U.S. Fish and Wildlife Service
Draft Recovery Plan
for
The Slabside Pearlymussel
(Pleuronaia dolabelloides, Lea 1840)

Photo courtesy of Alabama Department of Conservation and Natural Resources,
Alabama Aquatic Biodiversity Center, Marion, Alabama

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DISCLAIMER

Recovery plans delineate reasonable actions that are believed necessary to recover and/or protect the species. We, the U.S. Fish and Wildlife Service (Service), publish recovery plans, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Plans are reviewed by the public and subject to additional peer review before the Service adopts them. Objectives of the recovery plan will be attained, and funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the Service. They represent our official position only after they have been signed by the Director or Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director certifies that the information used in its development represents the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record, located at the Service's Tennessee Ecological Services Field Office, Cookeville, Tennessee.

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Draft Recovery Plan for the Slabside Pearlymussel (Pleuronaia dolabelloides)

INTRODUCTION

This Recovery Plan describes site-specific actions that will be necessary to achieve recovery of the slabside pearlymussel (*Pleuronaia dolabelloides*); criteria to aid in measuring progress towards achieving this plan's recovery vision as recovery actions are implemented and, when met, should result in a determination according to the 5-listing factors that the species be removed from the List of Threatened and Endangered Wildlife (50 CFR 17, hereafter List); and estimates of the time required and the cost to implement recovery actions and meet the recovery criteria. Additionally, cursory information on the species' biology and status are included, along with a brief discussion of factors limiting its populations. The Recovery Plan was informed by the Species Status Assessment (SSA) (Service 2022), which provides a more detailed account of the species' status, distribution, biology, and threats. A Recovery Implementation Strategy (RIS) has also been developed; it is the operational document that details on-the-ground activities for implementing recovery actions (e.g., the mechanisms for implementing actions and other details related to the timing, sequence, and duration of activities based on their scope, level of interdependence, geographic location, and involvement of specific partners). All activities in the RIS tier to actions described in this recovery plan. Implementation and completion of activities identified in the RIS contribute towards the achievement of the actions described in this recovery plan. The RIS and SSA are finalized separately from the Recovery Plan and will be updated on a routine basis as new information becomes available through recovery implementation, a 5-year status review, or other relevant feedback.

SPECIES STATUS

The slabside pearlymussel was federally listed as endangered on September 26, 2013 (78 FR 59269) under the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*) (Act). Critical Habitat was designated for the species on September 26, 2013 (78 FR 59555). The slabside pearlymussel is assigned a recovery priority of 5, which indicates the species faces a high degree of threat and a low recovery potential. Recovery potential is considered low because of its distribution in small, isolated populations, its continued vulnerability to threats, our incomplete understanding of the threats, and the low to moderate resiliency for many of the extant populations. Recovery will require diligent and long-term efforts to alleviate the threats. The species is listed as endangered by state agencies in Alabama, Mississippi, Tennessee, and Virginia (VDWR 2022, p. 3; MDWFP 2016, p. 33; TWRA 2018, p. 1; ADCNR 2017, p. 24).

The slabside pearlymussel is endemic to the Cumberland River and Tennessee River drainages of the Ohio River Basin, and has been reported from Alabama, Kentucky, Mississippi, Tennessee, and Virginia (Figure 1). The slabside pearlymussel historically occupied around 3,170 river kilometers (rkm) or 1,970 river miles (rm) of stream across it range, less than 40 percent of which is currently occupied (Service 2022, pp. 36-87). It has been extirpated from the Cumberland River drainage and from Kentucky. Approximately 1,562 rkm (971 rm) of stream

channel in Alabama, Mississippi, Tennessee, and Virginia have been designated as critical habitat for the slabside pearlymussel (78 FR 59555). The 13 critical habitat areas are as follows: North Fork Holston River, VA; Middle Fork Holston River, VA; Big Moccasin Creek, VA; Clinch River, TN, VA; Powell River, TN, VA; Nolichucky River, TN; Hiwassee River, TN; Sequatchie River, TN; Paint Rock River, AL; Elk River, AL, TN; Bear Creek, AL, MS; Duck River, TN; and Buffalo River, TN.

