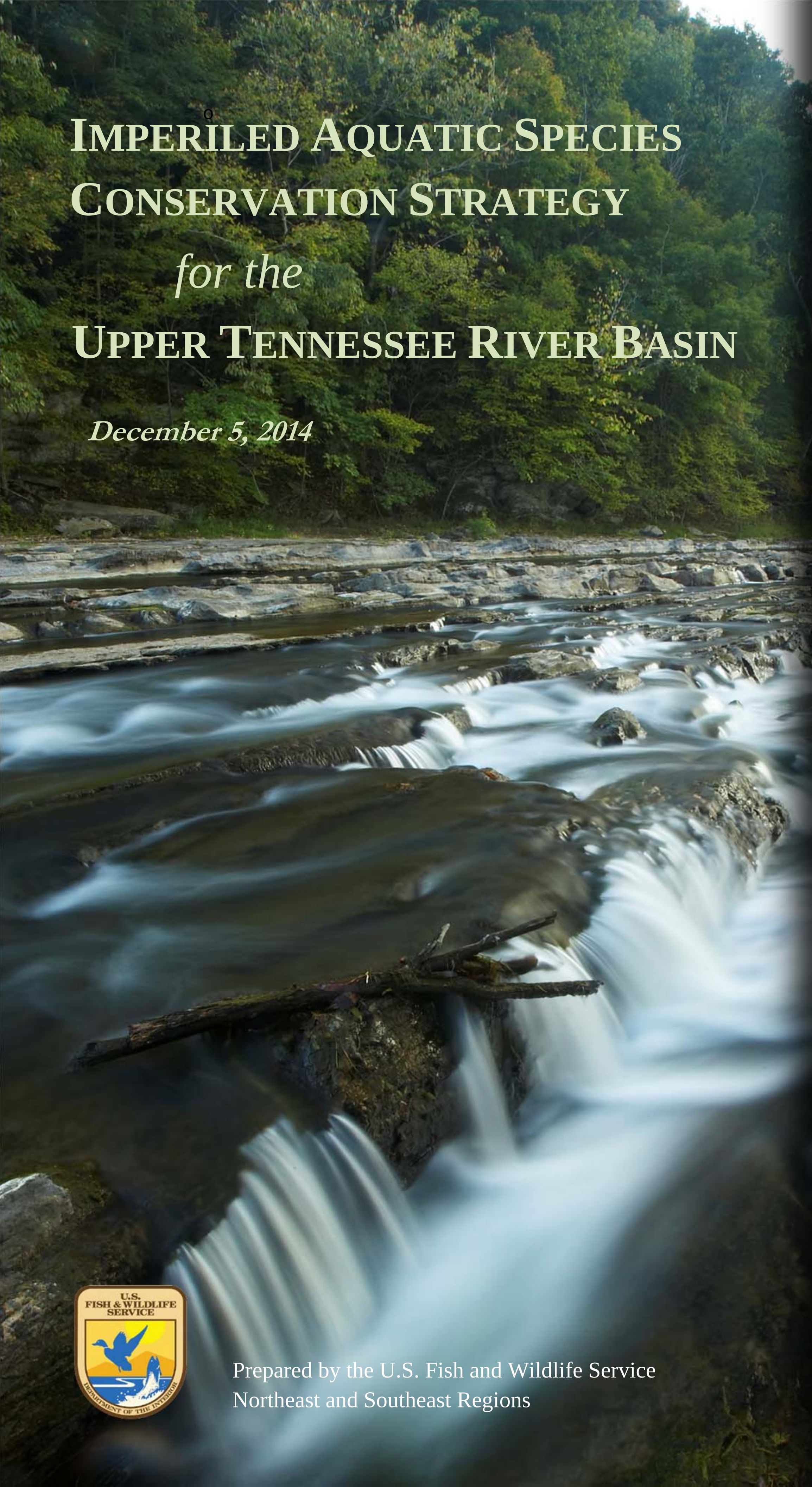

# Imperiled Aquatic Species Conservation Strategy *for the* Upper Tennessee River Basin

***December 5, 2014***


Prepared by the U.S. Fish and Wildlife Service
Northeast and Southeast Regions

## Front Cover Photo Credits

Background photo: North Fork Holston River by Jack Looney. Right column photos from top to bottom: snorkeler in Clinch River by Jack Looney; yellowfin madtom by Conservation Fisheries, Inc.; assorted freshwater mussels by Jack Looney; duskytail darter by Conservation Fisheries, Inc.; and tagged purple bean by Shane Hanlon.


## Acknowledgements

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## Disclaimer

This document recommends actions to maximize the conservation and recovery of federally listed, proposed, and candidate fishes and mussels and the Upper Tennessee River Basin ecosystem upon which they depend. It does not obligate any party to undertake specific actions and may not represent the views, official positions, or approval of any individuals or agencies involved in aquatic species recovery, other than the USFWS. This is a working document subject to modification, as dictated by new findings, changes in species status, evolving priorities, and completion of conservation actions.

## Recommended Citation


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## Executive Summary

The purpose of the Imperiled Aquatic Species Conservation Strategy for the Upper Tennessee River Basin (UTRB) (Strategy) is to provide a cost effective approach to guide conservation and management of imperiled freshwater fish and mussel species in the UTRB. For the purposes of this Strategy, the terms "imperiled" and "imperiled aquatic species" implies only those fishes and mussels that are federally listed, proposed listed, or candidates for listing under the Endangered Species Act (ESA). The Strategy identifies a management approach expected to achieve significant conservation benefits in an efficient manner and identifies priority species and locations for management focus. While the Strategy describes an effective and efficient approach towards recovery of imperiled aquatic species in the UTRB, it is not a rigid management prescription but is intended to guide management of these resources. The adaptability of the Strategy will help the U.S. Fish and Wildlife Service (USFWS) better integrate its efforts internally and with those of partners whose missions complement the goal of maximizing conservation and recovery of imperiled aquatic species and the UTRB ecosystem upon which they depend. It is important to note that we do not seek to direct the work of our partners with this Strategy; rather, we seek to prioritize USFWS efforts so that we can make the most effective use of a limited budget and continue to complement the work of our conservation partners. An added benefit of many of the conservation and management actions outlined in the Strategy will be realized for the remainder of species—rare and common alike—that comprise aquatic communities in the UTRB.

The UTRB, encompassing a landscape of 22,360 square miles primarily in Virginia, North Carolina, and Tennessee, harbors one of the most diverse assemblages of fishes and mussels in North America. Twelve extant fish species and 24 extant mussel species under Federal protection are considered in the Strategy, 14 of which have critical habitat designated within the UTRB. To achieve cost effective conservation for such a large number of species facing a variety of threats, the USFWS formed a conservation strategy team to develop the Strategy. The team sought to better understand what sorts of actions need to be emphasized within the UTRB to best achieve recovery of federally listed, proposed, and candidate fishes and mussels (i.e., imperiled aquatic species).

Strategy development began with articulation of conservation goals and objectives followed by comprehensive identification of management actions. The goal identified for the Strategy is to maximize conservation and recovery of imperiled aquatic species and the UTRB ecosystem upon which they depend. The two primary objectives that encompassed all other objectives were to: (1) maximize imperiled species persistence and viability and (2) maximize operational efficiency. The management actions were combined into broad approaches and compared to determine which approach was most likely to achieve the conservation objectives.

Using the principles and practices of structured decision making, formulation of alternative approaches was guided by those factors considered by the team to be most limiting to recovery of imperiled fishes and mussels. These broad limiting factors were deemed to be low population size and density (depensation), contaminants, and lack of dispersal/fragmentation. Management actions addressing these limiting factors were categorized into broad alternative approaches. After consideration of several alternatives, the team selected three approaches for in-depth analysis and comparison: (1) status quo management, continuing the implementation of management actions at the current level of effort by USFWS; (2) population management emphasis, addressing depensation and lack of dispersal/fragmentation by increasing extant populations and establishing additional populations through propagation and translocation of individuals into suitable habitat; and (3) habitat management emphasis, addressing water quality, physical habitat, and flow concerns by protecting or restoring occupied and unoccupied habitat within the historical range of UTRB species.

To compare the three alternative approaches, conservation benefits and management costs for each approach were projected over a 20-year period. Performance measures for species persistence and viability were combined with projections for operating costs to compare approaches and consider tradeoffs between conservation benefits and costs. Population management emphasis was identified as more effective and efficient across a wide range of objective weightings. It is important to note that the alternative approaches are not exclusive of each other. Rather they differ by emphasizing some management actions more than others. Population management emphasis includes habitat management actions and vice versa.

Population management emphasis shifts focus by increasing implementation of actions under ESA Sections 7 and 10, protection of existing and establishment of new populations, augmentation of extant populations, captive population management, and development of best management practices for managing instream and riparian habitats. To account for budget trade-offs, the approach continues, but reduces emphasis on, land acquisition/easements and active restoration of instream and riparian habitats. While maintaining existing population and habitat monitoring, other monitoring and research will be needed to support the approach. These include increasing life history research, evaluating and monitoring threats, genetics monitoring and research, population viability analyses, habitat evaluation for reintroduction, propagation and captive management research, and evaluation of ecosystem services. Increased outreach and establishment of partnerships are also needed to support the approach, while maintaining intra-agency communications.

Species were prioritized for focused management actions based on level of imperilment, expected maximum conservation benefit, and estimated management cost. Similarly, watersheds (for fishes) and stream reaches (for mussels) were prioritized for habitat management actions, given management feasibility and expected benefits to imperiled species. Prioritization of species and locations for management does not imply a defined threshold above which only those species and locations will be targeted for action. Rather, the prioritization is intended to guide the next stage of conservation where the Strategy is stepped down to specify optimal actions for particular species and locations. As conservation moves from broad strategic planning to project development and implementation—which are necessarily tempered by budgetary and other resource constraints—high priority species and locations will receive a higher level of consideration for management actions to maximize conservation benefits. The Strategy is therefore a combination of (1) the most advantageous and cost effective management approach for conserving imperiled fish and mussel species in the UTRB, (2) priority imperiled fish and mussel species for focused management consideration, and (3) priority areas for focused habitat management.

The Strategy reflects USFWS's commitment to Strategic Habitat Conservation and managing and conserving resources at the landscape scale. It also recognizes the need for cooperative efforts to improve efficiency in the face of declining budgets and the importance of adapting management to changing conditions and knowledge. When working with partners, USFWS intends to use the Strategy as a guide to adaptive management in the UTRB. To aid in implementation of the Strategy, USFWS will host an annual project planning meeting with partner agencies and organizations to discuss completed, ongoing, and future projects that help to achieve the goal and objectives of the Strategy. The USFWS will review and evaluate the Strategy's effectiveness, based on monitoring results, lessons learned, and other available information, and modify or adapt the Strategy as appropriate.

# Table of Contents

# Imperiled Aquatic Species Conservation Strategy
# for the
# Upper Tennessee River Basin

## Purpose

The purpose of the Imperiled Aquatic Species Conservation Strategy for the Upper Tennessee River Basin (UTRB) (Strategy) is to guide the U.S. Fish and Wildlife Service (USFWS) in the management of Federal candidate, proposed, and listed (herein collectively referred to as imperiled) aquatic species in the UTRB. Because nearly all imperiled aquatic species in the UTRB are fishes and mussels (Appendix 1), the Strategy is focused on these two faunal groups at present. The Strategy will (1) identify, prioritize, and guide implementation of on-the-ground actions, including population and habitat management, monitoring, and research, towards the recovery of imperiled aquatic species; and (2) integrate the efforts of internal and external partners, as appropriate. It is understood that implementation of many of the conservation and management actions outlined in the Strategy will directly or indirectly benefit other species that comprise aquatic communities in the UTRB. It is important to note that the USFWS does not seek to direct the work of our partners with this Strategy; rather, we seek to prioritize USFWS efforts so that we can make the most effective use of a limited budget and continue to complement the work of our conservation partners.

The USFWS will work cooperatively internally and externally to implement and monitor the progress of this Strategy. Through the Strategy, the USFWS seeks to coordinate implementation and monitoring of efforts intended to (1) conserve and recover imperiled aquatic species and the UTRB ecosystem upon which they depend, (2) lead to imperiled species stabilization and/or recovery, (3) provide information to all stakeholders and partners involved in conservation efforts, (4) encourage collaborative efforts among agencies and partners towards imperiled species conservation, and (5) help ensure compliance with pertinent laws, regulations, and policies. The goals, objectives, and management actions in this Strategy were developed for conservation implementation over a 20-year period, with periodic review and revision as needed.

## Introduction and Geographic Scope

The geographic scope of this Strategy is the UTRB, which drains portions of the Blue Ridge, Ridge and Valley, and Appalachian Plateau physiographic provinces of the southern Appalachian Mountains (Figure 1). This includes southwestern Virginia, western North Carolina, eastern Tennessee, and small portions of northeastern Alabama and northern Georgia (Figure 1). The UTRB in Virginia, North Carolina, and Tennessee is the focus of the Strategy. As defined herein, the basin encompasses 22,360 square miles (an area about the size of West Virginia), and is made up of the entire Tennessee River basin upstream of its confluence with and including the Sequatchie River drainage (Figure 1). Major tributaries of the UTRB include the French Broad (5,124 square miles), Clinch (4,413 square miles), Holston (3,776 square miles), Hiwassee (2,700 square miles), Little Tennessee (2,627 square miles), and Sequatchie (602 square miles) Rivers.

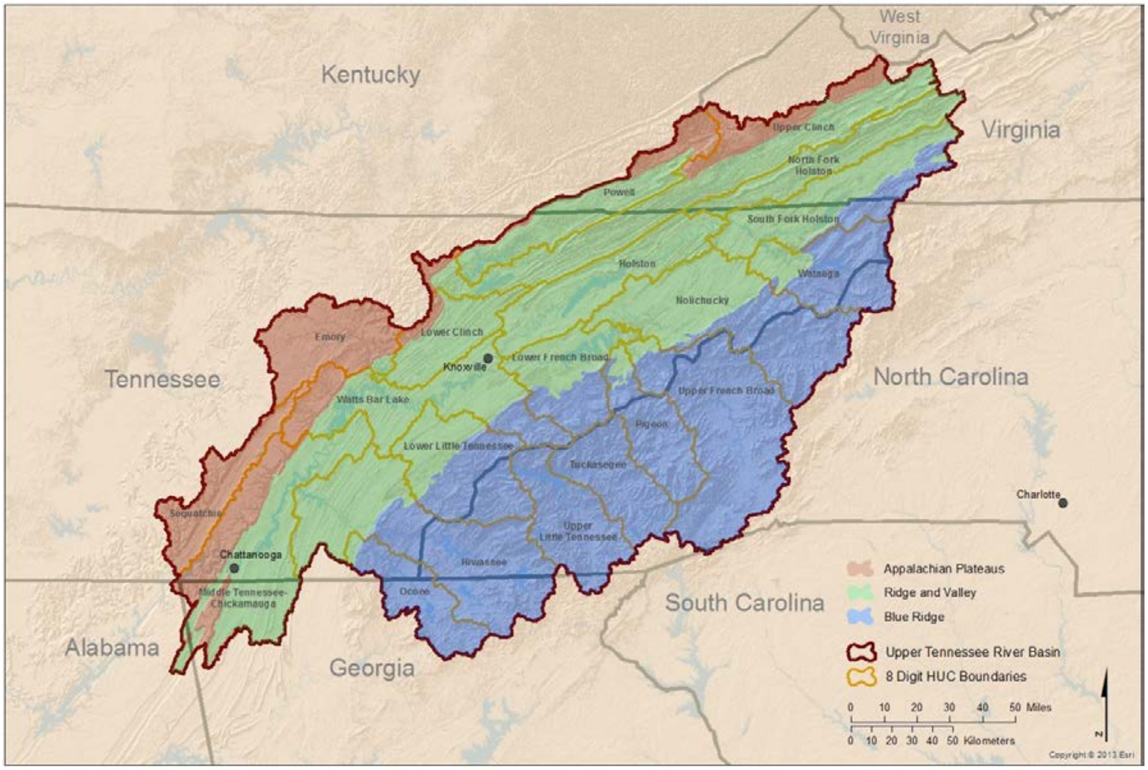



Figure 1. The UTRB encompasses about 22,360 square miles, includes the entire Tennessee River basin upstream of its confluence with and including the Sequatchie River, and falls within three major physiographic provinces.

The UTRB harbors one of the most diverse assemblages of aquatic animals, including fishes and mussels, in North America. Of the approximately 255 species of fishes and mussels known to occur historically in the UTRB (Etnier and Starnes 1993, Parmalee and Bogan 1998, Hampson 2003, Jelks et al. 2008), 45 are imperiled (Figures 2 and 3, Appendix 1). Within the United States, the UTRB is unsurpassed for its number of imperiled fishes, with 13 of the 172 species historically known from the UTRB under Federal protection (Figure 2, Appendix 1); and mussels, with 32 of the 83 species historically known from the UTRB under Federal protection (Figure 3, Appendix 1). This extraordinary biodiversity is one of the primary factors that led the United Nations Educational, Scientific, and Cultural Organization to designate the Southern Appalachians as a Man and the Biosphere Reserve in 1988 (http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=all&code=USA+44). Further, The Nature Conservancy (TNC) identified the UTRB as one of the most significant biodiversity hotspots in the U.S. (Stein et al. 2000, Figure 4).

In addition, the UTRB forms the core of the south-central portion of the mountain region of the Appalachian Landscape Conservation Cooperative (AppLCC, Figure 5), a public-private conservation research and management partnership composed of numerous Federal and State agencies, Tribes, non-governmental organizations (NGOs), academia, and others in parts of a 15-state area (http://applcc.org). The goals and objectives of the Strategy and associated recommendations can be integrated within the broader regional planning efforts of the AppLCC partnership.

For several decades, the USFWS and its partners have been working to conserve the imperiled fishes and mussels of the UTRB. Conservation efforts, guided in large part by the dozens of recovery plans for UTRB species listed under the Endangered Species Act (ESA), have included life history studies, distributional surveys, relocation, marking, monitoring, propagation, genetic analyses, toxicology, spill response, land acquisition, habitat protection and restoration, outreach, and education, among others. Though past planning to coordinate such conservation actions has helped organize species recovery efforts, the Strategy reflects USFWS's commitment to Strategic Habitat Conservation (http://www.fws.gov/landscape-conservation/vision.html) in managing and conserving resources at the landscape scale. It also recognizes the need for cooperative efforts to improve efficiency in the face of declining budgets and the importance of adapting management to changing conditions and knowledge. Acting on this commitment, workshops to develop this Strategy commenced in August 2011. Individuals from multiple programs in the USFWS's Northeast and Southeast Regions were invited to participate. Biologists from Ecological Services, Fisheries, and Science Applications, with facilitation from a specialist in strategic planning and structured decision making (SDM) from the U.S. Geological Survey, worked cooperatively to develop this Strategy. These individuals are listed in the Strategy Team Members section above.

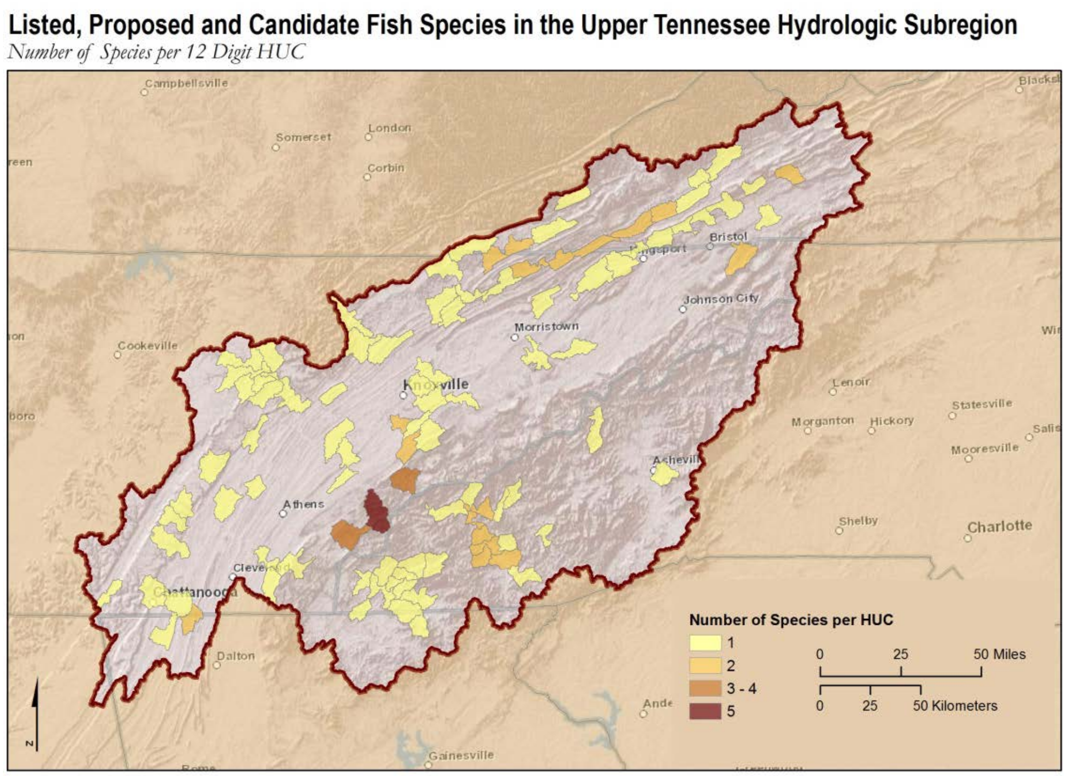



Figure 2. Imperiled fish species in the UTRB. Occurrences include extant and historical records. Areas within the UTRB boundary not shaded by a color denoted in the key have no records of imperiled fish species occurrences.

