U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Plethobasus cyphyus*

COMMON NAME: Sheepnose

LEAD REGION: Region 3

INFORMATION CURRENT AS OF: April 16, 2007

STATUS/ACTION:

___ Species assessment - determined species did not meet the definition of endangered or threatened under the Act and, therefore, was not elevated to Candidate status

___ New candidate

_X_ Continuing candidate

_X_ Non-petitioned

___ Petitioned - Date petition received:

__ 90-day positive - FR date:

__ 12-month warranted but precluded - FR date:

__ Did the petition requesting a reclassification of a listed species?

FOR PETITIONED CANDIDATE SPECIES:

a. Is listing warranted (if yes, see summary of threats below)?

b. To date, has publication of a proposal to list been precluded by other higher priority listing actions?

c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded.

___ Listing priority change

Former LP: ___

New LP: ___

Date when the species first became a Candidate (as currently defined): May 4, 2004

___ Candidate removal: Former LP: __

___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

___ F – Range is no longer a U.S. territory.

I – Insufficient information exists on biological vulnerability and threats to support listing.

___ M – Taxon mistakenly included in past notice of review.

___ N – Taxon does not meet the Act's definition of "species."

___ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Clam, freshwater mussel, family Unionidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Butler (2002) summarized the historic distribution. Historically, the sheepnose occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system and most lowland tributaries in the lower Mississippi River system. This species is known from the Mississippi, Ohio, Cumberland, Tennessee, and Ohio main stems, and scores of tributary streams rangewide. The sheepnose was historically known from 77 streams (including 1 canal) in 15 states and 3 Service regions (3, 4, and 5). These states are Minnesota, Wisconsin, Iowa, Illinois, Missouri, Ohio, West Virginia, Indiana, Kansas, Kentucky, Tennessee, Alabama, Mississippi, Pennsylvania, and Virginia.

CURRENT STATES/ COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Butler (2002) summarized the extant distribution. Extant populations of the sheepnose are known from 26 streams in the following 14 states (listed with streams): Alabama (Tennessee River), Illinois (Mississippi, Kankakee, Ohio [*contra* Cummings and Mayer 1997], Wabash Rivers), Indiana (Ohio, Wabash, Tippecanoe, Eel Rivers), Iowa (Mississippi River), Kentucky (Ohio, Licking, Kentucky, Green, Cumberland Rivers), Minnesota (Mississippi, St. Croix Rivers), Mississippi (Big Sunflower River), Missouri (Mississippi, Meramec, Bourbeuse, Osage Fork Gasconade Rivers), Ohio (Ohio, Muskingum Rivers), Pennsylvania (Allegheny River, Tionesta Creek), Tennessee (Duck, Tennessee, Holston, Clinch, Powell Rivers), Virginia (Clinch, Powell Rivers), West Virginia (Ohio, Kanawha Rivers), and Wisconsin (Mississippi, St. Croix, Chippewa, Flambeau, Wisconsin Rivers). Region 3 has the most extant streams of occurrence with 14, while Region 4 has 9, and Region 5 has 5.

LAND OWNERSHIP:
Numerous parcels of public land (e.g., state parks, state forests, wildlife management areas) occur along historic and extant streams of occurrence for the sheepnose or in their respective watersheds. However, vast tracts of riparian lands are privately owned. The sheepnose is a large river species. Riparian activities that occur outside or upstream of public lands may have a significant impact on their populations. Habitat protection benefits on public lands may be offset by detrimental activities upstream in the watershed. Following are some of the more significant public lands associated with important sheepnose populations.

The Upper Mississippi River National Wildlife and Fish Refuge and the Mark Twain National Wildlife Refuge on the Upper Mississippi River extend from Hastings, Minnesota, to downstream of Quincy, Illinois, encompassing about 265,000 acres of islands, shoreline, and floodplain habitat.

The St. Croix River population of the sheepnose receives protection by being located in the St. Croix National Scenic Riverway, Minnesota and Wisconsin. Riparian lands associated with the Riverway provide a buffer between the river and activities that occur in adjacent areas. In addition, several state public lands lie adjacent to some sections of the Riverway providing additional buffering of lands along the St. Croix. Dunnville and Washington Creek State Wildlife Areas are located on the banks of the lower Chippewa and lower Flambeau Rivers, respectively. Much of the lower Wisconsin River is bordered by units of the Lower Wisconsin River State Wildlife Area. Other public lands include Badger Army Ammunition Plant and Tower Hill and Wyalusing State Parks.

Small units of public land along the Meramec River include Meramec, Pacific Palisades, and River Round Conservation Areas; and Meramec, Onandaga Cave, and Robertsville State Parks. Parts of the lower Big Piney River and significant reaches of the upper Gasconade River flow adjacent or through the Mark Twain National Forest. The lower Big Piney also flows through Ft. Leonard Wood Military Reservation.

The most important public land holding in the Ohio River is the Ohio River Islands National Wildlife Refuge. The refuge includes all or parts of 21 islands and 3 mainland tracts totaling 3,220 acres in the Ohio from RM 35 (Shippingport, Pennsylvania) downstream to RM 397 (Manchester, Ohio, and adjacent Kentucky). Lands are actively managed in six Ohio River pools (i.e., New Cumberland, Hannibal, Willow Island, Belleville, Racine, Meldahl). A refuge expansion is planned to include potentially thousands of acres of additional islands and mainland parcels from RM 0 at Pittsburgh to RM 437 at Meldahl Lock and Dam, Kentucky and Ohio, in the last three intervening pools (P. Morrison, Service, pers. comm., 2002). Tippecanoe River public lands include Tippecanoe River State Park, where sheepnose are known to be extant, the Potawatomi Wildlife Park, and Prophetstown State Park.

The Nature Conservancy (TNC) has made bioreserves along two stream systems harboring extant populations of the sheepnose: the upper Clinch/Powell River, Tennessee and Virginia; and upper Green River, Kentucky. A third, on the lower Licking River, Kentucky, is in the formative stages of development. Although TNC has few riparian inholdings in these watersheds, they have carried out aggressive and innovative community-based projects in both watersheds that address aquatic species and instream habitat conservation on multiple scales. They have worked with scores of riparian landowners to help them restore and protect streambanks and riparian zones and partner with various other stakeholders in conserving aquatic resources. In addition to the sheepnose, these activities aid in the recovery of 19 listed mussels and fishes in the Clinch (the largest concentration of aquatic listed species in North America) and 5 listed mussels and a cave shrimp in the Green. The location of Mammoth Cave National Park in the upper Green River provides a significant level of localized watershed protection for the sheepnose population in that system. A small portion of the Clinch River watershed (e.g., several small tributaries) is located in the Jefferson National Forest. A small amount of the middle portion of the Duck River watershed is protected by state owned land associated with Yanahli Wildlife Management Area.