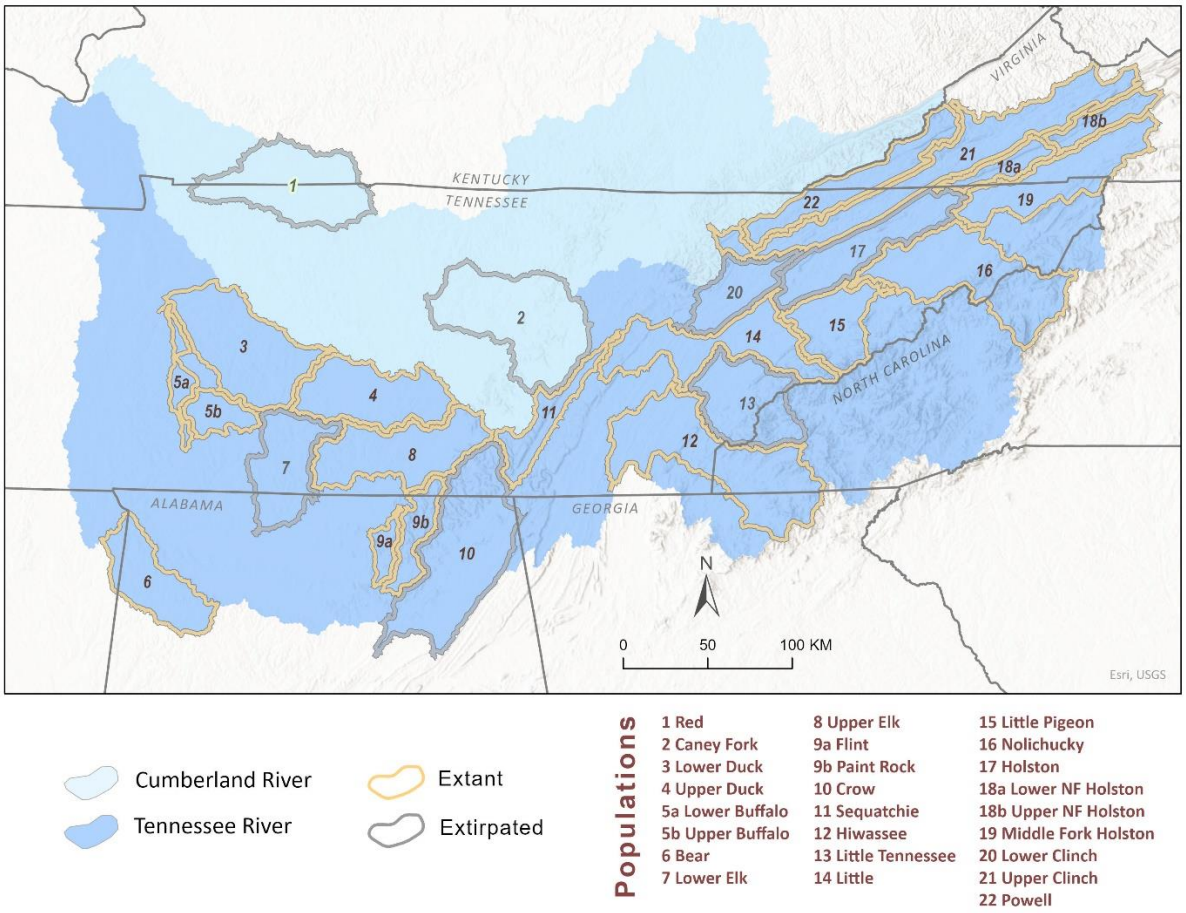

Figure 1. Slabside pearlymussel distribution and current condition (resiliency) within Management Units using the USGS 8-digit hydrological unit code (HUC8s).

SPECIES NEEDS AND LIMITING FACTORS

The slabside pearlymussel has an equilibrium life history strategy (Haag 2012, pp. 210-211, 272-276). Equilibrium strategists typically exhibit long life spans and late maturity, are short-term brooders with low batch fecundity, and have low to moderate growth rates (Haag 2012, pp. 210-211). The lifespan of the slabside pearlymussel is estimated to exceed 40 years (Grobler et al. 2006, p. 65). While the age at sexual maturity is not known for the slabside pearlymussel, age at maturity is likely greater than 3 years (e.g., 4-7 years) based upon its equilibrium life history strategy (Haag 2012, pp. 194, 210). For populations of slabside pearlymussel to persist they must successfully reproduce and maintain viable offspring. Adult survival among mussels is generally high with annual adult survival greater than 90 percent for many mussel species, however,

survival from the glochidial (larval) stage is exceptionally low (to the order of 10^{-5} to 10^{-6}) with individual females successfully producing only 0.1 to 1.3 juveniles per year (Haag 2012, p. 220). Increased juvenile recruitment, in addition to adult growth and survival, are indicative of population health and will increase resiliency for the slabside pearlymussel. As such, the recovery strategy will be aimed at addressing threats to the species that results in enhanced survival and reproduction.

