miles of the St. Croix River estimated that nearly one percent of the mussels were infested with zebra mussels (Kelner & Davis 2002, p. 36).

Meramec River: The Meramec River flows into the Mississippi River downstream of St. Louis in east-central Missouri. Its spectaclecase population represents one of the best remaining rangewide. In the late 1970s, Buchanan (1980, p. 13) reported this species from 31 sites, 19 with live individuals. Live or fresh dead individuals occurred from RM 17.5 to 145.7. Buchanan (1980, p. 6) considered it to be common in the lower 108 miles (174 km) of the Meramec River, but locally abundant from RM 17.5 to 84. In 1997, Roberts and Bruenderman (2000, pp. 39, 44), using similar sampling methods as Buchanan (1980, pp. 4–5), resurveyed the Meramec River system and collected spectaclecase from 23 sites, 19 of which had live individuals. They found the largest populations between RM 56.7 and 118.8. Among 17 sites where spectaclecase were found during both surveys, the species was less abundant at nine sites and more abundant at five sites in 1997. At three sites, only relic shells were found during both surveys. In the 1970s, Buchanan (1980, p. 10) reported finding 456 live individuals among the 17 shared sites, whereas Roberts and Bruenderman (2000, p. 44) recorded only 198. A reduction in spectaclecase numbers (260 to 33) at RM 59.5 accounted for most of the overall decrease in abundance between the studies. Confounding the decrease in numbers among shared survey sites, Roberts and Bruenderman (2000, p. 44) surveyed three sites between RM 56.7 and 118.8 that were unsampled by Buchanan (1980, pp. 1–69) and found 500, 538, and 856 live spectaclecase. The most specimens found at a single site in the earlier study was 260 (RM 59.5). Currently, the population in the Meramec River stretches over much of the mainstem, a distance of over 100 miles (161 km) from RM 18.5 to 120.4.

The spectaclecase represented 28 percent of all mussels sampled in the Meramec River in 1997 (Roberts & Bruenderman 2000, p. 39). Baird (2000, pp. 62, 68,77) extensively studied the demographics of the Meramec River spectaclecase population in the late 1990s. The mean estimated age of the population was 32 years. Individuals less than 10 years of age comprised only 2.8 percent of the Meramec population sampled (a total of 2,983 individuals). At the four sites he intentionally selected for their large spectaclecase populations, densities ranged from 0.01 to 0.12 per sq. ft (0.1 to 1.3 per sq. m) while estimated population numbers at these sites ranged from 933 to 22,697. Baird (2000, p. 71) thought that conditions for spectaclecase recruitment in the Meramec had declined in the past 20 to 30 years, but the causes were undetermined. The prevalence of larger adults in the Meramec population may be cause for concern, as it appears to indicate a low level of recruitment in the population.

Bourbeuse River: The Bourbeuse River is a northern tributary of the Meramec River joining it at RM 68. Its spectaclecase population was sampled in 1997 at a single site (RM 10.3), and 7 live individuals were found (Roberts & Bruenderman 2000, p. 91). Sampling near the mouth (RM 0.4), Buchanan (1980, p. 16) found only relic shells. The Bourbeuse population is probably dependent on the much larger Meramec population for long-term sustainability.

Big River: Another Meramec tributary with a population of the spectaclecase, the Big River flows northward into the Meramec River at RM 38. The spectaclecase is only known from the lower end (RM 1.3), where 14 live specimens were found in 1997 (Roberts & Bruenderman 2000, p. 96). At RM 0.4, Buchanan (1980, p. 13) found only relic shells. Similar to the Bourbeuse River population, the population in the Big River is probably dependent on the much larger Meramec population for sustainability. The Meramec River system, including the lower Bourbeuse, lower Big, and Meramec River mainstems, can be considered a single spectaclecase population cluster.

Lower Missouri River System

The spectaclecase was historically known from 10 streams in the Missouri River system. Currently, only four of these streams are thought to have extant populations.

Sac River: The Sac River is a large tributary to the Osage River. The spectaclecase was considered extirpated in the 2002 status review of the species (Butler 2002a). However, three old, live individuals were collected at two sites during a survey of the Sac River in 2004 (Hutson & Barnhart 2004, p. 17). The same survey revealed "numerous" relic shells from six other sites, indicating that the spectaclecase may have been relatively abundant at one time. Prior to the 2004 survey, the spectaclecase had not been collected from this river since 1978 (Bruenderman 2001, pers. comm.). Given the age of the live individuals and the abundance of shell material, Hutson & Barnhart (2004, p. 17) predicted the species would "soon be extirpated" from the river.

Gasconade River: The Gasconade River is a southern tributary of the Missouri River in south-central Missouri and flows into the mainstem east of Jefferson City. When Stansbery (1970, p. 13) included this species in the first compiled list of imperiled mussels, he noted that "the only population of substantial size presently known is found in the Gasconade River." In 1994, Buchanan found over 1,000 individuals between RM 7 and 84 (Buchanan 1994, pp. 5, 8–13). Today, one of the three best spectaclecase populations remaining rangewide occurs in the Gasconade. The spectaclecase population occurs over approximately 200 miles (322 km) of the mainstem from RM 4.9 upstream (Bruenderman *et al.* 2001, p. 54). Baird (2000, pp. 61, 71) studied the demographics of the Gasconade River spectaclecase population in the late 1990s. Based on his limited number of sampling sites, this species comprised about 20 percent of the entire mussel fauna in this system. The mean estimated age of the population was 25 years. Individuals less than 10 years of age comprised 10.4 percent of the Gasconade population sampled (n = 2,111), indicating a significant level of recent recruitment.

Historically, Stansbery (1967, p. 29) noted that "[t]he size of some aggregation[s] * * * is impressive," and that "the number of individuals may reach a density of well over a dozen per square foot." Both statements are probably in reference to the Gasconade River, Missouri, population, which he had described in the text of his note. Densities at the four sites Baird (2000, pp. 61, 71) intentionally selected for their large spectaclecase populations ranged from 0.03 to 0.06 per sq. ft (0.3 to 0.6 per sq. m); estimated population numbers at these selected sites ranged from 2,156 to 4,766. Baird (2000, p. 71) thought that conditions for spectaclecase recruitment in the Gasconade River had declined in the past 20 to 30 years, but the causes were undetermined.

Big Piney River: The Big Piney River, a southern tributary of the Gasconade River, harbors a small population of the spectaclecase. Although overlooked during a 1999 survey (Bruenderman *et al.* 2001, pp. 14, 28), 15 individuals were collected from the lower mainstem (RM 24) in 2004 (Barnhart *et al.* 2004, p. 5). The status of the population is unknown, but it is probably dependent on the much larger source population in the Gasconade River for sustainability (McMurray 2008, pers. comm.).

Osage Fork: The Osage Fork is a southwestern headwater tributary of the Gasconade River. The spectaclecase is known from the lower portion of this Gasconade River tributary, specifically from RM 13.9. Sampling in the Osage Fork in 1999 yielded 26 live individuals from this site (Bruenderman *et al.* 2001, p. 9). Relative abundance of the spectaclecase in the Osage Fork was 3.9 percent, and catch-per-unit effort was 1.3 per person-hour. This population is thought to be stable, but it may also be dependent on the much larger source population in the Gasconade River for long-term sustainability. The Gasconade River system, including the lower Big Piney, lower Osage Fork, and Gasconade mainstems, can be considered a single population cluster.

Ohio River System

The spectaclecase's continued existence in the Ohio River is extremely uncertain. Once known from five rivers, it has been extirpated from two, and two of the remaining three are recently represented by only one or two individuals each.

Ohio River: The Ohio River is the largest eastern tributary of the Mississippi River, with its confluence marking the divide between the upper and lower portions of the Mississippi River system. Historically, the spectaclecase was documented from the Ohio River from the vicinity of Cincinnati, Ohio, to its mouth. Although no specimens are known from the mainstem upstream of Cincinnati, populations are known from two upstream tributaries, the Muskingum and Kanawha Rivers. Nearly all spectaclecase records from the Ohio River were made around 1900 or before (Schuster 1988, p. 186). The only recent record is for a single live individual found in an abandoned gill net near the Illinois shore in 1994 (Cummings 2008, pers. comm.). If a population of the spectaclecase continues to occur in the Ohio River, its future persistence is extremely doubtful and continued existence seriously threatened by the exotic zebra mussel.

Kanawha River: The Kanawha River is a major southern tributary of the Ohio River that drains much of West Virginia. The spectaclecase was not known from this stream until 2002, when a single, very old, live individual was discovered near Glasgow, Kanawha County (Zimmerman 2002, pers. comm.). Another live individual was found in the same vicinity in 2005, as well as two additional weathered shells in 2006 (Clayton 2008a, pers. comm.). This site is approximately 20 miles (32.2 km) downstream of Kanawha Falls, below which is the only significant mussel bed known from the Kanawha River. It is doubtful that a recruiting spectaclecase population occurs in the Kanawha River due to the small number of individuals found and their advanced age.

Green River: The Green River is a lower Ohio River tributary in west-central Kentucky. The spectaclecase has been collected sparingly in the Green River. That it was not reported in early collections made in the system is indicative of the difficulty in finding specimens (Price 1900, pp. 75–79). Stansbery (1965, p. 13) was the first to find it in the mid-1960s at Munfordville, Hart County, where he reported 47 mussel species collected over a several-year period in the early 1960s. More recently, from 1987 to 1989, Cicerello and Hannan (1990, p. 20) reported single fresh dead specimens at six sites and relic specimens from an additional five sites in Mammoth Cave National Park (MCNP). A single specimen was recorded from MCNP, Edmonson County, in 1995. Sampling conducted from 1996 to 1998 located fresh dead specimens at two sites above MCNP, with a relic shell at a third site farther upstream (Cicerello 1999, pp. 17–18). At least one fresh dead specimen was reported from MCNP in 2001, as well as several live individuals in 2005 and 2006 (Layzer 2008, pers. comm.).

A small spectaclecase population remains in the upper Green River from below Lock and Dam 5 upstream through MCNP, Edmonson County, into western Hart County. Most recent specimens have been reported from the upstream portion of this reach, where it is generally distributed from MCNP upstream to western Hart County. Its distribution is much more sporadic and localized in the lower portion of this reach due to the pooling effect of two locks and dams (5 and 6). In 2001, a concerted effort (approximately 15 person-hours) to locate rare mussels below Lock and Dam 5 and at other sites downstream failed to find spectaclecase (live or shell), although a fresh dead shell had been collected in this area in 1993 (Cicerello 2008, pers. comm.). The occurrence of variable-sized individuals in the 1990s indicates different year classes but not necessarily recent recruitment (Cicerello 2008, pers. comm.). The long-term sustainability of the Green River population, primarily limited to an approximately 15-mile (24-km) reach of the river, is therefore questionable, and its status is unknown.

Cumberland River System

With few exceptions, most records of the spectaclecase in the Cumberland River system were made before the 1920s. It was historically known from the mainstem and four tributaries but appears currently to be restricted to the lowermost Cumberland River a few miles above its confluence with the Ohio River.

Cumberland River mainstem: The Cumberland River is a large southern tributary of the lower Ohio River. The spectaclecase was considered "not rare" in the Cumberland River by Hinkley and Marsh (1885, p. 6), whereas it was found at six sites by Wilson and Clark (1914, pp. 17, 19) during their survey primarily for commercial species in the Cumberland River system. In a 1947–1949 survey of the Kentucky portion of the upper Cumberland River, Neel and Allen (1964, p. 453) reported live specimens only from one of six mainstem sites that they sampled below Cumberland Falls. Neel and Allen (1964, p. 432) considered it to be "uncommon" in the lower Cumberland River (where they did not sample), a statement possibly based on its sporadic occurrence as reported by Wilson and Clark (1914, pp. 17, 19). One of the last mainstem records is that of a single live specimen found in the cold tailwaters of Wolf Creek Dam, Kentucky, near the Tennessee border in 1982 (Miller *et al.* 1984, p. 108). This was one of only two live mussels found during a survey of the dewatered river reach below the dam, the mussel community having been eliminated from decades of cold water releases. The most recent record is of a single live individual found at RM 10 below Barkley Lock and Dam in 2008 (Fortenbery 2008, p. 9). A thorough search of the area yielded no additional individuals.

Tennessee River System

The spectaclecase was originally known from the Tennessee River and nine of its stream systems. Ortmann (1924, p. 60) reported that the spectaclecase was "frequent… in the upper Tennessee," while acknowledging in an earlier paper (Ortmann 1918, p. 527) that it was locally abundant in parts of the upper Tennessee River system, but noted that it was "generally regarded as a rare species" rangewide.

Hundreds of miles of large river habitat on the Tennessee mainstem have been converted under nine reservoirs, with additional dams constructed in tributaries historically harboring this species (for example, Clinch, Holston, and Elk Rivers). Watters (2000, p. 262) summarizes the tremendous loss of mussel species from various reaches of the Tennessee. The spectaclecase is now known only from the Tennessee mainstem and three of its tributaries. Despite this fact, the Tennessee River system continues to represent one of the last strongholds of the spectaclecase rangewide.

Tennessee River mainstem: The Tennessee River is the largest tributary of the Ohio River, draining portions of seven states. The 53-mile (85-km) stretch of river in northwestern Alabama collectively referred to as the Muscle Shoals historically harbored 69 species of mussels, making it among the most diverse mussel faunas ever known (Garner & McGregor 2001, p. 155). The historical spectaclecase population in this reach was thought to be phenomenal given the amount of historical habitat that was available and literature accounts of the period. Hinkley (1906, p. 54), in 1904, considered the spectaclecase "plentiful," noting 200 individuals under a single slab boulder. Twenty years later, Ortmann (1925, p. 327) stated that "this species must be, or have been, abundant" at Muscle Shoals based on the "considerable number of dead shells" he observed. In these quotes he predicted the demise of the spectaclecase. The construction of three dams (Wilson in 1925, Wheeler in 1930, Pickwick Landing in 1940) inundated most of the historical habitat, leaving only small habitat remnants (Garner & McGregor 2001, p. 155). The largest remnant habitat remaining is the Wilson Dam tailwaters, a reach adjacent to and downstream from Florence, Alabama.

With the exception of 1976–1978 when it was "collected infrequently" from below Wilson Dam (Gooch *et al.* 1979, p. 90), no collections of the spectaclecase were reported at Muscle Shoals from 1931 to 1995 despite surveys conducted in 1956–1957, 1963–1964, and 1991 (Garner & McGregor 2001, p. 156).

Elsewhere along the Tennessee mainstem, a specimen was recently reported from the Guntersville Dam tailwaters in northern Alabama (Butler 2002a, p. 17). From 1997–1999, 10 live, 1 fresh dead, and 4 relic spectaclecase were reported from three sites in this river reach based on Ohio State University Museum (OSUM) records. The species is found only occasionally in the lower Tennessee River below Pickwick Landing Dam in southeastern Tennessee, having been unreported in various surveys (for example, Scruggs 1960, p. 12; van der Schalie 1939, p. 456). Yokley (1972, p. 61) considered it rare, having only found fresh dead specimens in his 3-year study. Hubbs and Jones (2000, p. 28) reported two live specimens found in 1998 at RM 170, Hardin County. The current status of these small populations is unknown (Garner 2008, pers. comm.; Hubbs 2008, pers. comm.).

Clinch River: The Clinch River is a major tributary of the upper Tennessee River in southwestern Virginia and northeastern Tennessee. Böpple and Coker (1912, p. 9) noted numerous spectaclecase shells in muskrat middens in a portion of the Clinch that is now inundated by Norris Reservoir. Ortmann (1918, p. 527) reported the spectaclecase as being locally abundant in the lower Clinch River, again in an area mostly flooded by Norris Reservoir. Oddly, he failed to find this species upstream of Claiborne County, yet, in later years, one of the spectaclecase's largest known populations was identified in this reach. The species was locally common at sites in the upper Clinch River, according to OSUM records from the 1960s. Ahlstedt (1991a, p. 98) considered this species to be relatively rare in the Clinch River based on survey work conducted during 1978 to 1983. He recorded 78 live specimens from 22 sites between RM 151 and 223, for an average of 3.5 per site. The spectaclecase population reported by Ahlstedt (1991a, pp. 89–90) from the lower Clinch River between Melton Hill and Norris Dam (11 specimens from 4 sites between RM 45 and 73) was considered to be small but stable. Once considered abundant in the Clinch River at Speers Ferry, Scott County, Virginia (Bates & Dennis 1978, pp. 18–19), the species is now extremely rare at this site (Neves 1991, p. 264).