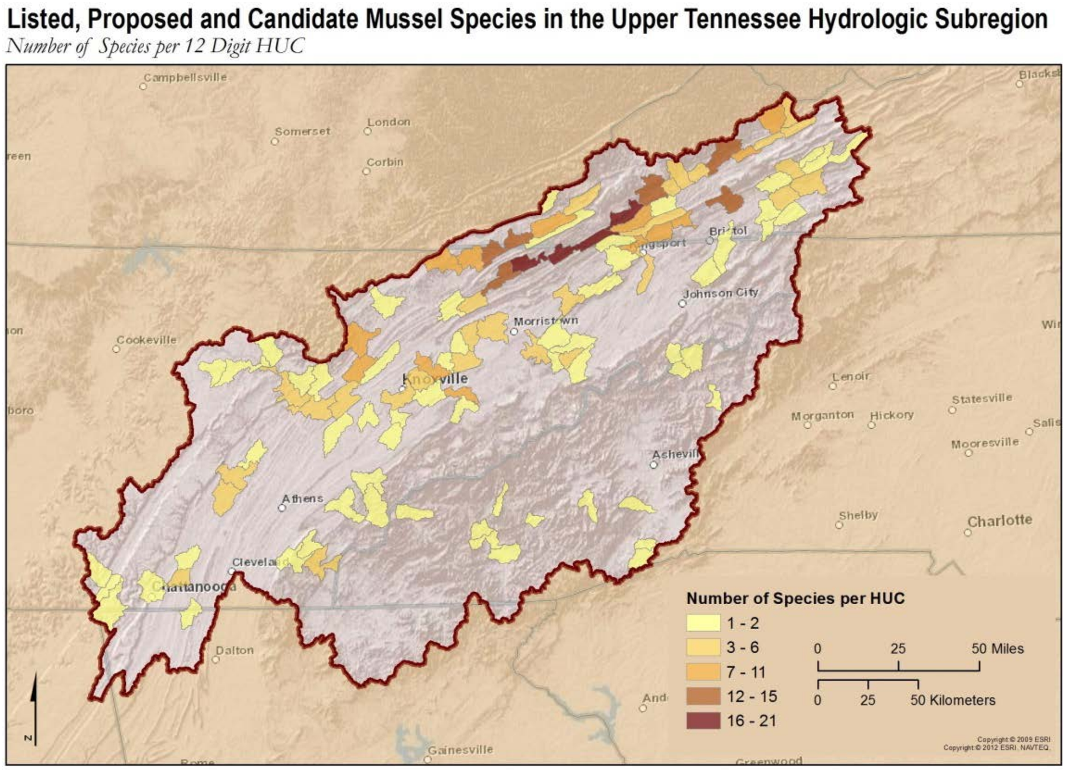



Figure 3. Imperiled mussel species in the UTRB. Occurrences include extant and historical records. Areas within the UTRB boundary not shaded by a color denoted in the key have no records of imperiled mussel species occurrences.

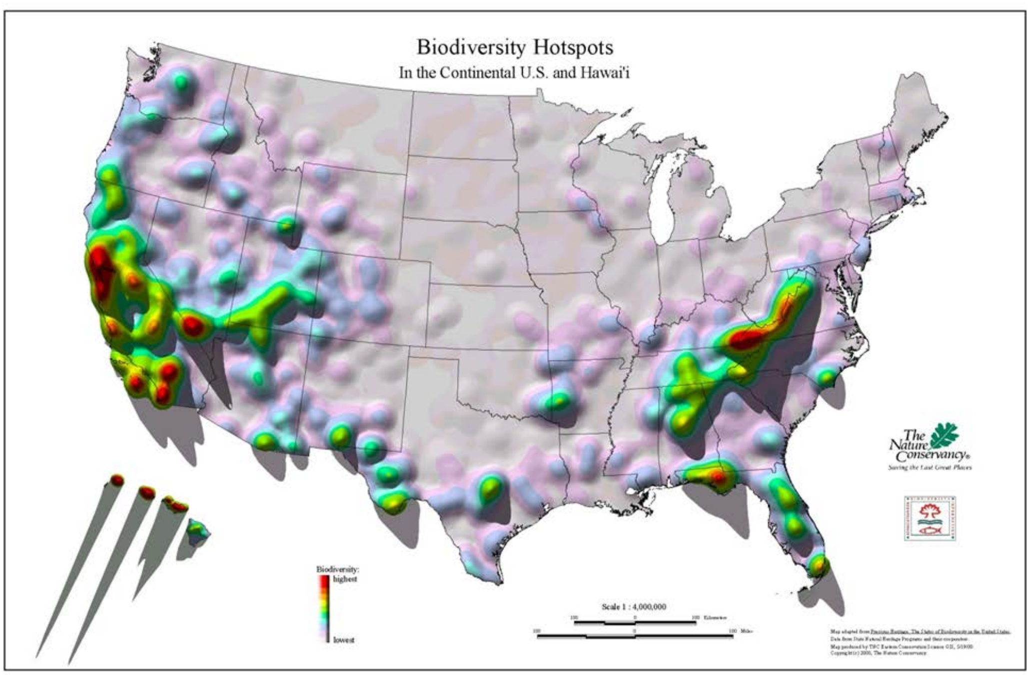



Figure 4. Biodiversity hotspots in the continental United States and Hawaii (Stein et al. 2000).


Figure 5. The Appalachian Landscape Conservation Cooperative (outlined in purple) and the UTRB (outlined in red), illustrating the importance of the UTRB as the core of the south-central portion of the Appalachian Landscape Conservation Cooperative.

# Species and Threat Information

## Distribution

There are 13 imperiled fish species extant in the UTRB, which represent 8% of the total fish fauna in the basin (Hampson 2003, Jelks et al. 2008), including 8 federally listed as endangered, 4 federally listed as threatened, and 1 Federal candidate (Appendix 1). One species is considered to be non-native to the UTRB, having been introduced, while a 14th species is extirpated from the basin (Appendix 1). Therefore, 12 imperiled fish species are included in this Strategy (Table 1, Appendix 1). Nine of these 12 imperiled fish species are endemic only to the UTRB (Table 1) and 7 species have critical habitat designated within the basin (Appendix 1).

Basic life history information, predominant threats, and likelihood of extinction of UTRB imperiled fishes is from Etnier and Starnes (1993) and Jenkins and Burkhead (1994) (Appendix 2). Information on threats to imperiled UTRB fishes is summarized from final rules in the Federal Register, species recovery plans, and 5-year reviews accessible at: http://www.fws.gov/endangered. Additionally, some information on threats was taken from the draft 5-year review for the spotfin chub (USFWS 2014). Imperiled fish species occurrence by 8-digit hydrologic unit code (HUC) is provided in Table 2.

There are 24 imperiled mussel species extant in the UTRB, which represents 29% of the total historic mussel fauna in the basin (Parmalee and Bogan 1998, Hampson 2003) (Appendix 1). All 24 species are federally listed as endangered and 6 of these have critical habitat designated within the UTRB. Therefore, 24 imperiled mussel species are included in this Strategy (Appendix 1, Table 1). Four of these extant imperiled mussel species are endemic only to the UTRB, and 3 others are now globally restricted to the UTRB. Two imperiled mussel species are considered extinct and 6 imperiled mussel species are extirpated from the UTRB (Appendix 1).

Basic life history information, distribution, abundance, and likelihood of extinction of UTRB imperiled mussels is from Parmalee and Bogan (1998), Williams et al. (2008), and the mussel population restoration and conservation plan developed by the Cumberlandian Region Mollusk Restoration Committee (2010) (Appendix 3). Imperiled mussel species occurrence by 8-digit HUC is in Table 2.

## Threats

Threats are sources of stressors that can interfere with the life history requirements of biota. Their effects are essentially magnified due to the status of imperiled species. Stressors can degrade or destroy imperiled species habitat and adversely affect population viability. The most ubiquitous stressor associated with threats to aquatic species in the UTRB, and globally, may be sedimentation. In addition, chemicals (e.g., ammonia, heavy metals, inorganic compounds, and pesticides) that alter water and sediment quality and disrupt species' life history processes are important stressors. Sources of sedimentation and other contaminants originate from fossil fuel extraction, agricultural and developmental activities, and insufficient sewage treatment in rural residential areas lacking modern infrastructure. Impoundments have had major impacts, altering natural flow and temperature regimes, eliminating habitat, interfering with migration, and prohibiting dispersal and genetic exchange. The stresses of population fragmentation and small population size include reduced fitness of subsequent generations through inbreeding depression and loss of genetic diversity, and increased risk of extirpation due to habitat alteration or stochastic events such as floods, droughts, and episodic chemical spills.

Since the early 1900s, numerous land use activities now common in the UTRB have been contributing sediments and contaminants, causing instream temperature changes, and otherwise acting as sources of stress to fish and mussel populations. Common land uses include urban, industrial, commercial, and residential development; livestock production; agricultural cropping (e.g., tobacco and corn); road and railroad networks; timber harvest/silviculture; and fossil fuel extraction. Both reclaimed coal mined lands and abandoned lands mined for coal prior to current Federal laws contribute to water quality problems in the UTRB. Other sources of stress within the UTRB include point source discharges from wastewater treatment and industrial facilities and atmospheric deposition of pollutants such as nitrates and mercury. Collectively, these and other stressors have contributed to the decline of the fish and mussel fauna in UTRB streams.

Table 1. Imperiled fish and mussel species extant in the UTRB included in the Strategy.

| Species[1] | Number of 8-digit HUCs of Occurrence[2] | Geographic Distribution |
|---|---|---|
| **Fishes** | | |
| Chucky madtom | 1 | UTRB endemic |
| Citico darter | 1 | UTRB endemic |
| Duskytail darter | 1 | UTRB endemic |
| Laurel dace | 2 | UTRB endemic |
| Marbled darter | 1 | UTRB endemic |
| Pygmy madtom | 1 | Tennessee River Basin endemic |
| Sicklefin redhorse | 3 | UTRB endemic |
| Slender chub | 2 | UTRB endemic |
| Smoky madtom | 1 | UTRB endemic |
| Snail darter | 8 | Tennessee River Basin endemic |
| Spotfin chub | 7 | Tennessee River Basin endemic |
| Yellowfin madtom | 3 | UTRB endemic |
| **Mussels** | | |
| Alabama lampmussel | 2 | Tennessee River Basin endemic |
| Appalachian elktoe | 5 | UTRB endemic |
| Appalachian monkeyface | 2 | UTRB endemic |
| Birdwing pearlymussel | 4 | Tennessee River Basin endemic |
| Cracking pearlymussel | 2 | Ohio River Basin endemic |
| Cumberland bean | 1 | Cumberlandian Region endemic[3] |
| Cumberland monkeyface | 1 | Tennessee River Basin endemic |
| Cumberlandian combshell | 3 | Cumberlandian Region endemic[3] |
| Dromedary pearlymussel | 3 | Cumberlandian Region endemic[3], currently restricted to UTRB |
| Fanshell | 2 | Ohio River Basin endemic |
| Finerayed pigtoe | 4 | Tennessee River Basin endemic, currently restricted to UTRB |
| Fluted kidneyshell | 6 | Cumberlandian Region endemic[3] |
| Golden riffleshell | 3 | Tennessee River Basin endemic, currently restricted to UTRB |
| Littlewing pearlymussel | 3 | Cumberlandian Region endemic[3] |
| Oyster mussel | 6 | Cumberlandian Region endemic[3], currently restricted to UTRB |
| Pink mucket | 6 | Mississippi River Basin endemic |
| Purple bean | 3 | UTRB endemic |
| Rough pigtoe | 2 | Ohio River Basin endemic |
| Rough rabbitsfoot | 2 | UTRB endemic |
| Sheepnose | 3 | Mississippi River Basin endemic |
| Shiny pigtoe | 3 | Tennessee River Basin endemic |
| Slabside pearlymussel | 5 | Cumberlandian Region endemic[3] |
| Snuffbox | 2 | Mississippi River and Great Lakes Basins endemic |
| Spectaclecase | 3 | Mississippi River Basin endemic |

[1]See Assumptions and Terminology section.
[2]Species occurrence in the UTRB by 8-digit HUC is in Table 2.
[3]Essentially, the Cumberland and Tennessee River Basins.

Table 2. UTRB imperiled fish and mussel occurrence by 8-digit HUC. Occurrences are based on post-1980 records. "O" indicates reintroduced population. Although in some streams where reintroductions have been attempted it may be too early to assess success, reintroductions were counted towards total species occurring in each 8-digit HUC.

| Species | Powell | Upper Clinch | Lower Clinch | North Fork Holston | South Fork Holston | Holston | Nolichucky | Upper French Broad | Lower French Broad | Emory | Pigeon | Tuckasegee | Upper Little Tennessee | Lower Little Tennessee | Middle Tennessee-Chickamauga | Watts Bar Lake | Hiwassee | Sequatchie | Ocoee | Number of 8-digit HUC Occurrences |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fishes** | | | | | | | | | | | | | | | | | | | | |
| Chucky madtom | | | | | | | X | | | | | | | | | | | | | 1 |
| Citico darter | | | | | | | | | | | | | | X | | | | | | 1 |
| Duskytail darter | | X | | | | | | | | | | | | | | | | | | 1 |
| Laurel dace | | | | | | | | | | | | | | | X | X | | | | 2 |
| Marbled darter | | | | | | | | | | | | | | | | X | | | | 1 |
| Pygmy madtom | | X | | | | | | | | | | | | | | | | | | 1 |
| Sicklefin redhorse | | | | | | | | | | | | X | X | | | | X | | | 3 |
| Slender chub | X | X | | | | | | | | | | | | | | | | | | 2 |
| Smoky madtom | | | | | | | | | | | | | | X | | | | | | 1 |
| Snail darter | | | | | | X | | | X | | | | | X | X | X | X | X | X | 8 |
| Spotfin chub | | | | X | X | X | | | | X | | | X | O | | X | | | | 7 |
| Yellowfin madtom | X | X | | | | | | | | | | | | X | | | | | | 3 |
| **Mussels** | | | | | | | | | | | | | | | | | | | | |
| Alabama lampmussel | | | | | | | | | | X | | | | | | | | O | | 2 |
| Appalachian elktoe | | | | | | | X | X | | | X | X | X | | | | | | | 5 |
| Appalachian monkeyface | X | X | | | | | | | | | | | | | | | | | | 2 |
| Birdwing pearlymussel | X | X | | | | | O | | O | | | | | | | | | | | 4 |
| Cracking pearlymussel | X | X | | | | | | | | | | | | | | | | | | 2 |
| Cumberland bean | | | | | | | | | | | | | | | | | X | | | 1 |
| Cumberland monkeyface | X | | | | | | | | | | | | | | | | | | | 1 |
| Cumberlandian combshell | X | X | | | | | O | | | | | | | | | | | | | 3 |
| Dromedary pearlymussel | X | X | | | | | | | | | | | | | X | | | | | 3 |
| Fanshell | | X | | | | | | | | | | | | | X | | | | | 2 |
| Finerayed pigtoe | X | X | | X | | | | | | | | | | | | X | | | | 4 |
| Fluted kidneyshell | X | X | | X | X | | O | | | | | | | O | | | | | | 6 |
| Golden riffleshell | | X | | | X | | | | | | | | | | | | X | | | 3 |
| Littlewing pearlymussel | | X | | X | | | | | | | | | X | | | | | | | 3 |
| Oyster mussel | O | X | | | | | X | | O | | | | | | | | O | X | | 6 |
| Pink mucket | | X | | | | X | O | | X | | | | | | X | X | | | | 6 |
| Purple bean | | X | | | | X | | | | X | | | | | | | | | | 3 |
| Rough pigtoe | | X | | | | | | | | | | | | | X | | | | | 2 |
| Rough rabbitsfoot | X | X | | | | | | | | | | | | | | | | | | 2 |
| Sheepnose | X | X | | | | X | | | | | | | | | | | | | | 3 |
| Shiny pigtoe | X | X | | X | | | | | | | | | | | | | | | | 3 |
| Slabside pearlymussel | X | X | | X | X | | | | | | | | | | | | X | | | 5 |
| Snuffbox | X | X | | | | | | | | | | | | | | | | | | 2 |
| Spectaclecase | | X | X | | | | X | | | | | | | | | | | | | 3 |
| No. of species extant in 8-digit HUC | 16 | 24 | 1 | 6 | 4 | 5 | 8 | 1 | 4 | 3 | 1 | 2 | 4 | 6 | 6 | 6 | 6 | 3 | 1 | |

The significance of various threats to UTRB imperiled aquatic species vary depending upon level of imperilment and where the species are distributed across the basin's three major physiographic provinces (Figure 1). Species inhabiting the Appalachian Plateau, which contains all of the coal fields and most of the oil and natural gas deposits in the UTRB, and those inhabiting receiving streams in the Ridge and Valley, are experiencing threats from energy extraction activities. Most residential development, transportation corridor construction, and other urbanization effects occur in the flatter, valley portions of the Ridge and Valley. Timbering, stream impoundment, and agriculture are dispersed more broadly across all three provinces.

## Assumptions and Terminology

Definitions specific to this Strategy are found in Appendix 4. During development of the Strategy, the following assumptions and terminology were used:

- Species federally listed as endangered or threatened, species proposed for Federal listing as endangered or threatened, and candidate species are considered imperiled species to the exclusion of other rare species in the UTRB.
- Common and/or scientific names currently accepted in scientific literature are used, but are not necessarily the common and/or scientific names under which the species were listed pursuant to the ESA. For example, the duskytail darter, *Etheostoma percnurum*, is the federally listed taxon. However, since its Federal designation, a taxonomic study was published splitting the species into four taxa (Blanton and Jenkins 2008). Three of these (duskytail, marbled, and Citico darters; Tables 1 and 2, Appendices 1 and 2) are endemic to the UTRB. Similarly, the golden riffleshell, *Epioblasma florentina aureola*, was recently determined to be a subspecies taxonomically distinct from the federally listed tan riffleshell, *Epioblasma florentina walkeri* (Jones and Neves 2010). Currently, *E. f. aureola* is globally restricted to the UTRB. No formal Federal actions have been undertaken to recognize these taxonomic revisions.
- Populations of fishes and mussels are generally considered extant (currently existing) if living individuals or fresh dead specimens (for mussels) have been collected since 1980.

## Strategy Development

Through a series of meetings, workshops, conference calls, webinars, and emails that took place from August 2011 through March 2014, SDM was used to develop and evaluate conservation strategies intended to increase persistence of imperiled aquatic species in the UTRB. The application of SDM to natural resource management is increasing, as its utility for assisting decision making in the face of competing objectives and uncertainty is being documented (Gregory and Long 2009, Martin et al. 2011, Gregory et al. 2012, Gregory et al. 2013, Conroy and Peterson 2013). SDM is values-focused and deconstructs the decision problem into universally recognizable components that can be deliberated by stakeholders, resource experts, and analysts. Transparency and explicitness are hallmarks of SDM. Identification of fundamental objectives is the first component considered after the problem is defined and framed. Development of alternatives follows identification of objectives. Optimal solutions can be found by evaluating the alternative management actions or strategies that best meet the objectives.

For the purposes of strategy development, we used expert elicitation to evaluate the consequences of alternative strategies. Expert elicitation can provide important information for decision making when sufficient data from research or monitoring is not complete or available (U.S. Environmental Protection Agency 2011, Drescher et al. 2013). We followed published best practices for expert elicitation to obtain experts' judgments on likely outcomes for conservation benefits and costs along with uncertainty in those judgments if alternative strategies were implemented (Gregory et al. 2012, Drescher et al. 2013). The general modified-Delphi process was to (1) carefully and systematically achieve a common understanding among experts of the questions being asked, (2) elicit a first round of judgments, (3) discuss the rational for those judgments, and (4) repeat the steps as necessary until experts finalized their judgments.

The decision problem was to identify the management approach that would best achieve the conservation objectives. The alternative management approaches were defined by the effort allocated to a set of specific management actions. Further, the team aimed to identify which species and locations would be most likely to benefit from the implementation of the best management approach.

The alternative management approaches do not emphasize any one set of management actions to the exclusion of another. For example, habitat management will continue if population management is emphasized, and stressors will continue to be identified, studied, and ameliorated. Rather than selecting one type of management action to the exclusion of another, the purpose of strategy development is to optimize allocation among a large array of management actions through a selected approach.

Strategy development included the following steps:

1. Determine conservation objectives and specify performance measures for each objective.
2. Identify a comprehensive set of management actions (Appendix 4) and formulate broad actions and approaches that address threats and factors limiting species recovery.
3. Predict the consequences on species and habitat and estimate the costs of implementing each management approach within management units of the UTRB.
4. Identify the management approach that best achieves the conservation objectives of maximizing conservation benefit while minimizing costs.
5. Prioritize species for focused management based on level of imperilment[1], likely conservation benefit (as predicted from step 3), and species-specific management cost.
6. Prioritize locations for general habitat management based on diversity (richness) of imperiled species and feasibility of habitat improvement at each location.

## Goals and Objectives

The goal of the Strategy is to maximize conservation and recovery of imperiled aquatic species and the UTRB ecosystem upon which they depend. Ecosystem conservation is implicit because to recover imperiled species ecosystems must be included. Objectives were outlined and used to guide the strategic planning process (Figure 6). A distinction is made between objectives that are

[1] The degree of imperilment is relative amongst species considered in the Strategy and a lower degree of imperilment should not be construed to suggest any specific determination regarding any pending listing/delisting action.

fundamentally important (i.e., fundamental objectives) and those that are means to achieving the fundamental objectives (i.e., means objectives). Fundamental objectives were to: (1) maximize imperiled species persistence and viability and (2) maximize operational efficiency (Figure 6). The species persistence and viability objective was considered separately for fishes and mussels to allow for faunal group-specific differences when considering conservation actions. Maximizing habitat quality and maintaining genetic diversity were treated as means objectives that would contribute to population persistence. The operational efficiency objective was defined as minimizing management costs so that the relative cost-benefits of conservation actions could be analyzed.

