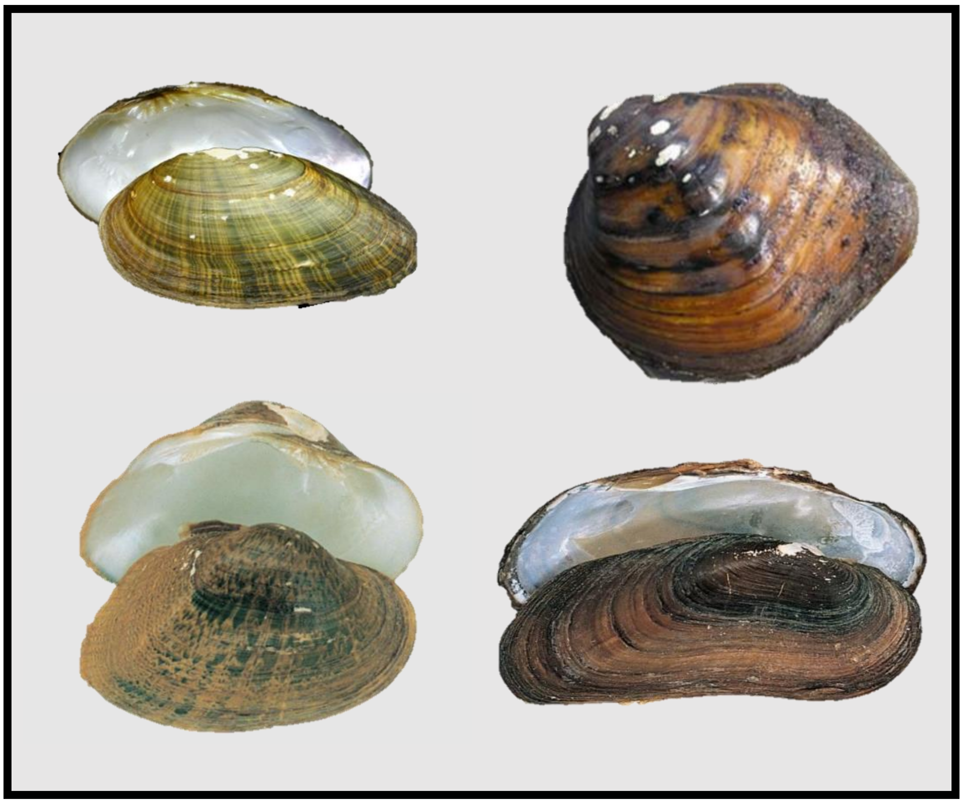
U. S. Fish and Wildlife Service

Recovery Plan for

Four Species of Freshwater Mussels

Rayed Bean (*Villosa fabalis*)
Sheepnose (*Plethobasus cyphyus*)
Snuffbox (*Epioblasma triquetra*)
Spectaclecase (*Cumberlandia monodonta*)



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September 2024

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

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DISCLAIMER

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq., section 4(f)), requires the development of recovery plans for listed species, unless such a plan would not promote the conservation of a particular species. Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. The U.S. Fish and Wildlife Service (Service) publishes the plans, which may be prepared with the assistance of recovery teams, contractors, state agencies and others, including the public. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than the Service. The plan represents the official position of the Service only after it has been signed by the Regional Director. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions. Please check https://ecos.fws.gov/ecp/ for updates or revisions before using. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year more than appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation.

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This document is available online at http://ecos.fws.gov.

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INTRODUCTION

The Service's recovery planning process entails developing a recovery plan (plan) and recovery implementation strategy (RIS). This document provides the Service's plan for the conservation and recovery of four species of freshwater mussels: the rayed bean (*Villosa fabalis*), sheepnose (*Plethobasus cyphyus*), snuffbox (*Epioblasma triquetra*), and spectaclecase (*Cumberlandia monodonta*). It describes the overall recovery strategy and required elements pursuant to section 4(f)(1)(B) of the Endangered Species Act (Act), which are recovery criteria, actions, and overall time and cost estimates to recovery. This recovery plan addresses these four species together for administrative efficiencies because of considerable overlap associated with the respective general recovery strategy and actions. However, this plan includes species-specific criteria, as appropriate. The RIS is a separate document from the recovery plan and is developed in close cooperation with partners. It serves as an operational document for stepping down the recovery actions into specific activities needed to achieve recovery and details how, when, and where they will be accomplished. The specifics of the RIS are updated as new information becomes available through recovery implementation, a 5-year review, or some other relevant feedback.