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LEAD FIELD OFFICE CONTACT: Kristen Lundh, Rock Island Ecological Services Field Office, Moline, IL; 309-757-5800 x 215

BIOLOGICAL INFORMATION:

Species Description: The following description of the sheepnose is found in Butler (2002) and is generally summarized from Oesch (1984) and Parmalee and Bogan (1998). The sheepnose is a medium-sized mussel that reaches nearly 5.5 inches in length. The shape of the shell is elongate ovate and moderately inflated 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 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 (external shell surface) is generally smooth, shiny, rayless, and light yellow to a dull yellowish brown. Concentric ridges resulting from rest periods are usually darker. Key characters useful for distinguishing the sheepnose from other mussels is its shell color, the occurrence of central tubercles, and its outline.

<u>Taxonomy:</u> The sheepnose 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 (on the Ohio River in the vicinity of Louisville, Kentucky, and adjacent Indiana) (Parmalee and Bogan 1998). Parmalee and Bogan (1998) summarized the synonomy of the sheepnose. Over the years, the specific epithet of this species has been variably spelled *cyphya, scyphius, cyphius, cyphia, cyphyum,* and ultimately as *cyphyus.* The sheepnose or its synonyms have been placed in the genera *Unio*, *Pleurobema, Margarita,* and *Margaron.* It was ultimately placed in the genus *Plethobasus* by Ortmann (1919), where it remains today (Turgeon et al. 1998). The Service recognizes *Unio aesopus* and *U. compertus* as synonyms of *Plethobasus cyphyus*. Sheepnose is the 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). The Service also recognizes bullhead and clear profit as older common names for the sheepnose.

<u>Habitat/Life History:</u> The sheepnose is primarily a larger-stream species. It frequents shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984). Habitats with sheepnose may also have mud, cobble, and boulders. Specimens in larger rivers may occur in deep runs (Parmalee and Bogan 1998). Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives.

<u>Historical Range/Distribution:</u> Historically, the sheepnose was fairly widespread in many Mississippi River system streams, although rarely very common. Archaeological evidence on relative abundance indicates that it has been an uncommon or even rare species in many streams for centuries (Morrison 1942; Patch 1976; Parmalee et al. 1980, 1982; Parmalee and Bogan 1986; Parmalee and Hughes 1994), and relatively common in only a few (Bogan 1990). This species is known from the Mississippi, Ohio, Cumberland, Tennessee, and Ohio main stems, and scores of tributary streams rangewide. The sheepnose was historically known from 77 streams (including 1 canal) in 14 states and 3 Service regions (3, 4, and 5). These include by stream system (with tributaries) the following: upper Mississippi River system (Mississippi [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 Rivers]); and lower Mississippi River system (Hatchie, Black, Yazoo [Big Sunflower River], Big Black Rivers). The sheepnose historically occurred in Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin. These states comprise Service Regions 3 (Midwest), 4 (Southeast), and 5 (Northeast).

The sheepnose was last reported from some 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) and Neves (1991), the sheepnose has been extirpated throughout much of its former range or reduced to isolated populations. The last extant records for other streams are from several decades ago. The only records known from some streams are archeological specimens (e.g., Little Pigeon, Big Black, Yazoo Rivers; Saline Creek).

<u>Current Range/Distribution:</u> Populations of the sheepnose were generally considered extant if live or fresh dead specimens have been collected since the mid-1980s. Extant populations of the sheepnose are known from 26 streams in 14 states and all 3 regions. Region 3 has the most extant streams of occurrence with 14, while Region 4 has 9, and Region 5 has 5. These include by stream system (with tributaries) the following: upper Mississippi River system (Mississippi River [St. Croix, Chippewa (Flambeau River), Wisconsin, Kankakee, Meramec (Bourbeuse River) Rivers]); lower Missouri River system (Osage Fork Gasconade River); Ohio River system (Ohio River [Allegheny (Tionesta Creek), Muskingum (Walhonding River), Kanawha, Licking, Kentucky, Wabash, Tippecanoe, Eel, Green Rivers]); Cumberland River system (Cumberland River); Tennessee River system (Tennessee River [Duck, Holston, Clinch (Powell River) Rivers]); and lower Mississippi River system (Big Sunflower River). The 26 extant sheepnose populations occur in the following 14 states (with streams): Alabama (Tennessee River), Illinois (Mississippi, Kankakee, Ohio [*contra* Cummings and Mayer 1997], Wabash Rivers), Indiana (Ohio, Wabash, Tippecanoe, Eel Rivers), Iowa (Mississippi River), Kentucky (Ohio, Licking, Kentucky, Green, Cumberland Rivers), Minnesota (Mississippi, St. Croix Rivers), Mississippi (Big Sunflower River), Missouri (Mississippi, Meramec, Bourbeuse, Osage Fork Gasconade Rivers), Ohio (Ohio, Muskingum Rivers), Pennsylvania (Allegheny River, Tionesta Creek), Tennessee (Tennessee, Holston, Clinch, Powell Rivers), Virginia (Clinch, Powell Rivers), West Virginia (Ohio, Kanawha Rivers), and Wisconsin (Mississippi, St. Croix, Chippewa, Flambeau, Wisconsin Rivers).

Population Estimates/Status: The sheepnose has been eliminated from two-thirds of the total number of streams from which it was historically known (26 streams currently compared to 77 streams historically). This species has also been eliminated from long reaches of former habitat in hundreds of miles of rivers such as the Illinois and Cumberland, and from several reaches of the Mississippi and Tennessee Rivers.

The majority of the remaining populations of sheepnose are small and geographically isolated. 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. Furthermore, this level of isolation makes natural repopulation of any extirpated population virtually impossible without human intervention. Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression.

The likelihood is high that some populations of the sheepnose are below the effective population size required to maintain long-term genetic and population viability. 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 viability may soon become apparent.

THREATS :

A. The present or threatened destruction, modification, or curtailment of its habitat or range.

The decline of the sheepnose in the Mississippi River system and other mussel species in the eastern United States (described by Butler 2002) is primarily the result of habitat loss and degradation (Neves 1991). These losses have been well documented since the mid-19th century (Higgins 1858). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Williams et al. 1993; Neves 1991, 1993; Neves et al. 1997; Watters 2000). Bourgeoning human populations will invariably increase the likelihood that many if not all of the factors in this section will continue to impact extant sheepnose populations.