The slabside pearlymussel like other freshwater mussels has a unique life cycle where it parasitizes a host species (usually a fish) to complete the transformation from its larval form (glochidial stage) to juveniles. The slabside pearlymussel is a short-term brooder. With short-term brooders, eggs are usually fertilized in the spring or summer and are brooded until they develop into mature glochidia in 2 to 6 weeks and are released onto fish hosts shortly thereafter. Spawning of slabside pearlymussel occurs in May to August (Ortmann 1921, pp. 83-84; Kitchel 1985, p. 53). Equilibrium strategists, like the slabside pearlymussel, tend to be better adapted to more stable habitats with low environmental variation (Haag 2012, p. 276). The following essential physical or biological features (previously referred to as primary constituent elements) of the critical habitat (78 FR 59555) for this mussel include:

- Riffle habitats within large, geomorphically stable stream channels (channels that maintain lateral dimensions, longitudinal profiles, and sinuosity patterns over time without aggrading or degrading bed elevation).
- Stable substrates of sand, gravel, and cobble with low to moderate amounts of fine sediment and containing flow refugia with low shear stress.
- A natural hydrologic flow regime (magnitude, frequency, duration, and seasonality of discharge over time) necessary to maintain benthic habitats where the species is found, and connectivity of rivers with the floodplain allowing the exchange of nutrients and sediment for habitat maintenance, food availability for all life stages, and spawning habitat for native fishes.
- Water quality with low levels of pollutants and including a natural temperature regime, pH (between 6.0 to 8.5), oxygen content (not less than 5.0 milligrams/liter), hardness, and turbidity necessary for normal behavior, growth, and viability of all life stages.
- The presence of abundant fish hosts, which may include the popeye shiner (*Notropis ariommus*), rosyface shiner (*N. rubellus*), saffron shiner (*N. rubricroceus*), silver shiner (*N. photogenis*), telescope shiner (*N. telescopus*), Tennessee shiner (*N. leuciodus*), whitetail shiner (*Cyprinella galactura*), white shiner (*Luxilus albeolus*), and eastern blacknose dace (*Rhinichthys atratulus*), necessary for recruitment of the slabside pearlymussel.

Habitat factors like stable substrate and water quality greatly influence the demographic factors important for survival and reproduction of a population, such as growth and recruitment. At the time of listing, the primary threats to slabside pearlymussel were associated with the destruction, modification, or curtailment of its habitat or range; and specific threats were impoundments, gravel and coal mining, siltation, water pollution, and stream channel alterations (78 FR 59269). There are over 2,000 legacy dams of various sizes directly and indirectly impacting nearly the entire range of the slabside pearlymussel. The construction of large impoundments occurred primarily from 1913 to 1976 (TVA 2022; USACE 2020), inundated many river kilometers within the species' range, and have altered habitat connectivity, spatial and temporal variability

in water flow and temperature regimes upstream and downstream of populations. These historical events have fragmented the current distribution of this low-mobility species into isolated populations. While it is unlikely that the large dams will be removed within the near future, efforts have been made to improve water quality conditions through coordinated dam releases to better mimic natural flow regimes suitable for native aquatic fauna downstream of those dams.

Ongoing land use activities, especially gravel and coal mining, urban development, and agriculture, continue to degrade habitat within the species' range by contributing sediment and chemical contaminants to streams and by physically altering stream channels and riparian habitat. Climate change is likely to adversely affect the species by altering hydrologic cycles and temperature regimes, but the extent or magnitude of this threat has not been quantified at this time. Disease was not identified as a substantial threat at the time of listing, however recent research suggests that pathogens, such as viral infection, or other causal agents (i.e., bacteria, parasites) can contribute to poor mussel health resulting in mussel die-offs as seen in the Clinch River beginning in 2016 (Henley et al. 2019, p. 681; Richard et al. 2020, entire; 2021, entire).