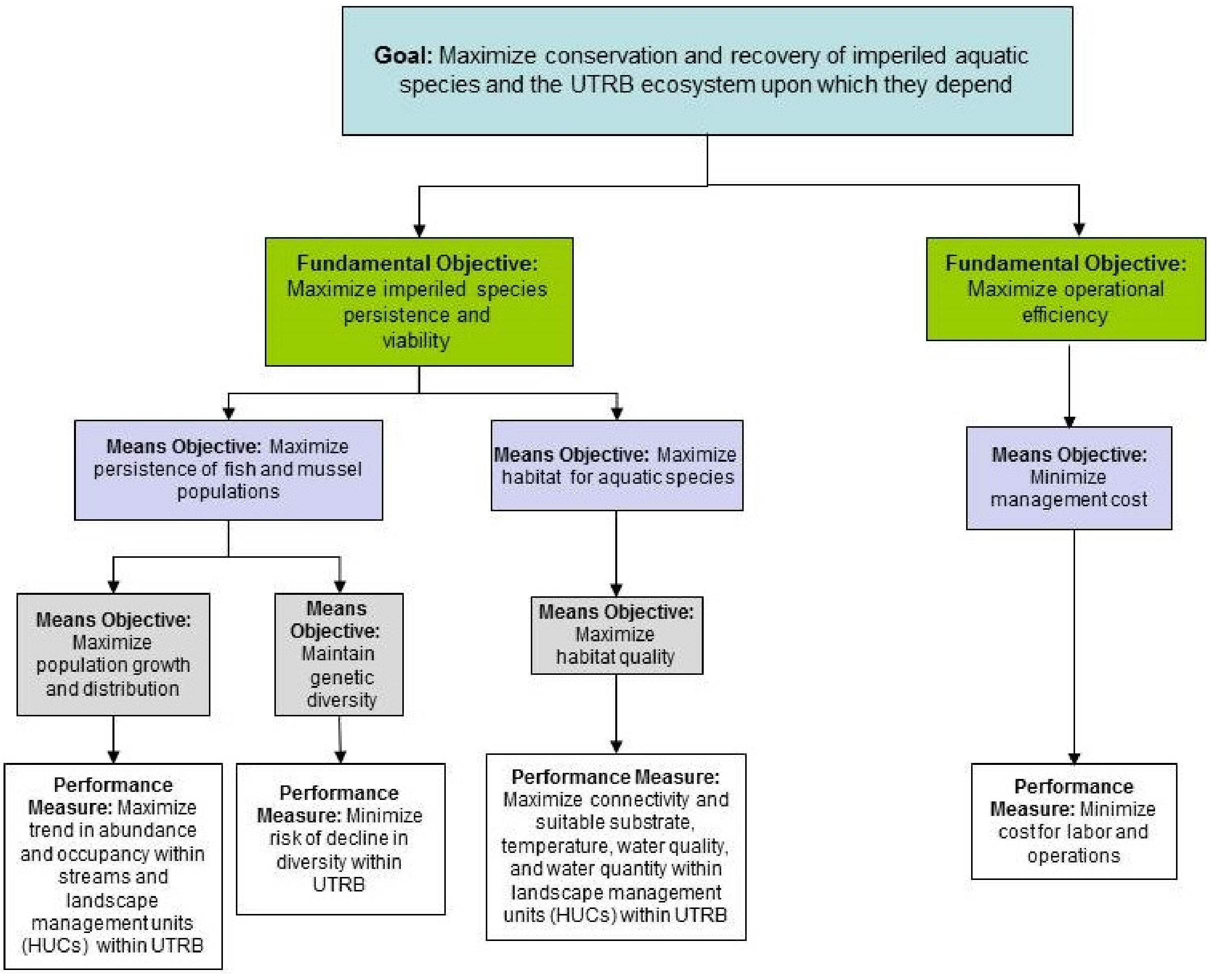



Figure 6. Hierarchy organizing the general goals and fundamental objectives for strategic decisions for conservation of imperiled aquatic species in the UTRB.

In SDM processes, performance measures are used to compare how well actions and approaches are likely to perform with respect to management objectives. These measures should not be arbitrary but should be easily recognized as relevant to the objectives (Keeney 1992, Game et al. 2013). In this application of SDM, the performance measures for the species persistence objective were trend in abundance, number of habitat units occupied (distribution), and risk of decline in genetic diversity. The performance measure for habitat quality was based on the presence of the following habitat elements: connectivity and suitable substrate, temperature, water quality, and water quantity. The performance measures for operational efficiency were based on management cost as measured by staffing levels and operational costs.

### Alternative Management Approaches

Formulation of alternative management approaches was guided by identifying primary threats and ecological factors that currently limit imperiled species population growth, distribution, and viability. The limiting factors considered were predation, invasive species, physical habitat, host fishes (mussels only), flows, water quality (dissolved oxygen, temperature, contaminants), lack of dispersal/fragmentation, disease, and depensation due to low density (Allee effect). Experts[2] ranked the top three limiting factors for imperiled fishes and mussels. A rank of 1, 2, and 3 received 30, 20, and 10 points, respectively, and then the points were summed for each factor separately for fishes and mussels. The summed scores were standardized between 0 and 100 for least to most important, respectively (Table 3). Depensation, contaminants, and lack of dispersal/fragmentation were among the top three limiting factors for both fishes and mussels.

Table 3. Ranking of factors that could limit the persistence of imperiled fishes and mussels in the UTRB.

| Potential Limiting Factors | Standardized Score for Fishes | Standardized Score for Mussels |
|---|---|---|
| Depensation (Allee effect) | 88 | 100 |
| Water quality – contaminants | 100 | 89 |
| Lack of dispersal/fragmentation | 88 | 78 |
| Physical habitat | 50 | 33 |
| Host fish | 0 | 22 |
| Flows | 13 | 11 |
| Predation | 0 | 0 |
| Invasive species | 0 | 0 |
| Water quality – dissolved oxygen | 0 | 0 |
| Water quality – temperature | 0 | 0 |
| Disease | 0 | 0 |

Two broad approaches were considered to address the limiting factors: population management emphasis and habitat management emphasis. Population management emphasis addresses low population size (depensation) and lack of dispersal/fragmentation by increasing extant populations (augmentations) and establishing additional populations (reintroductions/ introductions) through propagation and release of cultured individuals and translocated adults into suitable habitat. Habitat management emphasis addresses water quality, physical habitat, and flows by protecting or restoring occupied and unoccupied habitat within the historical range of imperiled species. These two approaches—population management emphasis and habitat management emphasis—were compared to a status quo management approach, which is a continuation of the management actions currently being implemented by USFWS.

An inventory of management actions (Appendix 4) was taken along with associated costs (Appendix 5). Management approaches were defined by the relative level of effort or agency resources committed to implementing management actions (Table 4). The three alternative approaches considered did not indicate exclusive reliance on either habitat or population management emphasis actions. Instead the alternatives represented different shifts in the types of management actions that would be emphasized (Table 4). For example, a high level of effort

[2] Brian Evans, Catherine Gatenby, Roberta Hylton, Cindy Schulz, and Peggy Shute.

Table 4. Relative level of effort to implement management actions under alternative management approaches. The management emphasis approaches were status quo, habitat, and population. Level of effort ranges from no implementation (0) to maximum implementation (1).

| Management Actions | | Basis for Level of Implementation | Alternative Approaches | | |
|---|---|---|---|---|---|
| **Type** | **Task[1]** | | **Status Quo Management** | **Habitat Management Emphasis** | **Population Management Emphasis** |
| Population Management | Implement ESA Section 7 and 10 regulations/influence agencies (A1a, A1b, B2a, B2b, B2c) | Level and consistency of enforcement | 0.7 | 0.7 | 0.8 |
| | Use available means to protect or establish populations (A1e1, A1e2, A1e3) | Number of species and populations | 0.5 | 0.5 | 0.9 |
| | Conduct status assessment/list candidate species (A1c, A1d) | Number of species | 0.3 | 0.3 | 0.3 |
| | Increase extant populations (A2a, A2b1, A2b2, A2b3, A2c) | Number of species and populations | 0.7 | 0.6 | 0.9 |
| | Establish new populations (A3a, A3b, A3c, A3d) | Number of species and populations | 0.5 | 0.2 | 0.9 |
| | Manage captive populations (C1a, C1b, C1c, C2a, C2b) | Number of species | 0.0 | 0.0 | 0.5 |
| Habitat Management | Develop best management practices (BMPs) for managing stream and riparian habitat (B1) | Number of sites | 0.6 | 0.8 | 0.7 |
| | Land acquisition and easements (B3a, B3b) | Number of sites | 0.2 | 0.3 | 0.1 |
| | Restoration of instream and riparian habitat (B4a, B4b, B4c) | Number of sites | 0.3 | 0.4 | 0.1 |
| Monitoring/ Research | Life history (D1) | Number of species | 0.4 | 0.6 | 0.6 |
| | Population and habitat monitoring (D2a, D2b, D3a, D3b, D3c, D3d) | Number of populations and sites | 0.5 | 0.5 | 0.5 |
| | Evaluate and monitor threats (D4a, D4b, D4c, D4d) | Number of species | 0.6 | 0.7 | 0.7 |
| | Genetics monitoring and research (D5a, D5b, D5c) | Number of species | 0.3 | 0.2 | 0.5 |
| | Population viability analyses (D6a, D6b, D6c) | Number of species | 0.2 | 0.0 | 0.7 |
| | Evaluate habitat for reintroductions (D7a, D7b, D7c) | Number of species | 0.1 | 0.1 | 0.8 |
| | Propagation and captive management research (D8a, D8b) | Number of species | 0.1 | 0.1 | 0.4 |
| | Evaluate ecosystem services (D9, D10a, D10b, D10c) | Categorical effort | 0.1 | 0.3 | 0.2 |
| Communication and Partnerships | Outreach (E1a, E1b, E1c, E1d, E1e) | Categorical level of effort | 0.3 | 0.8 | 0.5 |
| | Work with partners and industry (E2a, E2b, E2c, E2d, E2e, E3a, E3b, E4) | Potential partnerships established | 0.5 | 0.9 | 0.7 |
| Agency Operations | Intra-agency (F1) | Categorical level of effort | 0.5 | 0.5 | 0.5 |

[1]Items in parentheses correspond to management actions listed in Appendix 4 and relate to other parts of the Strategy as explained in Appendix 6.

would be committed to increasing extant populations through propagation under the population management emphasis approach, whereas reduced effort would be committed to that action under the habitat management emphasis or status quo management approaches. Management flexibility was incorporated in all alternatives.

## Comparing Alternative Management Approaches

We considered the conservation benefits and management costs of each approach on fundamental population objectives (Figure 6) for fishes at the 12-digit HUC level (Table 5, Figure 2) and on fundamental population objectives for mussels at the stream reach level (Table 6, Figure 3). A tradeoff analysis compared alternative approaches based on the simple multi-attribute rating technique (Goodwin and Wright 2004). Performance measures (i.e., measurable attributes) were projected over a 20-year period, standardized, and combined to result in a final score for each approach. Each performance measure is associated with a fundamental objective. Decision makers and stakeholders can give different levels of importance or value to each objective. To account for this relative importance, each performance measure was weighted when it was combined into a final score.

Table 5. Conservation benefits for imperiled fishes projected over a 20-year period to compare alternative management approaches. The management emphasis approaches were status quo, habitat, and population. Conservation benefits were measured by trend in abundance on a categorical scale (declining, stable, or increasing) and number of 12-digit HUCs occupied. The range for trend in abundance is –1 for high decline to +1 for high increase.

| | Trend in Abundance within UTRB: declining = -1, stable = 0, and increasing = +1 | | | | Number of 12-digit HUCs Occupied | | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Current** | **Status Quo** | **Habitat Emphasis** | **Population Emphasis** | **Current** | **Status Quo** | **Habitat Emphasis** | **Population Emphasis** |
| Chucky madtom | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 |
| Citico darter | 0 | 1 | 0 | 1 | 2 | 3 | 3 | 3 |
| Duskytail darter | 0 | -0.5 | 0 | 1 | 2 | 1 | 2 | 3 |
| Laurel dace | -1 | -1 | -0.5 | 0 | 4 | 2 | 3 | 4 |
| Marbled darter | -1 | -0.5 | 0 | 0.5 | 4 | 4 | 4 | 5 |
| Pygmy madtom | 0 | 0 | 0 | 0.5 | 1 | 1 | 1 | 3 |
| Sicklefin redhorse | 0 | 0.5 | 0.5 | 0.5 | 22 | 22 | 22 | 22 |
| Slender chub | -1 | -1 | -1 | -1 | 1 | 0 | 0 | 1 |
| Smoky madtom | 1 | 1 | 0 | 1 | 2 | 3 | 3 | 4 |
| Snail darter | 1 | 1 | 1 | 1 | 21 | 21 | 21 | 21 |
| Spotfin chub | 0 | 0 | 0.5 | 1 | 26 | 26 | 26 | 29 |
| Yellowfin madtom | 1 | 1 | 0.5 | 1 | 10 | 10 | 10 | 11 |
| Average | -0.08 | 0.04 | 0.00 | 0.46 | 8.00 | 7.83 | 8.00 | 8.92 |

Table 6. Conservation benefits for imperiled mussels projected over a 20-year period to compare alternative management approaches. The management emphasis approaches were status quo, habitat, and population. Conservation benefits were measured by trend in abundance on a categorical scale (declining, stable, or increasing) and number of significant stream reaches occupied. The range for trend in abundance is –1 for high decline to +1 for high increase.

| | Trend in Abundance within UTRB: declining = -1, stable = 0, and increasing = +1 | | | | Number of Significant Stream Reaches Occupied | | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Current** | **Status Quo** | **Habitat Emphasis** | **Population Emphasis** | **Current** | **Status Quo** | **Habitat Emphasis** | **Population Emphasis** |
| Alabama lampmussel | 0 | -0.5 | 0 | 0.5 | 1 | 1 | 1 | 1 |
| Appalachian elktoe | -1 | -1 | -1 | -0.5 | 4 | 4 | 4 | 4 |
| Appalachian monkeyface | -1 | -1 | -1 | -0.5 | 4 | 2 | 2 | 4 |
| Birdwing pearlymussel | 0.5 | 0.5 | 0.5 | 1 | 7 | 7 | 6 | 10 |
| Cracking pearlymussel | 0 | 0 | 0 | 0.5 | 3 | 3 | 3 | 10 |
| Cumberland bean | 0 | 0 | 0.5 | 1 | 1 | 1 | 1 | 1 |
| Cumberland monkeyface | -1 | -1 | -0.5 | 0.5 | 2 | 2 | 2 | 2 |
| Cumberlandian combshell | 0.5 | 0.5 | 0 | 1 | 6 | 6 | 6 | 10 |
| Dromedary pearlymussel | 0 | 0 | 0 | 1 | 5 | 5 | 5 | 10 |
| Fanshell | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 9 |
| Finerayed pigtoe | 0.5 | 0.5 | 1 | 1 | 7 | 4 | 4 | 10 |
| Fluted kidneyshell | 0.5 | 0.5 | 1 | 1 | 11 | 10 | 11 | 10 |
| Golden riffleshell | -1 | -1 | -1 | 0 | 1 | 0 | 0 | 1 |
| Littlewing pearlymussel | -1 | -1 | -1 | -0.5 | 2 | 0 | 0 | 6 |
| Oyster mussel | 0.5 | .0.5 | 0 | 1 | 7 | 7 | 7 | 10 |
| Pink mucket | -1 | 0 | -1 | 1 | 1 | 2 | 2 | 10 |
| Purple bean | 0 | 0 | 0.5 | 1 | 8 | 8 | 8 | 12 |
| Rough pigtoe | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 10 |
| Rough rabbitsfoot | 0 | 0 | 0.5 | 1 | 8 | 6 | 6 | 10 |
| Sheepnose | 0.5 | 0.5 | 0.5 | 1 | 7 | 7 | 7 | 10 |
| Shiny pigtoe | 0.5 | 0.5 | 1 | 1 | 8 | 5 | 5 | 10 |
| Slabside pearlymussel | -1 | -1 | -0.5 | 0 | 11 | 5 | 5 | 10 |
| Snuffbox | 0 | 0 | 0 | 1 | 5 | 5 | 5 | 10 |
| Spectaclecase | -1 | -1 | -1 | -1 | 4 | 4 | 4 | 4 |
| Average | -0.17 | -0.13 | -0.04 | 0.58 | 4.91 | 4.09 | 4.09 | 7.83 |

## ***Projecting the consequences of each approach***

Conservation benefits and management costs for each approach were projected over a 20-year period (Tables 5–8). To project conservation benefits and management costs, team members with knowledge and expertise for each particular subject were identified. We used common practices to elicit expert judgment for conservation benefits and management costs (Drescher et al. 2013). Species level consequences, or trends in abundance and occupancy of habitat units (12-digit HUCs for fishes and important stream reaches for mussels; Tables 5 and 6), and habitat quality (Table 7) that would result from approach implementation were projected by species experts[3]. Expected risks for decline in genetic diversity as a result of approach implementation were elicited from a population geneticist[4] (Table 9). Costs (staffing level and operational cost) for individual management actions were assessed under status quo management (Appendix 5), and then the relative effort among alternative approaches (Table 4) was used to estimate cost under each approach (Table 8). Cost estimates were generated for the three approaches:

- $4,856,000 for status quo management,
- $5,423,000 for habitat management, and
- $4,729,000 for population management.

[3] Species experts for fishes were Bob Butler, Brian Evans, and Peggy Shute. Species experts for mussels were Stephanie Chance, Catherine Gatenby, Shane Hanlon, and Jess Jones.
[4] Meredith Bartron, USFWS.

Table 7. Predicted habitat quality performance measure for current conditions and alternative management approaches. Characteristics of quality aquatic habitat for imperiled species include free-flowing streams and suitable substrate, temperature, water quality, and water quantity. One point was awarded for each characteristic present within a sub-basin, for a maximum of 5 points. This measure represents general habitat suitability and might not reflect species specific requirements. The average from this table is used in the consequence table (Table 9).

| | Predicted Habitat Quality (maximum of 5 points) | | | |
|---|---|---|---|---|
| **Sub-basin (8-digit HUC)** | **Current Condition** | **Status Quo Management** | **Habitat Management Emphasis** | **Population Management Emphasis** |
| Sequatchie | 3.0 | 3.0 | 4.0 | 3.0 |
| Hiwassee | 2.0 | 2.0 | 3.0 | 2.0 |
| Middle Tennessee-Chickamauga | 1.0 | 0.5 | 2.0 | 0.5 |
| Emory | 3.0 | 3.0 | 3.8 | 3.0 |
| Lower Little Tennessee | 4.0 | 4.0 | 4.5 | 4.0 |
| Upper Clinch | 4.0 | 4.0 | 4.5 | 4.0 |
| North Fork Holston | 3.5 | 3.5 | 4.0 | 3.5 |
| Powell | 3.5 | 3.5 | 4.0 | 3.5 |
| Holston | 2.5 | 2.5 | 3.0 | 2.5 |
| Nolichucky | 2.5 | 2.5 | 3.0 | 2.5 |
| Upper Little Tennessee | 4.0 | 4.0 | 4.0 | 4.0 |
| Watts Bar Lake | 1.0 | 0.5 | 1.0 | 0.0 |
| Average | 2.82 | 2.73 | 3.34 | 2.68 |

Table 8. Annual cost (in $1,000s) to implement actions under the status quo management approach (Appendix 5) and cost based on relative effort to implement alternative management approaches (Table 4).

| | Alternative Approaches ($1,000) | | |
|---|---|---|---|
| **Type of Management Action** | **Status Quo Management** | **Habitat Management Emphasis** | **Population Management Emphasis** |
| Population Management | 1,973 | 1,722 | 2,578 |
| Habitat Management | 1,632 | 2,176 | 563 |
| Monitoring/Research | 1,125 | 1,312 | 1,424 |
| Communication and Partnerships | 71 | 157 | 108 |
| Agency Operations | 56 | 56 | 56 |
| Total | 4,856 | 5,423 | 4,729 |

Table 9. Consequence table with performance measures to compare alternative management approaches.

| | | | Alternative Approaches | | |
|---|---|---|---|---|---|
| **Objective** | **Sub-objective (footnoted performance measures)** | **Direction** | **Status Quo Management** | **Habitat Management Emphasis** | **Population Management Emphasis** |
| Species persistence and viability | Fish abundance trend[1] | Maximize | 0.04 | 0.00 | 0.46 |
| | Fish distribution[2] | Maximize | 7.83 | 8.00 | 8.92 |
| | Mussel abundance trend[3] | Maximize | -0.13 | -0.04 | 0.58 |
| | Mussel distribution[4] | Maximize | 4.09 | 4.09 | 7.83 |
| | Genetic diversity[5] | Maximize | -0.17 | -0.17 | 0.52 |
| | Habitat quality[6] | Maximize | 2.73 | 3.34 | 2.68 |
| Operating costs | Staff[7] | Minimize | 9.5 | 11.5 | 11.5 |
| | Management costs[8] | Minimize | 4.8 | 5.4 | 4.7 |

[1]Average trend in abundance at UTRB level: declining, stable, improving (–1, 0, 1); averaged across species (Table 5).
[2]Average number of 12-digit HUCs occupied per species: averaged across species (Table 5).
[3]Average trend in abundance at UTRB level: declining, stable, improving (–1, 0, 1); averaged across species (Table 6).
[4]Average numbers of reaches occupied per species: averaged across species (Table 6).
[5]Risk to loss of genetic diversity: (–1 = no removal of threats and no add populations, 0 = addressing threats to existing populations, 1 = moving individuals using BMPs, 2 = both addressing threats and individuals using BMPs).
[6]Average habitat score (suitable habitat components: free-flowing and suitable substrate, temperature, water quality, and water quantity); averaged across 8-digit HUCs (Table 7).
[7]Staffing level (full-time equivalent) within UTRB.
[8]Millions of dollars per year (Table 8).

The performance measure for trend in abundance over a 20-year period was categorical (–1 = high decline, 0 = stability, +1 = high increase). The trend in abundance was projected for current conditions, and what would be expected as a consequence of implementing population management emphasis (primary focus is restoration and conservation/protection of populations), habitat management emphasis (primary focus is restoration and conservation/protection of habitat), and status quo management approaches (Tables 5 and 6). Trend in abundance was projected for each species, and the average across species was used in the consequence table (Table 9).

The performance measure for distribution was the number of habitat units occupied at the end of a 20-year period. Distribution was projected for current conditions, and what would be expected as a consequence of implementing population management emphasis, habitat management emphasis, or status quo management approaches (Tables 5 and 6). The number of occupied habitat units was projected for each species, and the average across species was used in the consequence table (Table 9).

The performance measure for habitat quality was based on the presence of suitable habitat components at the end of a 20-year period. The habitat components were free-flowing water, suitable substrate, suitable temperature, suitable water quality, and suitable water quantity. Habitat quality was projected at the 8-digit HUC level (Table 7), and the average across habitat units was used in the consequence table for each approach (Table 9).

The performance measure for risk for decline in genetic diversity over a 20-year period was related to removal of threats and expanding populations (–1 = no removal of threats and no additional populations, 0 = addressing threats to existing populations, 1 = moving individuals using BMPs, 2 = both addressing threats and individuals using BMPs). Risk for decline in genetic diversity for all species combined was projected for what would be expected as a consequence of implementing population management emphasis, habitat management emphasis, and status quo management approaches (Table 9).

***<u>Trade-off and sensitivity analyses</u>***

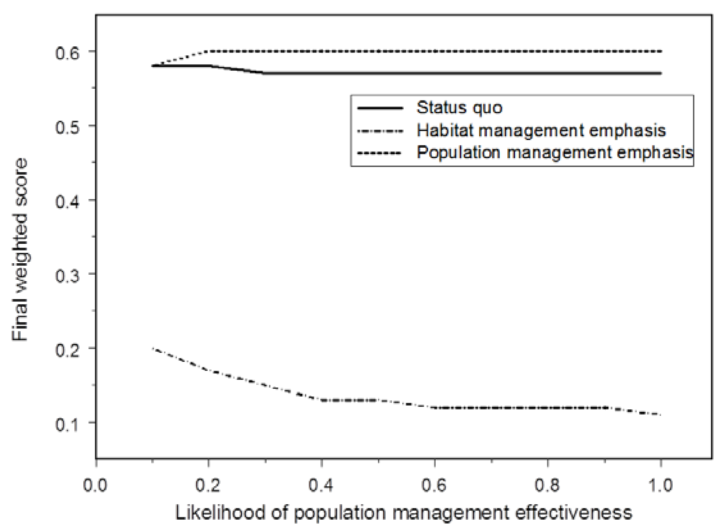
Conservation involves unavoidable trade-offs between achieving conservation benefits and minimizing management costs (Bottrill et al. 2008, Joseph et al. 2009). We evaluated those trade-offs in the comparison among management approaches (Table 9). To conduct the tradeoff analysis, the projected conservation benefits and management costs for each management approach were placed in a consequence table (Table 9) and followed the simple multi-attribute rating technique (Goodwin and Wright 2004). The first step is to normalize the raw projected performance measures (i.e., rows in Table 9), followed by taking a weighted average within each alternative management approach (i.e., columns in Table 9). The weights used in the weighted average are assigned to each fundamental objective (Figure 6). The weighted average of normalized measures becomes the final score and the basis for comparison. The optimal approach is the one with the highest final score (Appendix 7).

Weights assigned to the fundamental objectives reflect the relative importance of the various objectives, which can (and often does) vary among stakeholders. Specific weights for the objectives were not elicited from any specific stakeholders. Rather, a sensitivity analysis was conducted to determine the optimal approach for a wide range of weightings that assigned: (1) relative weight to species persistence/viability versus costs and (2) relative weight to abundance/distribution versus genetic diversity/habitat quality (Appendix 7). The purpose of the sensitivity analysis was to determine if the optimal approach was robust relative to how stakeholders might vary in how they place importance on the conservation objectives.

The population management emphasis approach was found to be optimal across a wide range of objective weightings and by extension, to variation in stakeholder values. Only when minimizing cost (labor and operations) was highly important (i.e., weight on species persistence and viability is <40% of total weight) did the status quo management approach become optimal (Appendix 7).

Uncertainty can obscure the identification of optimal management (Runge et al. 2011). One important source of uncertainty is management effectiveness. To examine the sensitivity of identifying the optimal approach to management effectiveness, the trade-off analysis (described above) was repeated for a range in the likelihood of management effectiveness. The likelihood of management effectiveness ranged from 0.1 to 1.0 (e.g., from a 10% chance to a 100% chance of management achieving the expected conservation benefit). As the likelihood declined from fully effective (i.e., 1.0) the population management emphasis approach remained optimal, and its final weighted score converged with that of status quo management only after management was deemed highly ineffective (i.e., likelihood <0.2) (Figure 7). Unless the likelihood of population management effectiveness drops below 0.1, the population management emphasis approach remained optimal.

Figure 7. Sensitivity analysis to examine how uncertainty about management effectiveness might alter selection of optimal approach. The final weighted score for each approach is shown across a range in likelihood of population management effectiveness. The optimal approach is indicated by the line with the highest final weighted score given management effectiveness. The particular scenario represents a boundary condition with 40% of total objective weight on maximizing persistence/viability and 60% on minimizing cost and with half of the weight on persistence allocated to abundance and distribution and half the weight on genetic diversity and habitat quality.




The approach that emphasized population management was found to be optimal for all other scenarios as long as the weight on maximizing persistence was at least 40% of total objective weighting relative to minimizing cost. The particular scenario shown in Figure 7 represents a boundary condition with 40% of total objective weight on maximizing persistence/viability and 60% on minimizing cost and with half of the weight on persistence allocated to abundance and distribution and half of the weight on genetic diversity and habitat quality. For all other scenarios where objective weight on maximizing persistence exceeded 0.4 and likelihood of management effectiveness exceeded 0.1, the final weighted score for population management emphasis exceeded that of the other two approaches. Therefore, the selection of population management emphasis as an optimal management approach was found to be robust to relative uncertainty in management effectiveness.

**Species and Location Prioritization**

Because conservation benefit is not likely to be achieved equally among all species and locations under the population management emphasis approach, species and locations were prioritized. Based on a trade-off between expected conservation benefit and management costs and while accounting for degree of imperilment, imperiled fishes and mussels were prioritized for management (Table 10 and 11). To prioritize locations for habitat management emphasis actions, richness of imperiled species and feasibility of management implementation were used as the driving variables (Table 12). These prioritizations are intended to allow for flexibility in decisions regarding specific conservation projects.

For species prioritization, the degree of imperilment was based on a qualitative assessment of rangewide extinction risk over the next 20 years (Appendices 2 and 3). Expected conservation benefit, the maximum gain in abundance trend and distribution over 20 years relative to the current condition, was calculated by the difference between current status and what would be expected to result from applying the population emphasis approach (Tables 5 and 6). For distribution, the numerical difference between current status and the population emphasis was divided by current status to account for species-specific distribution (Table 10 and 11). Management cost was on a categorical scale based on a summary of cost for management actions (Appendix 5).

Species prioritization was carried out in steps. The first priority score, which was based on imperilment and conservation benefit, was derived as follows:

- If gains in both abundance trend and distribution are expected, then assign priority 1
- If a gain in either abundance trend or distribution is expected,
    - and degree of imperilment is high, then assign priority 1
    - but degree of imperilment is not high, then assign priority 2
- If no gain in abundance trend and distribution is expected, then assign priority 3

The second priority score reflected the categorical scale for management cost. Lastly, a final priority was calculated by multiplying the first and second priority scores (Tables 10 and 11).

Table 10. Prioritization of imperiled fishes of the UTRB. Prioritization input variables included degree of imperilment, management cost, and expected conservation benefit from management actions accrued over the next 20 years. Degree of imperilment is based on a qualitative assessment of rangewide extinction risk over 20 years (Appendix 2). Expected conservation benefit is the maximum gain over 20 years relative to current status (Table 5). Management costs are a categorical summary based on management action costs (Appendix 5). Lower scores indicate higher priority.

| | | Expected Conservation Benefit Relative to Current Status | | Management Cost | | Prioritization Steps | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Degree of Imperilment** | **Net Gain in Abundance Trend** | **Net Gain in Distribution** | **Cost of Propagation** | **Cost of Reintroduction** | **Step One** | **Step Two** | **Priority** |
| Marbled darter | High | 1.5 | 0.3 | Low | Low | 1 | 1 | 1 |
| Citico darter | High | 1.0 | 0.5 | Low | Low | 1 | 1 | 1 |
| Duskytail darter | High | 1.0 | 0.5 | Low | Medium | 1 | 2 | 2 |
| Laurel dace | High | 1.0 | 0.0 | Medium | Low | 1 | 2 | 2 |
| Pygmy madtom | High | 0.5 | 2.0 | Medium | Medium | 1 | 3 | 3 |
| Smoky madtom | High | 0.0 | 1.0 | Medium | Medium | 1 | 3 | 3 |
| Spotfin chub | Low | 1.0 | 0.1 | Medium | High | 1 | 4 | 4 |
| Yellowfin madtom | Medium | 0.0 | 0.1 | Low | Medium | 2 | 2 | 4 |
| Sicklefin redhorse | Low | 0.5 | 0.0 | High | High | 2 | 5 | 10 |
| Chucky madtom | High | 0.0 | 0.0 | High | Medium | 3 | 4 | 12 |
| Slender chub | High | 0.0 | 0.0 | High | High | 3 | 5 | 15 |
| Snail darter | Low | 0.0 | 0.0 | High | Medium to High | 3 | 5 | 15 |

Table 11. Prioritization of imperiled mussels of the UTRB. Prioritization input variables included degree of imperilment, management cost, and expected conservation benefit from management actions accrued over the next 20 years. Degree of imperilment is based on a qualitative assessment of rangewide extinction risk over 20 years (Appendix 3). Expected conservation benefit is the maximum gain over 20 years relative to current status (Table 6). Management costs are a categorical summary based on management action costs (Appendix 5). Lower scores indicate higher priority.

| | | Expected Conservation Benefit Relative to Current Status | | Management Cost | Prioritization Steps | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Degree of Imperilment** | **Net Gain in Abundance Trend** | **Net Gain in Distribution** | **Cost of Propagation and Reintroduction** | **Step One** | **Step Two** | **Priority** |
| Cumberlandian combshell | Medium | 0.5 | 0.7 | Low | 1 | 1 | 1 |
| Alabama lampmussel | High | 0.5 | 0 | Low | 1 | 1 | 1 |
| Oyster mussel | Medium | 0.5 | 0.4 | Low | 1 | 1 | 1 |
| Snuffbox | Low | 1.0 | 1.0 | Low | 1 | 1 | 1 |
| Pink mucket | Low | 2.0 | 9.0 | Low | 1 | 1 | 1 |
| Dromedary pearlymussel | High | 1.0 | 1.0 | Medium | 1 | 2 | 2 |
| Purple bean | High | 1.0 | 0.5 | Medium | 1 | 2 | 2 |
| Fanshell | Medium | 1.0 | 2.0 | Medium | 1 | 2 | 2 |
| Birdwing pearlymussel | Medium | 0.5 | 0.4 | Medium | 1 | 2 | 2 |
| Cumberland bean | High | 1.0 | 0.0 | Medium | 1 | 2 | 2 |
| Golden riffleshell | High | 1.0 | 0.0 | Medium | 1 | 2 | 2 |
| Cracking pearlymussel | High | 0.5 | 2.3 | High | 1 | 3 | 3 |
| Littlewing pearlymussel | High | 0.5 | 2.0 | High | 1 | 3 | 3 |
| Shiny pigtoe | Medium | 0.5 | 0.3 | High | 1 | 3 | 3 |
| Finerayed pigtoe | Medium | 0.5 | 0.4 | High | 1 | 3 | 3 |
| Rough pigtoe | Medium | 0.5 | 9.0 | High | 1 | 3 | 3 |
| Rough rabbitsfoot | Medium | 1.0 | 0.3 | High | 1 | 3 | 3 |
| Cumberland monkeyface | High | 1.5 | 0.0 | High | 1 | 3 | 3 |
| Appalachian monkeyface | High | 0.5 | 0.0 | High | 1 | 3 | 3 |
| Sheepnose | Low | 0.5 | 0.4 | High | 1 | 3 | 3 |
| Appalachian elktoe | Medium | 0.5 | 0.0 | Medium | 2 | 2 | 4 |
| Fluted kidneyshell | Medium | 0.5 | 0.0 | Medium | 2 | 2 | 4 |
| Slabside pearlymussel | Medium | 1.0 | -0.1 | High | 2 | 3 | 6 |
| Spectaclecase | Medium | 0.0 | 0.0 | High | 3 | 3 | 9 |

For prioritization of location of habitat management, richness of imperiled species and feasibility of management implementation were used (Table 12). Species richness was at the scale of the 19, 8-digit HUC sub-basins (Figure 1) that comprise the UTRB (Table 2). For each sub-basin, feasibility of implementing habitat management actions (Appendix 4) was acquired through an averaged polling of expert opinion among the team using three categories:

- 1 = infeasible to low degree of feasibility. There is little or no opportunity for habitat restoration/protection and threat abatement. Threats will likely continue or increase over time even with significant investments in habitat restoration/protection.
- 2 = moderately feasible. There is limited opportunity for habitat restoration/protection and threat abatement. Threats may be reduced over time with significant investments in habitat restoration/protection.
- 3 = high degree of feasibility. There is substantial opportunity for habitat restoration/protection and threat abatement. Threats can likely be reduced over time with significant investments in habitat restoration/protection.

Both variables, species richness and management feasibility, were standardized as the difference from the minimum value divided by the difference between the minimum and maximum value. Standardized input values for species richness and management feasibility were multiplied by weighted values (0.63 and 0.37, respectively) derived from an averaged opinion of team members. Weighted values were summed, and then divided by the sum of weights to derive final scores.

Table 12. Prioritization of 8-digit HUC watersheds for location of habitat management actions based on species richness and management feasibility (see Table 2 for list of species by HUC). Species richness and management feasibility values were standardized and weighted to provide weighted average scores for prioritization. The weights of 0.63 and 0.37 on richness and feasibility, respectively, were elicited from members of the team most familiar with the watersheds. To standardize, the maximum received a 1, the minimum received a 0, and the intermediate values were interpolated between 0 and 1. Higher scores indicate higher priority.

| 8-digit HUC | Species Richness | Standardized Richness | Feasibility | Standardized Feasibility | Weighted Average |
|---|---|---|---|---|---|
| Upper Clinch | 24 | 1.00 | 2.50 | 0.7 | 0.90 |
| Powell | 16 | 0.65 | 2.33 | 0.6 | 0.65 |
| Nolichucky | 7 | 0.26 | 2.67 | 0.8 | 0.47 |
| Upper Little Tennessee | 4 | 0.13 | 3.00 | 1.0 | 0.45 |
| Hiwassee | 7 | 0.26 | 2.40 | 0.7 | 0.41 |
| Tuckasegee | 2 | 0.04 | 3.00 | 1.0 | 0.40 |
| North Fork Holston | 6 | 0.22 | 2.33 | 0.6 | 0.37 |
| Lower Little Tennessee | 6 | 0.22 | 2.33 | 0.6 | 0.37 |
| Emory | 3 | 0.09 | 2.60 | 0.8 | 0.35 |
| Sequatchie | 3 | 0.09 | 2.40 | 0.7 | 0.31 |
| Upper French Broad | 1 | 0.00 | 2.50 | 0.7 | 0.27 |
| Pigeon | 1 | 0.00 | 2.50 | 0.7 | 0.27 |
| South Fork Holston | 4 | 0.13 | 2.00 | 0.5 | 0.25 |
| Lower French Broad | 4 | 0.13 | 2.00 | 0.5 | 0.25 |
| Holston | 5 | 0.17 | 1.67 | 0.3 | 0.21 |
| Watts Bar Lake | 6 | 0.22 | 1.40 | 0.1 | 0.18 |
| Middle Tennessee-Chickamauga | 6 | 0.22 | 1.25 | 0.0 | 0.15 |
| Ocoee | 1 | 0.00 | 1.80 | 0.3 | 0.13 |
| Lower Clinch | 1 | 0.00 | 1.17 | 0.0 | 0.00 |

## Conclusions

Based on the outcome of the SDM analyses, population management emphasis emerged as the optimal approach for achieving conservation of imperiled aquatic species in the UTRB. By following this approach, USFWS will direct more available resources toward implementation of

ESA Sections 7 and 10, protection of existing populations and designated critical habitat, establishment of new populations, increasing extant populations, and initiation of a program for captive population management. Additionally, land acquisition and easements and restoration of instream and riparian habitat will continue but with reduced emphasis, while development of stream and riparian habitat BMPs will increase.

Information needed to support the population management emphasis approach includes increased life history research, threat analyses, genetics monitoring and research, population viability analyses, habitat evaluation for reintroduction, propagation and captive management research, and evaluation of ecosystem services, while maintaining existing population and habitat monitoring. Communication and partnerships to support population management emphasis include increased outreach and establishment of new partnerships, while maintaining intra-agency communications.

The Strategy incorporates the optimal management approach with priority species and locations (Figure 8). The Strategy helps to guide planning and management at the landscape scale across a large and diverse suite of species. As such, it is essential that managers and conservation practitioners recognize the flexibilities the Strategy affords and adapt its application at the local level to ensure conservation efforts will be effective. Thus, the next step is to advance from a coarse strategy to developing specific projects that implement population management emphasis for priority species and locations.

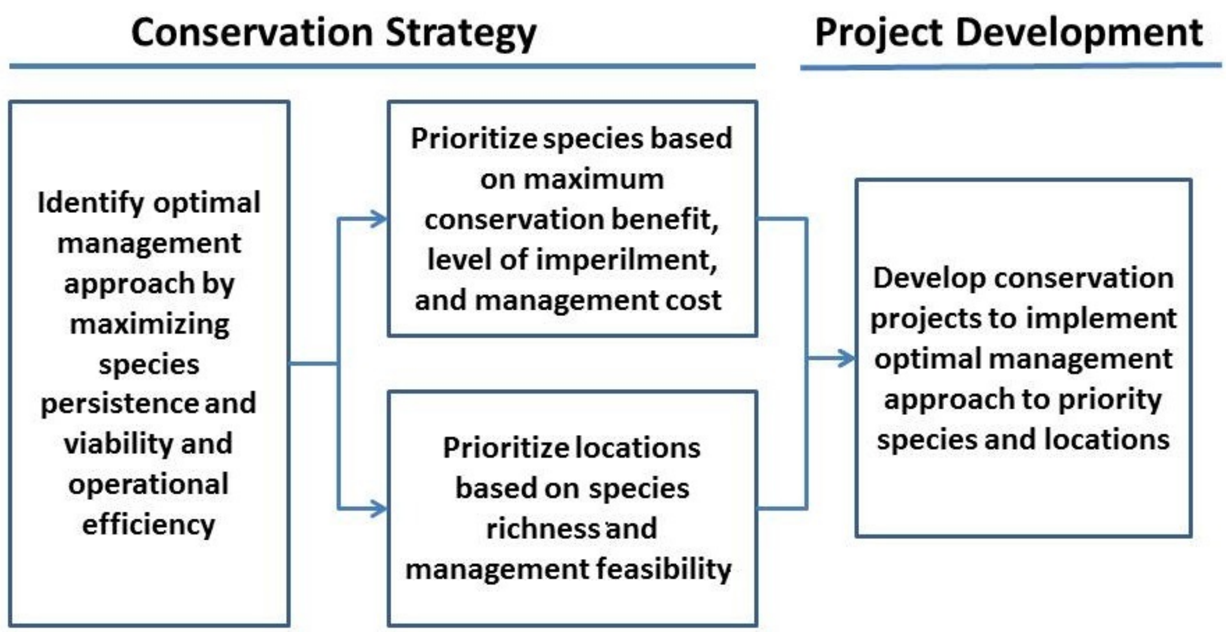



Figure 8. Diagram of Strategy components which feed into project development.

## Strategy Implementation

### Duration

The Strategy is a working document subject to revision and updating on a routine basis, as dictated by new findings, changes in species status, evolving priorities, and completion of conservation actions. It is intended to guide—not mandate—conservation actions and provides a forum for collaboration and coordination. The goals, objectives, and management actions in this Strategy were developed for conservation implementation over a 20-year period. Though some UTRB mussel species live 60 years or longer, within the 20-year timeframe of the Strategy successful recruitment for long-lived mussels can be measured and evaluated. Many of the imperiled fish species live 1–3 years and multiple generations will occur during a 20-year time period, allowing for evaluation of the effectiveness of the Strategy for their conservation. See the Adapting and Monitoring the Strategy and Monitoring Implementation and Effectiveness sections below for additional details.

### Approach

To conserve and recover imperiled aquatic species and the UTRB ecosystem upon which they depend, USFWS will focus personnel and financial resources on implementing management actions (Table 4, Appendix 4), as defined by the population management emphasis approach, for species (Tables 10 and 11) and habitats in locations (Table 12) most likely to benefit from these activities. The Strategy will be implemented by USFWS when (1) making decisions regarding priority species on which to focus recovery efforts, both in terms of staff time and resource dollars; (2) discussing species and management priorities for expending traditional Section 6 funds and State Wildlife Grant funds with State agencies; and (3) determining where to focus USFWS recovery and restoration program (e.g., National Fish Hatchery, Partners for Fish and Wildlife, National Fish Habitat and National Fish Passage) efforts. USFWS will implement/complete these management actions with the assistance of our partners and stakeholders.

### Implementation, Review, and Revision

As a working document, the Strategy will be implemented, reviewed, and revised as needed. This will entail an annual planning meeting to review projects and set action priorities, and meetings to review and modify the Strategy framework based on experience obtained and data that becomes available during Strategy implementation. A Strategy framework review may be triggered sooner than the 4-year cycle described below if monitoring observations indicate a significant inconsistency with underlying assumptions or it is determined that the framework no longer reflects adequately the current state of knowledge or policies. Additional Strategy framework review and project planning efforts could be triggered by factors such as funding increases/decreases, organizational changes, or other events.

***Annual project planning***

The USFWS will host annual project planning meetings to discuss completed and ongoing conservation efforts, evaluate lessons learned, and plan future actions and projects. Other agencies and organizations will be asked to participate and help build and strengthen partnerships for shared missions captured by the Strategy. In advance of each project planning meeting, a pre-meeting survey will be sent to a coordinating contact within each participating partner office to request a list of all recently completed, ongoing, and planned actions or projects that may help meet the goals and objectives of the Strategy. The survey will ask respondents to provide (1) titles and brief descriptions, including project purpose, of their organization's recently completed, ongoing, and planned projects/actions; (2) target completion dates; (3) funding details; and (4) project contact information. Survey results will be compiled, disseminated, reviewed, and discussed at project planning meetings. Examples of projects/actions for consideration could involve fish and mussel propagation, stream habitat restoration, population monitoring, and other activities related to conservation and recovery of imperiled aquatic species within the UTRB.

Duties associated with organizing project planning meetings will rotate among the USFWS's Ecological Services Field Offices in North Carolina, Tennessee, and Virginia since these offices have primary responsibility for conservation and recovery of imperiled species within the UTRB. However, other offices/entities may occasionally host the meeting. The office/entity hosting the meeting will (1) solicit and compile pre-meeting survey responses, (2) distribute meeting information, (3) chair the meeting, (4) compile meeting minutes, and (5) make all meeting materials and minutes available to project planning participants via electronic media.

***Strategy review and revision***

The USFWS will host meetings to review and evaluate the Strategy's effectiveness based on monitoring results, lessons learned, and other available information. Other agencies and organizations will be asked to participate and help build and strengthen partnerships for shared missions captured by the Strategy. This effort will result in modification and/or adaptation of the Strategy, as appropriate. The initial review will take place four years after finalization of the initial Strategy document, and will be coordinated by the USFWS's Southwestern Virginia Field Office. Subsequent reviews will be initiated within four years after the date any new or revised version of the Strategy is signed or deemed final and coordinating offices for future reviews will be determined.

The coordinating office will start the process by reaching out to USFWS staff and partners involved in implementing the Strategy to solicit comments on the most current version of the Strategy and request input on any modifications needed. After reviewing responses, the coordinating office will (1) draft an agenda for a meeting to address comments and suggested modifications, (2) draft a revised Strategy, and (3) propose any other action that will address responses and lead to completion of the review process. Draft agendas, draft Strategy revisions, and other proposed actions will be distributed to all concerned for additional comments and approval. Once agreement is reached on how to move forward with any review, the coordinating office will host the meeting, lead further editing and finalization of any Strategy modifications, and take other actions agreed to by the group. The coordinating office will be responsible for meeting arrangements; arranging conference calls; distributing/providing access to materials, meeting minutes, and draft products; achieving broad distribution of final products; working toward group consensus on decisions; ensuring any needed modifications to the Strategy are accomplished in a timely fashion; and cooperating with the next coordinating office to ensure a smooth transition for accomplishing future reviews.