Currently, the species is locally common in the Tennessee River system only in the upper Clinch River, and populations are primarily restricted to the Tennessee portion of that stream. Despite low numbers (0.02 per sq. ft (0.2 per sq. m)) detected in quantitative sampling (428; 2.7 sq. ft (0.25 sq. m) quadrats) in 1994 (Ahlstedt & Tuberville 1997, pp. 73, 81), the upper Clinch River in Tennessee may still yield two to three dozen specimens under individual slab boulders. Three individuals were collected at RM 223.6 in Virginia in 2005, and one old individual was collected in 2007 at RM 270.8, representing the farthest upstream record for the species (Eckert 2008, pers. comm.). The upper Clinch River population is considered to be reproducing, with fairly young individuals occasionally found, but overall the population appears to be declining (Ahlstedt 2008, pers. comm.). The recent occurrence of a disjunct population in the lower Clinch River (separated from the upper Clinch River population by Norris Reservoir) was recently verified (Fraley 2008, pers. comm.). The specimens sampled likely recruited since the Norris Dam gates closed in 1936 (Fraley 2008, pers. comm.), despite the cold tailwaters that destroyed the majority of the mussel fauna in this once incredibly diverse river reach.

Nolichucky River: The Nolichucky River is a tributary of the lower French Broad River, in the upper Tennessee River system in North Carolina and Tennessee. The spectaclecase population in this river was once sizable, judging from museum lots (for example, 23 fresh dead, OSUM 1971:0372). Sampling at 41 Nolichucky River sites in 1980, Ahlstedt (1991b, pp. 136–137) reported 8 live spectaclecase from 6 sites between RM 11.4 to 31.9. A small population of the spectaclecase also persists in a relatively short reach of the lower river (Ahlstedt 2008, pers. comm.). The current status of the Nolichucky River population is unknown.

Duck River: The Duck River is wholly in Tennessee and represents the farthest downstream significant tributary of the

Tennessee River, joining it in the headwaters of Kentucky Reservoir. A single spectaclecase, representing a new drainage record, was found live in lower Duck River, Hickman County, in 1999 (Hubbs 1999, p. 1; Powell 2008, pers. comm.). Since then, at least two individuals from the lower part of the river in Humphreys County have been documented, and several relic specimens have been reported farther upstream (Hubbs 2008, pers. comm.; Powell 2008, pers. comm.). These records cover an approximately 20-mile (32-km) reach of river, with the live individual reported from the lower end of this reach. The spectaclecase is considered extremely rare in the Duck River, and its status is unknown.

Lower Mississippi River System

The spectaclecase was apparently never widely distributed in the lower Mississippi River system. Records from only two streams are known, both from Arkansas.

Mulberry River: The Mulberry River is a tributary of the Arkansas River in northwestern Arkansas. Other than the Ouachita River records, the only other record of the spectaclecase in the lower Mississippi River system is a single specimen found in the mid-1990s in the Mulberry River. There is some uncertainty regarding the validity of this record, as the collectors were not experienced malacologists, and no specimen or photograph is available to substantiate the record. This record is, however, accepted as valid (Harris *et al.* 2009, p. 67; Harris 2010, pers. comm.). The status of the spectaclecase in the Mulberry River is unknown.

Ouachita River: The Ouachita River flows into lower Red River, a major western tributary of the lower Mississippi River, draining portions of Arkansas and Louisiana. This species was first reported in this portion of its range from the Ouachita River, southwestern Arkansas, in the early 1900s (Wheeler 1918, p. 121). Spectaclecase records in the Ouachita span a three-county reach of river. Only two live specimens were found in the mid-1990s, both in the lower portion of Ouachita County. A single relic shell (paired valves) was found in Montgomery County, at the upper end of its Ouachita River range in 2000. The population is considered very small and declining (Harris *et al.* 2009, p. 67; Harris 2010).

Summary of Extant Spectaclecase Populations

The spectaclecase appears to be declining rangewide, with the exception of a few significant populations. Its occurrence in the St. Croix, Meramec, Gasconade, and Clinch Rivers represent the only sizable, sustainable, and reproducing populations remaining, although the Clinch River population appears to be in decline. The spectaclecase has been eliminated from three-fifths of the total number of streams from which it was historically known (19 streams currently compared to 44 streams historically). This species has also been eliminated from long reaches of former habitat in thousands of miles of the Illinois, Ohio, Cumberland, and other rivers, and from long reaches of the Mississippi and Tennessee Rivers. In addition, the species is no longer known from the States of Ohio, Indiana, Kansas, and Nebraska. The extirpation of this species from numerous streams and stream reaches within its historical range signifies that substantial population losses have occurred.

Sheepnose Historical Range and Distribution

Historically, the sheepnose occurred in the Mississippi, Ohio, Cumberland, and Tennessee River systems and their tributaries, totaling at least 77 streams (including 1 canal) (Butler 2002b). Its distribution comprised portions of 14 States (Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin). Historical occurrence by stream system (with tributaries) include the following:

- Upper Mississippi River system (Mississippi River (Minnesota, St. Croix, Chippewa (Flambeau River), Wisconsin, Rock, Iowa, Des Moines, Illinois (Des Plaines, Kankakee, Fox, Mackinaw, Spoon, Sangamon (Salt Creek) Rivers; Quiver Creek; Illinois and Michigan Canal), Meramec (Bourbeuse, Big Rivers), Kaskaskia, Saline, Castor, Whitewater Rivers));
- Lower Missouri River system (Little Sioux, Little Blue, Gasconade (Osage Fork) Rivers);
- Ohio River system (Ohio River (Allegheny (Hemlock Creek), Monongahela, Beaver (Duck Creek), Muskingum (Tuscarawas, Walhonding (Mohican River), Otter Fork Licking Rivers), Kanawha, Scioto, Little Miami, Licking, Kentucky, Salt, Green (Barren River), Wabash (Mississinewa, Eel, Tippecanoe, Vermillion, Embarras, White (East, West Forks White River) Rivers) Rivers);
- Cumberland River system (Cumberland River (Obey, Harpeth Rivers; Caney Fork));
- Tennessee River system (Tennessee River (Holston (North Fork Holston River), French Broad (Little Pigeon River), Little Tennessee, Clinch (North Fork Clinch, Powell Rivers), Hiwassee, Duck Rivers)); and
- Lower Mississippi River system (Hatchie, Black, Yazoo (Big Sunflower River), Big Black Rivers).

Sheepnose Current Range and Distribution

Extant populations of the sheepnose are known from 24 rivers in all 14 States of historical occurrence. Current populations occur in the following systems (with tributaries):

- Upper Mississippi River system (Mississippi River (Chippewa (Flambeau River), Wisconsin, Kankakee, Meramec (Bourbeuse River) Rivers));
- Lower Missouri River system (Osage Fork, Gasconade River); Ohio River system (Ohio River (Allegheny, Muskingum (Walhonding River), Kanawha, Licking, Kentucky, Tippecanoe, Eel, Green Rivers));
- Tennessee River system (Tennessee River (Holston, Clinch, Duck (Powell River) Rivers)); and
- Lower Mississippi River system (Big Sunflower River).

The 24 extant sheepnose populations occur in the following 14 States (with streams):

- Alabama (Tennessee River),
- Illinois (Mississippi, Kankakee, Ohio, Wabash Rivers),
- Indiana (Ohio, Tippecanoe, Eel Rivers),
- Iowa (Mississippi River),
- Kentucky (Ohio, Licking, Kentucky, Green Rivers),
- Minnesota (Mississippi River),
- Mississippi (Big Sunflower River),
- Missouri (Mississippi, Meramec, Bourbeuse, Osage Fork Gasconade Rivers),
- Ohio (Ohio, Muskingum Rivers),
- Pennsylvania (Allegheny River),
- Tennessee (Tennessee, Holston, Clinch, Powell, Duck Rivers),
- Virginia (Clinch, Powell Rivers),
- West Virginia (Ohio, Kanawha Rivers), and
- Wisconsin (Mississippi, St. Croix, Chippewa, Flambeau, Wisconsin Rivers).

The sheepnose was last observed from over two dozen streams decades ago (*e.g.,* Minnesota, Rock, Iowa, Illinois, Des Plaines, Fox, Mackinaw, Spoon, Castor, Little Sioux, Little Blue, Monongahela, Beaver, Scioto, Little Miami, Salt, Mississenewa, Vermilion, Embarras, White, Obey, Harpeth, North Fork Holston, French Broad, North Fork Clinch Rivers; Caney Fork). According to Parmalee and Bogan (1998, p. 177) and Neves (1991, pp. 280–281), the sheepnose has been extirpated throughout much of its former range or reduced to isolated populations. The only records known from some streams are archeological specimens (for example, Little Pigeon, Big Black, Yazoo Rivers; Saline River).

Sheepnose Population Estimates and Status

The sheepnose has been eliminated from two-thirds of the total number of streams from which it was historically known (24 streams currently occupied compared to 77 streams historically) (Table 2). This species has also been eliminated from long reaches of former habitat including thousands of miles of the Mississippi, Wisconsin, Illinois, Ohio, Cumberland, and Tennessee Rivers and dozens of other streams and stream reaches.

Based on the population designation criteria (*see Species Distribution* section, above), of the 24 sheepnose populations that are considered extant, 11 are thought to be stable and 8 are considered declining (Table 2). Five other populations (Walhonding, Gasconade, Muskingum, Osage Fork, and Duck Rivers) are considered extant, but the status of these populations is unknown.

TABLE 2—SHEEPNOSE STATUS AT HISTORICAL LOCATIONS

River basin	Stream	Current status	Date of last observation	Comments
Upper Mississippi River	Mississippi River	Declining	2008	
	Minnesota River	Extirpated	~1944	
	St. Croix River	Extirpated	1988	
	Chippewa/Flambeau River	Stable	~1994	
	Wisconsin River	Declining	2002	
	Rock River	Extirpated	1926	
	Iowa River	Extirpated	1925	Relic shell collected in 1999.
	Des Moines River	Extirpated	~1915	
	Illinois River	Extirpated	1940	Relic shell collected in 1999.
	Des Plaines River	Extirpated	~1970	
	Kankakee River	Stable	2007	
	Fox River	Extirpated	~1913	
	Mackinaw River	Extirpated	~1970	
	Spoon River	Extirpated	1929	
	Sangamon River	Extirpated	~1919	Relic shell collected in 1989.
	Salt Creek	Extirpated	Unknown	Relic shell collected in 1989.
	Quiver Creek	Extirpated	1881	
	Illinois and Michigan (I & M) Canal	Extirpated	?	
	Meramec River	Stable	2002	
	Bourbeuse River	Declining	1997	
	Big River	Extirpated	1978	
	Kaskaskia River	Extirpated	1970	
	Saline River	Extirpated	?	
	Castor River	Extirpated	~1965	
	Whitewater River	Extirpated	1970s	
Lower Missouri River	Little Sioux River	Extirpated	1916	
	Little Blue River	Extirpated	~1915	
	Gasconade River	Unknown	~1965	
	Osage Fork	Unknown	1999	Represented by single specimen, presumably near extirpation.
Ohio River	Ohio River	Stable	2007	
	Allegheny River	Improving	2008	
	Hemlock Creek	Extirpated	Unknown	Relic shell collected in 1991.
	Monongahela River	Extirpated	~1897	
	Beaver River	Extirpated	~1910	
	Duck Creek	Extirpated	1930	
	Muskingum River	Unknown	1993	
	Tuscarawas River	Extirpated	Unknown	Relic shell collected in 1998.
	Walhonding River	Unknown	1993	
	Mohican River	Extirpated	1977	
	Otter Fork Licking River	Extirpated	1973	
	Kanawha River	Stable	2005	
	Scioto River	Extirpated	1963	
	Little Miami River	Extirpated	~1953	
	Licking River	Declining	1998	
	Kentucky River	Declining	1996	
	Salt River	Extirpated	~1900	
	Green River	Improving	2007	
	Barren River	Extirpated	Unknown	Relic shell collected in 1993.
	Wabash River	Extirpated	1988	
	Mississinewa River	Extirpated	1899	
	Eel River	Declining	1997	
	Tippecanoe River	Stable	1995	
	Vermillion River	Extirpated	Unknown	
	Embarras River	Extirpated	1953	
	White River	Extirpated	1913	
	East White River	Extirpated	1969	

TABLE 2—SHEEPNOSE STATUS AT HISTORICAL LOCATIONS—Continued

River basin	Stream	Current status	Date of last observation	Comments
	West Fork White River	Extirpated	1908	Relic shell collected in 2000.
Cumberland River	Cumberland River	Extirpated	1987	
	Obey River	Extirpated	1939	
	Harpeth River	Extirpated	?	
	Caney Fork River	Extirpated	Unknown	Relic shell collected in 1990.
Tennessee River	Tennessee River	Stable	2004	
	Holston River	Declining	2007	
	North Fork Holston River	Extirpated	1913	
	French Broad River	Extirpated	1914	
	Little Pigeon River	Extirpated	Unknown	
	Little Tennessee River	Extirpated	Unknown	Relic shell collected in 1971.
	Clinch River	Stable	2006	
	North Fork Clinch River	Extirpated	~1921	
	Powell River	Stable	2004	
	Hiwassee	Extirpated	Unknown	Relic shell collected in 1975.
	Duck River	Unknown	2003	Record represented by single specimen.
Lower Mississippi River	Hatchie River	Extirpated	1983	
	Black River	Extirpated	Unknown	
	Yazoo River	Extirpated	Unknown	
	Big Sunflower River	Declining	2000	
	Big Black River	Extirpated	Unknown	

Historically, the sheepnose was fairly widespread in many Mississippi River system streams, although rarely common. Archaeological evidence on relative abundance indicates that it has been an uncommon or even rare species in many streams for centuries (Morrison 1942, p. 357; Patch 1976, pp. 44–52; Parmalee *et al.* 1980, p. 101; Parmalee *et al.* 1982, p. 82; Parmalee and Bogan 1986, pp. 28, 30; Parmalee and Hughes 1994, pp. 25–26), and relatively common in only a few (Bogan 1990, p. 135).

Museum collections of this species are almost always few in number (Cummings 2010, pers. comm.), with the exception of the 1960s collections from the Clinch and Powell Rivers, Tennessee and Virginia. Moderate numbers of individuals were also commonly recorded historically from the upper Muskingum River system in Ohio and the lower Wabash River in Indiana and Ohio, based on museum lots. Schuster and Williams (1989, p. 21) reported the species as being not common in the Ohio River, while Cummings and Mayer (1992, p. 50) considered it rare throughout its range. The American Malacological Union considers the sheepnose to be threatened (Williams *et al.* 1993, p. 13).

Some known populations of the sheepnose are represented by the collection of a single specimen. Other populations have seen a dramatic range decline (for example, reduced from several hundred river miles to a single bed of a river system) or we have limited recent information on population status. The following summaries focus primarily on those populations for which we have sufficient information to make status and trend determinations, and less on those populations that are nearly extirpated, have no recruitment, or are of unknown status.

Upper Mississippi River System

Judging from the archeological record, the sheepnose may have been common at some sites on the Mississippi River (Bogan 1990, p. 135) but over the past century it has become a rare species throughout the mainstem (Grier 1922, pp. 13–31; van der Schalie and van der Schalie 1950, pp. 454–457). Robust populations may have been found in some tributary rivers. The sheepnose has been extirpated from eight Mississippi River tributaries (Minnesota, Rock, Iowa, Des Moines, Kaskaskia, Saline, Castor, and Whitewater Rivers) and all but one Illinois River tributary (the Kankakee River). Today, the sheepnose is extant (though in low numbers) in ten mainstem pools, and six tributary rivers of the Upper Mississippi River System.