Impoundments
Impoundments result in the dramatic modification of riffle and shoal habitats and the resulting loss of mussel resources, especially in larger rivers. Neves et al. (1997) and Watters (2000) reviewed the specific effects of impoundments on freshwater mollusks. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, and energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; decreasing stability due to subsequent sedimentation; blocking host fish passage; and isolating mussel populations from fish hosts. Even small low-head dams can have some of these effects on mussels. The reproductive process of riverine mussels is generally disrupted by impoundments making the sheepnose unable to successfully

reproduce and recruit under reservoir conditions. Some recruitment, however, is thought to be occurring in large rivers with locks and dams (e.g., Ohio, Muskingum).

In addition, dams can also seriously alter downstream water quality and riverine habitat, and negatively impact tailwater mussel populations (Allan and Flecker 1993, Layzer et al. 1993, Neves et al. 1997, Watters 2000). These changes include thermal alterations immediately below dams; changes in channel characteristics, habitat availability, and flow regime; daily discharge fluctuations; increased sediment loads from bank sloughing; and altered host fish communities. Coldwater releases from large non-navigational dams and scouring of the river bed from highly fluctuating, turbulent tailwater flows have also been implicated in the demise of mussel faunas (Layzer et al. 1993). There is no evidence that the sheepnose may persist in hypolimnetic tailwater conditions.

Population losses due to impoundments have probably contributed more to the decline and imperilment of the sheepnose and other Mississippi River system mussels than has any other single factor. Large river habitat throughout nearly all of the range of the sheepnose has been impounded leaving generally short isolated patches of vestigial habitat generally in the vicinity below dams. The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries, which were once strongholds for the sheepnose (Ortmann 1918, 1925), are now impounded. For example, over 2,300 river miles (about 20 percent) of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater were impounded by TVA by 1971 (Tennessee Valley Authority 1971). A total of 36 major dams are located in the Tennessee River system.

Approximately 90 percent of the 562-mile length of the Cumberland River downstream of Cumberland Falls is impounded (three locks and dams and Wolf Creek Dam). Other major Corps impoundments on Cumberland River tributaries (e.g., Obey River, Caney Fork) have inundated over 100 miles of additional potential riverine habitat for the sheepnose. Coldwater releases from Wolf Creek, Dale Hollow (Obey River), and Center Hill (Caney Fork) Dams continue to adversely impact otherwise riverine habitat in the Cumberland River system for the sheepnose. One-third of the streams that the sheepnose was historically known from occur in the Tennessee and Cumberland River systems. Watters (2000) summarizes the tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems. The sheepnose has been all but eliminated from the Cumberland River system, and is now limited to a few highly isolated stream reaches in the Tennessee River system. This scenario is typical in many other parts of its range, and include numerous navigational locks and dams (e.g., upper Mississippi, Ohio, Allegheny, Muskingum, Kentucky, Green, Barren Rivers), some high-wall dams (e.g., Wisconsin, Kaskaskia, Walhonding, Tippecanoe Rivers), and many low-head dams (e.g., St. Croix, Chippewa, Flambeau, Wisconsin, Kankakee, Bourbeuse Rivers) that have contributed to the loss of sheepnose habitat. Sediment accumulations behind dams of all sizes generally preclude the occurrence of the sheepnose. The construction of high level dams in the Ohio River has therefore further reduced the extent of suitable habitat for the sheepnose and other riverine mussels.

Channelization

Dredging and channelization activities have profoundly altered riverine habitats nationwide. Hartfield (1993), Neves et al. (1997), and Watters (2000) reviewed the effects of channelization on freshwater mollusks. Channelization impacts a stream's physical characteristics (e.g., accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological composition (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) (Hartfield 1993, Hubbard et al. 1993).

Channel maintenance operations for barge navigation have impacted habitat for the sheepnose in many large rivers rangewide. Channel maintenance may result in profound impacts downstream (Stansbery 1970), such as increases in turbidity and sedimentation, which may smother benthic organisms. The entire length of the upper Kankakee River in Indiana was channelized decades ago. The sheepnose is considered extirpated from the upper Kankakee and is now restricted to an un-channelized portion of the river in Illinois. Periodic maintenance may continue to adversely affect this species in the Upper Mississippi, Ohio, Muskingum, and Tennessee Rivers. A huge amount of dredge spoil was dumped on a sheepnose bed in the Muskingum River in the 1990s (G.T. Watters, OSUM, pers. comm., 2001). In the Tennessee River, a plan to deepen the navigation channel has been proposed (D.W. Hubbs, TWRA, pers. comm., 2002).

Chemical Contaminants

Contaminants contained in point and non-point discharges can degrade water and substrate quality and adversely impact, if not destroy, mussel populations. Although chemical spills and other point sources of contaminants may directly result in mussel mortality, widespread decreases in density and diversity may result in part from the subtle pervasive effects of chronic low-level contamination (Naimo 1995). The effects of heavy metals and other contaminants on freshwater mussels were reviewed by Mellinger (1972), Fuller (1974), Havlik and Marking (1987), Naimo (1995), Keller and Lydy (1997), and Neves et al. (1997).

The effects of contaminants are especially profound on juvenile mussels (Robison et al. 1996), which can readily ingest contaminants adsorbed to sediment particles while feeding, and on the glochidia which appear to be very sensitive to toxicants (Goudreau et al. 1993, Jacobson et al. 1997). Even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts (Huebner and Pynnönen 1992). Cadmium appears to be the heavy metal most toxic to mussels (Havlik and Marking 1987), although chromium, copper, mercury, and zinc also negatively affect biological processes (Naimo 1995, Keller and Zam 1991, Jacobson et al. 1997, Keller and Lydy 1997).

Contaminants associated with households and urban areas, particularly those from industrial and municipal effluents, may include heavy metals, chlorine, phosphorus, and numerous organic compounds. Wastewater is discharged through National Pollution Discharge Elimination System (NPDES) permitted (and some non-permitted) sites throughout the country. Elimination sites are ubiquitous in watersheds with sheepnose populations, providing ample opportunities for some pollutants to enter streams. For instance, over 250 NPDES sites are located in the Meramec River system alone (Figure 28, Roberts and Bruenderman 2000).

Ammonia has been shown to be lethal to mussels at concentrations of 5.0 ppm (Havlik and Marking 1987). Ammonia is associated with animal feedlots, nitrogenous fertilizers, and the effluents of out-dated municipal wastewater treatment plants (Goodreau et al. 1993). In stream systems, ammonia is most prevalent at the substrate/water interface (Frazier et al. 1996). Due to its high level of toxicity and the fact that the highest concentrations occur in the microhabitat where mussels live, ammonia should be considered among the factors potentially limiting survival and recovery of mussels at some locations (Augspurger et al. in prep.).