To develop this recovery plan, we prepared Species Status Assessments (SSAs) for each of the four species (Service 2022a-d). The contents of the SSA reports are as follows: (1) summary of the species' biology and life history requisites; (2) description of the influences on resource needs and viability; (3) discussion of conservation actions implemented to benefit the species and its habitat; (4) description of the subspecies' current condition in terms of resiliency, representation, and redundancy; and (5) description of the projected future condition in terms of resiliency, representation, and redundancy. The SSA reports are available on the species-specific page at https://ecos.fws.gov.

BACKGROUND

The **rayed bean (*Villosa fabalis*)** is a small mussel, usually less than 1.5 inches long (38 mm), that has an estimated lifespan of approximately 15 years. The mussel is found in rivers, streams, creeks, or lakes, in areas of moderate flow with sand and gravel substrate. The Tippecanoe darter (*Etheostoma tippecanoe*), spotted darter (*E. maculatum*), greenside darter (*E. blennioides*), rainbow darter (*E. caeruleum*), mottled sculpin (*Cottus bairdi*), and largemouth bass (*Micropterus salmoides*) have been identified as hosts. The rayed bean historically occurred in parts of the lower Great Lakes basin and throughout most of the Ohio and Tennessee River basins in at least 115 streams, lakes, and some human-made canals in 10 states: Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia; and Ontario, Canada. It has declined both in distribution and number of populations. It currently occurs in 37 streams and 1 lake in 7 states and 1 Canadian province, no longer occurs in Illinois and Virginia, and has been reintroduced into Kentucky (Service 2023, p. 3) (Figure 1; https://ecos.fws.gov/ecp/species/5862).

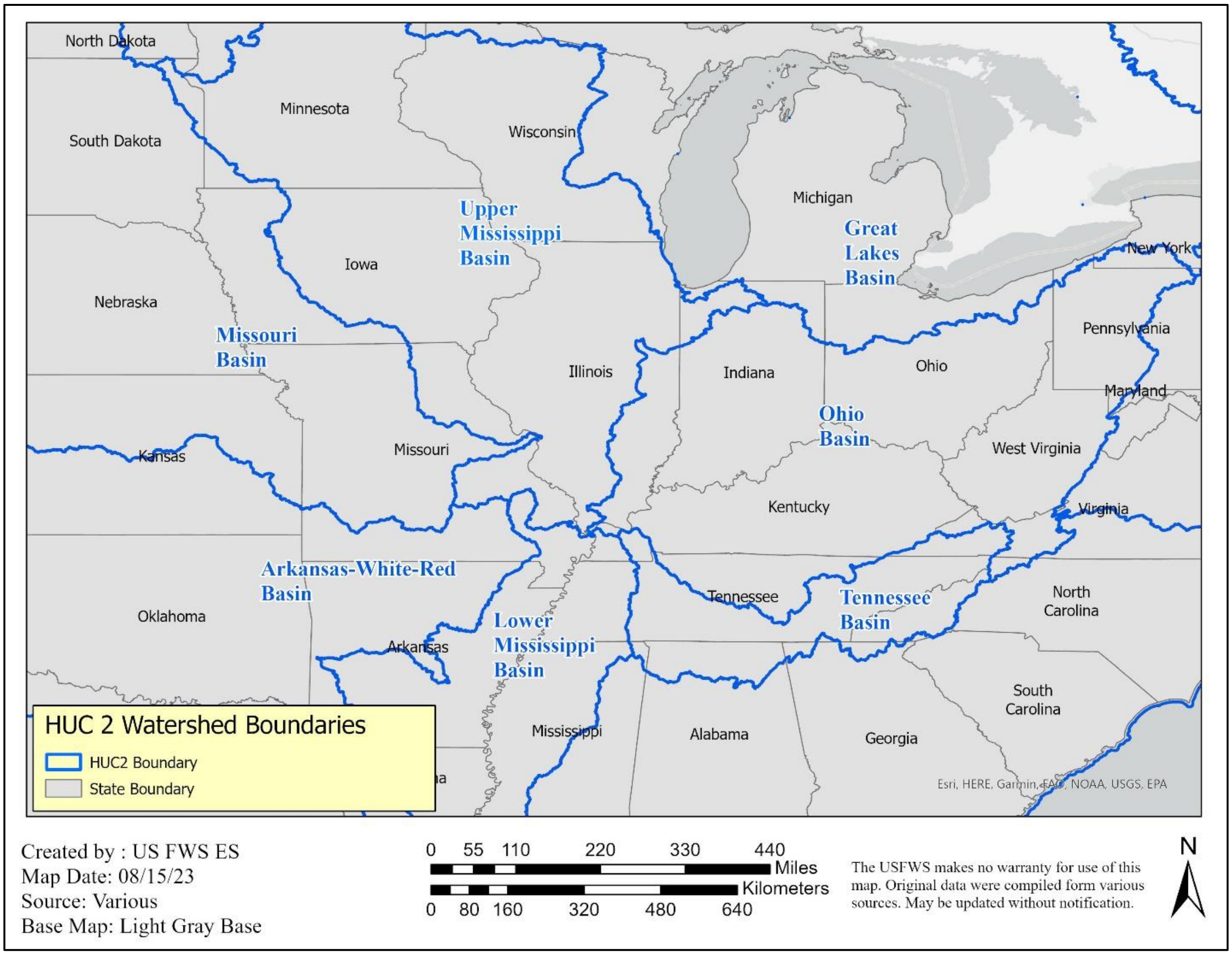

Figure 1. Map of HUC 2 watershed basins within the ranges of the rayed bean, sheepnose, snuffbox, and spectaclecase.

The **sheepnose (*Plethobasus cyphyus*)** is a medium-sized, thick-shelled species that can reach nearly 5.5 inches (13.97 cm) in length and has an estimated lifespan of approximately 30 years. It inhabits medium to large river systems, typically within shallow shoal habitats with moderate to swift currents over mixtures of coarse sand, gravel, and clay. Evidence suggests that habitat ranges from riffles a few inches deep to runs exceeding approximately 20 feet (6 m) in depth. To-date, laboratory studies have identified more than 30 species of suitable host fish, with varying degrees of juvenile production; however, documentation of natural infestations has been limited to sauger (*Sander canadensis*) and mimic shiner (*Notropis volucellus*). Sheepnose is historically known from 79 streams across 14 states (Alabama, Illinois, Indiana, Iowa, Kentucky, Minnesota, Mississippi, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin), including portions of the Upper Mississippi, Lower Missouri, Ohio, Cumberland, Tennessee, and Lower Mississippi River basins. Presently, sheepnose occurs in all 14 states of its historical range, but the species' distribution has decreased over time with extant population known from 22 streams range wide (Service 2022b, pp. 4-6) (Figure 1; https://ecos.fws.gov/ecp/species/6903).

The **snuffbox (*Epioblasma triquetra*)** is a small- to medium-sized mussel with males reaching up to 2.8 inches (7.0 cm) in length. The maximum length of females is about 1.8 inches (4.5 cm). It has an estimated lifespan of approximately 20 years. The mussel is found in rivers, streams, creeks, or lakes, in areas of moderate flow, in sand and gravel substrate. There are several known host fish for the snuffbox, including species of darters and sculpins in the genera *Etheostoma*, *Percina*, and *Cottus* with logperch (*Percina caprodes*) being the primary host. The snuffbox historically occurred in the upper and lower Great Lakes basins, Upper and Lower Mississippi River basins, lower Missouri River basin, Ohio River basin, Tennessee River basin, and White River basin in at least 211 streams and lakes in 18 States and 1 Canadian province: Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin; and Ontario, Canada. It has declined both in distribution and number of populations. It currently occurs in 85 streams in 14 states and 1 Canadian province and no longer occurs in Iowa, Kansas, Mississippi, and New York (Service 2024, p. 4) (Figure 1; https://ecos.fws.gov/ecp/species/4135).

The **spectaclecase (*Cumberlandia monodonta*)** is a large, long-lived species that reaches at least 9.25 inches (23.5 cm) in length with an estimated lifespan of more than 50 years. It inhabits larger stream systems and is generally found in microhabitats sheltered from both high and low extremes in flow, often found to be aggregated under slab boulders or bedrock shelves where they are protected from the current. Spectaclecase is the only known North American freshwater mussel species to use goldeye (*Hiodon alosoides)* and mooneye (*Hiodon tergisus*) as hosts for reproduction. It historically occurred in at least 61 watersheds in the Mississippi, Ohio, Tennessee, and Missouri river main stems and dozens of tributary streams in 14 states: Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Minnesota, Missouri, Ohio, Tennessee, Virginia, West Virginia, and Wisconsin. The number of known populations has declined by 60%, now occurring in 40 watersheds in 11 states (Service 2022d, pp. 1, 19), including all the historical States except Indiana, Kansas, and Ohio (Figure 1; https://ecos.fws.gov/ecp/species/7867).

The loss of many populations of freshwater mussels can be directly attributed to the anthropogenic destruction and modification of riverine habitat, e.g. construction of dams, channelization, invasive species, and pollution from chemical spills or municipal and industrial effluents (Service 2022a-d). Recently, biologists have determined that the chronic effect of these threats (e.g., fragmentation of habitat and isolation of populations), as well as interactions among them, are a source of continued decline in populations (Strayer et al. 2004, p. 435; Galbraith et al. 2010, entire). The general decline of freshwater mussels remains enigmatic, however, because the chronic effects of these threats do not fully explain the declines in their populations (Haag et al. 2019, entire) and further research is required.

RECOVERY STRATEGY

Recovery of these mussels is contingent on their viability, which is defined as their ability to sustain healthy populations in natural river systems within a biologically meaningful timeframe (Service 2022a-d). This includes a future where populations are sufficiently distributed within historical range, connectivity among those populations is high, and populations have demographic stability such that they can persist through normally variable aquatic conditions. In our SSA analyses, we used the conservation principles of resiliency, redundancy, and representation to assess viability of these four mussels at specific points in time (Service 2022a-d, entire; Wolf et al. 2015, p. 204).

Resiliency is the ability of populations to withstand stochastic events such as normal variation in temperature and rainfall, or ongoing threats such as the effects of anthropogenic activities (e.g., altered hydrology and fragmentation of riverine habitat). For resiliency, a freshwater mussel population needs to occur in stream reaches with sufficient spatial extent to support an abundance of individuals of multiple age classes and with reproduction and recruitment of juveniles into the population. To withstand catastrophic events, a species needs multiple healthy populations, with minimal threats, distributed across its range (redundancy), relative to the spatial occurrence of catastrophic events (e.g., widespread drought or flooding). Connectivity among populations is also required for the species as it increases the likelihood that any population can recover from catastrophic events. To maintain the species' ability to adapt to changing environmental conditions, or representation, healthy populations should be distributed across the diversity of genetic and ecological units.

Achieving recovery for these species depends on a strategy of cooperative work with partners to conserve habitat within watersheds with multiple, healthy populations across the historical range and high connectivity among those watersheds. The path to achieving recovery is structured by delineating units that ensure adaptive capacity is sufficient to allow for both near and long-term adaptation to changes in the species' environment and restoring redundancy and resiliency within these units to ensure the species can withstand existing and predicted future natural variations (e.g., temperature and rainfall), stressors, and potential catastrophes.

Within the recovery strategy framework, we define populations of these mussel species at the HUC 8 watershed scale. Because the overall genetic structure of populations of these species is lacking or limited, we used the HUC 2 watershed scale for grouping HUC 8 watersheds that occupy geographically and ecologically comparable areas into representation units (Service 2022a-d). Because of the substantial reduction in historical range, the number of watersheds currently classified as in low or functionally extirpated condition, the number of watersheds currently classified as at High risk, and the isolation of watersheds from each other (Service 2022a-d), the recovery strategy focuses on maintaining existing populations, increasing the health and reducing the risk of those existing populations, and, for those species that have suffered the most significant declines, increasing the number of populations through augmentations or reintroductions.

The first part of the recovery strategy focuses on maintaining those populations (HUC 8 watersheds) that are currently classified as High or Moderate condition (suggesting a stable or increasing population trend) and at Low to Moderate risk from threat factors (Service 2022a-d, Appendix E). This part of the strategy is important because most of the extant populations are projected to continue to decline or become extirpated without additional efforts (Service 2022a-d). This part of the strategy can be achieved by working collaboratively to eliminate or abate threats to the species (Service 2022a-d, Appendix B). Such activities may include developing conservation easements; using existing, or developing new, legislation, programs, and regulations to protect freshwater mussels and their habitats (e.g., protecting water quality); removing non-functional, aging, and unsound dams; planting or enhancing riparian vegetation to stabilize stream banks and decrease water temperature; and replacing culverts, bridges, or other restrictive structures to promote host fish passage and accommodate increased flows and natural sediment transportation.