RECOVERY STRATEGY

The recovery strategy for the slabside pearlymussel is focused on addressing threats that negatively affect the causal mechanisms of the species life-history strategy, especially adult survival and juvenile recruitment. Improved habitat and water quality conditions resulting from slabside pearlymussel recovery efforts will also have positive effects for the watersheds throughout areas of the Tennessee River and Cumberland River drainages in which they are found. Currently, the degraded habitat and water quality conditions affecting the slabside pearlymussel share effects with other overlapping listed species, as well as threaten drinking water quality which restricts human use of various creeks and rivers throughout these systems. By implementing a strategy that reduces threats affecting numerous aquatic species (e.g., excess sediment, pollution), we will not only create conditions that benefit the slabside pearlymussel and many other overlapping listed species, but also improve overall public health and increase the availability of recreational opportunities (e.g., fishing and swimming) for the communities that live within watersheds where the species occurs.

Resiliency

Achieving the recovery of the slabside pearlymussel will require implementing a strategy that improves water and habitat quality, restores connectivity, promotes population growth through increased adult survival and juvenile recruitment, and ultimately increases the overall numbers of resilient populations. Resilient populations are measured by using the following population elements: extent (number of HUC10s occupied by each contiguous population), abundance (number of individuals within a population), continuity (amount of continuously occupied habitat within a population), and complexity (number of tributaries occupied within a population). By increasing resiliency, populations of this equilibrium strategist, which are generally expected to respond poorly to environmental disturbance, will be less affected by stochastic events (e.g., major floods, severe droughts) and will be more likely to persist into the foreseeable future.

Habitat and water quality improvements will require working with various partners including private landowners, as much of the land within the watersheds currently or historically occupied by slabside pearlymussel are in private ownership. The potential to deliver actions that promote slabside pearlymussel conservation will vary spatially in relation to site characteristics, landscape context and compatibility of species needs with objectives of private and public-managing partners. Land acquisition for conservation will, in some instances, be an effective tool for mitigating threats contributing erosion, nutrient enrichment, and stream bank instability from legacy or future land uses that contribute to erosion, nutrient enrichment, and stream bank instability. However, the majority of habitat and water improvements will require education, coordination, and cooperation with landowners, other agencies, and interested parties to adopt and implement socially acceptable and effective recovery activities that benefit the slabside pearlymussel as well as numerous other overlapping listed species.

On-the-ground efforts and conservation practices (e.g., stabilizing streambanks, restricting livestock from streams, vegetative stream buffers, etc.) to reduce siltation and pollution will be an important part of recovering the species. These efforts will be particularly important on private lands as the vast majority of occupied stream reaches (e.g., 93 percent of designated critical habitat) are in private ownership. Collaborating with private landowners in ways that promote effective implementation of best management practices (BMPs) will play a key role in achieving the recovery vision for the species. Funding assistance provided through federal voluntary conservation programs and coordination with the Natural Resource Conservation Service in priority locations and on special initiatives like Working Lands for Wildlife and the Regional Conservation Partnership Program can, for example, contribute to the economy of rural communities and encourage landowners to invest in improved BMPs. These programs will benefit people and improve the quantity, condition, and connectivity of habitats supporting aquatic species including the slabside pearlymussel.

Reducing siltation and pollutants will also require utilizing environmental regulations to their full extent in protecting water quality. Existing water quality concerns indicate that recovery may require bolstering existing regulatory mechanisms to have more meaningful impact, as well as addressing gaps in regulations where water quality issues are not being addressed (e.g., non-point source pollution). For example, addressing water quality threats from land development and resource extraction may be achieved through enhancing National Pollutant Discharge Elimination permit requirements and by incorporating additional conservation measures. Partnering with agencies and organizations to increase public awareness, promote and incentivize compliance, and support consistent enforcement will also be essential to achieving recovery. The Service as well as the states within the range of the slabside pearlymussel have identified the protection of riparian corridors and watersheds; implementation of best management practices; restoration of degraded habitats; better management practices for stormwater, agricultural runoff, and development; and initiation of local watershed improvement projects, invasive species control, and migration barrier removals as activities important to the conservation of slabside pearlymussel.

Increasing the extent, abundance, continuity, and complexity of populations improves the potential for populations to withstand stochastic environmental events such as major floods and severe droughts. Increasing occupied stream lengths will be achieved through habitat improvement, population augmentation efforts, and migration barrier removal. Propagation and reintroduction techniques, plans, and protocols will need to be developed prior to any slabside pearlymussel population augmentation efforts. So far, there is still limited best available science for the species, and both Virginia and Alabama have identified this need for the slabside pearlymussel in their State Wildlife Action Plans (SWAP) (VDGIF 2015 and ADCNR 2017). Partnering with state agencies, academic institutions, and non-governmental organizations will be integral in developing captive propagation and reintroduction plans, identifying barrier removal opportunities, and implementing removals. Low head dam removal projects have the potential to convey some of the most enduring conservation outcomes that can be achieved for imperiled aquatic species and eliminate the deadly hazard they pose to public safety. Removal of migration barriers should reestablish connectivity of upstream and downstream movements of slabside pearlymussel and their host fishes.

Representation

The majority of slabside pearlymussel populations, both historical and current, occur within the Ridge and Valley and Interior Plateau ecoregions, while the remaining ecoregions (Southeastern Plains, Blue Ridge, Southwestern Appalachians, and Central Appalachians) are represented by four or less populations each. In addition to threat abatement, controlled propagation and augmentation within each ecoregion will be an important conservation tool in preserving the geographic and ecological representation of the species across its native range. Population augmentation will be necessary to increase resiliency in some ecoregions (e.g., Blue Ridge ecoregion), that are represented by only low resiliency populations (Figure 2; Table 1); refer to SSA document for a more detailed assessment of these low resiliency populations (Service 2022). The range of morphological, genetic, and behavioral variation should be preserved to maintain the evolutionary variation of the species.

Table 1. Comparing historic and current slabside pearlymussel populations in HUC10s - Level 3 Ecoregion variability.

Level 3 Ecoregion	Number of historically occupied HUC10s	Number of currently occupied HUC10s	% Decline
Southeastern Plains	3	3	0
Blue Ridge	1	1	0
Ridge and Valley	30	17	43
Southwestern Appalachians	4	2	50
Central Appalachians	2	1	50
Interior Plateau	20	12	40

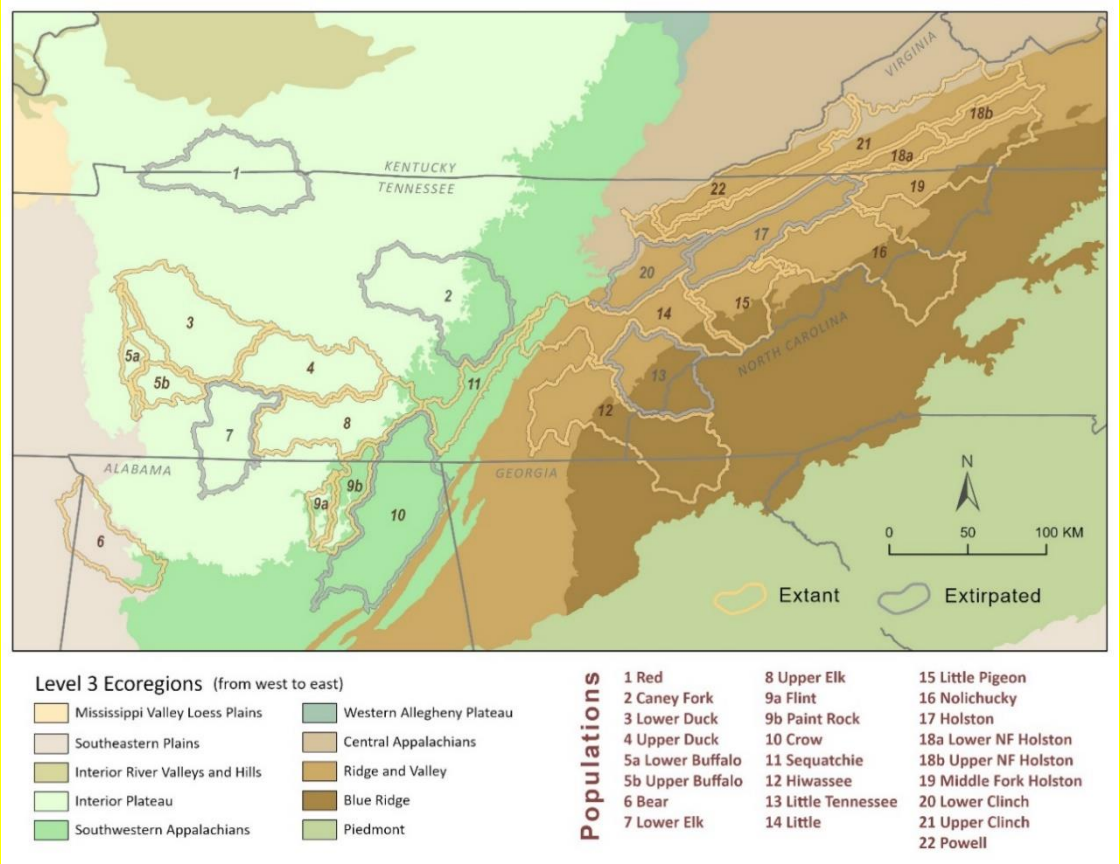

Figure 2. Slabside pearlymussel populations relative to level 3 ecoregions (USEPA 2010).

Redundancy

Maintaining extant populations may require augmentation of those with low resiliency. We will also need to discover or reintroduce at least two additional populations in order to meet a level of redundancy that will minimize the loss of representation and localized extirpation regarding range-wide persistence of the slabside pearlymussel. Virginia and Alabama identified development of propagation techniques for the slabside pearlymussel in their respective SWAP (VDGIF 2015 and ADCNR 2017). The Alabama SWAP also established a goal of establishing two or more additional reproducing populations of the slabside pearlymussel (ADCNR 2017). The Cumberlandian Regional Mollusk Population Restoration plan identifies multiple potential areas (e.g., the lower Elk, Nolichucky, Pigeon, Little Tennessee, and the Red River) for slabside pearlymussel restoration efforts (CRMRC 2010). The Red River or Caney Fork may be a priority area for reintroduction as the species is believed extirpated from the Cumberland River drainage.

RECOVERY CRITERIA

Recovery criteria are objective, measurable conditions that, when met, indicate that a species may warrant delisting. The slabside pearlymussel will be considered for delisting when the following conditions are met:

Criterion 1

At least 12 resilient populations (moderate to high, as defined in Chapter 4 of the SSA) are needed for recovery of the slabside pearlymussel.

Criterion 2

A minimum of 20 total populations of slabside pearlymussel, which includes the 12 needed for resiliency, are needed for species representation and redundancy. These populations need to be represented across all 6 ecoregions (Southeastern Plains, Blue Ridge, Ridge and Valley, Southwestern Appalachians, Central Appalachians, and Interior Plateau) to which it is native.

Criterion 3

Habitat for the slabside pearlymussel should exhibit the essential physical or biological features (previously referred to as primary constituent elements) outlined in the critical habitat rule (78 FR 59555).

JUSTIFICATION FOR RECOVERY CRITERIA

The proposed recovery criteria reflect the best available scientific and commercial information on the slabside pearlymussel. These criteria address the five factors described in section 4(a)(1) of the Act and incorporate the conservation principles of representation, resiliency, and redundancy (Shaffer and Stein 2000; Wolf *et al.* 2015).

Criterion 1

This criterion addresses the establishment of resilient populations, and the ability resilient populations convey to the species relative to persistence even after being negatively affected by stochastic events (e.g., severe droughts, toxic spills, major floods, etc.). Resilient populations will be needed for adaptive capacity and to provide broodstock for population restoration efforts across the slabside pearlymussel's range. To be resilient, populations need to exhibit sufficient extent, abundance, continuity, and complexity to overcome the effects of these events. Populations should also exhibit successful reproduction and recruitment in order to maintain viability. Resilient populations provide adaptive capacity for the species (e.g., genetic diversity, biodiversity of ecosystems, and heterogeneous ecosystems) and source populations for conservation and recovery efforts in other less resilient portions of the species' range. To maintain these resilient populations, habitat restoration actions that improve water quality and restore stream connectivity and ecological function will need to be prioritized across all 6 ecoregions. Additionally, connectivity between populations and among habitats should be restored or mitigated to allow appropriate genetic flow and exchange.

Criterion 2

This criterion would maintain representation across all native ecoregions and assist the species ability to adapt to changing environmental conditions over time by maintaining a degree of genetic and environmental diversity within and among the populations. Criterion 2 will also increase redundancy by increasing the number of populations beyond what is currently known,

protecting the species against irreplaceable loss of representation and minimizing the effect of localized extirpation by increasing range-wide persistence. By preserving representation of all the native ecoregions and increasing the total number of populations from what is currently known, the species will have gained an increased ability to withstand catastrophic events by distributing populations across a large geographic area.

Criterion 3

This criterion would address stressors and threats impacting the ability of the slabside pearlymussel to remain resilient. Threats to the slabside pearlymussel identified in the 2013 listing rule (78 FR 59269), 2013 critical habitat rule (78 FR59555), and the SSA (Service 2022), need to be ameliorated to recover and delist the species. To the extent necessary to support recovery, regulations and programs need to be in place to ensure that water quality parameters will be maintained at levels meeting the life history requirements of the slabside pearlymussel. Habitat degradation and stream impairment needs to be effectively managed or abated to a degree that does not impair the basic functions of feeding, breeding, and sheltering.

Recovery criteria serve as indicators that threats affecting the species have been abated, and when met, an analysis of the five factors upon which classification determinations are based, should result in a determination that the species can be delisted. Although not every identified threat needs to be completely eliminated to delist a species, current and foreseeable threats must be abated to the point where a recovered species is unlikely to become in danger of extinction again within the foreseeable future.

ACTIONS NEEDED

The recovery actions identified in the table below are those we believe are necessary to recover the slabside pearlymussel, based on the best scientific and commercial information. Recovery actions are assigned numerical priorities to address the most significant threats first to achieve the most recovery in the least amount of time (48 FR 43098).

Recovery Action ID Number	Recovery Action	Estimated Cost[1]	Priority[2]
1	Increase knowledge of the biology and ecology of the species, particularly its response to threats.	$1,000,000	1
2	Protect, improve, and restore stream habitat and riparian buffers to maintain and increase resiliency.	$50,000,000	1
3	Periodically monitor population and habitat conditions across the species range.	$5,000,000	2
4	Evaluate taxonomic uncertainty and genetic structure of populations across the species range.	$800,000	2
5	Develop and implement propagation techniques and protocols to augment extant and low resiliency populations.	$5,000,000	1

6	Assess historical populations to determine potential for threat abatement, habitat restoration, and population reintroductions.	$2,000,000	1
7	Conduct outreach to local communities within the range of the species to gain support for conservation and stewardship efforts to benefit the species.	$150,000	3
8	Reintroduce new populations to unoccupied habitat witin the historical range of the species.	$4,000,000	1
9	Search for undocumented populations and undocumented occupied reaches within the range of the species in order to achieve delisting criteria.	$200,000	2
	Total Estimated Cost: $68,150,000		

[1] Costs covered under existing programs are not included in this table.

[2] Recovery actions are assigned numerical priorities to highlight the relative contribution they may make toward species recovery (48 FR 43098):

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

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

Priority 3 – All other actions necessary to provide for full recovery of the species.

Estimated Cost of Delisting

The estimated costs associated with implementing recovery actions for delisting are $68,150,000. Cost estimates reflect costs for specific actions needed to achieve slabside pearlymussel recovery. Some costs for recovery actions, especially actions 2 and 8, are difficult to estimate at this time, because identifying specific activities under these actions depend on the outcomes from actions 1, 3, and 4. Because some costs are not determinable at this time, the total cost for recovery will likely be higher than this estimate. Some of the costs specified for recovering the slabside pearlymussel will be shared with recovery programs for other federally listed species and will benefit other species of greatest conservation need and of cultural significance within its range.

DATE OF RECOVERY

If all actions are fully funded and implemented as outlined, including full cooperation of all partners needed to achieve recovery, we anticipate that recovery could be achieved after the span of 40 years (a full life span of this mussel, approximately 10 generations) following the adoption of this plan.

LITERATURE CITED

Alabama Department of Conservation and Natural Resources (ADCNR). 2017. Alabama Wildlife Action Plan 2015-2025. 503 pp.

Cumberlandian Region Mollusk Restoration Committee (CRMRC). 2010. Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region. V + 145 pp.

Gatenby, C.M., R.J. Neves, and B.C. Parker. 1996. Influence of sediment and algal food on cultured juvenile freshwater mussels. *Journal of the North American Benthological Society* 15:597-609.

Grobler, P.J., J.W. Jones, N.A. Johnson, B. Beaty, J. Struthers, R.J. Neves, and E.M. Hallerman. 2006. Patterns of genetic differentiation and conservation of the slabside pearlymussel, *Lexingtonia dolabelloides* (Lea, 1840) in the Tennessee River Drainage. *Journal of Molluscan Studies* 72:65-75.

Haag, W.R. 2012. North American Freshwater Mussels: Natural History, Ecology, and Conservation. Cambridge University Press, Cambridge, New York. 538 pp.

Henley, W.F., B.B. Beaty, and J.W. Jones. 2019. Evaluations of organ tissues from *Actinonaias pectorosa* collected during a mussel die-off in 2016 at Kyles Ford, Clinch River, Tennessee. *Journal of Shellfish Research* 38:681-696.

Jones, J.W. and R.J. Neves. 2002. Annual progress report for 2001: life history and artificial culture of endangered mussels. Report submitted to Tennessee Wildlife Resources Agency, Nashville, Tennessee. 90 pages.