Agricultural sources of chemical contaminants are considerable, and include two broad categories: nutrient enrichment (e.g., runoff from livestock farms and feedlots, fertilizers from row crops) and pesticides (e.g., from row crops) (Frick et al. 1998). Nitrate concentrations are particularly high in surface waters downstream of agricultural areas (Mueller et al. 1995). Stream ecosystems are impacted when nutrients are added at concentrations that cannot be assimilated, resulting in over-enrichment, a condition exacerbated by low-flow conditions. Juvenile mussels utilizing interstitial habitats are particularly affected by depleted dissolved levels resulting from over-enrichment (Sparks and Strayer 1998). Increased risks from bacterial and protozoan infections to eggs and glochidia may also pose a threat (Fuller 1974).

Pesticide runoff commonly ends up in streams. The effects of pesticides on laboratory-tested mussels may be particularly profound (Fuller 1974, Havlik and Marking 1987), and commonly used pesticides have been directly implicated in a North Carolina mussel die-off (Fleming et al. 1995). Once widely used in parts of the Midwest and Southeast, organochlorine pesticides are still detected in streams and aquatic organisms decades after their use has been banned, and may still be found at levels in streams that often exceed chronic exposure criteria for the protection of aquatic life (Buell and Couch 1995, Frick et al. 1998). Fertilizers and pesticides are also commonly used in developed areas. These contaminants have the potential to impact all extant populations of the sheepnose.

Sediment from the upper Clinch River has been found to be toxic to juvenile mussels (Robison et al. 1996, Ahlstedt and Tuberville 1997). It was speculated that the presence of toxins in the Clinch River may explain the decline and lack of mussel recruitment at some sites in the Virginia portion of that stream (S.A. Ahlstedt, USGS, pers. comm., 2002).

Oil and gas exploration is accelerating in western Pennsylvania. Pollutants from these activities include brines and organics, and potentially threaten the sheepnose population in the Allegheny.

Numerous streams throughout the range of the sheepnose have experienced mussel and fish kills from toxic chemical spills, particularly in the upper Tennessee River system in Virginia where several major spills have been documented (Neves 1986, 1991; Jones et al. 2001). Catastrophic pollution events, coupled with pervasive sources of contaminants (e.g. municipal and industrial pollution, coal-processing wastes), have contributed to the decline of the sheepnose in the Clinch over the past several decades (Neves 1991). An alkaline fly ash pond spill in 1967 and a sulfuric acid spill in 1970 on the Clinch River at Carbo, Virginia, caused a massive mussel kill for up to 12 miles downstream from a power plant site (Cairns et al. 1971). Natural recolonization has not occurred in the impacted river reach (Ahlstedt 1991), possibly due to persistent copper contamination from the power plant at Carbo (Wilcove and Bean 1994).

One recent major spill in the upper Clinch River in 1998 eliminated over 7,000 mussel specimens of several species, which were found freshly dead (Jones et al. 2001). The death toll included at least 254 specimens of three federally listed species, but was thought to be much higher (S.A. Ahlstedt, USGS, pers. comm., 2001). An especially catastrophic spill in 1999 impacted an approximately 10-mile stretch of the Ohio River and resulted in a total loss of mussels. Roughly one million mussels, including the sheepnose and two federally listed species, were estimated lost (W.A. Tolin, Service, pers. comm., 2002). Given the relative abundance of the sheepnose in the Ohio from other studies, it is not inconceivable that potentially thousands of sheepnose specimens were eliminated in this single event. Chemical spills will invariably continue to occur and have the potential to completely eliminate sheepnose populations from restricted stream reaches and possibly entire streams.

Mining

Heavy metal-rich drainage from coal mining and associated sedimentation have adversely impacted portions of the upper Tennessee River system in Virginia. The low pH commonly associated with mine runoff can reduce glochidial encystment rates (Huebner and Pynnönen 1992). Acid mine runoff may thus be having local impacts on recruitment of the sheepnose. Mine discharge from the 1996 blowout of a large tailings pond on the upper Powell River resulted in a major fish kill (L.M. Koch, Service, pers. comm., 1996). The impact on the mussel fauna was not readily apparent but was presumed to be detrimental (S.A. Ahlstedt, USGS, pers. comm., 2002). Powell River mussel populations were inversely correlated with coal fines in the substrate; when coal fines were present, decreased filtration times and increased movements were noted in laboratory-held mussels (Kitchel et al. 1981). In a quantitative study in the Powell River, a decline of federally listed mussels and the long-term decrease in overall species composition since about 1980 was attributed to general stream degradation due primarily to coal mining activities in the headwaters (Ahlstedt and Tuberville 1997). If coal mining activities are reinitiated in western Pennsylvania, they could become a threat to the sheepnose in the Allegheny River.

Various mining activities take place in other systems that potentially impact current sheepnose populations. Lead and barite mining is common in the Big River, Meramec River system, Missouri. The Big River was impacted by a 1977 lead mine tailings-pond blowout that discharged 81,000 cubic yards of mine tailings, covered 25 stream miles and impacted the lower 80 miles of stream (Buchanan 1980, Roberts and Bruenderman 2000). High levels of zinc and lead are still found in river samples (Roberts and Bruenderman 2000) and may act as a hindrance to stream recovery. Forty-five tailings ponds and numerous other waste piles remain in the watershed (Roberts and Bruenderman 2000). A single live sheepnose specimen was reported from the Big River in 1978, but no live sheepnose have been recorded in the Big River since that time (S.A. Bruenderman, MDC, pers. comm., 2002). These impacts may have contributed to the extirpation of the sheepnose from the Big River.

Instream gravel mining has been implicated in the destruction of mussel populations (Hartfield 1993). Negative impacts associated with gravel mining include stream channel modifications (e.g., altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation), and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions) (Kanehl and Lyons 1992, Roell 1999).

Gravel mining activities may be a localized threat in some streams with extant sheepnose populations. This activity is pervasive in the Meramec River system. The U.S. Army Corps of Engineers (Corps) has issued 230 permits for gravel mining in the Meramec system (Roberts and Bruenderman 2000). Although guidelines sought to prohibit instream mining and to require 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 purview (Roberts and Bruenderman 2000). In the lower Tennessee River, mining is permitted in 18 reaches for a total of 47.9 river miles between the Duck River confluence and Pickwick Landing Dam, a distance of over 95 miles (D.W. Hubbs, TWRA, pers. comm., 2002). This reach is where good mussel recruitment has been noted for many otherwise rare species in recent years. These activities have the potential to impact the precarious sheepnose population.