**Adapting and Monitoring the Strategy**

How management can be adapted to new information depends on the frequency that decisions are made and the degree to which uncertainty affects those decisions. For recurrent (e.g., annual) management decisions, management can adapt to changing conditions (e.g., species status) at each decision point. For conservation strategies that are set in place for a period of time, perhaps indefinitely, strategies can employ adaptive management: (1) by periodic review of the framework that provided the rationale for the Strategy; (2) when monitoring observations are significantly inconsistent with assumptions underlying Strategy framework; or (3) at any time when the decision maker(s) determines that Strategy framework components should be revised to reflect new information, new methodologies, or changing values. The framework review and modification (see above) will provide the opportunity to review and adapt the Strategy as warranted.

As the Strategy is translated into specific projects (Figure 8), there will be many opportunities to use formal adaptive management methodologies (Williams et al. 2009, Runge 2011) to reduce key uncertainties and improve management effectiveness. For example, there is some uncertainty in BMPs when augmenting or establishing a population. Adaptive management in combination with controlled research could be a relatively rapid approach to develop BMPs, guiding population management into the future.

**Monitoring Implementation and Effectiveness**

A monitoring program will provide feedback on implementation and effectiveness of the Strategy. Inference from monitoring must account for multiple management scales—both landscape and local—where management projects are implemented. The monitoring program will measure attributes associated with conservation objectives including measures of recovery (e.g., trend in abundance, occupancy, habitat quality) and operational efficiencies and costs (e.g., staff and operational costs). Status of threats should be considered so that management effectiveness can be determined. Learning can occur by comparing predictions of management effectiveness to observed results, and in that way learning can be used to improve future management implementation. Other design considerations, such as sampling units and frequency, sample size, and location of units, may be determined by examining tradeoffs between the value of the information obtained and associated monitoring costs.

Methods to define sampling units and techniques should follow established guidelines (e.g., Strayer and Smith 2003). Procedures for database management and periodic reporting should be established and followed. Because of the complexity of designing an effective monitoring program, a separate workshop may be needed to coordinate among Federal, State, and NGO monitoring activities, standardization of sampling protocols, a centralized database, periodic reporting, and processes for incorporating what is learned from monitoring into improved future conservation and management actions.

## Related Documents and Policies

Implementation of actions described in this Strategy will support attainment of relevant reclassification and delisting criteria contained in approved USFWS fish and mussel recovery plans. Likewise, ongoing implementation of the Strategy will guide updated estimates of time and cost expenditures to achieve reclassification or delisting of UTRB species in the future. Additionally, the Strategy will help accomplish the identified aims of State agencies and NGOs that also have goals similar to USFWS for conserving and recovering UTRB imperiled aquatic species (e.g., National Native Mussel Conservation Committee 1998, TNC 2009, Cumberlandian Region Mollusk Restoration Committee 2010, Virginia Department of Game and Inland Fisheries 2010).

## Signatures

12/15/2014

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12/8/2014

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12/9/2014

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Appendix 1. Imperiled aquatic species known from the UTRB, their Federal status, and status regarding inclusion in the Strategy.

| Scientific Name[1] | Common Name[1] | Federal Status[2] | Included in Strategy | Explanation if Species not Included in Strategy |
|---|---|---|---|---|
| **Fishes** | | | | |
| *Chrosomus cumberlandensis* | Blackside dace | T | No | Introduced, non-native to UTRB |
| *Chrosomus saylori* | Laurel dace | E, CH | Yes | |
| *Erimystax cahni* | Slender chub | T, CH | Yes | |
| *Erimonax monachus* | Spotfin chub | T, CH | Yes | |
| *Etheostoma marmorpinnum* | Marbled darter | E | Yes | |
| *Etheostoma percnurum* | Duskytail darter | E | Yes | |
| *Etheostoma sitikuense* | Citico darter | E | Yes | |
| *Moxostoma* sp. | Sicklefin redhorse | C | Yes | |
| *Notropis albizonatus* | Palezone shiner | E | No | Extirpated from UTRB |
| *Noturus baileyi* | Smoky madtom | E, CH | Yes | |
| *Noturus crypticus* | Chucky madtom | E, CH | Yes | |
| *Noturus flavipinnis* | Yellowfin madtom | T, CH | Yes | |
| *Noturus stanauli* | Pygmy madtom | E | Yes | |
| *Percina tanasi* | Snail darter | T, CH | Yes | |
| **Mussels** | | | | |
| *Alasmidonta raveneliana* | Appalachian elktoe | E, CH | Yes | |
| *Cumberlandia monodonta* | Spectaclecase | E | Yes | |
| *Cyprogenia stegaria* | Fanshell | E | Yes | |
| *Dromus dromas* | Dromedary pearlymussel | E | Yes | |
| *Epioblasma brevidens* | Cumberlandian combshell | E, CH | Yes | |
| *Epioblasma capsaeformis* | Oyster mussel | E, CH | Yes | |
| *Epioblasma florentina aureola* | Golden riffleshell | E | Yes | |
| *Epioblasma torulosa gubernaculum* | Green blossom | E | No | Considered extinct |
| *Epioblasma triquetra* | Snuffbox | E | Yes | |
| *Epioblasma turgidula* | Turgid blossom | E | No | Considered extinct |
| *Fusconaia cor* | Shiny pigtoe | E | Yes | |
| *Fusconaia cuneolus* | Finerayed pigtoe | E | Yes | |
| *Hemistena lata* | Cracking pearlymussel | E | Yes | |
| *Lampsilis abrupta* | Pink mucket | E | Yes | |
| *Lampsilis virescens* | Alabama lampmussel | E | Yes | |
| *Lemiox rimosus* | Birdwing pearlymussel | E | Yes | |
| *Leptodea leptodon* | Scaleshell | E | No | Extirpated from UTRB |
| *Obovaria retusa* | Ring pink | E | No | Extirpated from UTRB |
| *Pegias fabula* | Littlewing pearlymussel | E | Yes | |
| *Plethobasus cicatricosus* | White wartyback | E | No | Extirpated from UTRB |
| *Plethobasus cooperianus* | Orangefoot pimpleback | E | No | Extirpated from UTRB |
| *Plethobasus cyphyus* | Sheepnose | E | Yes | |
| *Pleurobema plenum* | Rough pigtoe | E | Yes | |
| *Pleuronaia dolabelloides* | Slabside pearlymussel | E, CH | Yes | |
| *Ptychobranchus subtentus* | Fluted kidneyshell | E, CH | Yes | |
| *Quadrula cylindrica cylindrica* | Rabbitsfoot | T | No | Extirpated from UTRB |
| *Quadrula cylindrica strigillata* | Rough rabbitsfoot | E, CH | Yes | |
| *Quadrula intermedia* | Cumberland monkeyface | E | Yes | |
| *Quadrula sparsa* | Appalachian monkeyface | E | Yes | |
| *Toxolasma cylindrellus* | Pale lilliput | E | No | Extirpated from UTRB |
| *Villosa perpurpurea* | Purple bean | E, CH | Yes | |
| *Villosa trabalis* | Cumberland bean | E | Yes | |
| **Other Taxa** | | | | |
| *Athearnia anthonyi* | Anthony's riversnail | E | No | Extant in UTRB, but recovery potential unknown |
| *Marstonia ogmorhaphe* | Royal snail | E | No | Extant in UTRB, but recovery potential unknown |
| *Glyphopsyche sequatchie* | Sequatchie caddisfly | C | No | Extant in UTRB, but recovery potential unknown |

[1]For some species the common and/or scientific name currently accepted in scientific literature is being used in the Strategy, not necessarily the common and/or scientific name under which the species was listed pursuant to the ESA.
[2]C – candidate for Federal listing as endangered or threatened; CH – critical habitat designated in the UTRB; E – federally listed as endangered; T – federally listed as threatened.

Appendix 2. UTRB imperiled fishes' basic life history information (feeding, reproductive, and habitat guilds), predominant threats, and degree of imperilment (i.e., likelihood of extinction). Degree of imperilment is based on qualitative assessment of rangewide likelihood of extinction over the next 20 years and is used in an analysis of species prioritization shown in Table 10.

| Species | Feeding Guild | Reproductive Guild | Habitat Guild | Predominant Threats | Degree of Imperilment[1, 2] |
|---|---|---|---|---|---|
| Chucky madtom | Benthic insectivore | Nest builder – males guard nests in cavities under cover, such as cobbles and boulders | Benthic – in flowing pools and runs with pea-size gravel and slab-shaped cobble | Agriculture, small population size | High – a very small population may persist in Chucky Creek |
| Citico darter | Benthic insectivore | Nest builder – males guard nests with eggs attached to underside of cover, such as cobbles and boulders | Benthic – in flowing pools with predominantly cobble substrate | Recreation, timbering | High – a sizable population occurs in Citico Creek and the species has been reintroduced in Abrams Creek and is being reintroduced in Tellico River |
| Duskytail darter | Benthic insectivore | Nest builder – males guard nests with eggs attached to underside of cover, such as cobbles and boulders | Benthic – in flowing pools | Agriculture | High – a small population occurs in Copper Creek |
| Laurel dace | Primarily insectivore – feeds on larval and adult insects and, to lesser extent, grazes algae | Nest associate – spawns over gravel nests made by other minnow species; also uses nest-free gravel riffle areas | Water column – in pools or slow runs with cobble, gravel, or bedrock, and occasionally sand and silt | Agriculture, culverts and other obstacles to fish passage, residential development, timbering | High – small populations occur in 6 headwater streams in 3 independent tributaries of Tennessee River drainage |
| Marbled darter | Benthic insectivore | Nest builder – males guard nests with eggs attached to underside of cover, such as cobbles and boulders | Benthic – in flowing pools | Agriculture, residential development | High – a small population occurs in Little River (TN) |
| Pygmy madtom | Benthic insectivore | Nest builder – males guard nests in cavities under cover, such as cobbles and boulders | Benthic – in runs with cobble, gravel, and mussel shell substrate | Agriculture, life history characteristics (short-lifespan and low fecundity) | High – a very small population occurs in Clinch River; a very small population exists outside UTRB |
| Sicklefin redhorse | Benthic invertivore – consumes larval insects and small mollusks | Broadcast spawner – over gravel | Benthic – in riffles, runs, and the head and tail of pools; over gravel, cobble, and boulder with little to no silt; juveniles may drift into the heads of reservoirs | Agriculture, impoundments | Low – sizable populations occur in upper Little Tennessee River and Hiwassee River drainages |
| Slender chub | Benthic insectivore | Probably broadcast spawner – over small gravel | Benthic – in swift to moderately flowing runs over small, pea-sized, gravel | Agriculture, coal mining, small population size | High – very small populations may persist in Clinch River and Powell River |
| Smoky madtom | Benthic insectivore | Nest builder – males guard nests in cavities under cover, such as cobbles and boulders | Benthic – in pools and runs | Recreation, timbering | High – a sizable population occurs in Citico Creek and the species has been reintroduced in Abrams Creek and is being reintroduced in Tellico River |
| Snail darter | Benthic invertivore – consumes small mollusks and larval insects | Broadcast spawner – over gravel shoals | Benthic – in flowing pools and runs with sand and gravel substrate; pelagic juveniles may drift into the heads of reservoirs | Agriculture, impoundments | Low – small and sizable populations occur in lower Holston River, Lower French Broad River, Citico Creek, Sewee Creek, Hiwassee River, Ocoee River, South Chickamauga Creek, and Sequatchie River; a small population exists outside UTRB |

| | | | | | |
|---|---|---|---|---|---|
| Spotfin chub | Benthic insectivore | Crevice spawner – in thin gaps between flattened sides of rocks or in bedrock grooves | Benthic – in swift runs, over boulders, cobbles, and bedrock | Agriculture, natural gas development, timbering, urbanization | Low – sizable populations occur in upper Little Tennessee River and Emory River, and a small population occurs in Holston/North Fork Holston River drainages, and the species is being reintroduced in Cheoah River and Tellico River (a reintroduction attempt in Abrams Creek failed); one very small population exists outside UTRB |
| Yellowfin madtom | Benthic insectivore | Nest builder – males guard nests in cavities under cover, such as cobbles and boulders | Benthic – in flowing pools with cobble, gravel, and mussel shell substrate | Agriculture, coal mining, natural gas development, recreation, timbering | Medium – sizable populations occur in Powell River and Citico Creek, a small population occurs in Clinch River/ Copper Creek, and the species has been reintroduced into Abrams Creek and is being reintroduced in Tellico River ranges over the past 10 years |

[1]In some streams where reintroductions have been attempted, it may be too early to assess success. It is understood that some, particularly very small, populations may be extirpated.
[2]Likelihood of extinction probability over the next 20 years for imperiled species was divided into three categories: (1) Low = 10% or less, (2) Medium = 11–50%, and (3) High = 50% or greater. These categories correspond to a species abundance and distribution.

Appendix 3. UTRB imperiled mussels' basic life history information (reproductive strategy and fish hosts), distribution, abundance, and degree of imperilment (i.e., likelihood of extinction). Degree of imperilment is based on qualitative assessment of rangewide likelihood of extinction over the next 20 years and is used in an analysis of species prioritization shown in Table 11.

| **Species** | **Reproductive Strategy and Fish Hosts** | **UTRB Streams of Occurrence[1]** | **Abundance in UTRB[2]** | **Degree of Imperilment[3]** |
|---|---|---|---|---|
| Alabama lampmussel | Long-term brooder<br><br>Black basses in the genus *Micropterus* | Emory River<br><br>Reintroduced – Sequatchie River | Very Low | High – a small population occurs in Emory River and the species is being reintroduced in Sequatchie River; a small population exists outside of UTRB |
| Appalachian elktoe | Long-term brooder<br><br>Minnows in the genera *Campostoma*, *Clinostomus*, *Nocomis*, and *Rhinichthys*; darters in the genera *Etheostoma* and *Percina*; and sculpins in the genus *Cottus*; and Northern hogsucker | Little Tennessee River, Tuckasegee River, Cheoah River, Nolichucky River, North and South Toe Rivers, Cane River, Little River (NC), Pigeon River | Medium to Low | Medium – sizable populations occur in North Toe River, South Toe River, Little River (NC), and Tuckasegee River, small populations occur in Nolichucky River, Pigeon River , upper French Broad River and Little Tennessee River, and very small populations occur in Cane River, Mills River, and Cheoah River |
| Appalachian monkeyface | Short-term brooder<br><br>Unknown, but likely minnows | Clinch River, Powell River | Low to Very Low | High – a small population occurs in Powell River and a very small population occurs in Clinch River |
| Birdwing pearlymussel | Long-term brooder<br><br>Darters in the genus *Etheostoma* | Clinch River, Powell River<br><br>Reintroduced – Nolichucky River, French Broad River | Medium to Low | Medium – a sizable population occurs in Clinch River, a very small population occurs in Powell River, and the species is being reintroduced in lower French Broad River and Nolichucky River; a large population exists outside of UTRB |
| Cracking pearlymussel | Short-term brooder<br><br>Probably minnows in the genera *Cyprinella* and *Luxilus* and darters in the genus *Etheostoma* | Clinch River, Powell River | Medium to Low | High – a small population occurs in Clinch River and a very small population occurs in Powell River; a small population exists outside of UTRB |
| Cumberland bean | Long-term brooder<br><br>Darters in the genus *Etheostoma* and sculpins in the genus *Cottus* | Hiwassee River | Low to Very Low | High – a small population occurs in Hiwassee River; a few small populations exist outside of UTRB |
| Cumberland monkeyface | Short-term brooder<br><br>Minnows in the genus *Erimystax* | Powell River | Low to Very Low | High – a small population occurs in Powell River; a sizable population exists outside of UTRB |
| Cumberlandian combshell | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Powell River<br><br>Reintroduced - Nolichucky River | High to Medium | Medium – a large population occurs in Clinch River, a small population occurs in Powell River, and the species is being reintroduced in Nolichucky River; a few other populations exist outside of UTRB |
| Dromedary pearlymussel | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Powell River, Tennessee River | Medium to Low | High – a sizable population occurs in Clinch River, a small population occurs in Powell River, and a very small population occurs in Tennessee River |
| Fanshell | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Tennessee River | Medium to Low | Medium – a small population occurs in Clinch River and a very small population occurs in Tennessee River; a few sizable and small populations exist outside of UTRB |
| Finerayed pigtoe | Short-term brooder<br><br>Minnows in the genera *Cyprinella*, *Luxilus*, and *Notropis* | Clinch River, Powell River, North Fork Holston River, Little River (TN), Copper Creek | Medium to Low | Medium – a sizable population occurs in Clinch River. A small population occurs in Little River (TN), and very small populations occur in Powell River, North Fork Holston River, and Copper Creek |

| | | | | |
|---|---|---|---|---|
| Fluted kidneyshell | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Powell River, North Fork Holston River, Middle Fork Holston River<br><br>Reintroduced – Nolichucky River, Little Tennessee River, Hiwassee River | High to Medium | Medium – a large population occurs in Clinch River, small populations occur in Powell River, North Fork Holston River, a very small population occurs in Middle Fork Holston River, and the species is being reintroduced into Nolichucky River, lower Little Tennessee River, and Hiwassee River; a few small populations exist outside of UTRB |
| Golden riffleshell | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Middle Fork Holston River, Hiwassee River | Very Low | High – very small populations occur in upper Clinch River drainage, Middle Fork Holston River, and Hiwassee River |
| Littlewing pearlymussel | Long-term brooder<br><br>Darters in the genus *Etheostoma* and sculpins in the genus *Cottus* | Clinch River, North Fork Holston River, Little Tennessee River | Very Low | High – very small populations occur in upper Clinch River, North Fork Holston River, and Little Tennessee Rivers; a few small populations exist outside of UTRB |
| Oyster mussel | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Nolichucky River, Sequatchie River<br><br>Reintroduced – Powell River, French Broad River, Hiwassee River | High to Medium | Medium – a large population occurs in Clinch River a small population occurs in Nolichucky River, a very small population occurs in Sequatchie River, and the species is being reintroduced in Powell River, lower French Broad River, and Hiwassee River; the species is being reintroduced outside the UTRB |
| Pink mucket | Long-term brooder<br><br>Black basses in the genus *Micropterus* | Clinch River, French Broad River, Holston River, Tennessee River | Very Low | Low – very small populations occur in Clinch River, Holston River, French Broad River, and Tennessee River; numerous populations exist outside of UTRB |
| Purple bean | Long-term brooder<br><br>Darters in the genus *Etheostoma* and sculpins in the genus *Cottus* | Clinch River, Obed River, Emory River, Beech Creek, Copper Creek | Low to Very Low | High – small populations occur in Emory River and Beech Creek, and very small populations occur in Obed River and Copper Creek |
| Rough pigtoe | Short-term brooder<br><br>Unknown, but likely minnows | Clinch River, Tennessee River | Low | Medium – a small population occurs in Clinch River and a very small population occurs in Tennessee River; a few other small populations exist outside of UTRB |
| Rough rabbitsfoot | Short-term brooder<br><br>Minnows in the genera *Cyprinella*, *Luxilus*, and *Notropis* | Clinch River, Powell River | Medium to Low | Medium – a sizable population occurs in Clinch River and a small population occurs in Powell River |
| Sheepnose | Short-term brooder<br><br>Minnows in the genera *Cyprinella* and *Luxilus* and darters in the genus *Etheostoma* | Clinch River, Powell River, Holston River | Medium to Low | Low – small populations occur in Clinch, River, Powell River, and Holston River; numerous other populations exist outside of UTRB |
| Shiny pigtoe | Short-term brooder<br><br>Minnows in the genera *Cyprinella*, *Luxilus*, and *Notropis* | Clinch River, Powell River, North Fork Holston River, Copper Creek | Medium to Low | Medium – a sizable population occurs in Clinch River, a small population occurs in North Fork Holston River, and very small populations occur in Powell River and Copper Creek; a small population exists outside of UTRB |
| Slabside pearlymussel | Short-term brooder<br><br>Minnows in the genera *Cyprinella*, *Luxilus*, and *Notropis* | Clinch River, Powell River, North Fork Holston River, Middle Fork Holston River, Hiwassee River, Little River (TN) | Medium to Low | Medium – small populations occur in Clinch River, Powell River, and North Fork Holston River, and very small populations occur in Little River (TN) and Hiwassee River; a few mostly small populations exist outside of UTRB |
| Snuffbox | Long-term brooder<br><br>Darters in the genera *Percina* and *Etheostoma* | Clinch River, Powell River | Medium to Low | Low – a small population occurs in Clinch River and a very small population occurs in Powell River; numerous small populations exist outside of UTRB |

| | | | | |
|---|---|---|---|---|
| Spectaclecase | Unknown<br><br>Unknown | Clinch River, Nolichucky River | Low | Medium – a small population occurs in Clinch River and a very small population occurs in Nolichucky River; several mostly small populations exist outside of UTRB |

[1]In some streams where reintroductions have been attempted, it may be too early to assess success. It is understood that some, particularly very small, populations may be extirpated.

[2]Very Low = <1,000 individuals; Low = 1,000–5,000 individuals; Medium = 5,001–10,000 individuals; and High = >10,000 individuals.

[3]Likelihood of extinction probability over the next 20 years for imperiled species was divided into three categories: (1) Low = 10% or less, (2) Moderate = 10–50%, and (3) High = 50% or greater. These categories correspond to a species abundance and distribution. For example, a species with high abundance (10,000 individuals or greater) and comprised of multiple populations throughout its range would have a low probability of extinction over the next 20 years, whereas a species with very low abundance (less than 1,000 individuals) and comprised of only a single remaining population would have a high probability of extinction over the same time period.