Mississippi River mainstem: Sheepnose populations in the mainstem of the Upper Mississippi River are declining. Despite the discovery of a juvenile in Mississippi River Pool (MRP) 7 in 2001, recruitment is limited at best. The mainstem population is comprised of a few old individuals spread across a very large geographic range (MRP 3 through MRP 24 a distance of over 550 river miles (880 river km)) (Thiel 1981, p. 10; Havlik and Marking 1981, p. 32; Whitney *et al.* 1996, p. 17; Helms and Associates, Ecological Specialists Inc. 2008, p. 16). The status of this species in the Mississippi River is highly jeopardized (Butler 2002b, p. 7).

Pools with extant populations include MRP 3 (last seen live or fresh dead in 2000–01), MRP 4 (2008), MRP 7 (2001), MRP 11 (2007), MRP 14 (2006–07), MRP 15 (2005–06), MRP 16 (2003), MRP 17 (2004), MRP 20 (1992), and MRP 24 (1999). The 2001 MRP 7 record was for a live juvenile 1.3 inches (3.3 cm) long and estimated to be 3 years old (Davis 2008, pers. comm.).

St. Croix River: The St. Croix River population is isolated and comprised of old individuals with little to no recruitment (Heath 2010b, pers. comm.). Currently, the population is thought to be restricted to the lowermost mainstem below RM 1 in Washington County, Minnesota, and Pierce County, Wisconsin (Heath 2010b, pers. comm.). Three live individuals were collected in 1988, during a mussel relocation project for the U.S. Highway 10 bridge immediately upstream of the confluence with the Mississippi River (Heath 1989, p. 16). Hornbach (2001, p. 218) analyzed mussel collections throughout the St. Croix River and found that the sheepnose was absent in 15 of the 16 river reaches he sampled, only noting the 1988 occurrence. One historical occurrence is known from the vicinity of RM 53 in 1930; however, this is the only known record upstream of RM 1 (Heath 2010b, pers. comm.). Because there have been no recent collections in the St. Croix River since 1988, this population is most likely extirpated.

Chippewa/Flambeau River: The sheepnose population in the Chippewa River is extant in much of the river system including the lower end of its tributary, the Flambeau River. This population is stable with documented recruitment (Butler 2002b, p. 8). Balding and Balding (1996, p. 5) reported 50 live specimens sampled from 1989–1994, but more recent collections have expanded sites of occurrence to 20 of 67 sites in the middle and upper portions of the Chippewa River, with a relative abundance of 0.8 percent (Balding 2001, pers. comm.). Balding (1992, p. 166) found 12 live specimens and 31 dead shells from 5 of 37 sites in the lower river. Additional survey work extended the number of sites where it was found live to 10 of 45 (Balding 2001, pers. comm.). The Flambeau River supports a small sheepnose population below its lowest dam and near its confluence with the Chippewa River (lower 8 miles (13 km) of river), and is most likely dependent on the source population in the Chippewa River. The Chippewa River sheepnose population is considered one of the best known extant populations. The Flambeau River supports a small sheepnose population below its lowest dam and near its confluence with the Chippewa River (lower 8 miles (13 km) of river), and is most likely dependent on the source population in the Chippewa River.

Wisconsin River: The sheepnose is declining in the Wisconsin River. Historical records for the sheepnose are available throughout the lower 335 miles (539 km) of the 420-mile (676-km) Wisconsin River (Heath 2010c, pers. comm.). In July 2002, 20 live specimens were found in a dense mussel bed near Port Andrew (Seitman 2008, pers. comm.). Currently, the sheepnose is primarily confined to RM 133.7 downstream (a reduction of over 201 river miles (232 km)). The sheepnose population is probably recruiting in the river, primarily in the lower section (below RM 82) (Heath 2010b, pers. comm.). It is unknown if the middle river population, from RM 93 to 133.7, is recruiting because only three living individuals have been found in recent years (Heath 2010c, pers. comm.).

Kankakee River: The sheepnose once occurred along the lower two-thirds of the Kankakee River, an Upper Illinois River tributary, in Indiana and Illinois (Wilson and Clark 1912, p. 47; Lewis and Brice 1980, p. 4). The sheepnose has been extirpated from the channelized portion of the Kankakee in Indiana but persists in the Illinois portion of the river where it appears stable, with evidence of recent recruitment (Butler 2002b, p. 9). Records since 1986 identify the sheepnose in the Kankakee River from the Iroquois River confluence downstream approximately 30 river miles (48 km) (Cummings 2010, pers. comm.; Helms and Associates 2005, p. 3). A mussel relocation effort for a pipeline crossing in the Kankakee River in July 2002 found 11 sheepnose individuals, representing 0.32 percent of the total mussels relocated (Helms 2004, p. D–1). Subsequent monitoring of the site in 2004 and 2007 located four new individuals. One individual collected in 2004 measured 1.6 inches (40 mm) and was estimated to be a juvenile of 3 years of age.

Meramec River: The Meramec River flows into the Mississippi River downstream of St. Louis and drains east-central Missouri. The Meramec sheepnose population is stable and recruiting, and represents one of the best rangewide (Butler 2002b, p. 9). Two studies (Buchanan 1980, p. 4; Roberts & Bruenderman 2000, p. 20) extensively surveyed the mussel fauna of the Meramec River. The most notable difference in the results of these studies was the reduced range in which sheepnose were found. Buchanan (1980, p. 34) found live or fresh dead individuals from RM 4.5 to 145.7 (141.2 river miles (227.2 km)), whereas Roberts and Bruenderman (2000, p. 20) found live or fresh dead individuals from RM 25.6 to 91.3 (65.7 river miles (105.7 km)). The trend data from the late 1970s to 1997 indicate that the sheepnose declined 75.5 river miles (121.5 km) in total range within the Meramec River. The extent of the population in the lower end appears to be shrinking upriver (Butler 2002b, p. 10).

In 2002, a site associated with a railroad crossing in St. Louis County at RM 28 yielded 43 live specimens over 3 days of sampling, including at least one gravid female (Roberts 2008, pers. comm.). Collectively, these data reinforce the level of importance of the Meramec population for the sheepnose rangewide. Although the existing population has been described as stable and recruitment has been documented in the system (Butler 2002b, pp. 11–12), the population has shrunk by half of its former geographic range over the past 30 years.

Bourbeuse River: The Bourbeuse River sheepnose population is distributed in the downstream 90 river miles (145 km) of the river (Buchanan 1980, p. 34), but is considered rare. Although recruitment has been documented in the Bourbeuse River, the sheepnose population is considered declining (Roberts and Bruenderman 2000, p. 130; Roberts 2010, pers. comm.). In the late 1970s, Buchanan (1980, p. 10) found the sheepnose to represent 0.1 percent of the Bourbeuse River mussel fauna, with 10 live specimens sampled from 7 sites. Based on data collected by Buchanan (1980, p. 34) and additional survey work in 1980, live or fresh-dead individuals were found in the Bourbeuse from RM 6.5 to 90.0. Data from a resurvey of the Bourbeuse River collected in 1997 yielded nine live sheepnose from four sites (Roberts and Bruenderman 2000, p. 39) and fresh dead shells were located at an additional site. Sheepnose relative abundance was 0.4 percent. Live or fresh dead sheepnose were found between RM 1.4 to 66.3. This comparison indicates a decrease in the number of extant sites (7 to 4) and a range contraction of 18 river miles (29 km). The sheepnose in the Meramec and Bourbeuse Rivers represents a population cluster.

Lower Missouri River System

Osage Fork Gasconade River: The Lower Missouri River system population is represented by a single sheepnose specimen and is near extirpation. This individual was located in 1999 at RM 21.2 in the Osage Fork, a tributary to the Gasconade River (Bruenderman *et al.* 2001, p. 14). It is the only known record for sheepnose in the Gasconade River drainage for over 25 years.

Ohio River System

Historically, the sheepnose was documented from the entire length of the Ohio River (its type locality), and was first collected there in the early 1800s. Ohio River sampling of 664 river miles (1,068 km) along the northern border of Kentucky yielded 41 sheepnose (Williams 1969, p. 58). Most of these (29) were found in the upper portions of river (from RM 317 to 538), but the population extended downstream to RM 871. Relative abundance was 0.7 percent for the entire reach sampled. Currently, the mainstem Ohio River and 10 tributary streams have extant sheepnose populations.

Ohio River mainstem: The sheepnose is generally distributed, but rare, in most mainstem pools of the Ohio River. The population appears to be more abundant in the lower section of the river with a smaller population in the upper Ohio River pools (McGregor 2008, pers. comm.; Schuster and Williams 1989, p. 24; Zeto *et al.* 1987, p. 184). Long term monitoring data from 1993 to 2007 at RM 176 shows the sheepnose is usually collected each survey, recruitment is occurring, and the species comprises 1.0 percent of the mussels at the site (relative abundance) (Morrison 2008, pers. comm.). Live sheepnose have also been collected in recent years at RM 725 and RM 300 (Morrison 2008, pers. comm.). The population in the lower Ohio River mainstem is viable with documented recruitment, but the population overall continues to show signs of decline (Butler 2002b, p. 12).

Allegheny River: The Allegheny River drains northwestern Pennsylvania and western New York and joins the Monongahela River at Pittsburgh to form the Ohio River. A recruiting and improving population of sheepnose exists within the middle Allegheny River (Villella 2008, pers. comm.). Sampling efforts from 2006–2008 at 63 sites over 78 miles (125 km) of river produced sheepnose at 18 sites. A total of 244 individuals of 7 different age classes were collected (Villella 2008, pers. comm.) providing ample evidence of recent recruitment.

Kanawha River: The Kanawha River is a major southern tributary of the Ohio River draining much of West Virginia and with headwaters in Virginia and North Carolina. The Kanawha River harbors a small, but recruiting and stable, population of sheepnose in Fayette County, West Virginia (Butler 2002b, p. 14). The Kanawha population appears to be limited to 5 river miles (8 km) immediately below Kanawha Falls (Clayton 2008c, pers. comm.). Sheepnose collections from this reach in 1987 resulted in a density of 0.013 per sq. m (0.140 per sq. ft), and collections from 2005 found a density of 0.016 per sq. m (0.172 per sq. ft) (Clayton 2008c, pers. comm.).

Licking River: The sheepnose is known from the lower half of the Licking River, a southern tributary of the Ohio River in northeastern Kentucky. Currently, the species is known from roughly five sites in the middle Licking River (McGregor 2008, pers. comm.). There is no documented evidence of recent recruitment, and, therefore, the sustainability of the population is unknown. It is possible this population represents a population cluster with the Ohio River.

Green River: The Green River is a lower Ohio River tributary in west-central Kentucky. Currently, a recruiting and improving population remains over an approximately 25 river mile (40 river km) reach in the upper Green River from the vicinity of Mammoth Cave National Park upstream into Hart County (Butler 2002b, p. 15). An investigation of muskrat middens from 2002 and 2003 revealed 42 sheepnose shells, with 39 of the 42 between 1.2 and 2.2 inches (3.0 and 5.6 cm) in length and described as juveniles (Layzer 2008, pers. comm.). Sampling over the past several years (2005–2007) has documented a number of beds experiencing recruitment (McGregor 2008, pers. comm.).

Tippecanoe River: The Tippecanoe River drains the central portion of northern Indiana in the upper Wabash River system. This population of sheepnose is considered stable with relatively recent recruitment (Butler 2002b, p. 17). Survey work between 1987 and 1995 documented sheepnose at 14 sites throughout the river and extended the known range of the species upstream into Marshall County (Butler 2002b, p. 17). The sheepnose is now known from 45 miles (72 km) of the Tippecanoe River (Ecological Specialists, Inc. 1993, pp. 80–81; Cummings and Berlocher 1990, pp. 84, 98; Cummings 2008, pers. comm.; Fisher 2008, pers. comm.).

Kentucky, Wabash, Eel, Muskingum, and Walhonding Rivers: In addition to the aforementioned populations, sheepnose in the Ohio River system are known from the Kentucky, Wabash, and Eel Rivers, which are each represented by two or fewer specimens collected in the past 25 years. Populations of the sheepnose in these three river systems are considered to be declining and may be nearing extirpation (Butler 2002b, p. 15–16). A population cluster in two additional rivers, the Muskingum River and its tributary, the Walhonding River, have unknown populations. Although Watters and Dunn (1995, p. 240) documented recruitment in the lower Muskingum River in the mid-1980s, the sheepnose population in the river is extremely small, and distribution has been reduced to only the lower portion of the river where six individuals were collected in 1992 (Watters and Dunn 1995, pp. 253–254).

Cumberland River System

Historical sheepnose records in the system are known from throughout the mainstem downstream of Cumberland Falls and three of its tributaries (Obey, Harpeth, and Caney Fork Rivers). Wilson and Clark (1914, pp. 15–19, 57) reported the species to be generally uncommon from 14 mainstem sites from what is now Cumberland Reservoir, Kentucky, downstream to Stewart County, Tennessee, a distance of nearly 500 miles (~805 km). Sheepnose was last documented in the Tennessee portion of the river during the early 1980s (Butler 2002b, p. 67).

The only recent record for the Cumberland River is from 1987, at the extreme lower end of the river near its confluence with the Ohio River, below Barkley Dam (Butler 2002b, p. 18). This population may be influenced by the lower Ohio River sheepnose population (Butler 2002b, p. 18) and represents a population cluster. Surveys conducted in 2007–2009 found no sheepnose (Hubbs, 2010, pers. comm.) and so this population may be extirpated.

Tennessee River System

The sheepnose was originally known from the Tennessee River and 10 of its tributary streams. Historically, Ortmann (1925, p. 328) considered the sheepnose to occur "sparingly" in the lower Tennessee River, and to be "rare" in the upper part of the system (Ortmann 1918, p. 545). Hundreds of miles of large river habitat on the Tennessee River mainstem have been converted under nine reservoirs, with additional dams constructed in tributaries historically harboring the sheepnose (for example, Clinch, Holston, Little Tennessee, Hiwassee Rivers) (Tennessee Valley Authority 1971, p. 5). Sheepnose populations currently persist in limited reaches of the Tennessee River mainstem and four tributaries.

Tennessee River mainstem: The 53-mile (85-km) stretch of river in northwestern Alabama referred to as the Muscle Shoals, historically harbored 69 species of mussels, making it the most diverse mussel fauna ever known (Garner and McGregor 2001, pp. 155–157). However, with the construction of three dams (Wilson in 1925, Wheeler in 1930, and Pickwick Landing in 1940) most of the historical habitat was inundated, leaving only small, flowing habitat remnants (Garner and McGregor 2001, p. 158).

The species is found only occasionally in the lower Tennessee River below Pickwick Landing Dam in southwestern Tennessee. Scruggs (1960, p. 11) recorded a relative abundance of 0.2 percent, while Yokley (1972, p. 64) considered it to be "very rare" in this reach (relative abundance of 0.1 percent). Yokley reported only two specimens that were each estimated to be 20 or more years old.

The sheepnose persists in the tailwaters of Guntersville, Wilson, Pickwick Landing, and Kentucky Dams on the mainstem Tennessee River, where it is considered uncommon (Garner & McGregor 2001, p. 165; Gooch *et al.* 1979, p. 9). These populations are considered stable overall but with very limited recruitment (Garner and McGregor 2001, p. 165; McGregor 2008, pers. comm.). The species has been found in low numbers over the past 80 years from relic habitat in the Wilson Dam tailwaters, a several-mile reach adjacent to and downstream from Florence, Alabama (Butler 2002b, pp. 20–21).

Clinch River: The Clinch River in southwestern Virginia and northeastern Tennessee is one of the largest and most significant tributaries of the upper Tennessee River system. Based on archeological evidence, the sheepnose was "extremely rare" in the lower Clinch River (Parmalee and Bogan 1986, p. 28). As of 2002, the largest lots of museum material available for the sheepnose had been from the Clinch River and its tributary, the Powell River (Watters 2010, pers. comm.). Individual Clinch River museum lots collected during 1963 to 1969 include 36, 39, 70, and 82 fresh dead specimens. The sheepnose population in the Clinch River currently occurs over approximately 60 river miles (96 km) from northern Scott County, Virginia downstream into Hancock County, Tennessee, and is considered stable with recently documented recruitment (Eckert 2008, pers. comm.). Survey work between 1979 and 1994 (Ahlstedt & Tuberville 1997, p. 73) reported low densities of 0.009 to 0.018 individuals per sq. ft. (0.1 to 0.2 per sq. m). Sampling efforts in 2005 and 2006 reported densities from two sites (RM 223.6 and 213.2) in Scott County, Virginia, of 0.021 and 0.006 individuals per sq. m (0.226 and 0.064 per sq. ft), respectively (Eckert 2008, pers. comm.). Relative abundance for sheepnose at these locations was 1.5 percent and 1.0 percent, respectively.

Powell River: The largest sheepnose collection (OSUM) known rangewide was collected in the Powell River, the Clinch River's largest tributary, and included 6 live and 141 fresh dead specimens. Today, the sheepnose population in the Powell River is considered stable, and recruitment has been documented. In 1979, Ahlstedt (1991b, pp. 129–130) reported 45 live specimens from 17 of 78 sites (an average 2.6 individuals per site). Ahlstedt and Tuberville (1997, p. 96) conducted quantitative sampling in the Powell between 1979 and 1994, and found the sheepnose at densities of 0.01 to 0.08 per sq. m (0.107 and 0.861 per sq. ft). Sampling efforts in 2004 reported densities from two sites in Lee County, Virginia (RM 120.3 and 117.3), of 0.012 and 0.017 individuals per sq. m (0.129 and 0.183 per sq. ft), respectively (Eckert 2008, pers. comm.). Relative abundance for sheepnose was 0.82 percent and 0.99 percent, respectively.

Duck River: The Duck River population is recently represented by the collection of single 10+ year old animal in 2003. The sheepnose was likely always rare in the Duck River and, previous to 2003, the species was thought to be extirpated. The current status of the population is unknown.

Holston River: In July 2002, sampling in Holston River produced live sheepnose at 16 of 20 sites sampled below the Cherokee Dam. This reach extended from Nance Ferry to Monday Island (RM 14.6), Jefferson and Knox Counties (Fraley 2008, pers. comm.). A total of 206 specimens were found with an overall relative abundance of 18.2 percent among the 18 species reported live from this reach. The collection was comprised of extremely old individuals with no recently recruited individuals being found. Although the population appeared significant in numbers, the lack of recruitment in this population is indicative of a remnant population on its way to extirpation (Butler 2002b, p. 19). In 2007, Tennessee Valley Authority biologists located sheepnose in the Holston River while conducting fish surveys; however, no additional mussel survey work has been completed in the area since 2002 (Baxter 2010, pers. comm.).

Lower Mississippi River System

The sheepnose was apparently never widely distributed in the lower Mississippi River system. The only verified records are for Hatchie River in Tennessee and the Delta region in Mississippi. The only records for the Yazoo and Big Black Rivers are from archeological sites (Butler 2002b, p. 21). The sheepnose population in the Big Sunflower River, Mississippi, is the only one remaining in the lower Mississippi River system. Once abundant judging from museum and archeological records, there is now only a small declining population in the Big Sunflower River (Jones 2008, pers. comm.). The population is believed to be limited to a 12- to 15-mile (19- to 24-km) reach upstream of Indianola in Sunflower County, Mississippi. Although no juvenile mussels have been found in recent sampling efforts, variably-sized individuals indicate some, possibly very low, level of recruitment in the population (Jones 2008, pers. comm.).

Summary of Extant Sheepnose Populations

The sheepnose has experienced a significant reduction in range, and many of the extant populations are disjunct, isolated, and appear to be declining. The extirpation of this species from over 50 streams (more than 65 percent) within its historical range indicates that substantial population losses have occurred. In the majority of streams with extant populations, the sheepnose appears to be uncommon at best. Only in the Allegheny and Green Rivers is the species considered to be improving in population status. Several other extant populations are thought to exhibit some level of stability and have experienced relatively recent recruitment (Chippewa/Flambeau, Meramec, Ohio, Tippecanoe, Clinch, and Powell Rivers). Given the compilation of current distribution, abundance, and status trend information, the sheepnose appears to exhibit a high level of imperilment.

Previous Federal Actions

We identified the spectaclecase and sheepnose as candidate species in a notice of review published in the **Federal Register** on May 4, 2004 (69 FR 24875). The spectaclecase and sheepnose remained candidate species in subsequent notices, including: May 11, 2005 (70 FR 24869), September 12, 2006 (71 FR 53755), December 6, 2007 (72 FR 69033), December 10, 2008 (73 FR 75176), and November 9, 2009 (74 FR 57804). A candidate species is a species for which we have on file sufficient information on biological vulnerability and threats to support issuing a proposed rule to list the species as endangered or threatened.

Summary of Factors Affecting the Species

Section 4 of the Act (16 U.S.C. 1533), and its implementing regulations at 50 CFR part 424, set forth the procedures for adding species to the Federal lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, we may determine a species to be endangered or threatened due to one or more of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. Listing actions may be warranted based on any of the above threat factors, singly or in combination. Each of these factors is discussed below.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range.

The decline of mussels such as the spectaclecase and sheepnose is primarily the result of habitat loss and degradation (Neves 1991, pp. 252, 265). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, oil and gas development, and sedimentation (Neves 1991, pp. 252, 260–261; Neves 1993, pp. 1–7; Neves *et al.* 1997, pp. 63–72; Strayer *et al.* 2004, pp. 435–437; Watters 2000, pp. 261–268; Williams *et al.* 1993, p. 7). These threats to mussels in general (and spectaclecase and sheepnose where specifically known) are individually discussed below.

Dams and Impoundments

Dams eliminate or reduce river flow within impounded areas, trap silts and cause sediment deposition, alter water temperature and dissolved oxygen levels, change downstream water flow and quality, decrease habitat heterogeneity, affect normal flood patterns, and block upstream and downstream movement of species (Layzer *et al.* 1993, pp. 68–69; Neves *et al.* 1997, pp. 63–64; Watters 2000, pp. 261–264). Within impounded waters, decline of freshwater mollusks has been attributed to sedimentation, decreased dissolved oxygen, and alteration in resident fish populations (Neves *et al.* 1997, pp. 63–64; Pringle *et al.* 2009, pp. 810–815; Watters 2000, pp. 261–264). Dams significantly alter downstream water quality and habitats (Allen & Flecker 1993, p. 36), and negatively affect tailwater mussel populations (Layzer *et al.* 1993, p. 69; Neves *et al.* 1997, p. 63; Watters 2000, pp. 265–266). Below dams, mussel declines are associated with changes and fluctuation in flow regime, scouring and erosion, reduced dissolved oxygen levels and water temperatures, and changes in resident fish assemblages (Layzer *et al.* 1993, p. 69; Neves *et al.* 1997, pp. 63–64; Pringle *et al.* 2009, pp. 810–815; Watters 2000, pp. 265–266; Williams *et al.* 1992, p. 7). The decline and imperilment of freshwater mussels in several tributaries within the Tennessee, Cumberland, Mississippi, Missouri, and Ohio River basins have been directly attributed to construction of numerous impoundments in those river systems (Hanlon *et al.* 2009, pp. 11–12; Layzer *et al.* 1993, pp. 68–69; Miller *et al.* 1984, p. 109; Neves *et al.* 1997, pp. 63–64; Sickel *et al.* 2007, pp. 71–78; Suloway 1981, pp. 237–238; Watters 2000, pp. 262–263; Watters & Flaute 2010, pp. 3–7; Williams & Schuster 1989, pp. 7–10).

Population losses due to impoundments have likely contributed more to the decline and imperilment of the spectaclecase and the sheepnose than any other factor. Large river habitat throughout nearly all of the range of both species has been impounded, leaving generally short, isolated patches of vestigial habitat in the area below dams. Navigational locks and dams, (for example, on the upper Mississippi, Ohio, Allegheny, Muskingum, Kentucky, Green, and Barren Rivers), some high-wall dams (for example, on the Wisconsin, Kaskaskia, Walhonding, and Tippecanoe Rivers), and many low-head dams (for example, on the St. Croix, Chippewa, Flambeau, Wisconsin, Kankakee, and Bourbeuse Rivers) have contributed significantly to the loss of sheepnose and spectaclecase habitat (Butler 2002a, pp. 11–20 2002b, pp. 9–25).

The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries are now impounded. There are 36 major dams located in the Tennessee River system and about 90 percent of the Cumberland River downstream of Cumberland Falls (RM 550 (RKM 886)) is either directly impounded by U.S. Army Corps of Engineers (Corps) structures or otherwise impacted by cold tail water released from several dams. Major Corps impoundments on Cumberland River tributaries (for example, Stones River and Caney Fork) have inundated an additional 100 miles (161 km) or more of spectaclecase and sheepnose habitat. Coldwater releases from Wolf Creek, Dale Hollow (Obey River), and Center Hill (Caney Fork) Dams continue to degrade spectaclecase and sheepnose habitat in the Cumberland River system. Layzer *et al.* (1993, p. 68) reported that 37 of the 60 pre-impoundment mussel species of the Caney Fork River have been extirpated. Watters (2000, pp. 262–263) summarizes the tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems. Approximately one-third of the historical sheepnose and spectaclecase streams are in the Tennessee and Cumberland River systems.

Navigational improvements on the Ohio River began in 1830, and now include 21 lock and dam structures stretching from Pittsburgh, Pennsylvania, to Olmsted, Illinois, near its confluence with the Mississippi River. Historically, habitat now under navigational pools once supported up to 50 species of mussels, including the spectaclecase and sheepnose. Tributaries to the Ohio River, such as the Green and Allegheny rivers, were also altered by impoundments. A series of six locks and dams was constructed on the lower half of the Green River decades ago and extend upstream to the western boundary of Mammoth Cave National Park (MCNP). The upper two locks and dams destroyed spectaclecase habitat, particularly Lock and Dam 6, which flooded the central and western portions of MCNP. Approximately 30 river miles (48 km) of mainstem habitat were also eliminated with the construction of the Green River Dam in 1969. Locks and dams were also constructed on the lower reaches of the Allegheny, Kanawha, Muskingum, and Kentucky Rivers which disrupted historical riverine habitat for the sheepnose.

Similarly, dams impound most of the upper Mississippi River and many of its tributaries. A series of 29 locks and dams constructed since the 1930s in the mainstem resulted in profound changes to the nature of the river, primarily replacing a free-flowing alluvial (flood plain) system with a stepped gradient (higher pool area to riffle area ratio) river. Modifications fragmented the mussel beds where spectaclecase and sheepnose were found in the Mississippi River, reduced stable riverine habitat, and disrupted fish host migration and habitat use.

Dams and impoundments have fragmented and altered stream habitats throughout the Sac River Basin in the lower Missouri River system. Stockton Dam impounds 39 miles (63 km) of the upper Sac River and the Truman Dam inundates about 8 miles (13 km) of the lower Sac River and its tributaries (Hutson & Barnhart 2004, p. 7). The rarity of live spectaclecase in the Sac River, coupled with the large number of dead shells observed in a recent study, suggests that this species has decreased since the river was impounded, and that spectaclecase may soon be extirpated from the Sac River system (Hutson & Barnhart 2004, p. 17).

Dam construction has a secondary effect of fragmenting the ranges of aquatic mollusk species, leaving relict habitats and populations isolated by the structures as well as by extensive areas of deep uninhabitable, impounded waters. These isolated populations are unable to naturally recolonize suitable habitat that is impacted by temporary, but devastating events, such as severe drought, chemical spills, or unauthorized discharges (Cope *et al.* 1997, pp. 235–237; Layzer *et al.* 1993, pp. 68–69; Miller & Payne 2001, pp. 14–15; Neves *et al.* 1997, pp. 63–75; Pringle *et al.* 2009, pp. 810–815; Watters 2000, pp. 264–265, 268; Watters & Flaute 2010, pp. 3–7).

Sedimentation

Nonpoint source pollution from land surface runoff originates from virtually all land use activities and includes sediments; fertilizer, herbicide, and pesticide residues; animal or human wastes; septic tank leakage and gray water discharge; and oils and greases. Nonpoint source pollution can cause excess sedimentation, nutrification, decreased dissolved oxygen concentration, increased acidity and conductivity, and other changes in water chemistry that can negatively impact freshwater mussels. Land use types around the sheepnose and spectaclecase populations include pastures, row crops, timber, and urban and rural communities.

Excessive sediments are believed to impact riverine mollusks requiring clean, stable streams (Brim Box & Mosa 1999, p. 99; Ellis 1936, pp. 39–40). Impacts resulting from sediments have been noted for many components of aquatic communities. For example, sediments have been shown to affect respiration, growth, reproductive success, and behavior of freshwater mussels, and to affect fish growth, survival, and reproduction (Waters 1995, pp. 173–175). Potential sediment sources within a watershed include virtually all activities that disturb the land surface, and most localities currently occupied by the spectaclecase and sheepnose are affected to varying degrees by sedimentation.

Sedimentation has been implicated in the decline of mussel populations nationwide, and is a threat to spectaclecase and sheepnose (Brim Box & Mosa 1999, p. 99; Dennis 1984, p. 212; Ellis 1936, pp. 39–40; Fraley & Ahlstedt 2000, pp. 193–194; Poole & Downing 2004, pp. 119–122; Vannote & Minshall 1982, pp. 4105–4106). Specific biological impacts include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, limited burrowing activity, physical smothering, and disrupted host fish attractant mechanisms (Ellis 1936, pp. 39–40; Hartfield & Hartfield 1996, p. 373; Marking & Bills 1979, p. 210; Vannote & Minshall 1982, pp. 4105–4106; Waters 1995, pp. 173–175). In addition, mussels may be indirectly affected if high turbidity levels significantly reduce the amount of light available for photosynthesis and thus the production of certain food items (Kanehl & Lyons 1992, p. 7).

Studies indicate that the primary impacts of excess sediment on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box & Mosa 1999, p. 101). The physical effects of sediment on mussels are multifold, and include changes in suspended and bed material load; changes in bed sediment composition associated with increased sediment production and run-off in the watershed; changes in the form, position, and stability of channels; changes in depth or the width-to-depth ratio, which affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave mussels stranded (Brim Box & Mosa 1999, pp. 109–112; Kanehl & Lyons 1992, pp. 4–5; Vannote & Minshall 1982, p. 4106). The Chippewa River in Wisconsin, for example, has a tremendous bedload composed primarily of sand that requires dredging to maintain barge traffic on the mainstem Mississippi below its confluence (Thiel 1981, p. 20). The mussel diversity in the Mississippi River below the confluence with the Chippewa River has predictably declined from historical times. Lake Pepin, a once natural lake formed in the upper Mississippi River upstream from the mouth of the Chippewa River, has become increasingly silted in over the past century, reducing habitat for the spectaclecase and sheepnose (Thiel 1981, p. 20).

Increased sedimentation and siltation may explain in part why spectaclecase and sheepnose mussels appear to be experiencing recruitment failure in some streams. Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces are reduced (Brim Box & Mosa 1999, p. 100), thus reducing juvenile habitat. Furthermore, sediment may act as a vector for delivering contaminants such as nutrients and pesticides to streams and juveniles may ingest contaminants adsorbed to silt particles during normal feeding activities. Female spectaclecase and sheepnose produce conglutinates that attract hosts. Such a reproductive strategy depends on clear water during the critical time of the year when mussels are releasing their glochidia.

Agricultural activities are responsible for much of the sediment (Waters 1995, p. 170) and chemical discharge into streams, affecting 60 percent of the impaired river miles in the country (EPA 2007, p. 10). Unrestricted livestock access occurs on many streams and potentially threatens their mussel populations (Fraley & Ahlstedt 2000, pp. 193–194). Grazing may reduce infiltration rates and increase runoff; trampling and vegetation removal increases the probability of erosion (Armour *et al.* 1991, pp. 8–10; Brim Box & Mosa 1999, p. 103). The majority of the remaining spectaclecase and sheepnose populations are threatened by some form of agricultural runoff (nutrients, pesticides, sediment). Copper Creek, a tributary to the Clinch River, for example, has a drainage area that contains approximately 41 percent agricultural land (Hanlon *et al.* 2009, p. 3). Fraley and Ahlstedt (2000, p. 193) and Hanlon *et al.* (2009, pp. 11–12) attributed the decline of the Copper Creek mussel fauna to an increase in cattle grazing and resultant nutrient enrichment and loss of riparian vegetation along the stream, among other factors. This scenario is similar in other parts of the extant range of the spectaclecase and sheepnose.

Sedimentation and urban runoff may also be threats to the sheepnose in the Kankakee River system as the Chicago Metro area continues to expand. Declines in mussel diversity observed in the Ohio River are in part due to pollution from urban centers; in many of these areas the loss of diversity has not recovered from water quality problems that began prior to dam construction (Watters & Flaute 2010, pp. 3–7).

As the spectaclecase primarily inhabits deep water along the outside of bends, it may be particularly vulnerable to siltation. The current often slackens in this habitat, more so than in riffles and runs where other mussel species are typically found, and suspended sediment settles out. Spectaclecase beds covered with a thick layer of silt have been observed in Missouri, often downstream from reaches with eroding banks (Roberts 2008, pers. comm.).

Channelization

Dredging and channelization activities have profoundly altered riverine habitats nationwide. Hartfield (1993, pp. 131–139), Neves *et al.* (1997, pp. 71–72), and Watters (2000, pp. 268–269) reviewed the specific effects of channelization on freshwater mussels. Channelization impacts stream physically (for example accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, and loss of riparian vegetation) and biologically (for example decreased fish and mussel diversity, altered species composition and abundance, decreased biomass, and reduced growth rates) (Hartfield 1993, pp. 131–139). Channel construction for navigation increases flood heights (Belt 1975, p. 684), partly as a result of a decrease in stream length and an increase in gradient (Hubbard *et al.* 1993, p. 137 (in Hartfield 1993, p. 131)). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery 1970, p. 10), such as increases in turbidity and sedimentation, which may smother bottom-dwelling organisms.

Channel maintenance operations for commercial navigation have impacted habitat for the sheepnose and spectaclecase in many large rivers rangewide. Periodic channel maintenance may continue to adversely affect this species in the upper Mississippi, Ohio, Muskingum, and Tennessee rivers. Further modifications to the Mississippi River channel are anticipated with the recently authorized Navigation and Environmental Sustainability Program (NESP) (Water Resources Development Act of 2007 (Pub. L. 110–114)), which will consist of construction of larger locks and other navigation improvements downstream of MRP 14. Continual maintenance of the Mississippi River navigation channel requires dredging, wing and closing dam reconstruction and maintenance, and bank armoring. Dredging, maintenance, and construction activities destabilize instream fine sediments are likely to adversely affect the spectaclecase and the sheepnose. Spectaclecase tend to inhabit relatively deep water where they are particularly vulnerable to siltation. The current is slower in this habitat than in riffles and runs, and suspended sediment settles out in greater volume. Dredging to maintain barge traffic on the Mississippi River below the mouth of the Chippewa River in Wisconsin has reduced mussel diversity due to the increase in unstable sand substrates (Thiel 1981, p. 20; U.S. Army Corps of Engineers 1996, p. 1, Tab 14).

Channel maintenance dredging is also a major concern for mussel populations. A large amount of spoil (dredged earth and rock) was dumped directly on a mussel bed in the Muskingum River that included the sheepnose in the late 1990s (Watters 2008, pers. comm.). Thousands of mussels were killed as the result of this single event. Watters and Dunn (1995 p. 231) also noted that the lower ends of two mussel beds coincided with the mouths of Wolf and Bear Creeks. This led them to surmise that pollutants, such as sediment loads or agricultural runoff, in their watersheds may adversely impact mussels in the mainstem Muskingum River below the confluences of Wolf Creek and Bear Creek.

Mussels require a stable substrate to survive and reproduce and are particularly susceptible to channel instability (Neves *et al.* 1997, p. 23; Parmalee & Bogan 1998). Channel and bank degradation have led to the loss of stable substrates in the Meramec River Basin. Roberts and Bruenderman (2000, pp. 7–8, 21–23) pointed to the loss of suitable stable habitat as a major cause of decline in mussel abundance at sites previously surveyed in 1979.

The Tennessee River was once a stronghold for the spectaclecase (Ortmann 1924, p. 60; 1925, p. 327), and the sheepnose was originally known to occur in the Tennessee River and 10 of its tributaries (Ortmann 1925, p. 328). The mainstem of the Tennessee River is maintained as a navigational channel, and a plan to deepen it has been proposed (Hubbs 2008, pers. comm.). Severe bank erosion is ongoing along some reaches of the river below Pickwick Landing Dam, with some sites losing several feet of stream bank per year (Hubbs 2008, pers. comm.).

The sheepnose population within the Big Sunflower River is threatened by a Corps flood control project (Jones 2008, pers. comm.). Dredging for this project is planned to take place downstream of Indianaola, but head-cutting may ultimately destabilize the substrate in which sheepnose now exists. This activity, coupled with other threats potentially affecting sheepnose (*see* below), may lead to extirpation of the population within 10 years (Jones 2008, pers. comm.).

The upper Kankakee River in Indiana was channelized several decades ago. The sheepnose is now considered extirpated from the upper Kankakee, and is restricted to the unchannelized portion of the river in Illinois (Cummings 2008, pers. comm.).

Mining

Instream gravel mining has been implicated in the destruction of mussel populations (Hartfield 1993, pp. 136–138). Negative impacts associated with gravel mining include stream channel modifications (altered habitat, disrupted flow patterns, and sediment transport), water quality modifications (increased turbidity, reduced light penetration, and increased temperature), macroinvertebrate population changes (elimination, habitat disruption, and increased sedimentation), and changes in fish populations (impacts to spawning and nursery habitat and food web disruptions) (Kanehl & Lyons 1992, pp. 4–10).

Heavy metal-rich drainage from coal mining and associated sedimentation has adversely impacted portions of the Tennessee River system in Virginia. Low pH commonly associated with mine runoff can reduce glochidial encystment (attachment) rates (Huebner & Pynnonen 1992, pp. 2350–2353). Acid mine runoff may thus have local impacts on recruitment of the mussel populations close to mines.

Coal-related toxins in the Clinch River may explain the decline and lack of mussel recruitment at some sites in the Virginia portion of that stream (Ahlstedt 2008, pers. comm.). Patterns of mussel distribution and abundances have been found to be negatively correlated with proximity to coal-mining activities (Ahlstedt & Tuberville 1997, pp. 74–75). Known mussel toxicants, such as polycyclic aromatic hydrocarbons, heavy metals (for example, copper, manganese, and zinc), and other chemicals from coal mining and other activities contaminate sediments in the Clinch River (Ahlstedt & Tuberville 1997, p. 75). These chemicals are toxic to juvenile mussels (Ahlstedt & Tuberville 1997, p. 75). Pollutant inputs to the Clinch River from a coal-burning power plant in Carbo, Virginia, were shown to increase mortality and reduce cellulolytic activity (breaking down cellulose) in transplanted mussels (Farris *et al.* 1988, pp. 705–706). Site-specific copper toxicity studies of unionid glochidia in the Clinch River showed that freshwater mussels as a group were generally sensitive to copper, the toxic constituent of the power plant effluent (Cherry *et al.* 2002, p. 596). All of these studies indicate that acid mine runoff may have local impacts on spectaclecase recruitment and survival in this river.

Gravel-mining activities may also be a localized threat in some streams with extant sheepnose and spectaclecase populations. Gravel mining causes stream instability, increasing erosion, turbidity, and subsequent sediment deposition (Meador & Layher 1998, pp. 8–9). Gravel mining is common in the Meramec River system. Between 1997 and 2008, the Missouri Department of Natural Resources issued permits for 102 sand- and gravel-mining sites in the Meramec River (Zeaman 2008, pers. comm.). Although rigid guidelines prohibited instream mining and required streamside buffers, a court ruling deauthorized the Corps from regulating these habitat protective measures. The Corps still retains oversight for gravel mining, but many mining operations do not fall under Corps jurisdiction (Roberts & Bruenderman 2000, p. 23). In the lower Tennessee River, mining is permitted in 18 reaches for a total of 47.9 river miles (77.1 km) between the Duck River confluence and Pickwick Landing Dam, a distance of over 95 miles (153 km) (Hubbs 2008, pers. comm.). This is the reach where mussel recruitment has been noted for many rare species in recent years. These activities have the potential to impact the river's small sheepnose population. The Gasconade River and its tributaries have been subject to gravel mining and other channel modifying practices that accelerate channel destabilization. These physical habitat threats combined with poor water quality and agricultural nonpoint source pollution are serious threats to all existing mussel fauna in the system.

Oil and Gas Development

Coal, oil, and natural gas resources are present in some of the watersheds that are known to support sheepnose, including the Allegheny River. Exploration and extraction of these energy resources can result in increased siltation, a changed hydrograph, and altered water quality even at a distance from the mine or well field. Sheepnose habitat in larger streams can be threatened by the cumulative effects of multiple mines and well fields (adapted from Service 2008, p. 11).

Coal, oil, and gas resources are present in a number of the basins where sheepnose occur, and extraction of these resources has increased dramatically in recent years, particularly in Pennsylvania and West Virginia. Although oil and gas extraction generally occurs away from the river, extensive road networks are required to construct and maintain wells. These road networks frequently cross or occur near tributaries, contributing sediment to the receiving waterway. In addition, the construction and operation of wells may result in the discharge of brine. Point source discharges are typically regulated; however, nonpoint inputs such as silt and other contaminants may not be sufficiently regulated, particularly those originating some distance from a waterway. In 2006, more than 3,700 permits were issued for oil and gas wells by the Pennsylvania Department of Environmental Protection, which also issued 98 citations for permit violations at 54 wells (Hopey 2007; adapted from Service 2008, p. 12).

Chemical Contaminants

Chemical contaminants are ubiquitous throughout the environment and are considered a major threat in the decline of freshwater mussel species (Cope *et al.* 2008, p. 451; Richter *et al.* 1997, p. 1081; Strayer *et al.* 2004, p. 436; Wang *et al.* 2007a, p. 2029). Chemicals enter the environment through both point and nonpoint discharges including spills, industrial sources, municipal effluents, and agricultural runoff. These sources contribute organic compounds, heavy metals, pesticides, and a wide variety of newly emerging contaminants to the aquatic environment. As a result, water and sediment quality can be degraded to the extent that mussel populations are adversely impacted.

Chemical spills can be especially devastating to mussels because they may result in exposure of a relatively immobile species to extremely elevated concentrations that far exceed toxic levels and any water quality standards that might be in effect. Some notable spills that released large quantities of highly concentrated chemicals resulting in mortality to mussels include:

- Massive mussel kills on the Clinch River at Carbo, Virginia occurred from a power plant alkaline fly ash pond spill in 1967, and a sulfuric acid spill in 1970 (Crossman *et al.* 1973, p. 6);
- Approximately 18,000 mussels of several species, including 750 individuals from three endangered mussel species, were eliminated from the upper Clinch River near Cedar Bluff, Virginia in 1998, when an overturned tanker truck released 1,600 gallons (6,056 liters) of a chemical used in rubber manufacturing (Jones *et al.* 2001, p. 20; Schmerfeld 2006, p. 12); and
- An on-going release of sodium dimethyl dithiocarbamate, a chemical used to reduce and precipitate hexachrome, starting in 1999 impacted approximately 10 river miles (16 km) of the Ohio River and resulted in an estimated loss of one million mussels, including individuals from two federally listed species (DeVault 2009, pers. comm.; Clayton 2008b, pers. comm.).

These are not the only instances where chemical spills have resulted in the loss of high numbers of mussels (Brown *et al.* 2005, p. 1457; Jones *et al.* 2001, p. 20; Neves 1991, p. 252; Schmerfeld 2006, pp. 12–13), but are provided as examples of the serious threat chemical spills pose to mussel species. The sheepnose and spectaclecase are especially threatened by chemical spills because these spills can occur anywhere that highways with tanker trucks, industries, or mines overlap with sheepnose and spectaclecase distribution.

Exposure of mussels to lower concentrations of contaminants more likely to be found in aquatic environments can also adversely affect mussels and result in the decline of freshwater mussel species. Such concentrations may not be immediately lethal, but over time, can result in mortality, reduced filtration efficiency, reduced growth, decreased reproduction, changes in enzyme activity, and behavioral changes to all mussel life stages. Frequently, procedures which evaluate the ''safe'' concentration of an environmental contaminant (for example, national water quality criteria) do not have data for freshwater mussel species or exclude data that are available for freshwater mussels (March *et al.* 2007, pp. 2066–2067, 2073).

Current research is now starting to focus on the contaminant sensitivity of freshwater mussel glochidia and newly-released juvenile mussels (Goudreau *et al.* 1993, pp. 219–222; Jacobson *et al.* 1997, p. 2390; March *et al.* 2007, pp. 2068–2073; Valenti *et al.* 2006, pp. 2514–2517; Valenti *et al.* 2005, pp. 1244–1245; Wang *et al.* 2007c, pp. 2041–2046) and juveniles (Augspurger *et al.* 2003, p. 2569; Bartsch *et al.* 2003, p. 2561; March *et al.* 2007, pp. 2068–2073; Mummert *et al.* 2003, p. 2549; Valenti *et al.* 2006, pp. 2514–2517; Valenti *et al.* 2005, pp. 1244–1245; Wang *et al.* 2007b, pp. 2053–2055; Wang *et al.* 2007c, pp. 2041–2046) to such contaminants as ammonia, metals, chlorine, and pesticides. The toxicity information presented in this section focuses on recent water-only laboratory acute (sudden and severe exposure) and chronic (prolonged or repeated exposure) toxicity tests with early life stages of freshwater mussels using the standard testing methodology published by the American Society for Testing and Materials (ASTM) (American Society for Testing and Materials. 2008. Standard guide for conducting laboratory toxicity tests with freshwater mussels E2455–06. In *Annual Book of ASTM Standards,* Vol 11.06. Philadelphia, PA, pp. 1442–1493.) Use of this standard testing method generates consistent, reliable toxicity data with acceptable precision and accuracy (Wang *et al.* 2007a, p. 2035) and was used for toxicity tests on ammonia, copper, chlorine and select pesticides (Augspurger *et al.* 2007, p. 2025; Bringolf *et al.* 2007b, p. 2101; Bringolf *et al.* 2007c, p. 2087; Wang *et al.* 2007a, p. 2029; Wang *et al.* 2007b, p. 2048; Wang *et al.* 2007c, p. 2036). Use of these tests has documented that, while mussels are sensitive to some contaminants, they are not universally sensitive to all contaminants (Augspurger *et al.* 2007, pp. 2025–2026).

One chemical that is particularly toxic to early life stages of mussels is ammonia. Sources of ammonia include agricultural wastes (animal feedlots and nitrogenous fertilizers), municipal wastewater treatment plants, and industrial waste (Augspurger *et al.* 2007, p. 2026) as well as precipitation and natural processes (decomposition of organic nitrogen) (Augspurger *et al.* 2003, p. 2569; Goudreau *et al.* 1993, p. 212; Hickey & Martin 1999, p. 44; Newton 2003, p. 1243). Therefore, ammonia is considered a limiting factor for survival and recovery of some mussel species due to its ubiquity in aquatic environments and high level of toxicity, and because the highest concentrations typically occur in mussel microhabitats (Augspurger *et al.* 2003, p. 2574). In addition, studies have shown that ammonia concentrations increase with increasing temperature and low flow conditions (Cherry *et al.* 2005, p. 378; Cooper *et al.* 2005, p. 381), which may be exacerbated by the effects of climate change, and may cause ammonia to become more problematic for juvenile mussels. The EPA-established ammonia water quality criteria (EPA 1985, pp. 94–99) may not be protective of mussels (Augspurger *et al.* 2003, p. 2572; Sharpe 2005, p. 28) under current and future climate conditions.

Mussels are also affected by metals (Keller & Zam 1991, p. 543), such as cadmium, chromium, copper, mercury, and zinc, which can negatively affect biological processes such as growth, filtration efficiency, enzyme activity, valve closure, and behavior (Jacobson *et al.* 1997, p. 2390; Keller & Zam 1991, p. 543; Naimo 1995, pp. 351–355; Valenti *et al.* 2005, p. 1244). Metals occur in industrial and wastewater effluents and are often a result of atmospheric deposition from industrial processes and incinerators. Glochidia and juvenile freshwater mussels have recently been studied to determine the acute and chronic toxicity of copper to these life stages (Wang *et al.* 2007b, pp. 2048–2056; Wang *et al.* 2007c, pp. 2036–2047). The chronic values determined for copper ranged from 8.5 to 9.8 micrograms per liter (ug/L) for survival and from 4.6 to 8.5 ug/L for growth of juveniles. These chronic values are below the EPA 1996 chronic water quality criterion of 15 ug/L (hardness 170 mg/L) for copper (Wang *et al.* 2007b, pp. 2052–2055). March (2007, pp. 2066, 2073) identifies that copper water quality criteria and modified State water quality standards may not be protective of mussels.

Mercury is another heavy metal that has the potential to negatively affect mussel populations, and it is receiving attention due to its widespread distribution and potential to adversely impact the environment. Mercury has been detected throughout aquatic environments as a product of municipal and industrial waste and atmospheric deposition from coal-burning plants. One recent study evaluated the sensitivity of early life stages of mussels to mercury (Valenti *et al.* 2005, p. 1242). This study determined that for the mussel species used (rainbow mussel, *Villosa iris*) glochidia were more sensitive to mercury than were juvenile mussels, with the median lethal concentration value of 14 ug/L compared to 114 ug/L for the juvenile life stage. The chronic toxicity tests conducted determined that juveniles exposed to mercury greater than or equal to 8 ug/L exhibited reduced growth. These observed toxicity values are below EPA's Criteria Continuous Concentration and Criteria Maximum Concentration, which are 0.77 ug/L and 1.4 ug/L, respectively. Based on these data, we believe that EPA's water quality standards for mercury should be protective of juvenile mussels and glochidia, except in cases of illegal dumping, permit violations, or spills. However, impacts to mussels from mercury toxicity may be occurring in some streams. According to the National Summary Data reported by States to the EPA, 3,770 monitored waters do not meet EPA standards for mercury in the United States. (*http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T,* accessed 6/28/2010). Acute mercury toxicity was determined to be the cause of extirpation of a diverse mussel fauna for a 70-mile (112-km) portion of the North Fork Holston River (Brown *et al.* 2005, pp. 1455–1457).

In addition to ammonia, agricultural sources of chemical contaminants include two broad categories that have the potential to adversely impact mussel species: Nutrients and pesticides. Nutrients (such as nitrogen and phosphorus) can impact streams when their concentrations reach levels that cannot be assimilated, a condition known as over-enrichment. Nutrient over-enrichment is primarily a result of runoff from livestock farms, feedlots, and heavily fertilized row crops (Peterjohn & Correll 1984, p. 1471). Over-enriched conditions are exacerbated by low-flow conditions, such as those experienced during typical summer-season flows and that might occur with greater frequency and magnitude as a result of climate change. Bauer (1988, p. 244) found that excessive nitrogen concentrations can be detrimental to the adult freshwater pearl mussel (*Margaritifera margaritifera*), as was evident by the positive linear relationship between mortality and nitrate concentration. Also, a study of mussel life span and size (Bauer 1992, p. 425) showed a negative correlation between growth rate and eutrophication, and longevity was reduced as the concentration of nitrates increased. Nutrient over-enrichment can result in an increase in primary productivity, and the subsequent respiration depletes dissolved oxygen levels. This may be particularly detrimental to juvenile mussels that inhabit the interstitial spaces in the substrate where lower dissolved oxygen concentrations are more likely than on the sediment surface where adults tend to live (Sparks & Strayer 1998, pp. 132–133).

Elevated concentrations of pesticide frequently occur in streams due to pesticide runoff, overspray application to row crops, and lack of adequate riparian buffers. Agricultural pesticide applications often coincide with the reproductive and early life stages of mussel, and thus impacts to mussels due to pesticides may be increased (Bringolf *et al.* 2007a, p. 2094). Little is known regarding the impact of currently used pesticides to freshwater mussels even though some pesticides, such as glyphosate (Roundup), are used globally. Recent studies tested the toxicity of glyphosate, its formulations, and a surfactant (MON 0818) used in several glyphosate formulations, to early life stages of the fatmucket (*Lampsilis siliquoidea*), a native freshwater mussel (Bringolf *et al.* 2007a, p. 2094). Studies conducted with juvenile mussels and glochidia determined that the surfactant (MON 0818) was the most toxic of the compounds tested and that *L. siliquoidea* glochidia were the most sensitive organism tested to date (Bringolf *et al.* 2007a, p. 2094). Roundup, technical grade glyphosate isopropylamine salt, and isopropylamine were also acutely toxic to juveniles and glochidia (Bringolf *et al.* 2007a, p. 2097). The impacts of other pesticides including atrazine, chlorpyrifos, and permethrin on glochidia and juvenile life stages have also recently been studied (Bringolf *et al.* 2007b, p. 2101). This study determined that chlorpyrifos was toxic to both *L. siliquoidea* glochidia and juveniles (Bringolf *et al.* 2007b, p. 2104). The above results indicate the potential toxicity of commonly applied pesticides and the threat to mussel species as a result of the widespread use of these pesticides. All of these pesticides are commonly used throughout the range of the sheepnose and spectaclecase.

A potential, but undocumented, threat to freshwater mussel species, including sheepnose and spectaclecase, are contaminants referred to as “emerging contaminants” that are being detected in aquatic ecosystems at an increasing rate. Pharmaceuticals, hormones, and other organic contaminants have been detected downstream from urban areas and livestock production (Kolpin *et al.* 2002, p. 1202). A large potential source of these emerging contaminants is wastewater being discharged through both permitted (National Pollutant Discharge Elimination System, or NPDES) and non-permitted sites throughout the country. Permitted discharge sites are ubiquitous in watersheds with sheepnose and spectaclecase populations, providing ample opportunities for contaminants to impact the species (for example, there are more than 250 NPDES sites in the Meramec River, Missouri system, which harbors large, but declining, populations of sheepnose and spectaclecase; Roberts and Bruenderman 2000, p. 78).

The information presented in this section represents some of the threats from chemical contaminants that have been documented both in the laboratory and field and demonstrates that chemical contaminants pose a substantial threat to sheepnose and spectaclecase. This information indicates the potential for contaminants from spills that are immediately lethal to species, to chronic contaminant exposure, which results in death, reduced growth, or reduced reproduction of sheepnose and spectaclecase to contribute to declining sheepnose and spectaclecase populations.

Summary of Factor A

The decline of the freshwater mussels in the eastern United States is primarily the result of the long-lasting effects of habitat alterations such as impoundments, channelization, chemical contaminants, mining, oil and gas development, and sedimentation. Although efforts have been made to restore habitat in some areas, the long-term effects of large-scale and wide-ranging habitat modification, destruction, and curtailment will continue into the foreseeable future.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The spectaclecase and sheepnose are not commercially valuable species but may be increasingly sought by collectors as they become rarer. Although scientific collecting is not thought to represent a significant threat, unregulated collecting could adversely affect localized spectaclecase and sheepnose populations.

Mussel harvest is illegal in some States (for example, Indiana and Ohio), but regulated in others (for example, Alabama, Kentucky, Tennessee, and Wisconsin). These species may be inadvertently harvested by inexperienced commercial harvesters unfamiliar with species identification. Although illegal harvest of protected mussel beds occurs (Watters and Dunn 1995, p. 225, 247–250), commercial harvest is not known to have a significant impact on the spectaclecase and sheepnose.

On the basis of this analysis, we find that overutilization for commercial, recreational, scientific, or educational purposes is not now a threat to the spectaclecase or sheepnose in any portion of its range or likely to become a significant threat in the foreseeable future.

C. Disease or Predation

Little is known about diseases in freshwater mussels (Grizzle & Brunner 2007, p. 6). However, mussel die-offs have been documented in spectaclecase and sheepnose streams (Neves 1986, p. 9), and some researchers believe that disease may be a factor contributing to the die-offs (Buchanan 1986, p. 53; Neves 1986, p. 11). Mussel parasites include water mites, trematodes, oligochaetes, leeches, copepods, bacteria, and protozoa (Grizzle & Brunner 2007, p. 4). Generally, parasites are not suspected of being a major limiting factor (Oesch 1984, p. 6), but a recent study provides contrary evidence. Reproductive output and physiological condition were negatively correlated with mite and trematode abundance, respectively (Gangloff *et al.* 2008, pp. 28–30). Stressors that reduce fitness may make mussels more susceptible to parasites (Butler 2007, p. 90). Furthermore, nonnative mussels may carry diseases and parasites that are potentially devastating to the native mussel fauna, including spectaclecase and sheepnose (Strayer 1999, p. 88).

The muskrat (*Ondatra zibethicus*) is cited as the most prevalent mussel predator (Convey *et al.* 1989, p. 654–655; Hanson *et al.* 1989, pp. 15–16; Kunz 1898, p. 328). Muskrat predation may limit the recovery potential of endangered mussels or contribute to local extirpations of previously stressed populations, according to Neves and Odom (1989, p. 940), but they consider it primarily a seasonal or localized threat. Böpple and Coker (1912, p. 9) noted the occurrence of "large piles of shells made by the muskrats" on an island in the Clinch River, Tennessee, composed of "about one-third" spectaclecase shells. Predation by muskrats may be a seasonal and localized threat to spectaclecase and sheepnose populations but is probably not a significant threat rangewide.

Some species of fish feed on mussels (for example, common carp (*Cyprinus carpio),* freshwater drum (*Aplodinotus grunniens*), redear sunfish (*Lepomis microlophus*)) and potentially on this species when young. Various invertebrates, such as flatworms, hydra, non-biting midge larvae, dragonfly larvae, and crayfish, may feed on juvenile mussels (Neves 2008, pers. comm.). Although predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population, predation may amplify declines in small populations of this species. In addition, the potential now exists for the black carp (*Mylopharyngodon piceus*), a mollusk-eating Asian fish recently introduced into the waters of the United States (Strayer 1999, p. 89), to eventually disperse throughout the range of the spectaclecase and sheepnose.

The life cycle of freshwater mussels is intimately related to that of the freshwater fish they use as hosts for their parasitic glochidia. For this reason, diseases that impact populations of freshwater fishes also pose a significant threat to mussels. Viral hemorrhagic septicemia (VHS) disease has been confirmed from much of the Great Lakes and St. Lawrence River system. In June 2008, muskellunge (*Esox masquinongy*) from Clearfork Reservoir, near Mansfield, Ohio, tested positive for carrying VHS virus. This is the first known occurrence of VHS virus in the Mississippi River basin.

The VHS virus has been implicated as a mortality factor in fish kills throughout the Great Lakes region. It has been confirmed in 28 fish species, but no identified hosts for sheepnose are on the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) list of fish species susceptible to VHS (APHIS 2008, pp. 1–2). Since the host for spectaclecase is unknown, we do not know how VHS could affect reproduction for spectaclecase. If the VHS virus successfully migrates out of the Clearfork Reservoir and into the Ohio River, it could spread rapidly and cause fish kills throughout the Mississippi River basin. Few spectaclecase and sheepnose populations are currently recruiting at sustainable levels, and fish kills could further reduce encounters with hosts and potentially reduce recruitment.

In summary, disease in freshwater mollusks is poorly known and not currently considered a threat. Although there is no direct evidence at this time that predation is detrimentally affecting the spectaclecase or sheepnose, their small populations and limited ranges leaves them vulnerable to threats of predation from natural or introduced predators. Therefore, we conclude that predation currently represents a threat of low magnitude, but it could potentially become a significant future threat to the spectaclecase and sheepnose due to their small population sizes.

D. The Inadequacy of Existing Regulatory Mechanisms

States with extant spectaclecase and sheepnose populations prohibit the taking of mussels for scientific purposes without a State collecting permit. However, enforcement of this permit requirement is difficult.

The level of protection that spectaclecase and sheepnose receive from State listing varies from State to State. The sheepnose is State-listed in every State that keeps such a list. Collection of sheepnose in Pennsylvania for use as fish bait is limited to 50 individuals per day. The spectaclecase is State-listed in 8 of the 10 States that harbor extant populations. Only in Missouri and Tennessee is the spectaclecase not assigned conservation status and West Virginia does not have any State-specific legislation similar to the Act.

Nonpoint source pollution is considered a primary threat to sheepnose and spectaclecase habitat; however, current laws do not adequately protect spectaclecase and sheepnose habitat from nonpoint source pollution, as the laws to prevent sediment entering water ways are poorly enforced. Best management practices for sediment and erosion control are often recommended or required by local ordinances for construction projects; however, compliance, monitoring, and enforcement of these recommendations are often poorly implemented. Furthermore, there are currently no requirements within the scope of Federal environmental laws to specifically consider the spectaclecase and sheepnose during Federal activities.

Point source discharges within the range of the spectaclecase and sheepnose have been reduced since the inception of the Clean Water Act (33 U.S.C. 1251 *et seq.*), but this may not provide adequate protection for filter feeding organisms that can be impacted by extremely low levels of contaminants (*see* "Chemical Contaminants" discussion under Factor A). There is no specific information on the sensitivity of the spectaclecase and sheepnose to common industrial and municipal pollutants, and very little information on other freshwater mussels. Therefore, it appears that a lack of adequate research and data prevents existing regulations, such as the Clean Water Act (administered by the EPA and the Corps), from being fully used or effective.

The U.S. Army Corps of Engineers retains oversight authority and requires a permit for gravel-mining activities that deposit fill into streams under section 404 of the Clean Water Act. Additionally, a Corps permit is required under section 10 of the Rivers and Harbors Act (33 U.S.C. 401 *et seq.*) for navigable waterways including the lower 50 miles (80 km) of the Meramec River. However, many gravel-mining operations do not fall under these two categories.

Despite these existing regulatory mechanisms, the spectaclecase and sheepnose continue to decline due to the effects of habitat destruction, poor water quality, contaminants, and other factors. We find that these regulatory measures have been insufficient to significantly reduce or remove the threats to the spectaclecase and sheepnose, and therefore that the inadequacy of existing regulatory mechanisms is a threat to these species throughout all of their ranges.

Based on our analysis of the best available information, we have no reason to believe that the aforementioned regulations will offer adequate protection to the spectaclecase and sheepnose in the foreseeable future.

E. Other Natural or Manmade Factors Affecting Its Continued Existence

Temperature

Natural temperature regimes can be altered by impoundments, water releases from dams, industrial and municipal effluents, and changes in riparian habitat. Critical thermal limits for survival and normal functioning of many freshwater mussel species are unknown. High temperatures can reduce dissolved oxygen concentrations in the water, which slows growth, reduces glycogen stores, impairs respiration, and may inhibit reproduction (Fuller 1974, pp. 240–241). Low temperatures can significantly delay or prevent metamorphosis (Watters & O'Dee 1999, pp. 454–455). Water temperature increases have been documented to shorten the period of glochidial encystment, reduce righting speed, increase oxygen consumption, and slow burrowing and movement responses (Bartsch *et al.* 2000, p. 237; Fuller 1974, pp. 240–241; Schwalb & Pusch 2007, pp. 264–265; Watters *et al.* 2001, p. 546). Several studies have documented the influence of temperature on the timing of aspects of mussel reproduction (for example, Allen *et al.* 2007, p. 85; Gray *et al.* 2002, p. 156; Steingraeber *et al.* 2007, pp. 303–309). Peak glochidial releases are associated with water temperature thresholds that can be thermal minimums or thermal maximums, depending on the species (Watters & O'Dee 2000, p. 136). Abnormal temperature changes may cause particular problems to mussels whose reproductive cycles may be linked to fish reproductive cycles (for example,Young & Williams 1984).

Climate Change

It is a widely accepted fact that changes in climate are occurring worldwide (IPCC 2007, p. 30). Understanding the effects of climate change on freshwater mussels is of crucial importance, because the extreme fragmentation of freshwater drainage systems, coupled with the limited ability of mussels to migrate, will make it particularly difficult for mussels to adjust their range in response to changes in climate (Strayer 2008, p. 30). For example, changes in temperature and precipitation can increase the likelihood of flooding or increase drought duration and intensity, resulting in direct impacts to freshwater mussels (Golladay *et al.* 2004, p. 503; Hastie *et al.* 2003, pp. 40–43). Indirect effects of climate change may include declines in host fish stocks, sea level rise, habitat reduction, and changes in human activity in response to climate change (Hastie *et al.* 2003, pp. 43–44).

Population Fragmentation and Isolation

Most of the remaining spectaclecase and sheepnose populations are small and isolated and thus are susceptible to genetic drift, inbreeding depression, and random or chance changes to the environment, such as toxic chemical spills (Avise and Hamrick 1996, pp. 463–466; Smith 1990, pp. 311–321; Watters and Dunn 1995, pp. 257–258 Inbreeding depression can result in death, decreased fertility, smaller body size, loss of vigor, reduced fitness, and various chromosome abnormalities (Smith 1990, pp. 311–321). Despite any evolutionary adaptations for rarity, habitat loss and degradation increase a species' vulnerability to extinction (Noss and Cooperrider 1994, pp. 58–62). Numerous authors (including Noss and Cooperrider 1994, pp. 58–62; Thomas 1994, p. 373) have indicated that the probability of extinction increases with decreasing habitat availability. Although changes in the environment may cause populations to fluctuate naturally, small and low-density populations are more likely to fluctuate below a minimum viable population (the minimum or threshold number of individuals needed in a population to persist in a viable state for a given interval) (Gilpin and Soule 1986, pp. 25–33; Shaffer 1981, p. 131; Shaffer and Samson 1985, pp. 148–150).

These species were widespread throughout much of the upper two-thirds of the Mississippi River system, for example, when few natural barriers existed to prevent migration (via host species) among suitable habitats. Construction of dams, however, destroyed many spectaclecase and sheepnose populations and isolated others. Recruitment reduction or failure is a potential problem for many small sheepnose populations rangewide, a potential condition exacerbated by its reduced range and increasingly isolated populations. If these trends continue, further significant declines in total sheepnose population size and consequent reduction in long-term survivability may soon become apparent.

Spectaclecase are long-lived (up to 70 years; Havlik 1994, p. 19) while sheepnose are relatively long-lived (approximately 30 years; Watters *et al.* 2009, p. 221) Therefore, it may take decades for non-reproducing populations of both species to become extinct following their isolation by, for example, the construction of a dam. The occasional discovery of relatively young spectaclecase in river reaches between impoundments indicates that some post-impoundment recruitment has occurred. The level of recruitment in these cases, however, appears to be insufficient to ensure the long-term sustainability of the spectaclecase. Small isolated populations of spectaclecase and sheepnose that may now be comprised predominantly of adult specimens could be dying out slowly in the absence of recruitment, even without other threats described above. Isolated populations usually face other threats that result in continually decreasing patches of suitable habitat.

Genetic considerations for managing imperiled mussels and for captive propagation were reviewed by Neves (1997a, p. 1422) and Jones *et al.* (2006, pp. 527–535), respectively. The likelihood is high that some populations of the spectaclecase and sheepnose are below the effective population size (EPS) (Soule 1980, pp. 162–164) necessary to adapt to environmental change and persist in the long term. Isolated populations eventually die out when population size drops below the EPS or threshold level of sustainability. Evidence of recruitment in many populations of these two species is scant, making recruitment reduction or outright failure suspect. These populations may be experiencing the bottleneck effect of not attaining the effective population size. Small, isolated, below effective population size-threshold populations of short-lived species (most host fishes) theoretically die out within a decade or so, while below-threshold populations of long-lived species, such as the spectaclecase and sheepnose, might take decades to die out even given years of total recruitment failure. Without historical barriers to genetic interchange, small, isolated populations could be slowly expiring, a phenomenon termed the extinction debt (Tilman *et al.* 1994, pp. 65–66). Even given the totally improbable absence of anthropogenic threats, we may lose disjunct populations to below-threshold effective population size. However, evidence indicates that general degradation continues to decrease habitat patch size and to act insidiously in the decline of spectaclecase and sheepnose populations.

Spectaclecase and sheepnose mussels' scarcity and decreased population size makes maintaining adequate heterogeneity problematic for resource managers. Neves (1997b, p. 6) warned that "[i]f we let conservation genetics become the goal rather than the guidelines for restoring and recovering mussel populations, then we will be doomed to failure with rare species." Habitat alteration, not lack of genetic variability, is the driving force of population extirpation (Caro and Laurenson 1994, pp. 485–486; Neves *et al.* 1997, p. 60). Nevertheless, genetics issues should be considered in maintaining high levels of heterozygosity during spectaclecase recovery efforts. Treating disjunct occurrences of this wide-ranging species as a metapopulation would facilitate conservation management while increasing recovery options (for example, translocating adults or introducing infested hosts and propagated juveniles) to establish and maintain viable populations (Neves 1997b, p. 6). Due to small population size and probable reduction of genetic diversity within populations, efforts should be made to maximize genetic heterogeneity to avoid both inbreeding (Templeton & Read 1984, p. 189) and outbreeding depression (Avise & Hamrick 1996, pp. 463–466) whenever feasible in propagation and translocation efforts (Jones *et al.* 2006, p. 529).

We find that fragmentation and isolation of small remaining populations of the spectaclecase and sheepnose are current and ongoing threats to both species throughout all of their ranges that will continue into the foreseeable future. Further, stochastic events may play a magnified role in population extirpation when small, isolated populations are involved.

Exotic Species

Various exotic or nonnative species of aquatic organisms are firmly established in the range of the spectaclecase and sheepnose. The exotic species that poses the most significant threat to the spectaclecase and sheepnose is the zebra mussel (*Dreissena polymorpha*). Its invasion of freshwater habitats in the United States poses a threat to mussel faunas in many regions, and species' extinctions are expected as a result of its continued spread in the eastern United States (Ricciardi *et al.* 1998, p. 615). Strayer (1999, pp. 75–80) reviewed in detail the mechanisms in which zebra mussels impact native mussels. The primary means of impact is direct fouling of the shells of live native mussels. Zebra mussels attach in large numbers to the shells of live native mussels and are implicated in the loss of entire native mussel beds. Fouling impacts include impeding locomotion (both laterally and vertically), interfering with normal valve movements, deforming valve margins, and locally depleting food resources and increasing waste products. Heavy infestations of zebra mussels on native mussels may overly stress the animals by reducing their energy stores. They may also reduce food concentrations to levels too low to support reproduction, or even survival in extreme cases.

Other ways zebra mussels may impact spectaclecase and sheepnose is through filtering their sperm and possibly glochidia from the water column, thus reducing reproductive potential. Habitat for native mussels may also be degraded by large deposits of zebra mussel pseudofeces (undigested waste material passed out of the incurrent siphon) (Vaughan 1997, p. 11). Because spectaclecase are found in pools and zebra mussel veligers (larvae) attach to hard substrates at the point at which they settle out from the water column, spectaclecase are particularly vulnerable to zebra mussel invasion. The spectaclecase's colonial tendency could allow for very large numbers to be affected by a single favorable year for zebra mussels.

Zebra mussels are established throughout the upper Mississippi, lower St. Croix, Ohio, and Tennessee Rivers, overlapping much of the current range of the spectaclecase and sheepnose. The greatest potential for present zebra mussel impacts to the spectaclecase and sheepnose appears to be in the upper Mississippi River. Kelner and Davis (2002, p. ii) stated that zebra mussels in the Mississippi River from Mississippi River Pool 4 downstream are "extremely abundant and are decimating the native mussel communities." Huge numbers of dead and live zebra mussels cover the bottom of the river in some localities up to 1 to 2 inches (2.5 to 5.1 centimeters (cm)) deep (Havlik 2001a, p. 16), where they have reduced significantly the quality of the habitat with their pseudofeces (Fraley 2008, pers. comm.). Zebra mussels likely have reduced spectaclecase and sheepnose populations in these heavily infested waters.

As zebra mussels may maintain high densities in big rivers, large tributaries, and below infested reservoirs, spectaclecase and sheepnose populations in affected areas may be significantly impacted. For example, zebra mussel densities in the Tennessee River remained low until 2002, but are now abundant enough below Wilson Dam to be measured quantitatively (Garner 2008, pers. comm.). In addition, there is long-term potential for zebra mussel invasions into other systems that currently harbor spectaclecase and sheepnose populations. Zebra mussels occur in the lower St. Croix River, one of the strongholds for spectaclecase, although it is unclear whether they are likely to spread much further upstream due to the transition from lake-like conditions to almost exclusively riverine conditions above RM 25.

The Asian clam (*Corbicula fluminea*) has spread throughout the range of the spectaclecase and sheepnose since its introduction in the mid-1900s. Asian clams compete with native mussels, especially juveniles, for food, nutrients, and space (Leff *et al.* 1990, p. 415; Neves & Widlak 1987, p. 6) and may ingest unionid sperm, glochidia, and newly metamorphosed juveniles of native mussels (Strayer 1999, p. 82; Yeager *et al.* 2000, p. 255). Dense Asian clam populations actively disturb sediments that may reduce habitat for juveniles of native mussels (Strayer 1999, p. 82).

Asian clam densities vary widely in the absence of native mussels or in patches with sparse mussel concentrations, but Asian clam density is never high in dense mussel beds, indicating that the clam is unable to successfully invade small-scale habitat patches with high unionid biomass (Vaughn & Spooner 2006, pp. 334–335). The invading clam therefore appears to preferentially invade sites where mussels are already in decline (Strayer 1999, pp. 82–83; Vaughn & Spooner 2006, pp. 332–336) and does not appear be a causative factor in the decline of mussels in dense beds. However, an Asian clam population that thrives in previously stressed, sparse mussel populations might exacerbate unionid imperilment through competition and impeding mussel population expansion (Vaughn & Spooner 2006, pp. 335–336).

A molluscivore (mollusk eater), the black carp (*Mylopharyngodon piceus*) is a potential threat to native mussels (Strayer 1999, p. 89); it has been introduced into North America since the 1970s. The species has been proposed for widespread use by aquaculturists to control snails, the intermediate host of a trematode (flatworm) parasite that affects catfish in commercial culture ponds in the southeast and lower Midwest. Black carp are known to eat clams (*Corbicula* spp.) and unionid mussels in China, in addition to snails. They are the largest of the Asian carp species, reaching more than 4 ft. in length and achieving a weight in excess of 150 pounds (Nico & Williams 1996, p. 6). Foraging rates for a 4-year-old fish average 3 or 4 pounds (1.4–1.8 kg) a day, indicating that a single individual could consume 10 tons (9,072 kg) of native mollusks over its lifetime (MICRA 2005, p. 1). In 1994, 30 black carp escaped from an aquaculture facility in Missouri during a flood. Other escapes into the wild by non-sterile black carp are likely to occur.

The round goby (*Neogobius melanostomus*) is another exotic fish species released into the Great Lakes that is well established and likely to spread through the Mississippi River system (Strayer 1999, pp. 87–88). This species is an aggressive competitor of similar sized benthic fishes (sculpins, darters), as well as a voracious carnivore, despite its size (less than 10 in. (25.4 cm) in length), preying on a variety of foods, including small mussels and fishes that could serve as glochidial hosts (Janssen and Jude 2001, p. 325; Strayer 1999, p. 88). Round gobies may therefore have important indirect effects on the spectaclecase and sheepnose through negative effects to their hosts.

Additional exotic species will invariably become established in the foreseeable future (Strayer 1999, pp. 88–89). Added to potential direct threats, exotic species could carry diseases and parasites that may be devastating to the native biota. Because of our ignorance of mollusk diseases and parasites, "it is imprudent to conclude that alien diseases and parasites are unimportant" (Strayer 1999, p. 88).

Exotic species, such as those described above, are an ongoing threat to the spectaclecase and sheepnose—a threat that is likely to increase as these exotic species expand their occupancy within the ranges of the spectaclecase and sheepnose.

Summary of Threats

The decline of the spectaclecase and sheepnose in the eastern United States (described by Butler 2002a, entire; Butler 2002b, entire) is primarily the result of habitat loss and degradation (Neves 1991, p. 252). These losses have been well documented since the mid-19th century (Higgins 1858, p. 550). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Neves 1991, p. 252; Neves 1993, pp. 4–6; Neves *et al.* 1997, pp. 60, 63–75; Watters 2000, pp. 262–267; Williams *et al.* 1993, pp. 7–9). These stressors have had profound impacts on sheepnose and spectaclecase populations and their habitat.

The majority of the remaining populations of the spectaclecase and sheepnose are generally small and geographically isolated (Butler 2002a, p. 27; 2002b, p. 27). The patchy distributional pattern of populations in short river reaches makes them much more susceptible to extirpation from single catastrophic events, such as toxic chemical spills (Watters and Dunn 1995, p. 257). Furthermore, this level of isolation makes natural repopulation of any extirpated population virtually impossible without human intervention. In addition, the fish host of spectaclecase is unknown; thus, propagation to reestablish the species in restored habitats and to maintain non-reproducing populations and focused conservation of its fish host are currently not possible. Although there are ongoing attempts to alleviate some of these threats at some locations, there appear to be no populations without significant threats, and many threats are without obvious or readily available solutions.

Recruitment reduction or failure is a threat for many small spectaclecase and sheepnose populations rangewide, a condition exacerbated by reduced range and increasingly isolated populations (Butler 2002a, p. 28; 2002b, p. 28). If these trends continue, further significant declines in total spectaclecase and sheepnose population size and consequent reduction in long-term viability may soon become apparent.

Various exotic species of aquatic organisms are firmly established in the range of the spectaclecase and sheepnose. The exotic species that poses the most significant threat to the spectaclecase and sheepnose is the zebra mussel. The invasion of the zebra mussel poses a serious threat to mussel faunas in many regions, and species extinctions are expected as a result of its continued spread in the eastern United States (Ricciardi *et al.* 1998, p. 618).

Proposed Determination

The Act defines an endangered species as any species that is "in danger of extinction throughout all or a significant portion of its range" and a threatened species as any species "that is likely to become endangered throughout all or a significant portion of its range within the foreseeable future." We find that the spectaclecase and sheepnose are presently in danger of extinction throughout their entire range, based on the immediacy, severity, and scope of the threats described under Factors A, D, and E, above. Although there are ongoing attempts to alleviate some threats, there appear to be no populations without current significant threats, and many threats are without obvious or readily available solutions. These isolated species have a limited ability to recolonize historically occupied stream and river reaches and are vulnerable to natural or human-caused changes in their stream and river habitats. Their range curtailment, small population size, and isolation make the spectaclecase and sheepnose more vulnerable to threats such as sedimentation, disturbance of riparian corridors, changes in channel morphology, point and nonpoint source pollutants, urbanization, and introduced species and to stochastic events (for example, chemical spills). Therefore, on the basis of the best available scientific and commercial information, we propose listing the spectaclecase and sheepnose as endangered in accordance with sections 3(6) and 4(a)(1) of the Act.

Under the Act and our implementing regulations, a species may warrant listing if it is endangered or threatened throughout all or a significant portion of its range. Threats to the spectaclecase and sheepnose occur throughout their ranges; therefore, we assessed the status of the species throughout their entire ranges. The threats to the survival of the species occur throughout the species' ranges and are not restricted to any particular significant portion of those ranges. Accordingly, our assessment and proposed determination applies to both species throughout their entire ranges.

Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened under the Act include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain practices. Recognition through listing encourages and results in public awareness and conservation by Federal, State, and local agencies, private organizations, and individuals. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The protection required of Federal agencies and the prohibitions against take and harm are discussed, in part, below.

The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Subsection 4(f) of the Act requires the Service to develop and implement recovery plans for the conservation of endangered and threatened species, unless such a plan will not promote the conservation of the species. The recovery planning process involves the identification of actions that are necessary to halt or reverse the species' decline by addressing the threats to its survival and recovery. The goal of this process is to restore listed species to a point where they are secure, self-sustaining, and functioning components of their ecosystems.

Recovery planning includes the development of a recovery outline shortly after a species is listed, preparation of a draft and final recovery plan, and revisions to the plan as significant new information becomes available. The recovery outline guides the immediate implementation of urgent recovery actions and describes the process to be used to develop a recovery plan. The recovery plan identifies site-specific management actions that will achieve recovery of the species, measurable criteria that determine when a species may be downlisted or delisted, and methods for monitoring recovery progress. Recovery plans also establish a framework for agencies to coordinate their recovery efforts and provide estimates of the cost of implementing recovery tasks. Recovery teams (comprised of species experts, Federal and State agencies, non-government organizations, and stakeholders) are often established to develop recovery plans. When completed, the recovery outline, draft recovery plan, and the final recovery plan will be available on our Web site (*http://www.fws.gov/endangered*), or from our Rock Island, Illinois, Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section).

Implementation of recovery actions generally requires the participation of a broad range of partners, including other Federal agencies, States, Tribal, nongovernmental organizations, businesses, and private landowners. Examples of recovery actions include habitat restoration (e.g., restoration of native vegetation), research, captive propagation and reintroduction, and outreach and education. The recovery of many listed species cannot be accomplished solely on Federal lands because their range may occur primarily or solely on non-Federal lands. To achieve recovery of these species requires cooperative conservation efforts on private, State, and Tribal lands.

Listing will also require the Service to review any actions on Federal lands and activities under Federal jurisdiction that may adversely affect the two species; allow State plans to be developed under section 6 of the Act; encourage scientific investigations of efforts to enhance the propagation or survival of the animals under section 10(a)(1)(A) of the Act; and promote habitat conservation plans on non-Federal lands and activities under section 10(a)(1)(B) of the Act.

Section 7(a) of the Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is proposed or listed as endangered or threatened and with respect to its critical habitat, if any is designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. Federal agencies are required to confer with us informally on any action that is likely to jeopardize the continued existence of a proposed species. Section 7(a)(4) requires Federal agencies to confer with the Service on any action that is likely to jeopardize the continued existence of a species proposed for listing or result in destruction or adverse modification of proposed critical habitat. If a species is listed subsequently, section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the species or destroy or adversely modify its critical habitat. If a Federal action may adversely affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation with the Service.

Federal activities that may affect the sheepnose and spectaclecase include, but are not limited to, the funding of, carrying out of, or the issuance of permits for reservoir construction, natural gas extraction, stream alterations, discharges, wastewater facility development, water withdrawal projects, pesticide registration, mining, and road and bridge construction.

Jeopardy Standard

Prior to and following listing and designation of critical habitat, if prudent and determinable, the Service applies an analytical framework for jeopardy analyses that relies heavily on the importance of core area populations to the survival and recovery of the species. The section 7(a)(2) analysis is focused not only on these populations but also on the habitat conditions necessary to support them.

The jeopardy analysis usually expresses the survival and recovery needs of the species in a qualitative fashion without making distinctions between what is necessary for survival and what is necessary for recovery. Generally, if a proposed Federal action is incompatible with the viability of the affected core area population(s), inclusive of associated habitat conditions, a jeopardy finding is considered to be warranted, because of the relationship of each core area population to the survival and recovery of the species as a whole.

Section 9 Take

Section 9(a)(2) of the Act, and its 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 (includes harass, harm, pursue, hunt, shoot, wound, kill, trap, or collect, or to attempt any of these), import or export, ship in interstate commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It also is illegal to knowingly possess, sell, deliver, carry, transport, or ship any wildlife that has been taken illegally. Certain exceptions apply to agents of the Service and State conservation agencies.

We may issue permits to carry out otherwise prohibited activities involving endangered wildlife species under certain circumstances. Regulations governing permits are at 50 CFR 17.22 for endangered species. Such permits are available for scientific purposes, to enhance the propagation or survival of the species, or for incidental take in connection with otherwise lawful activities.

Our policy, as published in the **Federal Register** on July 1, 1994 (59 FR 34272), is to identify, to the maximum extent practicable, those activities that would or would not likely constitute a violation of section 9 of the Act. The intent of this policy is to increase public awareness as to the potential effects of this final listing on future and ongoing activities within a species' range. We believe that the following activities are unlikely to result in a violation of section 9:

(1) Existing discharges into waters supporting these species, provided these activities are carried out in accordance with existing regulations and permit requirements (for example, activities subject to sections 402, 404, and 405 of the Clean Water Act and discharges regulated under the National Pollutant Discharge Elimination System).

(2) Actions that may affect the spectaclecase or sheepnose and are authorized, funded, or carried out by a Federal agency when the action is conducted in accordance with any reasonable and prudent measures we have specified in accordance with section 7 of the Act.

(3) Development and construction activities designed and implemented under Federal, State, and local water quality regulations and implemented using approved best management practices.

(4) Existing recreational activities, such as swimming, wading, canoeing, and fishing, that are in accordance with State and local regulations, provided that if a spectaclecase or sheepnose is collected, it is immediately released, unharmed.

Activities that we believe could potentially result in take of spectaclecase or sheepnose include but are not limited to:

(1) Illegal collection or capture of the species;

(2) Unlawful destruction or alteration of the species' occupied habitat (for example, unpermitted instream dredging, channelization, or discharge of fill material);

(3) Violation of any discharge or water withdrawal permit within the species' occupied range; and

(4) Illegal discharge or dumping of toxic chemicals or other pollutants into waters supporting spectaclecase or sheepnose.

We will review other activities not identified above on a case-by-case basis to determine whether they are likely to result in a violation of section 9 of the Act. We do not consider these lists to be exhaustive and provide them as information to the public.

You should direct questions regarding whether specific activities may constitute a future violation of section 9 to the Field Supervisor of the Service's Rock Island, Illinois Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section). You may request copies of the regulations regarding listed wildlife from and address questions about prohibitions and permits to the U.S. Fish and Wildlife Service, Ecological Services Division, Henry Whipple Federal Building, 1 Federal Drive, Fort Snelling, MN 55111 (Phone (612) 713–5350; Fax (612) 713–5292).

Critical Habitat

Background

Critical habitat is defined in section 3 of the Act as:

(i) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features

(I) Essential to the conservation of the species, and

(II) That may require special management considerations or protection; and

(ii) Specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.

Conservation is defined in section 3 of the Act as the use of all methods and procedures needed to bring the species to the point at which listing under the Act is no longer necessary.

Critical habitat receives protection under section 7 of the Act through the prohibition against Federal agencies carrying out, funding, or authorizing the destruction or adverse modification of critical habitat. Section 7(a)(2) requires consultation on Federal actions that may affect critical habitat. The designation of critical habitat does not affect land ownership or establish a refuge, wilderness, reserve, preserve, or other conservation area. Such designation does not allow the government or public to access private lands. Such designation does not require implementation of restoration, recovery, or enhancement measures by non-Federal landowners. Where a landowner seeks or requests Federal agency funding or authorization for an action that may affect a listed species or critical habitat, the consultation requirements of section 7(a)(2) of the Act would apply, but even in the event of a destruction or adverse modification finding, the obligation of the Federal action agency and the applicant is not to restore or recover the species, but to implement reasonable and prudent alternatives to avoid destruction or adverse modification of critical habitat.

Prudency Determination

Section 4(a)(3) of the Act, as amended, and implementing regulations (50 CFR 424.12), require that, to the maximum extent prudent and determinable, we designate critical habitat at the time the species is determined to be endangered or threatened. Our regulations (50 CFR 424.12(a)(1)) state that the designation of critical habitat is not prudent when one or both of the following situations exist: (1) The species is threatened by taking or other human activity, and identification of critical habitat can be expected to increase the degree of threat to the species, or (2) such designation of critical habitat would not be beneficial to the species.

There is currently no imminent threat of take attributed to collection or vandalism under Factor B (overutilization for commercial, recreational, scientific, or educational purposes) for sheepnose and spectaclecase and identification of critical habitat is not expected to initiate such a threat. In the absence of finding that the designation of critical habitat would increase threats to a species, if there are any benefits to a critical habitat designation, then a prudent finding is warranted. The potential benefits include: (1) Triggering consultation under section 7(a)(2) of the Act, in new areas for actions in which there may be a Federal nexus where it would not otherwise occur because the species may not be present; (2) focusing conservation activities on the most essential habitat features and areas; (3) increasing awareness of important habitat areas among State or county governments or private entities; and (4) preventing inadvertent harm to the species.

Critical habitat designation includes the identification of the physical and biological features of the habitat essential to the conservation of each species that may require special management and protection. As such, these designations will provide useful information to individuals, local and State governments, and other entities engaged in activities or long-range planning that may affect areas essential to the conservation of the species. Conservation of the spectaclecase and sheepnose and essential features of their habitats will require habitat management, protection, and restoration, which will be facilitated by disseminating information on the locations and the key physical and biological features of those habitats. In the case of spectaclecase and sheepnose, these aspects of critical habitat designation would potentially benefit the conservation of the species. Therefore, since we have determined that the designation of critical habitat will not likely increase the degree of threat to these species and may provide some measure of benefit, we find that designation of critical habitat is prudent for the spectaclecase and sheepnose.

Primary Constituent Elements

In accordance with sections 3(5)(A)(i) and 4(b)(1)(A) of the Act and regulations at 50 CFR 424.12, in determining which areas to propose as critical habitat, we must consider those physical and biological features—primary constituent elements in the necessary and appropriate quantity and spatial arrangement—essential to the conservation of the species. We must also consider those areas essential to the conservation of the species that are outside the geographical area occupied by the species. Primary constituent elements include, but are not limited to:

(1) Space for individual and population growth and for normal behavior;

(2) Food, water, air, light, minerals, or other nutritional or physiological requirements;

(3) Cover or shelter;

(4) Sites for breeding, reproduction, and rearing (or development) of offspring; and

(5) Habitats that are protected from disturbance or are representative of the historical, geographical, and ecological distribution of a species.

We are currently unable to identify the primary constituent elements for spectaclecase and sheepnose because information on the physical and biological features that are considered essential to the conservation of these species is not known at this time. The apparent poor viability of the species' occurrences observed in recent years indicates that current conditions are not sufficient to meet the basic biological requirements of these species in many rivers. Since spectaclecase and sheepnose have not been observed for decades in many of their historical locations, and much of the habitat in which they still persists has been drastically altered, the optimal conditions that would provide the biological or ecological requisites of these species are not known. Although we can surmise that habitat degradation from a variety of factors has contributed to the decline of these species, we do not know specifically what essential physical or biological features of that habitat are currently lacking for spectaclecase and sheepnose.

Key features of the basic life history, ecology, reproductive biology, and habitat requirements of most mussels, including spectaclecase and sheepnose, are unknown. Species-specific ecological requirements have not been determined (for example, minimum water flow and effects of particular pollutants). Population dynamics, such as species' interactions and community structure, population trends, and population size and age class structure necessary to maintain a long-term viability, have not been determined for these species. Basics of reproductive biology for these species are unknown, such as age and size at earliest maturity, reproductive longevity, and the level of recruitment needed for species survival and long-term viability. Of particular concern to the spectaclecase is the lack of known host(s) species essential for glochidia survival and reproductive success. Similarly, although recent laboratory studies have produced successful transformation of sheepnose glochidia on a few fish species, many questions remain concerning the natural interactions between the sheepnose and its known hosts. Because the host(s) for spectaclecase is unknown and little is known about the sheepnose hosts, there is a degree of uncertainty at this time as to which specific areas might be essential to the conservation of these species (for example, the host(s)'s biological needs and population sizes necessary to support mussel reproduction and population viability) and thus meet a key aspect of the definition of critical habitat. As we are unable to identify many physical and biological features essential to the conservation of spectaclecase and sheepnose, we are unable to identify areas that contain these features. Therefore, although we have determined that the designation of critical habitat is prudent for spectaclecase and sheepnose, because the biological and physical requirements of these species are not sufficiently known, we find that critical habitat for spectaclecase and sheepnose is not determinable at this time.

Peer Review

In accordance with our policy, "Notice of Interagency Cooperative Policy for Peer Review in Endangered Species Act Activities," that was published on July 1, 1994 (59 FR 34270), we will seek the expert opinion of at least three appropriate independent specialists regarding this proposed rule. The purpose of such review is to ensure listing decisions are based on scientifically sound data, assumptions, and analysis. We will send copies of this proposed rule to the peer reviewers immediately following publication in the **Federal Register**. We will invite these peer reviewers to comment, during the public comment period, on the specific assumptions and the data that are the basis for our conclusions regarding the proposal to list spectaclecase and sheepnose as endangered and our proposal regarding critical habitat for this species.

Required Determinations

Clarity of the Rule

We are required by Executive Orders 12866 and 12988 and by the Presidential Memorandum of June 1, 1998, to write all rules in plain language. This means that each rule we publish must:

(a) Be logically organized;

(b) Use the active voice to address readers directly;

(c) Use clear language rather than jargon;

(d) Be divided into short sections and sentences; and

(e) Use lists and tables wherever possible.

If you feel that we have not met these requirements, send us comments by one of the methods listed in the **ADDRESSES** section. To better help us revise the rule, your comments should be as specific as possible. For example, you should tell us the names of the sections or paragraphs that are unclearly written, which sections or sentences are too long, the sections where you feel lists or tables would be useful, etc.

Executive Order 13211

On May 18, 2001, the President issued Executive Order 13211 on regulations that significantly affect energy supply, distribution, and use. Executive Order 13211 requires agencies to prepare Statements of Energy Effects when undertaking certain actions. This rule is not expected to significantly affect energy supplies, distribution, or use. Therefore, this action is not a significant energy action, and no Statement of Energy Effects is required.

Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.)

This proposed rule does not contain any new collections of information that require approval by the Office of Management and Budget (OMB) under the Paperwork Reduction Act. The rule would not impose new recordkeeping or reporting requirements on State or local governments, individuals, businesses, or organizations. We may not conduct or sponsor, and you are not required to respond to, a collection of information unless it displays a currently valid OMB control number.

National Environmental Policy Act

We determined that we do not need to prepare an environmental assessment, as defined under the authority of the National Environmental Policy Act of 1969 (42 U.S.C. 4321 *et seq.*), in connection with regulations adopted under section 4(a) of the Act. We published a notice outlining our reasons for this determination in the **Federal Register** on October 25, 1983 (48 FR 49244).

References Cited

A complete list of all references cited in this rule is available on the Internet at *http://www.regulations.gov* or upon request from the Field Supervisor, Rock Island, Illinois Ecological Services Field Office (*see* **FOR FURTHER INFORMATION CONTACT** section).

Authors

The primary authors of this proposed rule are the staff members of the Service's Rock Island and Twin Cities Field Offices (see **FOR FURTHER INFORMATION CONTACT** section).

List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and recordkeeping requirements, Transportation.

Proposed Regulation Promulgation

Accordingly, we propose to amend part 17, subchapter B of chapter I, title 50 of the Code of Feral Regulations, as follows:

PART 17—[AMENDED]

1. The authority citation for part 17 continues to read as follows:

Authority: 16 U.S.C. 1361–1407; 16 U.S.C. 1531–1544; 16 U.S.C. 4201–4245; Pub. L. 99–625, 100 Stat. 3500; unless otherwise noted.

2. In § 17.11(h) add the entries for "Sheepnose" and "Spectaclecase" in alphabetical order under CLAMS to the List of Endangered and Threatened Wildlife, as follows:

§ 17.11 Endangered and threatened wildlife.

* * * * *

(h) * * *

Species		Historical range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
*	*	*	*	*	*	*	
CLAMS							
*	*	*	*	*	*	*	
Sheepnose	*Plethobasus cyphyus*	U.S.A. (AL, IL, IN, IA, KY, MN, MS, MO, OH, PA, TN, VA, WV, WI).	NA	E		NA	NA
*	*	*	*	*	*	*	
Spectaclecase	*Cumberlandia monodonta*.	U.S.A. (AL, AR, IL, IN, IA, KS, KY, MN, MO, NE, OH, TN, VA, WV, WI).	NA	E		NA	NA
*	*	*	*	*	*	*	

*   *   *   *   *

Dated: December 16, 2010.

Rowan W. Gould,

Acting Director, U.S. Fish and Wildlife Service.

[FR Doc. 2011–469 Filed 1–18–11; 8:45 am]

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