Sedimentation

Sedimentation is a pervasive problem in streams and has been implicated in the decline of stream mussel populations (Ellis 1936, Marking and Bills 1979, Vannote and Minshall 1982, Dennis 1985, Brim Box 1999, Fraley and Ahlstedt 2000). Sources, biological effects, and the control of sediment in streams were reviewed by Waters (1995). Brim Box and Mossa (1999) reviewed how mussels are specifically affected by sediment and discussed land use practices that may impact mussels. Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis 1936, Stansbery 1971, Marking and Bills 1979, Vannote and Minshall 1982, Waters 1995). The effects of sediment on mussel habitat include changes in suspended and bed material load; bed sediment composition change associated with increased sediment production and run-off in the watershed; channel changes in form, position, and degree of stability; changes in depth or the width/depth ratio which affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave them high and dry (Vannote and Minshall 1982, Kanehl and Lyons 1992, Brim Box and Mossa 1999).

Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces may become reduced (Brim Box and Mossa 1999) thus reducing juvenile habitat. Sediment may act as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles during normal feeding activities and become subjected to potentially toxic effects.

Many Midwestern and Southeastern streams have high turbidity levels due to silt-laden run-off. The sheepnose produces conglutinates that appear to function in attracting potential hosts. Such a reproductive strategy depends on clear water during the critical time of the year when mussels are releasing their glochidia (Hartfield and Hartfield 1996). In addition, mussels may be indirectly affected when turbidity levels significantly reduce the amount of light available for photosynthesis and the production of food (Kanehl and Lyons 1992).

The Chippewa River has a bedload composed primarily of sand that requires a significant amount of dredging to maintain barge traffic on the main stem Mississippi below its confluence (Thiel 1981). The mussel diversity below the Chippewa has predictably declined from historical times due to the accretion unstable sand substrates from the Chippewa. 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 sheepnose and other mussels (Thiel 1981).

Agricultural activities produce significant amounts of sediment that enter streams (Waters 1995). Neves et al. (1997) stated that agriculture (including both sediment and chemical run-off) affects 72 percent of the impaired river miles in the country. Unrestricted access by livestock is a significant threat to many streams and their mussel populations (Fraley and Ahlstedt 2000). Grazing may reduce infiltration rates, increase run-off and increase erosion (Armour et al. 1991, Trimble and Mendel 1995, Brim Box and Mossa 1999). Fraley and Ahlstedt (2000) attributed the decline of the Copper Creek (an upper Clinch River tributary) mussel fauna between 1980 and 1998, among other factors, to an increase in cattle grazing and loss of riparian vegetation along the stream. These impacts may potentially affect the sheepnose population in the Clinch below the confluence of Copper Creek.

Other Activities Affecting Mussels

Droughts may also be a threat, exacerbated by global warming and water withdrawals for agricultural irrigation, municipal, and industrial water supplies. These activities lower water tables and increase the opportunity for water quality to be reduced to levels toxic to sheepnose and other mussel populations.

B. <u>Overutilization for commercial, recreational, scientific, or educational purposes</u>.

It is unlikely that exploitation activities have eliminated sheepnose populations (Butler 2002). The sheepnose is not currently a commercially valuable species, but it may be inadvertently harvested as bycatch or by inexperienced musselers unfamiliar with commercial species identification. Mussel harvest is illegal in some states (e.g., Indiana, Ohio), and tightly regulated in others (e.g., Alabama, Kentucky, Tennessee, Wisconsin). Most states with commercial harvest allow musselers to dive for mussels. In Kentucky, mussels may legally be harvested only by brail. Most states that allow commercial harvest have established mussel sanctuaries where harvest is off limits. Sanctuaries are generally associated with beds that have State or federally listed mussels in them. Although illegal harvest from protected mussel beds occurs (Watters and Dunn 1993-94), commercial harvest is not thought to have a significant impact on the sheepnose.

A rare species like the sheepnose may increasingly be sought by lay and experienced collectors. Although scientific collecting is not thought to represent a significant threat, localized populations could become impacted and possibly extirpated by overcollecting, particularly if this activity is unregulated.

C. Disease or predation.

The occurrence of disease in mussels is virtually unknown (Butler 2002). Several mussel dieoffs have been documented during the past 20 years (Neves 1986). Although the ultimate cause is unknown, some researchers believe that disease may be a factor. Parasites on mussels include water mites, trematodes, leeches, bacteria, and some protozoa, but are not suspected to be a major limiting factor for mussel populations (Oesch 1984).

Based on a study of muskrat predation on imperiled mussels in the upper North Fork Holston River in Virginia, Neves and Odum (1989) concluded that this activity could limit the recovery of endangered mussel species or contribute to the local extirpation of already depleted mussel populations. Predation by muskrats may represent a seasonal and localized, but probably not a significant threat to the sheepnose. Although other mammals (e.g., raccoon, mink, otter, and hogs) occasionally feed on mussels, the threat from these species is not significant. Some species of fish feed on mussels (e.g., freshwater drum, redear sunfish), and potentially upon this species. According to R.J. Neves (USGS, pers. comm., 2002), newly metamorphosed juvenile mussels may be fed upon by various invertebrates (e.g., flatworms, hydra, non-biting midge larvae, dragonfly larvae, crayfish). The overall threat posed by piscine and invertebrate predators of the sheepnose is not thought to be significant.

D. The inadequacy of existing regulatory mechanisms.

Most states with extant sheepnose populations prohibit the taking of mussels for scientific purposes without a State collecting permit (Butler 2002). However, enforcement of this permit requirement is difficult. Furthermore, State regulations do not generally protect mussels from other threats. See also the discussion in Factor B above relating to commercial harvest.

Existing authorities available to protect riverine ecosystems such as the Clean Water Act (CWA), which is administered by the Environmental Protection Agency and the Corps of Engineers, have not fully offset decades of impacts such as damming, sedimentation, and water quality degradation. These impacts have contributed to the general habitat degradation apparent in riverine ecosystems and loss of populations of aquatic species in the Southeast and Midwest. Listing the sheepnose under the Endangered Species Act (Act) would provide protection at the individual and population levels. Federal permits would be required to take the species, and Federal agencies would be required to consult with the Service when activities they fund, authorize, or carry out may adversely affect the species.

E. Other natural or manmade factors affecting its continued existence.

Population Fragmentation and Isolation
The majority of the remaining populations of the sheepnose are generally small and geographically isolated (Butler 2002). 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 1993-94). Furthermore, this level of isolation makes natural repopulation of any extirpated population virtually impossible without human

intervention. Population isolation prohibits the natural interchange of genetic material between populations, and small population size reduces the reservoir of genetic diversity within populations, which can lead to inbreeding depression (Avise and Hambrick 1996).