Kitchel, H.E. 1985. Life history of the endangered shiny pigtoe mussel, *Fusconaia edgariana*, in the North Fork Holston River, Virginia. Master's thesis, Virginia Polytechnic Institute and State University, Blacksburg. 124 pages.

Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP). 2016. Mississippi State Wildlife Action Plan 2015-2025. 692 pp.

Ortmann, A.E. 1921. The anatomy of certain mussels from the upper Tennessee. *The Nautilus* 34:81-91.

Parmalee, P.W., and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville, Tennessee. 328 pp.

Richard, J.C., E. Leis, C.D. Dunn, R. Agbalog, D. Waller, S. Knowles, J. Putnam, and T.L. Goldberg. 2020. Mass mortality in freshwater mussels (*Actinonaias pectorosa*) in the Clinch River, USA, linked to a novel densovirus. *Scientific Reports* (2020) 10:14498.

Richard, J.C., L.J. Campbell, E.M. Leis, R.E. Agbalog, C.D. Dunn, D.L. Waller, S. Knowles, J.G. Putnam, and T.L. Goldberg. 2021. Mass mortality and the microbiome: Evidence for shifts in the bacterial microbiome of a declining freshwater bivalve. *Microorganisms* (2021) 9:1-15.

Shaffer, M.L. and B.A. Stein. 2000. Safeguarding our precious heritage. In: Stein B.A., L.S. Kutner, and J.S. Adams, eds. Precious Heritage: the status of biodiversity in the United States. New York: Oxford University Press: pp. 301-321.

Strayer, D.L., J.A. Downing, W.R. Haag, T.L. King, J.B. Layzer, T.J. Newton, and S.J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. *BioScience* 54:429-439.

Tennessee Wildlife Resources Agency (TWRA). 2018. Rules of Tennessee Wildlife Resources Agency Biodiversity, Chapter 1660-01-32, Rules and Regulations for in Need of Management, Threatened, and Endangered Species. Effective date August 30, 2018. Nashville, Tennessee. 6 pp.

Tennessee Valley Authority (TVA). 2022. Hydroelectric. Available at: https://www.tva.gov /Energy/Our-Power-System/Hydroelectric (accessed June 1, 2022).

U.S. Army Corps of Engineers (USACE). 2020. National inventory of dams: U.S. Army Corps of Engineers. Website Version 3.22.0, API Version 3.22.0. Available at: https://nid.usace.army.mil/#/ (accessed June 1, 2022).

U.S. Environmental Protection Agency (USEPA). 2010. Level III ecoregions of the continental United States (revision of Omernik, 1987): Corvallis, Oregon, USEPA National Health and Environmental Effects Research Laboratory, Map M-1, various scales.

U.S. Fish and Wildlife Service (Service). 2022. Species status assessment report for the slabside pearlymussel (*Pleuronaia dolabelloides*), Version 1.0. April 2022. Atlanta, GA.

U.S. Fish and Wildlife Service (Service). 2013. Endangered and threatened wildlife and plants; Endangered species status for the fluted kidneyshell and slabside pearlymussel. *Federal Register* 78:59269-59287.

U.S. Fish and Wildlife Service (Service). 2013. Endangered and threatened wildlife and plants; Designation of critical habitat for the fluted kidneyshell and slabside pearlymussel. *Federal Register* 78:59556-59620.

Vaughn, C.C., Nichols, S.J., and D.E. Spooner. 2008. Community and foodweb ecology of freshwater mussels. *Journal of North American Benthological Society* 27:409-423.

Virginia Department of Game and Inland Fisheries (VDGIF). 2015. Virginia's 2015 Wildlife Action Plan. Henrico, Virginia. 1,135 pp.

Virginia Department of Wildlife Resources (VDWR). 2022. Special Status Faunal Species in Virginia. Version dated March 14, 2022. Available at: https://dwr.virginia.gov/wp-content/uploads/media/virginia-threatened-endangered-species.pdf (Accessed June 1, 2022).

Williams, J.D., A.E. Bogan, and J.T. Garner. 2008. Freshwater mussels of Alabama & the Mobile Basin in Georgia, Mississippi, & Tennessee. University of Alabama Press, Tuscaloosa, Alabama. 908 pp.

Wolf, S., B. Hartl, C., C. Carroll, M.C. Neel, and D.N. Greenwald. 2015. Beyond PVA: Why recovery under the Endangered Species Act is more than population viability. *BioScience* 65:200-207.

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