The second part of the recovery strategy focuses on increasing the health of and reducing the threats to key populations that are currently in Low condition and/or at High risk. For these populations, the initial step is to eliminate or abate known threats by implementing activities as described in part one of the strategy, to the extent practicable. Following, populations will be monitored for evidence of increasing numbers and recruitment over a specified number of years. Natural resource professionals may incorporate augmentation to increase abundance and genetic diversity (Strayer et al. 2019, p. 3), as determined necessary, throughout the second part of the recovery strategy. Another component of part two is to further investigate HUC8 populations categorized as “unknown” condition to determine their status and the appropriate recovery actions necessary within the framework of the recovery strategy.

The third part of the recovery strategy focuses on increasing species representation and redundancy through population augmentation or reintroduction in key watersheds that are either functionally extirpated or extirpated, as identified through the recovery implementation strategy. Again, this may first require implementing activities to eliminate or abate the threats that caused extirpation. Watersheds targeted for reintroductions will be determined by species experts and conservation professionals, with a focus on those that have the best chance for success and increasing range-wide representation and redundancy of the species. One example is the reintroduction of a mid-system population that connects a Low condition smaller tributary population that historically suffered significant water quality impairment with a High condition, large river system population. This both increases redundancy and representation of the species, while increasing the likelihood of population connectivity between historically isolated populations, therefore improving resiliency as well.

Currently, demographic trends for most populations of these species are not well known. Furthermore, the biology of these species, particularly in response to threats, is also poorly understood. Because this information is needed to guide implementation of specific recovery activities, we will develop and implement a standardized monitoring program to collect data to assess population trends and habitat quality, estimate abundance and recruitment, document die-off events, and evaluate recovery efforts. We will also develop and implement monitoring and control programs for invasive, non-native mussels, fish, or other aquatic species that compete with or are predators of native freshwater mussels and encourage efforts to limit their spread.

Engagement and support from partners and the public is integral to mussel conservation. Sustaining and expanding conservation partnerships and public participation is a cornerstone of this recovery strategy. Implementing recovery through close collaboration with partners and the public will shape short-term recovery efforts through priority ranking, support for implementation, and collaborative decision-making within the broader context of a synergic approach to recovery.

RECOVERY CRITERIA

Recovery criteria provide objective, measurable thresholds used to indicate when recovery has been achieved. These criteria are founded on the most current scientific information available for the species. Multiple important aspects to understand and identify recovery criteria thresholds remain obscured (see Background above). Therefore, the species-specific recovery criteria listed below represent targets based on available science and account for these unknowns to the best of the Service's ability. As new information becomes available, criteria will be re-evaluated and updated accordingly. We will work with stakeholders, including local landowners and species and habitat experts to identify the limits and opportunities relevant to each population. This will result in well-distributed populations that can withstand stochastic events and ongoing threats while ensuring that species management is based on robust and best available scientific methods and information. The following recovery criteria, when met collectively, would indicate that the species may no longer need the protections of the Act.

Rayed Bean (*Villosa fabalis*)

The rayed bean may be considered for delisting when there are at least 20 populations (i.e., HUC 8 watersheds) in High condition with Moderate or Low risk, or in Moderate condition with Low risk (conditions and risk categories are defined in Service 2022a, Tables 4.3 and 4.4 or the most recent version of that document) range wide with the following distribution:

Basin	Criteria
Great Lakes	At least 6 populations
Ohio	At least 8 populations
Great Lakes, Ohio, **and/or** Tennessee	At least 6 additional populations

Rationale: Recovery criteria for the rayed bean entail a minimum number of healthy populations be maintained within at least two major river basins: Great Lakes and Ohio River basins. Maintaining populations in at least two major river basins, resulting in multiple healthy connected populations, preserves both the ecological and genetic diversity needed to ensure persistence of the species into the foreseeable future.

Maintaining at least 20 healthy populations with at least 6 populations in the Great Lakes basin and 8 populations in the Ohio River basin comprises more than 75 percent of the current populations (Service 2022a, pp. 12-13) and increases the number of populations currently considered to be of High or Moderate demographic condition within each basin. Having an additional six populations within any of the three historical basins increases the species' ability to adapt to changing environmental conditions and withstand potential catastrophic events. Collectively, this approach will reflect the species historical distribution across basins and associated ecological and genetic diversity range-wide to allow the species to withstand future catastrophic events and adapt to changing environmental conditions. Having each of these populations in at least Moderate demographic condition, indicating a stable or increasing population trend with managed levels of threats, provides the ability to withstand year-to-year stochastic fluctuations.

<u>Sheepnose</u> (*Plethobasus cyphyus*)

The sheepnose may be considered for delisting when there are 32 populations (i.e., HUC 8 watersheds) range wide in High condition with Moderate or Low risk, or in Moderate condition with Low risk (conditions and risk categories are defined in Service 2022b, Tables 4.3 and 4.4 or the most recent version of that document) with the following distribution:

Basin	Criteria
Upper Mississippi River	At least 13 populations
Ohio River	At least 13 populations
Tennessee River	At least 4 populations
And at least ONE of the following:	
Lower Mississippi River	At least 2 populations
Lower Missouri River	At least 2 populations

Rationale: Recovery criteria for sheepnose entail a minimum number of healthy populations be maintained within four major river basins: Upper Mississippi River, Ohio River, Tennessee River, and *either* the Lower Mississippi River or Lower Missouri River basins. Although the overall genetic structure of sheepnose populations is lacking, one study (Schwarz and Roe 2022) investigated a portion of the sheepnose range and found populations to be genetically isolated at roughly the HUC 2 scale with low rates of genetic migration within each basin, but not between them (Schwarz and Roe 2022, p. 8). Maintaining populations in a minimum of four major river basins, resulting in multiple healthy connected populations, preserves both the ecological and genetic diversity needed to ensure persistence of the species into the foreseeable future.

Thirty-two populations meeting the delisting criteria above, (excluding the Lower Mississippi and Missouri Rivers) represent at minimum 25 percent of the estimated number of historical populations (Service 2022b, pp. 15-17) and increases the number of populations currently evaluated at High or Moderate demographic condition within each basin. An additional two populations within *either* the Lower Mississippi River basin (one known extant population in Low demographic condition) or Lower Missouri River basin (presumed extirpated) increases the number to 33 and 50 percent, respectively, of the historical number of populations within each of these two basins; however, we consider these populations necessary to maintain redundancy within the representation unit. They also increase the species' ability to adapt to changing environmental conditions and withstand potential catastrophic events range wide. We recognize that re-establishment of sheepnose within the Lower Missouri River basin would likely necessitate informed reintroductions from populations sourced from other basins; however, over time we would expect this population to experience different selective pressures, with the potential for this representation unit to become genetically distinct. Collectively, this approach will result in the maintenance of a minimum of 25 percent of the species' range, reflecting historical distribution across basins and associated ecological and genetic diversity range wide to allow the species to withstand future catastrophic events and adapt to changing environmental conditions. Sustaining each of these populations in at least Moderate demographic condition, indicating a stable or increasing population trend with managed levels of threats, provides the ability to withstand year-to-year stochastic fluctuations.

<u>Snuffbox</u> (*Epioblasma triquetra*)

The snuffbox may be considered for delisting when there are 40 populations (i.e., HUC 8 watersheds) range wide in High condition with Moderate or Low risk, or in Moderate condition with Low risk (condition and risk categories are defined in Service 2022c, Tables 4.3 and 4.4 or the most recent version of that document) with the following distribution:

Basin	Criteria
Great Lakes	At least 6 populations
Ohio	At least 15 populations
Tennessee	At least 3 populations
Upper Mississippi	At least 2 populations
Lower Mississippi	At least 1 population in High condition with Low risk or at least 2 populations in at least Moderate condition with Low risk
Arkansas-White-Red	At least 2 populations
Any of the 6 Basins	At least 11 additional populations

Rationale: Recovery criteria for the snuffbox entail a minimum number of healthy populations be maintained within six major river basins: Great Lakes, Ohio River, Tennessee River, Upper Mississippi River, Lower Mississippi River, and Arkansas-White-Red basins. Zanatta and Murphy (2008, entire) investigated the genetic structure of the snuffbox using seven populations throughout the species' range and found populations showed genetic structure varied among basins in the populations sampled. Additionally, Zanatta and Murphy (2008, p. 371) found that the single extant population in the Lower Mississippi River basin (St. Francis River) was genetically distinct. Maintaining populations in six major river basins, resulting in multiple healthy connected populations, preserves both the ecological and genetic diversity needed to ensure persistence of the species into the foreseeable future.

Maintaining and/or recovering 40 populations with at least 6 populations in the Great Lakes basin, 15 populations in the Ohio River basin, 3 populations in the Tennessee River basin, 2 populations in the Upper Mississippi River basin, 1 population in the Lower Mississippi River basin, and 2 populations in the Arkansas-White-Red basin comprises over 50 percent of the current populations (Service 2022c, pp. 12-13) and increases the number of populations currently considered to be of High or Moderate demographic condition within each basin. Having an additional 11 populations within any of the six basins increases the species' ability to adapt to changing environmental conditions and withstand potential catastrophic events. Collectively, this approach will reflect the species historical distribution across basins and associated ecological and genetic diversity range-wide to allow the species to withstand future catastrophic events and adapt to changing environmental conditions. Having each of these populations in at least Moderate demographic condition, indicating a stable or increasing population trend with managed levels of threats, provides the ability to withstand year-to-year stochastic fluctuations.

<u>Spectaclecase</u> (*Cumberlandia monodonta*)

The spectaclecase may be considered for delisting when there are 26 populations (i.e., HUC 8 watersheds) range wide in High condition with Moderate or Low risk, or in Moderate condition with Low risk (condition and risk categories are defined in Service 2022d, Tables 4.3 and 4.4 or the most recent version of that document) with the following distribution:

Basin	Criteria
Ohio River Basin	At least 4 populations
Tennessee River Basin	At least 6 populations
Upper Mississippi River Basin	At least 10 populations
Lower Mississippi River Basin	At least 1 population
Missouri River Basin	At least 5 populations

Rationale: Recovery criteria for the spectaclecase entail that a minimum number of healthy populations be maintained within five major river basins: Ohio River, Tennessee River, Upper Mississippi River, Lower Mississippi River, and Missouri River. Prior to recent losses of habitat and connectivity, the spectaclecase experienced a high degree of gene flow among all populations throughout its range, except for the population in the Lower Mississippi River basin representation unit (Inoue et al. 2014, p. 288, Inoue and Berg, 2017, p. 101). Currently, spectaclecase is represented by two distinct mitochondrial lineages; one representing most of its range and the other representing the Lower Mississippi River population (Inoue et al. 2014, p. 288). Maintaining populations in all five of these major river basins, especially in the Lower Mississippi River basin (resulting in multiple healthy populations), preserves both ecological and genetic diversity needed to ensure persistence of the species into the foreseeable future.

Maintaining and/or recovering a minimum of 26 populations with at least 4 populations in the Ohio River basin, 6 populations in the Tennessee River basin, 10 populations in the Upper Mississippi River basin, 1 population in the Lower Mississippi River Basin, and 5 populations in the Missouri River Basin comprises a minimum of 42 percent of the estimated number of historical populations (Service 2022d, pp. 15-28) and increases the number of populations currently considered to be of High or Moderate demographic condition within each basin. The minimum number of populations needed for each basin is based on maintaining and improving the number of populations that are currently extant, are not functionally extirpated, and have had multiple observations since 2000 (Service 2022d, Table 4.10). Having 26 populations distributed in this manner will result in the maintenance of a minimum of 42 percent of the species' range, reflecting historical distribution across basins and associated ecological and genetic diversity range wide to allow the species to withstand future catastrophic events and adapt to changing environmental conditions. Having each of these populations in at least Moderate demographic condition, indicating a stable or increasing population trend with managed levels of threats, provides the ability to withstand year-to-year stochastic fluctuations.

ACTIONS

The actions identified below in Table 1 are those we believe are necessary to address the recovery criteria and to recover the rayed bean, sheepnose, snuffbox, and spectaclecase, based on our current understanding of the recovery needs of the species. They apply to each of the basins, but specific implementation may differ by basin or region. Actions will be coordinated to the extent practicable to streamline conservation of multiple species. These broad categories of actions will be used to develop the recovery implementation strategy (RIS) for each species. The RIS will detail and prioritize specific activities required to implement these recovery actions, will be developed in coordination with our conservation partners, and will be updated as needed.

Table 1. Summary of recovery actions for 4 mussel species. Priority 1 conservation actions are those that are necessary to prevent extinction; priority 2 actions are necessary to prevent a significant decline in population size or habitat quality or some other significant negative impact; priority 3 actions are necessary to provide for full recovery of the species.

Recovery Action ID	**Recovery Action Priority #**	**Recovery Action**	**Potential Activities**
1	1 (if implemented in existing habitat) 2 (if implemented in potential habitat)	Manage, protect, and enhance existing and potential habitat	A) Creating and implementing habitat conservation measures (e.g., restoring and enhancing riparian buffers, population-specific adaptive land management and protection plans, land acquisition, improving connectivity) around existing populations and potential reintroduction sites.
			B) Creating and implementing best management practices that avoid or minimize impacts to populations or their habitat (e.g., reduce detrimental inputs such as contaminants and sedimentation, suitable dam flow management).
			C) Maintaining and enhancing in-stream habitat at existing populations and at potential reintroduction sites.
			D) Monitoring habitat restoration projects and refine techniques using adaptive management.
			E) Researching habitat requisites and best management practices to maintain or restore populations.
			F) Restoring and improving connectivity between occupied stream reaches and between areas of suitable habitat (e.g., fish passage, dam removal).
2	3	Assess population and habitat status through monitoring and surveys	A) Including, but not limited to developing and implementing rigorous standardized methods to monitor population health, habitat, and threats at existing and reestablished populations.
			B) Investigating the species' status and the habitat condition in historical streams or where status is unknown to determine suitability for reintroductions or augmentations.
			C) Researching ways to improve the effectiveness of monitoring techniques (e.g., eDNA survey techniques).

Recovery Action ID	Recovery Action Priority #	Recovery Action	Potential Activities
3	1 (extant populations) 2 (historical populations)	Manage, protect, and enhance populations	A) Augmenting existing populations through captive-rearing techniques in accordance with propagation plans with considerations for genetics and disease.
			B) Restoring historical populations, as feasible, through reintroductions or translocations (e.g., using captive-bred individuals) in accordance with propagation plans with considerations for genetics and disease.
			C) Developing and refining collection, propagation, culture, and release techniques.
			D) Researching biological, ecological, genetic, and life-history requisites to maintain or restore (e.g., stocking densities, post-relocation movement) populations.
4	2	Increase understanding of threats and alleviate threats into the foreseeable future	A) Researching the effects of climate change (e.g., changes in hydrological regime, stream morphology, stream temperatures) on the species, and determine and implement measures to alleviate those effects.
			B) Researching the effects of water quality parameters (e.g., contaminants, sedimentation, nutrients) and determine and implement measures to alleviate negative effects.
			C) Researching the effects of interacting and emerging threats and determine and implement measures to alleviate those effects.
			D) Determining the extent and effects of invasive species and how to alleviate those effects.
			E) Researching the possible causes of unexpected mass and species-specific mussel die-off events.
5	2	Engage the public and partners in freshwater mussel conservation	A) Developing outreach and education products and events to raise awareness and garner support for freshwater mussel conservation at local and regional levels.

Recovery Action ID	Recovery Action Priority #	Recovery Action	Potential Activities
			B) Disseminating targeted outreach to relevant partners and communities.
			C) Integrating planning and coordination among recovery partners.
			D) Engaging Federal agencies in proactive conservation actions to help fulfill their recovery obligations under section 7(a)(1) of the Act.

ESTIMATED COST OF RECOVERY

The estimated costs of implementing recovery actions for each species are included in Table 2. Some costs, such as the specific cost for land acquisition and activities that may be implemented as future research informs practices to reduce the effects of threats, are not determinable at this time. Therefore, the total cost may be higher than this estimate. Conversely, costs may be reduced through implementation of activities that benefit multiple species (e.g., dam removal, surveys and monitoring, research, habitat restoration).

Table 2. Estimated costs of implementing recovery actions for rayed bean, sheepnose, snuffbox, and spectaclecase.

Recovery Action	Estimated Cost: Rayed Bean	Estimated Cost: Sheepnose	Estimated Cost: Snuffbox	Estimated Cost: Spectaclecase
1. Manage, protect, and enhance habitat	$4,545,000	$4,545,000	$4,545,000	$4,545,000
2. Assess population and habitat status through monitoring and surveys	$12,125,000	$15,125,000	$12,125,000	$15,125,000
3. Manage, protect, and enhance populations	$4,675,000	$3,875,000	$4,675,000	$4,675,000
4. Increase understanding and alleviate threats	$5,500,000	$7,000,000	$5,500,000	$7,700,000
5. Engage the public and partners in freshwater mussel conservation	$700,000	$700,000	$700,000	$700,000
Total Estimated Cost:	**$27,535,000**	**$31,245,000**	**$27,535,000**	**$32,745,000**

ESTIMATED TIME TO RECOVERY

If all actions are fully funded and implemented as outlined, including full cooperation of all partners needed to achieve recovery, we anticipate delisting for each of these species could be achieved within 50 years following adoption of this plan. We note that the recovery program may change over time, or the timeframe estimated to implement the recovery actions to achieve recovery of each species may take longer than expected.

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