Genetic Considerations

The likelihood is high that some populations of the sheepnose are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability. 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 (Butler 2002). If these trends continue, further significant declines in total sheepnose population size and consequent reduction in long-term viability may soon become apparent. The present distribution and status of the sheepnose may be indicative of the detrimental bottleneck effect resulting when the effective population size is not attained. A once-diffuse population of this species occurred throughout much of the upper two-thirds of the Mississippi River system and in several larger tributary systems. Historically, there were presumably no absolute barriers preventing genetic interchange among its tributary sub-populations that occurred in various streams. With the completion of numerous dams on streams, such as the Cumberland and Tennessee Rivers during primarily the first half of this century, some main stem sheepnose populations were lost, and other populations became isolated.

Whereas small isolated tributary populations of imperiled short-lived species (e.g., most fishes) would have theoretically died out within a decade or so after impoundment, the long-lived sheepnose potentially takes decades to expire post-impoundment. Without the level of genetic interchange the species experienced historically (i.e., without barriers such as reservoirs or dams), small isolated populations that may now be comprised predominantly of adult specimens could be slowly dying out. Even given the improbable absence of the impacts addressed in Factors A through D above, we may still lose smaller isolated populations of this species to the consequences of below-threshold effective population size. Continued degradation of these isolated stream reaches is resulting in ever decreasing patches of suitable habitat and contributes to the decline of the sheepnose. The reduction of distribution to only 26 of 77 formerly occupied streams by the sheepnose testifies to these difficulties.

Alien Species

Various alien or nonnative species of aquatic organisms are firmly established in the range of the sheepnose. The alien species that poses the most significant threat to the sheepnose is the zebra mussel (*Dreissena polymorpha*) (Butler 2002). The invasion of the zebra mussel 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). Strayer (1999b) 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, resulting in the loss of individual native mussels and mussel beds. Fouling impacts include impeding locomotion (both laterally and vertically), interfering with normal valve movements, deforming valve margins, 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 in which zebras may impact native mussels is through filtering their sperm and possibly even their tiny glochidia from the water column. Habitat for native mussels may also be degraded by large deposits of zebra mussel pseudofeces (Vaughan 1997).

Overlapping much of the current range of the sheepnose, zebra mussels are thoroughly established in the upper Mississippi, St. Croix, Ohio, and Tennessee Rivers, and have been reported from the lower Meramec and Muskingum Rivers. In 2000, nearly 1% of the unionids in the lower St. Croix River were infested with zebra mussels (Kelner and Davis 2002). The extent to which they will impact the sheepnose in most areas is largely unknown. The greatest potential for present zebra mussel impacts to the sheepnose appears to be in the upper Mississippi River. Kelner and Davis (2002) considered zebra mussels in the Mississippi River from Pool 4 downstream to be extremely abundant and decimating the native mussel communities. Dead and live zebra mussels cover the bottom of the river in some localities up to 2-5 cm deep (Havlik 2001), where they have significantly reduced the quality of the habitat with their pseudofeces (S.J. Fraley, NCWRC, pers. comm., 2000). Zebra mussels have undoubtedly reduced sheepnose populations in these heavily infested waters. Until 2002, zebra mussel densities in the Tennessee River remained low, but are now abundant enough below Wilson Dam to be measured quantitatively (G.T. Garner, ADNR, pers. comm., 2002). As zebra mussels may maintain high densities in big rivers, large tributaries, and below infested reservoirs, sheepnose populations in affected areas may be significantly impacted. In addition, there is long-term potential for zebra mussel invasions into other systems that currently harbor sheepnose populations.

Native to China, the black carp (*Mylopharyngodon piceus*) is a potential threat (Strayer 1999b). Nico and Williams (1996) prepared a risk assessment of the black carp and summarized all known aspects of its ecology, life history, and intentional introduction (since the 1970s) into North America. A molluscivore (mollusk eater), the black carp has been proposed for widespread use by aquaculturists to control snails, the intermediate host of a trematode (flatworm) parasite affecting catfish in ponds in the Southeast and lower Midwest. They are known to eat clams (*Corbicula* spp.) and unionid mussels in China, in addition to snails. They are the largest of the Asiatic carp species, reaching more than 4 feet in length and achieving a weight in excess of 150 pounds (Nico and Williams 1996). During 1994, 30 black carp escaped from an aquaculture facility in Missouri during a flood. Other escapes into the wild by nonsterile black carp are deemed imminent by conservation biologists. If these species invade streams with mussel communities, they could have significant impacts on already stressed native mussel populations.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

Conservation activities that benefit the species include Funding Programs, Research and Surveys, Outreach, and Habitat Improvements and Conservation.

Funding Programs:

The Service's Partners for Fish and Wildlife program has funded millions of dollars in projects. Funding in this program has been provided to landowners to enhance riparian habitat in streams with sheepnose populations. For instance, specific watershed level projects that have benefited habitat for the sheepnose include the TNC Bioreserves in the Clinch and Green Rivers.

Other funding sources play significant roles in the Service's riparian habitat protection program. These include CWA Section 319, Natural Resource Conservation Service programs (e.g., Environmental Quality Incentives Program, Wildlife Habitat Improvement Program, Conservation Reserve Enhancement Program [CREP]), Landowners Incentives Program, National Fish and Wildlife Foundation (NFWF) habitat programs, and numerous other Federal programs that are potential sources of money for sheepnose habitat restoration and conservation. For instance, a CREP grant of $110 million has been secured by Kentucky to take up to 100,000 acres of riparian lands out of agricultural production in the upper Green River watershed. Efforts will focus on areas that should be of direct benefit to the Green's sheepnose population.

Several settlements from large chemical spills are currently being negotiated (J. Schmerfeld, Service, pers. comm., 2002). Money from these court cases has the potential to fund significant recovery-type projects benefiting a suite of imperiled species like the sheepnose. Similarly, money from an illegal harvest case was used to establish a Mussel Mitigation Trust Fund (MMTF). This trust is used to fund imperiled mussel recovery work.

Research and Surveys:

The St. Croix River Research Rendezvous is an annual meeting of biologists and conservationists dedicated to managing the St. Croix River and its diverse mussel fauna, including the sheepnose. Participants annually present their research, which are regularly abstracted in *Ellipsaria*, the newsletter of the Freshwater Mollusk Conservation Society. Recent research subjects involving mussels have included sediment contamination, juvenile toxicity, status surveys, population dynamics, and zebra mussel control. Vaughan (1997) outlined various measures implemented for mussel conservation in the St. Croix River.