Appendix 4. Management actions**.**

Definitions associated with management actions:

- Augment – stocking individuals (e.g., stocking hatchery-reared fishes or mussels, releasing glochidia-encysted host fish, stocking adult or sub-adult mussels) to either bolster existing populations or better connect aggregations of fishes or mussels that are located in close proximity to one another and likely represent a single population that is now disjunct.
- Extant – living individuals or fresh dead specimens (for mussels) that have been collected since 1980.
- Historical range – the geographic area where a species was known or believed to occur.
- Introduction/Reintroduction – stocking individuals (e.g., stocking hatchery-reared fishes or mussels, releasing glochidia-encysted host fish, stocking adult or sub-adult mussels) into areas with suitable habitat within the species' historical range for which no documentation exists of their occurrence or from which they have been extirpated and natural recolonization cannot reasonably be anticipated.
- Occupied habitat – areas where there is a record of an imperiled species since 1980.
- Propagation – producing offspring from brood stock, nests, or eggs in a captive setting.
- Refuge population – a population of an imperiled fish or mussel species that exhibits regular recruitment and occurs in habitat conditions likely capable of sustaining it for a long time period (e.g., > 100 years). These populations may be relict populations of a formerly more widespread species, and/or serve as primary sources of individuals for natural colonization of habitat within the watershed. These populations also may serve as reservoirs for stocking individuals to other localities and to obtain broodstock for propagation purposes.
- Restore – reconnecting (e.g., removing dams and other physical barriers) populations among stream reaches where at least one extant population exists and there are gaps in species distribution.
- Suitable habitat – areas that appear to have the necessary/appropriate requirements for imperiled species occupancy.

**A. Population Management: *in situ***

1. Protect imperiled species extant occurrences/aggregations.

1a. Implement ESA Sections 7 and 10 regulations: To avoid and minimize impacts to imperiled species, their habitat, and critical habitat where designated, ensure USFWS listed species recovery leads and biologists are up-to-date on completed formal consultations and all recent species information. Ensure that USFWS and State agencies are consistent in species-specific considerations for type of collecting apparatus authorized and number of individuals to be collected.

1b. Support agencies who enforce other regulations (Comprehensive Environmental Response, Compensation & Liability Act; Clean Water Act; National Pollutant Discharge Elimination System; Total Maximum Daily Load, etc.): Ensure Federal and State agencies consider imperiled species management or recovery when issuing permits by participating in meetings, reviewing documents, providing comments, etc. related to imperiled species.

1c. Conduct status assessments of rare aquatic species for possible candidate status.

1d. List candidate aquatic species: Complete administrative process to publish proposed rule to list species that have been determined to warrant ESA listing; complete administrative listing process for species on the candidate list according to candidate priority, funding, etc.

1e. Use other available means to protect imperiled aquatic species.

1e1. Protect candidate/proposed aquatic species: Develop/implement Candidate Conservation Agreements (CCAs) and CCAs with Assurances; establish conservation easements; during permit review include recommendations that consider State regulations to protect candidate and proposed aquatic species.

1e2. Protect listed aquatic species: Provide long-term management for areas considered essential for a species' continued existence and recovery by land or easement acquisition.

1e3. Protect or establish refuge populations.

2. Increase effective population size and/or geographic extent of extant imperiled fish and mussel populations within stream reaches or HUCs.

2a. Develop BMPs for augmenting populations: Develop standard peer-reviewed protocols for augmenting/reintroducing populations that would extend to: 1) permitting, planning, and approval process and documentation; 2) implementing conservation genetic management that considers genetic information for source of individuals used for reintroduction and recovery, including when is/is not appropriate to conduct augmentation; how many wild individuals to use in propagation and stocking programs for augmenting populations; how many wild individuals to use in stocking; 3) evaluating and verifying source populations will support removal/harvest for stocking; 4) handling procedures for collecting individuals for hatchery-rearing or stocking in the wild; 5) implementing hatchery management that considers feeding regimes for growth, reproduction, and basal metabolism, and water quality maintenance regimes; 6) monitoring to include tagging (if recommended), record keeping, and reporting; 7) applying adaptive management, an analysis of results and a process for adapting management actions; and 8) preparing and implementing plans to ensure work conducted or caused by natural resource agencies is not causing the spread of aquatic nuisance/non-target species; there are standard BMPs that can be adopted and developed (e.g., consider only working in one stream system per day, cleaning gear between sites).

2b. Augment existing populations.

2b1. Complete controlled propagation plans: Finalize a controlled propagation plan per USFWS guidelines (FR 56916–56922) and with stakeholder input prior to hatchery-rearing.

2b2. Evaluate facilities: Develop list of facilities (Federal and State hatcheries, academia, zoos, aquaria, and private facilities) with capability to hatchery-rear fishes and mussels (e.g., expertise, infrastructure, water quality, food availability, fish health testing) and evaluate their qualifications. Summarize the techniques used and species reared by various facilities propagating fishes and mussels in the U.S. to determine which facilities can be used to hatchery-rear UTRB fishes and mussels and if additional facilities need to be developed.

2b3. Stock hatchery-reared fishes and mussels, release glochidia-encysted host fish (using fish native to the stream), or stock adult or sub-adult mussels from more robust populations into river reaches where extant populations exist, to increase population size and improve likelihood of survival of extant population.

2c. Increase population connectivity: Stock hatchery-reared fishes or mussels, release glochidia-encysted host fish (using fish native to the stream), or stock adult or sub-adult mussels from more robust populations into river reaches where extant populations exist and there are gaps in species distribution.

3. Establish new populations of imperiled fishes and mussels within historical range.

3a. Develop BMPs for establishing new populations: Develop standard peer-reviewed protocols for reintroducing/introducing populations that extend to: 1) permitting, planning, and approval process and documentation; 2) appropriate selection of areas where a new population would be established that includes consideration of the species' historical range; 3) implementing conservation genetic management that considers genetic information for source of individuals used for establishing new populations; how many wild individuals to use in propagation and stocking programs for reintroducing populations; how many wild individuals to use in stocking; 4) evaluating and verifying source populations will support removal/harvest for stocking; 5) handling procedures for collecting individuals for hatchery-rearing or stocking in the wild; 6) implementing hatchery management that considers feeding regimes for growth, reproduction, and basal metabolism, and water quality maintenance regimes; 7) monitoring to include tagging (if recommended), record keeping, and reporting; 8) applying adaptive management, an analysis of results and a process for adapting management actions; and 9) preparing and implementing plans to ensure work conducted or caused by natural resource agencies is not causing the spread of aquatic nuisance/non-target species; there are standard BMPs that can be adopted and developed (e.g., consider only working in one stream system per day, cleaning gear between sites).

3b. Reintroduce populations: Stock individuals (methods might include all listed in A2) into suitable historical habitat from which they have been extirpated, and where natural recolonization cannot reasonably be anticipated, to increase connectivity between populations, improve gene flow, and increase number of viable populations.

3c. Designate non-essential experimental populations: Complete administrative process to propose non-essential experimental population designations, if this designation would facilitate species recovery efforts (e.g., establishing new populations) for species or groups of species that would otherwise be difficult to accomplish without this designation. Areas important for this action would be identified by criteria and prioritization scheme (see D3c and D7b).

3d. Introduce populations: Stock individuals into areas with suitable habitat within the species' historical range for which no documentation exists of their occurrences.

**B. Habitat Management**

1. Develop BMPs for managing instream and riparian habitat: Identify and produce a list of approved BMPs already in use, revise existing BMPs, or create new BMPs that would, if installed and maintained properly, ensure riparian and instream habitats are not adversely affected by land use activities or projects that could affect stream habitats (e.g., agriculture, silviculture, urban development, transportation, water withdrawal or outfall, hydro-fracking, culvert installation [fish passage concerns], oil and gas development).

2. Use regulatory authority to maintain or establish habitat connectivity: USFWS will use its regulatory authority to avoid and minimize impacts to imperiled aquatic species habitat and consider the potential for assisting in species recovery when issuing and reviewing permits (research permits, water quality permits, permits for development, etc.) that could affect stream reaches with existing populations or stream reaches with potential use as reintroduction or introduction sites.

2a. Support those who enforce other regulations (Comprehensive Environmental Response, Compensation & Liability Act; Clean Water Act; National Pollutant Discharge Elimination System; Total Maximum Daily Load, etc.) to ensure that habitat is protected: Ensure Federal and State agencies consider actions that may result in adverse effects to imperiled aquatic species habitat, both occupied and that with potential for use as reintroduction sites, when issuing permits by participating in meetings, reviewing documents, providing comments, etc.

2b. Minimize and avoid impacts to habitat: Ensure careful consideration of habitat and species-specific ecological requirements (e.g., habitat to ensure appropriate host fish populations) in conducting Section 7 consultations and permitting associated with Habitat Conservation Plans (HCPs).

2c. Minimize and avoid impacts to proposed or designated critical habitat: Consider whether a proposed project 'may affect, is likely to adversely affect' proposed or designated critical habitat during Section 7 consultation.

3. Land protection including easement and acquisition: In areas where extant aquatic imperiled species populations are known or in areas important to restore lost habitat connectivity, employ measures to protect riparian and instream habitats.

3a. Acquire conservation easements: Use the USFWS Partners for Fish and Wildlife Program or other programs to improve or maintain buffers in areas affected by poor agricultural practices to maintain or improve water and habitat quality.

3b. Acquire land: Assist State agencies and NGOs in purchasing and protecting lands to protect occupied imperiled aquatic species habitat and habitat with potential for reintroduction.

4. Restore habitat: In areas where extant mussel and fish populations are known or in areas important to restore lost habitat connectivity.

4a. Improve instream habitat quality: Implement site- or stream-specific activities to provide natural flow and temperature conditions. Examples include altering timing and type of releases from dams, removing dams, restoring stream meanders (in previously channelized sections), and providing bio-stabilization for eroded stream banks.

4b. Improve riparian habitat quality/increase riparian habitat quantity: Create or restore riparian habitats. Examples include reducing sediment runoff from land use activities and removing livestock from streams.

4c. Restore habitat connectivity: Acquire conservation easements and implement site- or stream-specific activities to provide natural flow and temperature conditions where habitat or physical barriers prevent genetic connectivity. Examples include removing dams, restoring stream meanders (in previously channelized sections), removing chemical barriers by removing point-source pollution, restoring habitats affected by nonpoint-source pollution by enforcing regulatory oversight for mining, agriculture, silviculture, and urban development.

**C. Population Management: *ex situ***

This action is different from hatchery-rearing and stocking of individuals as described in A. Population Management: *in situ* (A2 and A3), which uses only wild brood stock to propagate and culture individuals for stocking. This management action is often referred to as captive management or captive breeding, because populations or species are bred wholly in captivity, including the future brood stock and their progeny. Wild sources of brood stock, however, are often brought into the hatchery, when possible and according to genetic management plans, to invigorate the genetics of captively managed populations. Stocking individuals from a captive population may be desired when low population size is adversely affecting reproduction and recruitment in the wild. As well, there is an understanding that captive raised individuals would be released into the wild at some time in the future when habitat is restored or some other criteria are met. Prior to initiation of captive propagation and potential stocking, extensive planning and preparation will be required. The detail required to accomplish this has not been captured here and will need to be developed.

1. Prepare for captive management of imperiled fishes and mussels.

   1a. Complete controlled propagation plans: Prior to establishing a captive population finalize a controlled propagation plan per USFWS guidelines (FR 56916– 56922) and with stakeholder input.

   1b. Evaluate facilities: Develop list of facilities (Federal and State hatcheries, academia, zoos, aquaria, and private facilities) with capability to hatchery-rear fishes and mussels (e.g., expertise, infrastructure, water quality, food availability, fish health testing) and evaluate their qualifications. Summarize the techniques used and species reared by various facilities propagating fishes and mussels in the U.S. to determine which facilities can be used to hatchery-rear UTRB fishes and mussels and if additional facilities need to be developed.

   1c. Develop generic and species-specific BMPs/protocols for captive management: Develop BMPs for obtaining broodstock, transportation to suitable facility, captive holding, and breeding that consider the species genetic variation, life history, and feeding/nutritional requirements. Develop BMPs for breeding mussels in captivity that describe or recommend preferred culture system, diet, feeding regime, water quality, best host fish, and recommended ratio of males to females for spawning to maintain genetic variation. Develop BMPs for breeding fishes in captivity that describe or recommend preferred culture system, diet, feeding regime, water quality, and recommended number of mating pairs to maintain genetic variation.

2. Establish and manage captive populations: Manage populations or species wholly in captivity because suitable habitat no longer exists or is significantly lacking, or the threat of extinction is so great (e.g., lack of reproduction and recruitment in the wild) that a captive breeding program is necessary to preserve the species.

   2a. Initiate/manage captive breeding and rearing.

   2b. Develop imperiled aquatic species cooperative breeding programs among approved facilities: This will minimize loss of genetic diversity over time by pairing individuals using a mean kinship value. This will consider which facility has best success with a particular species.

**D. Monitoring/Research**

1. Conduct basic life history research in the wild (i.e., *in situ*) for imperiled fishes and mussels: Where there are species-specific data gaps, determine flow preferences, substrate, growth rates, habitat preferences, temperature preferences, etc.

2. Conduct imperiled fish and mussel population surveys/monitoring.

   2a. Identify species for which baseline surveys have/have not been completed, and for which regular population monitoring has/has not been conducted.

   2b. Conduct baseline surveys and subsequent routine monitoring: For natural, augmented, and newly established imperiled fish and mussel populations to assess effectiveness of conservation and recovery efforts.

3. Collect and maintain habitat data/monitor habitat for imperiled fishes and mussels.

   3a. Assemble baseline habitat data: Collect existing baseline habitat data (e.g., historical stream flow, temperature data from gaging stations) to be maintained and updated at a single, accessible location (e.g., SharePoint, website).

3b. Develop habitat monitoring protocols: Identify parameters for monitoring imperiled fish and mussel habitat utilizing standardized, repeatable survey/sampling protocols, as needed.

3c. Identify hot spots/focus areas: Using available habitat data identify quality stream reaches/HUCs, those needing protection, and areas needing augmentation/reintroduction.

3d. Monitor habitat: Using monitoring protocols and identified hot spots/focus areas, conduct standardized, repeatable habitat surveys to identify trends in habitat suitability or to assess effectiveness of management or recovery efforts.

4. Evaluate and monitor threats to imperiled fish and mussel species. Existing threats assessments should be compiled and reviewed to minimize duplication of effort.

4a. Assess threats (basin-wide or locally): Identify potential threats resulting from various land uses and other anthropogenic activities to habitat and water quality.

4b. Assess species-specific and/or cross-species threats: Rank identified threats based on geographic scale of activity, magnitude of activity, imminence, impact to the animals (biological, physical, critical to various life stages, etc.), and pervasive nature of the threat (species-specific vs. cross-species).

4c. Conduct contaminants assessments: Based on threat assessment and identification of potential contaminants, conduct laboratory tests on various life stages of fishes and mussels to determine potential toxicity from constituents for which data on sensitive fishes and mussels are not available.

4d. Identify threat response needs (e.g., spill response): Using data from threats analyses and contaminants assessments, identify areas where fish or mussel populations are likely to receive contamination from spills; prioritize need for spill plans that identify mechanisms of responding to toxic spill or other potential acute threat.

5. Conduct imperiled fish and mussel genetics monitoring/research: Identify species with and without appropriate amount of existing genetic data that allows for proper planning and implementation of conservation/recovery efforts.

5a. Monitor genetic diversity of extant populations: Regularly collect appropriate genetic data to identify trends in natural, augmented, and new populations. Use non-invasive survey techniques to document presence or absence of fish and mussel populations by stream reach (or geographically appropriate scope). Use non-invasive techniques to obtain tissue for testing (i.e., clips of fish fins, swabs or small clips of mussel tissue), use Polymerase Chain Reaction techniques, microsatellites markers or other more advanced or less invasive techniques as they become available (e.g., environmental DNA [eDNA]) to determine the average allelic richness, observed heterozygosity, and amount of genetic differentiation between listed species populations, compare with related taxa, compare with expected heterozygosity levels, and determine effective population sizes.

5b. Quantify level of genetic diversity in augmented and newly established populations.

5c. Monitor genetic diversity of captive populations.

6. Conduct imperiled fish and mussel population viability analyses (PVA): PVAs require life history, demographic, and other species-specific data, and include environmental variables.

6a. Determine species needing and eligible for PVAs: Identify species for which PVAs have/have not been completed. Prioritize species for PVA analyses using perceived risk of extinction and availability of biological and environmental parameters.

6b. Conduct needed demographic research: According to prioritization (D6a), obtain species-specific demographic data needed to conduct PVAs.

6c. Conduct species-specific PVAs: Conduct analyses according to prioritization.

7. Evaluate areas with potential habitat for imperiled fish and mussel reintroductions.

7a. Evaluate quality of occupied habitat: Establish criteria for ranking quality of habitats with known populations of imperiled fishes and mussels that include consideration of species' genetic information, life history requirements, threats, development of management plans, monitoring, reporting, adaptive management, etc.

7b. Identify and evaluate potential reintroduction sites: Use criteria from D7a to identify existing populations where reintroduction would allow for geographic expansion (or increase viability) or to identify unoccupied stream reaches within a species' geographic range where habitat appears appropriate for reintroduction.

7c. Identify and evaluate prospective refuge populations: Rate existing populations and identify viable populations that may provide important genetic source for future augmentation or reintroduction, which may be an important part of a metapopulation and may be more easily protected.

8. Conduct research related to imperiled fish and mussel captive propagation and management: Determine efficacy of experimental techniques (using surrogates for imperiled species, as appropriate).

8a. Prioritize species (fishes and mussels) for which propagation techniques have not been developed: Prioritization could include rarity and probability of extinction, availability of taxonomic information to identify what species could be used as surrogates for propagation trials, availability of individuals of the identified surrogate species for propagation trials, availability of suitable habitat for creation of new populations (see several actions identified above), or existing populations with an identified management need including augmentation, etc.

8b. Identify life history and physiological requirements for propagation, growth, and maintenance, including effects of propagation and captive management on condition of broodstock and cultured progeny: Includes requirements necessary for reproductive conditioning of broodstock, growth, basal metabolism, optimal feeding regimes, appropriate water quality requirements for maintaining and optimizing growth in captivity, suitable host fish, suitable production of host fish for mussel propagation, effect of host fish on survival and condition of hatchery-reared mussels, etc.

9. Evaluate trophic interactions and ecological functions of fishes and mussels in the environment.

10. Identify the social and economic value of functioning aquatic ecosystems.

10a. Conduct audience analysis of habits, attitudes, behaviors, and uses for aquatic ecosystems.

10b. Quantify economic value of healthy streams to local, regional, and national economies.

10c. Quantify ecosystem goods and services provided by fishes and mussels to aquatic resources.

**E. Communication and Partnerships**

1. Develop a communication and outreach strategy.

1a. Identify target audiences.

1b. Develop communication message to target audiences.

1c. Engage communication specialist: To create and maintain a digital communication strategy (website, Facebook, graphic and text materials). Website will identify priority areas, research needs, where on-the-ground projects are taking place, areas where threats need to be addressed, and economic, social, and aesthetic values of healthy streams (aquatic ecosystems and individual resource components).

1d. Provide information and education: To public, potential partners, and target audiences (congressional, industry, private landowners). Develop outreach materials including hands-on activities with children that can be used at outreach events.

1e. Develop a Friends group: Establish a Friends group within UTRB that conducts targeted outreach and networking on behalf of the Strategy.

2. Work with partners (e.g., industry, non-governmental organizations, private landowners, agencies, AppLCC) to maintain and/or restore habitats or populations: Emphasize coordination with stakeholders (including within USFWS) to ensure actions are effectively implemented to assist in attaining goals and objectives of UTRB Conservation Strategy; USFWS should become stakeholder in other partnerships.

2a. Develop/implement CCAs and CCAs with Assurances for candidate or proposed species: As appropriate.

2b. Develop Safe Harbor Agreements for listed species: As appropriate.

2c. Develop voluntary agreements, easements, etc.: As appropriate.

2d. Leverage funding for joint projects.

2e. USFWS or partners provide funding for research, on-the-ground projects, etc.: Actions to fund will be determined and prioritized based on Strategy.

3. Work with industry to restore habitat: Restoration could involve addressing areas with existing pre-Surface Mining Control and Reclamation Act of 1977 coal mining impacts, silviculture, agriculture, commercial gravel dredging, wind farm infrastructure, urbanization, etc.

   3a. Identify priority restoration areas: Prioritize areas for potential restoration projects based on established criteria. See also D3c.

   3b. Promote restoration of priority areas: Ensure development of drought management plans, spill response plans, etc. is included as appropriate.

4. Facilitate external communication and cooperation: UTRB members participate in efforts of other partners and stakeholders, as appropriate, to further purposes of Strategy.

**F. Agency Operations**

1. Dedicate USFWS staff to Strategy: Create cross-program steering committee to oversee implementation and updating of Strategy.

Appendix 5. Status quo management action cost estimates (status quo means to continue management action with current USFWS management direction/policies/regulations in place over 20-year life of Strategy). Note that the cost estimates for management actions provided below are exactly that, an estimate of the cost for the USFWS to conduct that action each year given the current state of the knowledge. The purpose of the cost estimates was to compare/contrast approaches during development of the Strategy. Hence, specific project proposals were not developed to determine precise costs, nor or other factors such as monetary inflation taken into account.

| **Management Action** | **Management Action Narrative** | **Assumptions About Management Action** | **Deriving Status Quo Management Cost Estimates (cost that USFWS will pay annually to accomplish action over 20-year life of Conservation Strategy)** | **Status Quo Management Annual Cost Estimates** |
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| **A. Population Management:** ***in situ*** | | | | |
| A1a – Implement ESA Sections 7 and 10 regulations | To avoid and minimize impacts to imperiled species, their habitat, and critical habitat where designated, ensure USFWS listed species recovery leads and biologists are up-to-date on completed formal consultations and all recent species information. Ensure that USFWS and State agencies are consistent in species-specific considerations for type of collecting apparatus authorized and number of individuals to be collected. | Ensure that USFWS and state agencies are consistent in species-specific considerations for type of collecting apparatus authorized and number of individuals to be collected. No HCPs for aquatic UTRB species have been conducted/are being considered in VA or NC. 2 HCPs are in process in TN that consider aquatics. | 3.5 full-time equivalents (FTEs) (2 in VA, 1 in TN, 0.5 in NC) conducting Section 7 consultations in UTRB @ $125,000/FTE/yr = $437,500/yr. 0.1 FTE in TN working on HCPs in UTRB @ $125,000/FTE/yr = $12,500/yr. | 450,000.00 |
| A1b – Support agencies who enforce other regulations (Comprehensive Environmental Response, Compensation & Liability Act; Clean Water Act; National Pollutant Discharge Elimination System; Total Maximum Daily Load, etc.) | Ensure Federal and State agencies consider imperiled species management or recovery when issuing permits by participating in meetings, reviewing documents, providing comments, etc. related to imperiled species. | | 1 FTE each in VA, NC, and TN @ $125,000/FTE/yr = 3 FTEs x $125,000/FTE/yr = $375,000/yr. | 375,000.00 |
| A1c – Conduct status assessments of rare aquatic species for possible candidate status | | | VA has spent less than an average of few hundred dollars/yr at most. This is not the purpose of most survey work done in VA; also true in NC. 2011 Multi-District Litigation settlement may change this. In TN, Tennessee Wildlife Resources Agency (TWRA) is willing to spend most of their Section 6 funds on this over the next few years. Cost = $100,000/yr. | 100,000.00 |
| A1d – List candidate aquatic species | Complete administrative process to publish proposed rule to list species that have been determined to warrant ESA listing; complete administrative listing process for species on the candidate list according to candidate priority, funding, etc. | $500,000/listing package. | 2-mussel rule just finished was $500,000. Assume half of the 24 petitioned species in UTRB warrant listing over 20-yr life of Strategy. $500,000 x 12 species = $6,000,000/20 yrs = $300,000/yr (total for NC, TN, VA). | 300,000.00 |
| A1e1 – Protect candidate/proposed aquatic species | Develop/implement CCAs and CCAs with Assurances; establish conservation easements; during permit review include recommendations that consider state regulations to protect candidate and proposed aquatic species. | Estimated cost for a CCA = $150,000. | In VA, NC, and TN no CCAs recently. VA = 1% of an FTE/yr @ $125,000/FTE/yr = $1,250 for easements. NC = $1,250/yr for easements. TN = $4,000/yr for easements. Consideration of candidates in permit review @ 0.75 FTE/yr (0.25 in VA, 0.25 in TN, 0.25 in NC) x $125,000/FTE/yr = $93,750/yr. | 100,250.00 |

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| A1e2 – Protect listed aquatic species | Provide long-term management for areas considered essential for a species' continued existence and recovery by land or easement acquisition. | | Duplicates cost estimate in A1e1 and B3b. | 0.00 |
| A1e3 – Protect or establish refuge populations | | Refuge populations have not been identified to date or in a formal manner. | Not being done at present. | 0.00 |
| A2a – Develop BMPs for augmenting populations | Develop standard peer-reviewed protocols for augmenting/reintroducing populations that would extend to: 1) permitting, planning, and approval process and documentation; 2) implementing conservation genetic management that considers genetic information for source of individuals used for reintroduction and recovery, including when is/is not appropriate to conduct augmentation; how many wild individuals to use in propagation and stocking programs for augmenting populations; how many wild individuals to use in stocking; 3) evaluating and verifying source populations will support removal/harvest for stocking; 4) handling procedures for collecting individuals for hatchery-rearing or stocking in the wild; 5) implementing hatchery management that considers feeding regimes for growth, reproduction, and basal metabolism, and water quality maintenance regimes; 6) monitoring to include tagging (if recommended), record keeping, and reporting; 7) applying adaptive management, an analysis of results and a process for adapting management actions; and 8) preparing and implementing plans to ensure work conducted or caused by natural resource agencies is not causing the spread of aquatic nuisance/non-target species; there are standard BMPs that can be adopted and developed (e.g., consider only working in one stream system per day, cleaning gear between sites). | There is an existing document by American Fisheries Society about augmenting/reintroducing rare fishes. Don't know if a similar document has been published for mussels. | Accomplished via USFWS staff coordination through work with others. 0.25 FTE x 3 years (= 1,095 days) x $789 ($789 is USFWS Virginia Field Office [VAFO] bio day rate) = $215,989. Assuming this will need to be completed 1 time over 20-yr life of Strategy. $215,989/20 yrs = $10,799/yr. | 10,799.00 |
| A2b1 – Complete controlled propagation plans | Finalize a controlled propagation plan per USFWS guidelines (FR 56916–56922) and with stakeholder input prior to hatchery-rearing. | | Not being done at present. | 0.00 |
| A2b2 – Evaluate facilities | Develop list of facilities (Federal and State hatcheries, academia, zoos, aquaria, and private facilities) with capability to hatchery-rear fishes and mussels (e.g., expertise, infrastructure, water quality, food availability, fish health testing) and evaluate their qualifications. Summarize the techniques used and species reared by various facilities propagating fishes and mussels in the U.S. to determine which facilities can be used to hatchery-rear UTRB fishes and mussels and if additional facilities need to be developed. | | Cost is $35,000/5 yrs. Will do this 4 times over 20-yr life of Strategy. Cost = $35,000 x 4 = $140,000/20 yrs = $7,000/yr. | 7,000.00 |

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| A2b3 – Stock hatchery-reared fishes and mussels, release glochidia-encysted host fish (using fish native to the stream), or stock adult or sub-adult mussels from more robust populations into river reaches where extant populations exist | To increase population size and improve likelihood of survival of extant population. | Augmentation sites are known. Aquaculture technology exists to support mass production or consistent production. Infrastructure in place—building, utilities, equipment, expertise. Economy of scale achieved for multiple species, including maximizing field collection efforts for multiple species where possible. Much of the animal's life history and environmental requirements are known. | Cost at Freshwater Mollusk Conservation Center at Virginia Tech (FMCC) and Aquatic Wildlife Conservation Center (AWCC) for USFWS Natural Resources Damage Assessment and Restoration (NRDAR) averages ~$100,000/facility/yr. Cost at White Sulphur Springs National Fish Hatchery (WSSNFH) = $30,000/yr. Cost at Conservation Fisheries, Inc. (CFI) ~$50,000/yr (Section 6, flex funds, etc.) and cost at TWRA ~$37,500/yr (Section 6 State Wildlife Grant). CFI and TWRA total annual costs split between augmentation (here) and introduction A3b. NC Appalachian elktoe propagation technology ~$10,000/yr. Cost is ($100,000 x 2) + $30,000 + ($50,000 + $37,500/2) + $10,000 = $283,750/yr. | 283,750.00 |
| A2c – Increase population connectivity | Stock hatchery-reared fishes or mussels, release glochidia-encysted host fish (using fish native to the stream), or stock adult or sub-adult mussels from more robust populations into river reaches where extant populations exist and there are gaps in species distribution. | | Duplicates cost estimate in A2b. | 0.00 |
| A3a – Develop BMPs for establishing new populations | Develop standard peer-reviewed protocols for reintroducing/introducing populations that extend to: 1) permitting, planning, and approval process and documentation; 2) appropriate selection of areas where a new population would be established that includes consideration of the species' historical range; 3) implementing conservation genetic management that considers genetic information for source of individuals used for establishing new populations; how many wild individuals to use in propagation and stocking programs for reintroducing populations; how many wild individuals to use in stocking; 4) evaluating and verifying source populations will support removal/harvest for stocking; 5) handling procedures for collecting individuals for hatchery-rearing or stocking in the wild; 6) implementing hatchery management that considers feeding regimes for growth, reproduction, and basal metabolism, and water quality maintenance regimes; 7) monitoring to include tagging (if recommended), record keeping, and reporting; 8) applying adaptive management, an analysis of results and a process for adapting management actions; and 9) preparing and implementing plans to ensure work conducted or caused by natural resource agencies is not causing the spread of aquatic nuisance/non-target species; there are standard BMPs that can be adopted and developed (e.g., consider only working in one stream system per day, cleaning gear between sites). | | Accomplished via USFWS staff coordination through work with others. 0.25 FTE x 3 years (= 1,095 days) x $789 ($789 is VAFO bio day rate) = $215,989. Assuming this will need to be completed 1 time over 20-yr life of Strategy. Cost = $215,989/20 yrs = $10,799/yr. | 10,799.00 |

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| A3b – Reintroduce populations | Stock individuals (methods might include all listed in A2) into suitable historical habitat from which they have been extirpated, and where natural recolonization cannot reasonably be anticipated, to increase connectivity between populations, improve gene flow, and increase number of viable populations. | Aquaculture technology exists to support mass production or consistent production. Infrastructure in place—building, utilities, equipment, expertise. Economy of scale achieved for multiple species, including maximizing field collection efforts for multiple species where possible. Much of the animal's life history and environmental requirements are known. | Average cost estimate for fishes where protocols have been worked out in TN is $25,000/species/yr. In UTRB 5 fish species being propagated under status quo (this funding may not continue in future). 5 species x $25,000 = $125,000/yr for fishes. For easier species such as many of the *Epioblasma* and *Ptychobranchus* cost is ~$10,000/species/yr. For more difficult species such as *Dromus*, *Hemistena*, *Fusconaia*, cost would be at least $20,000/species/yr. In a given year if for example we worked on 5 species, though we could do more, and we focused on 3 easy and 2 difficult species, a minimum cost would be about $60,000/yr. These figures are based on current costs at FMCC. Annual cost is $125,000 + $60,000 = $185,000/yr. | 185,000.00 |
| | | Cost for locating reintroduction sites includes: travel, suitable habitat evaluation, analyses, seasonal FTEs. | Locating reintroduction sites in Clinch, Powell, North Fork Holston, and Blue Ridge for 3 field seasons will cost $200,000. This will need to be done once every 10 yrs. This is cost to contract with academia, would be more expensive if work was done directly by USFWS employees. Cost = ($200,000 x 2)/20 yrs = $20,000/yr. | 20,000.00 |
| | | Cost for conservation genetic management plan. | TN is doing this now. Estimate is $30,000 for 1 species source population and genetic analysis or reintroduction effort. | 30,000.00 |
| A3c – Designate non-essential experimental populations | Complete administrative process to propose non-essential experimental population designations, if this designation would facilitate species recovery efforts (e.g., establishing new populations) for species or groups of species that would otherwise be difficult to accomplish without this designation. Areas important for this action would be identified by criteria and prioritization scheme (see D3c and D7b). | Same cost as listing a species. $500,000/designation. | This cost is sometimes accounted for in listing package preparation. Sometimes non-essential experimental populations are designated after listing. Assuming 1 post-listing non-essential experimental population designated every 5 yrs. Cost = ($500,000/designation x 4 designations over 20-yr life of Strategy)/20 yrs = $100,000. | 100,000.00 |
| A3d – Introduce populations | Stock individuals into areas with suitable habitat within the species' historical range for which no documentation exists of their historical occurrences. | See A3b | Duplicates cost estimate in A3b. | 0.00 |
| **B. Habitat Management** | | | | |

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| B1 – Develop BMPs for managing instream and riparian habitat | Identify and produce a list of approved BMPs already in use, revise existing BMPs, or create new BMPs that would, if installed and maintained properly, ensure riparian and instream habitats are not adversely affected by land use activities or projects that could affect stream habitats (e.g., agriculture, silviculture, urban development, transportation, water withdrawal or outfall, hydro-fracking, culvert installation [fish passage concerns], oil and gas development). | Industry BMPs likely exist in most instances, but will need to be modified to be protective of riparian and instream habitats. Revising BMPs will require lengthy coordination with other agencies and industries. | Accomplished via USFWS staff coordination through work with other agencies and industry. 0.25 FTE x 3 years (= 1,095 days) x $789 ($789 is VAFO bio day rate) = $215,989. Assuming this will need to be completed 2 times over 20-yr life of Strategy, $215,989 x 2 = $431,978/20 yrs = $21,599/yr. | 21,599.00 |
| B2a – Support those who enforce other regulations (Comprehensive Environmental Response, Compensation & Liability Act; Clean Water Act; National Pollutant Discharge Elimination System; Total Maximum Daily Load, etc.) to ensure that habitat is protected | Ensure Federal and State agencies consider actions that may result in adverse effects to imperiled aquatic species habitat, both occupied and that with potential for use as reintroduction sites, when issuing permits by participating in meetings, reviewing documents, providing comments, etc. | | Duplicates cost estimate in A1b. | 0.00 |
| B2b – Minimize and avoid impacts to habitat | Ensure careful consideration of habitat and species-specific ecological requirements (e.g., habitat to ensure appropriate host fish populations) in conducting Section 7 consultations and permitting associated with HCPs. | | Duplicates cost estimate in A1a. | 0.00 |
| B2c – Minimize and avoid impacts to proposed or designated critical habitat | Consider whether a proposed project 'may affect, is likely to adversely affect' proposed or designated critical habitat during Section 7 consultation. | Many designated critical habitat reaches, some without species occurrences, which might trigger Section 7 consultation by Federal action agencies. | Duplicates cost estimate in A1a. | 0.00 |
| B3a – Acquire conservation easements | Use the USFWS Partners for Fish and Wildlife Program or other programs to improve or maintain buffers in areas affected by poor agricultural practices to maintain or improve water and habitat quality. | Natural Resources Conservation Service (NRCS) conservation easement costs vary. Statewide easement payments average ~$4,000/acre. NRCS easement costs do not include staff time or cost for recordation, survey, appraisal, and title insurance, which NRCS covers. NGOs estimated cost is $5,000/acre. NGOs may receive donated easements. Costs include recordation, survey, and appraisal for simple easement on 100-acre parcel. Easement costs are highly variable, depending on type of easement, size, appraisal, survey and attorney costs, and complexity, and are not feasible in some areas due to separation of mineral rights from surface rights. | In VA easements require 1% of an FTE/yr @ 125,000/FTE/yr = $1,250. In TN estimate same 1% as in VA. Assuming same cost in NC. Cost = 3% of an FTE/yr @ 125,000/FTE/yr = $3,750/yr. | 3,750.00 |
| B3b – Acquire land | Assist State agencies and NGOs in purchasing and protecting lands to protect occupied aquatic imperiled species habitat and habitat with potential for reintroduction. | | Duplicates cost estimate in A1a and A1b. | 0.00 |
| B4a – Improve instream | Implement site- or stream-specific activities to | Altering timing and type of releases from dams. | Duplicates cost estimate in A1a and A1b. | 0.00 |

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| habitat quality | provide natural flow and temperature conditions. Examples include altering timing and type of releases from dams, removing dams, restoring stream meanders (in previously channelized sections), and providing bio-stabilization for eroded stream banks. | Includes only dam removal. Does not include surveys, engineering design, permitting, consultation, utility relocation, monitoring, etc. | $100,000/yr in VA. $300,000/yr in NC (includes all cost noted in column B). Average annual TN cost $100,000, but could vary from $5,000 depending on who does work. Cost = $100,000/yr + $300,000/yr + $100,000/yr = $500,000/yr. | 500,000.00 |
| | | Instream restoration assumes rural setting, no utilities. Restoration and stabilization $50–200/lf instream restoration. | 100 lf @ $200/lf = $20,000/yr in VA. 100 lf @ $200/lf = $20,000/yr in NC. 100 lf @ $200/lf = $20,000/yr in TN. Cost = $20,000/yr x 3 = $60,000/yr. | 60,000.00 |
| | | BMPs Guide $10–50/lf bio stabilization. | 250 lf @ $50/lf = $12,500/yr in VA. 750 lf @ $100/lf = $75,000/yr in NC. 250 lf @ $50/lf = $12,500/yr in TN. Cost = ($12,500/yr x 2) + $75,000/yr = $100,000/yr. | 100,000.00 |
| B4b – Improve riparian habitat quality/increase riparian habitat quantity | Create or restore riparian habitats. Examples include reducing sediment runoff from land use activities and removing livestock from streams. | $2–3/lf buffer fencing. | 2,640 lf @ $3/lf = $7,920/yr in VA. 2,500 lf @ $5/lf = $12,500/yr in NC. 10–15 miles/yr = ~$200,000/yr in TN. Cost = $7,920/yr + $12,500/yr + $200,000/yr = $220,420/yr. | 220,420.00 |
| | | $950/ac buffer planting. | 5 ac @ $950/ac = $4,750/yr in VA. 3 ac @ $240/ac = $720/yr in NC. 5–10 acres/yr, but little cost ~$500/yr in TN. Cost = $4,750/yr + $720/yr + $500/yr = $5,970/yr. | 5,970.00 |
| | | USFWS contributes staff time in the form of tech assistance to NRCS to accomplish this. $3,000/ac critical (eroding) area planting. | 1 staff day @ $789/day = $789/yr in VA. 1 staff day @ $789/day = $789/yr in NC. 1 staff day @ $789/day = $789/yr in TN. $789 is VAFO FY12 bio day rate. Cost = 3 staff days x $789/day = $2.367/yr. | 2,367.00 |
| | | USFWS contributes staff time in the form of tech assistance to NRCS to accomplish this. $4,000 for hardened stream crossing. | 2 staff days @ $789/day = $1,578/yr in VA. 1 staff day @ $789/day = $789/yr in NC. $789 is VAFO FY12 bio day rate. Cost of crossings in TN = $5,500, and 10 crossings/yr = $55,000/yr. Cost = $1,578/yr + $789/yr + $55,000/yr = $55,367/yr. | 57,367.00 |
| B4c – Restore habitat connectivity | Acquire conservation easements and implement site- or stream-specific activities to provide natural flow and temperature conditions where habitat or physical barriers prevent genetic connectivity. Examples include removing dams, restoring stream meanders (in previously channelized sections), removing chemical barriers by removing point-source pollution, restoring habitats affected by nonpoint-source pollution by enforcing regulatory oversight for mining, agriculture, silviculture, and urban development. | Acquire conservation easements. | VA = 1% of an FTE/yr @ $125,000/FTE/yr = $1,250 for easements. NC = $1,250/yr for easements. TN = $4,000/yr for easements. Consideration of candidates in permit review @ 0.75 FTE/yr (0.25 in VA, 0.25 in TN, 0.25 in NC) x $125,000/FTE/yr = $93,750/yr. | 100,250.00 |
| | | Includes only dam removal. Does not include surveys, engineering design, permitting, consultation, utility relocation, monitoring, etc. | $100,000/yr in VA. $300,000/yr in NC (includes all cost noted in column B). Average annual TN cost $100,000, but could vary from $5,000 depending on who does work. Cost = $100,000/yr + $300,000/yr + $100,000/yr = $500,000/yr. | 500,000.00 |
| | | Restoring stream meanders. Instream restoration assumes rural setting and no utilities. Restoration and stabilization $50–200/lf instream restoration. | 100 lf @ $200/lf = $20,000/yr in VA. 100 lf @ $200/lf = $20,000/yr in NC. 100 lf @ $200/lf = $20,000/yr in TN. Cost = $20,000/yr x 3 = $60,000/yr. | 60,000.00 |
| | | Removing chemical barriers by removing point-source pollution. | Duplicates cost estimate in A1a and A1b. | 0.00 |

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| | | Restoring habitats that have been affected by nonpoint-source pollution by enforcing regulatory oversight for mining, agriculture, silviculture, urban development, etc. | Duplicates cost estimate in A1a and A1b. | 0.00 |
| **C. Population Management:** ***ex situ*** | | | | |
| C1a – Complete controlled propagation plans | Prior to establishing a captive population finalize a controlled propagation plan per USFWS guidelines (FR 56916–56922) and with stakeholder input. | | Not being done at present. Future cost: 1 FTE @ 5 days/plan. Can complete plans for all listed aquatic species in 3 yrs; 2 plans/yr, one plan for 3–5 fish species and one plan for 5–7 mussel species. Assuming this will need to be completed 1 time over 20-yr life of Strategy; 3 yrs x 10 days $789 ($789 is VAFO bio day rate) = $23,670/20 yrs = $1,184/yr. | 0.00 |
| C1b – Evaluate facilities | Develop list of facilities (Federal and State hatcheries, academia, zoos, aquaria, and private facilities) with capability to hatchery-rear fishes and mussels (e.g., expertise, infrastructure, water quality, food availability, fish health testing) and evaluate their qualifications. Summarize the techniques used and species reared by various facilities propagating fishes and mussels in the U.S. to determine which facilities can be used to hatchery-rear UTRB fishes and mussels and if additional facilities need to be developed. | | Duplicates cost estimate in A2b2. | 0.00 |
| C1c – Develop generic and species-specific BMPs/protocols for captive management | Develop BMPs for obtaining broodstock, transportation to suitable facility, captive holding, and breeding that consider the species genetic variation, life history, and feeding/nutritional requirements. Develop BMPs for breeding mussels in captivity that describe or recommend preferred culture system, diet, feeding regime, water quality, best host fish, and recommended ratio of males to females for spawning to maintain genetic variation. Develop BMPs for breeding fishes in captivity that describe or recommend preferred culture system, diet, feeding regime, water quality, and recommended number of mating pairs to maintain genetic variation. | | Not being done at present. Future cost: generic BMPs for endangered fishes mostly complete. BMP development for mussels will be done via USFWS staff coordination through work with others. 0.25 FTE x 3 years (= 1,095 days) x $789 ($789 is VAFO bio day rate) = $215,989. Assuming this will need to be completed 1 time over 20-yr life of Strategy, cost = $215,989/20 yrs = $10,799/yr. | 0.00 |
| C2a – Initiate/manage captive breeding and rearing | | Aquaculture technology exists to support consistent production of organisms. Infrastructure in place—building, utilities, equipment, expertise. NPDES permits and other permits exist. | Not being done at present. Future cost: $200,000 for captive management of 4-5 species. $30,000/yr per species to hold a fish in captivity. Assuming 10 species in captivity/yr, cost = $400,000 for 10 species = $400,000/20 yrs = $20,000/yr. | 0.00 |
| C2b – Develop imperiled aquatic species cooperative breeding programs among approved facilities | This will minimize loss of genetic diversity over time by pairing individuals using a mean kinship value. This will consider which facility has best success with a particular species. | Assumes genetic monitoring of hatchery-reared organisms. Genetic breeding plan developed based on apriori knowledge of wild populations. | Not being done at present. Future cost: ~10% of an FTE/yr @ $125,000/FTE/yr = $12,500/yr. | 0.00 |
| **D. Monitoring/Research** | | | | |

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| D1 – Conduct basic life history research in the wild (i.e., *in situ*) for imperiled fishes and mussels | Where there are species specific data gap, determine flow preferences, substrate, growth rates, habitat preferences, temperature preferences, etc. | | Potentially conduct work through academia. Combine a few representative species from major mussel taxa groups (anodontines, lampsilines, amblemines). May be compiling/synthesizing existing data. $40,000–$50,000/yr, take 4 yrs to complete. This work would need to be repeated 3–4 times over 20-yr life of Strategy. For the listed UTRB fish species this basic life history information has been obtained, so no further cost is associated with this task. Cost = ($50,000/yr x 4 yrs) x 4 repetitions = $800,000/20 yrs = $40,000/yr. | 40,000.00 |
| D2a – Identify species for which baseline surveys have/have not been completed, and for which regular population monitoring has/has not been conducted | | | Onetime cost of $20,000. $20,000/20 yrs = 1,000/yr. | 1,000.00 |
| D2b – Conduct baseline surveys and subsequent routine monitoring | For natural, augmented, and newly established imperiled fish and mussel populations to assess effectiveness of conservation and recovery efforts. | Cost will vary with range of species. | TN, NC, and VA estimate $50,000 each/yr in traditional Section 6 funds. Cost = $50,000/yr x 3 = $150,000/yr. | 150,000.00 |
| D3a – Assemble baseline habitat data | Collect existing baseline habitat data (e.g., historical stream flow, temperature data from gaging stations) to be maintained and updated at a single, accessible location (e.g., SharePoint, website). | 1 FTE for 2 years to facilitate development of SharePoint/website to accumulate existing data and establish process for others to add and update. After 2 years, 0.5 FTE for maintenance. | Not being done at present. | 0.00 |
| D3b – Develop habitat monitoring protocols | Identify parameters for monitoring imperiled fish and mussel habitat utilizing standardized, repeatable survey/sampling protocols, as needed. | Identification of habitat parameters can be accomplished via expert elicitation. | Accomplished via expert elicitation during a 1-day meeting, plus 1 additional day to prepare report of results. 5 FTEs x 2 days x $789 ($789 is VAFO bio day rate) = $7,890/20 yrs = $394.50/yr. | 395.00 |
| D3c – Identify hot spots/focus areas | Using available habitat data identify quality reaches/HUCs, those needing protection, and areas needing augmentation/reintroduction. | Hotspot focal areas, habitat monitoring of key sites, fish and mussel population monitoring of selected species, demographic data collection and parameter estimation, and PVA analysis of selected species could be combined into one project and conducted by a Ph.D. graduate student and technicians. | D3c, D3d, D6b, D6c can be conducted together by a Ph.D. graduate student and technicians for $140,000 over 4 yrs. This work would need to be conducted 3 times over 20-yr life of Strategy. Cost = $140,000 x 3 repetitions = $420,000/20 yrs = $21,000/yr. | 21,000.00 |
| D3d – Monitor habitat | Using monitoring protocols and identified hot spots/focus areas, conduct standardized, repeatable habitat surveys to identify trends in habitat suitability or to assess effectiveness of management or recovery efforts. | See D3c. | Duplicates cost estimate in D3c. | 0.00 |

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| D4a – Assess threats (basin-wide or locally) | Identify potential threats resulting from various land uses and other anthropogenic activities to habitat and water quality. | USFWS is currently doing this in a variety of venues (e.g., EPA's Clinch-Powell ERA, CPCRI, AppLCC, VA Ecological Services Strategic Plan, 5-year status reviews, candidate assessments). | ~8 FTEs in VA work in UTRB and 20% of that time they are assessing threats (8 FTEs x 0.2 = 1.6 FTEs). There are twice as many FTEs working in UTRB in TN compared to VA (1.6 FTEs x 2 = 3.2 FTEs). There are half as many FTEs working in UTRB in NC compared to VA (1.6 FTEs x 0.5 = 0.8 FTEs). Total is 5.6 FTEs (VA, TN, and NC) assessing threats @ $125,000/FTE/yr = $700,000/yr. | 700,000.00 |
| D4b – Assess species-specific and/or cross-species threats | Rank identified threats based on geographic scale of activity, magnitude of activity, imminence, impact to the animals (biological, physical, critical to various life stages, etc.), and pervasive nature of the threat (species-specific vs. cross-species). | This is done in listing packages. | This is done in listing packages and a separate cost is not needed here. | 0.00 |
| D4c – Conduct contaminants assessments | Based on threat assessment and identification of potential contaminants, conduct laboratory tests on various life stages of fishes and mussels to determine potential toxicity from constituents for which data on sensitive fishes and mussels are not available. | Being done now in Clinch-Powell. | Based on 3-yr project funded by USFWS in Clinch River that is underway. Cost of this 3-yr project is $300,000. Assuming that USFWS will continue to fund similar assessments over 20-yr life of Strategy. Cost = $300,000/3 yrs = $100,000/yr. | 100,000.00 |
| D4d – Identify threat response needs (e.g., spill response) | Using data from threats analyses and contaminants assessments, identify areas where fish or mussel populations are likely to receive contamination from spills; prioritize need for spill plans that identify mechanisms of responding to toxic spill or other potential acute threat. | | Not being done at present. | 0.00 |
| D5a – Monitor genetic diversity of extant populations | Regularly collect appropriate genetic data to identify trends in natural, augmented, and new populations. Use non-invasive survey techniques to document presence or absence of fish and mussel populations by stream reach (or geographically appropriate scope). Use non-invasive techniques to obtain tissue for testing (i.e., clips of fish fins, swabs or small clips of mussel tissue), use Polymerase Chain Reaction techniques, microsatellites markers, or other more advanced or less invasive techniques as they become available (e.g., eDNA) to determine the average allelic richness, observed heterozygosity, and amount of genetic differentiation between listed species populations, compare with related taxa, compare with expected heterozygosity levels, and determine effective population sizes. | | $30,000 for one species source population and genetic analysis of reintroduction effort. Recommend per DNA sample (individual) that 1 mitochondrial DNA (mtDNA) gene and 10 nuclear DNA microsatellites per survey. Perhaps just materials and sequencing costs, no labor, overhead? That's 2,000 samples per year, quite a lot of work if doing mtDNA and nuclear DNA. | 30,000.00 |

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| D5b – Quantify level of genetic diversity in augmented and newly established populations | | | $30,000 for one species source population and genetic analysis of reintroduction effort. Recommend per DNA sample (individual) that 1 mtDNA gene and 10 nuclear DNA microsatellites per surveyed. Perhaps just materials and sequencing costs, no labor, overhead? That's 2,000 samples per year, quite a lot of work if doing mtDNA and nuclear DNA. | 30,000.00 |
| D5c – Monitor genetic diversity of captive populations | | | Not being done at present. | 0.00 |
| D6a – Determine species needing and eligible for PVAs | Identify species for which PVAs have/have not been completed. Prioritize species for PVA analyses using perceived risk of extinction and availability of biological and environmental parameters. | Accomplished via expert elicitation. | Accomplished via expert elicitation during a 1-day meeting, plus 1 additional day to prepare report of results. This meeting would need to occur every 3 yrs, which is 6 times over 20-yr life of Strategy. Cost = 5 FTEs x 2 days x $789 ($789 is VAFO bio day rate) x 6 repetitions = $47,340/20 yrs = $2,367/yr. | 2,367.00 |
| D6b – Conduct needed demographic research | According to prioritization (D6a), obtain species-specific demographic data needed to conduct PVAs. | See D3c. | Duplicates cost estimate in D3c. | 0.00 |
| D6c – Conduct species-specific PVAs | Conduct analyses according to prioritization. | See D3c. | Duplicates cost estimate in D3c. | 0.00 |
| D7a – Evaluate quality of occupied habitat | Establish criteria for ranking quality of habitats with known populations of imperiled fishes and mussels that include consideration of species' genetic information, life history requirements, threats, development of management plans, monitoring, reporting, adaptive management, etc. | Accomplished via expert elicitation. | Accomplished via expert elicitation during 40 hours via meetings and/or emails. 5 FTEs x 5 days x $789 ($789 is VAFO bio day rate) = $19,725. Will do this one time over 20-yr life of Strategy. Cost = $19,725/20 yrs = $986.25/yr. | 986.00 |
| D7b – Identify and evaluate potential reintroduction sites | Use criteria from D7a to identify existing populations where reintroduction would allow for geographic expansion (or increase viability) or to identify unoccupied stream reaches within a species' geographic range where habitat appears appropriate for reintroduction. | Accomplished via expert elicitation. | Accomplished via expert elicitation during 2-day meeting and/or emails. Will do this one time over 20-yr life of Strategy. Cost = 5 FTEs x 2 days x $789 ($789 is VAFO bio day rate) = $7,890/20 yrs = $394.50/yr. | 395.00 |
| D7c – Identify and evaluate prospective refuge populations | Rate existing populations and identify viable populations that may provide important genetic source for future augmentation or reintroduction, which may be an important part of a metapopulation and may be more easily protected. | Accomplished via expert elicitation. | Accomplished via expert elicitation during 2-day meeting and/or emails. Will do this one time over 20-yr life of Strategy. 5 FTEs x 2 days x $789 ($789 is VAFO bio day rate) = $7,890/20 yrs = $394.50/yr. | 395.00 |
| D8a – Prioritize species (fishes and mussels) for which propagation techniques have not been developed | Prioritization could include rarity and probability of extinction, availability of taxonomic information to identify what species could be used as surrogates for propagation trials, availability of individuals of the identified surrogate species for propagation trials, availability of suitable habitat for creation of new populations (see several actions identified above), or existing populations with an identified management need including augmentation, etc. | | Accomplish this action at the same meeting as D6a, so no additional cost. | 0.00 |

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| D8b – Identify life history and physiological requirements for propagation, growth, and maintenance, including effects of propagation and captive management on condition of broodstock and cultured progeny | Includes requirements necessary for reproductive conditioning of broodstock, growth, basal metabolism, optimal feeding regimes, appropriate water quality requirements for maintaining and optimizing growth in captivity, suitable host fish, suitable production of host fish for mussel propagation, effect of host fish on survival and condition of hatchery-reared mussels, etc. | Combine with D8a. Includes optimal temperatures for holding, feeding requirements, dietary requirements, optimal water quality, etc. | A graduate student could evaluate 4 representative species which includes GRA stipend, materials, supplies, travel, fringe, overhead, etc. May take 3 yrs to complete. ~$50,000/species/3 yrs. Total cost is $200,000/3 yrs. Would be less costly for future, additional species. Would not need to be done for every species. $20,000/yr is estimate over 20-yr life of Strategy. | 20,000.00 |
| D9 – Evaluate trophic interactions and ecological functions of fishes and mussels in the environment | | | $35,000/yr for PhD student for 4 yrs. Will do this 1 time over 20-yr life of Strategy. Cost = $35,000 x 4 yrs = $140,000/20 yrs = $7,000/yr. | 7,000.00 |
| D10a – Conduct audience analysis of habits, attitudes, behaviors, and uses for aquatic ecosystems | | These analyses would also feed the communication strategy. | $80,000 for 2 yrs to review literature, create survey, poll people, etc. Will do this 2 times over 20-yr life of Strategy. Cost = $80,000 x 2 repetitions = $160,000/20 yrs = $8000/yr. | 8,000.00 |
| D10b – Quantify economic value of healthy streams to local, regional, and national economies | | | $55,000 for 2 yrs to hire an economist working part-time. Will do this 2 times over 20-yr life of Strategy. Cost = $55,000 x 2 repetitions = $110,000/20 yrs = $5,500/yr. | 5,500.00 |
| D10c – Quantify ecosystem goods and services provided by fishes and mussels to aquatic resources | | | $150,000 for 4 yrs to hire a PhD student. Will do this 1 time over 20-yr life of Strategy. Cost = $150,000/20 yrs = $7,500/yr. | 7,500.00 |
| **E. Communication and Partnerships** | | | | |
| E1a – Identify target audiences | | Accomplished in D10a. | Not being done at present. | 0.00 |
| E1b – Develop communication message to target audiences | | Develop the message through peer/audience survey. Assuming audience analyses is completed, $5,000 is annual cost of communication specialist time to work with USFWS on messaging. | Not being done at present. | 0.00 |
| E1c – Engage communication specialist | To create and maintain a digital communication strategy (website, Facebook, graphic and text materials). Website will identify priority areas, research needs, where on-the-ground projects are taking place, areas where threats need to be addressed, and economic, social, and aesthetic values of healthy streams (aquatic ecosystems and individual resource components). | At least $35,000 for a one-third time dedicated communication specialist plus $50,000 to design and develop website, and other original print materials. | Not being done at present. | 0.00 |
| E1d – Provide information and education | To public, potential partners, and target audiences (congressional, industry, private landowners). Develop outreach materials including hands-on activities with children that can be used at outreach events. | Brochures, print material, web and digital material, presentations, etc. that would be needed to reach the various audiences. | $25,000/yr for printing brochures, updating and maintaining web page development, etc., and communication and outreach materials. | 25,000.00 |
| | | Includes hands-on activities for kids. | $10,000/yr for USFWS staff to attend festivals, provide outreach, etc. | 10,000.00 |
| E1e – Develop a Friends group | Establish a Friends group within UTRB that conducts targeted outreach and networking on behalf of the Strategy. | Group of organized partners that advocate for the mission and goals of the Strategy. | Not being done at present. | 0.00 |

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| E2a – Develop/implement CCAs and CCAs with Assurances for candidate or proposed species | As appropriate. | Estimated cost for a CCA = $150,000. | Duplicates cost estimate in A1e1. | 0.00 |
| E2b – Develop Safe Harbor Agreements for listed species | As appropriate. | | In VA have not completed an SHA for fishes or mussels. | 0.00 |
| E2c – Develop voluntary agreements, easements, etc. | As appropriate. | | Duplicates cost estimate in A1e1, A1e2, B3a, and B3b. | 0.00 |
| E2d – Leverage funding for joint projects | | USFWS staff doing grant writing for Flex funds, NRCS working lands, Abandoned Mine Lands projects, etc. | VA grant writing and fund seeking, 1 FTE x 10 days/yr x $789 ($789 is VAFO bio day rate) = $7,890/yr. TN grant writing and fund seeking, 1 FTE x 20 days/yr x $789 = $15,780/yr. NC grant writing and fund seeking, 1 FTE x 5 days/yr x $789 = $3,945/yr. WSSNFH grant writing and fund seeking, 1 FTE x 10 days/yr x $789 = $7,890/yr. Cost = $7,890/yr + $15,780/yr + $3,945/yr + $7,890/yr = $35,505/yr. | 35,505.00 |
| E2e – USFWS or partners provide funding for research, on-the-ground projects, etc. | Actions to fund will be determined and prioritized based on Strategy. | Assume action would focus on industry input to research related to impacts of their activities to water quality/habitat. TNC-VA may already have list of needs and costs for this action. USFWS input would be annual funding. | Not being done at present. | 0.00 |
| E3a – Identify priority restoration areas | Prioritize areas for potential restoration projects based on established criteria. See also D3c. | Expand TNC's work on Cumberland mollusk project to entire UTRB ($10,000), 0.5 FTE to coordinate input from staff with expertise (estimated 10 USFWS staff @ 10% time each for 2 yrs) to produce list of prioritized UTRB areas for restoring fishes and mussels. | Not being done at present. | 0.00 |
| E3b – Promote restoration of priority areas | Ensure development of drought management plans, spill response plans, etc. is included as appropriate. | Using E3a identification of priority areas, FTEs would work with external partners (industry and others—coal, silviculture, agriculture, urbanization—that affect habitat and water quality) to gain on-the-ground restoration. | Not being done at present. | 0.00 |
| E4 – Facilitate external communication and cooperation | UTRB members participate in efforts of other partners and stakeholders, as appropriate, to further purposes of Strategy. | Could range 0.1 FTE/State/yr up to 0.5 or more FTE/State/yr, depending upon which approach is selected; whether focus is habitat or focus is species. | Not being done at present. | 0.00 |
| **F. Agency Operations** | | | | |
| F1 – Dedicate USFWS staff to Strategy | Create cross-program steering committee to oversee implementation and updating of Strategy. | Effectively 0.25 FTE/yr dedicated to coordinating efforts among all USFWS divisions and with partners including communication with EA. | 1 individual will be point of contact which will be 0.2 FTE/yr @ $125,000/FTE/yr. Remainder of group's time will total 0.25 FTE/yr @ $125,000/FTE/yr. Cost = (0.2 FTE/yr x $125,000/FTE/yr) + (0.25 FTE/yr @ $125,000/FTE/yr) = $56,250/yr. | 56,250.00 |
| | | | **TOTAL** | **4,855,614.00** |

Appendix 6. Calculations related to Table 4 and Appendices 4 and 5.

| Task Number[1] | Relative Level of Effort | | | Cost ($) | | |
|---|---|---|---|---|---|---|
| | Status Quo Management | Habitat Management Emphasis | Population Management Emphasis | Status Quo Management[3] | Habitat Management Emphasis[4] | Population Management Emphasis[5] |
| 1 | 0.7 | 0.7 | 0.8 | 825,000.00 | 825,000.00 | 942,857.14 |
| 2 | 0.5 | 0.5 | 0.9 | 100,250.00 | 100,250.00 | 180,450.00 |
| 3 | 0.3 | 0.3 | 0.3 | 400,000.00 | 400,000.00 | 400,000.00 |
| 4 | 0.7 | 0.6 | 0.9 | 301,549.00 | 258,470.57 | 387,705.86 |
| 5 | 0.5 | 0.2 | 0.9 | 345,799.00 | 138,319.60 | 622,438.20 |
| 6 | 0 | 0 | 0.5 | 0 | 0 | 44,483.00[2] |
| 7 | 0.6 | 0.8 | 0.7 | 21,599.00 | 28,798.67 | 25,198.83 |
| 8 | 0.2 | 0.3 | 0.1 | 3,750.00 | 5,625.00 | 1,875.00 |
| 9 | 0.3 | 0.4 | 0.1 | 1,606,374.00 | 2,141,832.00 | 535,458.00 |
| 10 | 0.4 | 0.6 | 0.6 | 40,000.00 | 60,000.00 | 60,000.00 |
| 11 | 0.5 | 0.5 | 0.5 | 172,395.00 | 172,395.00 | 172,395.00 |
| 12 | 0.6 | 0.7 | 0.7 | 800,000.00 | 933,333.33 | 933,333.33 |
| 13 | 0.3 | 0.2 | 0.5 | 60,000.00 | 40,000.00 | 100,000.00 |
| 14 | 0.2 | 0 | 0.7 | 2,367.00 | 0 | 8,284.50 |
| 15 | 0.1 | 0.1 | 0.8 | 1,776.00 | 1,776.00 | 14,208.00 |
| 16 | 0.1 | 0.1 | 0.4 | 20,000.00 | 20,000.00 | 80,000.00 |
| 17 | 0.1 | 0.3 | 0.2 | 28,000.00 | 84,000.00 | 56,000.00 |
| 18 | 0.3 | 0.8 | 0.5 | 35,000.00 | 93,333.33 | 58,333.33 |
| 19 | 0.5 | 0.9 | 0.7 | 35,505.00 | 63,909.00 | 49,707.00 |
| 20 | 0.5 | 0.5 | 0.5 | 56,250.00 | 56,250.00 | 56,250.00 |
| Total Cost (extrapolated from Table 4 and Appendix 5) | | | | 4,855,614.00 | 5,423,292.50 | 4,728,977.20 |

[1]Corresponds to individual rows from Table 4 "Task" column.
[2]Relative effort for status quo was 0 and cost was $0. Used sum of cost per year reported for C1a thru C2b in column labeled "Deriving Status Quo Management Cost…" of Appendix 5 to derive this cost. More or less effort than status quo results in increased or decreased cost, respectively, except when no effort for an action under status quo results in no cost.
[3]Status Quo Management Cost = sum of Appendix 5 costs for all actions listed in parentheses by a given task in Table 4, which is represented below as "SQ$."
[4]Habitat Management Emphasis Cost = [(SQ$) x (Relative level of effort for the given task under Habitat Management Emphasis)]/Relative level of effort for the task under Status Quo Management.
[5]Population Management Emphasis Cost = [(SQ$) x (Relative level of effort for the given task under Population Management Emphasis)]/Relative level of effort for the task under Status Quo Management.

Appendix 7. Sensitivity analysis to examine how the optimal approach would change in response to importance placed on the (1) viability objective relative to the cost objective and (2) abundance and distribution subobjectives relative to the genetic diversity and habitat quality subobjectives. Final scores are shown for each alternative management approach, given relative-importance scenarios. The alternative management approach with the highest final score for each scenario is indicated as the optimal approach.

| **Percent of weight placed on viability objective relative to cost objective** | **Percent of weight placed on population abundance and distribution relative to genetic diversity and habitat quality** | **Approaches** | | | |
|---|---|---|---|---|---|
| | | **Status Quo Management** | **Habitat Management Emphasis** | **Population Management Emphasis** | **Optimal Approach** |
| 30 | 20 | 0.66 | 0.12 | 0.53 | Status Quo |
| 30 | 30 | 0.66 | 0.11 | 0.55 | Status Quo |
| 30 | 40 | 0.66 | 0.10 | 0.56 | Status Quo |
| 30 | 50 | 0.66 | 0.09 | 0.58 | Status Quo |
| 30 | 60 | 0.66 | 0.07 | 0.59 | Status Quo |
| 30 | 70 | 0.66 | 0.06 | 0.61 | Status Quo |
| 30 | 80 | 0.66 | 0.05 | 0.62 | Status Quo |
| 40 | 20 | 0.57 | 0.17 | 0.54 | Status Quo |
| 40 | 30 | 0.57 | 0.15 | 0.56 | Status Quo |
| 40 | 40 | 0.57 | 0.13 | 0.58 | Population Emphasis |
| 40 | 50 | 0.57 | 0.11 | 0.60 | Population Emphasis |
| 40 | 60 | 0.57 | 0.10 | 0.62 | Population Emphasis |
| 40 | 70 | 0.57 | 0.08 | 0.64 | Population Emphasis |
| 40 | 80 | 0.57 | 0.06 | 0.66 | Population Emphasis |
| 50 | 20 | 0.48 | 0.21 | 0.55 | Population Emphasis |
| 50 | 30 | 0.48 | 0.19 | 0.58 | Population Emphasis |
| 50 | 40 | 0.48 | 0.16 | 0.60 | Population Emphasis |
| 50 | 50 | 0.48 | 0.14 | 0.63 | Population Emphasis |
| 50 | 60 | 0.48 | 0.12 | 0.65 | Population Emphasis |
| 50 | 70 | 0.48 | 0.10 | 0.68 | Population Emphasis |
| 50 | 80 | 0.48 | 0.08 | 0.70 | Population Emphasis |
| 60 | 20 | 0.39 | 0.25 | 0.56 | Population Emphasis |
| 60 | 30 | 0.39 | 0.22 | 0.59 | Population Emphasis |
| 60 | 40 | 0.39 | 0.20 | 0.62 | Population Emphasis |
| 60 | 50 | 0.39 | 0.17 | 0.65 | Population Emphasis |
| 60 | 60 | 0.39 | 0.14 | 0.68 | Population Emphasis |
| 60 | 70 | 0.39 | 0.12 | 0.71 | Population Emphasis |
| 60 | 80 | 0.39 | 0.09 | 0.74 | Population Emphasis |
| 70 | 20 | 0.30 | 0.29 | 0.57 | Population Emphasis |
| 70 | 30 | 0.30 | 0.26 | 0.61 | Population Emphasis |
| 70 | 40 | 0.30 | 0.23 | 0.64 | Population Emphasis |
| 70 | 50 | 0.30 | 0.20 | 0.68 | Population Emphasis |
| 70 | 60 | 0.30 | 0.17 | 0.71 | Population Emphasis |
| 70 | 70 | 0.30 | 0.14 | 0.75 | Population Emphasis |
| 70 | 80 | 0.30 | 0.11 | 0.78 | Population Emphasis |