The Green River Bioreserve TNC staff has contracted with the Corps of Engineers to explore ways in which flow releases from the Green River dam can be modified to improve seasonal flow patterns and instream habitat in the Green. These efforts may pay dividends in improving conditions for the sheepnose and a host of other imperiled aquatic organisms in the upper Green River.

Age and growth, reproductive potential, and habitat requirements of the sheepnose and other mussel species in the lower Holston River are presently being investigated by J.B. Layzer, B.D. Adair, and J.M. Wisniewski (USGS, Cooperative Fisheries Research Unit, Tennessee Technical University, Cookeville, Tennessee); and R.J. Neves and B.J. Ostby (USGS, Cooperative Fisheries Research Unit, Virginia Polytechnic Institute and State University, Blacksburg, Virginia).

Host fish and life cycle investigations are being conducted at the FWS Genoa National Fish Hatchery in Genoa, Wisconsin. Staff will be checking on the breeding status of sheepnose from the Chippewa River weekly. Once gravid females are found, they will test different fish as potential hosts. Staff will also be collecting fish from the Chippewa River and looking for natural infestation from sheepnose glochidia.

Kevin Roe, Iowa State University, has submitted a proposal to Iowa DNR to carry out a genetic structure and intraspecific phylogeography of the sheepnose. Project objectives include documentation of genetic diversity, population structure, the extent of gene flow, and the historical connections between populations.

Survey work continues in many portions of the range of the sheepnose. For instance, intensive sampling is currently planned for portions of the lower Allegheny River (R. Villella Baumgardner, USGS, pers. comm., 2002). Surveys related to development projects on the Upper Mississippi River have located sheepnose individuals. Information gathered from these surveys will help determine its population status, and generates other data useful for conservation management and recovery efforts.

Management:
Relocation of a mussel community is often used to minimize the impact of specific development-related projects (e.g., highway crossings, channel dredging, mooring cells) on important mussel resources, including listed species. This technique, however, may provide limited benefit for overall species conservation and recovery. Further, failed relocation attempts have resulted in increased mortality of both relocated and resident populations in some circumstances. During Interagency Consultation, or in the development of a Habitat Conservation Plan, minimization and mitigation of adverse effects to listed mussel species should consider conservation measures, in addition to relocation, which further species recovery goals. Species of concern and candidate species, such as the sheepnose, receive no regulatory protection under the Act, however, the Service strongly encourages Federal agencies and other planners to consider them when planning and implementing their projects. Efforts to conserve these species now may include options that may not be available if the species population declines further. Such efforts now may preclude the need to list them as endangered or threatened under the Act in the future.

Some of the Service ecosystems in the range of the sheepnose have made imperiled mussels a high priority resource for conservation. The Ohio River Valley Ecosystem Mollusk Subgroup recommended to the Service the need for a status review. Ecosystem teams will be a source for identifying future funding needs for the sheepnose.

Outreach/Education:
Service public outreach/environmental education staff are involved in various efforts to demonstrate to the public the benefits of habitat preservation and water quality. For instance, in the Southern Appalachian Ecosystem comprising the headwaters of the Tennessee River system (and other drainages), aquatic issues form a major part of the outreach efforts in the ecosystem among Service representatives and partners. Representative projects have included posters and videos highlighting aquatic faunal groups, a riparian restoration and conservation video for streamside landowners, endangered species pamphlets, and mussel trunks (outreach/education kits) for educators.

Habitat Improvements and Conservation:
The Mississippi River hosts about 285,000 acres of National Wildlife Refuge lands and waters, some of which contain mussel beds known to harbor sheepnose. Management of mussel resources is a primary goal of Ohio River Islands National Wildlife Refuge. A National Wildlife Refuge on the Clinch River is under consideration. This non-traditional fish and wildlife refuge

is planned to be slowly implemented over time. Other refuges may be established in other stream systems harboring sheepnose populations in the future.

Reservoir releases from TVA dams have been modified in recent years to improve water quality and habitat conditions in many tailwaters. Improvements have enabled partners to attempt the reintroduction of extirpated species. Numerous experimental populations of federally listed species are now in various stages of planning and implementation.

SUMMARY OF THREATS:

The decline of the sheepnose in the Mississippi River system and other mussel species in the eastern United States (described by Butler 2002) is primarily the result of habitat loss and degradation (Neves 1991). These losses have been well documented since the mid-19th century (Higgins 1858). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Williams et al. 1993; Neves 1991, 1993; Neves et al. 1997; Watters 2000).

The majority of the remaining populations of the sheepnose are generally small and geographically isolated (Butler 2002). 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 1993-94). Furthermore, this level of isolation makes natural repopulation of any extirpated population virtually impossible without human intervention.

The likelihood is high that some populations of the sheepnose are below the effective population size (Soulé 1980) required to maintain long-term genetic and population viability. 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 (Butler 2002). If these trends continue, further significant declines in total sheepnose population size and consequent reduction in long-term viability may soon become apparent.

Various alien or nonnative species of aquatic organisms are firmly established in the range of the sheepnose. The alien species that poses the most significant threat to the sheepnose is the zebra mussel (*Dreissena polymorpha*) (Butler 2002). 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).

Native to China, the black carp (*Mylopharyngodon piceus*) is a potential threat (Strayer 1999b). Nico and Williams (1996) prepared a risk assessment of the black carp and summarized all known aspects of its ecology, life history, and intentional introduction (since the 1970s) into North America. A molluscivore (mollusk eater), the black carp has been proposed for widespread use by aquaculturists to control snails, the intermediate host of a trematode (flatworm) parasite affecting catfish in ponds in the Southeast and lower Midwest. They are known to eat clams (*Corbicula* spp.) and unionid mussels in China, in addition to snails. They are the largest of the Asiatic carp species, reaching more than 4 feet in length and achieving a weight in excess of 150 pounds (Nico and Williams 1996). During 1994, 30 black carp escaped from an aquaculture facility in Missouri during a flood. Other escapes into the wild by nonsterile black carp are deemed imminent by conservation biologists. If these species invade streams with mussel communities, they could have significant impacts on already stressed native mussel populations.

We find that this species is warranted for listing throughout all of its range, and therefore, it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

RECOMMENDED CONSERVATION MEASURES

- **Determine all host fishes**: The sauger has been determined to be a host fish for the sheepnose, but other fishes must serve as host for this species. Research into other hosts is critical. Knowing all its host fishes rangewide will facilitate sheepnose recovery.
- **Develop propagation technologies**: Propagation technology for the sheepnose should be developed. By propagating significant numbers of juveniles in laboratory or hatchery settings, population augmentation and reintroduction into historical habitats will become much more feasible.
- **Research life history and habitat needs**: Very little information is available on the life history of the sheepnose. Life history information will be needed to successfully implement the recovery tasks. In addition, the habitats (e.g., relevant physical, biological, chemical components) for each sheepnose life-history stage need to be elucidated. The sensitivity of each life history stage to contaminants and general threats to the species also need investigating.
- **Monitor zebra mussel populations**: Monitoring existing populations of the zebra mussel and its spread into new systems should be implemented in the most at-risk systems. These include, among others, the Mississippi, Chippewa, Meramec, Ohio, and Tennessee Rivers.
- **Determine population attributes necessary for long-term viability**: Criteria that determine long-term population viability are crucial if we are to understand what constitutes a healthy sheepnose population. Detailed information is needed on the demographic structure, effective population size, and other genetic attributes of extant populations.
- **Develop parameters for species augmentation**: A set of biological, ecological, and habitat parameters is needed to determine if an extant sheepnose population will be suitable for species augmentation. This is particularly important in habitats that may be marginal (e.g., where the sheepnose appears to be barely hanging on). Prioritized populations and potential augmentation sites for this task will be selected based on present population size, demographic composition, population trend data, potential site threats, habitat suitability, and any other limiting factor that might decrease the likelihood of long-term benefits from population augmentation efforts. Augmentation activities should not be conducted at totally unprotected sites or at sites with significant uncontrollable threats.
- **Develop parameters for reintroduction**: A set of biological, ecological, and habitat characterization parameters is needed to determine if a site will be suitable for sheepnose

reintroduction. These will include habitat suitability, substrate stability, presence of host fishes, potential site threats, and any other limiting factor that might decrease the likelihood of long-term benefits from population reintroduction efforts. Reintroduction activities should not be conducted at totally unprotected sites or at sites with significant uncontrollable threats.

- **Survey for additional populations**: The loss of much of its historical habitat, coupled with past and ongoing threats, clearly indicates the heightened level of imperilment of the sheepnose. Survey work to search for potentially new sheepnose populations, and possibly extirpated populations would be beneficial.
- **Determine potential taxonomic distinctions of populations**: A rangewide phylogenetic study on the sheepnose should be conducted to determine if there are any populations that may be taxonomically distinct. There is a possibility that disjunct populations, such as the upper Tennessee River system or the Ozark populations in Missouri, may represent undescribed taxa. Numerous endemic mussels, fishes, and other aquatic organisms are known particularly from the Tennessee River system, which has been geologically stable for eons longer than glaciated streams in much of the remainder of the sheepnose=s range.
- **Develop and implement cryogenic techniques**: Developing and implementing cryogenic techniques to preserve sheepnose genetic material until such time as conditions are suitable for reintroduction may be beneficial to recovery. If a population were lost to a catastrophic event, such as a toxic chemical spill, cryogenic preservation could allow for the eventual reestablishment of the population using genetic material preserved from that population.

LISTING PRIORITY:

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	**Imminent**	Monotypic genus	1
		Species	2*
		Subspecies/population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6

Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude:
All populations of sheepnose face serious threats to their continued existence. Only four populations appear to be viable and at least one of these appears to be shrinking within its reach. None of these populations have been found to harbor much more than 50 individuals except one site. On the Holston River in Tennessee, 206 individuals were found in 2002, but signs of recruitment were absent. Only the sauger is known to act as host, though there may be others.

The sheepnose has experienced a significant reduction in range and most of its populations are disjunct, isolated, and appear to be declining rangewide. The extirpation of this species from over 50 streams within its historical range indicates that substantial population losses have occurred. The sheepnose has been eliminated from two-thirds of the total number of streams from which it was historically known (26 streams currently compared to 77 streams historically). This species has also been eliminated from long reaches of former habitat in hundreds of miles of the Illinois, Cumberland, and other rivers, and from several reaches of the Mississippi and Tennessee Rivers.

In the vast majority of streams with extant populations, the sheepnose appears to be uncommon at best. Small population size and/or restricted stream reaches of current occurrence are a real threat to the sheepnose due to the negative aspects of genetics of small, geographically isolated populations. Several extant populations are thought to exhibit some level of population viability (e.g., Chippewa, Flambeau, Wisconsin, Meramec, Bourbeuse, Muskingum, Green, Tippecanoe, Clinch Rivers).

Threats to the continued existence of sheepnose include exotic species especially zebra mussels, impoundments, fluctuating flow releases from dams, sedimentation, small population size, isolation of populations, gravel mining, channel dredging, municipal pollutants, agricultural run-off, nutrient enrichment, and coal processing pollution. Many of these threats may be catastrophic such as spills, or chronic, such as zebra mussel infestation and habitat quality degradation, but all act against the recovery of the species. Therefore, we consider the threats to sheepnose to be of high magnitude.

Imminence:
Threats to the sheepnose discussed above could result in extinction of the species due to the exceptionally small numbers estimated at extant locations. Though information indicates that some reproduction is occurring, data do not clearly indicate whether any population is viable.

Such small numbers of individuals may have extreme difficulty in successfully reproducing. Threats which impact the ability to reproduce over time could result in essentially sterile, aging disjunct populations. Although there are on-going attempts to alleviate some of these threats, there appears to be no populations without current significant threats and many threats are without obvious or readily available solutions. Therefore, given this compilation of current distribution, abundance, and trend information, coupled with ongoing, uncontrolled threats, those threats to the sheepnose appear to be imminent.

_Yes___ Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted?
Emergency listing is not warranted at this time. Although the magnitude and immediacy of threats to the sheepnose range-wide are high, expected losses to populations during the normal listing process would not risk the continued existence of the entire species or loss of significant recovery potential.

DESCRIPTION OF MONITORING:
The lead Service field office is developing a GIS database for sheepnose. Once the database is established, other field offices will be asked to provide updates for their geographic area. In addition, we have tracked the latest surveys from the Upper Mississippi River for occurrences and have received reports from the Ohio River mussel coordinator.

COORDINATION WITH STATES:
Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment: TN, WI, MO, IN, MN, AL, PA, VA, MS, KY, WV, IA, IL,

Indicate which State(s) did not provide any information or comments:

Indicate which states include sheepnose as a species of conservation concern in their State Wildlife Action Plan: AL, IL, IA, IN, KY, MN, MS, MO, TN, VA, WV, WI

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APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: Charlie Wooley 5/3/07

ACTING Regional Director, Fish and Wildlife Service Date

Concur: ______________________________

Director, Fish and Wildlife Service Date

Do not concur: ______________________________

Director, Fish and Wildlife Service Date

Director's Remarks:

Date of annual review:
Conducted by: