The Southeastern Aquatic Biodiversity Conservation Strategy

river basin CENTER

UNIVERSITY OF GEORGIA 1785

TENNESSEE AQUARIUM Conservation Institute

The Southeastern Aquatic Biodiversity Conservation Strategy

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Cover Photo Credits:
Top: A wavy-rayed lampmussel, *Lampsillis fasciola*, nestled in the substrate uses its lure to bring fish close. Clinch River. Jeffrey Basinger, Freshwaters Illustrated.
Middle: A whitetail shiner, *Cyprinella galactura*, swims in the Hiwassee river. Jeffrey Basinger, Freshwaters Illustrated.
Bottom: Crayfish in the Conasauga River. Jeremy Monroe, Freshwaters Illustrated.

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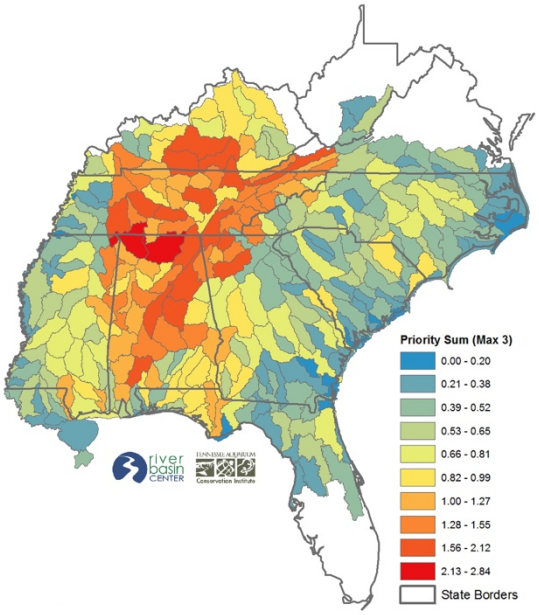
EXECUTIVE SUMMARY

The Southeastern United States is a global hotspot of freshwater biodiversity, supporting almost two-thirds of the country's fish species, over 90% of the US total species of mussels and nearly half of the global total for crayfish species. More than a quarter of this region's species are found nowhere else in the world. Unfortunately, this region is also a hotspot for imperilment. The number of imperiled freshwater fish species in the Southeast has risen 125% in the past 20 years, in part because recent intensive human development of this region is coupled with a low priority for conservation. Scientific research has extensively documented the causes of species imperilment, yet efforts to reverse these trends have been hampered by limited funding and lack of public awareness. Relative to other areas of the United States, the Southeast has little land in national parks or other forms of protected areas and receives a disproportionately small percentage of federal expenditures for endangered species protection; in the case of listed fishes in budget years 2012-2014, Southeastern endemics received approximately 1%, per species, of the amount spent on fishes found elsewhere in the country.

This report summarizes an effort to prioritize watersheds within this region to support future conservation investments. We first describe the data sources and methods used to assemble a dataset of almost 1,050 species of fishes, mussels, and stream-associated crayfishes and the locations where they are found, the first entirely data-driven attempt to map these three taxa on a consistent footing across this broad geography. We aggregated these collection points into 290 watersheds, then calculated species richness, imperilment, and endemism scores for each. Working with an advisory team of fourteen respected federal, state, and university biologists, we combined these scores to derive a single overall prioritization for watersheds in the Southeast. While State Wildlife Action Plans (SWAPs) that incorporate detailed surveys of population status and trajectory must continue to guide conservation decisions within individual states, our regional analysis indicates that the highest priority areas are in the Alabama River basin, particularly the Coosa system, and the Tennessee River basin, particularly the Middle-Tennessee.



From this list of prioritized areas, we selected ten for further analysis of threats to biodiversity and developed management recommendations to address each. These analyses rely on information drawn from SWAPs supplemented by finer scale watershed or species-specific plans, where available. Our goal was not to identify a definitive set of conservation priorities for the region. Instead, we propose these ten as a tractable set of locations where conservation

investments are likely to have a good return. We have also excerpted state- and basin-level prioritizations, for potential use in smaller scale planning, and an analysis highlighting areas with high numbers of vulnerable species where pilot conservation projects might effect rapid recoveries.

As an adjunct to the analysis of biodiversity, threats, and management actions, we investigated the capacity of the conservation community across the Southeast using a database of watershed groups assembled by the EPA. Although this analysis was inconclusive due to limitations in the dataset, the groups that did respond to our inquiries appear to be robust and actively engaged in conservation projects across the Southeast.

Finally, we assessed what level of investment might be required to achieve meaningful and long-term conservation objectives at the scale of the regional analysis. A useful comparison to get a comprehensive snapshot of is Raccoon Creek in the Etowah River basin of Georgia. Based on a decade of actions by several groups, we conducted a preliminary assessment of the funding that would be sufficient for a comprehensive suite of successful conservation actions (with a heavy focus on acquisition) resulting in good probability of the long-term health of the entire 35,100-acre watershed. This is an important benchmark, but it also important to know that targeted projects that address key threats and opportunities may have disproportionate benefits for a much smaller price tag. While the funding needs are high, there are numerous locations where conservation activities on the ground can still make a meaningful difference to conserve and enhance this globally important resource.

INTRODUCTION

Freshwater ecosystems are in peril across the globe. Almost 6% of the world's described species live in fresh water, despite the fact that these habitats occupy only 0.8% of the Earth's surface and freshwater itself is only 0.01% of the earth's water (Dudgeon et al. 2006). Declines in biodiversity are far greater in fresh waters than in the most terrestrial ecosystems because humans live disproportionately near waterways and extensively modify riparian zones. Even in sparsely populated areas, freshwater ecosystems may be negatively affected by the runoff and refuse of human activity (Sala et al. 2000) or by alterations of hydrology via dams or water diversions (Lehner et al 2011). Almost one-third of known crayfish species are imperiled worldwide (Richman et al. 2015), along with one-third of fish species and nearly three-quarters of mussel species (Williams et al. 1989; Williams et al. 1993; Warren and Burr 1994). In the United States approximately 39% freshwater fish species are at risk of extinction (Jelks et al. 2008) and Burkhead (2012) estimates that the extinction rate for U.S. fishes from 1900-2010 was almost nine hundred times higher than the background extinction rate in preceding millennia. However, these dire figures may be underestimates, as a significant portion of freshwater biodiversity remains uncatalogued or undescribed—so we may be losing species we do not even know exist (Burkhead and Jelks 2000).

From the cold, clear mountain streams of the Appalachian Mountains to the bayous of the Eastern Gulf Coastal Plain, and from the pocosins of North Carolina to the cave complexes of Kentucky, the lakes, rivers, and streams of the southeastern United States are the most diverse on the North American Continent and arguably the most biologically rich in the temperate world. The region is geologically and topographically diverse, with streams that drain toward the Atlantic, the Gulf of Mexico, and the Mississippi River. This diversity of habitats, which were spared the most recent glaciation, has provided the locus for sustained evolutionary diversification (Bulkhead and Jelks, 2000). Global assessments of aquatic biodiversity (Abell et al. 2000, Collen et al. 2014) have repeatedly found that streams and rivers in the southeastern United States contain levels of diversity and endemism that rival the tropics. Approximately half the world's crayfish species are found in the Southeast (Taylor et al. 2007), as are almost 40% of the world's freshwater mussel species (91% of mussel species in the US are southeastern; Graf and Cummings 2007, Neves et al. 1997). The southeastern landscape has also been extensively altered by human activities, and these modifications have taken a toll on aquatic species (Benz and Collins 1997). The rate of imperilment may be increasing; the most recent assessment by Warren et al. (2000) assigned an imperiled status to 28% of southeastern fishes and noted that this "represents a 75% increase in jeopardized southern fishes since 1989 and a 125% increase in 20 years."

Lack of funding for southeastern aquatic animals and habitats

Although the southeastern United States has the greatest aquatic biodiversity on the continent and in the temperate world, others areas of the country receive far more funds for freshwater aquatic conservation. Federal and state expenditures on federally listed aquatic species in the United States over three fiscal years (USFWS 2012, 2013, 2014) shows lower spending on freshwater aquatic species found solely within the area of this project (290 HUC-8 sub-basins, see *Defining the Project Area*, below) versus those found solely outside of our area. For

example, the vast majority of federally listed freshwater mussels are restricted to the Southeast (50-60 species or 83.3-85.3%) but only receive 61.7-71.5% of funding allocated. Species found solely outside of the Southeast receive 2.3-3.4 times more funding per species. Few freshwater crustaceans (crayfishes included) were federally threatened or endangered in 2012-2014, but a significant percent are present in the Southeast (19.0-21.1, 4 species) yet only receive 2.1-5.0% of funding; species outside of this area receive 4.4-12.5 times the funding per species. Finally, our study area has 35-36 listed species of freshwater fishes (28.8-29.2%) but only receives 0.8-1.1% of funding. Species outside of the Southeast receive an astonishing 35.3-52.0 times more funding per species. This disparity will continue to grow, as many of the 404 southeastern aquatic species that have been for listing (CBD 2010, USFWS 2011) are ultimately expected to receive federal protection.

History of Aquatic Conservation Planning and Protection in the Southeast

The need for aquatic conservation in the Southeast has not gone unremarked. In their "Global 200" list of outstanding and representative ecoregions, Olson and Dinerstein (1998) listed Mississippi Piedmont rivers and streams and Southeastern rivers and streams as two of the 18 entries in their category for small rivers and streams. Twelve years later, A World Wildlife Fund report identified 145 sites as priorities for North American freshwater conservation (including Canada and Mexico), of which almost one-third (45) were in the Southeast (Abell et al. 2000). In 2002, The Nature Conservancy produced an extensive assessment of priority areas for conservation in the Southeast (Smith et al. 2002). The analysis and prioritization presented in this report owe a significant debt to these efforts.

The existing network of conservation lands is clearly insufficient to preserve the aquatic biodiversity of the Southeast. On the national scale, most protected lands are in the intermountain West (Figure 1), while priority areas for biodiversity conservation are in the Southeast, California and Texas (Jenkins et al. 2015). Protected areas such as the National Parks system provide a foundation, but only support 18% of imperiled fishes nationwide (Lawrence et al. 2011). Of lands in public or private conservation within our project area, just under 3.5% has permanent protection free of extractive uses, with or without disturbance management (GAP program status codes 1 and 2). There is comparatively little federal land in the Southeast—also about 3.5% of the study area—although there are scattered large tracts such as Great Smoky Mountains National Park, the Okeefenokee Swamp, and several state and national forests in coastal Florida. Many of these conservation lands belong to the National Parks System, but only about 43% of southeastern fish species are represented within this system, and sometimes only in small numbers (Long et al. 2012). Protected lands also do not encompass the full range of habitats within watersheds in the Southeast (e.g., Thieme et al. 2016), as they are disproportionately at high elevations with limited aquatic biodiversity (Warren et al. 2000).

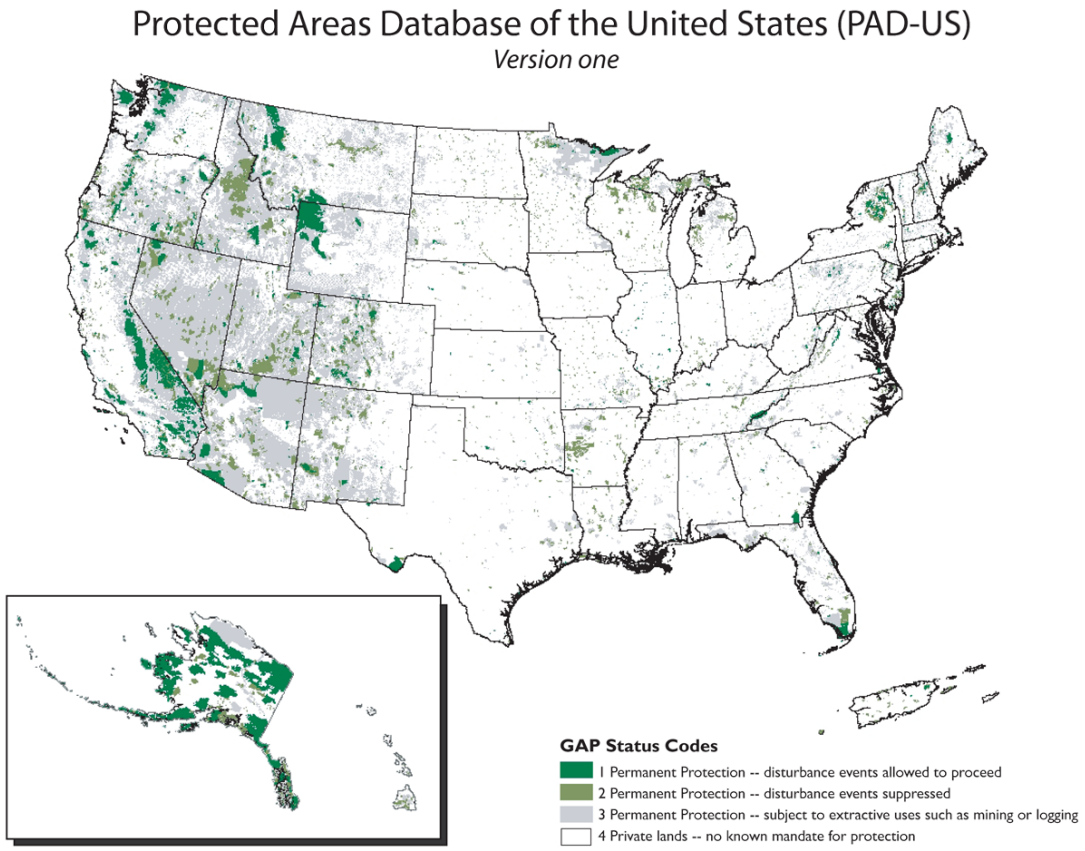


Figure 1. Protected Areas of the US. Source: USGS (http://gapanalysis.usgs.gov/)

If public lands are more foundation than solution for conservation in the Southeast, what other opportunities are present? A number of avenues exist to effect meaningful conservation projects on private lands, including the Partners for Fish and Wildlife Program at the US Fish and Wildlife Service, which provides expert technical assistance and cost-share incentives directly to private landowners to restore fish and wildlife habitats. Partners projects require that landowners sign a voluntary cooperative agreement with a duration of at least ten years. This program traces its authority back to the Fish and Wildlife Act of 1956 and was formally established by the Partners for Fish and Wildlife Act, passed in 2006, in which Congress recognized that "it is imperative to facilitate private landowner-centered and results-oriented efforts that promote efficient and innovative ways to protect and enhance natural resources." The Partners program has expanded from prairie wetlands protection after droughts in the 1980s to include planted grass buffers around the wetlands, upland habitat work, stream restoration, fish habitat and endangered species habitat restoration.

It is important to note that primary responsibility for wildlife management before a federal listing is the purview of the 50 states. State fish and wildlife agencies have been particularly successful at projects for conserving game species, typically with funds from hunting and fishing license fees and federal excise taxes. The conservation of the far more numerous non-game species has, since 2000, been funded substantially through the State and Tribal Wildlife Grants

program, commonly called “State Wildlife Grants” or “SWGs,” through which federal dollars support cost-effective conservation aimed at preventing wildlife from becoming threatened or endangered.

A wide variety of non-governmental organizations also takes responsibility for conservation on private lands. These organizations vary in scope and sophistication, from large, science-driven national non-profits such as The Nature Conservancy to local “adopt-a-stream” groups focused on clean-ups and monitoring of a few miles of river in a single watershed. In some river basins, there may be many local NGO groups working alongside one another; in other basins, there may be none at all. In a later section of this report, we report on the results of a preliminary “capacity analysis”—an attempt to estimate the number of NGOs operating in different basins within the Southeast.

Existing Planning Efforts

There have been many attempts to define areas or identify priority species for conservation across the Southeast. The most comprehensive of these efforts is the State Wildlife Action Plans developed by the state wildlife agencies. Other, watershed- or taxa-specific plans have been developed by federal agencies and NGOs.

Congress established the SWG program in 2001 to address important wildlife issues that have traditionally been underfunded. Funds are awarded based on a formula that considers each state’s population and total geographic area. Under this program, states are required to develop comprehensive plans to guide the conservation of nongame species with the goals of identifying species in need of conservation attention and preventing threatened and endangered species listings. To qualify for the SWG program, each state and territory is required to develop a “Comprehensive Wildlife Conservation Strategy,” sometimes called a State Wildlife Action Plan or SWAP. At a minimum, SWAPs must be updated every 10 years. In the Southeast, most states’ first SWAPs were approved in 2005, which led to a round of revisions in 2015.

Each SWAP must contain 8 required elements (source: *http://teaming.com/swap-overview*):

1. *Information on the distribution and abundance of wildlife species, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state’s wildlife;*
2. *Descriptions of locations and relative condition of key habitats and community types essential to conservation of the species identified in (1);*
3. *Descriptions of problems which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats;*
4. *Descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions;*
5. *Proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions;*

6. *Descriptions of procedures to review the strategy at intervals not to exceed ten years;*
7. *Plans for coordinating the development, implementation, review, and revision of the plan with federal, state and local agencies and Indian tribes that manage significant land and water areas within the state or administer programs that significantly effect the conservation of identified species and habitats;*
8. *Inclusion of broad public participation as an essential element of developing and implementing these plans.*

To satisfy objective 1, all plans identify the "species of greatest conservation need," including many species which have experienced significant population declines. Threats to these species are also described in the SWAPs and include such factors as habitat loss or fragmentation, competition from non-native species, and stressors related to climate change. The SWAPs identify habitats and actions needed to restore or maintain viable populations of these species. Because these plans represent contemporary efforts with identical goals, albeit substantially differing methodologies, that have been reviewed by state, federal, academic, and NGO biologists, they form the foundation of our analysis of watershed threats and recommended conservation actions.

One difficulty with developing a regional synthesis from a set of statewide plans is the problem of assessing the status of species whose ranges encompass multiple states. If a species with a widespread distribution is found in only a small numbers in a particular state, its apparent "rarity" is often grounds for inclusion among that state's Species of Greatest Conservation Need (SGCN). Other difficulties in reconciling priorities across state borders arise due to differences in the scale of analysis or planning chosen by the various state SWAP committees. Some states use the relatively fine 10-digit Hydrologic Unit Code (HUC) or "watershed" level, while others use a coarser 8-digit HUC or "sub-basin," while still others use a mix of areal and linear (i.e. stream-reach) units or simply major habitat/ecoregion types (see Box 2, below). We ultimately chose to standardize our analysis by using published range-wide imperilment rankings for each species from the scientific literature and to standardize on the HUC-8 sub-basin as our unit of analysis, as described in the next section.

In addition to the SWAPs, there are numerous basin-level, regional, and sub-regional plans for the Southeast. Some examples of these include:

- The 2014 Imperiled Aquatic Species Conservation Strategy for the Upper Tennessee River Basin (UTRB). This project's goal was to develop a cost-effective approach to guide conservation and management of imperiled freshwater fish and mussel species in the UTRB.
- The Dale Hollow National Fish Hatchery developed a plan for the Lower Duck in 2014 based on a local prioritization.
- The Southeast Aquatic Resource Partnership (SARP) developed plans in 2005 for four pilot watersheds in the Southeastern U.S. (the Duck River, the Altamaha River, the Roanoke in NC & VA, and the Pascagoula in MS) to test the development of the Southeastern Aquatic Habitat Plan.

- The Tennessee Freshwater Mollusk Strategic Plan developed by The Nature Conservancy in 2013
- A preliminary project plan for the Conasauga National Wildlife Refuge developed by the Fish and Wildlife Service in 2009
- A Green River Conservation Business Plan developed by TNC for FY2015-2019
- An Upper Tennessee Mussel Restoration Strategy published in 2010 by the Virginia Department of Game and Inland Fisheries
- An Alabama River and Mobile Bay watershed assessment prepared for the EPA in 2014, to identify healthy watersheds and characterize relative watershed health across the state and basin
- A set of Florida Surface Water Improvement and Management (SWIM) Act plans dated between 1997-2011 for
    - St. Johns River
    - Apalachicola River and Bay
    - Choctawhatchee River and Bay
    - Ochlockonee River and Bay
    - Pensacola Bay System
    - St. Andrew Bay
    - St. Marks River
    - Perdido River and Bay
- A TNC watershed assessment from 2015 assessing opportunities post-Deepwater Horizon spill in the Perdido

An Integrated Plan

This project was initiated by a grant from the National Fish and Wildlife Foundation to the University of Georgia River Basin Center and the Tennessee Aquarium Conservation Institute to identify potential freshwater conservation priorities in the Southeast, in order to help guide potential future conservation investments (by any interested party). Given the large number of existing plans, including recently completed SWAPs, we initially proposed to stitch together a coherent, integrated plan by drawing on this past work. This approach was also intended to avoid exacerbating the problem of "planning fatigue," particularly among overtaxed agency biologists. However, it soon became apparent that differences in SWAP methodologies (see box) would make this approach challenging and potentially ineffective. At the same time, we discovered that there was a larger amount of readily available, good-quality species occurrence data that could be used as the basis for an empirical, data-driven approach to spatial prioritization. Therefore, we revised the approach to include the following elements:

1) A spatial analysis that scored watersheds (at the HUC8 scale) on the basis of richness, endemism and imperilment for available taxonomic groups.
2) Multiple rankings of watersheds based on these scores, including an overall combined ranking, a state-by-state ranking, and a within-basin ranking, to support different applications of the results. We also created a user-friendly database to allow additional analyses of the watershed-scale data.
3) A limited, preliminary capacity analysis.

4) A brief analysis of the cost-benefit of conservation spending in the region, based on a case study.
5) Analysis of likely threats and potential management actions for ten of the highest-scoring watersheds. This extensive document is included as Appendix III.

METHODS

Project Advisory Committee

Although the core project team has over 90 years combined experience with aquatic conservation in the Southeast, our knowledge is primarily with fishes and concentrated in the Alabama/Mobile and Tennessee/Cumberland drainages. To ensure sufficient taxonomic and geographic breadth, our first step was to assemble an advisory committee composed of experts with diverse specializations from across the project area and including both state and federal biologists, along with academics (Table 1). This committee had several roles: to facilitate data acquisition, to help develop the overall analytic approach, and to vet the interim and final results. We communicated with this group primarily through webinars but convened one in-person work session in November, 2015.

Table 1 Advisory Board Members

Name	Affiliation
Susie Adams	US Forest Service
Paul Angermeier	Virginia Tech University
Katherine Baer	River Network
Art Bogan	NC Museum of Natural Sciences
Bob Butler	US Fish & Wildlife Service
Stephanie Chance	US Fish & Wildlife Service
Tanya Darden	SC Department of Natural Resources
Jessica Graham	Southeastern Aquatic Resources Partnership
Mike Harris	US Fish & Wildlife Service
Michael LaVoie	Eastern Band Cherokee Indians
Pat O'Neil	Geological Survey of Alabama
Peggy Shute	US Fish & Wildlife Service
Todd Slack	US Army Corps of Engineers- Engineer Research and Development Center
Matt Thomas	KY Department of Fish & Wildlife Resources

Beyond regular consultation with our advisory committee, we conducted several levels of outreach and review throughout this process. We presented several sets of interim results at regional and national meetings (Southeastern Fishes Council, American Society of Ichthyologists and Herpetologists) and to meetings of the "At-Risk Species Committee" of the Southeast Association of Fish and Wildlife Agencies (Box 1). Once our prioritization method was finalized, we published a draft prioritization in August, 2016, on our website, asked our advisory committee and those on the crayfish and mussel committees to review and solicit the review of their professional networks, and requested comments from the Science Managers of the Landscape Conservation Cooperatives within our project boundaries (the South Atlantic, Appalachian, Gulf Coast Prairie Ozark, and Peninsular Florida LCCS).

Box 1. Presentations during the project period

*Presenter is shown in **bold***

Elkins, D.C., A.L. George, S.C. Hazzard, **B. Kuhajda**, and S.J. Wenger. 2016. The southeastern aquatic biodiversity conservation strategy. Cumberland Plateau, Ridge & Valley, and Northern Piedmont National Forest At-risk Species Workshop, Asheville, NC.

Elkins, D.C., A.L. George, S.C. Hazzard, **B. Kuhajda**, and S.J. Wenger. 2016. The southeastern aquatic biodiversity conservation strategy. Mississippi and north-central Alabama public lands At-risk Species Workshop, Jackson, MS.

Elkins, D.C., A.L. George, S.C. Hazzard, **B. Kuhajda**, and S.J. Wenger. 2016. The southeastern aquatic biodiversity conservation strategy. Tennessee Rare Fishes meeting, Nashville, TN.

Elkins, D.C., A.L. George, S.C. Hazzard, **B. Kuhajda**, and S.J. Wenger. 2016. The southeastern aquatic biodiversity conservation strategy. Annual Mollusk and Crayfish Meeting, Fort Payne, AL.

George, A.L. September 2016. Protecting an underwater rainforest: Advancing freshwater conservation science in the southeastern United States. Association of Zoos and Aquariums, San Diego, CA.

George, A.L., D.C. Elkins, S.C. Hazzard, B.R. Kuhajda, and S.J. Wenger. August 2016. Conservation planning for southeastern aquatic biodiversity. Tennessee River Basin Biodiversity Network Meeting, Chattanooga, TN.

George, A.L., D.C. Elkins, S.C. Hazzard, B.R. Kuhajda, and S.J. Wenger. July 2016. Conservation planning for southeastern aquatic biodiversity. Joint Meeting of Ichthyologists and Herpetologists, New Orleans, LA.

Elkins, D.C., A.L George, S.C. Hazzard, B.R. Kuhajda, and S.J. Wenger. July 2016. Who follows the fish? Patterns in the fishes, mussels, and crayfishes of the Southeast. Joint Meeting of Ichthyologists and Herpetologists, New Orleans, LA.

Elkins, D.C., A.L George, S.C. Hazzard, B.R. Kuhajda, and S.J. Wenger. November 2015.The Southeastern Aquatic Biodiversity Conservation Strategy (Poster). Annual Meeting of the Southeastern Fishes Council, Gainesville, FL.

Defining the Project Area

We defined the project area (Figure 2) using a combination of geographic and biogeographic boundaries drawn from fish distributions, as follows:

Atlantic Slope The northern limit is the Roanoke River in Virginia/North Carolina. This is the last major drainage south of the Chesapeake Bay drainages, and is the most species-rich Atlantic Slope drainage for fishes. There is also a distributional break between the Roanoke River and the James River drainage to the north, with nine species of fishes reaching their northern limit in the Roanoke and six different species reaching their southern limit in the James. The southern limit is the St. Johns River drainage in Florida. This is where 20 species of fishes reach their southern limit along the Atlantic Slope.

Gulf Slope Twelve fish species reach their eastern limit in the Suwannee River drainage in Florida/Georgia, but by extending our area slightly south to include the Crystal-Pithlachascotte and Withlacoochee HUC-8 (i.e., the 8-digit hydrologic unit code watersheds) sub-basins we were able to include the entire distribution of an additional eight species. The western limit of our area along the Gulf Slope is the Lake Pontchartrain drainage in Southeast Louisiana and south Mississippi, where twelve species reach their western limit.

Mississippi River Drainage All direct eastern tributaries to the Mississippi River downstream of the mouth of the Ohio River are included. These systems contain numerous narrow endemic species of madtoms and darters and are the western terminus for many more wide-ranging southeastern fishes.

Ohio River Drainage With one exception (see below), the eastern limit for a drainage connecting to the Ohio River is the Licking River drainage in Kentucky. This drainage is the stronghold for many fishes found further upstream in the Ohio River basin, and the last upstream stronghold on the southern side of the Ohio River for five fish species. Ohio River Basin tributaries further upstream are excluded due to logistical constraints, as are HUCs that straddle the main stem of the Ohio River in Kentucky and extend into Ohio, Indiana, and Illinois. The one exception is the Kanawha River drainage in West Virginia, Virginia, and North Carolina, which is included due to its reach (the New River) into the Southeast (North Carolina). The downstream extent for our area is at Kanawha Falls; eight endemic fish species are found above these falls in the New and Gauley rivers.

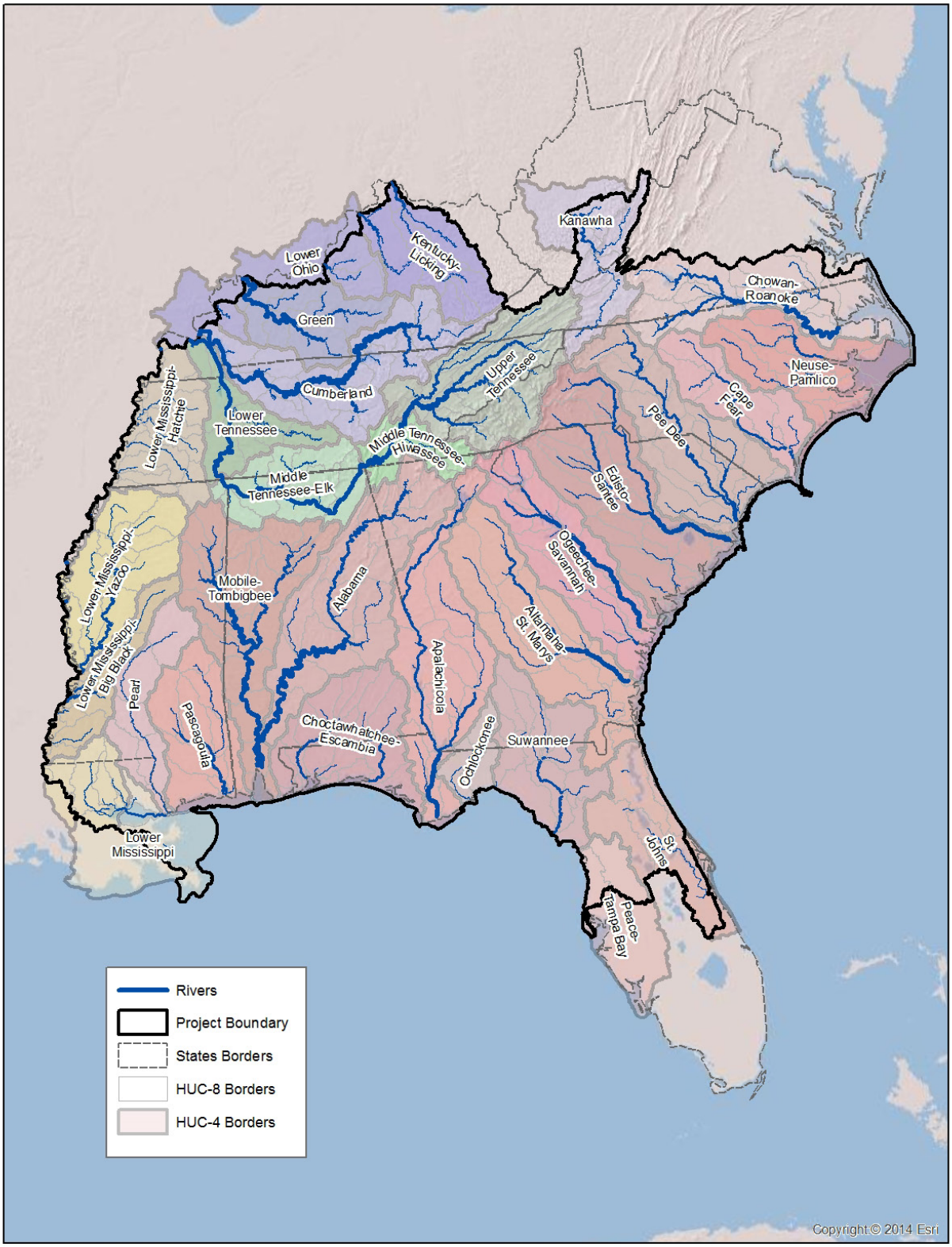


Figure 2 Project Area: "The Southeast." Additional maps of all HUC-8 sub-watersheds in the project area map be found in Appendix II.

Data Sources and Aggregation

To identify the watersheds which, if protected and restored, would contain the highest biodiversity of native aquatic organisms in the Southeast, we compiled datasets of field observations from university researchers, museums, state agencies, and online databases derived from these sources (see fish, crayfish, and mussel sections for full list of data sources). We found that the number and distribution of observations was sufficient to build maps for fishes, crayfishes, and mussels, but not for other invertebrates such as aquatic snails. We elected not to include amphibians in this analysis due to logistical and time constraints, particularly because of the additional analysis required to exclude species that were only minimally dependent on aquatic habitat. Most of the observations consisted of point records, reflecting one survey at a specific time, but some agencies provided us with polygon coverages, reflecting areas in which a particular species has been collected over a longer period of time. Polygon coverages were more typical for imperiled species.

Box 2. Issues in Integrating State Wildlife Action Plans

One key to the success of this effort was to build on the foundation of the SWAPs, which contain the best contemporary synthesis of population status, threats, and conservation opportunities for the states in the Southeast. However, we encountered several challenges in our attempts to integrate SWAPs. First, the state committees chose differing spatial scales for the SWAP analyses and priority areas. This was a problem even where Alabama's prioritization extended into Georgia and Florida. For example, not all of the areas in Alabama's Upper Coosa River Tributaries Strategic Habitat Unit basin were ranked high priority by Georgia's analysis. Similarly, Alabama's Conecuh Strategic River Reach is in neither of the lists of 12 river basins Florida highlights as special priority for conservation or enhancement.

Second, primarily because Species of Greatest Conservation Need (SGCN) are designated on the basis of rarity within a state's political boundaries rather than across their native range, there were a number of discrepancies between the SGCN lists of adjacent states that derived from widespread species that were found only in watersheds that crossed state lines. We called this "S1G5 inflation" in reference to species that were, according to the NatureServe conservation status system, globally secure (G5 designation) but locally critically imperiled (S1 designations). Resolving this would have required a species-by-species review of each state's SGCN list to avoid incorrectly elevating a regionally secure species to imperiled status.

Third, the states took different approaches to developing and categorizing their SCGN lists and different interpretations of the charge to "keep common species common" to prevent federal listing of species under the Endangered Species Act. In some cases, notably Tennessee, the highest priority SCGN tier specifically excluded ESA-listed species, while in Georgia aquatic species were added to the SCGN if they had been petitioned for listing under the ESA. This, as above, would have required an extensive reanalysis of each state's species list.

We aggregated all point and polygon collection data by 8-digit Hydrologic Unit Code (HUC-8; this is technically referred to as a "sub-basin" but here we also use the common-language term "watershed"). This resulted in species range maps covering 290 planning units for the Southeast with an average size of 3,500 square kilometers (1,351 square miles) each. Although management decisions are often made at finer scales, we judged this to be an appropriate scale for aggregation to minimize discontinuous distributions resulting from uneven sampling.

For all taxonomic groups we only included native species. We included undescribed species if they were recognized in literature (published papers, books, SWAPs) and there was information available on their distribution and imperilment status. We did not include species known to be extinct but retained records of species thought to be currently extirpated, on the assumption that re-introduction from another population could be possible. Where possible, we excluded introduced ranges. Species which had their entire range within the 290 HUC-8 sub-basin area were classified as southeastern endemics. It should be noted that biogeographic patterns for other taxa may not align exactly with our representation of a southeastern fauna for fishes. Species characterized as "southeastern crayfishes," in particular, might reasonably extend into portions of Louisiana and Arkansas. We did not anticipate being able to develop a crayfish layer for the entire region when we set the project boundaries, and acknowledge that this may impose a downward bias on the crayfish endemism scores for sub-basins in western Mississippi and western Tennessee.

Predictably, many of the original records contained errors, either spatial or taxonomic. S. Hazzard organized and corrected raw data so draft maps could be produced for all species. Further corrections were made by other team members, advisory board members and other experts, as described in the subsequent sections.

Fishes

Fish data were downloaded from Multistate Aquatic Resources Information System (MARIS), FishNet2, and the Global Biodiversity Information Facility (GBIF). Aggregated fish data were vetted by species and HUC-8 sub-basins by B. Kuhajda using published "Fishes of" state books, online atlases, or primary literature for recently described species. (A list of the references consulted is provided in the References section under the sub-heading "Citations for vetting of fish data.") As a group, fishes are the best-studied freshwater taxon in the Southeast, both with regard to taxonomy and distribution, with numerous distributional references at the country, state and drainage levels. For this reason, it was not necessary to heavily consult with outside experts as we did with mussels and crayfishes. We assigned imperilment status for fish species using the ranks in Jelks, et al., 2008, modified in some cases for new taxonomy or where an updated assessment was available. Imperilment categories were "endangered, "threatened," and "vulnerable." These categories do not necessarily correspond to listing status under the Endangered Species Act or state programs.

Crayfishes

We contacted southeastern astacologists beginning with those who had attended the 2015 symposium "Conservation, Ecology, and Taxonomy of Southeastern Crayfish" at the annual

meeting of the Southern Division of the American Fisheries Society in Savannah, Georgia, and asked if they had relevant datasets of crayfish distributions that they would be willing to have aggregated for this project. In some cases, they referred us to another researcher or a museum database. Ultimately, we received polygon or point data from 17 sources (
Table 2), including one query of the GBIF online database for records from the Florida Museum of Natural History and one query covering most of Georgia from the Smithsonian Museum's database, which returned records that we manually georeferenced using road and stream intersections.

We convened a meeting in Chattanooga, TN, on June 1 and 2, 2016, that included most of the researchers who had provided data. In this meeting, we reviewed the distribution maps for HUC-8 level range maps generated by the combination and aggregation of the input datasets. This initial list included cave species and species not classified as primary burrowers and contained some species with unclear or disputed taxonomy. The group corrected taxonomic and geographic errors and assigned southeast endemism for most species, although approximately twenty species were flagged for further review by individuals not at the meeting or where a more extensive literature search was required. These maps were subsequently corrected via email communications. The crayfish committee also added to our species set a small number of primary burrowers which the group agreed were sufficiently flowing-water associated to be considered stream-dependent. While we refer to "crayfishes" throughout the document, it should be noted that our exclusion of primary burrowing species neglects approximately 15% of described species, including almost a third of those with "critically imperiled" conservation status (Welch and Eversole, 2005). We assigned crayfish imperilment ranks based on consultation with Chris Taylor of the Illinois Natural History Survey, who maintains an updated list from the most recent American Fisheries Society status paper (Taylor, et al, 2007).

Table 2 Astacologists who contributed data or reviewed crayfish distribution maps

Name	Affiliation	Provided Data	In-Person Review	Email Review
Susie Adams	USFS	X	X	X
Tyler Black	NC Wildlife Resources Commission	X	X	
Chris Skelton	HNTB Corporation	X	X	
Arnie Eversole	Clemson Univ.	X	X	X
Bob Jones	MS Museum of Natural Science	X		
Zach Loughman	West Liberty Univ.	X	X	X
Guenter Schuster	Eastern KY Univ. (retired)	X		X
Chris Taylor	IL Natural History Survey	X		X
Roger Thoma	Midwest Biodiversity Institute	X	X	
Bronwyn Williams	NC Museum of Natural Sciences	X	X	
Carl Williams	TN Wildlife Resources Agency	X		
David Withers	TN Department of Environment and Conservation	X	X	X

Name	Affiliation	Provided Data	In-Person Review	Email Review
Geological Survey of AL		X		
IL Natural History Survey		X		
KY Department of Fish & Wildlife Resources		X		
Jeff Simmons	TN Valley Authority	X		X
Smithsonian NMNH		X		
GBIF		X		
Stuart McGregor	Geological Survey of AL		X	X
Rebecca Bearden	Geological Survey of AL		X	

Mussels

Museum records were the primary source of mussel point locations. We requested all mussel records for the study area or queried the online databases of the Ohio State University Museum of Biological Diversity, the North Carolina Museum of Natural Science, and the Mississippi Museum of Natural Science. We also obtained the state databases for Alabama, Kentucky, and Georgia. All contributors are listed in Table 3.

Table 3 Malacologists who contributed data or reviewed mussel distribution maps

Name	Affiliation	Data	Review
Jeff Garner	AL Department of Conservation & Natural Resources	X	
Stuart McGregor	Geological Survey of AL	X	
Jason Wisniewski	GA Department of Natural Resources	X	X
Bob Jones	MS Museum of Natural Science	X	X
Art Bogan	NC Museum of Natural Sciences	X	X
	Ohio State University Museum of Biological Diversity	X	
Jim Williams	Florida Museum of Natural History	X	X
Bob Butler	US Fish & Wildlife Service		X
Wendell Haag	US Forest Service		X
Jess Jones	VA Department of Fish and Wildlife Conservation		X
Don Hubbs	TN Wildlife Resources Agency		X
	KY Department of Fish and Wildlife	X	
	Geological Survey of AL	X	
	GA Department of Natural Resources	X	

These point records (HUC-12 polygons for Kentucky) were aggregated and species range maps were produced as for fishes. We employed an expert-opinion approach, emailing collections of range maps to malacologists with regional expertise (Table 3) who assigned endemism and delivered corrected maps in writing or over the phone. Most areas were assigned to more than

one reviewer, and conflicts were rare. However, this process was not as thorough as the multi-party discussion that occurred within the crayfish review group. Mussel imperilment scores were drawn from an in-press distribution and imperilment appendix for mussels from Jim Williams, developed for the Freshwater Mollusk Conservation Society.

Priority Calculations

We calculated species richness for fishes, crayfishes, and mussels for each HUC-8 sub-basin as the sum of individual species present in each. We calculated weighted imperilment sums for each HUC-8 by assigning 3 points for each endangered species found there, 2 points for each threatened species, and 1 point for each vulnerable species. This point system was admittedly arbitrary; other point systems are possible.

In an effort to capture not only the total biodiversity in an area but also the distinct biota of the Southeast, we derived an endemism score for each HUC-8 area. We considered a species to be a southeastern endemic if its entire range occurred within the 290-HUC study area. For each of these species, we calculated an endemism score as the reciprocal of the number of HUC-8 sub-basins in which it occurs. Thus, a narrow endemic which occurred in a single HUC-8 received a score of 1/1 (1), while a more widely-distributed species occurring in 10 HUC-8s received a score of 1/10 (0.1). The sum of the endemism scores of all the fish, crayfish, or mussel species that occur within a HUC-8 was the endemism score for that watershed.

Although there are exceptions, as noted below, the similarities in the patterns of distribution and imperilment among fishes, crayfishes, and mussels suggested that it was reasonable to produce an overall prioritization for the three groups in aggregate. We considered two approaches to combine these taxa-specific priorities. The first was to give fishes, mussels, and crayfishes each an equal contribution toward a maximum 9-point final priority score. However, we ultimately decided that the overall diversity analysis ought to account for the fact that there are 589 fish species, 234 mussel species, and 221 crayfish species; weighting each group equally would have effectively made each fish species count for less than half of a mussel or crayfish. Therefore, our final priority score is an “all species equal” sum that uses all 1,044 species in the normalized biodiversity, endemism, and imperilment sums.

RESULTS

Priority Areas for Fishes

The resulting maps of species richness, endemism, and imperilment for fishes, crayfishes, and mussels highlight areas of particular concern for each group. Fish species richness is generally highest in the Lower Tennessee River and Alabama River Basins, with the area of highest endemism including these regions but also the Upper Coosa River system and the Upper Clinch River. Weighted imperilment is similarly highest in the Cahaba, Etowah, Conasauga, Pickwick Lake, and Upper Clinch.

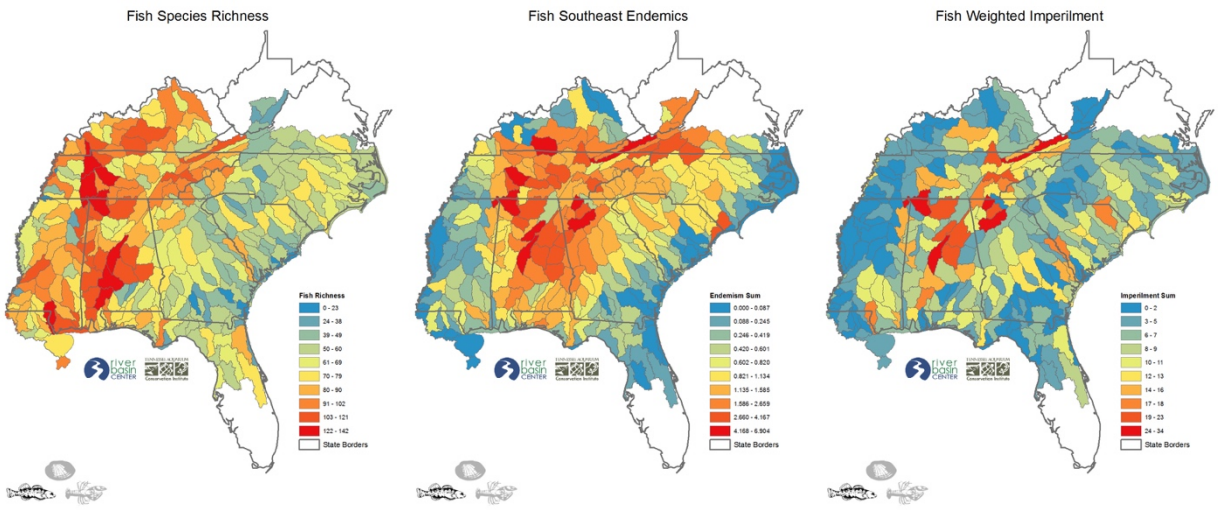


Figure 3 Richness, endemism, and imperilment scores for fishes. Note: large, high resolution versions are included in Appendix I.

The standardized and summed richness, endemism, and imperilment scores for fish lead to the highest priorities in the Pickwick Lake HUC-8, followed by the Upper Clinch and most of the Alabama-Coosa River system.

Table 4 Top 15 sub-basins by combined priority score for fishes

Fish Only Rank	HUC-8 Name	Major Drainage	Score (Max 3)
1	Pickwick Lake	Tennessee	2.65
2	Upper Clinch	Tennessee	2.58
3	Cahaba	Alabama	2.46
4	Etowah	Alabama	2.45
5	Conasauga	Alabama	2.17
6	Lower Duck	Tennessee	2.13
7	Locust	Alabama	1.98
8	Lower Coosa	Alabama	1.95
9	Wheeler Lake	Tennessee	1.91
10	Middle Coosa	Alabama	1.82
11	Barren	Green	1.82
12	Lower Tallapoosa	Alabama	1.80
13	Watts Bar Lake	Tennessee	1.74
14	Lower Little Tennessee	Tennessee	1.73
15	South Fork Cumberland	Cumberland	1.71

Priority Areas for Crayfishes

Crayfish species richness is highest in the Pickwick Lake and Wheeler Lake HUCs, along with the Lower and Middle Tombigbee River, the Barren River in Kentucky, and the Pascagoula River.

Crayfish endemism is highest in Wheeler Lake, with Pickwick Lake scoring third on this measure behind the St. Andrews/St. Josephs Bay HUC in Florida. Weighted imperilment scores were less evenly distributed, with Wheeler Lake again scoring highest.

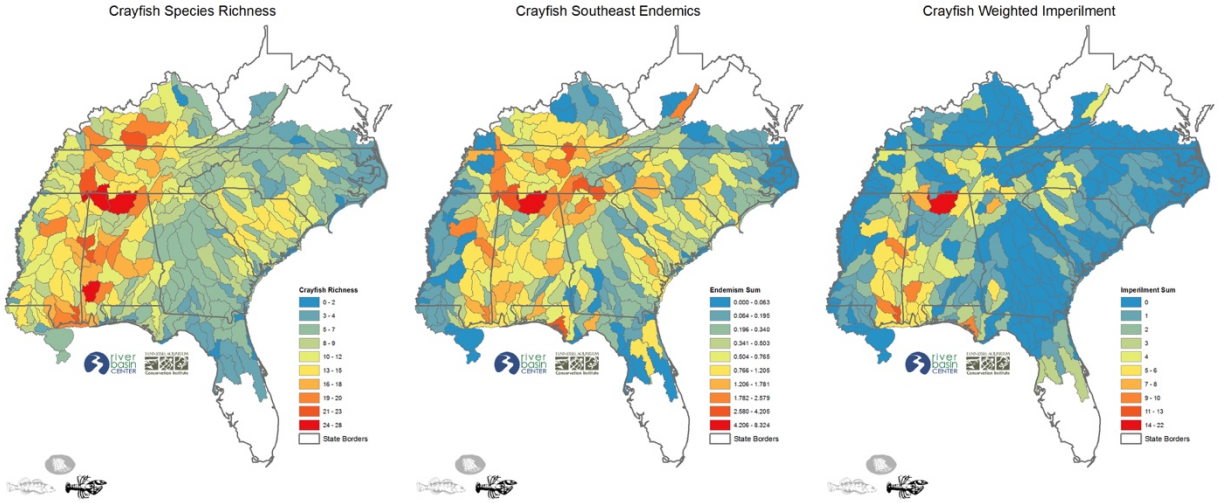


Figure 4 Richness, endemism, and imperilment scores for crayfishes. Note: large, high resolution versions are included in Appendix I.

These scores combine to give Wheeler Lake the highest overall priority for crayfishes, with scores dropping off rapidly thereafter. Note that the majority of the top watersheds for crayfishes lie outside the Tennessee River system.

Table 5 Top 15 sub-basins by combined priority score for crayfishes

Crayfish Only Rank	HUC-8 Name	Major Drainage	Score (Max 3)
1	Wheeler Lake	Tennessee	3.00
2	Pickwick Lake	Tennessee	1.74
3	Pascagoula	Pascagoula	1.65
4	Lower Tombigbee	Mobile-Tombigbee	1.52
5	Noxubee	Mobile-Tombigbee	1.36
6	Yalobusha	Lower Mississippi-Yazoo	1.30
7	Black	Pascagoula	1.29
8	St. Andrew-St. Joseph Bays	Choctawhatchee-Escambia	1.25
9	Guntersville Lake	Tennessee	1.22
10	Obey	Cumberland	1.22
11	Lower Tennessee-Beech	Tennessee	1.22
12	Middle Tombigbee-Lubbub	Mobile-Tombigbee	1.18
13	Mississippi Coastal	Pascagoula	1.13
14	Sucarnoochee	Mobile- Tombigbee	1.10
15	Lower Alabama	Alabama	1.10

Priority Areas for Mussels

Mussel species richness is highest for the Pickwick Lake, Wheeler Lake, the Upper Green (Green River, Kentucky), Guntersville Lake (Tennessee River), and Lower Cumberland (Cumberland River) sub-basins. The Coosa system is also the area of highest mussel endemism, with four of the top five sub-basins, although the Lower Chattahoochee sub-basin scores second. Mussel imperilment is highest in the HUCs for Pickwick Lake, Wheeler Lake, the Upper Clinch and Holston Rivers.

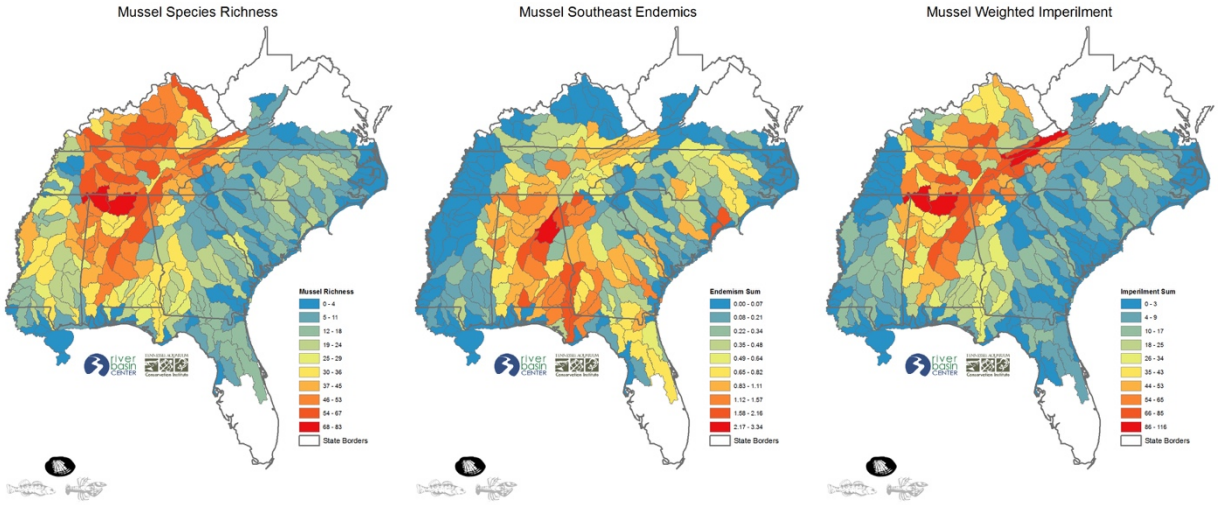


Figure 5 Richness, endemism, and imperilment scores for mussels. Note: large, high resolution versions are included in Appendix I.

The highest priority areas for mussels are the now-familiar cluster of Pickwick Lake, the Coosa River (represented by the Middle Coosa and Lower Coosa), Wheeler Lake, and the Cahaba.

Table 6 Top 15 sub-basins by combined priority score for mussels

Mussel Only Rank	HUC-8 Name	Major Drainage	Score (Max 3)
1	Pickwick Lake	Tennessee	2.47
2	Middle Coosa	Alabama	2.38
3	Wheeler Lake	Tennessee	2.18
4	Cahaba	Alabama	1.90
5	Lower Coosa	Alabama	1.80
6	Guntersville Lake	Tennessee	1.79
7	Upper Clinch	Tennessee	1.79
8	Holston	Tennessee	1.77
9	Conasauga	Alabama	1.71
10	Upper Coosa	Alabama	1.70
11	Caney	Cumberland	1.65
12	Upper Cumberland-Lake Cumberland	Cumberland	1.58
13	Upper Duck	Tennessee	1.55
14	Upper Alabama	Alabama	1.55
15	Powell	Tennessee	1.54

All Taxa Priority Areas

The highest ranking huc-8 sub-basins, overall, are Pickwick Lake and Wheeler Lake, two Middle Tennessee River systems that include the highest-ranking basins for fishes, crayfishes, and mussels, individually, and which support a high number of cave and spring endemic species. Five of the next seven HUC-8 sub-basins are in the Alabama River drainage, including the Cahaba River, the Middle Coosa, and the Conasauga River. The Upper Clinch River is the fourth highest-priority sub-basin overall, scoring highest for fish imperilment and relatively high for fish endemism and mussel imperilment. In general, richness, endemism, and imperilment tracked fairly closely (Figure 6), although there was more differentiation between the sub-basins on the speciose end of the scale.

Table 7 Top 15 sub-basins by combined priority score for fishes, crayfishes, and mussels

All-Taxa Rank	HUC-8 Name	Major Drainage	Score (Max 3)
1	Pickwick Lake	Tennessee	2.84
2	Wheeler Lake	Tennessee	2.84
3	Cahaba	Alabama	2.12
4	Upper Clinch	Tennessee	2.08
5	Middle Coosa	Alabama	1.95
6	Lower Duck	Tennessee	1.88
7	Conasauga	Alabama	1.76
8	Lower Coosa	Alabama	1.74
9	Etowah	Alabama	1.71
10	Caney	Cumberland	1.71
11	Barren	Green	1.70
12	Upper Green	Green	1.66
13	Upper Duck	Tennessee	1.64
14	Lower Tennessee-Beech	Tennessee	1.64
15	South Fork Cumberland	Cumberland	1.62

On the map (Figure 7), the highest priority scores fall toward the middle of the project region, running roughly up the Alabama River basin through the Middle and Upper Tennessee systems, with additional high-priority areas in the headwaters of the Green River basin. Thirty-two of the top 33 sub-basins are in the Tennessee, Cumberland, Alabama, or Green River systems and these four contain 41 of the top 50 sub-basins, along with the Mobile (8 sub-basins) and Pascagoula (1 sub-basin) systems. The Atlantic coastal plain and Mississippi Valley score comparatively lower on this overall ranking.

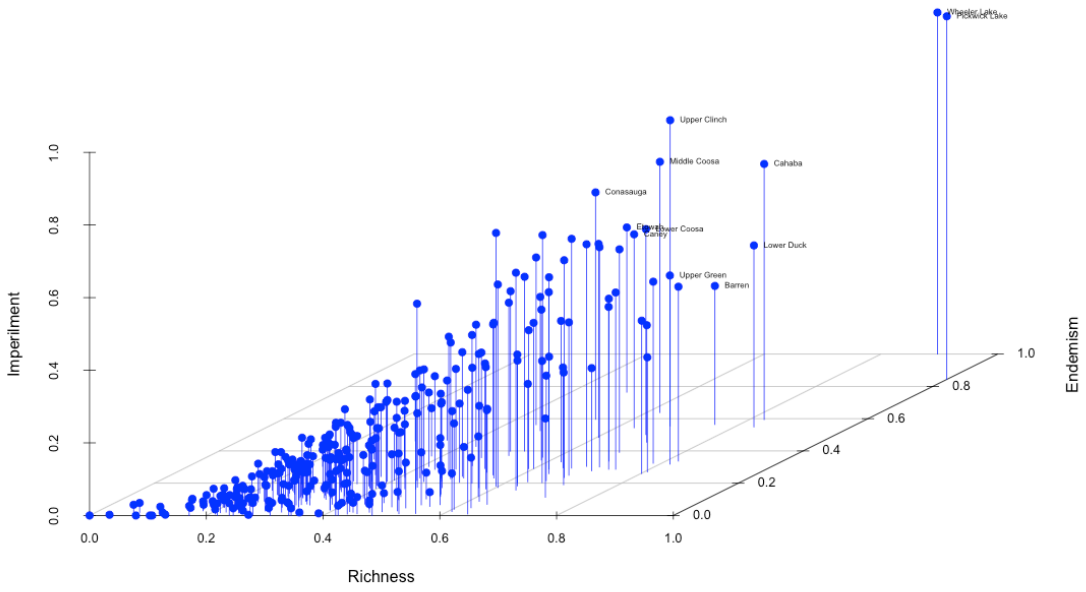


Figure 6 Scaled species richness, southeast endemism, and weighted imperilment for all taxa in 290 HUC-8 sub-basins. Labels indicate the top 12 sub-basins based on the combined priority ranking.

Based on these scores, we wanted to select a relatively small number of high-priority watersheds for further analysis of threats and management actions (Appendix III). This should **not** be viewed as an attempt to identify a definitive set of conservation priorities for the region. Rather, we view this as a reasonable method for using biological data to transparently select a set of priority locations in which conservation investments are likely to have a good return.

Examining an ordered plot of priority scores from all 290 sub-basins (Figure 8), there is a steep drop-off from the first two sub-basins, followed by a slight plateau at 1.71 consisting of the ninth and tenth sub basins (the Etowah and Caney), beyond which the marginal decay in the watershed score becomes much more gradual. This corresponds to the 97th percentile for this dataset, and 10 watersheds is a manageable number for further attention. However, many watersheds below this point are very similar in conservation value, and slight changes to our algorithm (in particular, an alternative assignment of scores for vulnerable, threatened, and endangered species) would change the membership of the top 10 list.

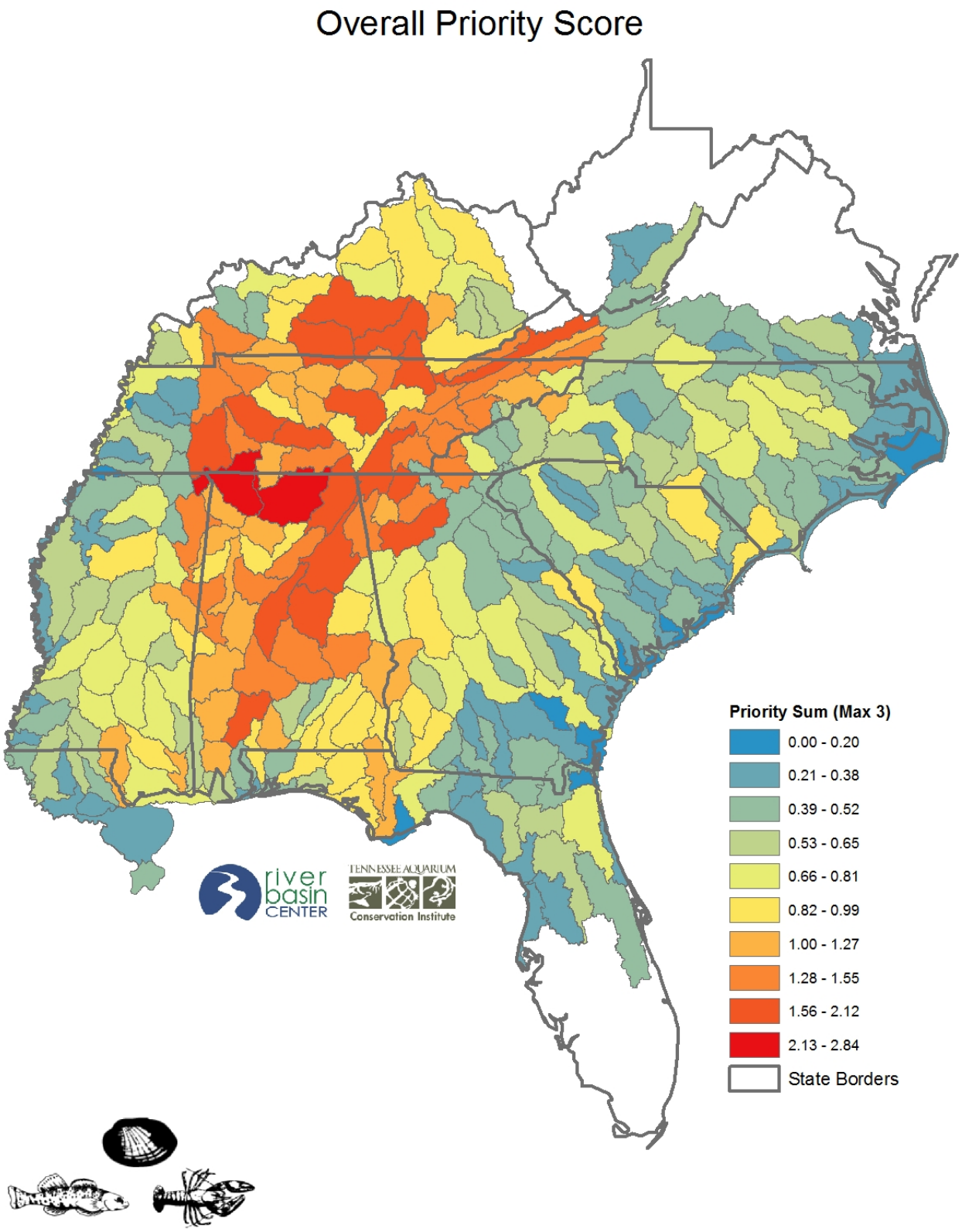


Figure 7 Overall priority score by sub-basin for the combined set of fishes, mussels, and crayfishes.

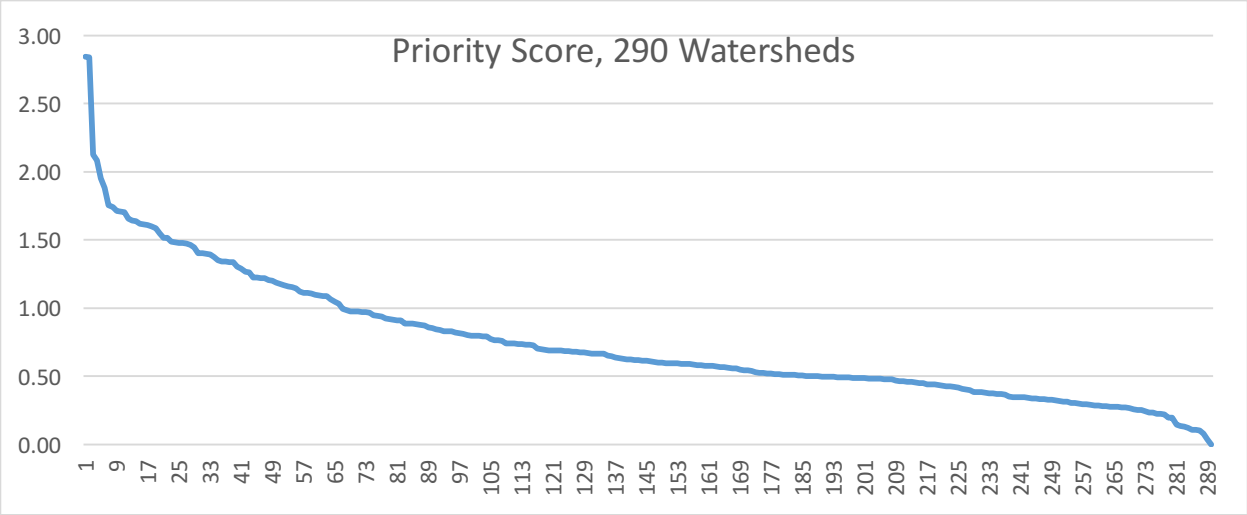


Figure 8 Sorted overall priority score by sub-basin

The nine highest scoring watersheds include four from the Tennessee River system and five from the Alabama-Coosa system, which might be expected to share many species. We tabulated the number of unique species added with each additional watershed beyond the 252 species in Pickwick Lake (Table 8). This shows that the Lower Coosa adds only two additional species, whereas the Barren River watershed in Kentucky adds 26 species. Consequently, we elected to omit the Lower Coosa from the top 10 list and replace it with the Barren. Beyond the Barren, the marginal increase in species declines again and the next sub-basin in a drainage not already included does not appear until the Middle Tombigbee-Lubbub at rank 22.

Table 8 Number of additional species included in the total species list with the addition of each new sub-basin (watershed) in priority rank order (only the first 13 are shown).

Priority Rank	Priority Score	Sub-basin	Major Drainage	Additional Unique Species
1	2.84	Pickwick Lake	Tennessee	252
2	2.84	Wheeler	Tennessee	22
3	2.12	Cahaba	Alabama	110
4	2.08	Upper Clinch	Tennessee	29
5	1.95	Middle Coosa	Alabama	15
6	1.88	Lower Duck	Tennessee	19
7	1.76	Conasauga	Alabama	9
8	1.74	Lower Coosa	Alabama	2
9	1.71	Etowah	Alabama	16

Priority Rank	Priority Score	Sub-basin	Major Drainage	Additional Unique Species
10	1.71	Caney	Cumberland	21
11	1.70	Barren	Green	26
12	1.66	Upper Green	Green	9
13	1.64	Upper Duck	Tennessee	1

This is a somewhat ad-hoc approach to addressing the conservation principle of complementarity. An alternative method would be to use a formal reserve-design algorithm that aims to maximize the total coverage of species. However, such algorithms are intended for true reserves in which the full area is genuinely protected; here we are identifying watersheds in which conservation management actions (potentially including preservation) can have substantial conservation benefit. We argue that the resulting top-10 list (Figure 9) is reasonable, while acknowledging that other methods might produce alternative, equally reasonable lists.

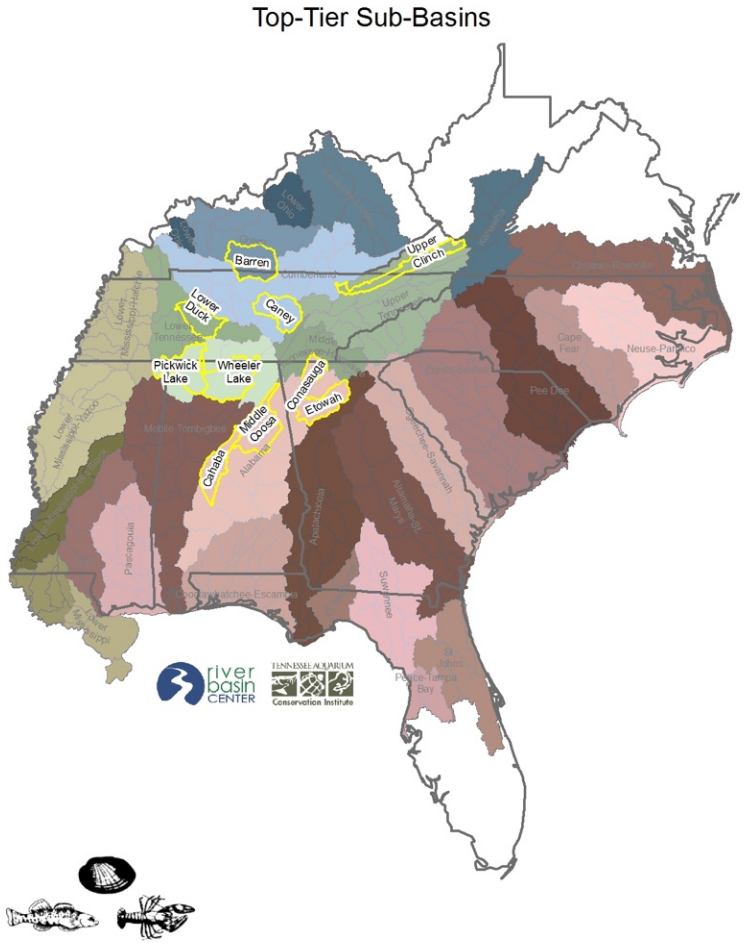


Figure 9. Ten highly biodiverse watersheds where management actions could have major conservation benefits. Shading reflects HUC-2 and HUC-4 boundaries, as in Figure 2.

A Parallel Prioritization: Hotspots for Vulnerable Species

One alternative prioritization using this dataset would be to identify areas with high numbers of vulnerable species, where more modest investments now could forestall species declines that would require significant work to arrest or reverse in the future. This approach aligns with the oft-stated conservation goal of "keeping common species common." Highlighting just those species classified as vulnerable reveals several areas that are not part of the top tier in the overall prioritization, including the Hiwassee river in Georgia, North Carolina, and Tennessee, two high Cumberland River sub-basins in Kentucky and Tennessee, and the Buffalo river in the Lower Tennessee basin.

Although the Tennessee and Alabama-Mobile systems score high on this metric, as in the overall priority analysis, they are joined near the top by of the rankings by the sub-basins in the Cumberland drainage. Atlantic Slope systems are also more prominent in this analysis, especially the Pee Dee River and Savannah River drainages.

Table 9 Top 25 sub-basins ranked by number of imperiled species with "Vulnerable" status

Sub-Basin (HUC-8 code)	Major Drainage	Vulnerable species
Hiwassee (06020002)	Tennessee	19
Pickwick Lake (06030005)	Tennessee	19
Wheeler Lake (06030002)	Tennessee	19
Upper Clinch (06010205)	Tennessee	18
Upper Cumberland-Lake Cumberland (05130103)	Cumberland	17
South Fork Cumberland (05130104)	Cumberland	17
Buffalo (06040004)	Tennessee	17
Upper Duck (06040002)	Tennessee	17
Cahaba (03150202)	Alabama	17
Caney (05130108)	Cumberland	17
Lower Clinch (06010207)	Tennessee	16
Lower Duck (06040003)	Tennessee	16
Nolichucky (06010108)	Tennessee	16
Lower Pee Dee (03040201)	Pee Dee	16
Stones (05130203)	Cumberland	16
Upper Green (05110001)	Green	16
Middle Savannah (03060106)	Savannah	16
Guntersville Lake (06030001)	Tennessee	16
Upper Flint (03130005)	Apalachicola	15
Watts Bar Lake (06010201)	Tennessee	15

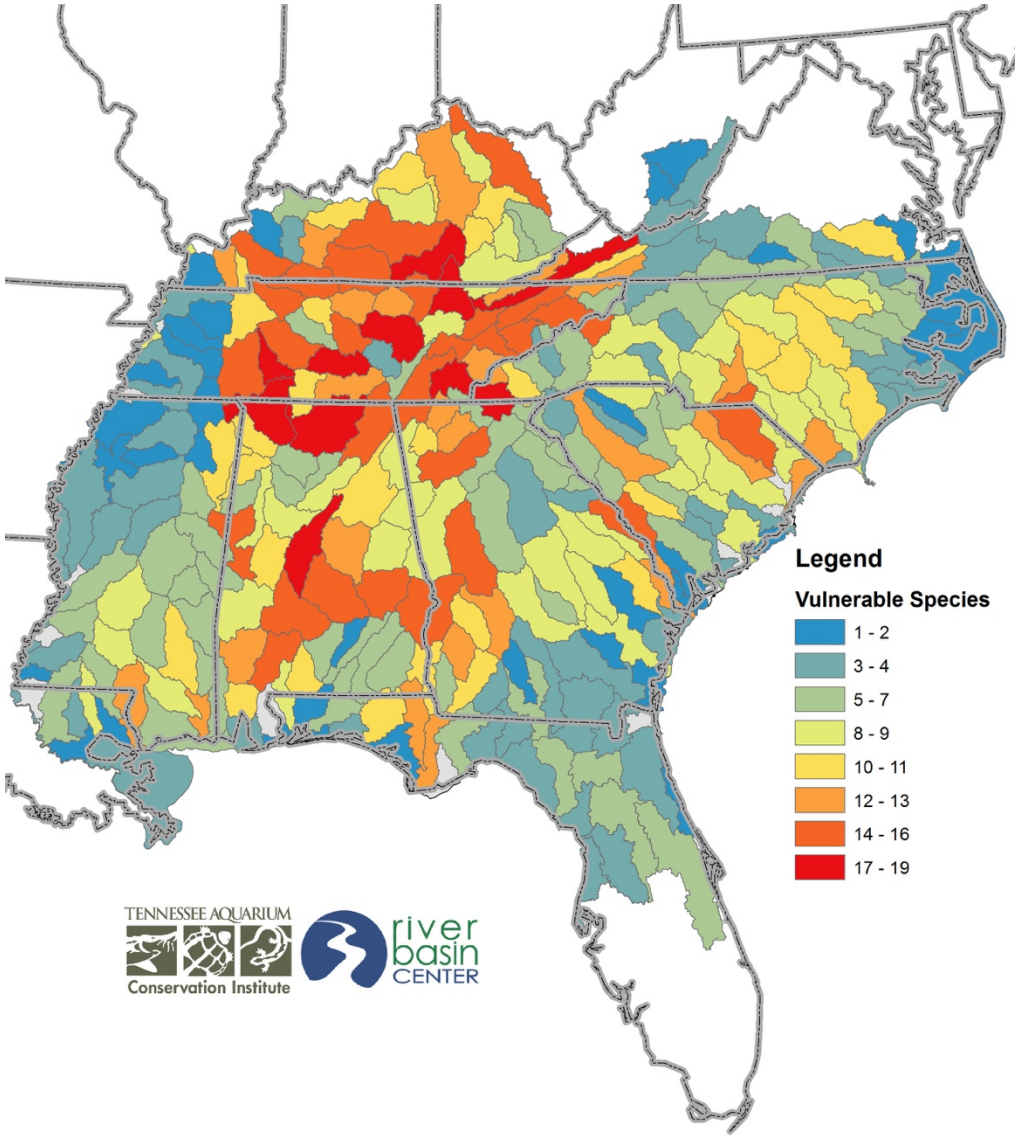


Figure 10 - Count of imperiled species (fishes, crayfishes, and mussels) with "Vulnerable" status by sub-basin.

Sub-Basin Priority by State

We recognize that many conservation decisions will not be made at the regional level. For instance, state wildlife agencies direct their efforts within their political boundaries, and many foundations that could support conservation projects focus their efforts within a particular geography. To facilitate such smaller-scale planning efforts, the following tables and maps use the same ranking methodology as the the overall 290 sub-basin analysis, but subset the results by state (top 10 shown) and by HUC-4 sub-region. Since many sub-basins cross state lines, we have included a column listing the percentage of the watershed within the state of interest.

Alabama

Table 10 Top sub-basins in Alabama by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Pickwick Lake	06030005	1	1	63%
Wheeler Lake	06030002	2	2	91%
Cahaba	03150202	3	3	100%
Middle Coosa	03150106	5	4	100%
Lower Coosa	03150107	8	5	100%
Lower Alabama	03150204	17	6	100%
Middle Tennessee-Chickamauga	06020001	18	7	3%
Guntersville Lake	06030001	19	8	83%
Middle Tombigbee-Lubbub	03160106	22	9	76%
Upper Alabama	03150201	23	10	100%

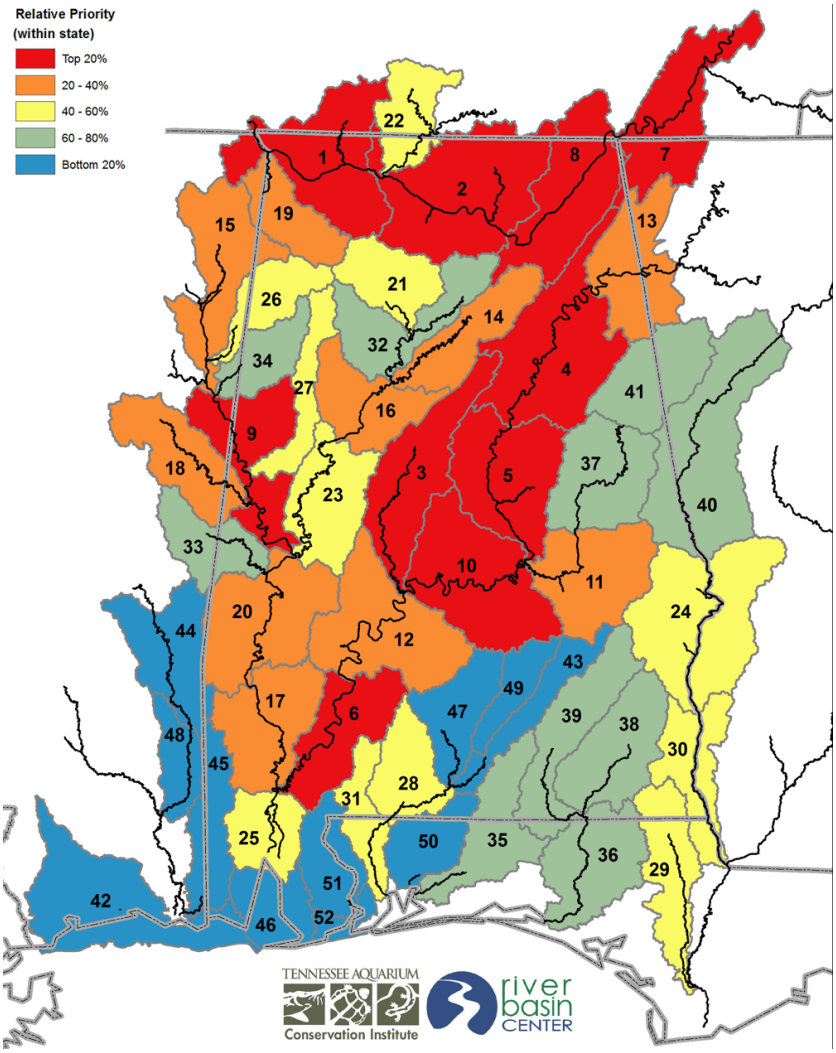


Figure 11 Within-state all-taxa priority rankings for sub-basins in Alabama

Florida

Table 11 Top sub-basins in Florida by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Apalachicola	03130011	60	1	96%
Chipola	03130012	66	2	79%
Escambia	03140305	72	3	53%
Yellow	03140103	79	4	62%
Lower Choctawhatchee	03140203	81	5	92%
Pea	03140202	92	6	7%
St. Andrew-St. Joseph Bays	03140101	94	7	100%
Lower Ochlockonee	03120003	117	8	84%
Lower St. Johns	03080103	134	9	100%
Lower Suwannee	03110205	155	10	100%

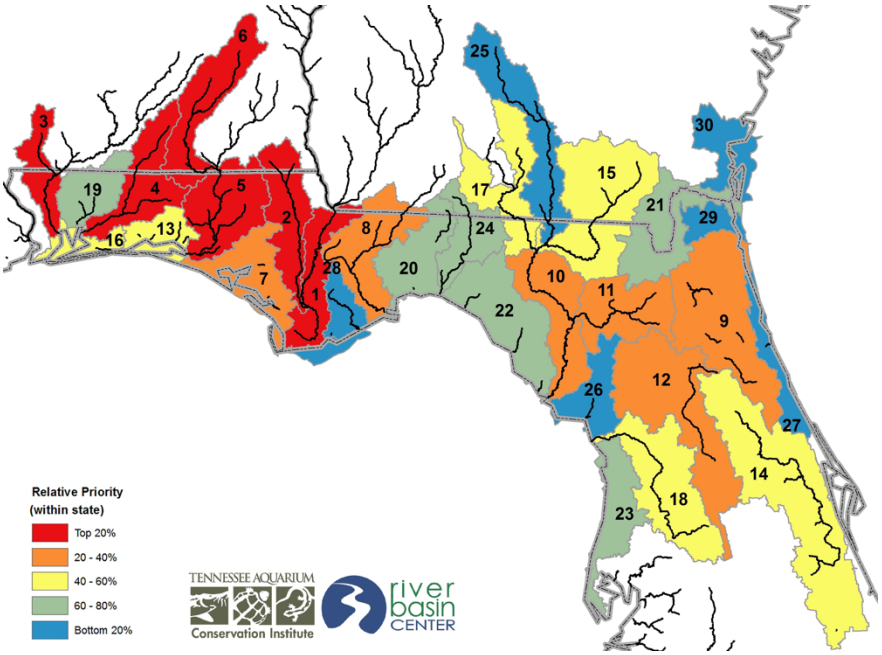


Figure 12 Within-state all-taxa priority rankings for sub-basins in Florida

Georgia

Table 12 Top sub-basins in Georgia by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Conasauga	03150101	7	1	83%
Etowah	03150104	9	2	100%
Middle Tennessee-Chickamauga	06020001	18	3	31%
Coosawattee	03150102	26	4	100%
Hiwassee	06020002	29	5	21%
Upper Coosa	03150105	30	6	46%

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Middle Chattahoochee-Walter F	03130003	56	7	49%
Oostanaula	03150103	59	8	100%
Apalachicola	03130011	60	9	4%
Upper Flint	03130005	78	10	100%

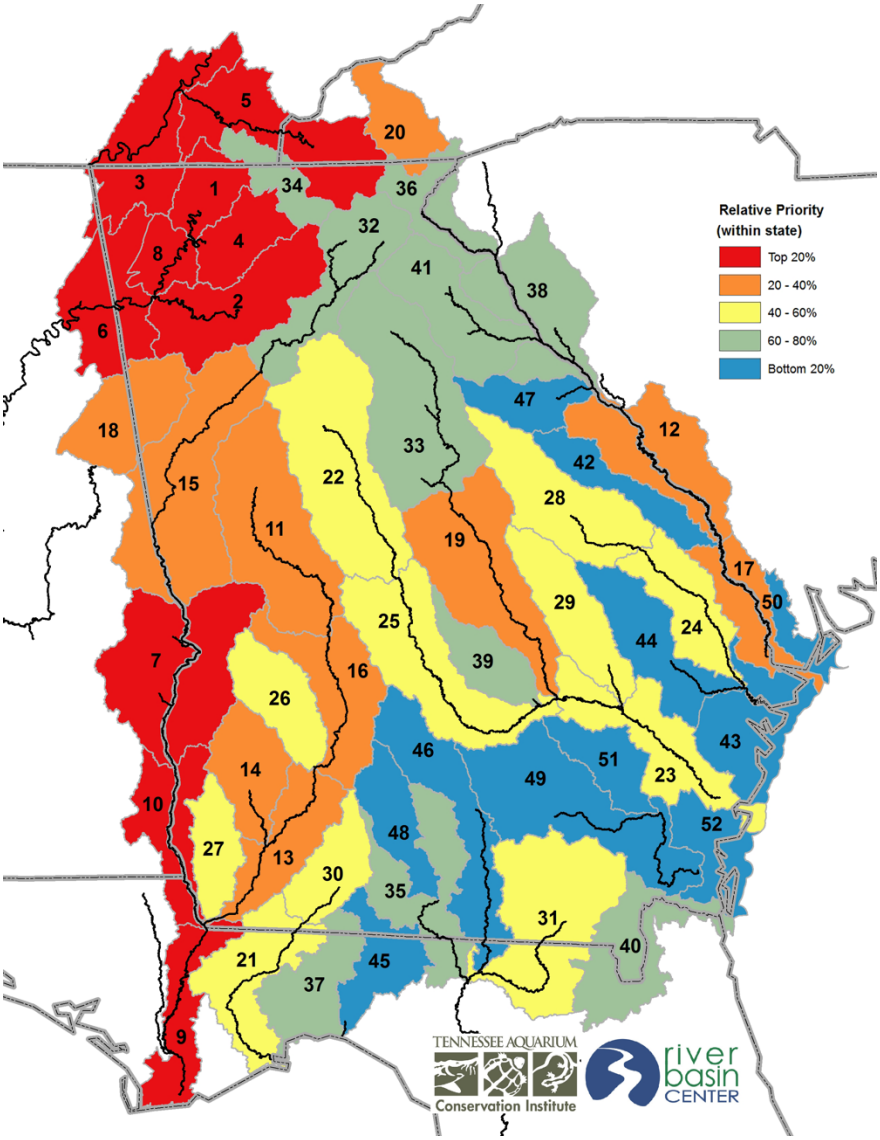


Figure 13 Within-state all-taxa priority rankings for sub-basins in Georgia

Kentucky

Table 13 Top sub-basins in Kentucky by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Barren	05110002	11	1	80%
Upper Green	05110001	12	2	100%

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
South Fork Cumberland	05130104	15	3	28%
Upper Cumberland-Lake Cumberland	05130103	16	4	99%
Lower Cumberland	05130205	24	5	58%
Kentucky Lake	06040005	33	6	20%
Obey	05130105	40	7	19%
Red	05130206	53	8	48%
Rockcastle	05130102	62	9	100%
Licking	05100101	67	10	100%

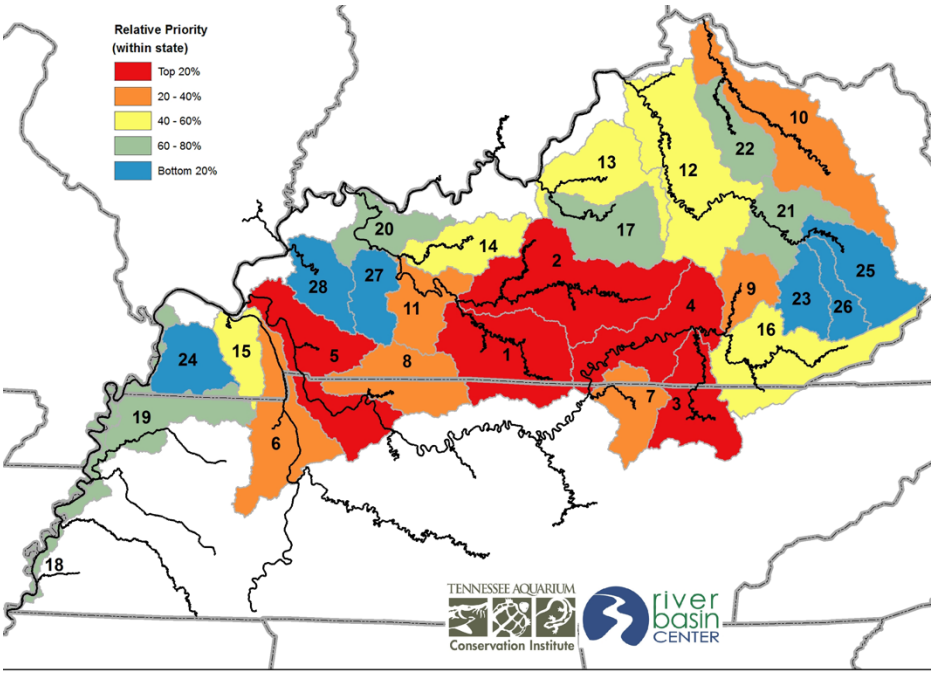


Figure 14 Within-state all-taxa priority rankings for sub-basins in Kentucky

Mississippi

Table 14 Top sub-basins in Mississippi by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Pickwick Lake	6030005	2	1	10%
Lower Tennessee-Beech	6040001	14	2	2%
Middle Tombigbee-Lubbub	3160106	24	3	24%
Upper Tombigbee	3160101	35	4	93%
Noxubee	3160108	49	5	91%
Pascagoula	3170006	51	6	100%
Bear	6030006	52	7	13%
Buttahatchee	3160103	61	8	22%
Lower Pearl	3180004	67	9	72%

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Sucarnoochee	3160202	81	10	58%

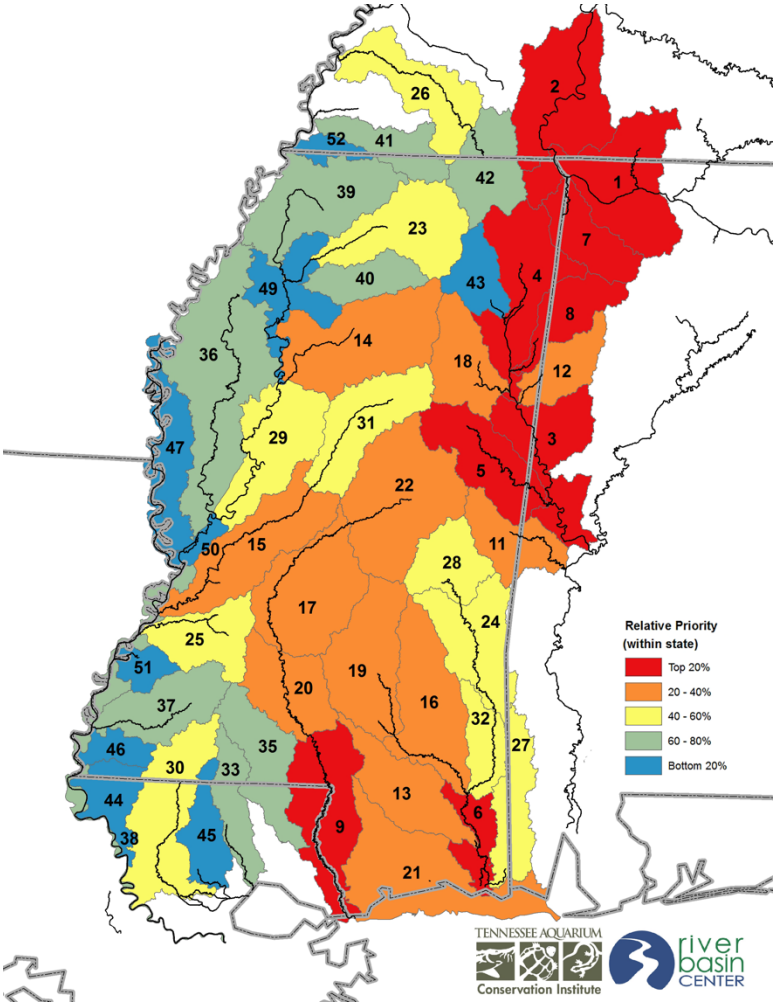


Figure 15 Within-state all-taxa priority rankings for sub-basins in Mississippi

North Carolina

Table 15 Top sub-basins in North Carolina by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Hiwassee	06020002	29	1	31%
Lower Little Tennessee	06010204	37	2	26%
Nolichucky	06010108	45	3	38%
Waccamaw	03040206	68	4	64%
Black	03030006	82	5	32%
Lower Pee Dee	03040201	91	6	20%
Upper Neuse	03020201	102	7	100%
Saluda	03050109	106	8	0%

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Upper Tar	03020101	110	9	100%
Upper Little Tennessee	06010202	115	10	95%

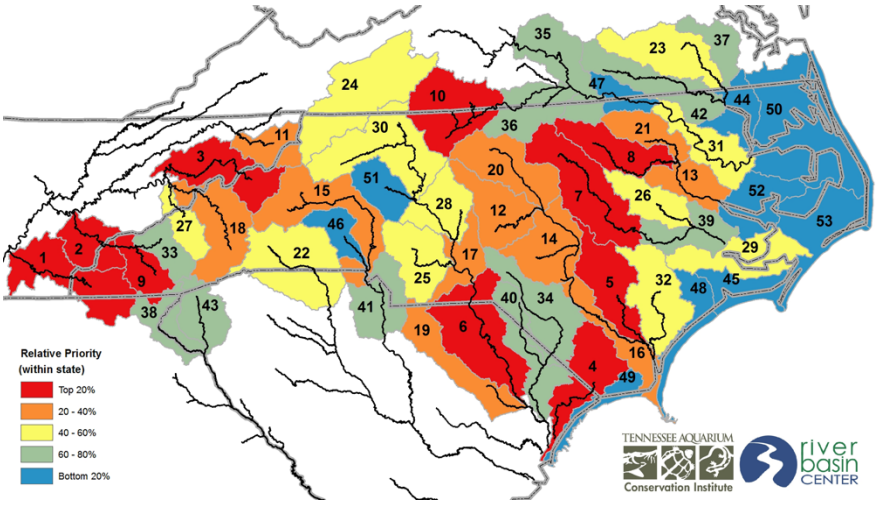


Figure 16 Within-state all-taxa priority rankings for sub-basins in North Carolina

South Carolina

Table 16 Top sub-basins in South Carolina by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Waccamaw	03040206	68	1	36%
Middle Savannah	03060106	80	2	54%
Black	03040205	82	3	42%
Lower Pee Dee	03040201	91	4	80%
Saluda	03050109	106	5	100%
Lynches	03040202	142	6	99%
Upper Broad	03050105	148	7	39%
Congaree	03050110	152	8	100%
Wateree	03050104	158	9	100%
Lake Marion	03050111	178	10	100%

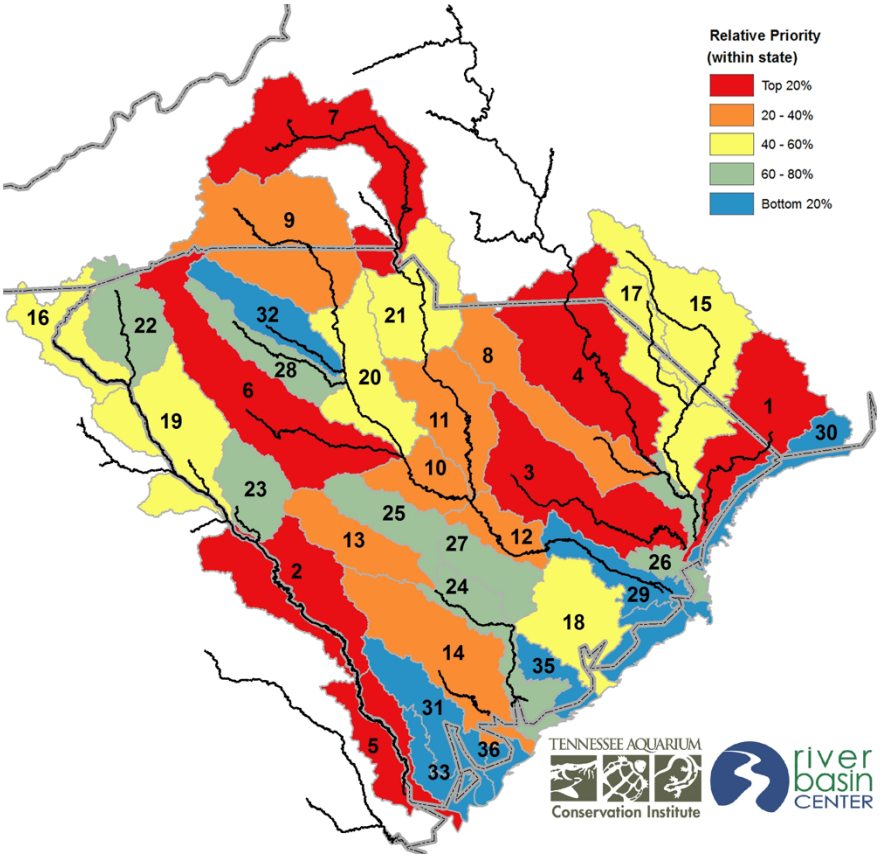


Figure 17 Within-state all-taxa priority rankings for sub-basins in South Carolina

Tennessee

Table 17 Top sub-basins in Tennessee by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Pickwick Lake	06030005	1	1	28%
Upper Clinch, Tennessee, Virginia	06010205	4	2	36%
Conasauga	03150101	7	3	17%
Lower Duck	06040003	6	4	100%
Caney	05130108	10	5	100%
Lower Tennessee-Beech	06040001	14	6	98%
Upper Duck	06040002	13	7	100%
Middle Tennessee-Chickamauga	06020001	18	8	65%
South Fork Cumberland	05130104	15	9	72%
Guntersville Lake	06030001	19	10	17%
Forked Deer	08010206	288	50	100%

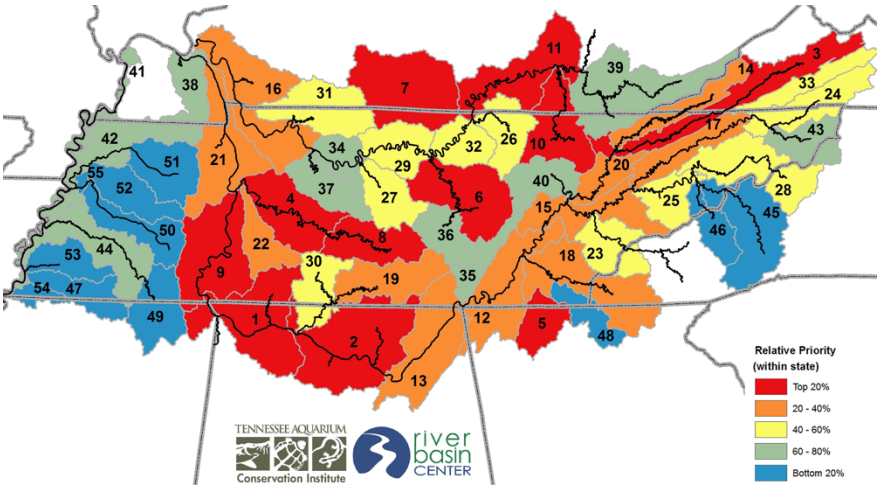


Figure 18 Within-state all-taxa priority rankings for sub-basins in Tennessee

Virginia

Table 18 Top sub-basins in southern Virginia by overall priority rank

Sub-basin Name	HUC-8	Regional Rank	State Rank	% In State
Upper Clinch	06010205	4	1	64%
Powell	06010206	20	2	57%
South Fork Holston	06010102	38	3	52%
North Fork Holston	06010101	55	4	96%
Upper Dan	03010103	120	5	57%
Nottoway	03010201	153	6	100%
Upper New	05050001	159	7	73%
Middle Roanoke	03010102	201	8	82%
Lower Dan	03010104	202	9	44%
Middle New	05050002	207	10	52%

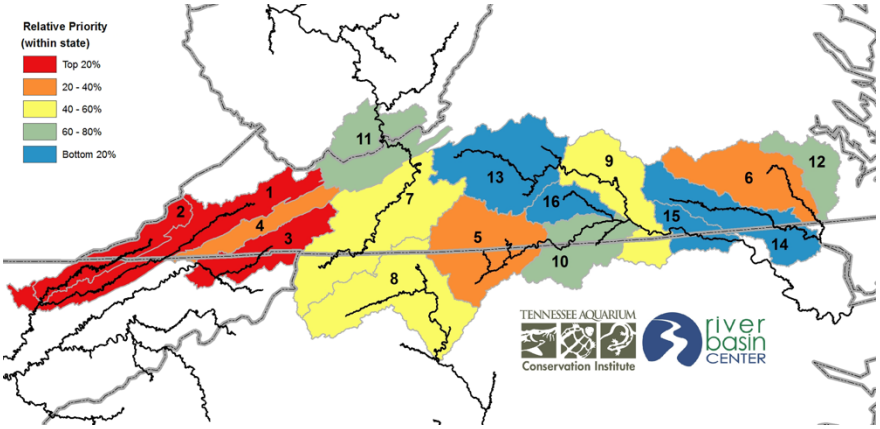


Figure 19 Within-state all-taxa priority rankings for sub-basins in southern Virginia

Sub-Basin Priority within Sub-Regions (HUC-4)

Table 19 Within-basin (HUC-4) and overall priority ranks for all 290 sub-basins.

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Chowan-Roanoke (0301)	Upper Dan (03010103)	120	1
Chowan-Roanoke (0301)	Nottoway (03010201)	153	2
Chowan-Roanoke (0301)	Lower Roanoke (03010107)	188	3
Chowan-Roanoke (0301)	Middle Roanoke (03010102)	201	4
Chowan-Roanoke (0301)	Lower Dan (03010104)	202	5
Chowan-Roanoke (0301)	Upper Roanoke (03010101)	220	6
Chowan-Roanoke (0301)	Meherrin (03010204)	224	7
Chowan-Roanoke (0301)	Chowan (03010203)	230	8
Chowan-Roanoke (0301)	Roanoke Rapids (03010106)	259	9
Chowan-Roanoke (0301)	Albemarle (03010205)	267	10
Chowan-Roanoke (0301)	Blackwater (03010202)	272	11
Chowan-Roanoke (0301)	Banister (03010105)	276	12
Neuse-Pamlico (0302)	Upper Neuse (03020201)	102	1
Neuse-Pamlico (0302)	Upper Tar (03020101)	110	2
Neuse-Pamlico (0302)	Lower Tar (03020103)	128	3
Neuse-Pamlico (0302)	Fishing (03020102)	145	4
Neuse-Pamlico (0302)	Contentnea (03020203)	172	5
Neuse-Pamlico (0302)	Lower Neuse (03020204)	181	6
Neuse-Pamlico (0302)	Middle Neuse (03020202)	211	7
Neuse-Pamlico (0302)	White Oak River (03020301)	245	8
Neuse-Pamlico (0302)	New River (03020302)	262	9
Neuse-Pamlico (0302)	Pamlico (03020104)	271	10
Neuse-Pamlico (0302)	Pamlico Sound (03020105)	279	11
Cape Fear (0303)	Deep (03030003)	126	1
Cape Fear (0303)	Upper Cape Fear (03030004)	130	2
Cape Fear (0303)	Lower Cape Fear (03030005)	137	3
Cape Fear (0303)	Haw (03030002)	143	4
Cape Fear (0303)	Northeast Cape Fear (03030007)	192	5
Cape Fear (0303)	Black (03030006)	205	6
Pee Dee (0304)	Waccamaw (03040206)	68	1
Pee Dee (0304)	Lower Pee Dee (03040201)	91	2
Pee Dee (0304)	Upper Pee Dee (03040104)	139	3
Pee Dee (0304)	Lynches (03040202)	142	4
Pee Dee (0304)	Rocky (03040105)	160	5
Pee Dee (0304)	Lower Yadkin (03040103)	180	6
Pee Dee (0304)	Upper Yadkin (03040101)	187	7
Pee Dee (0304)	Black (03040205)	196	8
Pee Dee (0304)	Lumber (03040203)	197	9

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Pee Dee (0304)	Little Pee Dee (03040204)	213	10
Pee Dee (0304)	Carolina Coastal-Sampit (03040207)	254	11
Pee Dee (0304)	Coastal Carolina (03040208)	264	12
Pee Dee (0304)	South Yadkin (03040102)	270	13
Edisto-Santee (0305)	Saluda (03050109)	106	1
Edisto-Santee (0305)	Upper Catawba (03050101)	133	2
Edisto-Santee (0305)	Upper Broad (03050105)	148	3
Edisto-Santee (0305)	Congaree (03050110)	152	4
Edisto-Santee (0305)	Wateree (03050104)	158	5
Edisto-Santee (0305)	Lake Marion (03050111)	178	6
Edisto-Santee (0305)	South Fork Edisto (03050204)	185	7
Edisto-Santee (0305)	Salkehatchie (03050207)	193	8
Edisto-Santee (0305)	Cooper (03050201)	215	9
Edisto-Santee (0305)	Lower Broad (03050106)	219	10
Edisto-Santee (0305)	Lower Catawba (03050103)	222	11
Edisto-Santee (0305)	Edisto River (03050206)	242	12
Edisto-Santee (0305)	North Fork Edisto (03050203)	247	13
Edisto-Santee (0305)	South Fork Catawba (03050102)	250	14
Edisto-Santee (0305)	Four Hole Swamp (03050205)	255	15
Edisto-Santee (0305)	Enoree (03050108)	258	16
Edisto-Santee (0305)	Santee (03050112)	260	17
Edisto-Santee (0305)	Broad-St. Helena (03050208)	273	18
Edisto-Santee (0305)	Tyger (03050107)	277	19
Edisto-Santee (0305)	Bulls Bay (03050209)	286	20
Edisto-Santee (0305)	South Carolina Coastal (03050202)	289	21
Edisto-Santee (0305)	St. Helena Island (03050210)	290	22
Ogeechee-Savannah (0306)	Middle Savannah (03060106)	80	1
Ogeechee-Savannah (0306)	Lower Savannah (03060109)	104	2
Ogeechee-Savannah (0306)	Lower Ogeechee (03060202)	127	3
Ogeechee-Savannah (0306)	Upper Ogeechee (03060201)	149	4
Ogeechee-Savannah (0306)	Tugaloo (03060102)	210	5
Ogeechee-Savannah (0306)	Upper Savannah (03060103)	217	6
Ogeechee-Savannah (0306)	Seneca (03060101)	226	7
Ogeechee-Savannah (0306)	Broad (03060104)	227	8
Ogeechee-Savannah (0306)	Stevens (03060107)	229	9

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Ogeechee-Savannah (0306)	Brier (03060108)	231	10
Ogeechee-Savannah (0306)	Ogeechee Coastal (03060204)	241	11
Ogeechee-Savannah (0306)	Canoochee (03060203)	246	12
Ogeechee-Savannah (0306)	Little (03060105)	256	13
Ogeechee-Savannah (0306)	Calibogue Sound-Wright River (03060110)	280	14
Altamaha-St. Marys (0307)	Lower Oconee (03070102)	114	1
Altamaha-St. Marys (0307)	Upper Ocmulgee (03070103)	121	2
Altamaha-St. Marys (0307)	Altamaha (03070106)	125	3
Altamaha-St. Marys (0307)	Lower Ocmulgee (03070104)	129	4
Altamaha-St. Marys (0307)	Ohoopee (03070107)	169	5
Altamaha-St. Marys (0307)	Upper Oconee (03070101)	195	6
Altamaha-St. Marys (0307)	Little Ocmulgee (03070105)	223	7
Altamaha-St. Marys (0307)	St. Marys (03070204)	225	8
Altamaha-St. Marys (0307)	Satilla (03070201)	268	9
Altamaha-St. Marys (0307)	Little Satilla (03070202)	281	10
Altamaha-St. Marys (0307)	Nassau (03070205)	283	11
Altamaha-St. Marys (0307)	Cumberland-St. Simons (03070203)	284	12
St. Johns (0308)	Lower St. Johns (03080103)	134	1
St. Johns (0308)	Oklawaha (03080102)	166	2
St. Johns (0308)	Upper St. Johns (03080101)	177	3
St. Johns (0308)	Daytona-St. Augustine (03080201)	274	4
Peace-Tampa Bay (0310)	Withlacoochee (03100208)	244	1
Peace-Tampa Bay (0310)	Crystal-Pithlachascotee (03100207)	249	2
Suwannee (0311)	Lower Suwannee (03110205)	155	1
Suwannee (0311)	Santa Fe (03110206)	162	2
Suwannee (0311)	Upper Suwannee (03110201)	189	3
Suwannee (0311)	Withlacoochee (03110203)	204	4
Suwannee (0311)	Econfina-Steinhatchee (03110102)	240	5
Suwannee (0311)	Aucilla (03110103)	251	6
Suwannee (0311)	Alapaha (03110202)	253	7
Suwannee (0311)	Waccasassa (03110101)	263	8
Suwannee (0311)	Little (03110204)	278	9
Ochlockonee (0312)	Lower Ochlockonee (03120003)	117	1

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Ochlockonee (0312)	Upper Ochlockonee (03120002)	186	2
Ochlockonee (0312)	Apalachee Bay-St. Marks (03120001)	216	3
Apalachicola (0313)	Middle Chattahoochee-Walter F (03130003)	56	1
Apalachicola (0313)	Apalachicola (03130011)	60	2
Apalachicola (0313)	Chipola (03130012)	66	3
Apalachicola (0313)	Lower Chattahoochee (03130004)	70	4
Apalachicola (0313)	Upper Flint (03130005)	78	5
Apalachicola (0313)	Lower Flint (03130008)	88	6
Apalachicola (0313)	Ichawaynochaway (03130009)	90	7
Apalachicola (0313)	Middle Chattahoochee-Lake Harding (03130002)	100	8
Apalachicola (0313)	Middle Flint (03130006)	103	9
Apalachicola (0313)	Kinchafoonee-Muckalee (03130007)	138	10
Apalachicola (0313)	Spring (03130010)	144	11
Apalachicola (0313)	Upper Chattahoochee (03130001)	190	12
Apalachicola (0313)	New (03130013)	282	13
Apalachicola (0313)	Apalachicola Bay (03130014)	287	14
Choctawhatchee-Escambia (0314)	Lower Conecuh (03140304)	64	1
Choctawhatchee-Escambia (0314)	Escambia (03140305)	72	2
Choctawhatchee-Escambia (0314)	Yellow (03140103)	79	3
Choctawhatchee-Escambia (0314)	Lower Choctawhatchee (03140203)	81	4
Choctawhatchee-Escambia (0314)	Upper Choctawhatchee (03140201)	89	5
Choctawhatchee-Escambia (0314)	Pea (03140202)	92	6
Choctawhatchee-Escambia (0314)	St. Andrew-St. Joseph Bays (03140101)	94	7
Choctawhatchee-Escambia (0314)	Upper Conecuh (03140301)	113	8
Choctawhatchee-Escambia (0314)	Sepulga (03140303)	156	9
Choctawhatchee-Escambia (0314)	Choctawhatchee Bay (03140102)	167	10
Choctawhatchee-Escambia (0314)	Patsaliga (03140302)	191	11
Choctawhatchee-Escambia (0314)	Pensacola Bay (03140105)	199	12
Choctawhatchee-Escambia (0314)	Blackwater (03140104)	208	13
Choctawhatchee-Escambia (0314)	Perdido (03140106)	212	14

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Choctawhatchee-Escambia (0314)	Perdido Bay (03140107)	232	15
Alabama (0315)	Cahaba (03150202)	3	1
Alabama (0315)	Middle Coosa (03150106)	5	2
Alabama (0315)	Conasauga (03150101)	7	3
Alabama (0315)	Lower Coosa (03150107)	8	4
Alabama (0315)	Etowah (03150104)	9	5
Alabama (0315)	Lower Alabama (03150204)	17	6
Alabama (0315)	Upper Alabama (03150201)	23	7
Alabama (0315)	Lower Tallapoosa (03150110)	25	8
Alabama (0315)	Coosawattee (03150102)	26	9
Alabama (0315)	Middle Alabama (03150203)	28	10
Alabama (0315)	Upper Coosa (03150105)	30	11
Alabama (0315)	Oostanaula (03150103)	59	12
Alabama (0315)	Middle Tallapoosa (03150109)	86	13
Alabama (0315)	Upper Tallapoosa (03150108)	105	14
Mobile-Tombigbee (0316)	Middle Tombigbee-Lubbub (03160106)	22	1
Mobile-Tombigbee (0316)	Locust (03160111)	34	2
Mobile-Tombigbee (0316)	Upper Tombigbee (03160101)	35	3
Mobile-Tombigbee (0316)	Upper Black Warrior (03160112)	41	4
Mobile-Tombigbee (0316)	Lower Tombigbee (03160203)	42	5
Mobile-Tombigbee (0316)	Noxubee (03160108)	44	6
Mobile-Tombigbee (0316)	Middle Tombigbee-Chickasaw (03160201)	49	7
Mobile-Tombigbee (0316)	Sipsey Fork (03160110)	50	8
Mobile-Tombigbee (0316)	Lower Black Warrior (03160113)	52	9
Mobile-Tombigbee (0316)	Mobile-Tensaw (03160204)	57	10
Mobile-Tombigbee (0316)	Buttahatchee (03160103)	58	11
Mobile-Tombigbee (0316)	Sipsey (03160107)	63	12
Mobile-Tombigbee (0316)	Mulberry (03160109)	74	13
Mobile-Tombigbee (0316)	Sucarnoochee (03160202)	76	14
Mobile-Tombigbee (0316)	Luxapallila (03160105)	77	15
Mobile-Tombigbee (0316)	Tibbee (03160104)	99	16
Mobile-Tombigbee (0316)	Mobile Bay (03160205)	151	17
Mobile-Tombigbee (0316)	Town (03160102)	221	18

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Pascagoula (0317)	Pascagoula (03170006)	46	1
Pascagoula (0317)	Black (03170007)	82	2
Pascagoula (0317)	Lower Leaf (03170005)	97	3
Pascagoula (0317)	Upper Leaf (03170004)	107	4
Pascagoula (0317)	Mississippi Coastal (03170009)	111	5
Pascagoula (0317)	Upper Chickasawhay (03170002)	131	6
Pascagoula (0317)	Escatawpa (03170008)	140	7
Pascagoula (0317)	Chunky-Okatibbee (03170001)	146	8
Pascagoula (0317)	Lower Chickasawhay (03170003)	161	9
Pearl (0318)	Lower Pearl (03180004)	65	1
Pearl (0318)	Middle Pearl-Strong (03180002)	101	2
Pearl (0318)	Middle Pearl-Silver (03180003)	109	3
Pearl (0318)	Upper Pearl (03180001)	118	4
Pearl (0318)	Bogue Chitto (03180005)	170	5
Kanawha (0505)	Upper New (05050001)	159	1
Kanawha (0505)	Greenbrier (05050003)	163	2
Kanawha (0505)	Middle New (05050002)	207	3
Kanawha (0505)	Gauley (05050005)	238	4
Kanawha (0505)	Lower New (05050004)	261	5
Kentucky-Licking (0510)	Licking (05100101)	67	1
Kentucky-Licking (0510)	Lower Kentucky (05100205)	73	2
Kentucky-Licking (0510)	Upper Kentucky (05100204)	124	3
Kentucky-Licking (0510)	South Fork Licking (05100102)	132	4
Kentucky-Licking (0510)	South Fork Kentucky (05100203)	147	5
Kentucky-Licking (0510)	North Fork Kentucky (05100201)	165	6
Kentucky-Licking (0510)	Middle Fork Kentucky (05100202)	174	7
Green (0511)	Barren (05110002)	11	1
Green (0511)	Upper Green (05110001)	12	2
Green (0511)	Middle Green (05110003)	71	3
Green (0511)	Rough (05110004)	85	4
Green (0511)	Lower Green (05110005)	122	5
Green (0511)	Pond (05110006)	175	6

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Cumberland (0513)	Caney (05130108)	10	1
Cumberland (0513)	South Fork Cumberland (05130104)	15	2
Cumberland (0513)	Upper Cumberland-Lake Cumberland (05130103)	16	3
Cumberland (0513)	Lower Cumberland (05130205)	24	4
Cumberland (0513)	Obey (05130105)	40	5
Cumberland (0513)	Stones (05130203)	43	6
Cumberland (0513)	Lower Cumberland-Old Hickory Lake (05130201)	47	7
Cumberland (0513)	Red (05130206)	53	8
Cumberland (0513)	Upper Cumberland-Cordell Hull Reservoir (05130106)	54	9
Cumberland (0513)	Lower Cumberland-Sycamore (05130202)	61	10
Cumberland (0513)	Rockcastle (05130102)	62	11
Cumberland (0513)	Collins (05130107)	75	12
Cumberland (0513)	Harpeth (05130204)	83	13
Cumberland (0513)	Upper Cumberland (05130101)	95	14
Lower Ohio (0514)	Salt (05140102)	84	1
Lower Ohio (0514)	Rolling Fork (05140103)	108	2
Lower Ohio (0514)	Tradewater (05140205)	200	3
Upper Tennessee (0601)	Upper Clinch, Tennessee, Virginia (06010205)	4	1
Upper Tennessee (0601)	Powell (06010206)	20	2
Upper Tennessee (0601)	Watts Bar Lake (06010201)	21	3
Upper Tennessee (0601)	Holston (06010104)	27	4
Upper Tennessee (0601)	Lower Clinch (06010207)	32	5
Upper Tennessee (0601)	Lower Little Tennessee (06010204)	37	6
Upper Tennessee (0601)	South Fork Holston (06010102)	38	7
Upper Tennessee (0601)	Lower French Broad (06010107)	39	8
Upper Tennessee (0601)	Nolichucky (06010108)	45	9
Upper Tennessee (0601)	North Fork Holston (06010101)	55	10
Upper Tennessee (0601)	Emory (06010208)	96	11
Upper Tennessee (0601)	Upper Little Tennessee (06010202)	115	12

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Upper Tennessee (0601)	Watauga, North Carolina, Tennessee (06010103)	123	13
Upper Tennessee (0601)	Upper French Broad (06010105)	141	14
Upper Tennessee (0601)	Pigeon (06010106)	179	15
Upper Tennessee (0601)	Tuckasegee (06010203)	194	16
Middle Tennessee-Hiwassee (0602)	Middle Tennessee-Chickamauga (06020001)	18	1
Middle Tennessee-Hiwassee (0602)	Hiwassee (06020002)	29	2
Middle Tennessee-Hiwassee (0602)	Sequatchie (06020004)	69	3
Middle Tennessee-Hiwassee (0602)	Ocoee (06020003)	203	4
Middle Tennessee-Elk (0603)	Pickwick Lake (06030005)	1	1
Middle Tennessee-Elk (0603)	Wheeler Lake (06030002)	2	2
Middle Tennessee-Elk (0603)	Guntersville Lake (06030001)	19	3
Middle Tennessee-Elk (0603)	Upper Elk (06030003)	31	4
Middle Tennessee-Elk (0603)	Bear (06030006)	48	5
Middle Tennessee-Elk (0603)	Lower Elk (06030004)	51	6
Lower Tennessee (0604)	Lower Duck (06040003)	6	1
Lower Tennessee (0604)	Upper Duck (06040002)	13	2
Lower Tennessee (0604)	Lower Tennessee-Beech (06040001)	14	3
Lower Tennessee (0604)	Kentucky Lake (06040005)	33	4
Lower Tennessee (0604)	Buffalo (06040004)	36	5
Lower Tennessee (0604)	Lower Tennessee (06040006)	87	6
Lower Mississippi-Hatchie (0801)	Lower Mississippi-Memphis (08010100)	112	1
Lower Mississippi-Hatchie (0801)	Obion (08010202)	116	2
Lower Mississippi-Hatchie (0801)	Lower Hatchie (08010208)	136	3
Lower Mississippi-Hatchie (0801)	Bayou De Chien-Mayfield (08010201)	164	4
Lower Mississippi-Hatchie (0801)	Wolf (08010210)	198	5
Lower Mississippi-Hatchie (0801)	Upper Hatchie (08010207)	206	6
Lower Mississippi-Hatchie (0801)	South Fork Forked Deer (08010205)	218	7
Lower Mississippi-Hatchie (0801)	South Fork Obion (08010203)	233	8
Lower Mississippi-Hatchie (0801)	North Fork Forked Deer (08010204)	239	9
Lower Mississippi-Hatchie (0801)	Loosahatchie (08010209)	257	10
Lower Mississippi-Hatchie (0801)	Horn Lake-Nonconnah	285	11

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
	(08010211)		
Lower Mississippi-Hatchie (0801)	Forked Deer (08010206)	288	12
Lower Mississippi-St. Francis (0802)	Lower Mississippi-Helena (08020100)	269	1
Lower Mississippi-Yazoo (0803)	Yalobusha (08030205)	93	1
Lower Mississippi-Yazoo (0803)	Little Tallahatchie (08030201)	119	2
Lower Mississippi-Yazoo (0803)	Upper Yazoo (08030206)	154	3
Lower Mississippi-Yazoo (0803)	Big Sunflower (08030207)	173	4
Lower Mississippi-Yazoo (0803)	Coldwater (08030204)	182	5
Lower Mississippi-Yazoo (0803)	Yocona (08030203)	184	6
Lower Mississippi-Yazoo (0803)	Deer-Steele (08030209)	237	7
Lower Mississippi-Yazoo (0803)	Lower Mississippi-Greenville (08030100)	243	8
Lower Mississippi-Yazoo (0803)	Tallahatchie (08030202)	248	9
Lower Mississippi-Yazoo (0803)	Lower Yazoo (08030208)	266	10
Lower Mississippi-Big Black (0806)	Lower Big Black (08060202)	98	1
Lower Mississippi-Big Black (0806)	Bayou Pierre (08060203)	135	2
Lower Mississippi-Big Black (0806)	Upper Big Black (08060201)	157	3
Lower Mississippi-Big Black (0806)	Lower Mississippi-Natchez (08060100)	171	4
Lower Mississippi-Big Black (0806)	Homochitto (08060205)	176	5
Lower Mississippi-Big Black (0806)	Buffalo (08060206)	236	6
Lower Mississippi-Big Black (0806)	Coles Creek (08060204)	275	7
Lower Mississippi-Lake Maurepas (0807)	Amite (08070202)	150	1
Lower Mississippi-Lake Maurepas (0807)	Tangipahoa (08070205)	168	2
Lower Mississippi-Lake Maurepas (0807)	Lower Mississippi-Baton Rouge (08070100)	183	3
Lower Mississippi-Lake Maurepas (0807)	Bayou Sara-Thompson (08070201)	228	4
Lower Mississippi-Lake Maurepas (0807)	Tickfaw (08070203)	235	5
Lower Mississippi-Lake Maurepas (0807)	Lake Maurepas (08070204)	265	6
Lower Mississippi (0809)	Liberty Bayou-Tchefuncta (08090201)	209	1
Lower Mississippi (0809)	Lower Mississippi-New Orleans (08090100)	214	2
Lower Mississippi (0809)	Eastern Louisiana Coastal (08090203)	234	3

Huc-4 Name (HUC-4 Code)	HUC-8 Name (HUC-8 Code)	Regional Priority	Basin Priority
Lower Mississippi (0809)	Lake Pontchartrain (08090202)	252	4

Extinction, Extirpation, and Error Rates

In an effort to be transparent about the limitations of our approach, the following section examines the sources of bias and error in our analysis and attempts to quantify these for the top-tier watersheds. As we assembled the datasets used to calculate the species presence matrix that underpins the richness, imperilment, and endemism maps, we excluded records from species known to be extinct (two fishes, *Moxostoma lacerum* and *Fundulus albolineatus*, and a number of mussel species, e.g., *Epioblasma metastriata, Epioblasma othcaloogensis,* and *Pleuroblema fibuloides* in the Conasauga River). It should be noted, however, that the increasing recognition of cryptic biodiversity (Williams et al. 2008, Powers et al. 2012, Baker et al. 2013) among southeastern species suggests that there may be multiple undocumented extinctions hidden in our historical data. We did not exclude records in areas where species have been extirpated, reasoning that 1) extirpation is difficult to document using point samples from multiple sources collected with differing techniques and 2) a local extirpation is an opportunity for a reintroduction, if the habitat is capable of now supporting the species and an appropriate source population can be found. Such reintroductions have been performed by groups such as Conservation Fisheries Incorporated and the Alabama Aquatic Biodiversity Center with increasing regularity. However, we recognize that such extirpations are probably widespread as a result of human alterations including dams, mining, and land conversion and that such extirpations bias our species richness estimates upward relative to the extant biodiversity in streams and rivers today. It would be very difficult to reliably infer extirpations across the region using the field data we assembled and to do so from the literature would require consulting multiple published and unpublished accounts of over 1000 individual species. Nevertheless, we wanted to estimate the effect of this bias on our prioritization system by using our top-ranked watersheds as a sample. We consulted published reports for fish extirpations in the top 11 watersheds in the overall prioritization. These are summarized in Table 20, along with the circumstances of the extirpation, where provided. Within these 11 of the richest sub-basins for fish diversity, there is an average of 4 extirpated species (3.3%) and this varied from 0 (two sub-basins) to 10 (Pickwick Lake). We found no accounts in the reference material for these sub-basins of species that we had not recorded (i.e., no false positives).

Table 20 Fish extirpations in the top 11 watersheds

Cahaba	130 total species, 7 extirpated	(5.4%)
	Species	Putative cause
	Acipsenser oxirynchus desotoi	dams
	Alosa alabamae	dams
	Cyprinella caerulea	sedimentation

	Hybognathus nuchalis	dams
	Fundulus stellifer	unknown
	Mugil cephalus	dams
	Sander sp. cf. vitreus	unknown, possibly hydridization
Lower Coosa	107 total species, 3 extirpated	(2.8%)
	Species	Putative cause
	Acipsenser oxirynchus desotoi	dams
	Scaphirhynchus suttkusi	dams
	Alosa alabamae	dams
Middle Coosa	87 total species, 1 extirpated	(1.1%)
	Species	Putative cause
	Percina brevicauda	dams
Etowah	81 total species, 1 extirpated	(1.2%)
	Species	Putative cause
	Cyprinella caerulea	sedimentation
Conasauga	80 total species, 2 extirpated	(2.5%)
	Species	Putative cause
	Noturus sp. cf. munitus	Sedimentation & water quality
	Percina shumardi	unknown
Lower Duck	133 total species, none extirpated	(0%)
Pickwick Lake	142 total species, 10 extirpated	(7%)
	Species	Putative cause
	Scaphirhynchus platorynchus	dams
	Hiodon alosoides	dams
	Hybognathus hayi	drainage of wetlands
	Hybognathus nuchalis	dams
	Notropis albizonatus	dams
	Notropis ariommus	dams
	Noturus miurus	sedimentation & water quality
	Etheostoma cinereum	dams
	Percina vigil	dams
	Elassoma alabamae	dams
Wheeler	120 total species, 7 extirpated	(5.8%)
	Species	Putative cause
	Scaphirhynchus platorynchus	dams

	Lepisosteus platostomus	dams
	Hiodon alosoides	dams
	Hybognathus hayi	drainage of wetlands
	Hybognathus nuchalis	dams
	Phenacobius uranops	dams
	Noturus crypticus	sedimentation & water quality
Upper Clinch	110 total species, 4 extirpated	(3.6%)
	Species	Putative cause
	Macrhybopsis hyostoma	dams
	Notropis albizonatus	dams
	Notropis buchanani	dams
	Cycleptus elongatus	dams
Caney Fork	86 total species, no extirpations	(0%)
Barren	109 total species, 4 extirpations	(3.7%)
	Species	Putative cause
	Hybognathus nuchalis	dams
	Notropis amnis	unknown
	Noturus exilis	unknown
	Percina evides	dams

We asked several mussel experts to assess extirpations in the same areas. Bob Butler with the US Fish and Wildlife Service provided us with galley proofs of an in-press assessment (Ahlstedt, et al. 2016) of the Clinch and Powell systems. Their survey of the segment corresponding to the Upper Clinch sub-basin, i.e. the Clinch above Norris Lake, lists 55 total species known, of which 48 are considered extant, with 4 extirpations (*Leptodea fragilis, Leptodea leptodon, Quadrula intermedia, Villosa fabalis*) and 3 extinctions (*Epioblasma haysiana*, *Epioblasma lenior*, and *Epioblasma torulosa gubernaculum*). Our database contains 55 species, including the three extirpations (5.5%), plus four that do not appear in their species list (*Fusconaia ozarkensis, Lampsilis cardium, Plethobasus cicatricosus, Villosa vibex*). Our list is missing one species, *Venustaconcha trabalis*, that has been the subject of recent taxonomic revision; we had removed records for *V. troostensis* based on the proposal in Lane, et al. (2016) that this species is found only in drainages of the Cumberland River. We suspect these records are probably *V. trabalis*, based on Ahlstedt, et al. 2016.

Jeff Garner with Alabama Department of Conservation and Natural Resources assessed the sub-basins from set of 11 highest-priority basins that occur in Alabama (Table 21). Within these 5 of the highest-ranking basins for species richness, there are an average of 14 extirpated species, approximately 20% of the total. In addition, there are an average of 6.6 species per watershed

(10%) that he judged to be erroneous. However, the Mussels of Alabama (Williams et al. 2008), lists a pre-dam record for one of these, *Pegias fabula*, in Bluewater Creek of the Pickwick Lake sub-basin, so it may in fact belong among the extirpated.

Table 21 Mussel extirpations in high-priority Alabama sub-basins

Middle Coosa	57 total species, 11 extirpations (19%) Species *Elliptio arca* *Epioblasma penita* *Lasmigona etowaensis* *Ligumia recta* *Medionidus parvulus* *Obovaria arkansasensis* *Obovaria unicolor* *Pleurobema hanleyianum* *Pleurobema hartmanianum* *Pleurobema stabile* *Pleurobema taitianum*
Lower Coosa	52 total species, 9 extirpations (17%) Species *Elliptio arca* *Epioblasma penita* *Lasmigona etowaensis* *Ligumia recta* *Medionidus parvulus* *Obovaria unicolor* *Pleurobema hanleyianum* *Pleurobema hartmanianum* *Pleurobema stabile*
Cahaba	58 total species, 6 extirpations (10%) Species *Elliptio arca* *Medionidus parvulus* *Obovaria arkansasensis* *Obovaria unicolor* *Pleurobema georgianum* *Pleurobema perovatum*
Pickwick Lake	83 total species, 29 extirpations (35%) Species *Actinonaias ligamentina* *Actinonaias pectorosa* *Alasmidonta marginata*

	Alasmidonta viridis *Dromus dromas* *Epioblasma ahlstedti* *Epioblasma brevidens* *Epioblasma capsaeformis* *Epioblasma obliquata obliquata* *Epioblasma triquetra* *Fusconaia cor* *Fusconaia cuneolus* *Hemistena lata* *Lasmigona costata* *Leptodea leptodon* *Medionidus conradicus* *Obovaria olivaria* *Obovaria retusa* *Obovaria subrotunda* *Plethobasus cooperianus* *Pleurobema clava* *Pleurobema oviforme* *Pleuronaia dolabelloides* *Ptychobranchus subtentus* *Quadrula intermedia* *Quadrula sparsa* *Strophitus undulatus* *Toxolasma cylindrellus* *Villosa trabalis*
Wheeler Lake	78 total species, 15 extirpations (19%) Species *Actinonaias ligamentina* *Cyprogenia stegaria* *Dromus dromas* *Epioblasma brevidens* *Epioblasma capsaeformis* *Epioblasma florentina aureola* *Lemiox rimosus* *Obovaria olivaria* *Obovaria retusa* *Plethobasus cicatricosus* *Plethobasus cooperianus* *Pleurobema clava* *Ptychobranchus subtentus* *Quadrula intermedia* *Strophitus undulatus*

We also consulted Williams et al. (2008) and compared the list of species records for the Conasauga. Nine of the 45 species with records in our database for that sub-basin are not listed in the book, an error rate of 20%, and Jason Wisniewski, aquatic zoologist with the Georgia DNR Nongame program and principal malacologist in the state, estimates that the Conasauga historically supported at least 33 species but reports that recent surveys have found approximately 23 species, which suggests that as many as 10-13 species (22-29%) have been extirpated.

The extent of extirpation for crayfishes is even less clear. We asked our crayfish committee if they knew of any HUC-8 sub-basin level extirpations in the Southeast and they suggested three local examples (i.e., observed in smaller areas): two populations (*Cambarus pristinus* and *C. clivosus*) in the Caney Fork putatively due to dams and an undescribed species similar to *Cambarus crinipis* in the Obed drainage putatively due to an introduced species.

Thus, among the basins we assessed, we can confidently say the inflation of current species richness due to possible or confirmed fish extirpations is less than 5%, on average. For mussels, the overall rate is on the order of 20-25%, with comparable level of false-positives due to location errors, misidentified specimens or uncorrected taxonomic revisions in the source data. Since these two assessments were performed using species lists from well-surveyed, high-diversity basins, we expect that these estimates should be no worse elsewhere in the project region, although the extirpation rate will likely be highest in sub-basins that are heavily dammed. For crayfishes, the situation is difficult to assess. It may be that crayfishes are more resilient to the perturbations that have extirpated populations of mussels and fishes. However, it is also likely that the relatively lower level of attention that crayfishes have traditionally received has played a role. This sentiment was captured by Chris Taylor, Curator of Fishes and Crustaceans at the Prairie Research Institute of the Illinois Natural History Survey, who wrote, “I'm not aware of any HUC-wide extirpations of crayfishes. This situation may in part be due to the paucity of historical collections of crayfishes in many regions of the Southeast relative to fishes and mussels (i.e. we may have missed some).”

We feel confident that error rates in the dataset for fishes and crayfishes are minimal, given the limitations of the available data, although for different reasons. Though we are cognizant of cryptic biodiversity, the large number of field samples, relative vigor and maturity of the fish taxonomy in this region, and the availability of published references for each state enabled us to make a thorough, if still laborious, assessment of historic fish distributions. In contrast, the field of astacology is still comparatively small and we were able to gather many of the region’s crayfish experts together to combine and review collections with which they were, in most cases, intimately familiar. Although there have been many fewer field collections and many taxonomic questions remain, the attention and curation the team donated establishes our dataset as a clear snapshot of the current state of crayfish biogeography.

We were unable to achieve a similar level of confidence in the mussel dataset, as evidenced by the error statistics relative to published species lists. Although the state collections are larger

for mussels than for crayfishes, and the georeferenced museum collections much larger, these are apparently still replete with misidentified specimens and uncorrected taxonomic revisions. Although all our range maps were reviewed by at least one malacologist, and typically two or more, these sessions were not as collaborative as the crayfish sessions due simply to the fact that the reviewers were not in the same room. We would welcome the opportunity to revise and improve this dataset further, but this was not feasible given the timing of the data review and the mussel panel's availability during the field season.

While we acknowledge that extirpations and spurious mussel records bias our species richness estimates upwards, we argue that the overall prioritization is still reasonable since these rates were low for fishes and crayfishes, which together make up 78% of the overall species count. Therefore, we did not attempt to correct any of the prioritization scores to account for potential errors, even for the 11 watersheds for which we conducted the error analysis. To correct just these watersheds would have introduced a clear bias in the results.

SOUTHEASTERN CONSERVATION CAPACITY ANALYSIS

An important factor in considering the potential success of conservation investments is the existing capacity within a watershed, as indicated by active government management programs, NGO management programs, and existing investments. This is not straightforward to quantify, but as a simple indicator we sought to identify the number of active NGOs in each watershed in the region. We queried the database of groups on the Environmental Protection Agency's "Adopt Your Watershed" page for groups working in the Southeast and found 632 different organizations registered as focusing on at least one watershed sub-basin in the region. On average, a group listed all or portions of 3.5 sub-basins as their focus area, with this ranging from 1 sub-basin (395 groups) to 96 sub-basins (Alabama Land Trust). These focus areas are not evenly distributed across the Southeast (Figure 20), with as many as 32 groups focusing some effort on the Upper Chattahoochee while 3 or fewer groups focus on most of the state of Mississippi (Figure 9). In general, the Tennessee River system is the focus of many groups, although no groups are focused on the Lower Elk and Pickwick Lake in western Tennessee and northwestern Alabama.

As shown in Table 22, of the 2,229 sub-basin records in the database, 842 project objectives (38%) were described as "Restoration/Conservation Project," while "Watershed Alliance/Council," was listed as an objective in 697 sub-basins (31%) and "Education Project" was listed as an objective in 291 sub-basins (13%).

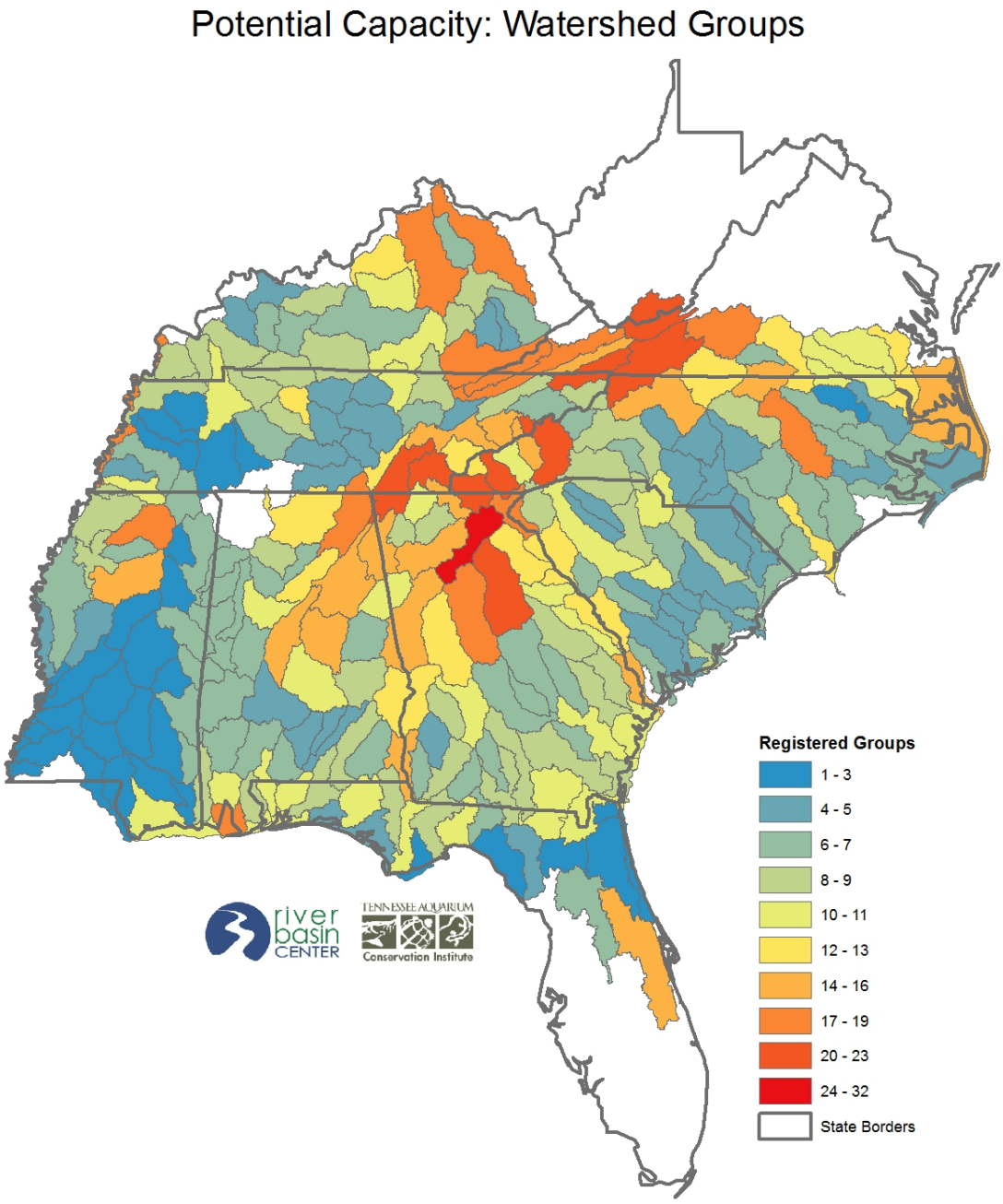


Figure 20 Total number of watershed groups registered in EPA database, per sub-basin, in August 2015. Blank areas within the project region reflect sub-basins where no groups were registered.

Table 22 Activity classes for project objectives in EPA database of watershed groups

Activity Category	# Groups/Projects
Restoration/Conservation Project	730
Watershed Alliance/Council	645
Other	308
Volunteer Monitoring	223
Education Project/Program	193
Education Project/Program, Restoration/Conservation Project, Watershed Alliance/Council, Other	32
Education Project/Program, Restoration/Conservation Project	31
Education Project/Program, Restoration/Conservation Project, Volunteer Monitoring	26
Education Project/Program, Restoration/Conservation Project, Volunteer Monitoring, Watershed Alliance/Council	11
(blank)	11
Education Project/Program, Restoration/Conservation Project, Volunteer Monitoring, Other	3
Volunteer Monitoring, Watershed Alliance/Council	3
Restoration/Conservation Project, Volunteer Monitoring	2
Education Project/Program, Restoration/Conservation Project, Watershed Alliance/Council	2
Education Project/Program, Watershed Alliance/Council	2
Restoration/Conservation Project, other	2
Education Project/Program, Volunteer Monitoring	2
Education Project/Program, Restoration/Conservation Project, Volunteer Monitoring, Watershed Alliance/Council, Other	1
Education Project/Program, Restoration/Conservation Project, Other	1
Restoration/Conservation Project, Watershed Alliance/Council	1
Grand Total	**2229**

Since the average age of a record in this dataset was just over 5.9 years, and the EPA makes no attempt to keep the database current, we decided to survey the groups listed and assess their current level of activity. We constructed a web survey that asked respondents to confirm the information about the area of geographic focus listed in the database. We were also interested in a better assessment of the capacity of each group, so we also included questions about the number of full- and part-time employees, whether the group had recently received external funding, and a brief summary of current projects. Finally, we asked whether respondents could recommend any other groups working in their geographic area for us to contact.

Of the 632 groups in the database, 453 had listed a contact email address when they registered. We emailed surveys to these addresses on September 11, 2015 and followed up with a reminder 10 days later. We found that 175 addresses were no longer current; only 39 surveys were completed, for an initial survey response rate of 8.4%. We were able to find updated contact emails via web searches for 109 of the 453, and we re-mailed survey invitations to those on Dec 7, 2015. Of those, 14 contacts were no longer current and 12 surveys were

completed. In all, two rounds of surveys resulted in 51 responses, a final response rate of 11.3%.

Of the 51 surveys returned, one group is no longer active and all but nine updated either their contact name, email, website, zip, or geographic focus. Exactly half of those who responded to the geographic focus question (21 of 42) did not update their geographic focus. Among those who confirmed or updated their geographic focus, the average number of sub-basins in the focus area was 5.9, with a range from 1 to 49, after two groups listed "statewide" for Georgia (Figure 21).

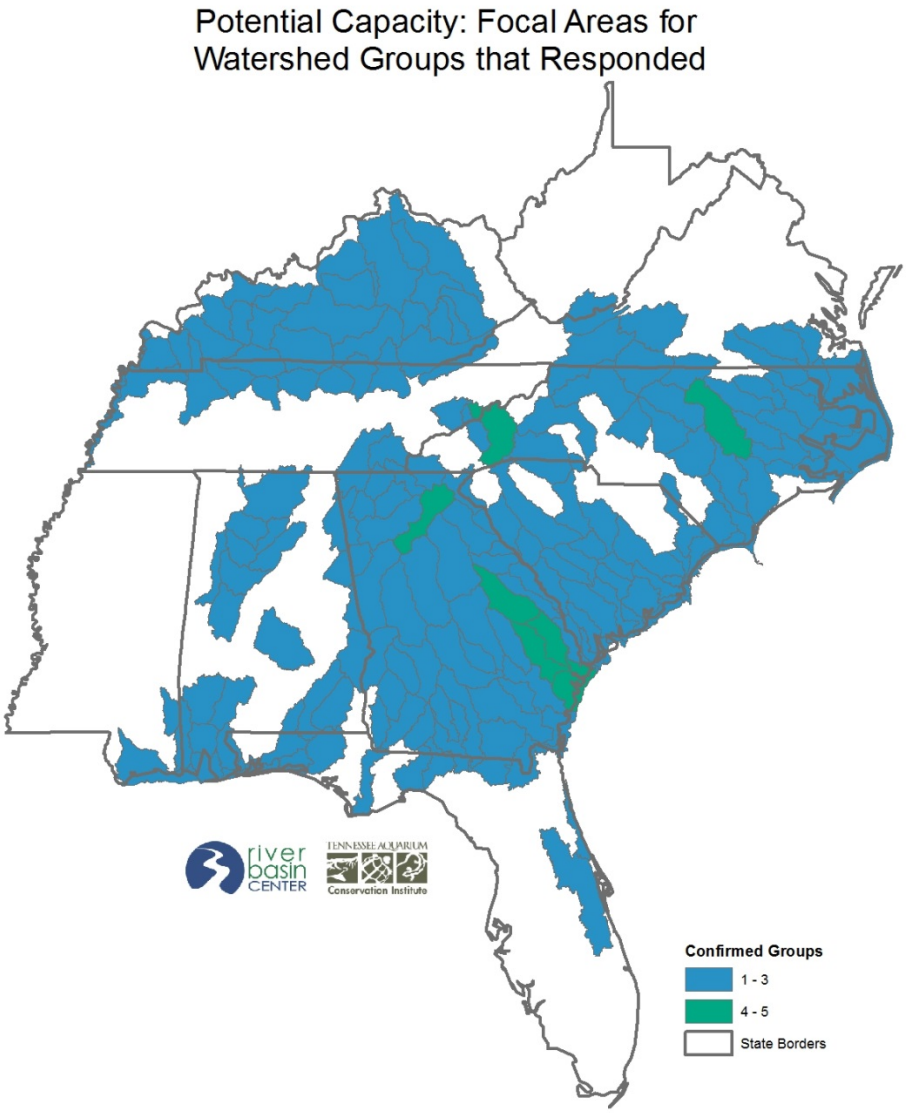


Figure 21 Total number of watershed groups registered, per sub-basin, among survey respondents. Blank areas of the map within the project area were not associated with any group that responded.

The most common activity listed by respondents (Figure 22) was “Education Project/Program,” by 57% of respondents, followed by “Volunteer Monitoring” (49%) and “Restoration/Conservation Project” (35%).

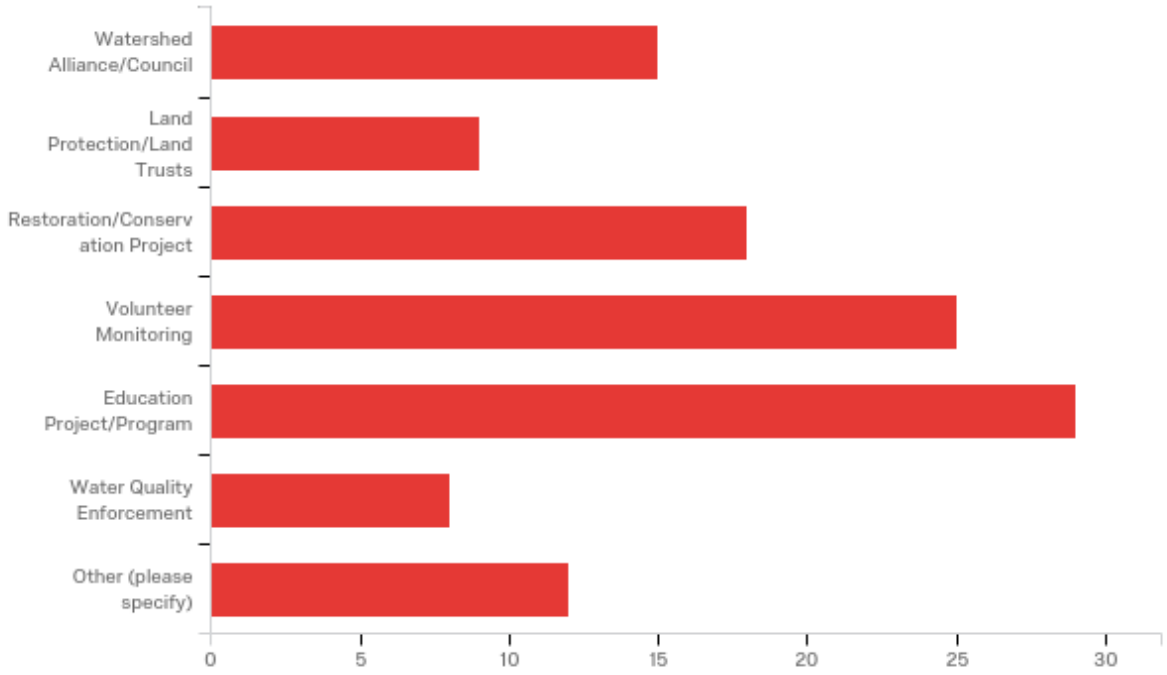


Figure 22- Frequency of group or project objectives on the responses of 51 watershed groups completing surveys. (Respondents were allowed to select more than one response.)

On average, groups reported 3.7 full-time employees, 1.2 part-time employees, and 156 volunteers. Twenty of the respondents (39%) listed at least one externally funded project with a budget exceeding $2000 since 2005.

Capacity Conclusions

While we had hoped that the EPA database would provide a robust foundation for a regional analysis of conservation capacity, this was not the case. Perhaps due to the age of the records, our survey return rate was low and the resulting updated dataset of 50 active organizations was insufficient for a regional analysis. Notably, the organization priorities expressed by the respondents emphasized markedly different activities, with almost 44% more respondents naming educational activities, although the overall proportion reporting restoration or conservation projects was fairly consistent (35% vs. 38%). We suspect that the responses were biased toward active, well-funded organizations, given that they averaged almost 4 FTEs and had substantial success obtaining outside funding. Even among this group, however, the spatial data in the EPA database was incorrect half of the time and the listed contact information was correct for only one in five. While we are reluctant to extrapolate from the corrections supplied for 11% of the dataset, it is clear that the only a small subset of the groups active in the Southeast are sufficiently mature to have a transition plan for receiving external

communications as leadership changes and that the spatial information in the EPA's database is somewhat unreliable, whether as a result of errors at registration or changes in group's interest area over time.

WHAT DOES CONSERVATION COST?

One reason to prioritize river basins is to be able to concentrate conservation investments in a few locations in order to have demonstrable impacts, rather than spreading dollars thinly across a broad landscape. But how much is enough? What does, say, $10 million in funding achieve? This is an exceedingly difficult question to answer due to fundamental differences among species, disparities in land prices, indirect benefits, and the difficulty in detecting population trends (many populations naturally have large year-to-year fluctuations that can mask recovery) to determine whether a project was successful. Perhaps in the case of a very narrowly distributed endemic—such as a species confined to a single headwaters location—we can feasibly estimate the cost of land management, acquisition, or conservation easements. But what is the benefit of a compelling video that is widely viewed and results in changes to public attitudes toward conservation? Ultimately this could be the best investment of all, but quantifying the benefit prospectively is nearly impossible.

Nevertheless, we have good individual projects to evaluate and by examining one of these multi-faceted, long-term conservation campaigns we can provide a ballpark estimate of the cost of conserving a suite of species. For ten years, the Nature Conservancy and its partners have concentrated their efforts in the Etowah Basin within a single sub-watershed: Raccoon Creek. Raccoon Creek is the only tributary of the Lower Etowah with a known population of federally endangered Etowah darters (*Etheostoma etowahae*). It also supports the largest population of the Lower ESU (evolutionarily significant unit) of Cherokee darters (*Etheostoma scotti*). At least 41 other fish species occur in the sub-watershed. Much of Raccoon Creek is covered in secondary forest, with relatively small amounts of urban/suburban development and agriculture.

Since 2005 The Nature Conservancy (TNC) has worked with US Fish and Wildlife Service (FWS), Georgia Department of Natural Resources (DNR) and Paulding County to acquire critical tracts of land throughout the upper Raccoon Creek watershed. Raccoon Creek was identified by TNC and FWS as a priority area based on the local populations of imperiled Cherokee and Etowah darters and the associated highly endemic fish fauna and because the watershed supports the largest remnant longleaf pine population in northwest Georgia. A large portion of the funding came from a $15 million bond passed by Paulding County in 2006 for "preservation of open space, wildlife habitat and recreational areas." County funding has frequently served as match for state land acquisition funds; most notably, they jointly purchased the 6,500-acre Paulding Forest Wildlife Management Area in 2008. This tract covers much of the Raccoon Creek headwaters. In 2013 TNC, FWS and DNR purchased 2,400 acres owned by the Jones Company, most of which lay within the watershed.

Of equal importance, the same partners have also conducted major restoration projects within

the watershed. Between 2008 and 2013, TNC received three Partners For Wildlife Landscape Scale grants to restore a 6,441 linear foot reach of Raccoon Creek immediately downstream from the Paulding County Wildlife Management Area. The reach, which was impacted by a power line right of way, was restored in two phases between 2010 and 2013. In 2014 and 2015 the USFWS, DNR, Paulding County, local landowners, the Chestatee/Chattahoochee Resource Conservation & Development district, and TNC collaborated on the removal of an undersized six-barrel culvert that impeded fish passage from Raccoon Creek into Pegamore Creek, one of its largest tributaries. The culvert was replaced with a 32' free-span steel bridge. Monitoring of Etowah darters and Cherokee darters has been conducted annually by Brett Albanese (DNR) or Bill Ensign (Kennesaw State University) since the initiation of restoration activities, and has shown that populations are steady or increasing. High-profile restoration projects such as these can capture the attention of both the public and decision-makers because they represent the possibility of actual recovery and improvement. Arguably, such efforts catalyze and pave the way for more prosaic conservation activities such as land preservation.

Katie Owens of TNC estimated that conservation spending within the Raccoon Creek watershed between 2005 and 2016 totaled approximately $30 million, of which about 90% was for land acquisition (personal communication, September 2016). She said that TNC's major restoration and preservation goals had been achieved, and these were likely to be lasting because the strong partnership with Paulding County had institutionalized a conservation ethic with respect to Raccoon Creek. The difficulty now, she said, was in steering partners to other priority watersheds in the Upper Etowah (starting with Smithwick Creek) in order to replicate the Raccoon Creek success.

In short, $30 million may be a reasonable figure for a comprehensive suite of successful conservation actions—with a heavy focus on acquisition—resulting in good probability of the long-term health of a 35,100-acre watershed. However, Raccoon Creek is just one of several high-quality tributaries that would require similar investments to more broadly protect the aquatic fauna of the Etowah, so to declare success in the basin as a whole might require several times this amount. (For comparison, the Georgia Conservancy estimates that $150 million, divided equally between state, federal, and private sources, will be required to adequately protect Gopher Tortoise habitat in the state of Georgia, a multi-species conservation problem analogous to that of conserving a watershed because of the complex role of tortoises in their habitat.) The cost elsewhere might be somewhat lower, as the Etowah sits on the outer fringes of Atlanta and its property values are higher than many other priority basins. But this is a reasonable starting point for the cost of a comprehensive, multi-species conservation effort.

That said, in every basin there will be opportunities for projects that represent low-hanging fruit that will meaningfully reduce pressure on at-risk species. One example would be removal of a barrier blocking a critical migration path or restoration of a critical spawning location that could have benefits out of proportion to the low cost. This could be a particularly ripe area given the increasing attention and support being given at the federal and state level to the removal of smaller, outdated dams. The efforts of multiple actors, including of the Southeast Aquatic Resources Partnership, TNC, the South Atlantic Landscape Conservation Cooperative,

and American Rivers to identify and prioritize barriers for removal as well as build capacity for removal teams in the Southeast are helping to create a bigger picture on barrier removal. Another model is the successful implementation of landowner incentives for the planting of herbaceous and vegetative buffers in the Elk River watershed of Tennessee. The Elk River project, a coordinated effort of Tennessee Wildlife Resources Agency (TWRA), the Tennessee Valley Authority (TVA), the National Fish and Wildlife Foundation (NFWF), the Natural Resources Conservation Service (NRCS), TNC, and other partners, encourages landowners to participate in stream restoration. The project supplements the payments already available through NRCS in an area where high commodity process had made buffer implementation unattractive. This resulted in increased adoption rates and improved water quality along a 26-mile stretch of river in the Middle Tennessee River watershed atop the biologically diverse Cumberland Plateau. The project achieved almost 200 acres of buffer planting in trees or native warm-season grasses at a cost of just over $315,000 and is a good example of how success can be had, even at lower prices. As mentioned above, such activities can also serve as starting points for broader, multi-pronged campaigns by showing early successes, generating excitement, cementing partnerships, and opening the door to other funding sources.

CONCLUSIONS

Southeastern aquatic ecosystems are the most imperiled in North America and urgently in need of increased conservation activity. The dollar figures described in this section may sound high at first, but compared to conservation spending elsewhere in the US, they are quite modest. For example, Bonneville Power Administration (BPA), which manages reservoirs in the Columbia River Basin, spends $252 million on salmon recovery *each year.* Watershed restoration that occurs in this basin occurs within a complex regulatory and legal framework that increases costs dramatically. This should be a cautionary example for other regions of the country to take notice of aquatic species conservation, before endangerment. Combined with costs due to altered operations to benefit salmon, BPA spends nearly 20% of its budget managing for salmon.

The good news is that most of the imperiled species of the Southeast are easier to manage than salmon, which have complex life cycles and undergo long migrations. Many of our species are imperiled due to small range size, which means that conservation benefits can be obtained for relatively little spending. However, even though there are scores of southeastern aquatic species that are legally protected under the ESA, hundreds more are imperiled and have been petitioned for formal protection. We have already moved beyond the proverbial “ounce of prevention,” since much has been lost in these streams and rivers though centuries of misuse and neglect, yet an outstanding level of biodiversity still remains. But the price tag for maintaining this biodiversity will be much higher in the future. The time to invest is now.

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Electronic Data Requests

Point data were requested from GBIF, Fishnet2, and MARIS online repositories, as follows:

GBIF.org (9th December 2015) GBIF Occurrence Download http://doi.org/10.15468/dl.jsszn8
GBIF.org (5th January 2016) GBIF Occurrence Download http://doi.org/10.15468/dl.xucy9n
GBIF.org (28th March 2016) GBIF Occurrence Download http://doi.org/10.15468/dl.zpv8wv (Only records from the Florida Museum of Natural History within this query were used in this analysis.)

Data obtained from the Museum of Southwestern Biology, California Academy of Sciences, Texas A&M University Biodiversity Research and Teaching Collection, University of Washington Fish Collection, Louisiana State University Museum of Zoology, Michigan State University Museum (MSUM), Ohio State University - Fish Division, University of Alabama Ichthyological Collection, University of Michigan Museum of Zoology, Universidad Nacional Autonoma de Mexico - IBiologia - CNPE/Coleccion Nacional de Peces, Australian Museum, Mississippi Museum of Natural Science, Fort Hays Sternberg Museum of Natural History, MCZ-Harvard University, Florida Fish and Wildlife Conservation Commission, Illinois Natural History Survey, University of Kansas Biodiversity Institute - Tissues, University of Colorado Museum of Natural History, Yale University Peabody Museum, UNELLEZ Museo de Zoologia, Colleccion de Peces, Los Angeles County Museum of Natural History (LACM), Tulane University Museum of Natural History - Royal D. Suttkus Fish Collection, University of Alberta Museums, Oregon State University, Texas Natural History Science Center - Texas Natural History Collections, Sam Noble Oklahoma Museum of Natural History, Royal Ontario Museum, Auburn University Museum of Natural History, Canadian Museum of Nature, DGR Fishes Specimens, University of Kansas Biodiversity Institute - Specimens, National Museum of Natural History, Smithsonian Institution, Field Museum, Florida Museum of Natural History, Western New Mexico University , Swedish Museum of Natural History, University of Nebraska State Museum, Cornell University Museum of Vertebrates (CUMV), Santa Barbara Museum of Natural History, Academy of Natural Sciences at Philidelphia, North Carolina State Museum of Natural Sciences, University of Arkansas Collections Facility, UAFMC (Accessed through the Fishnet2 Portal, www.fishnet2.net, 11/29/2016).

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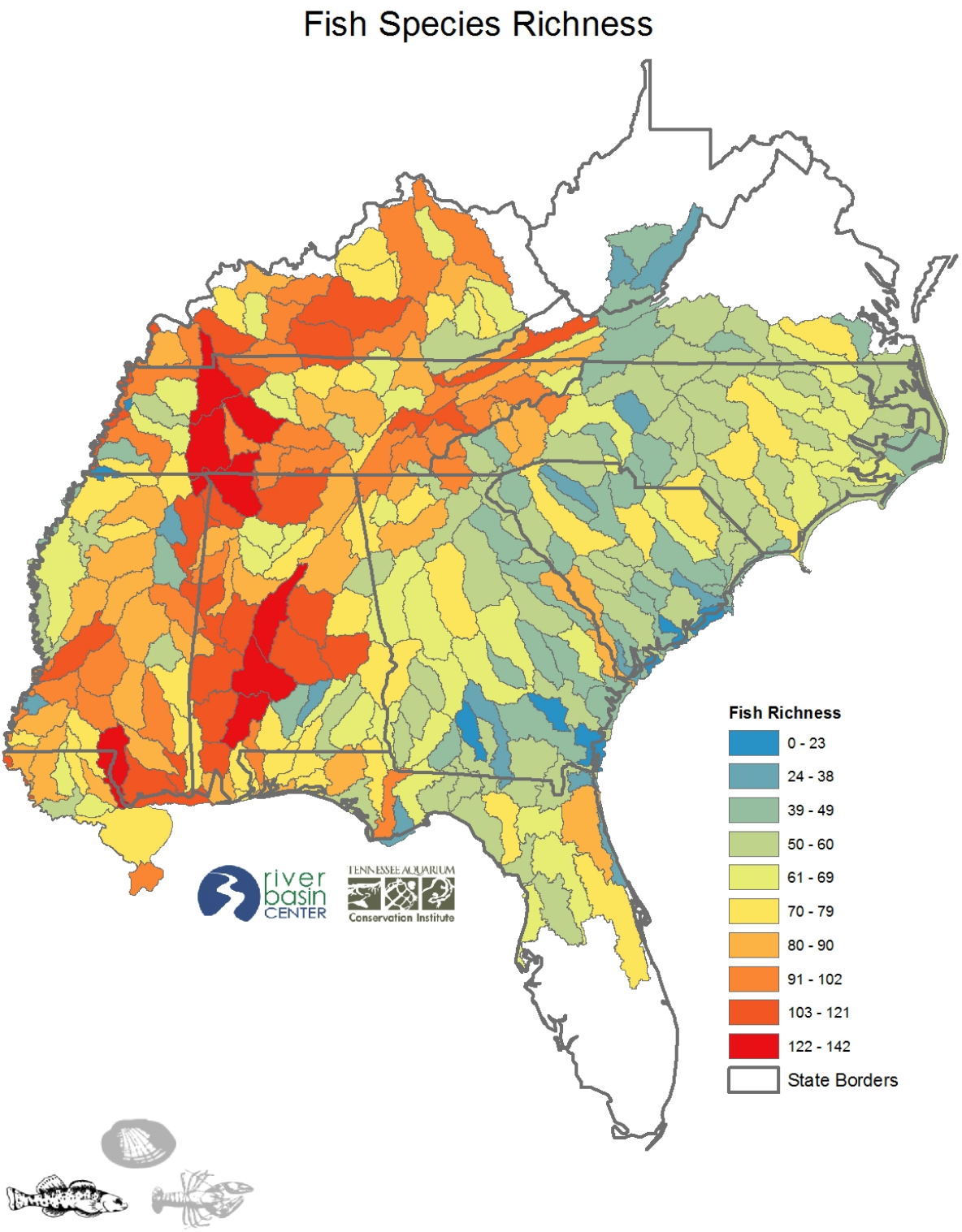
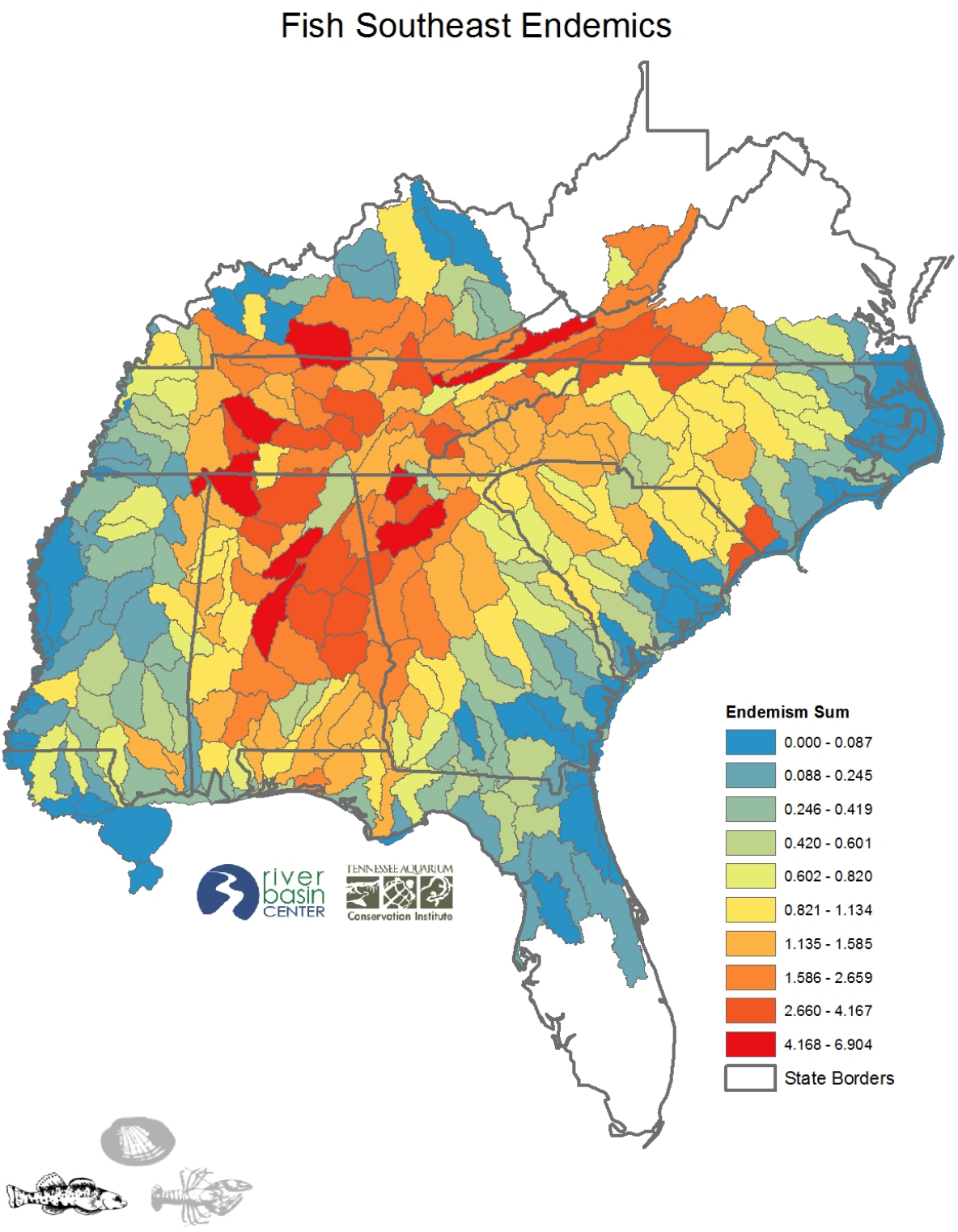
APPENDIX I: FISH, CRAYFISH, AND MUSSEL MAPS

The maps in this section duplicate the inset maps from the results section at a larger size, for better on-screen viewing. Digital versions will be available at www.southeastfreshwater.org


Fish Species Richness
Fish Richness
0 - 23
24 - 38
39 - 49
50 - 60
61 - 69
70 - 79
80 - 90
91 - 102
103 - 121
122 - 142
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute


Fish Southeast Endemics
Endemism Sum
0.000 - 0.087
0.088 - 0.245
0.246 - 0.419
0.420 - 0.601
0.602 - 0.820
0.821 - 1.134
1.135 - 1.585
1.586 - 2.659
2.660 - 4.167
4.168 - 6.904
State Borders
river basin CENTER
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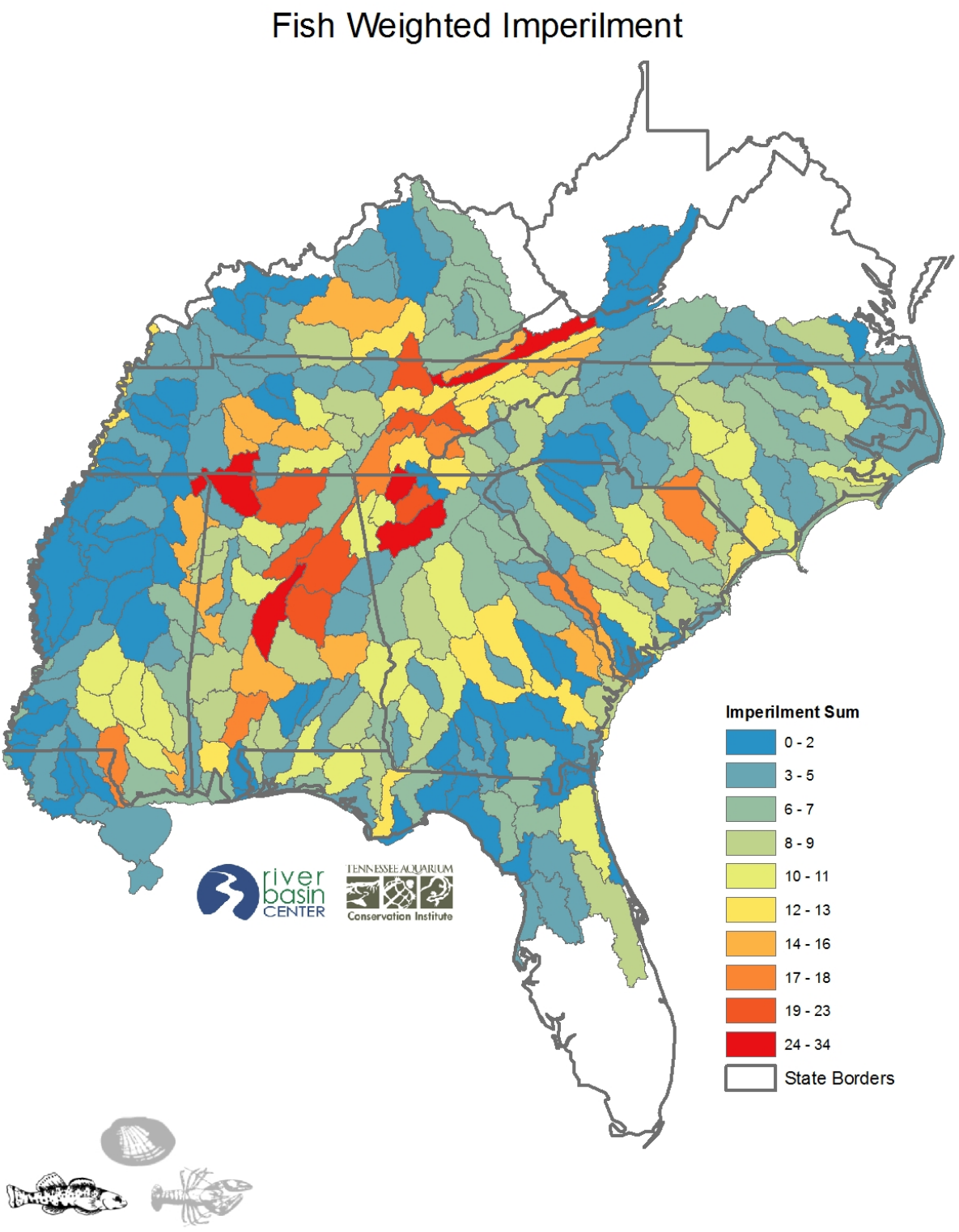
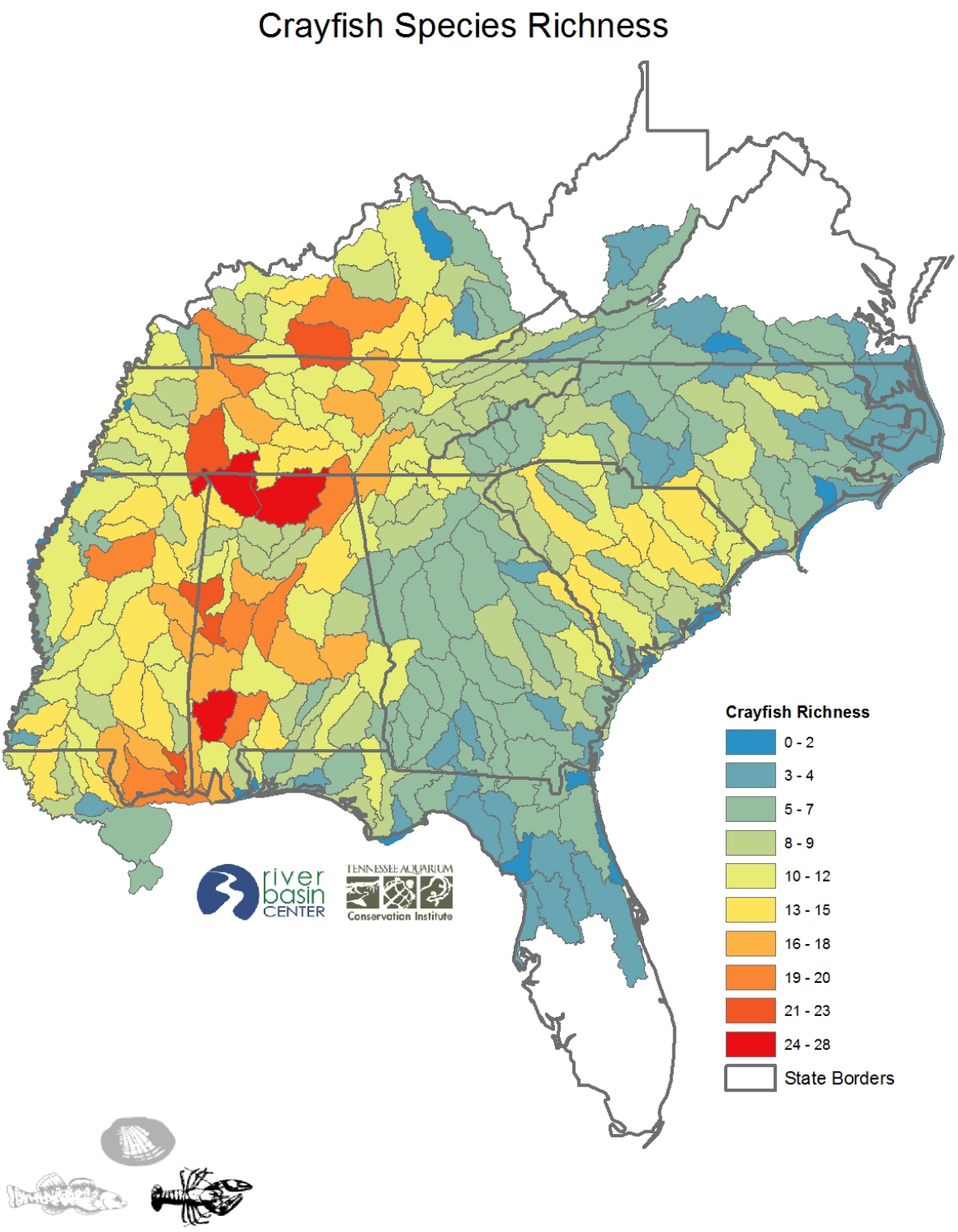
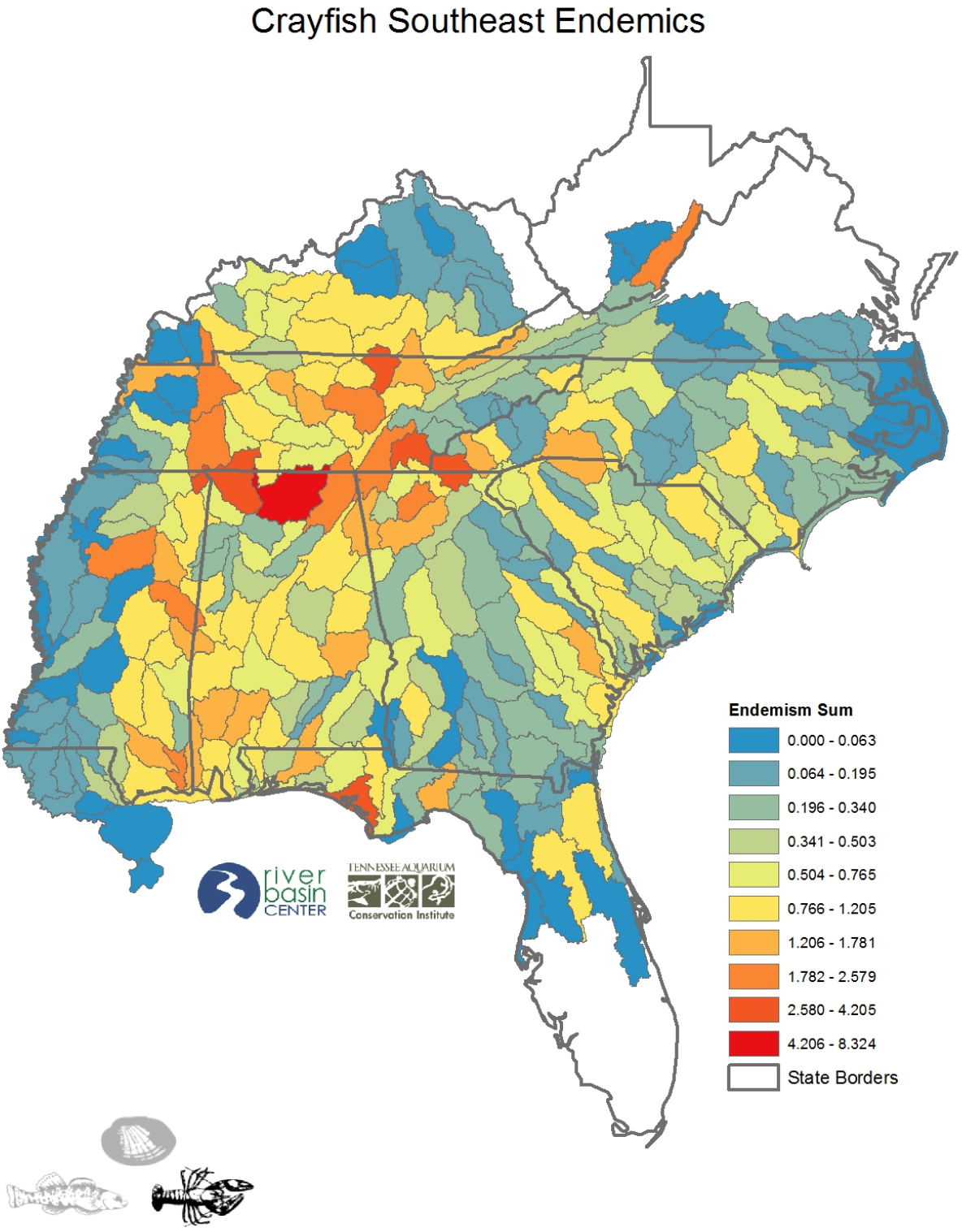
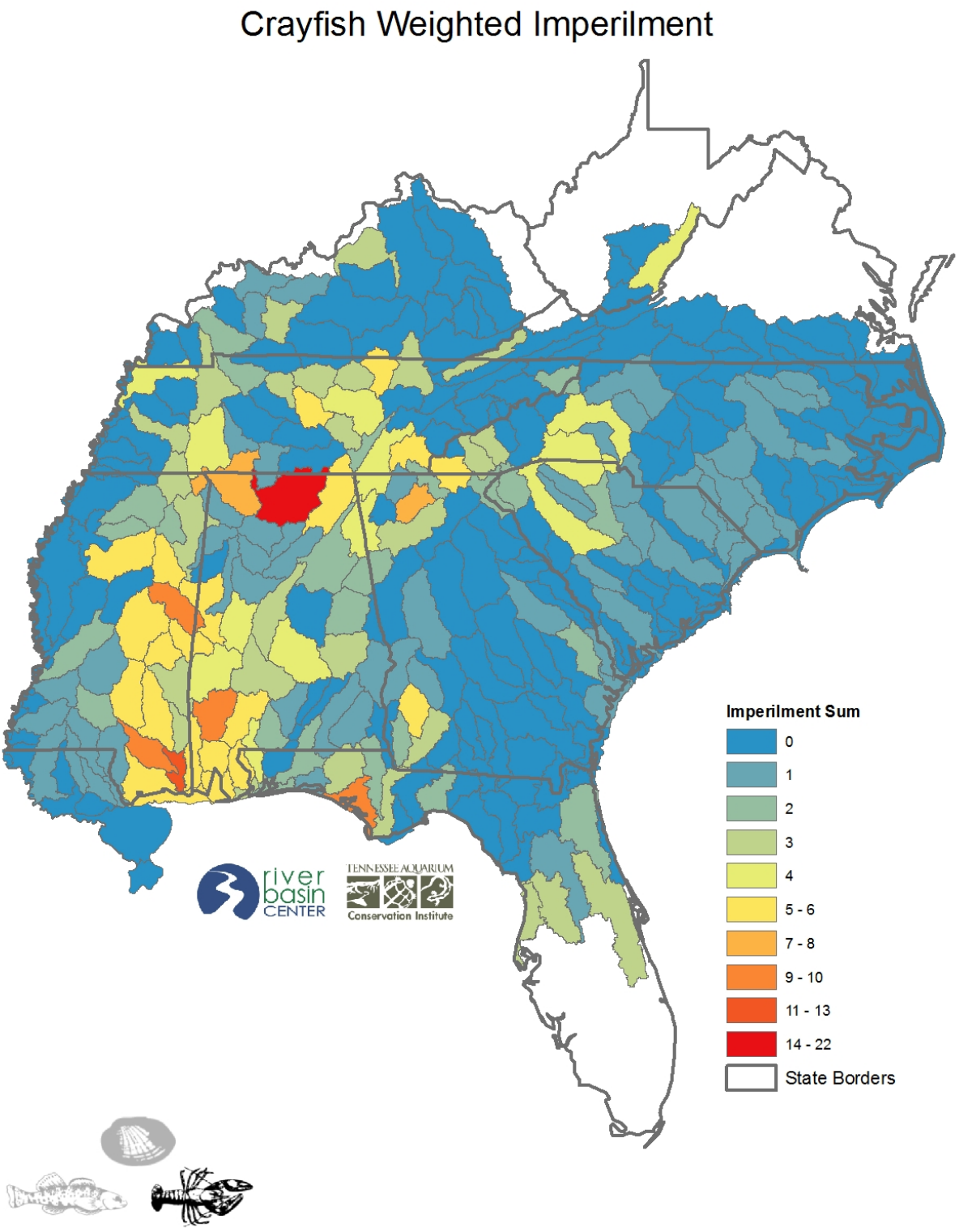
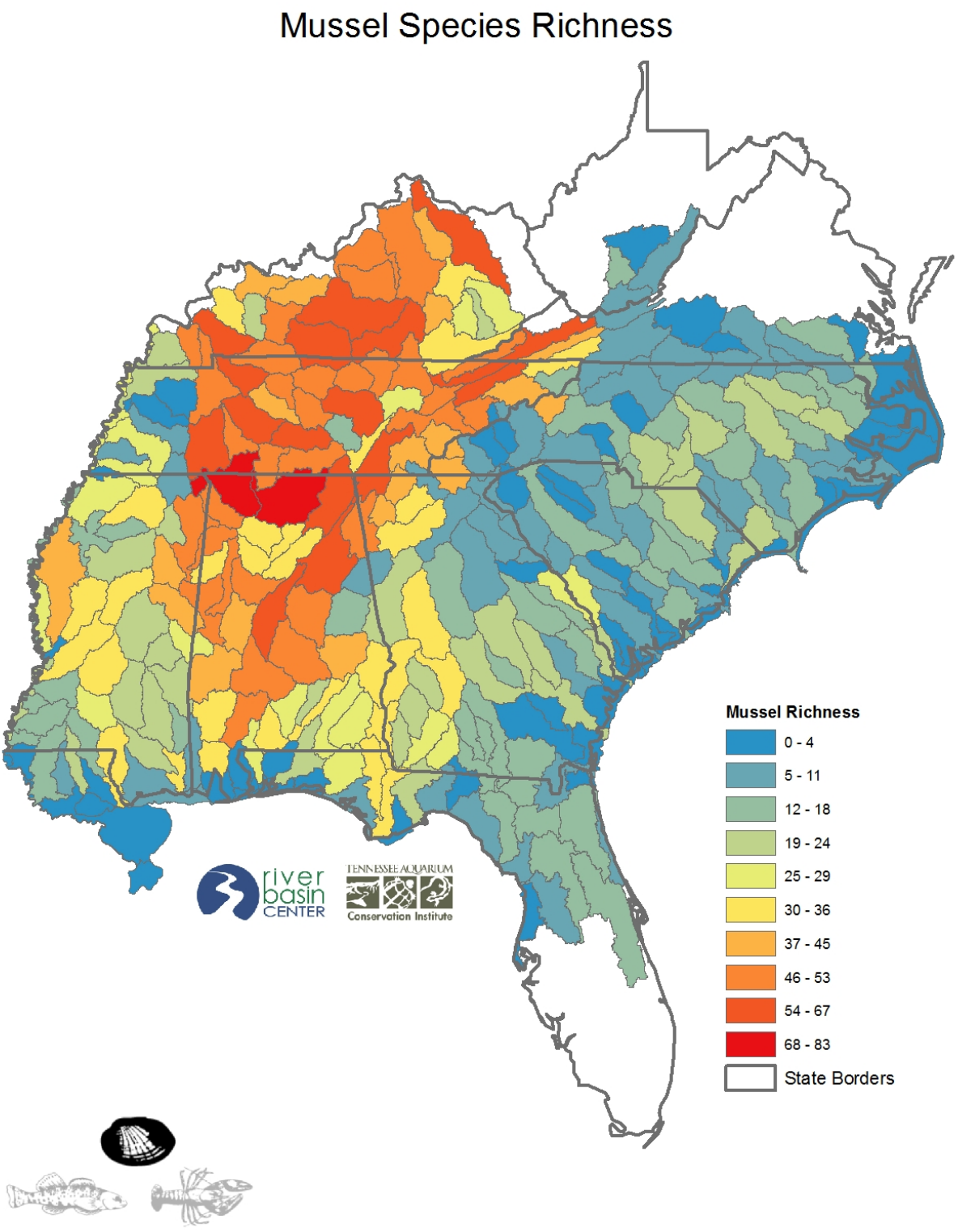
Conservation Institute

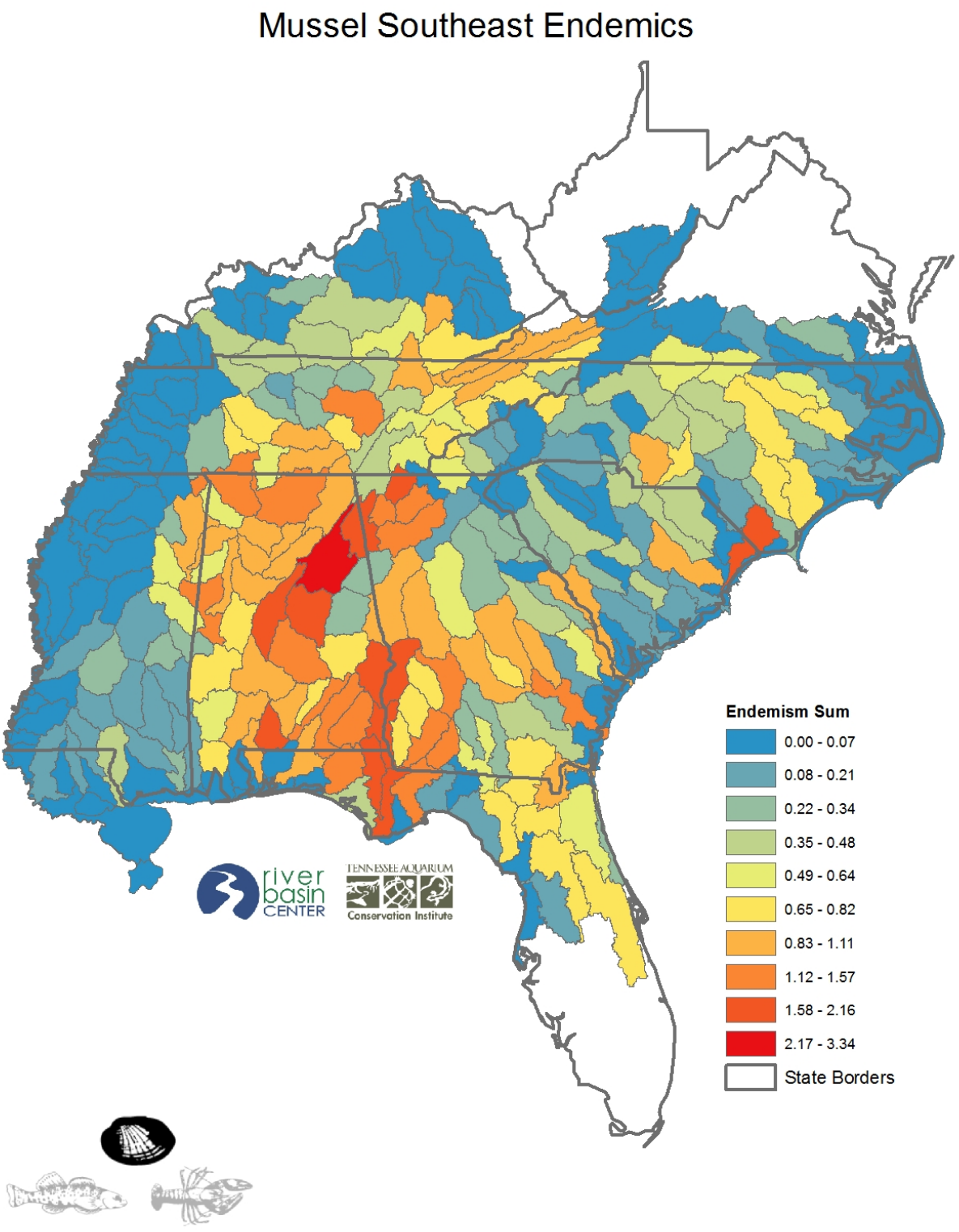

Fish Weighted Imperilment
Imperilment Sum
0 - 2
3 - 5
6 - 7
8 - 9
10 - 11
12 - 13
14 - 16
17 - 18
19 - 23
24 - 34
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute

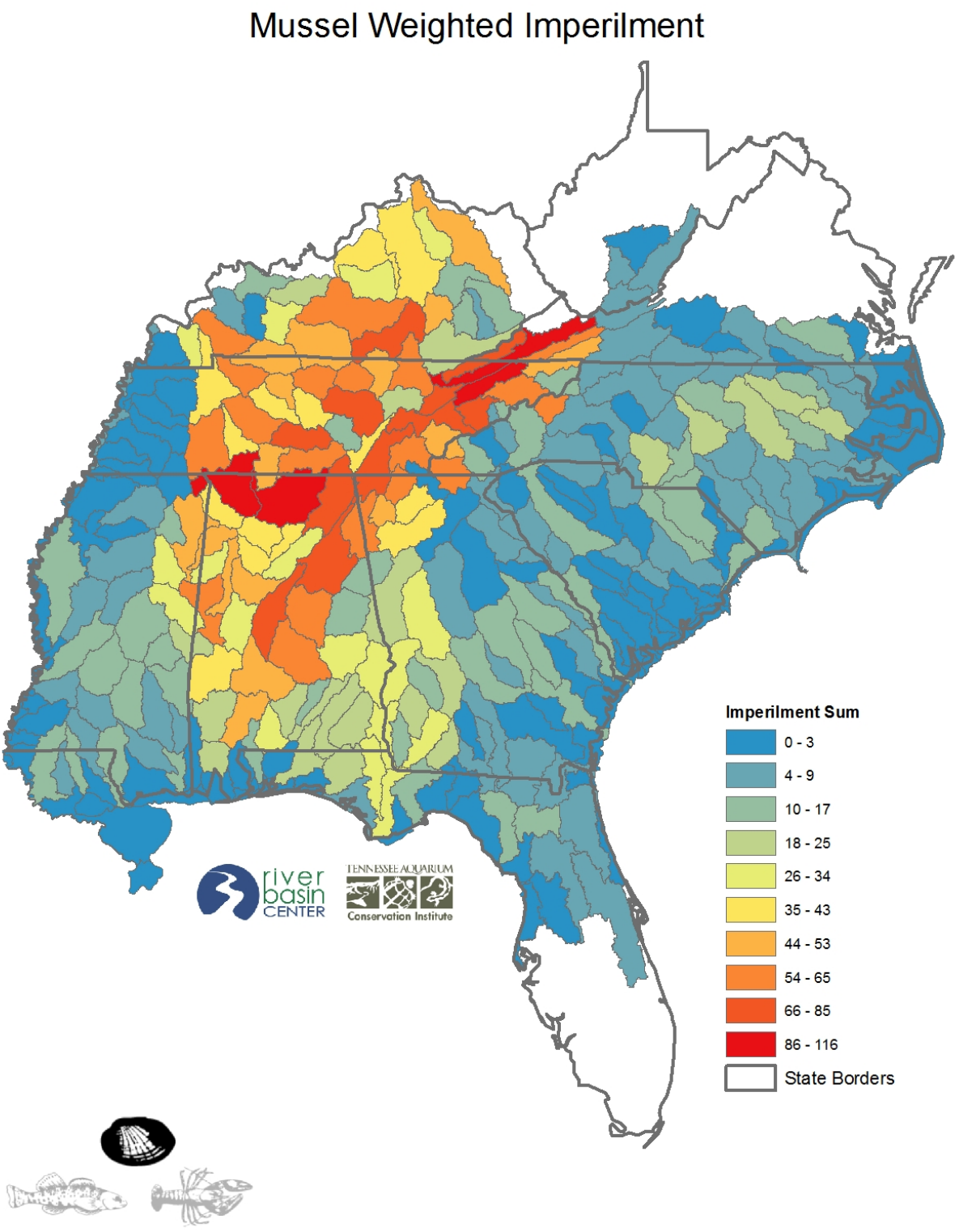

Crayfish Species Richness
Crayfish Richness
0 - 2
3 - 4
5 - 7
8 - 9
10 - 12
13 - 15
16 - 18
19 - 20
21 - 23
24 - 28
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute


Crayfish Southeast Endemics
Endemism Sum
0.000 - 0.063
0.064 - 0.195
0.196 - 0.340
0.341 - 0.503
0.504 - 0.765
0.766 - 1.205
1.206 - 1.781
1.782 - 2.579
2.580 - 4.205
4.206 - 8.324
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute


Crayfish Weighted Imperilment
Imperilment Sum
0
1
2
3
4
5 - 6
7 - 8
9 - 10
11 - 13
14 - 22
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute

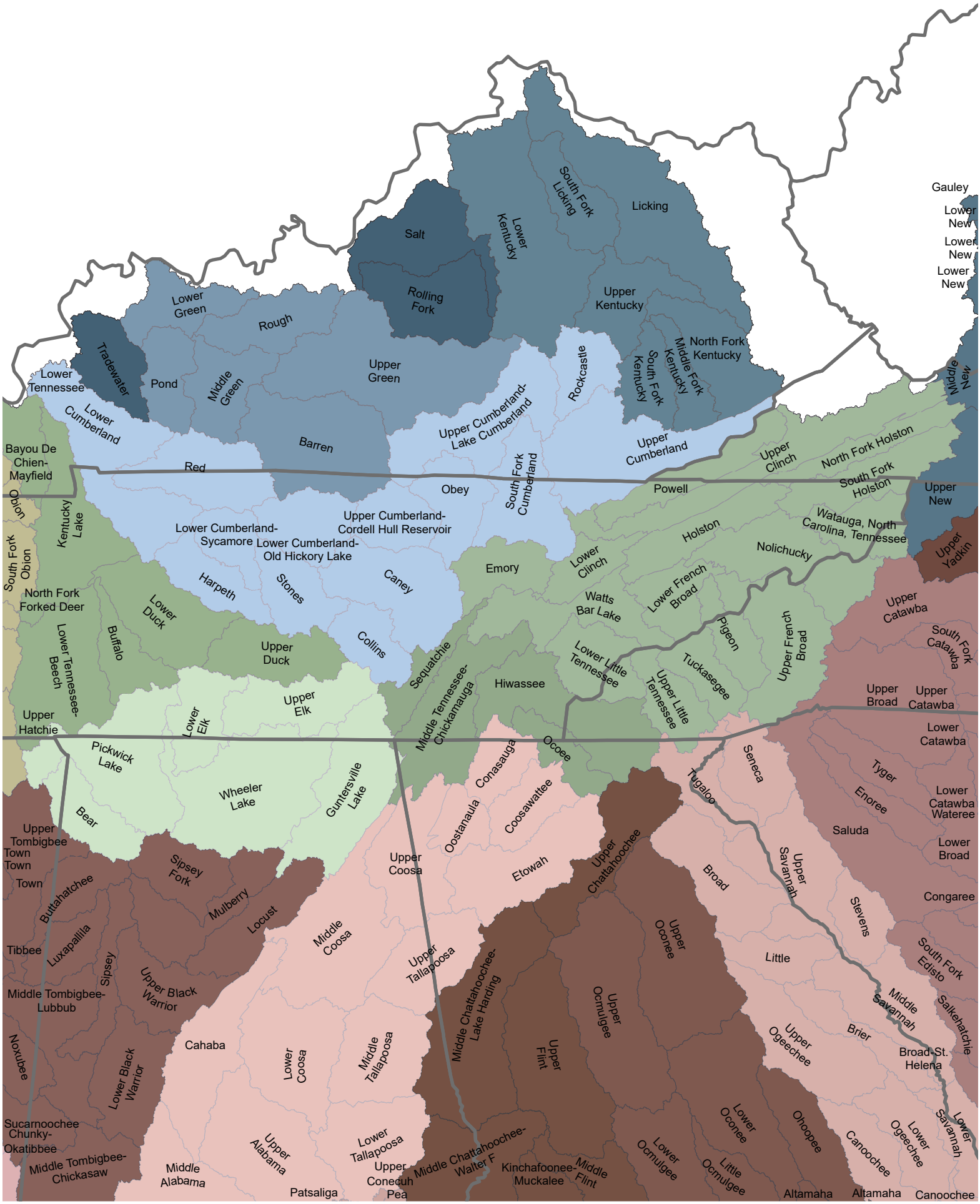

Mussel Species Richness
Mussel Richness
0 - 4
5 - 11
12 - 18
19 - 24
25 - 29
30 - 36
37 - 45
46 - 53
54 - 67
68 - 83
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute


Mussel Southeast Endemics
Endemism Sum
0.00 - 0.07
0.08 - 0.21
0.22 - 0.34
0.35 - 0.48
0.49 - 0.64
0.65 - 0.82
0.83 - 1.11
1.12 - 1.57
1.58 - 2.16
2.17 - 3.34
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute

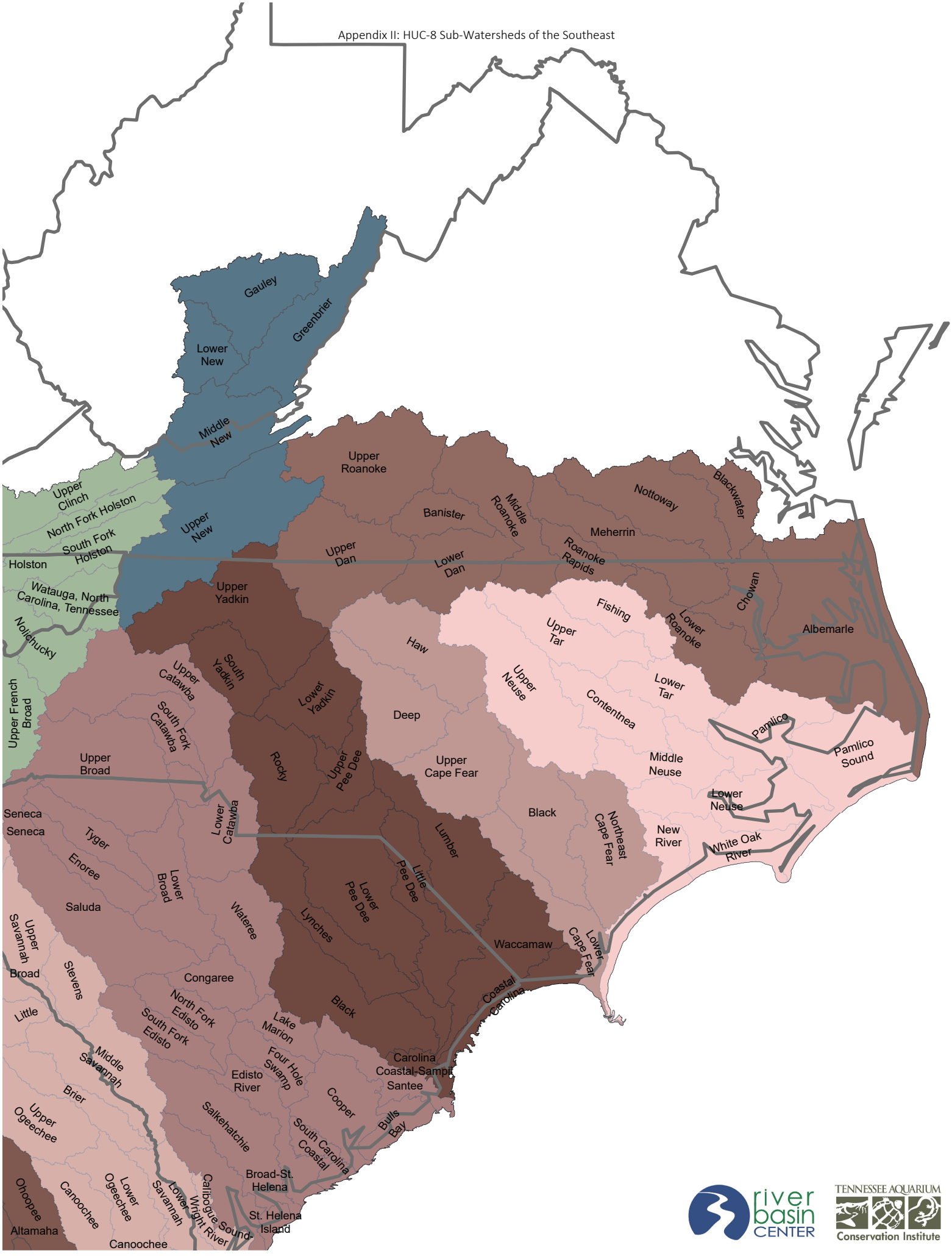

Mussel Weighted Imperilment
Imperilment Sum
0 - 3
4 - 9
10 - 17
18 - 25
26 - 34
35 - 43
44 - 53
54 - 65
66 - 85
86 - 116
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute

APPENDIX II. NAMES OF HUC-8 SUB-BASINS IN THE SOUTHEAST

The maps in this section show the 270 HUC-8 Sub-basins in the project area, with names. HUC boundaries and names data drawn from the USGS National Watershed Boundary Dataset (http://nhd.usgs.gov/wbd.html). Colors reflect HUC-2 and shading reflects HUC-4 boundaries.

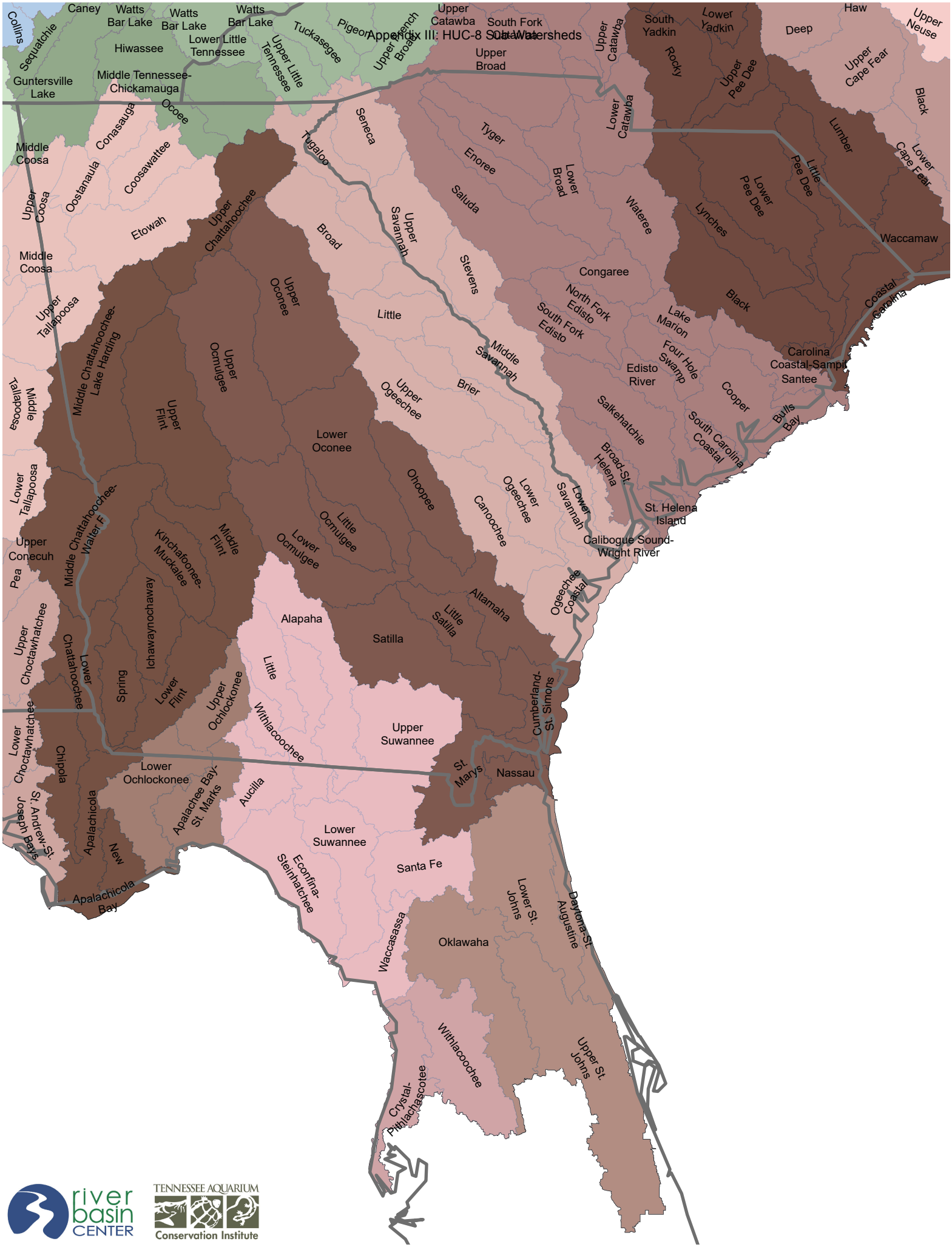

Gauley
Lower New
Lower New
Lower New
Salt
Lower Kentucky
South Fork Licking
Licking
Rolling Fork
Upper Kentucky
Lower Green
Rough
Tradewater
Pond
Middle Green
Upper Green
Rockcastle
South Fork Kentucky
Middle Fork Kentucky
North Fork Kentucky
Lower Tennessee
Lower Cumberland
Barren
Upper Cumberland-Lake Cumberland
Upper Cumberland
Bayou De Chien-Mayfield
Red
Obey
South Fork Cumberland
Powell
Upper Clinch
North Fork Holston
South Fork Holston
Upper New
Obion
Kentucky Lake
Lower Cumberland-Sycamore
Upper Cumberland-Cordell Hull Reservoir
Lower Cumberland-Old Hickory Lake
Holston
Watauga, North Carolina, Tennessee
Nolichucky
Upper Yadkin
South Fork Obion
North Fork Forked Deer
Harpeth
Stones
Caney
Emory
Lower Clinch
Lower French Broad
Watts Bar Lake
Lower Duck
Buffalo
Collins
Upper Duck
Lower Tennessee-Beech
Sequatchie
Middle Tennessee-Chickamauga
Hiwassee
Lower Little Tennessee
Upper Little Tennessee
Tuckasegee
Pigeon
Upper French Broad
Upper Catawba
South Fork Catawba
Upper Broad
Upper Catawba
Upper Hatchie
Lower Elk
Upper Elk
Ocoee
Lower Catawba
Pickwick Lake
Wheeler Lake
Guntersville Lake
Bear
Conasauga
Oostanaula
Coosawattee
Seneca
Tugaloo
Tyger
Enoree
Lower Catawba Wateree
Saluda
Upper Tombigbee
Town
Town
Sipsey Fork
Upper Coosa
Etowah
Upper Chattahoochee
Broad
Upper Savannah
Lower Broad
Congaree
Buttahatchee
Mulberry
Locust
Stevens
Tibbee
Luxapallila
Middle Coosa
Upper Oconee
Little
South Fork Edisto
Sipsey
Upper Black Warrior
Upper Tallapoosa
Middle Chattahoochee-Lake Harding
Upper Ocmulgee
Middle Savannah
Salkehatchie
Middle Tombigbee-Lubbub
Noxubee
Cahaba
Lower Coosa
Middle Tallapoosa
Upper Flint
Upper Ogeechee
Brier
Broad-St. Helena
Lower Black Warrior
Sucarnoochee
Chunky-Okatibbee
Middle Tombigbee-Chickasaw
Middle Alabama
Upper Alabama
Lower Tallapoosa
Upper Conecuh Pea
Middle Chattahoochee-Walter F
Kinchafoonee-Muckalee
Middle Flint
Lower Ocmulgee
Little Ocmulgee
Lower Oconee
Ohoopee
Canoochee
Lower Ogeechee
Lower Savannah
Patsaliga
Altamaha
Altamaha
Canoochee

Appendix II: HUC-8 Sub-Watersheds of the Southeast



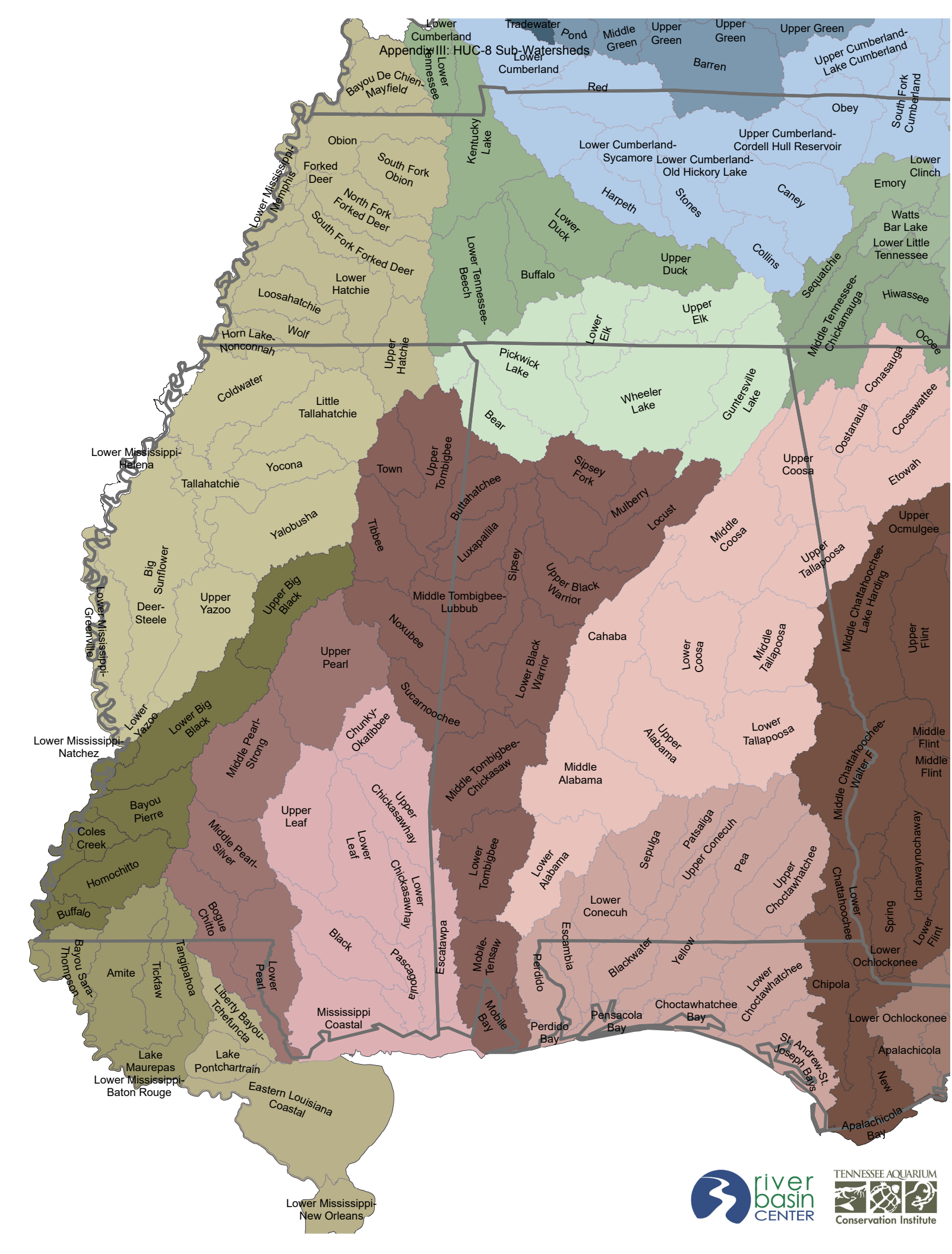
river basin CENTER

TENNESSEE AQUARIUM Conservation Institute



river basin CENTER

TENNESSEE AQUARIUM Conservation Institute


Appendix III: HUC-8 Sub-Watersheds
Lower Cumberland
Tradewater
Pond
Middle Green
Upper Green
Upper Green
Upper Green
Upper Cumberland-Lake Cumberland
Barren
Red
Obey
South Fork Cumberland
Bayou De Chien-Mayfield
Lower Tennessee
Kentucky Lake
Obion
Forked Deer
South Fork Obion
Lower Mississippi-Memphis
North Fork Forked Deer
South Fork Forked Deer
Lower Hatchie
Loosahatchie
Wolf
Horn Lake-Nonconnah
Upper Hatchie
Coldwater
Little Tallahatchie
Yocona
Tallahatchie
Yalobusha
Big Sunflower
Deer-Steele
Upper Yazoo
Lower Mississippi-Greenville
Upper Big Black
Lower Mississippi-Helena
Lower Yazoo
Lower Big Black
Lower Mississippi-Natchez
Middle Pearl-Strong
Bayou Pierre
Coles Creek
Homochitto
Buffalo
Bogue Chitto
Amite
Tickfaw
Tangipahoa
Bayou Sara-Thompson
Lower Pearl
Liberty Bayou-Tchefuncta
Lake Maurepas
Lake Pontchartrain
Lower Mississippi-Baton Rouge
Eastern Louisiana Coastal
Lower Mississippi-New Orleans
Mississippi Coastal
Middle Pearl-Silver
Upper Leaf
Lower Leaf
Black
Pascagoula
Escatawpa
Mobile-Tensaw
Mobile Bay
Perdido
Perdido Bay
Pensacola Bay
Choctawhatchee Bay
St. Andrew-St. Joseph Bays
Apalachicola Bay
Apalachicola
New
Lower Ochlockonee
Chipola
Lower Choctawhatchee
Blackwater
Yellow
Escambia
Lower Conecuh
Upper Choctawhatchee
Pea
Upper Conecuh
Patsaliga
Sepulga
Lower Alabama
Lower Tombigbee
Upper Chickasawhay
Lower Chickasawhay
Chunky-Okatibbee
Middle Tombigbee-Chickasaw
Middle Alabama
Upper Alabama
Lower Tallapoosa
Middle Tallapoosa
Lower Coosa
Cahaba
Middle Chattahoochee-Walter F
Middle Chattahoochee-Lake Harding
Upper Flint
Middle Flint
Lower Flint
Chattahoochee
Lower Spring
Ichawaynochaway
Upper Tallapoosa
Upper Coosa
Middle Coosa
Upper Ocmulgee
Etowah
Oostanaula
Conasauga
Coosawattee
Middle Tennessee-Chickamauga
Ocoee
Hiwassee
Sequatchie
Lower Little Tennessee
Watts Bar Lake
Lower Clinch
Emory
Caney
Collins
Upper Duck
Lower Duck
Harpeth
Stones
Lower Cumberland-Sycamore
Lower Cumberland-Old Hickory Lake
Upper Cumberland-Cordell Hull Reservoir
Lower Tennessee-Beech
Buffalo
Upper Elk
Lower Elk
Pickwick Lake
Wheeler Lake
Guntersville Lake
Bear
Upper Tombigbee
Town
Tibbee
Buttahatchee
Luxapallila
Sipsey
Upper Black Warrior
Middle Tombigbee-Lubbub
Noxubee
Lower Black Warrior
Sucarnoochee
Upper Pearl
Sipsey Fork
Mulberry
Locust
River Basin Center
Tennessee Aquarium Conservation Institute

Appendix III:
Potential Threats and Management Actions for 10 Priority Watersheds

This appendix to the Southeastern Aquatic Biodiversity Conservation Strategy provides an overview of each of the top ten priority watersheds. The information provided is intended to help NFWF or other organizations determine which types of strategies might be most successful at conserving or restoring freshwater aquatic biodiversity in each watershed. It is important to note that while the watershed overviews provide information useful for developing watershed-scale aquatic biodiversity conservation strategies, they are not watershed plans. Additional research and planning will be necessary for organizations seeking to develop comprehensive conservation strategies for these watersheds.

Each watershed overview includes the following sections:

- Watershed Description: This section provides the location of each watershed in the state or states in which it lies, the larger river drainage system it is a part of, the ecoregion or ecoregions it includes, and a description of common natural features. It also includes information on land uses and communities within the watershed.

- Species: The total number of species of fishes, mussels, and crayfishes in the watershed are provided, as well as numbers of southeastern endemics, imperiled species (vulnerable, threatened, and endangered), and Species of Greatest Conservation Need (SGCN) as identified by State Wildlife Action Plans (SWAPs). A species table is provided for each watershed that provides these details, plus the common and scientific names for all SGCN species. Species tables may include extirpated species.

- Potential Threats and Management Actions: This section describes primary and secondary potential threats to species and habitat in each watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research

may be necessary to confirm if potential threats are indeed affecting species. A variety of implementable management actions that could help address each threat are provided. A table for each watershed provides additional information on management actions for that watershed, when available. Additional information can include prioritization and other planning documents, details on instances when a particular management action has been implemented in that watershed, and guidance documents or other tools to aid in implementation.

Reservoirs are listed as secondary threats for most watersheds. In actuality, the impoundment of the Tennessee and Coosa River systems—the hottest of the hotspots of aquatic biodiversity—is arguably the greatest contributor to the overall imperilment of aquatic species in the Southeast. Converting the mainstems of these rivers into a series of lakes has led to the elimination of the great majority of large-river habitat for lotic species, since by definition lotic species require flowing water. These impoundments have also increased the population fragmentation of species that inhabit tributaries. While it is not theoretically impossible for large dams to be removed or for reservoir operations to change to reduce downstream impacts, for day-to-day conservation management purposes we consider large reservoir impacts to be a *fait accomplis*, much like historic land use. Nevertheless, we note that if an opportunity were to arise to remove a large dam or to discontinue hydropeaking operations at a large dam, the benefit could be equivalent to tens of millions of dollars' worth of small conservation actions, and such an opportunity should be considered the highest of priorities.

- Management Actions to Support Species: Some management actions are not, in some situations, designed to respond to immediate threats, but do support species survival. These actions are listed and additional information is provided in the management actions table, when available.

- Programs and Organizations: A non-exhaustive list of organizations and programs working on some aspect of aquatic conservation in the watershed is provided. A brief description of the organization and a link to more information is included when possible.

- Plans and Other Resources: A non-exhaustive list of plans and other resources that concern the watershed is provided. A brief description of the resource and a link are included when possible.

Although the watershed profiles are not intended as stand-alone documents, we recognize the potential that they could be used as such. For this reason, there is substantial redundancy among them.

Prior to the watershed profiles, we provide an overview of common threats and potential management actions in the Southeast.

griculture

Agricultural impacts to water quality are widespread across the southeastern United States. Two specific types of agricultural operations – livestock operations and crop production – are most common and likely cause the most impacts when proper best management practices (BMPs) are not implemented. When these activities occur in areas with karst geology, impacts to aquatic resources can be exacerbated; karst features such as fissures in bedrock allow agricultural runoff to enter sensitive groundwater systems with little to no treatment from natural infiltration.

- Livestock operations: Livestock pasture can cause multiple impacts to aquatic species and habitat health. Nutrient inputs from livestock waste on adjacent pasture can enter surface water and groundwater as runoff, particularly when riparian buffers are nonexistent. Cattle often have access to surface waters and sinkholes and can erode streambanks and defecate directly into waters.
- Crop production: Major issues with row crop production are chemical (pesticide) and nutrient (fertilizer) runoff and erosion and sedimentation, particularly when riparian buffers are nonexistent.

Forestry

Poorly managed forestry operations can cause erosion and sedimentation, alter hydrology, and degrade wetland systems. As with agricultural operations, they can be particularly harmful if they occur in areas with karst resources.

Groundwater withdrawal

Excessive groundwater usage, whether for agricultural, municipal, or other uses, can deplete aquifer storage and impact specialized habitats that drive the exceptional freshwater biodiversity in the southeastern U.S. These stresses on springs, spring-fed creeks, and caves will likely increase with climate change.

Impoundments and barriers

Impoundments and barriers can alter hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Industry

Industrial facilities can discharge a wide variety of contaminants into aquatic systems, including toxic chemicals. These substances can pollute both the water itself and sediments in stream, river, and lake beds, making habitat unsuitable and spawning grounds unusable for many species.

Invasive species

The southeastern U.S. is host to many species of invasive flora and fauna. Aquatic species include several types of carp, zebra mussels, varieties of watermilfoil, and water hyacinth. These species can displace native species and, in some instances, impact water quality (water hyacinth, for example, can form dense mats that block sunlight and reduce dissolved oxygen concentrations). Non-aquatic species can also impact aquatic resources. Defoliation by insects such as the emerald ash borer and hemlock wooly adelgid can, for example, alterhydrology and water temperature.

Land use legacies

Land use legacies include hydrologic and habitat changes from historic practices in a watershed. Depending on the magnitude of changes and location in the watershed, species survival in disturbed areas can remain impacted decades or even centuries later. In the Etowah River Watershed, for example, hydraulic mining caused major sedimentation of the river and its tributaries that is likely still impacting the distribution of imperiled fishes.

Landfills

Depending on their siting, design, and other factors, landfills have the potential to leach contaminants such as heavy metals and manmade chemicals into groundwater and surface waters.

Mines

Mines of all types can impact aquatic resources through hydrologic alteration, erosion, and sedimentation. Coal mines, common in some southeastern watersheds, can cause severe impacts through acid mine drainage, characterized by high acidity, and high concentrations of dissolved metals. Coal mining was for all intents and purposes unregulated prior to passage of the Surface Mining Control and Reclamation Act in 1977. Pre-1977 mining operations were typically conducted with no environmental controls.

Power plants – coal ash ponds

Coal-fired power plants often include coal ash ponds, where toxic soot from coal ash fires is stored as a slurry. Spills from these ponds, which have occurred in the Southeast in recent years, can cause massive aquatic species kills and clog waterways with toxic materials. Many plants are closing their coal ash ponds, but these facilities can still cause impacts. A recent study of 21 southeastern coal ash ponds from Duke University found evidence of pond leaks at all 21 facilities. Concentrations of some trace elements exceeded EPA water quality standards at nearly a third of the study sites.[1]

Reservoir development

Reservoirs are typically major projects that cause substantial and in many cases essentially irreversible impacts to aquatic habitat and species, including inundation of habitat, alteration of hydrologic regimes, fragmentation of habitat, and isolation of populations.

Sinkhole dumping

Sinkholes are a normal part of karst landscapes. Unfortunately, sinkhole dumping is a common occurrence in some communities as sinkholes offer what appears to be a convenient disposal location for residential refuse, animal carcasses, and other materials. Sinkholes provide an almost direct conduit to groundwater resources, so contaminants dumped in them can reach these pristine, sensitive waters with little to no infiltration.

Stormwater injection into karst systems

Stormwater management can be difficult in communities underlain by karst resources. In some communities, untreated stormwater is injected directly into karst "wells," where it can contaminate sensitive and pristine groundwater resources depended on by many aquatic species.

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[1] Harkness, et al, *Evidence for Coal Ash Ponds Leaking in the Southeastern United States*, 50 (12) Environ. Sci. & Technol. 6583-6592 (American Chemical Society 2016).

Urbanization

Streams in urban areas are often threatened by sedimentation, hydrologic changes, extensive riparian buffer loss, contaminants, species movement barriers, channelization, and piping. In most developed areas, the most substantial impacts come from runoff from impervious surfaces. In areas underlain by karst resources, groundwater quality and quantity impacts are also a concern: runoff may enter karst features with little to no natural filtration and impervious surfaces in groundwater recharge areas inhibits natural infiltration, reducing the amount of groundwater available to karst aquatic habitats.

Wastewater systems

Municipal wastewater treatment plants and individual septic systems can both cause impacts to aquatic species and habitats. Sanitary sewer overflows and leaking sewer lines are two common issues with municipal plants. Their regular discharges can also be a problem, as most southeastern states do not have numeric water quality criteria for nutrients. Treatment plants may therefore be discharging nitrogen and phosphorus into surface waters that contribute to issues such as low dissolved oxygen and eutrophication, while still maintaining compliance with their permits. Aging and poorly sited, designed, installed, or maintained septic systems are an issue in many communities (although typically regarded as a rural or suburban issue, malfunctioning septic systems exist in urban areas, as well). Malfunctioning septic systems can contribute to water quality problems because they may not be treating wastewater sufficiently before discharging it to a drainfield. In some places, homemade septic systems, including "straight pipe" systems that discharge wastewater directly into surface waters, are still common.

Management Actions to Address Threats

Alternative dump sites

In areas with karst resources, dumping trash and other waste materials into sinkholes can, unfortunately, be common. One method to curtail this practice is to offer free alternative dumping sites readily available for community members. These sites can be available year-round or materials can be dropped off at specific sites in annual events.

Aquatic restoration

Stream, streambank, and wetland restoration project are meant to restore the hydrologic, chemical, and biological functions of these resources. Because of their floodwater attenuation and pollutant filtering capabilities, restored wetlands are particularly useful for a number of environmental and other goals.

Barrier modification for fish passage

A large number of fish passage barriers exist in southeastern streams. Low head dams, fords, and other barriers can often be modified to provide passage for fish. Options include replacement with bridges and installing fish-friendly culverts.

Conservation locking

In dams with lock systems, conservation locking can be employed to allow for fish passage during spawning season. Locks are opened several times a day during spawning months to allow fish to pass; often water pumps are used to create a current that attracts fish to the lock.

Conservation planning
Conservation planning can refer to a wide range of activities, including watershed planning, that are designed to direct development away from environmentally sensitive areas, including wetlands, groundwater recharge areas, karst terrain, and floodplains. It often includes identification of suitable areas for ecological restoration.

Constructed wetlands (including constructed tertiary treatment wetlands)
Constructed wetlands are used for many water quality purposes. In this project they were singled out to address agricultural and municipal wastewater impacts, but they may also be useful for mitigating the impacts of urbanization or as a component of conservation planning. Constructed wetlands are intended to perform many of the same services as natural wetlands, including water quality improvement, floodwater attenuation and control, and hydrological restoration. Constructed tertiary treatment wetlands are sometimes used as a component of the treatment process at some municipal wastewater plants. They can be more effective than traditional engineered plants at removing pharmaceuticals and other difficult to treat contaminants.

Construction BMPs
Construction BMPs are used to minimize impacts from the development process. They are typically geared towards erosion and sedimentation control, and include silt fences, erosion blankets and mats, practices for site entries and exits, and other measures.

Crop production BMPs
Crop best management practices (BMPs) cover a wide range of activities designed to reduce the environmental impacts of crop production, including tilling practices, fertilizer and pesticide application rates, and use of cover crops.

Culvert replacement
Road crossings through streams can impede the passage of fish and other aquatic fauna, fragmenting habitat and isolating populations. To prevent these impacts, culverts should be designed and installed to allow for passage of water and aquatic organisms.

Determining recharge areas for and specific habitats supplied by aquifers
Site specific investigations into the connections between aquifers, the terrestrial areas that recharge them, and the aquatic habitats they supply are required to address groundwater withdraw impacts. Hydrologists and other researchers have developed a number of approaches that can provide this information.

Ecological flows
Impoundments disrupt the natural flow of surface water systems needed to support healthy populations of freshwater fauna. Restoring ecological flows is one method for mitigating impacts related to large dams. Ecological flows are water releases from dams that simulate “natural” quantity and timing of flows required to support water quality, temperature, sediment movement and deposition, and fish and wildlife.

Farmland restoration
Permanently reforesting or revegetating farmland is a technique used in some watersheds where erosion on livestock and crop production operations contribute to water quality problems. These kinds of

activities are often coupled with land conservation programs: land is purchased from a farmer (in fee or a purchase of development rights) and then restored.

Forestry BMPs

Forestry BMPs include activities for streamside management zones, stream crossings, forest roads, timber harvesting, reforestation, forested wetland management, and stabilization. Forestry BMPs are voluntary in most southeastern states.

Impoundment removal

Demolishing dams helps restore the natural flow of surface waters. Small dam removal is quite common, and large dam removal is becoming more common as public pressure to remove aging dams that provide limited services mounts. Most large dam removal projects in the U.S. in recent years have been for river restoration and fish passage purposes.

Improved stormwater management (including green infrastructure)

Nonpoint source pollution impacts from stormwater runoff is one of the leading causes of water quality pollution in the U.S. In many communities, improved stormwater management is needed. A wide variety of strategies can be utilized. Gaining in popularity are so-called "green infrastructure" practices. The term "green infrastructure" can be used to refer to a variety of practices utilized to limit the impacts of development on both aquatic and terrestrial resources. It often includes better site planning, which directs development away from sensitive resources; better site design, which minimizes land disturbance and creation of new impervious surfaces; and low impact development, small-scale stormwater management practices that reduce post-construction stormwater runoff rates, volumes, and pollutant loads (including, for example, bioswales and rain gardens).

Invasive species control

Invasive fauna can alter ecosystem structure and function by outcompeting native species for resources such as food and habitat (and sometimes using native species themselves as a food source). Invasive flora, such as *Hydrilla*, some species of watermilfoil, and Chinese privet, can overtake aquatic habitats, often leading to problems with dissolved oxygen. Invasive aquatic fauna such as the Asian carp, Asian clams, and zebra mussels have impacted southern waterways. Invasive species control measures often include prevention, detection, assessment, eradication, containment, control, and mitigation.

Irrigation BMPs

BMPs intended to improve the efficiency of agricultural irrigation include information gathering and planning practices, crop and land management practices, and water-efficient on-farm water delivery systems.

Land conservation

Land conservation can be used to mitigate or prevent threats from a number of activities. It can provide a buffer between threats and important aquatic resources and prevent threats from occurring on important sites.

Livestock BMPs

A wide range of livestock BMPs can be used to minimize impacts to aquatic resources. They include soil testing for pasture fertilizer application, nutrient management plans, proper manure fertilization, legume

establishment, heavy use area protection, and other practices. Two very common, and very important, livestock BMPs are highlighted below.

- Livestock exclusion: Livestock operations are common throughout the Southeast, and many small to mid-sized cattle operations are found in priority watersheds of the Southeastern Aquatic Biodiversity Conservation Strategy. Although streams and sinkholes can make convenient watering areas for cattle, animals often erode soils on streambanks and around sinkholes and defecate in the water as they drink. Livestock exclusion devices are a rather simple and inexpensive method for restoring aquatic health in many areas. They typically include fencing animals out of streams or sinkholes and providing an alternate water source. Usually the most difficult aspect of any livestock exclusion project is convincing the property owner that is should be installed.
- Livestock waste management: Livestock waste management uses a variety of techniques to prevent the introduction of manure from cattle, hogs, chicken, and other animals into surface waters and karst systems. It often includes animal waste control facilities, land application strategies, and loafing lot management.

Mine site reclamation

Mine reclamation is restoring a mining site to a natural or otherwise usable site. There are a number of approaches to mine site reclamation, but it typically includes removing hazardous materials, reshaping the land, restoring topsoil, and planting native grasses, trees, or ground cover.

EPA Good Samaritan Initiative intended to encourage voluntary cleanups by limiting liability and allowing partial cleanup, but some liability questions remain unanswered and cleanups may be prohibitively expensive for some groups.

Mine remediation activities

Mine remediation activities, as opposed to site reclamation, involve activities that are outside of the mining site itself. Often called "passive" remediation, they are typically used to combat the effects of acid mine drainage from abandoned coal mines. These activities include installing limestone channels and restoring and constructing wetlands. Restored and constructed wetlands have had mixed results.

Monitoring spring and cave flows

Monitoring spring and cave flows is critical for determining the effect of groundwater withdrawals on karst water resources and karst-dependent species.

Outreach and education

The natural landscape of the South is important to the region's well-being and culture; however, many residents have little knowledge or appreciation of the extraordinary freshwater aquatic biodiversity or the threats to these resources. Outreach and education initiatives are, therefore, critical for instilling a culture of biodiversity conservation. In fact, outreach and education will likely be necessary to obtain community or landowner buy-in for many projects, particularly in areas historically wary of outsider influence (or meddling).

Riparian buffers

Buffers are one of the most commonly used methods for protecting and restoring water quality. A simple concept that is relatively easy to implement (assuming a willing landowner), buffers can help control streambank erosion, slow stormwater runoff, and filter pollutants. Buffers that contain trees can also regulate surface water temperatures by providing shade. Buffer widths and lengths needed to provide measurable water quality benefits may depend on topography and the width of floodplains.

Septic system remediation

Septic systems are used as the primary method for wastewater treatment in many communities across the south. These systems can be effective, permanent wastewater infrastructure, but only if they are properly sited, designed, operated, and maintained. Unfortunately, the southern landscape (and many other parts of the country) contains many areas where systems are poorly designed or were sited in unsuitable areas. Proper operation and maintenance of septic systems is also a very common issue in most communities; few states or local governments have effective maintenance requirements. Many systems across the South need extensive repairs or replacement, but these improvements may be prohibitively expensive for homeowners. Programs that identify areas with problematic systems that impact aquatic health, help pay for system fixes, and establish a maintenance program are particularly effective. Other programs, like education initiatives or maintenance incentive programs, can also be helpful. In many cases, funding is needed to first identify the locations of systems within a community. This can be time-consuming, but is a necessary first step for many remediation programs.

Species-sensitive reservoir evaluations

As part of the Etowah Aquatic Habitat Conservation Plan, project partners developed a template for water supply reservoir evaluations that addressed impacts to aquatic species. Similar evaluations may be conducted in other priority watersheds to gauge the efficacy of various potential sites for these projects.

Turf management BMPs

Residential and other turf management BMPs seek to minimize fertilizer and chemical inputs from these areas into local waters. They include turfgrass selection, fertilizer and pesticide application rates and timing, irrigation practices, and other measures.

Water conservation

Water conservation initiatives have recently become more commonplace in the southeastern U.S. as water supply issues – and lawsuits – have garnered widespread attention in the region. A wide variety of program options exist, including education and outreach, incentives, and regulatory mandates.

Water quality monitoring

Water quality monitoring downstream of potential major sources of impairment – such as municipal wastewater treatment systems, industrial dischargers, power plant coal ash ponds, and landfills – can alert residents and others to potential issues at these facilities and may spur action.

General Management Actions to Support Species

Aquatic restoration

Aquatic restoration activities, such as stream and wetland restoration, are necessary in many areas to provide suitable habitat and opportunities for species migration and recruitment.

Basic research
Basic research includes classification, taxonomy, range, population status, demography, life history, etc.

Captive propagation for reintroduction and augmentation
Population augmentation is typically unsuccessful for fishes, may never have been done for crayfishes, and is usually conducted for mussels in populations with few old, non-reproducing individuals. Reintroductions must occur in places where the cause of extirpation has been remedied.

Genetic research
Genetic research has been recommended in conjunction with recovery plans for mussels.

Land conservation
Land conservation is important for preserving healthy or recovering populations and important habitat.

Barren

Kentucky, Tennessee

Watershed Description

The Barren River Watershed is located in south-central Kentucky and north-central Tennessee in the Interior Low Plateau ecoregion of both states. It is a major tributary of the Green River, part of the Ohio River system, and drains 2,262 square miles (1,852 in Kentucky, 410 in Tennessee). It is formed by the confluence of Line Creek and East Fork in Monroe County, Kentucky, and its principal tributaries are Drakes Creek, Skaggs Creek, and Gasper River. The watershed's topography is characterized by rugged areas in the headwaters and near the river's mouth, with more gently rolling areas near the center of the watershed. The northwest-central portion of the watershed contains a belt of cavernous limestone where subterranean drainage is prevalent. Karst features are also found in the Tennessee portion of the watershed. Impoundments in the watershed have changed some waters from cool, free-flowing riffles and shoal areas to slower, warm water pools. There is one mainstem impoundment on the Barren River, the 10,100 acre Barren River Lake. The Barren Watershed is listed as an Aquatic Conservation Area in the Kentucky State Wildlife Action Plan (SWAP).

The Barren River and Barren County were named after The Barrens, meadow lands found in the northern part of the watershed.

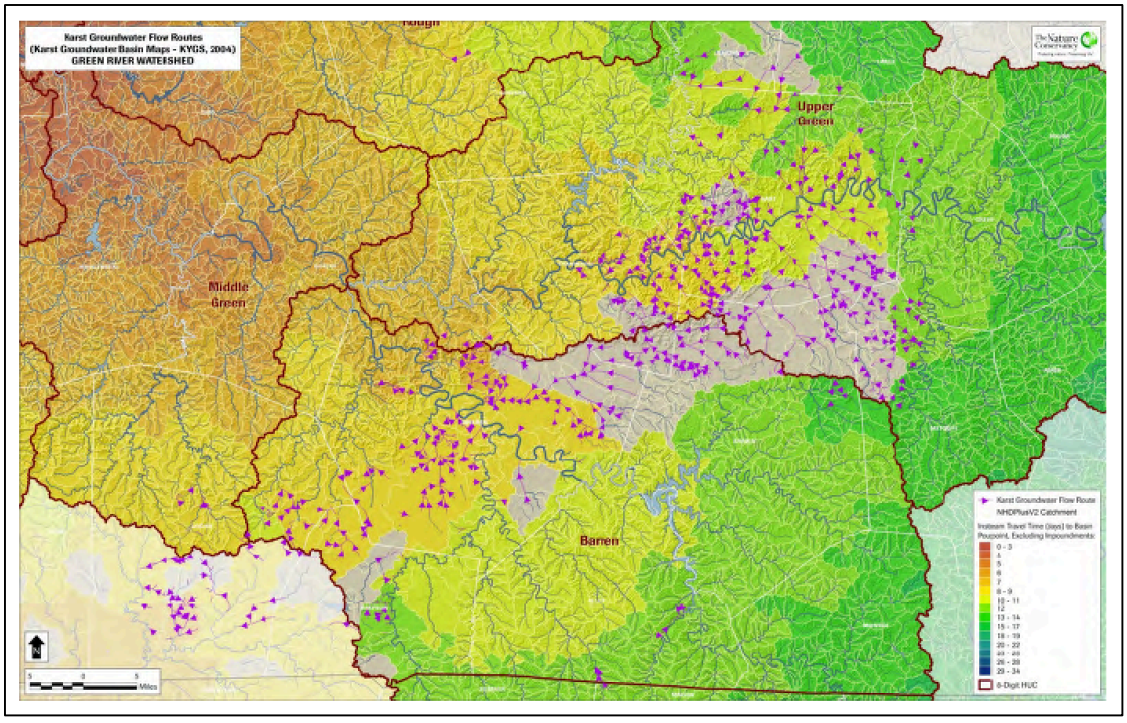

Figure 1. A map depicting karst/subsurface flow in the Green River Basin, including the Barren Watershed in Kentucky. © TNC 2014 (Green River Basin Conservation Business Plan)

The predominant land use in the Barren River Watershed is agriculture (51% of watershed area), followed by forests (37%) and urban areas (8%; see map below). Most agricultural land uses are

pasture/hay for livestock production (40%), but row crops are also common (11%), particularly in the western portion of the watershed. A dense swath of row crop lands extends from the northeast of Bowling Green, where these lands occupy a narrow band, to the southwest of the city, where they encompass a larger area.

The principal city in the watershed is Bowling Green, the third largest city in Kentucky. Its metropolitan area has a population of a little over 165,000, and shares a statistical area with the City of Glasgow, population 220,000.

Species

The Green River, of which the Barren is a major tributary, was a smaller, more isolated headwater tributary of the ancestral Ohio River before the last glacial period ("ice age"). This isolation led to the evolution of a suite of local endemic species, contributing to the overall species richness of the Green and its tributaries. Mussel diversity is particularly exceptional.

The Barren Watershed contains a total of 191 species of fishes, mussels, and crayfishes, including 29 southeastern endemics (see table below). Of these species, 14 are vulnerable, 7 are threatened, and 10 are endangered. The Kentucky State Wildlife Action Plan (SWAP) lists 32 Species of Greatest Conservation Need (SGCN) in the watershed, and the Tennessee SWAP lists 40.[2]

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Barren watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Aquatic species in the Barren Watershed are likely threatened primarily by row crop production practices, urbanization, stormwater injection into karst systems, and sinkhole dumping. Other potential threats include impoundments and barriers and livestock operations. Many management actions appropriate in the watershed address multiple threats and will benefit

[2] The total number of SGCN species in the watershed, as identified by both states, is less than the sum of these totals because some species listed as SGCN in Kentucky are also listed as SCGN in Tennessee. State SWAPs, however, define what constitutes a SGCN differently, and providing a sum of total SCGN might incorrectly indicate that all of the SGCN species have similar conservation needs.

multiple species. More information on individual management actions, including watershed-specific information when available, is found in the table at the end of the section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

Primary Threats and Associated Management Actions

Agriculture – row crop production. Although pasture and hay for livestock production is the most common agricultural land use in the Barren River Watershed, the most widespread impacts to water quality, species, and habitat likely stem from row crop production. Issues with row crop production are nutrient and chemical inputs from fertilizer and pesticides, respectively, erosion and sedimentation from tillage practices on highly erodible soils, and a lack of riparian buffers. Threats from these agricultural practices are particularly significant when they occur in karst areas, as contaminants may enter the karst system directly and are not filtered through soil before entering groundwater storage.

Management actions that address row crop production include:

- Crop production BMPs
- Riparian buffers
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Urbanization. Urban development does not occur throughout the entire Barren River Watershed, but it is significant enough in some areas to deserve recognition as a potential primary threat to aquatic species and habitat. Of highest concern is the Bowling Green-Glasgow Combined Statistical Area, which has been one of the fastest growing areas of Kentucky in recent years. Land use conversion has increased impervious surfaces resulting in issues primarily associated with stormwater runoff and its management (see below). As with agriculture, land

development best management practices are important for protecting aquatic resources in the Barren River Watershed because of the region's significant karst resources.

Management actions that address urbanization include:

- Riparian buffers
- Improved stormwater management (including green infrastructure)
- Conservation planning
- Land conservation
- Aquatic restoration
- Outreach and education

Stormwater injection and waste dumping in karst systems. Besides agriculture and general urban impacts, two other threats related to karst topography are important – stormwater injection and sinkhole dumping. The City of Bowling Green has historically managed its stormwater using stormwater injection wells, which direct untreated runoff into subterranean drainages.[3] This could be addressed by improved stormwater management (including green infrastructure). In addition to stormwater, waste is dumped into sinkholes in many parts of Tennessee and Kentucky, including parts of the Barren River Watershed. Although education campaigns exist to deter people from dumping in sinkholes, the practice still occurs.[4] Management actions to address this include identifying alternative dump sites and outreach and education.

Other Threats and Associated Management Actions

Impoundments and barriers. One large reservoir (Barren River Lake) and one small lock and dam structure exists on the Barren River mainstem in Kentucky. The potential for establishing ecological flows at Barren River Lake is being investigated by some organizations (see table). Other small impoundments exist in the river's tributaries as well as an unknown number of potential barriers such as hanging culverts. These structures alter hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Management actions to address impoundments and barriers include:

- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage
- Ecological flows

[3] *See* TNC, GREEN RIVER BASIN CONSERVATION BUSINESS PLAN, Appendix C, p. 12, Strategy III.A (2014).
[4] Greg Wells, *Counties get cash to clean up dumps*, Bowling Green Daily News, August 17, 2005, *available at* http://www.bgdailynews.com/news/counties-get-cash-to-clean-up-dumps/article_cbc3ddd2-d08e-568b-80a7-86db636cadd5.html.

Agriculture – livestock operations. Nutrients, pathogens, and sediment are an issue when livestock operations are not managed to protect aquatic habitats. Improperly managed manure from livestock (mostly cows in the Barren River watershed) can enter surface waters and seep into karst drainages. When livestock have access to surface waters, they can erode stream banks and defecate directly into the channel.

Management actions to address livestock operations include:

- Riparian buffers
- Livestock exclusion
- Livestock waste management
- Livestock BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Barren River Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

TNC Kentucky: TNC's Kentucky office has been working in the Green River Watershed since the 1990s. Since then, the organization has worked with landowners and other partners on a number of land protection and conservation initiatives, including a partnership with the Army Corps of Engineers to manage the Green River Lake dam to mimic more natural flows. TNC has expanded its focus to include the lower portions of the watershed, including the Barren River, and is working with the Corps to improve flows from Barren River Lake to support species and habitat.
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/kentucky/placesweprotect/kentucky-green-river-feature-collection.xml

Barren River Area Development District: The Barren River Area Development District is part of a state network of development districts that provide planning and development assistance to multi-county regions, including assistance with planning and zoning laws and recreation planning. http://www.bradd.org/index.php

Kentucky Waterways Alliance: The Kentucky Waterways Alliance, founded in 1993, works with communities on local watershed issues and with state and federal actors to advocate for protective regulations. The organization has engaged in projects in the Barren River Watershed. http://kwalliance.org

Watershed Watch in Kentucky: Watershed Watch in Kentucky is a statewide citizen water quality monitoring program that collects data in the Barren River Watershed. https://sites.google.com/site/watershedwatch/home

Bowling Green Canoe and Kayak: Bowling Green Canoe and Kayak is a kayaking and canoeing group that has engaged in local river and creek "Clean-Up Paddles." http://www.meetup.com/paddling-51/

Forecastle Foundation: The Forecastle Foundation is a nonprofit organization dedicated to protecting the world's most biologically rich and highly threatened areas. It is the activist arm of the Forecastle Festival, held in Louisville, Kentucky, since 2002. The Forecastle Foundation has partnered with TNC to protect the Green River Watershed, including the lower portions that include the Barren River. http://www.forecastlefoundation.org/tnc/

Plans and Other Resources

Barren River Water Quality Management Plan (TDEC 2007): This plan, developed by the Tennessee Department of Environment and Conservation according to the "Watershed Approach" to water quality, provides background on that approach, a detailed description of the watershed in Tennessee, a review of water quality sampling and assessment, as assessment of point and nonpoint sources of pollution in the watershed, descriptions of partnerships between agencies and landowners, and provides approaches to water quality problems in the watershed. https://tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-barren-2007.pdf

Green River Basin Conservation Business Plan (TNC 2014): This plan will "guide [TNC's] strategies and internal and partner collaboration to address major freshwater conservation challenges for the Green River Basin… [It] is meant to create a formal structure for TNC staff, identify 10-year desired conservation outcomes, high priority basin-scale strategies, and implementation recommendations … to advance this work in the next 5 years." It includes the Green River Basin Spatial Priorities Model draft maps in Appendix B. Available from TNC Kentucky.

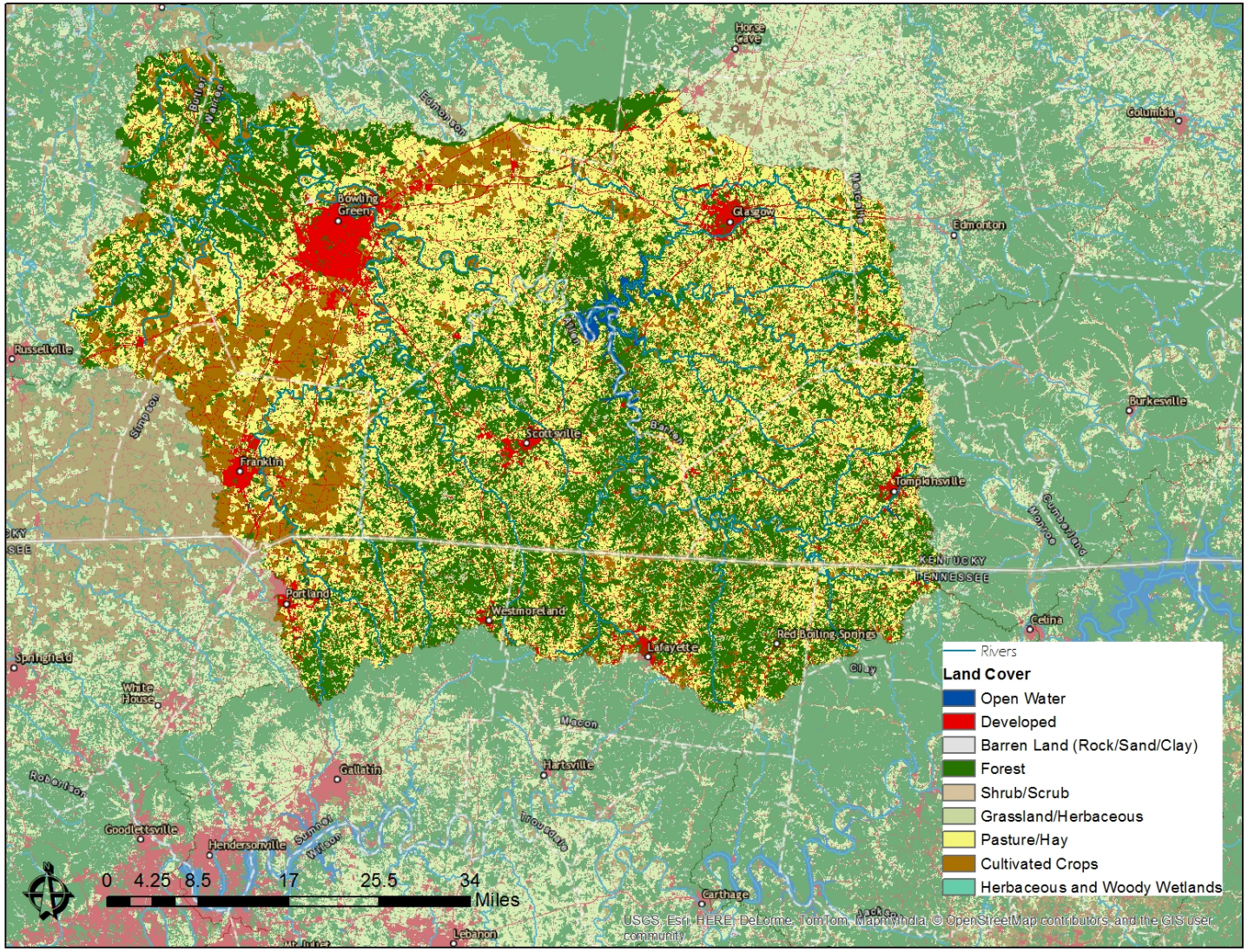

Figure 2. Land Use / Land Cover in the Barren River Watershed

Barren

Kentucky, Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Barren Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	109	14	0	2	4
Mussels	60	3	10	5	10
Crayfishes	22	12	0	0	0
TOTAL	191	29	10	7	14

Kentucky SWAP Species of Greatest Conservation Need that Occur in the Barren				
	Tier I.	Tier II.	Tier III.	Tier IV.
	Extirpated (EX).	Extirpated/Conservation Action Underway (EXCAU).	Critical Conservation Need (P1).	Very High Conservation Need (P2).
Fishes TOTAL: 8	2 goldeye (*Hiodon alosoides*), popeye shiner (*Notropis ariommus*)	0	2 speckled chub (*Macrhybopsis hyostoma*), slenderhead darter (*Percina phoxocephala*)	4 streamline chub (*Erimystax dissimilis*), brindled madtom (*Noturus miurus*), gilt darter (*Percina evides evides*), stargazing minnow (*Phenacobius uranops*)
Mussels	3 Hickorynut (*Obovaria olivaria*), ring pink (*Obovaria retusa*), clubshell (*Pleurobema clava*)	0	16 mucket (*Actinonaias ligamentina*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), fanshell (*Cyprogenia stegaria*), spike (*Elliptio dilatata*), snuffbox (*Epioblasma triquetra*), longsolid (*Fusconaia subrotunda*), pink mucket (*Lampsilis abrupta*), round hickorynut (*Obovaria subrotunda*), sheepnose (*Plethobasus cyphyus*), Ohio pigtoe (*Pleurobema cordatum*), rough	2 black sandshell (*Ligumia recta*), monkeyface (*Quadrula metanevra*)

Kentucky SWAP Species of Greatest Conservation Need that Occur in the Barren				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 21			pigtoe (*Pleurobema plenum*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), kidneyshell (*Ptychobranchus fasciolaris*), creeper (*Strophitus undulatus*)	
Crayfishes TOTAL: 3	0	0	1 boxclaw crayfish (*Cambarus distans*)	2 depression crayfish (*Cambarus rusticiformis*), saddle crayfish (*Orconectes durelli*)
				TOTAL KY SGCN: 32

Tennsee SWAP Species of Greatest Conservation Need in the Barren River Watershed		
	Tier I	Tier III
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 11	11 streamline chub (*Erimystax dissimilis*), teardrop darter (*Etheostoma barbouri*), splendid darter (*Etheostoma barrenense*), orangefin darter (*Etheostoma (Nothonotus) bellum*), spotted darter (*Etheostoma (Nothonotus) maculatum*), flame chub (*Hemitremia flammea*), longhead darter (*Percina macrocephala*), slenderhead darter (*Percina phoxocephala*), frecklebelly darter (*Percina stictogaster*), blackfin sucker (*Thoburnia atripinnis*), southern cavefish (*Typhlichthys subterraneus*)	0
Mussels TOTAL: 24	15 mucket (*Actinonaias ligamentina*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), longsolid (*Fusconaia subrotunda*), fatmucket (*Lampsilis siliquoidea*), black sandshell (*Ligumia recta*), hickorynut (*Obovaria olivaria*), round hickorynut (*Obovaria subrotunda*), Ohio pigtoe (*Pleurobema cordatum*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), creeper (*Strophitus undulatus*), purple lilliput (*Toxolasma lividum*), rainbow (*Villosa iris*), little spectaclecase (*Villosa lienosa*)	9 fanshell (*Cyprogenia stegaria*), catspaw (*Epioblasma obliquata ssp. obliquata*), snuffbox (*Epioblasma triquetra*), pink mucket (*Lampsilis abrupta*), ring pink (*Obovaria retusa*), sheepnose (*Plethobasus cyphyus*), clubshell (*Pleurobema clava*) rough pigtoe (*Pleurobema plenum*), rabbitsfoot (*Quadrula cylindrica cylindrica*)
Crayfishes TOTAL: 5	5 bottlebrush crayfish (*Barbicambarus cornutus*), cavespring crayfish (*Cambarus tenebrosus*), Barren River crayfish (*Orconectes barrenensis*), surgeon crayfish (*Orconectes forceps*), Mammoth Cave crayfish (*Orconectes pellucidus*)	0
		TOTAL TN SGCN: 40

Management Actions to Address Threats in the Barren River Watershed*		
Management Action	**Threats Addressed**	**Notes**
Ecological flows	Impoundments and barriers	The Nature Conservancy is working towards incorporating ecological flows at all river dams in the Green River Watershed (KY), including Barren River Lake dam. Adoption of ecological flows at Barren River Lake is, however, more challenging than at other dams in the Green River Watershed.[5]
Barrier modification for fish passage	Impoundments and barriers	
Impoundment removal	Impoundments and barriers	The Nature Conservancy is working towards removing Barren River Lock and Dam 1, a navigation facility that is no longer in use.[6]
Culvert replacement	Impoundments and barriers	
Outreach and education	Agriculture, urbanization, sinkhole dumping	The Nature Conservancy plans to conduct outreach in the Bowling Green community related to karst management and water conservation.[7] The Kentucky Geological Survey's *Protect Kentucky's Karst Aquifers from Nonpoint-Source Pollution* fact sheet is an excellent outreach and education tool.[8]
Crop production BMPs	Agriculture	The Kentucky Agriculture Water Quality Plan contains BMPs for crop production.[9]
Livestock exclusion	Agriculture	The Kentucky Agriculture Water Quality Plan contains BMPs for livestock operations, including stream exclusion.[10]
Livestock waste management	Agriculture	
Livestock BMPs	Agriculture	
Riparian buffers	Agriculture, urbanization	
Farmland restoration	Agriculture	

[5] TNC, Green River Basin Conservation Business Plan, Appendix C, Strategy I.A (2015).
[6] TNC, Green River Basin Conservation Business Plan, Appendix C, Strategy I.B (2015).
[7] TNC, Green River Basin Conservation Business Plan, Appendix C, Strategy III.A (2015).
[8] Kentucky Geological Survey, Protect Kentucky's Karst Aquifers from Nonpoint-Source Pollution, *available* http://kgs.uky.edu/kgsweb/olops/pub/kgs/mc27_12.pdf.
[9] Kentucky Division of Conservation, THE KENTUCKY AGRICULTURE WATER QUALITY PLAN (2014), *available at* http://conservation.ky.gov/pages/agriculturewaterquality.aspx.
[10] Kentucky Division of Conservation, THE KENTUCKY AGRICULTURE WATER QUALITY PLAN (2014), *available at* http://conservation.ky.gov/pages/agriculturewaterquality.aspx

Management Actions to Address Threats in the Barren River Watershed*		
Management Action	**Threats Addressed**	**Notes**
Alternative dump sites	Sinkhole dumping	Barren County holds an annual "spring cleaning" event where residents can bring solid waste to county trucks posted at volunteer fire departments, dumpsters, and recycling trailers.[11]
Aquatic restoration	Agriculture, urbanization	A wetland restoration project at Calvert Springs in the Barren River WMA was completed in 2006, restoring 45 acres of spring-fed marsh along Barren River Lake. The Tennessee Stream Restoration mapper provides information on projects throughout the state.
Land conservation	Agriculture, urbanization, impacts to karst resources	
Conservation planning	Urbanization	In 2012, the Kentucky Geological Survey released *Model Ordinance for Development on Karst in Kentucky: Guidance for Construction on Karst Terrain and the Reduction of Property Damage and Threat to Human Health Resulting from Karst Geologic Hazard*. This document may help local governments understand the issues with developing in karst terrains, better equip them to direct development away from these areas, and manage stormwater so that it poses less of a risk to groundwater resources. The model ordinance should, however, be reviewed by karst water quality experts to ensure recommendations are in line with current knowledge regarding these sensitive resources.[12]
Improved stormwater management (including green infrastructure)	Urbanization, stormwater injection into karst resources	Watershed Watch in Kentucky's *Kentucky Green Infrastructure Action Plan* provides Kentucky communities with strategies to help manage stormwater runoff and wet weather sewage overflows with green infrastructure.[13] Also see information on the *Model Ordinance for Development on Karst in Kentucky*, above.

** The Kentucky and Tennessee SWAPs contain a large number of Conservation Actions that support these Management Actions. See Kentucky SWAP, Appendix 3.3, and Tennessee SWAP, Appendix G.*

[11] Melinda Overstreet, *Clean it up Barren County: Spring clean-up event will begin March 21*, GLASGOW DAILY TIMES, Mar. 12, 2015, *available at* http://www.glasgowdailytimes.com/news/clean-it-up-barren-county-spring-clean-up-event-will/article_f5fd316a-c934-11e4-94a5-5ba69d31f965.html.

[12] James C. Currens, MODEL ORDINANCE FOR DEVELOPMENT ON KARST IN KENTUCKY: GUIDANCE FOR CONSTRUCTION ON KARST TERRAIN AND THE REDUCTION OF PROPERTY DAMAGE AND THREAT TO HUMAN HEALTH RESULTING FROM KARST GEOLOGIC HAZARD (Kentucky Geological Survey 2012), available at http://kgs.uky.edu/kgsweb/olops/pub/kgs/IC25_12.pdf.

[13] Watershed Watch in Kentucky, THE KENTUCKY GREEN INFRASTRUCTURE ACTION PLAN (2012), *available at* http://kwalliance.org/wp-content/uploads/2013/01/ky_green_infrstruc_action_plan.pdf.

General Management Actions to Support Species in the Barren River Watershed	
Management Action	**Notes**
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	
Captive propagation for reintroduction and augmentation	Kentucky's Center for Mollusk Conservation was founded in 2002 to restore and recover rare and imperiled freshwater mollusks in Kentucky.[14]

[14] *See* KY Dept. of Fish and Wildlife Services, CENTER FOR MOLLUSK CONSERVATION (BROCHURE), *available at* http://fw.ky.gov/Wildlife/Documents/CenterBrochure2013.pdf.

Cahaba

Alabama

Watershed Description

The Cahaba River Watershed is an approximately 1,800 square mile drainage in central Alabama. At 191 miles long, it is the longest unimpounded river in the state and the third largest tributary to the Alabama River in the Mobile River Basin. The Cahaba rises in the Ridge and Valley ecoregion in Jefferson County, running through steep banks and rocky shoals in what is commonly referred to as the Upper Cahaba. Once it crosses the Fall Line and enters the Southeastern Plains ecoregion, the Cahaba is a dramatically different river. The Lower Cahaba slows, widens, and deepens, and wide beach sandbars and cypress swamps become common. The river is very popular for canoeing, fishing, swimming, and environmental education.

Although the entirety of the Cahaba Watershed is mostly forested (60% of the overall watershed area), there are distinct differences in land use between the upper and lower reaches. In the Upper Cahaba Watershed, the impacts of urban land uses dominate. The Upper Cahaba contains much of the Birmingham-Hoover Metropolitan Statistical Area, which has a population of over one million and has grown almost 20% since 1990. The river's headwaters are the primary water source for the Birmingham Water Works Board system, Alabama's largest drinking water provider. The Lower Cahaba, on the other hand, contains few developed areas. There, forests (including many timber operations) and agriculture are the dominant land uses.

Figure 3. Cahaba River, Bibb County. © Alan Cressler.

Species

The Cahaba has more fish species per mile than any other river system in North America. The watershed contains a total of 191 species of fishes, mussels, and crayfishes, including 29 southeastern endemics (see table). Of these, 31 species are imperiled – 14 species are vulnerable, 7 are threatened, and 10 are endangered.[15] There are 32 Species of Greatest Conservation Need (SGCN), as identified by the Alabama State Wildlife Action Plan (SWAP).

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Cahaba Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

The Cahaba Watershed faces distinctly different potential threats in its upper and lower reaches. This threat assessment is, therefore, divided into two segments – the first highlights potential threats and management actions in the Upper Cahaba, the second focuses on the Lower Cahaba. The boundary between the Upper and Lower reaches of the Cahaba is roughly demarcated by US-82 that runs just north of Centreville in Bibb County.

Many management actions appropriate in the watershed address multiple potential threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in the table below. The entire Cahaba River Watershed is a priority area for conservation action in the Alabama SWAP.

Upper Cahaba Watershed

Primary potential threats in the Upper Cahaba Watershed are urbanization in the Birmingham-Hoover Metropolitan Statistical Area and active and abandoned mines. Secondary potential threats include impoundments and barriers and wastewater systems.

[15] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

Primary Potential Threats and Associated Management Actions

Urbanization. Development activities and developed areas in the Birmingham-Hoover Metropolitan Statistical Area are the primary potential threats to aquatic species and habitat in the upper part of the watershed. Sediment inputs are a major water quality issue, and many of these impacts are attributed to residential and industrial/commercial construction activities. Stormwater runoff is often a major issue in urbanized watersheds. In the Upper Cahaba, it has been linked to nutrient, pathogen, sediment, turbidity, and habitat alteration impairments in surface waters.

Management actions to address urbanization include:

- Improved stormwater management (including green infrastructure)
- Riparian buffers
- Aquatic restoration
- Land conservation
- Conservation planning
- Outreach and education

Mines. There are 263 active permitted mines and at least 163 closed permitted coal mines in the Upper Cahaba Watershed. The Southern Environmental Law Center and partner organizations have filed lawsuits concerning coal mining in the Black Warrior watershed, which lies just west of the Cahaba.[16]

Management actions to address mines include:

- Mine site reclamation
- Mine remediation activities
- Aquatic restoration

[16] *See* Southern Environmental Law Center, COAL MINING: A THREAT TO ALABAMA WATERS, https://www.southernenvironment.org/cases-and-projects/coal-mining-a-threat-to-alabama-waters (last visited Sept. 28, 2016).

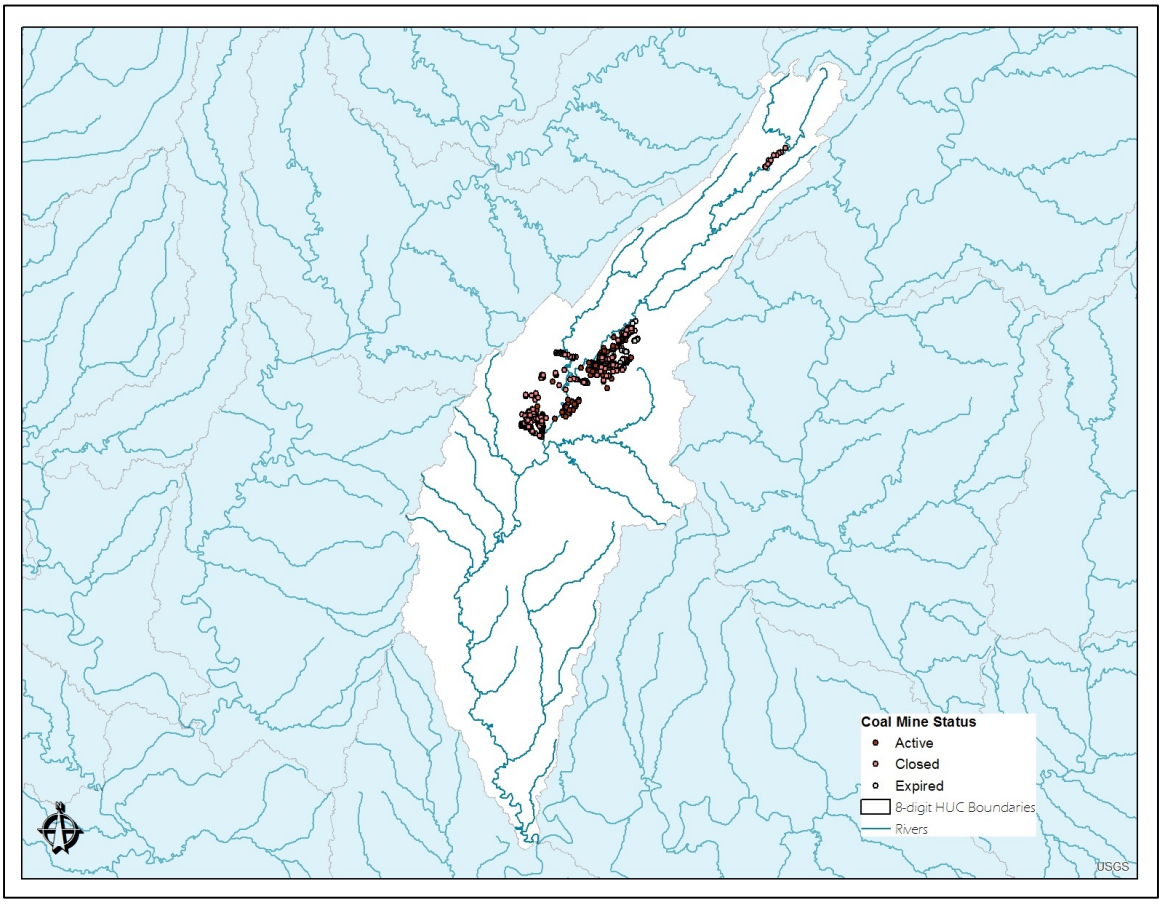

Figure 4. Coal mines sites in the Cahaba Watershed. © USGS.

Figure 5. An abandoned mine shaft outside of Birmingham. © Naaman Fletcher 2014.

Secondary Potential Threats and Management Actions.

Impoundments and barriers. Although the main stem is free-flowing, there are several low dams at or below Highway 280 near Birmingham, including those forming Acton Lake and Cahaba Lake. There are also hundreds of impoundments in Cahaba tributaries as well as an unknown number of potential barriers such as low water crossings (fords) and culverts. The Alabama SWAP notes that these impoundments and barriers can impede or prevent migration, resulting in fragmented populations, restricted gene flow, and local extirpations.

Management actions to address impoundments and barriers include:

- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage

Wastewater systems. Privately owned septic systems and public municipal treatment plants have caused water quality issues in the Upper Cahaba.

- Septic systems: Some areas of the Upper Cahaba have high concentrations of septic systems that could be impacting surface waters and groundwater with nutrients and pathogens.
- Municipal treatment plant discharges: There are 12 major and 19 minor permitted wastewater discharge points in the Upper Cahaba.[17] These facilities are covered by permits that allow them to discharge a certain amount of pollutants based on water quality standards applicable to the receiving water body. In Alabama, numeric nutrient water quality standards currently only exist for reservoirs, so municipal plants that discharge to streams and rivers may be contributing to nutrient issues even if they are in compliance with their permits.
- SSOs: Heavy rains often cause sanitary sewer overflows (SSOs) in municipal treatment systems, including those in the Cahaba Watershed.

Management actions to address septic systems include:

- Septic system remediation
- Conservation planning
- Outreach and education

[17] USFWS, WATER RESOURCE INVENTORY AND ASSESSMENT, CAHABA RIVER NATIONAL WILDLIFE REFUGE 2 (2013).

Most management actions that would directly mitigate municipal treatment plant impacts on aquatic resources in the Cahaba Watershed are business or regulatory decisions. There are, however, some potentially fundable management actions that could help clarify or ameliorate some impacts. These include:

- Water quality monitoring (to highlight or clarify impacts and/or develop nutrient water quality standards)
- Construction of tertiary treatment wetland systems

Lower Cahaba

In the lower, less populated reaches of the watershed, agricultural practices may be the most significant potential primary impact to species, followed by forestry practices. Secondary threats include impoundments and barriers and septic systems.

Primary Potential Threats and Associated Management Actions

Agriculture. After forests, agriculture is the predominant land use in the Lower Cahaba. Livestock operations are the most common agricultural use, followed by row crops. Many agricultural activities occur in the Cahaba's wide, flat floodplains; these can exacerbate impacts to surface waters if best management practices such as proper disposal of animal wastes and riparian buffers are not implemented.

Management actions that address agricultural impacts include:

- Riparian buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Crop production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Forestry. Forestry is a common practice in the Lower Cahaba, and an important component of many local economies. Logging practices can contribute to sedimentation, hydrologic modification, and other issues when best management practices are not in place.

Management actions to address forestry include:

- Forestry BMPs
- Riparian buffers
- Aquatic restoration
- Land conservation
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Impoundments and barriers. There are hundreds of impoundments in Cahaba tributaries, and an unknown number of low water crossings (fords) and culverts. According to the Alabama SWAP, these impoundments and barriers can impede or prevent migration, resulting in fragmented populations, restricted gene flow, and local extirpations.

Management actions to address impoundments include:

- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage

Septic systems. Many communities in the Lower Cahaba Watershed depend entirely on septic systems for wastewater treatment. If inappropriately designed, installed, operated, or maintained, these systems could pollute groundwater and surface waters with pathogens and nutrients.

Management actions to address septic systems include:

- Septic system remediation
- Conservation planning
- Outreach and education

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Cahaba Watershed. They include:

- Land conservation
- Aquatic restoration

- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

The Cahaba River National Wildlife Refuge: The Cahaba River National Wildlife Refuge was established in 2002 to protect and manage a unique section of the Cahaba River and land adjacent to it. https://www.fws.gov/cahabariver/

Cahaba Riverkeeper: The Cahaba Riverkeeper "defend[s] the ecological integrity of the Cahaba, its tributaries and watershed and … ensure[s] clean water, a healthy aquatic environment, and the recreational and aesthetic values of the river." http://cahabariverkeeper.org

Cahaba River Society: The Cahaba River Society's mission is to restore and protect the Cahaba River Watershed and its rich diversity of life. It was founded in 1988 and has worked on a wide variety of issues, including stormwater management, impoundment removal, municipal wastewater disposal issues, riparian buffer projects, and acid mine runoff surveys, identification, and prioritization. http://www.cahabariversociety.org

Cahaba River Group of the Alabama Sierra Club: The Cahaba River Group is an affiliate of the National and Alabama Sierra Clubs. It serves the Birmingham metropolitan area and north central Alabama. http://www.sierraclub.org/alabama/cahaba

Friends of Shades Creek: Founded in 1998, Friends of Shades Creek is a nonprofit dedicated to educating and engaging the community in preservation efforts of Shades Creek. http://shadescreek.org

Freshwater Land Trust: Founded in 1996 and based in Birmingham, the Freshwater Land Trust owns and manages more than 5,000 acres in central Alabama communities, including lands in the Cahaba River Watershed, including along Shades Creek. http://www.freshwaterlandtrust.org

Alabama Clean Water Partnership: The Alabama Clean Water Partnership connects stakeholders to help protect Alabama's water resources and aquatic ecosystems. The organization is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection. http://www.cleanwaterpartnership.org

The Nature Conservancy Alabama: TNC has worked in Alabama for over 25 years. In 2015, TNC Alabama began an urban conservation program in Birmingham to protect and restore natural

systems for the benefit of people and nature.
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/alabama/

Southern Environmental Law Center – Alabama Office: The Southern Environmental Law Center is an active advocate for environmental protection in Alabama and other southeastern states. In Alabama, the SELC is particularly active in addressing threats from coal mining and coal ash. https://www.southernenvironment.org/our-states/alabama

Living River: Living River is a nonprofit organization located on the banks of the Cahaba River in Shelby and Bibb Counties. It offers summer camp and environmental education programs, and has engaged in some coal mine remediation work on site. http://www.livingriver.org

The Birmingham Canoe Club, Inc.: The Birmingham Canoe Club is a local paddling club with over 150 members that is committed to conserving waterways and promoting access.
http://www.birminghamcanoeclub.org

Alabama Rivers Alliance: Founded in 1993, the Alabama Rivers Alliance "is a statewide network of groups working to protect and restore all of Alabama's water resources through building partnerships, empowering citizens, and advocating for sound water policy and its enforcement."
http://alabamarivers.org

Plans and Other Resources

Cahaba River NWR Habitat Management Plan (USFWS 2007): Like other NWR management plans, the Cahaba plan provides "refuge managers [with] a decision making process; guidance for the management of refuge habitat; and long-term vision, continuity, and consistency for habitat management on refuge lands. Each plan incorporates the role of refuge habitat in international, national, regional, tribal, State, ecosystem, and refuge goals and objectives; guides analysis and selection of specific habitat management strategies to achieve those habitat goals and objectives; and utilizes key data, scientific literature, expert opinion, and staff expertise." https://www.fws.gov/cahabariver/pdf/Cahaba%20River%20HMP-Final.pdf

Comprehensive Conservation Plan for Cahaba River NWR (in progress): USFWS is beginning work on a comprehensive conservation plan for the Cahaba River National Wildlife Refuge.
https://www.fws.gov/cahabariver/ccp.html

A Citizen's Guide to Alabama Rivers – Black Warrior and Cahaba (Alabama Cooperative Extension System 2002): This guide offers an introduction to the history and environmental significance of the Cahaba and Black Warrior River Basins.
http://www.aces.edu/dept/fisheries/natural-resources/pdf/war-cah.pdf

Little Shades Creek Restoration Project (TNC 2010): A report detailing a restoration project on Little Shades Creek. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/alabama/little-shades-creek-restoration-project-portfolio.pdf.

Water Resource Inventory and Assessment, Cahaba River National Wildlife Refuge (USFWS 2013): "This Water Resource Inventory and Assessment (WRIA) report for Cahaba River National Wildlife Refuge describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources." https://catalog.data.gov/dataset/cahaba-river-national-wildlife-refuge-water-resource-inventory-and-assessment

Cahaba River Basin Management Plan (ADEM 2004): This plan provides a description of the watershed, a prioritization of issues, a quite of alternatives, and a strategy for protection. http://www.adem.state.al.us/programs/water/nps/files/CahabaBMP.pdf.

Fishes of the Cahaba River System in Alabama (Geological Survey of Alabama 1989): Details on the fish species found in the Cahaba River System.

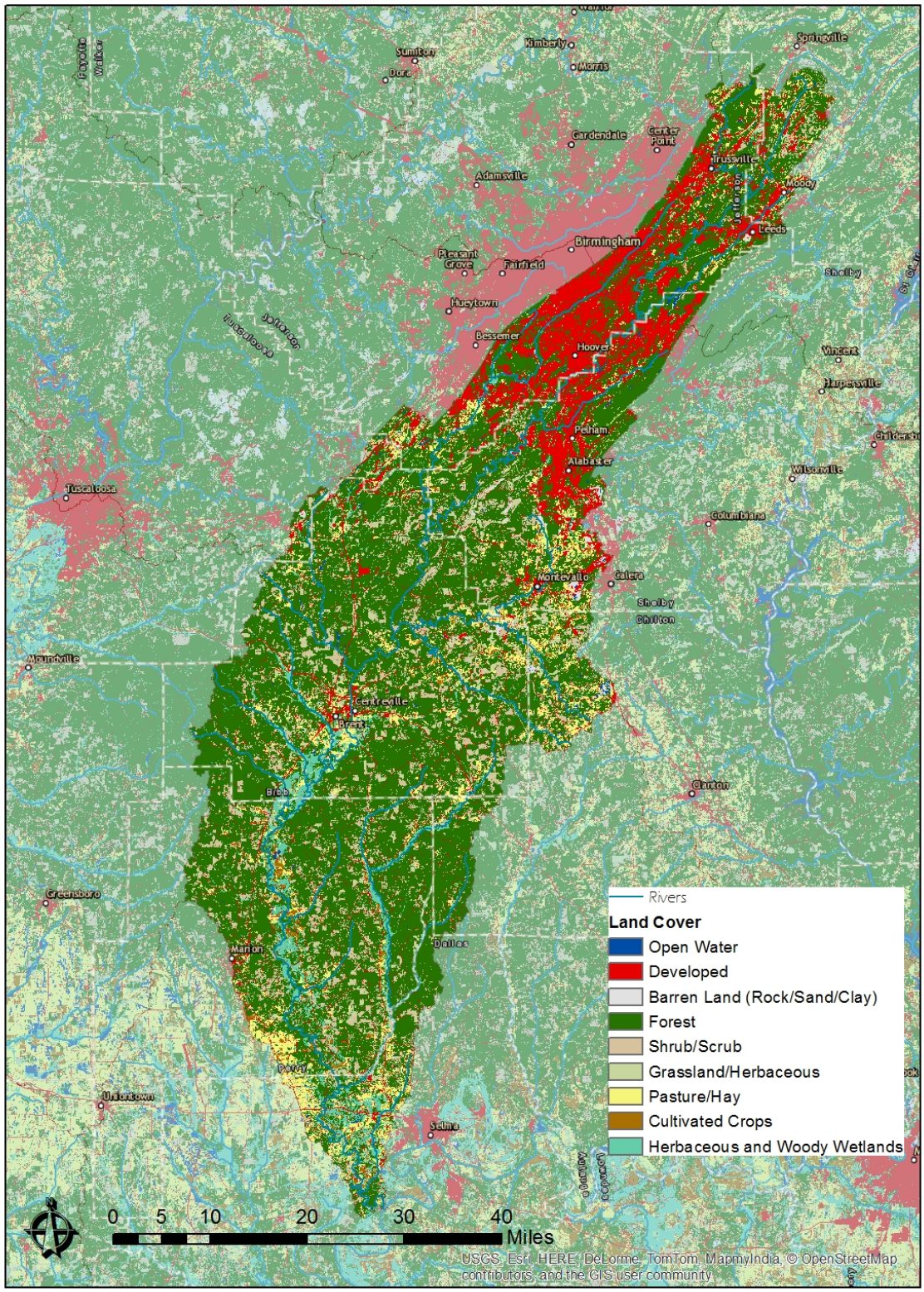

Figure 6. Land Use / Land Cover in the Cahaba River Watershed

Cahaba

Alabama

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Cahaba River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	130	42	4	6	6
Mussels	58	33	16	9	8
Crayfishes	20	14	0	0	3
TOTAL	208	89	20	15	17

Alabama SWAP Species of Greatest Conservation Need that Occur in the Cahaba River Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
	Extirpated (EX).	Extirpated/Conservation Action Underway (EXCAU).	Critical Conservation Need (P1).	Very High Conservation Need (P2).
Fishes TOTAL: 8	0	0	4 Alabama shad (*Alosa alabamae*), blue shiner (Cyprinella caerulea), Cahaba shiner (*Notropis cahabae*), Alabama sturgeon (*Scaphirhynchus suttkusi*)	4 gulf sturgeon (*Acipenser oxyrinchus desotoi*), goldline darter (*Percina aurolineata*), coal darter (*Percina brevicauda*), bluenose shiner (*Pteronotropis welaka*)
Mussels	1 Coosa orb (*Quadrula kieneriana*)	2 Southern combshell (*Epioblasma penita*), Coosa moccasinshell (*Medionidus parvulus*)	10 Alabama spike (*Elliptio arca*), shinyrayed pocketbook (*Hamiota subangulata*), Alabama moccasinshell (*Medionidus acutissimus*), Southern pigtoe (*Pleurobema georgianum*), ovate clubshell (*Pleurobema perovatum*), warrior pigtoe (*Pleurobema rubellum*), heavy pigtoe (*Pleurobema taitianum*), rayed kidneyshell (*Ptychobranchus foremanianus*), triangular	13 rayed creekshell (*Anodontoides radiatus*), delicate spike (*Elliptio arctata*), finelined pocketbook (*Hamiota altilis*), orangenacre mucket (*Hamiota perovalis*), Etowah heelsplitter (*Lasmigona etowaensis*), black sandshell (*Ligumia recta*), Alabama hickorynut (*Obovaria unicolor*), Southern clubshell (*Pleurobema decisum*), inflated heelsplitter

Alabama SWAP Species of Greatest Conservation Need that Occur in the Cahaba River Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 26			kidneyshell (*Ptychobranchus greenii*), Southern purple lilliput (*Toxolasma corvunculus*)	(*Potamilus inflatus*), monkeyface (*Quadrula metanevra*), Alabama creekmussel (*Strophitus connasaugaensis*), Alabama rainbow (*Villosa nebulosa*), Coosa creekshell (*Villosa umbrans*)
Crayfishes TOTAL: 3	0	0	0	3 Prominence Riverlet crayfish (*Hobbseus prominens*), smoothnose crayfish (*Procambarus hybus*), crisscross crayfish (*Procambarus marthae*)
				TOTAL AL SCGN: 37

Management Actions to Address Threats in the Upper Cahaba River Watershed		
Management Action	**Threats Addressed**	**Notes**
Riparian buffers	Urbanization	
Improved stormwater management (including green infrastructure)	Urbanization	
Conservation planning	Urbanization, septic systems	
Land conservation	Urbanization	The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[18]

[18] AL Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

Management Actions to Address Threats in the Upper Cahaba River Watershed		
Aquatic restoration	Urbanization, mines, wastewater systems	The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[19]
Outreach and education	Urbanization, impoundments, septic systems	
Mine site reclamation	Mines	The Alabama Department of Labor's Abandoned Mine Reclamation Program prioritizes abandoned mines and develops reclamation engineering plans that are put out for bid.[20] Birmingham's Red Mountain Park is a 1,500 acre community park is the largest park in the world built on reclaimed mine lands.[21]
Mine remediation activities	Mines	
Septic system remediation	Septic systems	
Water quality monitoring	Wastewater systems (municipal plants)	
Construction of tertiary treatment wetlands	Wastewater systems (municipal plants)	
Impoundment removal	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	

[19] AL Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

[20] AL Dept. of Labor, *Abandoned Mine Land Reclamation*, at https://www.labor.alabama.gov/Inspections/Mining/reclamation.aspx.

[21] Red Mountain Park, *About the Park*, http://redmountainpark.org/about/.

Management Actions to Address Threats in the Lower Cahaba River Watershed		
Management Action	**Threats Addressed**	**Notes**
Barrier modification for fish passage	Impoundments and barriers	The Alabama SWAP notes that fish passage should be provided by the Army Corps of Engineers at Alabama River dams to provide access for Alabama Sturgeon to historic habitat in the Cahaba River.
Impoundment removal	Impoundments and barriers	Removal of the Marvel Slab, a low head dam built across the Cahaba 50 years ago for coal and logging truck crossing, was the first dam removal for environmental purposes in the state of Alabama.[22]
Culvert replacement	Impoundments and barriers	
Riparian buffers	Agriculture, silviculture, urbanization	
Livestock exclusion	Agriculture	
Livestock waste management	Agriculture	
Farmland restoration	Agriculture	
Livestock production BMPs	Agriculture	
Crop production BMPs	Agriculture	
Forestry BMPs	Forestry	*Alabama's Best Management Practices for Forestry* provides voluntary practices for foresters in the state.[23]
Green infrastructure	Urbanization	
Conservation planning	Urbanization, septic systems	
Land conservation	Agriculture, urbanization, forestry	
Aquatic restoration	Agriculture, urbanization, mines, wastewater systems	
Outreach and education	Agriculture, urbanization, impoundments, septic systems, forestry	
Septic system remediation	Wastewater systems (septic systems)	

[22] A presentation regarding the removal of Marvel Slab can be found here: http://www.cahabariver.net/documents/COE-TNC_Partnership-Marvel_Slab_Dam_Removal_11-17-2004.pdf.

[23] AL Forestry Comm'n., ALABAMA'S BEST MANAGEMENT PRACTICES FOR FORESTRY (2007), *available at* http://www.forestry.state.al.us/publications/BMPs/2007_BMP_Manual.pdf.

General Management Actions to Support Species in the Cahaba River Watershed	
Management Action	**Notes**
Land conservation	The Alabama SWAP recommends expanding the Cahaba River National Wildlife Refuge to fulfill its acquisition boundaries as a "Highest Priority Conservation Action."
Aquatic restoration	
Genetic research	
Basic research	The Alabama SWAP details priority research, survey, and monitoring needs for SGCN species in the Cahaba beginning page 272.
Captive propagation for reintroduction and augmentation	To address mussel extinction and endangerment, the Alabama Dept. of Conservation and Natural Resources created the Alabama Aquatic Biodiversity Center (AABC) to lead recovery efforts through propagation and reintroduction. The Alabama SWAP states that augmentation and/or reintroduction is may be required to maintain viability of most SGCN mussel species, all snail SGCN species, all crayfish SGCN species, and the Alabama Sturgeon. In 2012 and 2013, the AABC reintroduced 74 Southern Combshells and 25,727 Spotted Rocksnails to the Cahaba River.

Watershed Description

The Caney Fork Watershed is an approximately 1,800 square mile watershed in eleven counties in central Tennessee. The Caney Fork was named for dense cane breaks that grew along its banks when European explorers first came to the area. It is a major tributary of the Cumberland River and drains a substantial portion of the southwestern Cumberland Plateau and southeastern Highland Rim ecoregions. As of 2003, the TDEC Division of Water Supply inventoried 48 dams in the watershed.[24] The two impoundments on the Caney Fork itself create the 1,800 acre Great Falls Lake and the 18,220 acre Center Hill Lake. There are numerous protected and recreational areas in the watershed, including five state parks.

The Caney Fork Watershed contains low to moderate gradient streams cut down into limestone. It has nutrient-rich, productive waters with algae, rooted vegetation, and occasionally high densities of fishes. There are numerous springs and caves in the watershed, as well as waterfalls and cascades.

Most of the Caney Fork Watershed is forested (58% of the landcover in 2011). The second most common land use is livestock pasture (20%), followed by developed (8%) and row crops (5%).

Approximately 128,000 people live in the Caney Fork Watershed. It covers eleven counties and contains the cities of Cookeville, Sparta, Spencer, Smithville, Pleasant Hill, Monterey, Baxter, Doyle, Alexandria, and Auburntown. Cookeville, home of Tennessee Technological University, has the highest population with around 30,000 residents.

In 2014, *Tennessee Uncharted*, which airs weekly on PBS stations across the state, released an episode on the Caney Fork Watershed that highlights the natural wonders of the area, including the Muskellunge or "Musky" – the largest member of the pike family.[25]

Species

The Caney Fork Watershed contains a total of 159 species of fishes, mussels, and crayfishes, including 115 southeastern endemics (see table). Of these species, 17 are vulnerable, 8 are

[24] TDEC inventories only count dams that either retain 30 acre-feet of water or have structures at least 20 feet high. TDEC, CANEY FORK RIVER WATERSHED WATER QUALITY MANAGEMENT PLAN Ch. 2, 6 (2003), *available at* https://tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-caney-2003.pdf.

[25] Tennessee Uncharted, Episode 106 – "The Caney Fork Watershed," http://www.tnuncharted.com/season1episodes/2014/10/11/episode-106-caney-fork-watershed (last visited Sept. 28, 2016).

threatened, and 16 are endangered.[26] There are 41 Species of Greatest Conservation Need (SGCN), as identified by the Tennessee State Wildlife Action Plan (SWAP).

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Caney watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Aquatic species in the Caney Fork Watershed are likely threatened primarily by agriculture (livestock operations) and urbanization.[27] Other potential threats include mines, agriculture (crop production), wastewater systems, and impoundments and barriers. Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in the tables at the end of this section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

[26] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

[27] *See* Cumberland River Compact: Caney Fork Watershed, http://cumberlandrivercompact.org/resources/cumberland-river-basin/caney-fork-watershed/ (last visited Sept. 28, 2016).

Primary Potential Threats and Associated Management Actions

Agriculture – livestock operations. Agriculture is the second most common land use in the Caney Fork Watershed after forests. Livestock operations are the most common type of agricultural use, and may cause the most widespread impacts to aquatic health. The most likely significant issues are livestock (typically cattle) access to streams and the absence of riparian vegetation.[28] When livestock have access to streams, they typically defecate in the water and erode streambanks. Pasture is also often eroded and can contribute to sedimentation of waterways during precipitation events. Erosion is further exacerbated if riparian vegetation has been removed or streambanks have been compromised. Livestock operations can be particularly harmful if they occur without best management practices in areas with karst resources.

Management actions that address agricultural impacts from livestock operations include:

- Riparian buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Urbanization. Although not widespread throughout the Caney Fork Watershed, urban development is the second potential primary threat to aquatic health. Streams in Cookeville have, for example, been impaired by urban runoff and hydrologic alterations.[29] The Pigeon Roost Creek Watershed, which Cookeville partially comprises, contains the most urban land area of all Caney Fork subwatersheds and is the most impaired, primarily due to stormwater and other urban impacts.

Management actions that address urbanization include:

- Riparian buffers

[28] *See* TDEC, TOTAL MAXIMUM DAILY LOAD (TMDL) FOR SILTATION AND HABITAT ALTERATION IN THE CANEY FORK WATERSHED, Table 2, *available at* https://tn.gov/assets/entities/environment/attachments/watershed_epa-approved_caney-fork-sed.pdf; *see also* TDEC, TOTAL MAXIMUM DAILY LOAD (TMDL) FOR PATHOGENS IN THE CANEY FORK WATERSHED, Table 2, *available at* https://tn.gov/assets/entities/environment/attachments/watershed_epa-approved_caney-fork-path-f1.pdf.

[29] *Id.*

- Improved stormwater management (including green infrastructure)
- Construction BMPs
- Conservation planning
- Land conservation
- Aquatic restoration
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Mines. The Caney Fork Watershed contains a number of abandoned mines and one active coal mine.[30] There are at least six stream segments in the Caney Fork Watershed impaired by abandoned mines.[31] Segments of Clifty Creek, Puncheoncamp Creek, Piney Creek, Gardner Creek, Rocky River, and Dry Fork have high levels of metals and/or low pH. All of these streams are located in the eastern portion of the watershed.

A 2009 TMDL for these streams recommends the management actions below for remediating these impairments:

- Mine site reclamation (specifically, re-grading of spoil and isolation of acid-producing materials from water contact)
- Mine remediation activities (specifically, limestone channels and constructed wetlands)

Agriculture – crop production. Row crops are not particularly common in the Caney Fork, but agricultural practices have caused water quality impacts in some streams.[32] As in other watersheds, principal issues with row crops are erosion and sedimentation and pesticide and fertilizer runoff.

Management actions that address crop production include:

- Crop production BMPs
- Riparian buffers
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

[30] *See* TDEC, TOTAL MAXIMUM DAILY LOAD (TMDL) FOR PH AND METALS IN THE CANEY FORK WATERSHED, Table 5 (2009), *available at* https://tn.gov/assets/entities/environment/attachments/watershed_epa-approved_caney-fork-ph.pdf.
[31] *Id.* at 7.
[32] *See* TDEC, TOTAL MAXIMUM DAILY LOAD (TMDL) FOR PATHOGENS IN THE CANEY FORK WATERSHED, Table 2, *available at* https://tn.gov/assets/entities/environment/attachments/watershed_epa-approved_caney-fork-path-f1.pdf.

Wastewater systems. Municipal treatment plants and septic systems likely cause some impacts to species and/or habitat in the Caney Fork Watershed. Municipal plants have been identified as contributing to pathogen impairments of streams in the watershed, through their discharges and collection systems failures.[33] In addition, Tennessee currently has no numeric water quality standards for nutrients (nitrogen and phosphorus), so treatment plants in compliance with their discharge permits may still be contributing to nutrient issues in surface waters. Septic systems are also identified as a likely source of some fecal coliform loading in the watershed.[34]

Most management actions that would directly mitigate municipal plant impacts on aquatic resources in the Caney Fork Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Discharge/outfall monitoring
- Outreach and education

Management actions to address septic systems include:

- Septic system remediation
- Conservation planning
- Outreach and education

Impoundments and barriers. Two large reservoirs (Great Falls Lake and Center Hill Lake) exist on the Caney Fork mainstem. Other small impoundments exist in the river's tributaries as well as an unknown number of potential barriers such hanging culverts. These structures alter hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Management actions to address impoundments and barriers include:

- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage
- Ecological flows

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are

[33] *Id.*
[34] *Id.* at 19.

used to directly support species survival. These actions would be beneficial for a number of species in the Caney Fork Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

The Cumberland River Compact: Founded in 1997, the Cumberland River Compact is a member organization dedicated to improving water quality in the Cumberland River Basin. With an annual budget of around one million dollars, the Compact focuses efforts on stormwater solutions, stream restoration, outreach and education, and planning.
http://cumberlandrivercompact.org

Caney Fork Watershed Association: The Caney Fork Watershed Association promotes conservation and improvement of the aquatic ecosystems of the watershed. *(May no longer be active; website is not functioning as of September 2016.)*

NFWF Cumberland Plateau Stewardship Fund: The Cumberland Plateau Stewardship Fund is dedicated to restoring native forests to conditions that will improve associated wildlife species and the health of freshwater systems, while advancing strategies to support working forests.
http://www.nfwf.org/cumberland/Pages/home.aspx

Plans and Other Resources

Caney Fork River Watershed Water Quality Management Plan (TDEC, 2003): This plan contains a description of the watershed approach to water quality, a description and water quality assessment of the Caney Fork River Watershed, a point and nonpoint source pollution characterization of its subwatersheds, a description of water quality partnerships, and a section on "future directions" for the watershed.
https://tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-caney-2003.pdf

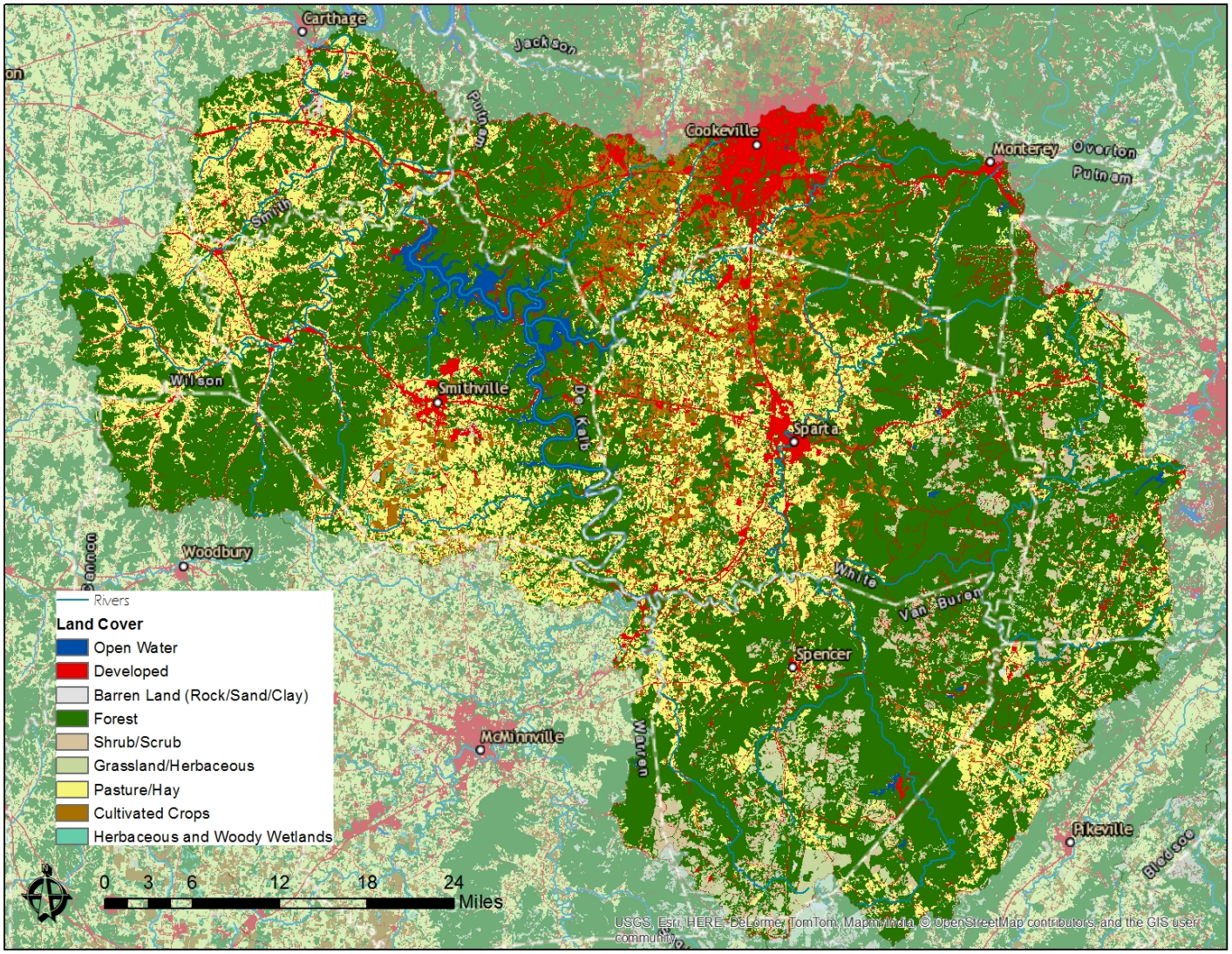

Figure 7. Land Use / Land Cover in the Caney Fork Watershed

Caney Fork

Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Caney Fork Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	86	15	1	0	5
Mussels	55	14	15	6	12
Crayfishes	18	15	0	2	0
TOTAL	159	44	16	8	17

Tennessee SWAP Species of Greatest Conservation Need in the Caney Fork Watershed		
	Tier I	Tier III
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 7	5 blotched chub (*Erimystax insignis insignis*), sooty darter (*Etheostoma olivaceum*), flame chub (*Hemitremia flammea*), bedrock shiner (*Notropis rupestris*), Southern cavefish (*Typhlichthys subterraneus*)	2 bluemask darter (*Etheostoma akatulo*), paddlefish (*Polyodon spathula*)
Mussels TOTAL: 28	15 mucket (*Actinonaias ligamentina*), pheasantshell (*Actinonaias pectorosa*), elktoe (*Alasmidonta marginata*), longsolid (*Fusconaia subrotunda*), Tennessee heelsplitter (*Lasmigona holstonia*), black sandshell (*Ligumia recta*), Cumberland moccasinshell (*Medionidus conradicus*), round hickorynut (*Obovaria subrotunda*), Ohio pigtoe (*Pleurobema cordatum*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), purple lilliput (*Toxolasma lividum*), rainbow (*Villosa iris*), painted creekshell (*Villosa taeniata*), mountain creekshell (*Villosa vanuxemensis*)	13 Cumberland elktoe (*Alasmidonta atropurpurea*), spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*) dromedary pearlymussel (*Dromus dromas*), Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), catspaw (*Epioblasma obliquata obliquata*), snuffbox (*Epioblasma triquetra*), pink mucket (*Lampsilis abrupta*), littlewing pearlymussel (*Pegias fabula*), sheepnose (*Plethobasus cyphyus*), slabside pearlymussel (*Pleuronaia dolabelloides*), rabbitsfoot (*Quadrula cylindrica cylindrica*)
Crayfishes TOTAL: 6	6 short mountain crayfish (*Cambarus clivosus*), hairyfoot crayfish (*Cambarus crinipes*), pristine crayfish (*Cambarus pristinus*), cavespring crayfish (*Cambarus tenebrosus*), Southern cave crayfish (*Orconectes australis*), surgeon crayfish (*Orconectes forceps*)	0
		TOTAL TN SGCN: 41

Management Actions to Address Threats in the Caney Fork Watershed		
Management Action	**Threats Addressed**	**Notes**
Riparian buffers	Agriculture, urbanization, wastewater systems	The Tennessee Urban Riparian Buffer Handbook contains information on establishing buffers in a range of urban settings, a set-by-set guide on how to complete buffer projects, handouts for volunteers, and a regionalized buffer plant list.[35]
Livestock exclusion	Agriculture	Funding is available through the Agricultural Resources Conservation Fund (see below).
Livestock waste management	Agriculture	Funding is available through the Agricultural Resources Conservation Fund (see below).
Livestock production BMPs	Agriculture	The Agricultural Resources Conservation Fund provides cost-share assistance to Tennessee landowners to install Best Management Practices (BMPs) that reduce agricultural water pollution. This assistance is facilitated primarily through Soil Conservation Districts although Resource Conservation and Development Councils, universities, and other agricultural associations may participate. A wide range of BMPs are available for cost-share, from those that curtail soil erosion to ones that help to remove pollutants from water runoff from agricultural operations. Landowners may be eligible to receive up to 75% of the cost of a BMP installation. Part of the fund is available for educational projects which raise awareness of soil erosion/water quality problems and promote BMP use.[36]
Farmland restoration	Agriculture	Funding is available through the Agricultural Resources Conservation Fund (see above).
Aquatic restoration	Agriculture, urbanization, wastewater systems	
Land conservation	Agriculture, urbanization, septic systems	
Outreach and education	Agriculture, urbanization	

[35] TN Dept. of Agriculture, TENNESSEE URBAN RIPARIAN BUFFER HANDBOOK (2015), *available at* http://www.tn.gov/agriculture/topic/ag-forests-turb.

[36] TN Dept. of Agriculture, GUIDELINES FOR THE AGRICULTURAL RESOURCES CONSERVATION FUND (FY 2017), *available at* https://tn.gov/assets/entities/agriculture/attachments/AgFarARCFguidelines.pdf.

Management Actions to Address Threats in the Caney Fork Watershed		
Management Action	**Threats Addressed**	**Notes**
Improved stormwater management (including green infrastructure)	Urbanization	Since 2008, the Tennessee Stormwater Association (TNSA), the Tennessee Valley Authority (TVA), and the Tennessee Department of Transportation (TDOT) have partnered together with the Tennessee Department of Environment & Conservation (TDEC) to offer a Green Development Grant program that was developed as an effort to encourage the advancement of green infrastructure projects across the state.[37]
Conservation planning	Urbanization, septic systems	
Impoundment removal	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	
Ecological flows	Impoundments and barriers	
Mine site reclamation	Mines	A 2009 TMDL for streams in the Caney Fork Watershed recommended re-grading of spoil and isolation of acid-producing materials from water contact as appropriate mine site reclamation activities. The Tennessee Dept. of Environment and Conservation's Land Reclamation Section receives state and federal funding to reclaim abandoned mine sites. Staff identify potential reclamation project sites, design reclamation plans and specifications for those sites, award reclamation contracts, and inspect the reclamation work as it progresses.[38]
Mine remediation activities	Mines	A 2009 TMDL for the Caney Fork Watershed recommended limestone channels and constructed wetlands as appropriate mine remediation activities.
Crop production BMPs	Agriculture	
Water quality monitoring	Municipal wastewater systems	
Construction of tertiary treatment wetland systems	Municipal wastewater systems	
Septic system remediation	Septic systems	

[37] *See more at* TN Dept. of Environment & Conservation, *Green Development*, at http://www.tennessee.gov/environment/topic/wr-green-development.

[38] *See more at* TN Dept. of Env. & Conservation, *Mining Information and Permits*, https://tn.gov/environment/topic/wr-mining-information-permits#sthash.m7geASeZ.dpuf.

General Management Actions to Support Species in the Caney Fork Watershed	
Management Action	**Notes**
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	
Captive propagation for reintroduction and augmentation	The *Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region* outlines opportunities for augmentation and reintroduction in the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.[39]

[39] Cumberlandian Region Mollusk Restoration Committee, PLAN FOR THE POPULATION RESTORATION AND CONSERVATION OF IMPERILED FRESHWATER MOLLUSKS OF THE CUMBERLANDIAN REGION (2010), available at http://applcc.org/plan-design/aquatic-species-conservation-strategy/reports-documents/plan-for-the-population-restoration-and-conservation-of-imperiled-freshwater-mollusks-of-the-cumberland-region/view.

Conasauga

Georgia, Tennessee

Watershed Description

The Conasauga River Watershed is located in north-central/east Georgia and southeast Tennessee. This unimpounded river rises in the Cohutta Wilderness in the Chattahoochee National Forest in Georgia in the Blue Ridge physiographic province, then flows northward into the Cherokee National Forest in the Valley and Ridge province in Tennessee. It then turns back southwards into Georgia, where it remains in the Valley and Ridge. This region is characterized by limestone bedrock, fertile soils, and extensively farmed bottomlands. The river passes by the City of Dalton, the center of Georgia's carpet industry, and eventually joins the Coosawattee to form the Oostanaula near Resaca, Georgia. Major tributaries of the Conasauga include the Jack's River in the Georgia headwaters, Coahulla Creek in Tennessee and Georgia, and Holly Creek in Georgia. Other tributaries include Mill Creek (Tennessee), Sugar Creek, Sumac Creek, Mill Creek (Georgia), and Rock Creek.

The upper reaches of the Conasauga, from its headwaters to the western boundary of the Cherokee National Forest, contain significant areas of federally managed wilderness. Water quality is generally best here and aquatic biodiversity is high. In the middle sections of the watershed, from the national forest boundary to the confluence of Mill Creek in Murray County, agriculture, forestry operations, and residential development become more common. Water quality degrades somewhat here, but is still relatively good. Aquatic biodiversity is highest in this segment of the watershed, but species losses here have been greater than in the upper portion where refugia are much more prevalent. In the lower reaches of the river to its confluence with the Coosawattee, water quality and species diversity are much lower than in the upper and middle sections of the watershed. In addition to agriculture and residential development, industrial activities exist in this section of the Conasauga.

In Tennessee, the Conasauga Watershed comprises parts of Bradley and Polk Counties. In Georgia, it is mostly located in Whitfield and Murray Counties, with the river forming the border between the two; small parts of the watershed are also located in Fannin, Gordon, Walker, and Gilmer Counties.

Species

The Conasauga River Watershed contains a total of 136 species of fishes, mussels, and crayfishes, including 65 southeastern endemics (see table). Of these species, 14 are vulnerable, 8 are threatened, and 22 are endangered. The Georgia State Wildlife Action Plan (SWAP) lists 41 Species of Greatest Conservation Need (SGCN) in the watershed, and the Tennessee SWAP lists 35.[40]

[40] The total number of SGCN species in the watershed, as identified by both states, is less than the sum of these totals because many species listed as SGCN in Georgia are also listed as SCGN in Tennessee. State SWAPs,

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Conasauga Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Aquatic species in the Conasauga River Watershed are likely threatened primarily by agriculture, with urbanization, industry, and impoundments and barriers constituting secondary potential threats. Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section. The Conasauga River is listed as a High Priority Water in the Georgia SWAP.

Primary Potential Threats and Associated Management Actions

Agriculture – crop production. The principal threats to the imperiled species of the Conasauga River appear to be related to agricultural practices, primarily crop production. The most robust populations of several imperiled and sensitive species persist in the forested headwaters above the agricultural region, even though they historically occurred in larger numbers further downstream. One species, the Coosa Madtom, has been extirpated from the Conasauga River within the last 20 years, and other species have shown declines within the agricultural region. The nature of the agricultural threats are unclear, however. Possible stressors include sedimentation, nutrient pollution, and pesticide contamination. Management efforts to date have focused on riparian restoration, but drainage ditches appear to effectively bypass riparian buffers in at least some locations. The US Fish and Wildlife Service, NRCS and the Nature Conservancy are now testing a new approach involving the installation of constructed wetlands to intercept and treat agrichemical runoff.[41]

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however, define what constitutes a SGCN differently, and providing a sum of total SCGN might incorrectly indicate that all of the SGCN species have similar conservation needs.

[41] "The dominant land use in the upper Conasauga River Basin is agriculture, primarily no-till cropland planted in corn, soybeans, and wheat. Most of the cropland is located in bottomland areas that are flat, have poor drainage, and are prone to flooding. In a recent assessment of 40 miles of the mainstem Conasauga and five tributaries, TNC determined agricultural drainage ditches were one of the most prominent man-made structures throughout the assessment. Man-made drainage networks are extremely efficient at draining croplands; however, they also create efficient conduits for pesticides and nutrients to move into rivers." USFWS, Georgia Ecological Services, *Conasauga*

Management actions to address agricultural impacts include:

- Crop production BMPs
- Riparian buffers
- Constructed wetlands
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Urbanization. Expanding urban and suburban land uses constitute a secondary potential threat to aquatic health in the Conasauga River Watershed. Dalton (pop. ~34,000) and Chatsworth (pop. ~5,000) have both seen population increases in recent decades. In 2015, the Georgia Ports Authority announced plans for the Appalachian Regional Port, an "inland port" in Murray County that would receive containers by rail from the Port of Savannah and offload them onto trucks. The 42-acre site would handle up to 100,000 containers per year and would require expanded infrastructure which could threaten aquatic habitat and attract further development.

Management actions to address urbanization include:

- Riparian buffers
- Improved stormwater management (including green infrastructure)
- Conservation planning
- Aquatic restoration
- Outreach and education

Industry. The lower reaches of the Conasauga River Watershed have a sizable manufacturing industry. This is particularly true in the area around Dalton, which bills itself as the "carpet manufacturing capital of the world."

Most management actions that would directly industrial impacts on aquatic resources in the Conasauga River Watershed are business or regulatory decisions. There are, however, some Management Actions covered by this project that could help ameliorate some impacts. These include:

River Watershed Planning: An Initiative to Recover Imperiled Species (2009), *available at* https://www.fws.gov/athens/rivers/FactSheetConasaugaRiver.pdf.

- Water quality monitoring
- Outreach and education

Small impoundments and barriers. Unlike many other watersheds, large impoundments that fragment habitat and disrupt hydrology are not a threat to species in the Conasauga River Watershed. Some threats are, however, posed by an unknown number of small impoundments, hanging culverts, and other barriers on watershed tributaries. These structures lead to fragmentation of aquatic habitat, isolating
populations, and restriction of movement into headwater habitats.

Management actions to address barriers include:

- Impoundment removal
- Culvert replacement
- Barrier modification for passage

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Caney Fork Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

Conasauga River Alliance: Founded in 1995, the Conasauga River Alliance includes citizens brought together by the Limestone Valley Resource Conservation Development Council, through a grant from NRCS, to protect and improve the river while maintaining private property rights. http://cift.pair.com/shasta/Conasauga/index.html

TNC – Georgia and Tennessee: TNC state offices have been involved in restoration and protection efforts in the Upper Coosa Basin, including the Conasauga River Watershed. Efforts include restoration of Raccoon Creek, land acquisition, and promotion of agricultural best management practices.
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/georgia/placesweprotect/georgia-upper-coosa-river-basin.xml

Limestone Valley Resource Conservation and Development Council: On May 12, 1939 the Limestone Valley Soil and Water Conservation District was organized and is a legal subdivision of the Georgia State Government. The District exists to serve the public and to ensure a healthy and productive environment. It helped form the Conasauga River Alliance, hosts an annual Conasauga River Watershed Clean-up, and engages in other watershed protection projects and programs. http://limestonevalley.org

University of Georgia River Basin Center, USGS, and Georgia Museum of Natural History: The River Basin Center is the public service and outreach arm of the Odum School of Ecology at UGA, the world's first standalone ecology college. The RBC is a team of scientists and policy professionals who work together to connect freshwater science to management and policy. For over 15 years, the RBC, USGS, and the Georgia Museum of Natural History have worked together to conduct regular species and water quality surveys in the Conasauga River Watershed. www.rivercenter.uga.edu

North Georgia Citizens to Preserve the Environment: North Georgia Citizens to Preserve the Environment is a nonprofit organization recently formed to oppose the Appalachian Regional Port. https://www.facebook.com/NGCPE

Plans and Other Resources

Conasauga Summit and proposed National Wildlife Refuge: Organized by TNC and USFWS, the 2008 Conasauga Summit gathered about 70 participants to discuss the status of imperiled species, discuss ongoing efforts to improve habitat, and develop a list of action items needed to recover species. The Summit is informing Strategic Habitat Conservation. In 2009, USFWS developed a proposal for a Conasauga National Wildlife Refuge to protect and restore high quality aquatic and riparian habitat.
http://www.fws.gov/athens/rivers/FactSheetConasaugaRiver.pdf

Prioritizing Areas of the Conasauga River Subbasin in Georgia and Tennessee for Preservation and Restoration (UGA River Basin Center 2009): A prioritization plan for land preservation and restoration that utilizes the "Zonation" algorithm, which uses species occurrence to identify localities of highest biodiversity, greatest interconnectivity, and (optionally) lowest cost.
http://trace.tennessee.edu/cgi/viewcontent.cgi?article=1169&context=sfcproceedings

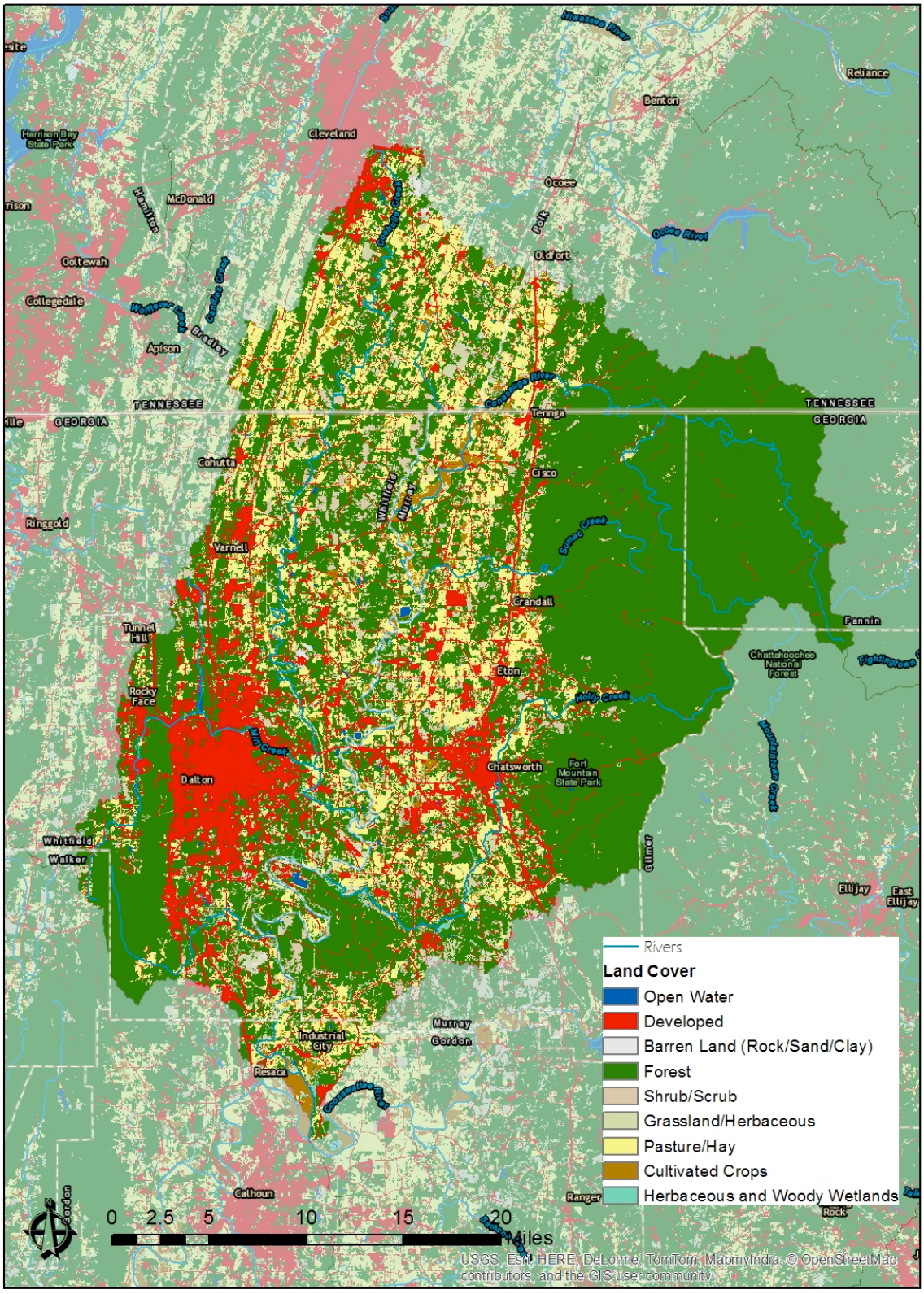

Figure 8. Land Use / Land Cover in the Conasauga River Watershed

Conasauga

Georgia, Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Conasauga River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	80	30	8	2	3
Mussels	46	28	14	6	10
Crayfishes	10	7	0	0	1
TOTAL	136	65	22	8	14

Tennessee SWAP Species of Greatest Conservation Need in the Conasauga River Watershed		
	Tier I	Tier II
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 15	12 lake sturgeon (*Acipenser fulvescens*), holiday darter (*Etheostoma brevirostrum*), coldwater darter (*Etheostoma ditre*ma), rock darter (*Etheostoma rupestre*), trispot darter (*Etheostoma trisella*), lined chub (*Hybopsis lineapunctata*), Southern brook lamprey (*Ichthyomyzon gagei*), burrhead shiner (*Notropis asperifrons*), rainbow shiner (*Notropis chrosomus*), bridled darter (*Percina kusha*), riffle minnow (*Phenacobius catostomus*) brook trout (*Salvelinus fontinalis*)	3 blue shiner (*Cyprinella caerulea*), amber darter (*Percina antesella*), Conasauga logperch (*Percina jenkinsi*)
Mussels TOTAL: 18	11 Alabama spike (*Elliptio arca*), delicate spike (*Elliptio arctata*), Tennessee heelsplitter (*Lasmigona holstonia*), black sandshell (*Ligumia recta*), warrior pigtoe (*Pleurobema rubellum*), Alabama creekmussel (*Strophitus connasaugaensis*), little spectaclecase (*Villosa lienosa*), Alabama rainbow (*Villosa nebulosa*), Coosa creekshell (*Villosa umbrans*), southern rainbow (*Villosa vibex*), mountain creekshell (*Villosa vanuxemensis*)	7 finelined pocketbook (*Hamiota altilis*), Alabama moccasinshell (*Medionidus acutissimus*), Coosa moccasinshell (*Medionidus parvulus*), Southern clubshell (*Pleurobema decisum*), Southern pigtoe (*Pleurobema georgianum*), Georgia pigtoe (*Pleurobema hanleyianum*), rayed kidneyshell (*Ptychobranchus foremanianus*)
Crayfishes TOTAL: 2	2 mountain crayfish (*Cambarus conasaugaensis*), greensaddle crayfish (*Cambarus manningi*)	0
		TOTAL TN SGCN: 35

Conasauga

Georgia, Tennessee

Georgia SWAP Species of Greatest Conservation Need in the Conasauga River Watershed		
	Tier I	Tier II
Tier description	Highest Priority and Special Concern	Special Concern
Fishes TOTAL: 17	16 lake sturgeon (*Acipenser fulvescens*), blue shiner (*Cyprinella caerulea*), holiday darter (*Etheostoma brevirostrum*), coldwater darter (*Etheostoma ditrema*), rock darter (*Etheostoma rupestre*), trispot darter (*Etheostoma trisella*), mooneye (*Hiodon tergisus*), lined chub (*Hybopsis lineapunctata*), least brook lamprey (*Lampetra aepyptera*), mountain shiner (*Lythrurus lirus*), river redhorse (*Moxostoma carinatum*), burrhead shiner (*Notropis asperifrons*), amber darter (*Percina antesella*), Conasauga logperch (*Percina jenkinsi*), bridled darter (*Percina kusha*), freckled darter (*Percina lenticula*)	1 river darter (*Percina shumardi*)
Mussels TOTAL: 23	17 Alabama spike (*Elliptio arca*), delicate spike (*Elliptio arctata*), finelined pocketbook (*Hamiota altilis*), Southern fatmucket (*Lampsilis straminea*), Tennessee heelsplitter (*Lasmigona holstonia*), Alabama moccasinshell (*Medionidus acutissimus*), Coosa moccasinshell (*Medionidus parvulus*), Southern clubshell (*Pleurobema decisum*), Southern pigtoe (*Pleurobema georgianum*), Georgia pigtoe (*Pleurobema hanleyianum*), Cherokee pigtoe (*Pleurobema hartmanianum*), rayed kidneyshell (*Ptychobranchus foremanianus*), Alabama creekmussel (*Strophitus connasaugaensis*), Southern purple lilliput (*Toxolasma corvunculus*), Savannah lilliput (*Toxolasma pullus*), Alabama rainbow (*Villosa nebulosa*), Coosa creekshell (*Villosa umbrans*)	6 Coosa fiveridge (*Amblema elliottii*), Etowah heelsplitter (*Lasmigona etowaensis*) bleufer (*Potamilus purpuratus*), ridged mapleleaf (*Quadrula rumphiana*), fawnsfoot (*Truncilla donaciformis*), mountain creekshell (*Villosa vanuxemensis*)
Crayfishes TOTAL: 1	1 greensaddle crayfish (*Cambarus manningi*)	0
		TOTAL TN SGCN: 41

Management Actions to Address Threats in the Conasauga River Watershed		
Management Action	**Threats Addressed**	**Notes**
Riparian buffers	Agriculture, urbanization	TNC, Conasauga River Alliance, and others have engaged in buffer projects in the Conasauga Watershed. A 2002 report stated that "A general consensus among biologists and practitioners in the watershed is that the number one habitat treatment needed … is the establishment of vegetation buffers along streams in the watershed."[42]
Land conservation	Agriculture, urbanization	TNC and other organizations have engaged in numerous land conservation projects in the Conasauga Watershed. The Georgia SWAP recommends "[p]rotecting critical reaches of the Conasauga River system through targeted acquisition and easements with willing landowners" as a Highest Priority Conservation Action.[43] USFWS and partners have created a restoration and protection prioritization map for the watershed.
Aquatic restoration	Agriculture, urbanization	
Outreach and education	Agriculture, urbanization, industry	The 2008 Conasauga Summit was a successful meeting of academics, agency personnel, NGO representatives, consultants, local government officials, industry officials, and farmers that informed stakeholders on research results and local coordination activities and developed a list of action items for recovering imperiled species.[44] The Georgia SWAP recommends "[p]roviding targeted outreach and technical transfer to farmers to help minimize agricultural impacts to river" as a Highest Priority Conservation Action.[45] USFWS worked with TNC, the Conasauga River Alliance, and the Upper

[42] USFS, Limestone Valley RC&D, CONASAUGA RIVER ALLIANCE WATERSHED PROJECT, COMMUNITY BASED PARTNERSHIP, 2002 REPORT, *available at* http://www.fs.fed.us/largewatershedprojects/annualreports/2002%20Annual%20Reports/Conasauga.pdf.

[43] GA Wildlife Resources Div., GEORGIA STATE WILDLIFE ACTION PLAN (2015) 90, *available at* http://www.georgiawildlife.com/sites/default/files/uploads/wildlife/nongame/SWAP/SWAP2015MainReport_92015.pdf.

[44] USFWS, Georgia Ecological Services, CONASAUGA RIVER WATERSHED PLANNING: AN INITIATIVE TO RECOVER IMPERILED SPECIES (2009), *available at* https://www.fws.gov/athens/rivers/FactSheetConasaugaRiver.pdf.

[45] GA Wildlife Resources Div., GEORGIA STATE WILDLIFE ACTION PLAN (2015) 90, *available at* http://www.georgiawildlife.com/sites/default/files/uploads/wildlife/nongame/SWAP/SWAP2015MainReport_92015.pdf.

Management Actions to Address Threats in the Conasauga River Watershed		
Management Action	**Threats Addressed**	**Notes**
		Etowah River Alliance to develop conservation playing cards for fishes and mussels of the watershed.[46]
Crop production BMPs	Agriculture	
Constructed wetlands	Agriculture	A TNC project in the Conasauga installed constructed wetlands in agricultural drainage ditches to treat pollutants.[47]
Farmland restoration	Agriculture	
Improved stormwater management (including green infrastructure)	Urbanization	
Conservation planning	Urbanization	
Water quality monitoring	Industry	
Impoundment removal	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	

[46] USFWS, Georgia Ecological Services, CONASAUGA RIVER WATERSHED PLANNING: AN INITIATIVE TO RECOVER IMPERILED SPECIES (2009), *available at* https://www.fws.gov/athens/rivers/FactSheetConasaugaRiver.pdf.

[47] TNC Georgia, *A River Runs Through It: Pastures and Parking Lots*, available at http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/georgia/coosa-basin-spring-2010-newsletter-feature-1.pdf.

Etowah

Georgia

Watershed Description

The Etowah River Watershed is a 1,858 square mile watershed in northwest/north-central Georgia. A major tributary of the Coosa River system, its name is the Cherokee version of the Muskogee word *Etalwa*, which means "trail crossing." The headwaters of the Etowah River are in the Blue Ridge physiographic province, but the majority of the Upper Etowah is in the Piedmont. The Lower Etowah is a mix of Piedmont and Valley and Ridge physiographic provinces. Important tributaries to the Etowah include Amicalola Creek, Raccoon Creek, the Little River, Allatoona Creek, Shoal Creek, Smithwick Creek, Long Swamp Creek, Sharp Mountain Creek, Pumpkinvine Creek, and Euharlee Creek.

The Etowah Watershed has a long history (and prehistory) of human occupation, as evidenced by the Etowah Indian Mounds, which date from 1000-1500AD. Land uses intensified with European settlement in the 1800s, when much of the watershed was cleared for row crop agriculture (including extensive cotton cultivation). The upper watershed in the region around Dahlonega was also the site of America's first gold rush in 1829, and the subsequent use of hydraulic mining likely caused massive sedimentation of the river and its tributaries. There is evidence that the current distributions of imperiled fish in the Etowah are still influenced by these historical land use practices.[48] Agriculture steadily declined through the 20th century and farmland in the southern portion of the watershed has largely been converted to suburban and urban land uses. However, agricultural activity persists in the northern and western portions of the watershed, particularly in the more fertile Valley & Ridge physiographic province. Substantial pockets of secondary forest remain, including the 10,000 acre Dawson Forest tract and the 25,000 acre Paulding Forest.

[48] Wenger, et al, *Stream fish occurrence in response to impervious cover, historic land use, and hydrogeomorphic factors*, 65(7) CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES 1250-1264 (2008), *available at* http://www.tu.org/sites/default/files/science/pdfs/Wenger_et_al_2008.pdf.

Figure 9. Hydraulic mining in the Etowah Watershed.

The Etowah Watershed lies on the northern edge of the Atlanta metropolitan region and is home to well over half a million people. The region has experienced large population growth in the last several decades, resulting in significant urbanization of the Etowah River Watershed, which exceeded 20% urban/suburban land use in 2011. Most people in the region live in mid-density suburban communities in the lower part of the watershed that have effectively joined previously separate towns and cities. Beyond this are a few other distinct municipal areas, including Cartersville, Dallas, Rockmart, Dawsonville, Dahlonega, and Jasper, among others. There is one mainstem impoundment on the Etowah River, the 12,000 acre Lake Allatoona.

Species

The Etowah Watershed contains a total of 126 species of fishes, mussels, and crayfishes, including 60 southeastern endemics (see table). Of these species, 15 are vulnerable, 8 are threatened, and 13 are endangered. There are 30 Species of Greatest Conservation Need (SGCN), as identified by the Georgia State Wildlife Action Plan (SWAP).

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Etowah Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have

been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Aquatic species in the Etowah Watershed are threatened primarily by urbanization. Secondary potential threats include land use legacies, current agriculture, impoundments and barriers, power plants (coal ash ponds), and future reservoir development. Many management actions appropriate in this watershed address multiple threats and benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section. The Etowah River, Amicalola Creek, Little River, and Raccoon Creek are designated as High Priority Waters in the Georgia SWAP.

Primary Potential Threats and Associated Management Actions

Urbanization. Urbanization of the Etowah River Watershed is the most prominent potential threat to aquatic species and habitat.[49] Impacts stem from existing urban areas – primarily from runoff from impervious surfaces[50] – and new development activities. Although the pace of development slowed drastically during the recession that began in 2008, growth appears to be accelerating again. Impacts stem from a number of specific activities related to urban development, including:

- Primary home construction: Primary homes are typically built in the lower, Piedmont section of the watershed. As noted above, these are often mid-density suburban communities typical of the metropolitan Atlanta region. Sedimentation can be a major issue if construction best management practices are not appropriately installed and maintained. Developments can also cause hydrologic changes due to increased impervious surfaces that negatively impact aquatic ecosystem health.
- Secondary home construction: Second homes are typically found in the upper, Blue Ridge region of the watershed in places like Dahlonega and Jasper. Although development is much less widespread than in the Piedmont, impacts can be noteworthy. The mountainous terrain of this area can exacerbate erosion and sedimentation, and sedimentation due to construction activities can impact ecologically sensitive headwater streams.
- Commercial development: Like primary homes, most commercial development is located in the Piedmont section of the watershed. Sedimentation and hydrologic changes are also issues realted to this type of development.
- Road/utility crossings: Stream crossings by roads or utilities can impede fish passage, fragment habitat, and isolate populations. Research on stream crossings in the Etowah indicates that as many as one-third of the existing crossings on small streams are likely to impede small fish passage. Passage problems are more likely when pipes are utilized and less likely with box culverts.
- Runoff: Stormwater runoff is a major issue in the Etowah Watershed. Impervious surface coverage in the watershed has increased substantially in the growth that has occurred in the Atlanta region in the last several decades, and surface water quality, aquatic habitat,

[49] Wenger, et al, 97(1) *Conservation planning for imperiled aquatic species in an urbanizing environment,* LANDSCAPE AND URBAN PLANNING 11-21 (2010); Roy, et al, *Investigating hydrologic alteration as a mechanism of fish assemblage shifts in urbanizing streams*, 24(3) JOURNAL OF THE NORTH AMERICAN BENTHOLOGICAL SOCIETY 656-678 (2005).

[50] Wenger, et al, *Stream fish occurrence in response to impervious cover, historic land use, and hydrogeomorphic factors*, 65(7) CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES 1250-1264 (2008); Wenger, et al, *Twenty-six key research questions in urban stream ecology: an assessment of the state of the science*, 28(4) JOURNAL OF THE NORTH AMERICAN BENTHOLOGICAL SOCIETY 1080-1098 (2009); Walsh, et al, *The urban stream syndrome: current knowledge and the search for a cure*, 24(3) JOURNAL OF THE NORTH AMERICAN BENTHOLOGICAL SOCIETY 706-723 (2005).

andbiodiversity have suffered significant impacts. Most stream impairments in the Etowah Watershed are caused primarily by urban runoff.

- Residential and commercial fertilizer application: Fertilizer overuse and use at inappropriate times can result in nutrient contamination of surface waters. This is a runoff issue, but it is highlighted due to the potential extent of its impacts and specific management actions used for mitigation.

Management actions that address urbanization include:

- Riparian buffers
- Improved stormwater management (including green infrastructure)
- Construction BMPs
- Turf management BMPs
- Conservation planning
- Land conservation
- Aquatic restoration
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Land use legacies. Historical land use practices such as hydraulic mining in the upper reaches of the Etowah River Watershed near Dahlonega likely caused major sedimentation of the river and its tributaries. There is evidence that the current distribution of imperiled fishes is still impacted by these land use legacies.

Management actions to address land use legacies will likely be prohibitively expensive in most situations but in some cases may be warranted. They include:

- Aquatic restoration

Impoundments and barriers. One large reservoir (Allatoona Lake) exists on the Etowah River mainstem. Other small impoundments exist in the river's tributaries as well as an unknown number of potential barriers such hanging culverts. These structures alter hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Management actions to address impoundments include:

- Impoundment removal
- Ecological flows
- Culvert replacement

- Barrier modification for fish passage

Reservoir development. Much of the Etowah River Watershed is in the Atlanta metropolitan area where water supply development is a priority to the state and many local governments. Several proposed reservoirs in the watershed would impact significant tributaries and aquatic species, including those at Shoal Creek, Long Swamp Creek, and Sharp Mountain Creek. If developed, these reservoirs will inundate aquatic habitat, alter hydrologic regimes, fragment habitat, and isolate populations. They would be particularly damaging to populations of Etowah Darters.

Management actions to address reservoir development include:

- Species-sensitive reservoir evaluations
- Water conservation
- Outreach and education

Agriculture. Agricultural practices likely cause impacts in some regions, particularly in the more fertile Ridge and Valley physiographic province areas in western part of the watershed. Most agriculture in the Etowah is livestock operations, so nutrient and sedimentation issues from improper waste management and livestock stream access are likely the most substantial issues.

Management actions to address agriculture include:

- Riparian buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Power plant – coal ash pond. Georgia Power's Plant Bowen is the nation's ninth-largest power plant in net generation of electricity.[51] It is also one of the largest coal-fired power plants in North America. It sits between the Etowah River and Euharlee Creek 9 miles southwest of Cartersville. The most significant potential threat to aquatic species and habitat posed by Plant Bowen is its coal ash pond, where toxic soot from coal ash fires is stored as a kind of slurry. The pond is in an area prone to sinkholes, and in 2002, a sinkhole opened and spilled 2.25 million

[51] Georgia Power Plant Bowen Fact Sheet, https://www.georgiapower.com/docs/about-us/1400756-.PDF (last visited Sept. 28, 2016).

gallons of coal ash waste into a tributary of Euharlee Creek. Another sinkhole in 2008 resulted in ash covering nearby residential properties. Georgia Power upgraded the pond and recently announced plans to close it. Even closed ponds, however, present threats to aquatic species and habitat. Spills from closed ponds have occurred in the Southeast in recent years, and a recent study of 21 southeastern coal ash ponds from Duke University found evidence of pond leaks at all of them. Concentrations of some trace elements exceeded EPA water quality standards at nearly a third of the study sites.[52]

Most management actions that would directly mitigate potential coal ash pond impacts on aquatic resources in the Etowah Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Water quality monitoring
- Outreach and education

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Middle Coosa Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations

University of Georgia River Basin Center: The River Basin Center (RBC) is the public service and outreach arm of the Odum School of Ecology at UGA, the world's first standalone ecology college. The RBC is a team of scientists and policy professionals who work together to connect freshwater science to management and policy. The RBC played a central role in the development of the Etowah Habitat Conservation Plan. The Etowah Habitat Conservation Plan was developed by an interdisciplinary team of stakeholders, scientists, engineers and lawyers between 2001 and 2007 to allow for both imperiled species recovery and continued development in the watershed. While never formally adopted by local governments as originally

[52] Harkness, et al, *Evidence for Coal Ash Ponds Leaking in the Southeastern United States*, 50 (12) ENVIRON. SCI. & TECHNOL. 6583-6592 (American Chemical Society 2016).

intended, the plan still guides actions of the US Fish and Wildlife Service and The Nature Conservancy in the watershed. It calls for effective management of stormwater runoff, along with minimum standards for riparian buffer protection, road crossings, utility crossings, and other activities that affect aquatic biota. The plan includes a prioritization scheme in which higher stormwater management standards are required in higher priority areas (corresponding to the best habitat for the most critically imperiled species). www.rivercenter.uga.edu and http://www.etowahaquatichcp.org/index.htm

The Nature Conservancy: TNC has worked in the Upper Coosa Watershed, of which the Etowah River Watershed is a part, for many years. One of the organization's most successful projects is the restoration of Raccoon Creek, a biologically important tributary of the Etowah River. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/georgia/explore/improving-water-quality-in-north-georgia.xml

Upper Etowah River Alliance: The Upper Etowah River Alliance is a community-based watershed protection group that works in the Etowah River Watershed upstream of Lake Allatoona. Formed in 1997, the group promotes watershed protection strategies in five counties – Cherokee, Forsyth, Pickens, Dawson, and Lumpkin. www.etowahriver.org

Coosa River Basin Initiative: The Coosa River Basin Initiative is a nonprofit advocacy organization founded in 1992 to inform and empower citizens to protect, preserve, and restore the Coosa River Basin, which includes the Etowah River Watershed. Among many other initiatives, the CRBI has published the *Etowah River User's Guide*. http://www.coosa.org

Georgia River Network: The Georgia River Network is an advocacy organization that works to support healthy waterways for all Georgians. One initiative the organization has spearheaded is establishment of a Georgia Water Trails Network, which includes the 163-mile long Etowah River Water Trail. http://www.garivers.org/erwt.html

Friends of Amicalola Falls State Park: Friends of Amicalola Falls State Park help raise awareness about the value of the falls, which are the tallest cascade in the Southeast and a major tourist attraction in North Georgia. https://friendsofgastateparks.org/parks/amicalola-falls

Plans and Other Resources

Etowah Habitat Conservation Plan (UGA River Basin Center 2006): The Etowah Aquatic Habitat Conservation Plan was developed by an interdisciplinary team of stakeholders, scientists, engineers and lawyers between 2001 and 2007 to allow for both imperiled species recovery and continued development in the watershed. While never formally adopted by local governments as originally intended, the plan still guides actions of the US Fish and Wildlife Service and The Nature Conservancy in the watershed. It calls for effective management of stormwater runoff,

along with minimum standards for riparian buffer protection, road crossings, utility crossings, and other activities that affect aquatic biota. The plan includes a prioritization scheme in which higher stormwater management standards are required in higher priority areas (corresponding to the best habitat for the most critically imperiled species). See map below. The full plan is available here: http://etowahaquatichcp.org/index.htm.

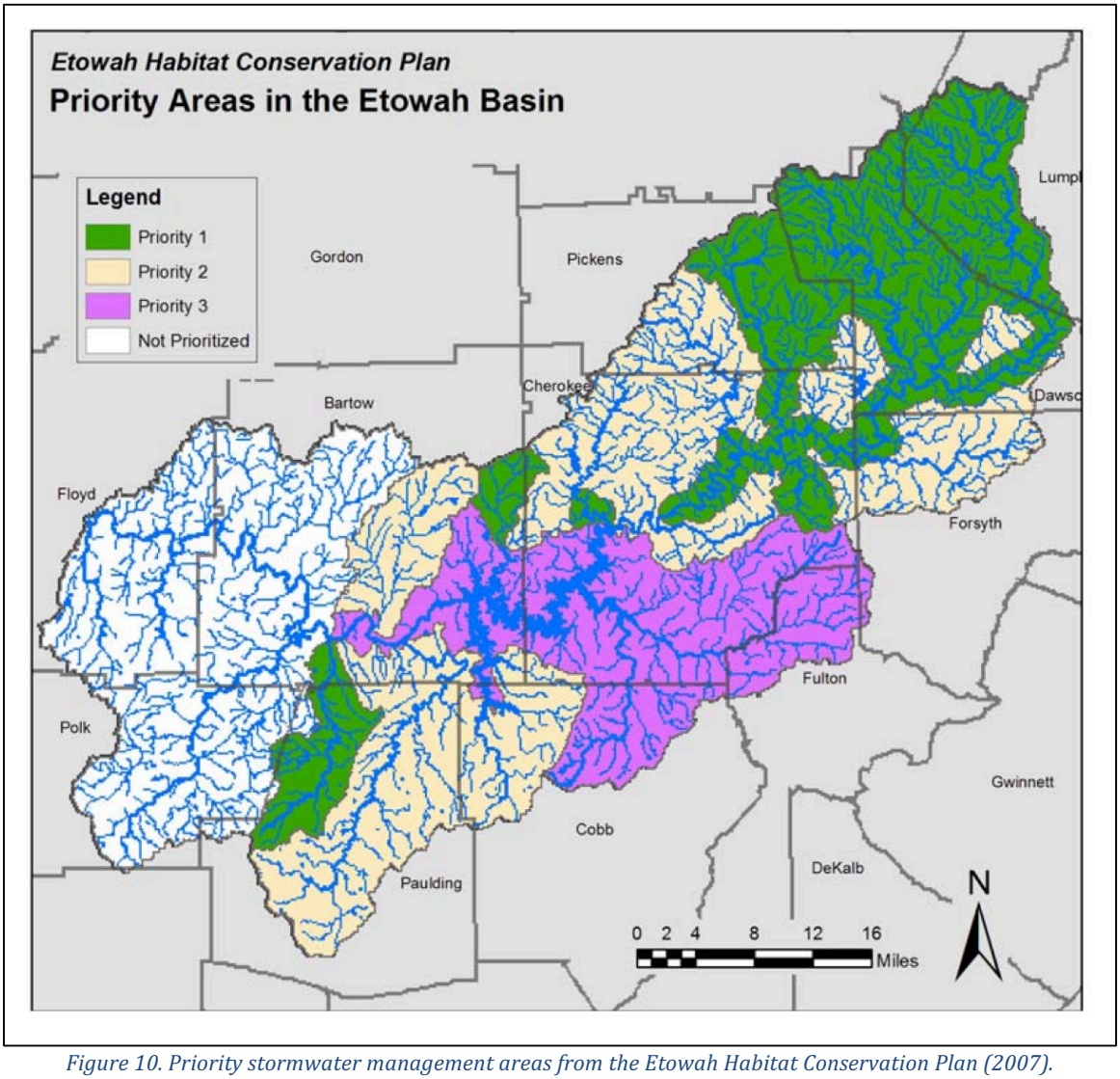

Figure 10. Priority stormwater management areas from the Etowah Habitat Conservation Plan (2007).

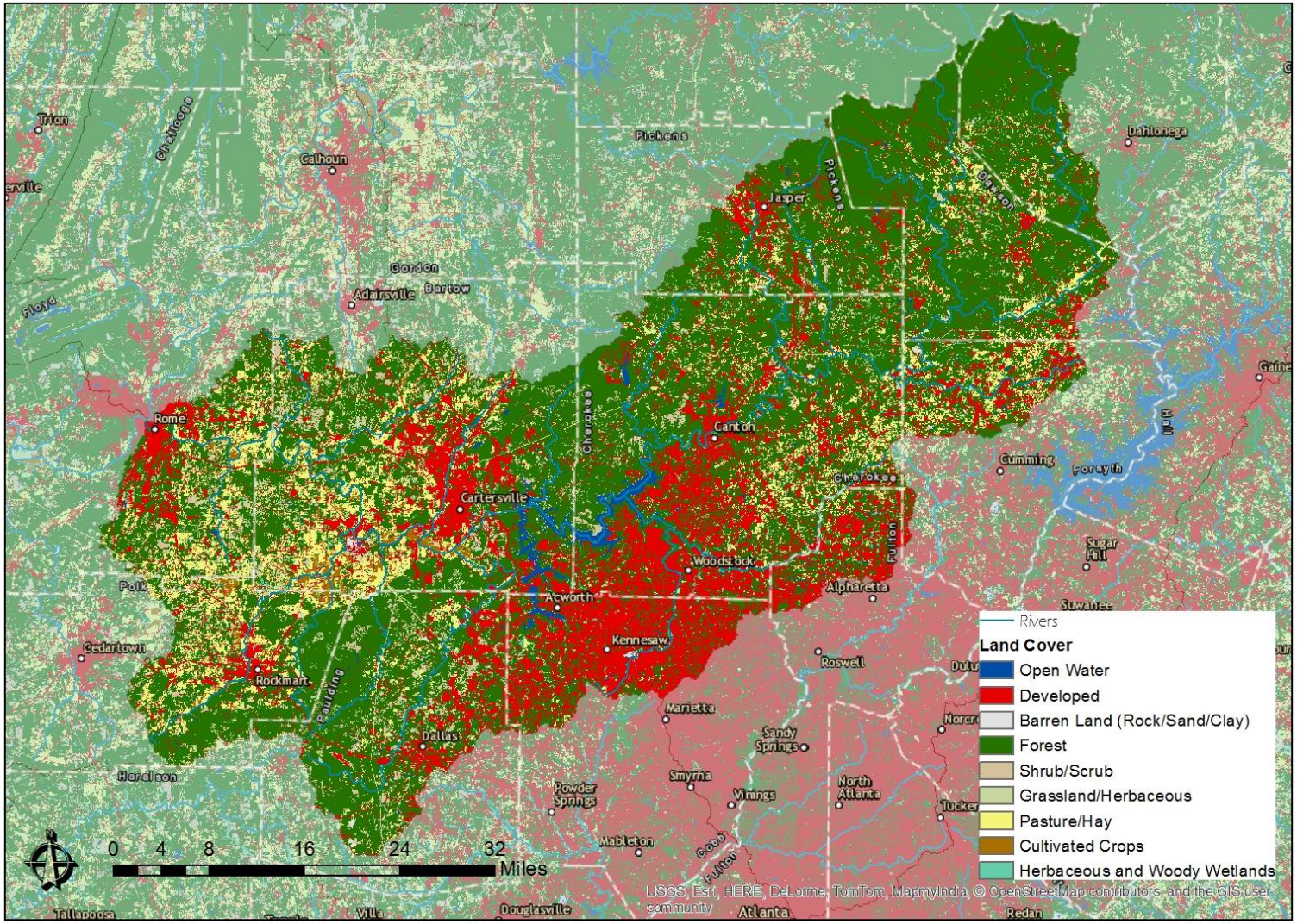

Figure 11. Land Use / Land Cover in the Etowah River Watershed

Etowah

Georgia

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Etowah River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	81	33	7	2	5
Mussels	37	21	6	5	9
Crayfishes	8	6	0	1	1
TOTAL	126	60	13	8	15

Georgia SWAP Species of Greatest Conservation Need in the Etowah River Watershed		
	Tier X	Tier X
Tier description	Highest Priority and Special Concern	Special Concern
Fishes TOTAL: 13	13 lake sturgeon (*Acipenser fulvescens*), blue shiner (*Cyprinella caerulea*), holiday darter (*Etheostoma brevirostrum*), Etowah darter (*Etheostoma (Nothonotus) etowahae*), rock darter (*Etheostoma rupestre*), Cherokee darter (Etheostoma *scotti*), mooneye (*Hiodon tergisus*), lined chub (*Hybopsis lineapunctata*), least brook lamprey (*Lampetra aepyptera*), mountain shiner (*Lythrurus lirus*), amber darter (*Percina antesella*), bridled darter (*Percina kusha*), freckled darter (*Percina lenticula*)	0
Mussels TOTAL: 16	12 fat threeridge (*Amblema neislerii*), Alabama spike (*Elliptio arca*), delicate spike (*Elliptio arctata*), finelined pocketbook (*Hamiota altilis*), Southern fatmucket (*Lampsilis straminea*), Tennessee heelsplitter (*Lasmigona holstonia*), Southern clubshell (*Pleurobema decisum*), Southern pigtoe (*Pleurobema georgianum*), Alabama creekmussel (*Strophitus connasaugaensis*), Savannah lilliput (*Toxolasma pullus*), Alabama rainbow (*Villosa nebulosa*), Coosa creekshell (*Villosa umbrans*)	4 Coosa fiveridge (*Amblema elliottii*), Etowah heelsplitter (*Lasmigona etowaensis*), ridged mapleleaf (*Quadrula rumphiana*), mountain creekshell (*Villosa vanuxemensis*)
Crayfishes TOTAL: 1	1 Etowah crayfish (*Cambarus fasciatus*)	0
		TOTAL TN SGCN: 30

Management Actions to Address Threats in the Etowah River Watershed		
Management Action	**Threats Addressed**	**Notes**
Aquatic restoration	Urbanization, agriculture, land use legacies	The Georgia SWAP recommends developing a baseline database of stream geomorphic characteristics in high quality Cherokee Darter streams for use in revising stream restoration methods used in the Etowah Watershed. TNC, USFWS, and other partners completed an extensive watershed-scale restoration project in Raccoon Creek in 2012.[53] The Georgia SWAP recommends continuing restoration of Raccoon Creek, and continuing restoration and developing similar projects in Shoal and Smithwick Creeks, as Highest Priority Conservation Actions. Aquatic restoration may mitigate impacts from land use legacies in some cases, but is not likely to be cost-effective.
Improved stormwater management (including green infrastructure)	Urbanization	The Etowah Habitat Conservation Plan (HCP) contains a Stormwater Management Policy that recommended "Better Site Design" techniques developed by the Center for Watershed Protection as well as other best management practices.[54] It also contains a model conservation subdivision ordinance for use in the watershed.[55]
Conservation planning	Urbanization	
Land conservation	Urbanization, agriculture	The Georgia SWAP recommends continuing land conservation in Raccoon Creek, Shoal Creek, and Smithwick Creek as Highest Priority Conservation Actions.
Outreach and education	Urbanization, agriculture, reservoir development, power plants	

[53] *See* Appalachian Landscape Conservation Cooperative, *Raccoon Creek Stream Restoration for Imperiled Aquatic Species in Lower Etowah River Drainage*, http://applcc.org/projects/sarp/raccoon-creek-stream-restoration-for-imperiled-aquatic-species-in-lower-etowah-river-drainage.

[54] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. A – TECHNICAL COMMITTEE REPORT: STORMWATER MANAGEMENT POLICY INCLUDING THE RUNOFF LIMITS PROGRAM, *available at* http://etowahaquatichcp.org/hcp_components.htm.

[55] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. D – TECHNICAL COMMITTEE REPORT: CONSERVATION SUBDIVISION ORDINANCE, *available at* http://etowahaquatichcp.org/hcp_components.htm.

Management Actions to Address Threats in the Etowah River Watershed		
Management Action	**Threats Addressed**	**Notes**
Culvert replacement	Impoundments and barriers	The Etowah HCP contains a Stream Crossing and Culvert Design Policy intended to maximize fish passage in the watershed.[56]
Impoundment removal	Impoundments and barriers	
Ecological flows	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	
Riparian buffers	Urbanization, agriculture	The Etowah HCP contains a report on stream buffer ordinances appropriate for the watershed.[57]
Construction BMPs	Urbanization	The Etowah HCP contains a Standard Operating Procedure for Erosion and Sedimentation Control and Grading Ordinance with specific recommendations appropriate for the watershed.[58]
Turf management BMPs	Urbanization	
Species-sensitive reservoir evaluations	Reservoir development	The Etowah HCP contains a report detailing a Protocol for Evaluating Water-Supply Reservoir Options for Effects on Imperiled Fish Species.[59]
Water conservation	Reservoir development	
Livestock exclusion	Agriculture	
Livestock waste management	Agriculture	
Livestock production BMPs	Agriculture	
Farmland restoration	Agriculture	
Water quality monitoring	Power plants	

[56] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. B – TECHNICAL COMMITTEE REPORT: STREAM CROSSING AND CULVERT DESIGN POLICY, *available at* http://etowahaquatichcp.org/hcp_components.htm.

[57] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. E – TECHNICAL COMMITTEE REPORT: STREAM BUFFER ORDINANCES, *available at* http://etowahaquatichcp.org/hcp_components.htm.

[58] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. G – TECHNICAL COMMITTEE REPORT: STANDARD OPERATING PROCEDURE FOR EROSION AND SEDIMENTATION CONTROL AND GRADING ORDINANCE, *available at* http://etowahaquatichcp.org/hcp_components.htm.

[59] DRAFT ETOWAH AQUATIC HABITAT CONSERVATION PLAN APP'X. C – TECHNICAL COMMITTEE REPORT: PROTOCOL FOR EVALUATING WATER-SUPPLY RESERVOIR OPTIONS FOR EFFECTS ON IMPERILED STREAM FISHES, *available at* http://etowahaquatichcp.org/hcp_components.htm.

General Management Actions to Support Species in the Etowah River Watershed	
Management Action	**Notes**
Land conservation	See notes above about land conservation in Raccoon Creek, Shoal Creek, and Smithwick Creek.
Aquatic restoration	See notes above about restoration in Raccoon Creek, Shoal Creek, and Smithwick Creek.
Genetic research	
Basic research	The Georgia SWAP recommends continuing UGA surveys and monitoring of rare species in the Etowah, including monitoring species in Raccoon Creek, as a Highest Priority Conservation Action.
Captive propagation for reintroduction and augmentation	

Lower Duck

Tennessee

Watershed Description

The Lower Duck is a 1,548 square mile watershed in central Tennessee that includes portions of 9 counties. It is part of the Tennessee River drainage basin and is in the Interior Plateau ecoregion. It is a medium-sized, low-gradient river, with one main tributary—the Buffalo River—and several minor tributaries. Karst geology is somewhat common in the Lower Duck and is most prevalent in the upper/southeastern and lower/northeastern parts of the watershed. A portion of the Lower Duck is designated as a State Scenic River. A small mainstem dam operated by Tennessee Electric Power Company is located in Columbia at the upper end of the Lower Duck Watershed (rivermile 133.5). Kentucky Lake, an impoundment on the mainstem Tennessee River, also impounds the lowermost 15-20 miles of the Duck River.

Most of the watershed is forested (65% forested land cover in 2011), with agriculture as the second most common land use (20% livestock pasture cover followed by 3% row crops). Urban areas do not make up a significant percentage of the watershed (<6% land cover), but populations and development in some communities (particularly Spring Hill) have been rapidly increasing in recent years. Most urban and agricultural areas are located in the upper part of the watershed in Maury and Williamson Counties. As of 2005, there were 53 dams inventoried by the TDEC Division of Water Supply in the Lower Duck. TDEC inventories dams that either retain 30 acre-feet of water or are at least 20 feet high.

The largest municipalities in the Lower Duck Watershed are Columbia (population ~35,000), Spring Hill (population ~33,000), Mount Pleasant (population ~5,000), and Centerville (population ~3,600). Spring Hill has had exceptionally rapid population growth in the last ten years, adding nearly 20,000 residents, and is expected to double over the next two decades. Important sectors of local economies of the Lower Duck are manufacturing, agriculture, and resource extraction (forestry, iron ore, mineral limonite, phosphorus).[60] Most manufacturing jobs are related to lumber, rubber, plastics, and fabricated metal.[61] Outdoor recreation is another important aspect of the economy of Lower Duck communities.

Species

The Lower Duck Watershed contains a total of 210 species of fishes, mussels, and crayfishes, including 159 southeastern endemics (see table). Of these species, 16 are vulnerable, 12 are

[60] Southeast Aquatic Resources Partnership & The Nature Conservancy, CONSERVING THE DUCK RIVER: A PLAN FOR COLLABORATIVE ACTION 5 (Nov. 2005), *available at* http://southeastaquatics.net/resources/pdfs/DuckRiverCAP-2005v2.1.pdf.

[61] *Id.*

threatened, and 12 are endangered.[62] There are 45 Species of Greatest Conservation Need (SGCN), as identified by the Tennessee State Wildlife Action Plan (SWAP).

Unlike most of the Tennessee River Drainage Basin, the Duck River has hosted extensive mussel recovery since 1988 with significant increases in mussel density at all sampling locations, increased species richness, and range increases for some endangered species.[63] A 2005 plan by The Nature Conservancy and Southeastern Aquatic Research Partnership attributed this recovery to "land protection and restoration efforts, improvements in reservoir releases by the Tennessee Valley Authority, the settling of channel morphology from earlier destabilizing events, removal of historic point and nonpoint sources of pollution from phosphate and iron ore mining, and the natural hardness of the water and abundance of groundwater inputs to the system."[64] The plan notes that these successes were the product of a long-term focus on critical system needs.

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Lower Duck Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Aquatic species in the Lower Duck Watershed are threatened primarily by agricultural activities (primarily livestock production, but crop production is also a significant issue), urbanization (home building and commercial/industrial development), and wastewater treatment. Other threats include forestry operations and impoundments and barriers. Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More

[62] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

[63] *See* Ahlstedt, et al, HISTORICAL AND CURRENT EXAMINATION OF FRESHWATER MUSSELS (BIVALVIA: MARGARITIFERIDAE, UNIONIDAE) IN THE DUCK RIVER BASIN TENNESSEE (TN WRA 2004); *see also* Dubbs, et al, 2010 DUCK RIVER QUANTITATIVE MUSSEL SURVEY (TN WRA 2010).

[64] Southeast Aquatic Resources Partnership & The Nature Conservancy, CONSERVING THE DUCK RIVER: A PLAN FOR COLLABORATIVE ACTION 2 (Nov. 2005), *available at* http://southeastaquatics.net/resources/pdfs/DuckRiverCAP-2005v2.1.pdf.

information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

Primary Potential Threats and Associated Management Actions

Agricultural activities. Agriculture is a major land use and economic driver in the Lower Duck Watershed. It is also likely the most significant threat to species and habitat health. Agricultural management practices associated with livestock and crop production are both potential threats , particularly because they often occur in the Lower Duck's flat floodplains. A 2005 plan developed by TNC and the Southeastern Aquatic Resources Partnership (SARP) listed the threat from livestock production as "very high" in Nashville Basin streams, and "high" in the mainstem and in streams in the Western Highland Rim. Problematic livestock practices include a lack (and sometimes removal) of riparian vegetation, livestock access to streams for watering, channelization of small and medium streams, and diversion of surface runoff to sinkholes.[65] The 2005 TNC/SARP plan listed crop production as a "high" threat in the Lower Duck mainstem, and "medium" in streams of the Western Highland Rim and Nashville Basin. Issues with crop production include riparian buffer impacts and inputs of pesticides, fertilizers, and sediment.

Management actions that address agricultural activities include:

- Riparian and karst buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

[65] *Id.* at 44.

Urbanization. Development activities are most prevalent in the Western Highland Rim (particularly near Spring Hill and Columbia) and Nashville Basin portions of the Lower Duck Watershed. In those regions, streams have been impacted by primary home construction and industrial/commercial development in recent years; the TNC/SARP 2005 plan lists these activities as "high" threats in those areas. It notes specific impacts to Rutherford, Big and Little Bigby, and Lytle Creeks, and the Piney River in the Western Highland Rim. In the Lower Duck mainstem, primary home construction and industrial/commercial activities are "medium" threats, per the TNC/SARP plan. Both of these activities pose similar issues, including changes to hydrologic regimes, sedimentation from improper construction practices, increased stormwater runoff, and installation of septic systems in inappropriate areas.

Management actions that address urbanization include:

- Conservation planning
- Riparian buffers
- Land conservation
- Improved stormwater management (including green infrastructure)
- Aquatic restoration
- Outreach and education

Wastewater treatment. Like other threats, wastewater treatment issues are most prevalent in the communities in the Western Highland Rim and Nashville Basin regions in the Lower Duck. The TNC/SARP 2005 plan lists the threat from wastewater treatment in these areas as "high." The plan noted that geology and soils in many areas in the watershed are inappropriate for septic system use, and noted the need for identifying areas where system failures are common and places where systems should not be installed. It also noted specific impacts from municipal wastewater treatment plants to Western Highland Rim streams, including Blue Creek (McEwen plant), Rockhouse Creek (Hohenwald plant), Big Bigby (Mt. Pleasant plant), and Rutherford Creek (Spring Hill plant).[66]

Most management actions that would directly mitigate municipal plant impacts on aquatic resources in the Lower Duck Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Discharge/outfall monitoring
- Aquatic restoration

[66] *Id.* at 45.

Management actions to address septic systems include:

- Septic system remediation
- Conservation planning
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Forestry. The forest product industry is a substantial component of local economies of some communities in the Lower Duck Watershed, particularly along the Lower Duck mainstem and in the West Highland Rim region. Improperly managed forestry operations have the potential to impact hydrologic regimes, water quality, and habitat.

Management actions that address forestry operations include:

- Forestry BMPs
- Aquatic restoration
- Land conservation
- Outreach and education

Impoundments and barriers. The mainstem of the Lower Duck has no large dams nor impoundments, but Western Highland Rim streams have a significant number of small instream impoundments. There are at least 50 tributary dams in this region that are inventoried by TDEC (those that retain at least 30 acre-feet of water or have structures at least 20 feet high).[67] There are also an unknown number of potential barriers such hanging culverts in smaller tributaries.

Management actions that address impoundments to tributaries include:

- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Lower Duck Watershed. They include:

- Land conservation

[67] *Id.* at 47.

- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

Tennessee Duck River Development Agency: The mission of the Tennessee Duck River Development Agency is to "develop, protect, and sustain a clean and dependable water resource for all citizens of the Duck River Region." Its projects are divided into four programs – water supply, water quality, water conservation, and watershed education and community. http://www.duckriveragency.org

Tennessee Scenic Rivers Association Duck River Opportunities Project: The TSRA Duck River Opportunities Project was founded in 1999 to monitor water quality of the Duck River and its tributaries. The organization has also mobilized volunteers for participation in other projects such as bank stabilization and tree planting. http://www.paddletsra.org/programs/conservation/updates/2016/08/16/duck-river-opportunities-project-drop.2157874

Duck River Watershed Association: The Duck River Watershed Association "works to preserve, protect, enhance, and restore the ecological health and biodiversity of the Duck River and the natural resources within its watershed for the people, aquatic life and wildlife who depend on it." http://www.duckriverwatershed.org/Welcome.html

Buffalo-Duck River Resource Conservation & Development Council: The mission of the Buffalo-Duck River Resource Conservation & Development Council is to "Improve the quality of life through natural resource management and conservation, and the advancement of economic, educational, social and cultural opportunities working in partnership with national, state, and local Resource Conservation & Development Councils." http://bdrrcdtn.org

Swan Conservation Trust: Swan Conservation Trust is a land trust operating in the Big Swan Creek and Big Bigby Creek watersheds of the Lower Duck. It has projects on over 11,000 acres in the area. http://swantrust.org

Save our Buffalo River: Save our Buffalo River is a citizens monitoring group that takes samples, removes litter, and distributes and educational brochure.

Plans, etc.

Water Resources of the Duck River Watershed, Tennessee (USGS 2007): This study was an assessment of the hydrology of the Duck River Watershed from Normandy Dam to Columbia, TN. The emphasis of the study was to "characterize the temporal and spatial variability of the various components that make up streamflow in the Duck River in this study area." http://pubs.usgs.gov/sir/2007/5105/pdf/sir20075105.pdf

Lower Duck River Water Quality Management Plan (TDEC 2005): This plan includes a description of the watershed approach to water quality, a description of the Lower Duck River Watershed, a water quality assessment of the watershed, a point and nonpoint source pollutant characterization of the watershed (by subwatershed), a description of water quality partnerships in the region, and future plans.
http://www.tennessee.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-lower-duck-2005.pdf

Conserving the Duck River: *A plan for collaborative action* (SARP, TNC 2005): This comprehensive plan was developed by many agencies and organizations with direct, ongoing management activities in the Duck River Watershed. It includes aquatic system conservation targets, threats to system health, conservation objectives and strategies, conservation success measures, and an implementation timeline.
http://southeastaquatics.net/resources/pdfs/DuckRiverCAP-2005v2.1.pdf

Draft Plan: Augmentation and Reintroduction of Freshwater Mussel Populations in the Duck River, Tennessee (USGS 2004): This plan is a proposal to restore all freshwater mussels that historically occurred in the Duck River.

Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region (Cumberlandian Region Mollusk Restoration Committee 2010): This plan provides a framework for the restoration of freshwater mollusks and their ecological functions to reaches of the Cumberlandian Region (the Tennessee and Cumberland River systems) through reintroduction, augmentation, and controlled propagation. Available through the Appalachian Landscape Conservation Cooperative website at http://applcc.org.

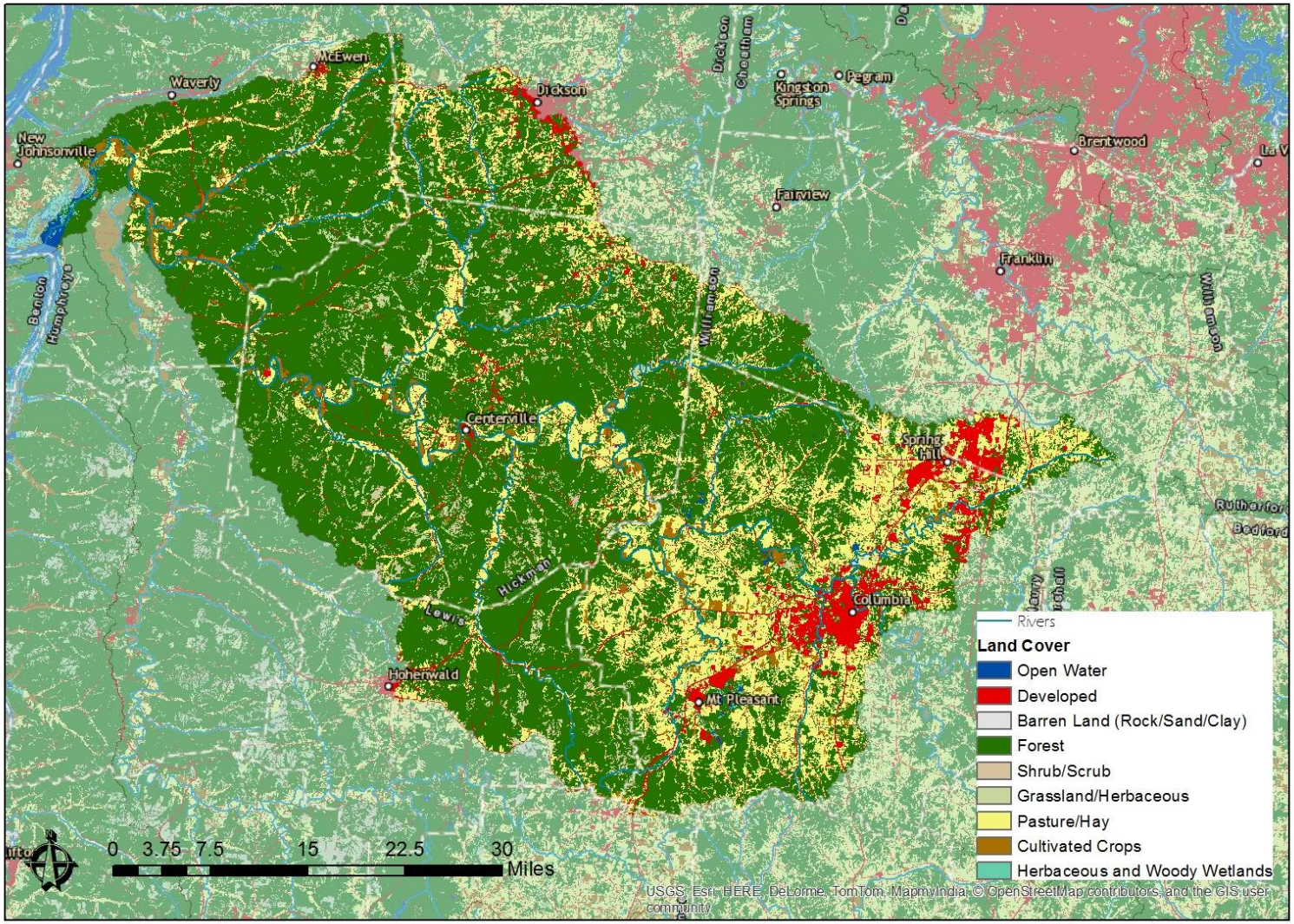

Figure 12. Land Use / Land Cover in the Lower Duck River Watershed

Lower Duck

Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Lower Duck River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	133	27	1	4	4
Mussels	60	11	11	8	12
Crayfishes	17	13	0	0	0
TOTAL	210	51	12	12	16

Tennessee SWAP Species of Greatest Conservation Need in the Lower Duck River Watershed		
	Tier I	Tier III
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 14	13 highfin carpsucker (*Carpiodes velifer*), blue sucker (*Cycleptus elongatus*), streamline chub (*Erimystax dissimilis*), blotched chub (*Erimystax insignis insignis*), coppercheek darter (*Etheostoma (Nothonotus) aquali*), golden darter (*Etheostoma (Nothonotus) denoncourti*), redband darter (*Etheostoma luteovinctum*), egg-mimic darter (*Etheostoma pseudovulatum*), striated darter (*Etheostoma striatulum*), flame chub (*Hemitremia flammea*), saddled madtom (*Noturus fasciatus*), blotchside logperch (*Percina burtoni*), slenderhead darter (*Percina phoxocephala*)	1 pygmy madtom (*Noturus stanauli*)
Mussels	18 mucket (*Actinonaias ligamentina*), pheasantshell (*Actinonaias pectorosa*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), black sandshell (*Ligumia recta*), Cumberland moccasinshell (*Medionidus conradicus*), round hickorynut (*Obovaria subrotunda*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), Tennessee pigtoe (*Pleuronaia barnesiana*), salamander mussel (*Simpsonaias ambigua*), creeper (*Strophitus undulatus*), purple lilliput (*Toxolasma lividum*), rainbow	10 spectaclecase (*Cumberlandia monodonta*), snuffbox (*Epioblasma triquetra*), pink mucket (*Lampsilis abrupta*), sheepnose (*Plethobasus cyphyus*), slabside pearlymussel (*Pleuronaia dolabelloides*), rabbitsfoot (*Quadrula cylindrica cylindrica*), winged mapleleaf (*Quadrula fragosa*), Cumberland monkeyface (*Quadrula intermedia*), pale lilliput (*Toxolasma cylindrellus*), rayed bean (*Villosa fabalis*)

TOTAL: 28	(*Villosa iris*), painted creekshell (*Villosa taeniata*), mountain creekshell (*Villosa vanuxemensis*)	
Crayfishes TOTAL: 3	3 shortfinger crayfish (*Cambarus brachydactylus*), cavespring crayfish (*Cambarus tenebrosus*), surgeon crayfish (*Orconectes forceps*)	0
		TOTAL TN SGCN: 45

Management Actions to Address Threats in the Lower Duck River Watershed		
Management Action	**Threats Addressed**	**Notes**
Aquatic restoration	Urbanization, agriculture, forestry	The TN Scenic Rivers Association's Duck River Opportunities Project focused a large part of its efforts in the fast growing city of Spring Hill, including tree planting and riverbank stabilization projects. The Project's web page says that "eventually residents took the lead in those projects." TVA has engaged in streambank stabilization projects in Marshall County.[68]
Riparian and karst buffers	Agriculture, urbanization, forestry	The Tennessee Urban Riparian Buffer Handbook contains information on establishing buffers in a range of urban settings, a set-by-set guide on how to complete buffer projects, handouts for volunteers, and a regionalized buffer plant list.[69]
Livestock exclusion	Agriculture	
Livestock waste management	Agriculture	
Livestock production BMPs	Agriculture	The Agricultural Resources Conservation Fund provides cost-share assistance to Tennessee landowners to install Best Management Practices (BMPs) that reduce agricultural water pollution. This assistance is facilitated primarily through Soil Conservation Districts although Resource Conservation and Development Councils, universities, and other agricultural associations may participate. A wide range of BMPs are available for cost-share, from those that curtail soil erosion to ones that help to remove pollutants from water

[68] TVA, DUCK RIVER BANK STABILIZATION RIVER MILE 176.8 ENVIRONMENTAL ASSESSMENT (2015), *available at* https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/Environmental%20Reviews/Duck%20River/Final_Duck%20River%20Stabilization%20EA.pdf.

[69] TN Dept. of Agriculture, TENNESSEE URBAN RIPARIAN BUFFER HANDBOOK (2015), *available at* http://www.tn.gov/agriculture/topic/ag-forests-turb.

Management Actions to Address Threats in the Lower Duck River Watershed		
Management Action	**Threats Addressed**	**Notes**
		runoff from agricultural operations. Landowners may be eligible to receive up to 75% of the cost of a BMP installation. Part of the fund is available for educational projects which raise awareness of soil erosion/water quality problems and promote BMP use.[70]
Farmland restoration	Agriculture	
Land conservation	Agriculture, urbanization, forestry	
Outreach and education	Agriculture, urbanization, forestry, impoundments, septic systems	
Crop production BMPs	Agriculture	
Improved stormwater management (including green infrastructure)	Urbanization	Since 2008, the Tennessee Stormwater Association (TNSA), the Tennessee Valley Authority (TVA), and the Tennessee Department of Transportation (TDOT) have partnered together with the Tennessee Department of Environment & Conservation (TDEC) to offer a Green Development Grant program that was developed as an effort to encourage the advancement of green infrastructure projects across the state.[71]
Conservation planning	Urbanization, septic systems	
Septic system remediation	Septic systems	
Water quality monitoring	Wastewater systems (municipal)	
Construction of tertiary treatment wetlands	Wastewater systems (municipal)	
Forestry BMPs	Forestry	The *Guide to Forestry Best Management Practices in Tennessee* provides voluntary management practices for foresters in the state.[72]
Culvert replacement	Impoundments and barriers	
Impoundment removal	Impoundments and barriers	
Barrier modification for fish passage		

General Management Actions to Support Species in the Lower Duck River Watershed

[70] TN Dept. of Agriculture, GUIDELINES FOR THE AGRICULTURAL RESOURCES CONSERVATION FUND (FY 2017), *available at* https://tn.gov/assets/entities/agriculture/attachments/AgFarARCFguidelines.pdf.

[71] TN Dept. of Environment & Conservation, *Green Development*, http://www.tennessee.gov/environment/topic/wr-green-development.

[72] TN Dept. of Agriculture, Div. of Forestry, GUIDE TO FORESTRY BEST MANAGEMENT PRACTICES IN TENNESSEE (2003), *available at* https://www.tn.gov/assets/entities/agriculture/attachments/AgForBMPs.pdf

Management Action	Notes
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	
Captive propagation for reintroduction and augmentation	The *Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region* outlines opportunities for augmentation and reintroduction in the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.[73] The TVA Cumberland River Aquatics Center breeds rare mussel and fish species of the Cumberland River.[74] *See* Draft Plan: Augmentation and Reintroduction of Freshwater Mussel Populations in the Duck River, Tennessee (USGS 2004). In 2013, federal and state biologists reintroduced 103 winged mapleleaf mussels into the Duck River.[75]

[73] Cumberlandian Region Mollusk Restoration Committee, PLAN FOR THE POPULATION RESTORATION AND CONSERVATION OF IMPERILED FRESHWATER MOLLUSKS OF THE CUMBERLANDIAN REGION (2010), available at http://applcc.org/plan-design/aquatic-species-conservation-strategy/reports-documents/plan-for-the-population-restoration-and-conservation-of-imperiled-freshwater-mollusks-of-the-cumberland-region/view.

[74] TVA, The Cumberland River Aquatic Center, https://www.tva.gov/Energy/Our-Power-System/Coal/The-Cumberland-River-Aquatic-Center.

[75] USFWS News Release: Welcome Home, Winged Mapleleaf Mussel, Sept. 9, 2013, https://www.fws.gov/southeast/news/2013/055.html.

Watershed Description

The Middle Coosa Watershed encompasses approximately 2,571 square miles in the Coosa River Basin in northeast Alabama. It is part of the larger Mobile River Basin, which has historically suffered from the highest number of aquatic extinctions in the nation.[76] The majority of the Middle Coosa is in the Cumberland and Southern Ridge and Valley ecoregions, with a small southeastern portion of the watershed in the Piedmont. Two major Alabama Power dams are located in the watershed that form Lake Neely Henry (11,200 acres) and Logan Martin Lake (15,263 acres), and numerous other impoundments are located on tributaries.

The Middle Coosa has over 20 named tributaries. Several of these contain substantial aquatic biodiversity. Choccolocco Creek is likely the most biologically diverse tributary in the Middle Coosa; the Auburn University Water Resources Center states that this tributary watershed "may support the largest number of endangered and threatened species found in any Alabama waterway of comparable size," and is the most diverse Coosa tributary in Alabama for snails.[77] Big and Little Wills Creeks and Big Canoe Creek harbor a large number of fish species and all flow into Neely Henry Lake. Like Choccolocco Creek, Shoal Creek is known for its snail diversity.

The Middle Coosa contains two Metropolitan Statistical Areas. The first is the Gadsden Metropolitan Statistical Area, which includes the city of Gadsden and is comprised of all of Etowah County in the northern end of the watershed. It has a population of over 100,000, and is one of the most densely populated counties in the state. At one point in the 19th century Gadsden was Alabama's second most important center of commerce and industry (trailing Mobile). The Middle Coosa also contains the Anniston-Oxford Metropolitan Statistical Area, which includes Anniston, Oxford, and Jacksonville, and has a population of over 110,000. It is the second most populated metropolitan area in northeast Alabama after Huntsville. The municipalities of Talladega, Pell City, and Springville are also in the watershed, with populations of about 16,000, 12,000, and 4,000, respectively.

Most of the Middle Coosa Watershed is forested, with almost 59% of the land cover in 2011 in forested uses. Agriculture, primarily pasture in 14% of the watershed, is the second most prominent land use, followed by urban areas (11%). Land use coverage in subwatersheds varies widely. Manufacturing dominates community economies in the region. Agriculture is also an important economic driver.

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[76] TNC, ALABAMA NATURAL HERITAGE PROGRAM, MIDDLE COOSA RIVER, UPPER COOSA RIVER, EIGHTMILE CREEK, AND COTACO CREEK WATERSHEDS NONPOINT SOURCE PRIORITIZATION PROJECT, VOLUME 1: MIDDLE AND UPPER COOSA RIVER WATERSHEDS 10 (2004), *available at* http://www.alnhp.org/reports/Coosa-vol-i.PDF.

[77] *See* Auburn University Water Resources Center, Coosa River Basin: Tributaries, http://aaes.auburn.edu/wrc/resource/rivers-of-alabama/coosa-basin/tributaries/ (last visited Sept. 28, 2016).

Species

The Middle Coosa watershed contains a total of 157 species of fishes, mussels, and crayfishes, including 84 southeastern endemics (see table). Of these species, 11 are vulnerable, 11 are threatened, and 24 are endangered.[78] There are 33 Species of Greatest Conservation Need (SGCN), as identified by the Alabama State Wildlife Action Plan (SWAP).

A 2004 study from TNC and the Alabama Natural Heritage Program found that very few occurrences of rare species were associated with the main stem of the Coosa in the Middle Coosa watershed; most were found in tributaries. This report found that sections of South Branch Cane Creek in Calhoun County, Black Creek in Etowah County, and Choccolocco and Shoal Creeks in Cleburne County were species rich, but noted that further surveys were needed to confirm these results.[79] As noted above, the Auburn University Water Resources Center identifies Choccolocco Creek, Big and Little Wills Creeks, Big Canoe Creek, and Shoals Creek as also being species-rich.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Middle Coosa Watershed. Potential threats are activities that tend to cause impacts in places

[78] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

[79] TNC, ALABAMA NATURAL HERITAGE PROGRAM, MIDDLE COOSA RIVER, UPPER COOSA RIVER, EIGHTMILE CREEK, AND COTACO CREEK WATERSHEDS NONPOINT SOURCE PRIORITIZATION PROJECT, VOLUME 1: MIDDLE AND UPPER COOSA RIVER WATERSHEDS 21 (2004).

where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

The Coosa River Basin has a long history of human activities and substantial impacts to aquatic resources, and there are many threats to aquatic species that stem from both current and historical practices. The watershed includes substantial agricultural areas, urbanization, industrial sites, and active and abandoned mines. These are all primary threats; however, their impacts vary by subwatershed. Other threats include impoundments and barriers, wastewater systems, power plants, forestry, and groundwater withdrawal. Many suggested management actions address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section.

Primary Potential Threats and Associated Management Actions

Agriculture. Livestock operations and row crop production are an important part of some local economies in the Middle Coosa Watershed, particularly in DeKalb and Blount Counties. Although livestock operations are common across the entire watershed, the prevalence and type of agriculture varies widely by subwatershed; the 2004 TNC/Alabama Natural Heritage Program provided a list of subwatersheds with significant agricultural activities.[80] Cattle operations occur in all subwatersheds, and poultry production occurs in a subset of others. The northern end of the Choccolocco Creek watershed and the Broken Arrow Creek watershed have both likely been impaired by agricultural activities.

Management actions that address agricultural activities include:

- Riparian buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Crop production BMPs
- Farmland restoration
- Aquatic restoration

[80] TNC, ALABAMA NATURAL HERITAGE PROGRAM, MIDDLE COOSA RIVER, UPPER COOSA RIVER, EIGHTMILE CREEK, AND COTACO CREEK WATERSHEDS NONPOINT SOURCE PRIORITIZATION PROJECT, VOLUME 1: MIDDLE AND UPPER COOSA RIVER WATERSHEDS 113, Table 10 (2004).

- Land conservation
- Outreach and education

Urbanization. The Middle Coosa Watershed has a large population frelative to the rest of the state and contains two Metropolitan Statistical Areas. It has also experienced urban encroachment from Birmingham, directly west of the watershed. In urbanized areas, nutrient inputs from urban runoff is common and has contributed to nutrient enrichment and low dissolved oxygen, both of which likely impact biodiversity and habitat. Neely Henry Lake and Logan Martin Lake are both impaired due to nutrient enrichment/dissolved oxygen, and nutrients. Neely Henry Lake is also listed due to pH (in lakes, typically a direct product of nutrient enrichment).

Management actions that address urbanization include:

- Improved stormwater management (including green infrastructure)
- Riparian buffers
- Aquatic restoration
- Land conservation
- Conservation planning
- Outreach and education

Industry. Industry plays a large role in the economies of the Middle Coosa. There are over 100 permitted industrial dischargers in the watershed and over 60 toxic release inventory sites. Most of these sites are clustered around urban areas, particularly Gadsden and Anniston. In 1929, in a plant in Anniston on Choccolocco Creek, PCBs (polychlorinated biphenyls) were first commercially manufactured. By the time the plant shut down in 1971, PCBs had contaminated Snow Creek, Choccolocco Creek, Lake Logan Martin, and Lay Lake. Today, it is unsafe to consume fish from many of these waters.

Most management actions that would directly mitigate industrial impacts on aquatic resources in the Middle Coosa Watershed are business or regulatory decisions. There are, however, some Management Actions covered by this project that could help ameliorate some impacts or prevent others. These include:

- Water quality monitoring
- Aquatic restoration
- Land conservation
- Outreach and education

Mines. There are over 400 active and abandoned mines scattered throughout the Middle Coosa

Watershed.[81] Many raw materials are mined in this region of Alabama, including gravel, limestone, gold, platinum, granite, and coalbed methane. A large marble formation, the Marble Valley, extends northeast from the Coosa in Talladega County for about 60 miles. Mines can cause soil erosion and stream turbidity, toxic metal and acid runoff, and altered water tables and spring flows.

Management actions to address mines include:

- Mine site reclamation
- Mine remediation activities
- Aquatic restoration

Secondary Potential Threats and Associated Management Actions

Impoundments and barriers. Impoundments on the main stem (Lake Neely Henry and Logan Martin Lake) and tributaries of the Middle Coosa are the primary contributor to loss of riverine habitat; fragmentation and isolation of streams and aquatic biodiversity; and modification of the natural flow regime. Impoundments also exacerbate problems with nutrient pollution and low dissolved oxygen. Historic impoundments were responsible for the extinction of more than 40 species of mussels and snails. The Alabama SWAP states that the remaining free-flowing reaches in the Coosa are "essential to restoration of a high number of SGCN." In the Middle Coosa, these are short reaches below Neely Henry and Logan Martin dams. Both of these dams are currently in the FERC relicensing process.[82] There are also an unknown number of potential barriers on smaller tributaries such as hanging culverts.

Despite the significant historic impacts to species and habitats from major impoundments in the Middle Coosa River Watershed, this threat is listed as secondary because these manmade features are not likely primarily responsible for the majority of current species declines. In addition, it is very unlikely that the mainstem dams, whichwere responsible for past extinctions of many watershed species, will be removed at any time in the near future. Management actions such as conservation locking and ecological flows should, however, be pursued at major dams, and other actions appropriate for smaller tributary impoundments and barriers might also reduce this threat.

[81] TNC, ALABAMA NATURAL HERITAGE PROGRAM, MIDDLE COOSA RIVER, UPPER COOSA RIVER, EIGHTMILE CREEK, AND COTACO CREEK WATERSHEDS NONPOINT SOURCE PRIORITIZATION PROJECT, VOLUME 1: MIDDLE AND UPPER COOSA RIVER WATERSHEDS 101 (2004).

[82] *See* Alabama Power, Hydro Relicensing, http://www.alabamapower.com/community/lakes/hydro/home.asp (last visited Sept. 28, 2016).

Management actions that address impoundments and barriers include:

- Conservation locking
- Barrier modification for fish passage
- Ecological flows
- Impoundment removal
- Culvert replacement

Wastewater systems. Municipal treatment plants and septic systems are both potential contributors to aquatic impacts in some urbanized segments in the Middle Coosa Watershed. There are many municipal treatment plants in the watershed; discharges, sanitary sewer overflows, and leaking sewer lines can all impact aquatic health. Impacts from septic systems vary from subwatershed to subwatershed. The 2004 TNC/Alabama Natural Heritage Program study from 2004 referenced 1998 data that said the threat from septic systems was high in the Big Cove Creek, Coosa River/Neely Henry Reservoir, and Greens Creek subwatersheds.[83]

Most management actions that would directly mitigate potential municipal plant impacts on aquatic resources in the Middle Coosa Watershed are business or regulatory decisions. There are, however, some Management actions covered by this project that could help ameliorate some impacts. These include:

- Discharge/outfall monitoring
- Aquatic restoration
- Outreach and education

Management actions to address septic systems include:

- Septic system remediation
- Conservation planning
- Outreach and education

Forestry. Forests are the dominant land cover in the Middle Coosa Watershed, and improper forestry practices likely cause impacts to species and habitat in some subwatersheds.

Management actions to address forestry include:

- Forestry BMPs
- Riparian buffers
- Aquatic restoration

[83] *Id.* at Table 11.

- Land conservation
- Outreach and education

Power plants. Two power plants on the Coosa, the Ernest C. Gaston Steam Plant in Wilsonville on Lay Lake and the Gadsden Steam Plant on Lake Neely Henry, contribute to atmospheric deposition of mercury in the watershed, consume water, and contribute to thermal pollution at their outfalls. They also have large coal ash ponds that contain a slurry that includes toxic materials. These activities may currently be, or have the potential to, impact species and habitat.

Most management actions that would directly mitigate power plant impacts on aquatic resources in the Middle Coosa Watershed are business or regulatory decisions. There are, however, some Management actions covered by this project that could help ameliorate some impacts. These include:

- Water quality monitoring
- Aquatic restoration

Groundwater withdrawal. Aquifers in the Valley and Ridge provide cool, consistent, high quality water for springs and spring-fed creeks. Groundwater habitats such as springs are specialized habitats for many of the endemic biodiversity found in this watershed. Use of groundwater for agricultural irrigation and municipal/industrial use, especially during drought conditions, has the potential to cause severe stress on many of these specialized habitats, and this stress will likely increase with climate change.

Management actions to address groundwater withdrawal include:

- Determining recharge areas for and specific habitats supplied by aquifers
- Monitoring spring and cave flows
- Outreach and education

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Middle Coosa Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research

- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

Coosa Riverkeeper: Coosa Riverkeeper is a citizen-based river conservation group with a mission to protect, restore and promote the Coosa River and its tributaries in Alabama. Its focus is on the Middle and Lower Coosa. http://coosariver.org

Choccolocco Creek Watershed Alliance: The Choccolocco Creek Watershed Alliance's goal is "to develop a consolidated stewardship effort comprised of informed stakeholders of Choccolocco Creek with a common interest in implementing strategies to improve, protect, and promote the watershed." http://www.choccoloccocreekalliance.org

The Nature Conservancy Alabama: TNC has been active in Alabama since 1989. Its first land acquisition in the state was a bog on the Coosa. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/alabama/placesweprotect/coosa-bog-preserve.xml

Friends of Big Canoe Creek: Friends of Big Canoe Creek was formed in 2008 to "coordinate efforts to preserve and protect the Big Canoe Creek watershed through community education and participation. The primary aim of The Friends of Big Canoe Creek is to foster awareness of the value of the watershed's resources. In addition to its quarterly meetings, the group sponsors periodic educational, recreational and community-service activities such as guest speakers, films, rain barrel workshops, float trips, and creek cleanups." http://www.bigcanoecreek.org

Logan Martin Lake Protection Association: Formed in 1994, the Logan Martin Lake Protection Association's mission is to "advocate and promote the general welfare of Logan Martin Lake and that of the homeowners, businesses, and users of Logan Martin Lake and the surrounding areas." http://www.lmlpa.org

Neely Henry Lake Association: The Neely Henry Lake Association is a volunteer group that represents all counties along the lake. It works on water quality and water quantity projects. http://www.neelyhenrylakeassoc.org

Environmental Policy and Information Center, Jacksonville State University: The Environmental Policy and Information Center at Jacksonville State University "work[s] closely with organizations, government, business, and the public to guide and provide sound programs and policies that encourage economic development through sustainable practices, the protection of natural, recreational and cultural resources." http://www.jsu.edu/epic/index.html

Plans and Other Resources

Mid-Coosa River Basin Management Plan (Alabama Clean Water Partnership 2003): This document was a locally developed plan "designed to provide common sense, environmentally protective and economically achievable strategies to address water quality using a basin wide management approach."
http://www.cleanwaterpartnership.org/uploadedFiles/Middle%20Coosa%20Basin%20Management%20Plan.pdf

Middle Coosa River, Upper Coosa River, Eightmile Creek, and Cotaco Creek Watersheds Nonpoint Source Prioritization Project, Volume 1: Middle and Upper Coosa River Watersheds (TNC, Alabama Natural Heritage Program 2004): The scope of this project was to locate sensitive areas and habitats for Threatened & Endangered species and identify potential stresses to these areas in the Middle and Upper Coosa River watersheds.
http://www.alnhp.org/reports/Coosa-vol-i.PDF

Recovery Plan for Mobile River Basin Aquatic Ecosystem: USFWS plan for recovery of 22 aquatic species in the Mobile Basin (2000).
https://www.fws.gov/southeast/grants/pdf/001117.pdf.

Watershed Assessment of the Big Canoe Creek System for Recovery and Restoration of Imperiled Aquatic Species: Bulletin 185 (Geological Survey of Alabama 2016): A presentation overview of the watershed assessment for Big Canoe Creek. http://aaes.auburn.edu/wrc/wp-content/uploads/sites/108/2015/10/WynnE-2015ALWRC.pdf

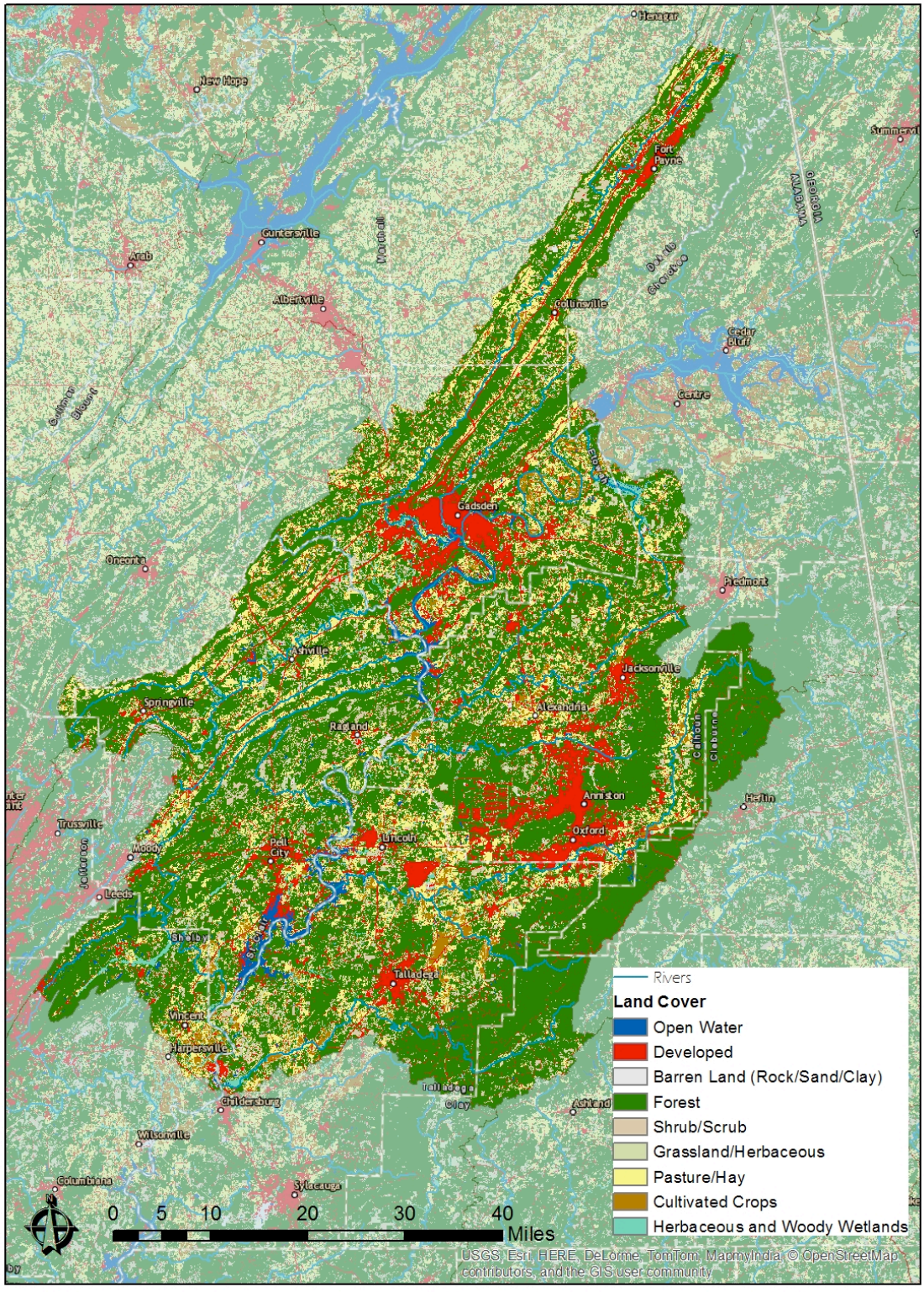


Figure 13. Land Use / Land Cover in the Middle Coosa River Watershed

Middle Coosa

Alabama

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Middle Coosa River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	87	29	5	2	4
Mussels	57	33	19	8	7
Crayfishes	13	11	0	1	0
TOTAL	157	73	24	11	11

	Alabama SWAP Species of Greatest Conservation Need in the Middle Coosa River Watershed			
	Tier I.	Tier II.	Tier III.	Tier IV.
	Extirpated (EX).	Extirpated/Conservation Action Underway (EXCAU).	Critical Conservation Need (P1).	Very High Conservation Need (P2).
Fishes TOTAL: 6	0	0	3 pygmy sculpin (*Cottus paulus*), blue shiner (*Cyprinella caerulea*), holiday darter (*Etheostoma brevirostrum*)	3 coldwater darter (*Etheostoma ditrema*), trispot darter (*Etheostoma trisella*), coal darter (*Percina brevicauda*)
Mussels TOTAL: 27	3 Cherokee pigtoe (*Pleurobema hartmanianum*), Coosa pigtoe (*Pleurobema stabile*), Coosa orb (*Quadrula kieneriana*)	2 Southern combshell (*Epioblasma penita*), Coosa moccasinshell (*Medionidus parvulus*)	11 Alabama spike (*Elliptio arca*), Alabama moccasinshell (*Medionidus acutissimus*), Canoe Creek clubshell (*Pleurobema athearn*i), Southern pigtoe (*Pleurobema georgianum*), Georgia pigtoe (*Pleurobema hanleyianum*), ovate clubshell (*Pleurobema perovatum*), warrior pigtoe (*Pleurobema rubellum*), heavy pigtoe (*Pleurobema taitianum*), rayed kidneyshell (*Ptychobranchus foremanianus*), triangular kidneyshell (*Ptychobranchus greenii*), Southern purple lilliput (*Toxolasma corvunculus*)	11 delicate spike (*Elliptio arctata*), finelined pocketbook (*Hamiota altilis*), orangenacre mucket (*Hamiota perovalis*), Etowah heelsplitter (*Lasmigona etowaensis*), black sandshell (*Ligumia recta*), Alabama hickorynut (*Obovaria unicolor*), Southern clubshell (*Pleurobema decisum*), monkeyface (*Quadrula metanevra*), Alabama creekmussel (*Strophitus connasaugaensis*), Alabama rainbow (*Villosa nebulosa*), Coosa creekshell (*Villosa umbrans*)
Crayfishes TOTAL: 1	0	0	0	1 greensaddle crayfish (*Cambarus manningi*)

Middle Coosa

Alabama

TOTAL AL SCGN: 34

Management Actions to Address Threats in the Middle Coosa River Watershed		
Management Action	**Threats Addressed**	**Notes**
Conservation locking	Impoundments	Used at large locks and dams where seasonal migrations of fish need passage. Conservation locking has been implemented at some Alabama dams; locks are opened twice a day during migratory season to help fish move past the dam.
Barrier modification for fish passage	Impoundments and barriers	Both major dams on the Middle Coosa – Logan Martin and Neely Henry – are currently in the FERC relicensing process.
Ecological flows	Impoundments	
Impoundment removal	Impoundments and barriers	Useful for small impoundments such as culverted road crossings and low head dams (likely infeasible for main stem dams). The Coosa Riverkeeper and TNC Alabama have been involved in impoundment removal projects in the Coosa Watershed, including removal of Big Canoe Creek dam in Springville in the Middle Coosa Watershed.
Culvert replacement	Impoundments and barriers	
Outreach and education	Impoundments, agriculture, urbanization, septic systems, forestry, industry, groundwater withdrawal	
Riparian buffers	Agriculture, urbanization, industry, wastewater systems, forestry, power plants	The Watershed Assessment of the Big Canoe Creek System for Recovery and Restoration of Imperiled Aquatic Species (Big Canoe Creek Watershed Assessment) states that "maintaining adequate riparian zones and establishing healthy streamside management zones around smaller intermittent tributaries will result in significant conservation opportunities for Trispot Darter populations."
Livestock exclusion	Agriculture	
Livestock waste management	Agriculture	
Livestock production BMPs	Agriculture	
Farmland restoration	Agriculture	
Crop production BMPs	Agriculture	
Aquatic restoration	Agriculture, urbanization, industry, mines, wastewater systems, power plants, forestry	The Middle Coosa Watershed does not have large emergent wetlands or bottomland floodplains found in other parts of Alabama, but these ecosystems are still a very important part of the watershed.

Management Actions to Address Threats in the Middle Coosa River Watershed		
Management Action	**Threats Addressed**	**Notes**
		The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[84]
Forestry BMPs	Forestry	The Big Canoe Watershed Assessment recommends more widespread implementation of forestry BMPs such as selected harvesting in wetland and riparian areas as a management action to support species (specifically, the Trispot Darter) in the Little Canoe Creek subwatershed of Big Canoe Creek, an important tributary of the Middle Coosa.
Improved stormwater management (including green infrastructure)	Urbanization	
Construction BMPs	Urbanization	The Big Canoe Watershed Assessment notes that a failure to implement construction BMPs in subwatersheds of the Middle Coosa could degrade nonbreeding habitat of the Trispot Darter; it specifically mentions the portion of Little Canoe Creek between I-59 and Alabama Highway 174.
Conservation planning	Urbanization, septic systems	
Land conservation	Urbanization, agriculture, industry, wastewater systems, power plants, forestry	The Choccolocco Creek Watershed Alliance maintains that developing more natural, protected areas open to the public could increase local stewardship of the watershed and lessen impacts from developed areas.[85] The Big Canoe Watershed Assessment notes that "conservation easements on private land connected to significant Trispot Darter breeding sites" is a viable strategy for habitat protection in Little Canoe Creek and Upper Big Canoe Creek, important tributaries to the Middle Coosa. The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[86]

[84] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

[85] *See* Zach Tyler, *Advocates highlight natural resources of Choccolocco Creek*, THE ANNISTON STAR, June 2, 2015, *available at* http://www.annistonstar.com/news/advocates-highlight-natural-resources-of-choccolocco-creek/article_b2d2c05e-097f-11e5-afcf-df0416ea7763.html.

[86] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

Management Actions to Address Threats in the Middle Coosa River Watershed		
Management Action	**Threats Addressed**	**Notes**
Mine site reclamation	Mines	The Alabama Department of Labor's Abandoned Mine Reclamation Program prioritizes abandoned mines and develops reclamation engineering plans that are put out for bid.[87]
Mine remediation activities	Mines	
Water quality monitoring	Municipal treatment plants, industry, power plants	
Installation of tertiary treatment constructed wetlands	Municipal treatment plants	
Septic system remediation	Septic systems	
Determining recharge areas for and specific habitats supplied by aquifers	Groundwater withdrawal	
Monitoring spring and cave flows	Groundwater withdrawal	
Water conservation	Groundwater withdrawal	
Irrigation BMPs	Groundwater withdrawal	

General Management Actions to Support Species in the Middle Coosa River Watershed	
Management Action	**Notes**
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	The Alabama SWAP details priority research, survey, and monitoring needs for SGCN species in the entire Coosa watershed beginning page 281. The Alabama Aquatic Biodiversity Center (AABC) has conducted life history studies of Coosa River Basin species.
Captive propagation for reintroduction and augmentation	To address mussel extinction and endangerment, the Alabama Dept. of Conservation and Natural Resources created the AABC to lead recovery efforts through propagation and reintroduction. AABC has propagated and reintroduced several species into the Coosa River.

[87] AL Dept. of Labor, *Abandoned Mine Land Reclamation*, at https://www.labor.alabama.gov/Inspections/Mining/reclamation.aspx.

	The Big Canoe Creek Watershed Assessment notes that a “plan addressing the specific biological and habitat needs and recovery goals for the Trispot Darter needs to be devised in order to implement” propagation for reintroduction and augmentation in the watershed.

Pickwick Lake

Alabama, Mississippi, Tennessee

Watershed Description

The Pickwick Lake Watershed includes over a dozen tributaries and spans nine counties in northeast Mississippi, northwest Alabama, and south-central Tennessee (see Figure 1). The watershed is named for Pickwick Lake, a 52-mile long, 43,100 acre Tennessee River reservoir created by the Pickwick Landing Dam in Hardin County, Alabama, constructed in 1938. The watershed also includes Wilson Lake, formed by Wilson Dam at Muscle Shoals, which impounds a further 15,500 acres. In Alabama, the Pickwick Lake Watershed is part of the Interior Plateau ecoregion (also known as the Highland Rim), where erodible limestone is common and valleys, basins, and karst landscapes full of springs, caves and sinkholes are prevalent. In Mississippi, it is part of the Northeast Hills, Tennessee River Drainage, which is characterized by "relatively high gradient and extensive areas of coarse substrate ranging from gravel to boulders, as well as exposed areas of bedrock."[88] In Tennessee, the watershed is in the Southeastern Plains and Interior Plateau terrestrial ecoregions, the Tennessee River aquatic ecoregion, and the Central Uplands subterranean ecoregion.

[88] MS Dept. of Wildlife, Fisheries, and Parks, MISSISSIPPI'S STATE WILDLIFE ACTION PLAN 2015-2025 DRAFT 492, *available at* https://www.mdwfp.com/media/308158/mdwfpconservationstrategy_2015_2025_3-29__1_.pdf.

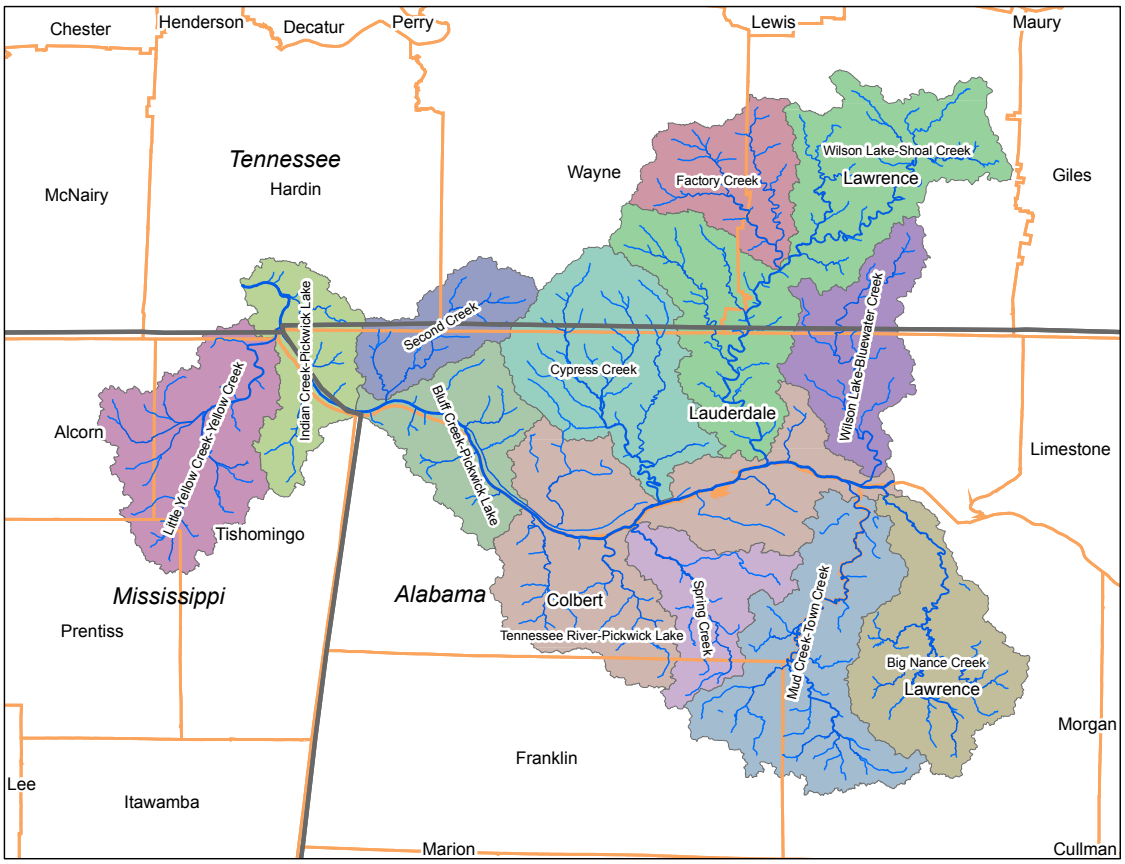


Figure 14. Pickwick Lake Watershed. © Tennessee River Aquarium 2016.

The primary land use in the Pickwick Lake Watershed is forest (40% of the land cover was forested in 2011), followed by agriculture (24% pasture/hay, 9% cultivated crops). Some areas, particularly in Alabama, are primarily in agricultural land uses. The region has very productive soils, but they are highly erodible. There is also a highly concentrated poultry industry in the watershed, which produces thousands of tons of litter annually. Much of this litter is applied to agricultural lands as fertilizer.

Populations in some communities in the Pickwick Lake Watershed grew significantly in the late 1990s and early 2000s, but this growth has leveled off across the region. Pickwick Lake Watershed contains the Florence-Muscle Shoals Metropolitan Statistical Area (also known as "The Shoals"), which includes the cities of Florence, Muscle Shoals, Tuscumbia, and Sheffield. The Shoals has a population of about 200,000, and over 400,000 additional people commute there daily.

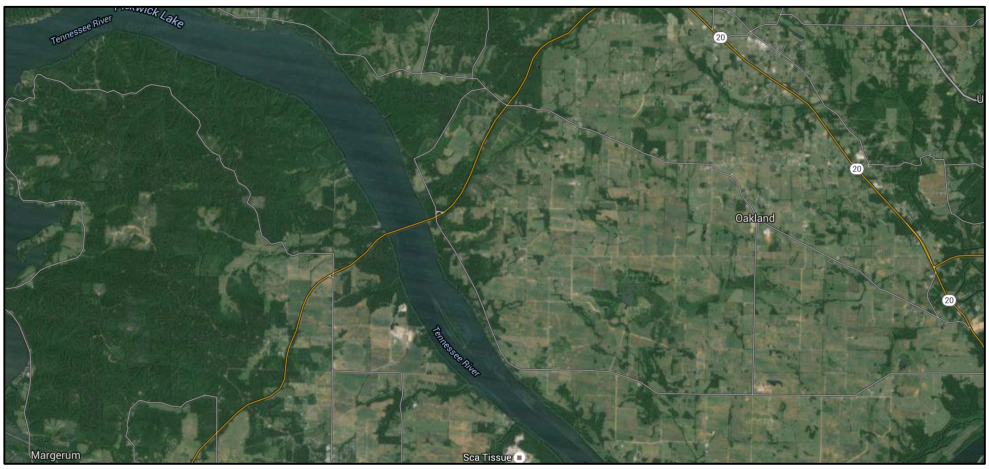


Figure 15. Satellite imagery of a portion of the Pickwick Lake Watershed in northwest Alabama showing areas that are primarily forested (left) and those that are primarily in agricultural land uses (right). © Google 2016.

Figure 16. The legendary FAME Recording Studios in Muscle Shoals, Alabama. © Carol Highsmith.

Species

Pickwick Lake is biologically important in part due to the species diversity found in its twelve tributary watersheds (see Figure 1). The Tennessee River itself is impounded and consequently has lost some native species richness, but tail waters below dams still harbor a substancial number of species that are large-river specialists. Many of these subwatersheds and areas along Pickwick and Wilson Lake contain karst geology and associated springs and caves, which form habitat that isimportant to many fishes and crustaceans. The watershed contains a total of 252 species of fishes, mussels, and crayfishes, including 73 southeastern endemics (see tables at the end of this section). Of these species, 19 are vulnerable, 14 are threatened, and 35 are endangered.[89] There are 69 Species of Greatest Conservation Need (SGCN) identified in the

[89] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions

Tennessee State Wildlife Action Plan (SWAP), 72 SCGN in the Alabama SWAP, and 57 in the Mississippi SWAP (see tables at the end of this section).[90]

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in Pickwick Lake Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Primary potential threats in the Pickwick Lake Watershed are agricultural activities, groundwater withdrawal, and urbanization. Secondary potential threats include impoundments and barriers, forestry, invasive species, landfills, and power plants (coal ash ponds). Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

[90] The total number of SGCN species in the watershed, as identified by both states, is less than the sum of these totals because many species listed as SGCN in Georgia are also listed as SCGN in Tennessee. State SWAPs, however, define what constitutes a SGCN differently, and providing a sum of total SCGN might incorrectly indicate that all of the SGCN species have similar conservation needs.

Primary Potential Threats and Associated Management Actions

Agriculture. In the three states in the Pickwick Lake watershed, agricultural activities are likely the leading threat to aquatic species and habitat health. After forests, agricultural lands are the second most common land use in the watershed. In Alabama, the leading agricultural threats are likely associated with row crops and poultry operations, followed by livestock pasture operations. In Mississippi, the leading agricultural threat is likely row crops, followed by livestock pasture operations. In Tennessee, livestock pasture is likely the leading threat with row crops not far behind. Highly erodible soils are common in the watershed, so erosion and sedimentation issues are common. Agricultural activities can be particularly harmful to species and habitat in the Pickwick Lake Watershed when they occur in karst areas without the use of appropriate best management practices such as buffers and livestock exclusion fencing around springs, sinkholes, and caves.

Management actions that address agricultural impacts include:

- Riparian and karst buffers
- Livestock exclusion/stream fencing
- Livestock waste management
- Livestock production BMPs
- Crop production BMPs (including poultry litter application rates)
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Groundwater withdrawal. Aquifers in the Interior Plateau provide cool, consistent, high quality water for springs, spring-fed creeks, and caves. Groundwater habitats are one of the major drivers for the endemic biodiversity found in this watershed. Use of groundwater for agricultural irrigation and municipal/industrial use, especially during drought conditions, can cause severe stress on many of these specialized habitats, and this stress will likely increase with climate change.

Management actions to address groundwater withdrawal include:

- Determining recharge areas for and specific habitats supplied by aquifers
- Monitoring spring and cave flows
- Outreach and education

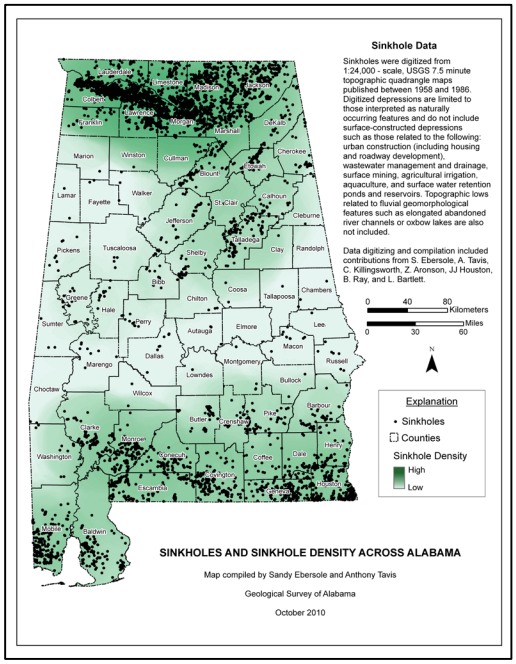


Figure 17. A map of sinkholes in Alabama shows the abundance of these karst features in the Pickwick Lake Watershed in northwest Alabama. © Geological Survey of Alabama.

Urbanization. The Pickwick Lake Watershed is not heavily urbanized, but developed areas are likely contributors to species and habitat impacts in some tributary watersheds and karst areas, particularly in the Florence-Muscle Shoals Metropolitan Statistical Area. Impervious surfaces in groundwater recharge areas decrease the amount of groundwater available in karst habitat. Buffers around sinks and caves, stormwater management practices such as green infrastructure, and conservation planning that directs development away from sensitive areas can help.

Management actions that address urbanization include:

- Riparian buffers
- Improved stormwater management (including green infrastructure)
- Conservation planning
- Land conservation
- Aquatic restoration
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Impoundments and barriers. Two large reservoirs (Pickwick and Wilson Lake) exist on the Tennessee River mainstem. Other small impoundments exist in the river's tributaries as well as an unknown number of potential barriers such hanging culverts. These structures alter

hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Management actions to address impoundments include:

- Conservation locking
- Fish passage
- Dam removal
- Ecological flows
- Culvert replacement

Forestry. Forests are the most common land use in the Pickwick Watershed, and at least one SWAP (Mississippi's) lists improper logging and wood harvesting practices as a "high" threat in the region. Improperly managed logging operations can result in erosion and sedimentation in the watershed. Proper forestry practices are particularly important on steep slopes and around caves and sinks.

Management actions that address logging and wood harvesting impacts include:

- Forestry BMPs
- Aquatic restoration
- Riparian buffers
- Land conservation
- Outreach and education

Invasive species. Invasive species can displace native species by, among other things, depredation and competition for resources. They can also, in some instances, impact water quality. Aquatic invasive species are present in Pickwick Lake Watershed, including bighead carp, silver carp, and zebra mussels. The Alabama SWAP notes that introduction of, or a failure to eradicate or control these species is a problem in the greater Tennessee River Basin.[91]

Management actions that address invasive species include:

- Outreach and education
- Invasive species control

Landfills. In 2013, the Tennessee Riverkeeper sued the owners of the old City of Florence landfill for violations of the Clean Water Act, alleging that leachate from the landfill had been bubbling

[91] AL Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 237, *available at* http://www.outdooralabama.com/al-comprehensive-wildlife-conservation-strategy.

up from a nearby spring for decades. The Riverkeeper eventually settled with the landfill owners, which required owners to fund a water quality project in Cypress Creek and apply for a permit under the National Pollutant Discharge Elimination System (NPDES) from the Alabama Department of Environmental Management (ADEM). As of January 2016, ADEM had not yet issued the landfill owners a permit.

In 2015, the Tennessee Riverkeeper conducted water conductivity testing at the new Florence landfill that indicated that pollutants may be leaking into seven nearby creeks, including Ram, Lewis, and Big Red.

Most management actions that would directly mitigate landfill impacts on aquatic resources in the Pickwick Lake Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Water quality monitoring
- Education and outreach

Power plants – coal ash ponds. TVA's Colbert Power Plant ended electrical power generation in 2016, but large quantities of coal ash remain in a coal ash pond that the Authority plans to drain and cover in lieu of removal. Environmental groups worry that the remaining ash, which contains potentially toxic heavy metals such as mercury, cadmium, and arsenic, could leach into groundwater or, worse yet, a dam breach could spill ash directly into the Tennessee River.

Spills from closed ponds have occurred in the Southeast in recent years; a recent study of 21 southeastern coal ash ponds from Duke University found evidence of pond leaks at all of them. Concentrations of some trace elements exceeded EPA water quality standards at nearly a third of the study sites.[92]

Most management actions that would directly mitigate coal ash pond impacts on aquatic resources in the Pickwick Lake Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Water quality monitoring
- Outreach and education

[92] Harkness, et al, *Evidence for Coal Ash Ponds Leaking in the Southeastern United States*, 50 (12) ENVIRON. SCI. & TECHNOL. 6583-6592 (American Chemical Society 2016).

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Middle Coosa Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

Alabama Clean Water Partnership: The Alabama Clean Water Partnership is a statewide nonprofit that seeks to improve communication, share data and information, improve coordination, and provide opportunities for collaboration. http://www.cleanwaterpartnership.org

Tennessee Riverkeeper: The Tennessee Riverkeeper is an advocacy organization dedicated to protecting the river and its tributaries by enforcing environmental laws and educating the public. http://www.tennesseeriver.org/staff.html

Shoals Earth Month, Inc.: The mission of Shoals Earth Month, Inc., which is located in Sheffield, Alabama, is to provide educational opportunities to enhance understanding of the interconnectedness of all natural systems and to celebrate biodiversity. http://www.shoalsearthmonth.com

Shoals Environmental Alliance: The Shoals Environmental Alliance is an environmental activities and watch-dog alliance established to promote the preservation of the natural resources, scenic beauty, and recreational opportunities of the Muscle Shoals, Alabama, area of northwest Alabama. Information available at http://www.ag.auburn.edu/auxiliary/grassroots/groups/sea.php.

East Lauderdale Environment Conscious Citizens: East Lauderdale Environment Conscious Citizens (ELECC) is a non-profit corporation dedicated to the preservation of environmentally sensitive areas along Mill and Bluewater Creeks. Information available at http://www.ag.auburn.edu/auxiliary/grassroots/groups/elecc.php

Lawrence Countians for a Safe Environment: The Lawrence Countians for a Safe Environment have a very specific mission of monitoring operation of 1,500 tons per day landfill that drains into a creek that lies upstream of the county's drinking water plant.

Alabama Scenic River Trail: The Tennessee River comprises part of the Alabama Scenic River Trail. http://www.alabamascenicrivertrail.com

Land Trust of North Alabama: The Land Trust of North Alabama preserves and protects land and its legacies, including wildlife habitats, farms, historic sites, waterways, and mountains for conservation, public recreation, and environmental education to enhance quality of life in North Alabama.
http://www.landtrustnal.org

Plans and Other Resources

Pickwick Reservoir Watersheds Watershed Management Plan (MDEQ 2010): A TMDL management plan to address impaired tributaries of the Pickwick Lake Watershed. https://www.deq.state.ms.us/mdeq.nsf/pdf/WQSB_TN_PickwickLakeWIP05122010/$File/TN_Pickwick_Lake_WIP_05-12-10.pdf?OpenElement.

Pickwick Lake Watershed Water Quality Management Plan (TDEC 2003): This plan includes a description of the watershed approach to water quality, a description of the Pickwick Lake Watershed, a water quality assessment of the watershed, a point and nonpoint source pollutant characterization of the watershed (by subwatershed), a description of water quality partnerships in the region, and future plans. http://www.tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-pickwick-2003.pdf

Tennessee River Basin Watershed Management Plan (ADEM 2003): The goal of this plan is to "initiate, revitalize, and encourage local restoration efforts to improve, maintain, and protect the waters of the Tennessee River basin to the intended goals of the original Clean Water Act of 1972, 'fishable and swimmable waters for all Americans.'"
http://www.adem.state.al.us/programs/water/nps/files/TennesseeBMP.pdf

Spring Creek Embayment, Wheeler Reservoir, Intensive Basin Survey (ADEM 2009): A description of a basin survey of Spring Creek Embayment; it provides data that can be used to assess water quality, identify trends, and develop TMDLs and water quality criteria. http://adem.alabama.gov/programs/water/wqsurvey/table/2009/WHEL-9.pdf.

Protecting our Waters: The Tennessee River Basin (AL Clean Water Partnership): An educational document regarding the Tennessee River Basin.
http://www.cleanwaterpartnership.org/uploadedFiles/File/ACWP_Tennessee_FINAL_Web.pdf.

Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region (Cumberlandian Region Mollusk Restoration Committee 2010): This plan provides a framework for the restoration of freshwater mollusks and their ecological functions to reaches of the Cumberlandian Region (the Tennessee and Cumberland River systems) through reintroduction, augmentation, and controlled propagation. Available through the Appalachian Landscape Conservation Cooperative website at http://applcc.org.

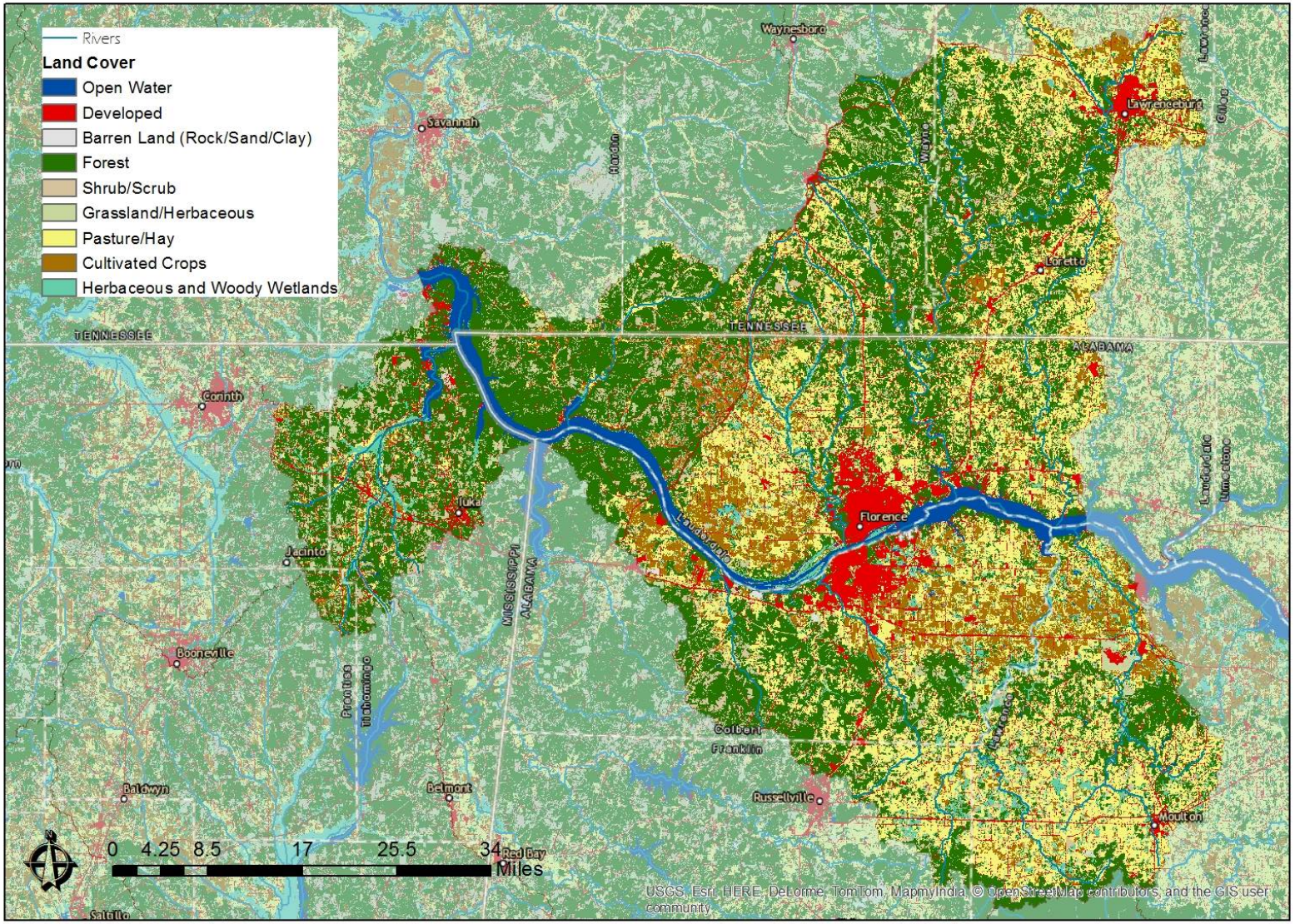


Figure 18. Land Use / Land Cover in the Pickwick Lake Watershed

Pickwick Lake

Alabama, Mississippi, Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in Pickwick Lake Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	142	30	4	6	4
Mussels	83	24	29	8	13
Crayfishes	27	19	2	0	2
TOTAL	252	73	35	14	19

Tennessee SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed		
	Tier I	Tier III
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 18	13 highfin carpsucker (*Carpiodes velifer*), blue sucker (*Cycleptus elongatus*), streamline chub (*Erimystax dissimilis*), blotched chub (*Erimystax insignis*), ashy darter (*Etheostoma cinereum*), crown darter (*Etheostoma corona*), lollypop darter (*Etheostoma neopterum*), tuscumbia darter (*Etheostoma tuscumbia*), flame chub (*Hemitremia flammea*), Southern brook lamprey (*Ichthyomyzon gagei*), blotchside logperch (*Percina burtoni*), slenderhead darter (*Percina phoxocephala*), Southern cavefish (*Typhlichthys subterraneus*)	5 spotfin chub (*Erimonax monachus*), slackwater darter (*Etheostoma boschungi*), boulder darter (*Etheostoma (Nothonotus) wapiti*), palezone shiner (*Notropis albizonatus*), paddlefish (*Polyodon spathula*)
Mussels	22 mucket (*Actinonaias ligamentina*), pheasantshell (*Actinonaias pectorosa*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), longsolid (*Fusconaia subrotunda*), black sandshell (*Ligumia recta*) Cumberland moccasinshell (*Medionidus conradicus*), hickorynut (*Obovaria olivaria*), round hickorynut (*Obovaria subrotunda*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), Tennessee pigtoe (*Pleuronaia barnesiana*), Alabama creekmussel (*Strophitus connasaugaensis*), creeper (*Strophitus undulatus*)	26 spectaclecase mussel (*Cumberlandia monodonta*), fanshell mussel (*Cyprogenia stegaria*), dromedary pearlymussel (*Dromus dromas*), Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), catspaw (*Epioblasma obliquata obliquata*), snuffbox (*Epioblasma triquetra*) shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), cracking pearlymussel (*Hemistena lata*), pink mucket (*Lampsilis abrupta*), Alabama lampmussel (*Lampsilis virescens*), scaleshell (*Leptodea leptodon*), ring pink (*Obovaria retusa*), littlewing pearlymussel (*Pegias fabula*), white wartyback (*Plethobasus cicatricosus*), orangefoot pimpleback (*Plethobasus*

Pickwick Lake

Alabama, Mississippi, Tennessee

Tennessee SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed		
	Tier I	Tier III
TOTAL: 48	purple lilliput (*Toxolasma lividum*), rainbow mussel (*Villosa iris*), little spectaclecase (*Villosa lienosa*), painted creekshell (*Villosa taeniata*), mountain creekshell (*Villosa vanuxemensis*), Southern rainbow (*Villosa vibex*)	*cooperianus*), sheepnose (*Plethobasus cyphyus*), clubshell (*Pleurobema clava*), rough pigtoe (*Pleurobema plenum*), slabside pearlymussel (*Pleuronaia dolabelloides*), rabbitsfoot (*Quadrula cylindrica cylindrica*), Cumberland monkeyface (*Quadrula intermedia*), Appalachian monkeyface (*Quadrula sparsa*), pale lilliput (*Toxolasma cylindrellus*), Cumberland bean (*Villosa trabalis*)
Crayfishes TOTAL: 3	3 cavespring crayfish (*Cambarus tenebrosus*), Alabama crayfish (*Orconectes alabamensis*), surgeon crayfish (*Orconectes forceps*)	0
		TOTAL TN SGCN: 69

Alabama SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
	Extirpated (EX). Taxa that historically occurred in Alabama, but are now absent, may be rediscovered or be reintroduced from populations existing outside the state.	Extirpated/Conservation Action Underway (EXCAU). Taxa that historically occurred in Alabama, were absent for a period of time, and currently are being reintroduced, or have a plan for being reintroduced, into the state from populations outside the state.	Critical Conservation Need (P1). Faces an extremely high risk of extinction or extirpation. Populations of these species are at critically low levels, face immediate threat(s), or occur within an extremely limited range. Intense and immediate management action is needed.	Very High Conservation Need (P2). Has a high risk of extinction or extirpation. Populations of these species are at very low levels, face real threat(s), or occur within a very limited distribution. Immediate management is needed for stabilization and recovery.
Fishes	4 ashy darter (*Etheostoma cinereum*), goldeye (*Hiodon alosoides*), popeye shiner (*Notropis ariommus*), shovelnose sturgeon	1 spotfin chub (*Erimonax monachus*)	6 slackwater darter (*Etheostoma boschungi*), lollypop darter (*Etheostoma neopterum*), palezone shiner (*Notropis albizonatus*),	8 streamline chub (*Erimystax dissimilis*), tuscumbia darter (*Etheostoma tuscumbia*), bandfin darter (*Etheostoma zonistium*), ghost shiner

Alabama SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 19	(*Scaphirhynchus platorynchus*)		blotchside logperch (*Percina burtoni*), slenderhead darter (*Percina phoxocephala*), Alabama cavefish (*Speoplatyrhinus poulsoni*)	(*Notropis buchanani*), stonecat (*Noturus flavus*), brindled madtom (*Noturus miurus*), gilt darter (*Percina evides evides*), stargazing minnow (*Phenacobius uranops*)
Mussels	12 pheasantshell (*Actinonaias pectorosa*), dromedary pearlymussel (*Dromus dromas*), Duck River dartersnapper (*Epioblasma ahlstedti*), scaleshell (*Leptodea leptodon*), hickorynut (*Obovaria olivaria*), ring pink (*Obovaria retusa*), littlewing pearlymussel (*Pegias fabula*), orangefoot pimpleback (*Plethobasus cooperianus*), clubshell (*Pleurobema clava*), fluted kidneyshell (*Ptychobranchus subtentus*), Cumberland monkeyface (*Quadrula intermedia*), Appalachian monkeyface (*Quadrula sparsa*)	2 oyster mussel (*Epioblasma capsaeformis*), Cumberland bean (*Villosa trabalis*)	27 mucket (*Actinonaias ligamentina*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), spike (*Elliptio dilatata*), Cumberlandian combshell (*Epioblasma brevidens*), snuffbox (*Epioblasma triquetra*), shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), longsolid (*Fusconaia subrotunda*), cracking pearlymussel (*Hemistena lata*), pink mucket (*Lampsilis abrupta*), Alabama lampmussel (*Lampsilis virescens*), Cumberland moccasinshell (*Medionidus conradicus*), round hickorynut (*Obovaria*	6 orangenacre mucket (*Hamiota perovalis*), black sandshell (*Ligumia recta*), Tennessee pigtoe (*Pleuronaia barnesiana*), monkeyface (*Quadrula metanevra*), Alabama creekmussel (*Strophitus connasaugaensis*), painted creekshell (*Villosa taeniata*)

Alabama SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 47			*subrotunda*), white wartyback (*Plethobasus cicatricosus*), sheepnose (*Plethobasus cyphyus*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*), rough pigtoe (*Pleurobema plenum*), pyramid pigtoe (*Pleurobema rubrum*) round pigtoe (*Pleurobema sintoxia*), slabside pearlymussel (*Pleuronaia dolabelloides*), kidneyshell (*Ptychobranchus fasciolaris*), creeper (*Strophitus undulatus*), pale lilliput (*Toxolasma cylindrellus*)	
Crayfishes TOTAL: 6	0	0	2 Tennessee bottlebrush crayfish (*Barbicambarus simmonsi*), phantom cave crayfish (*Cambarus pecki*)	4 Alabama cave crayfish (*Cambarus jonesi*), depression crayfish (*Cambarus rusticiformis*), saddle crayfish (*Orconectes durelli*), shrimp crayfish (*Orconectes lancifer*)
				TOTAL AL SCGN: 72

Pickwick Lake

Alabama, Mississippi, Tennessee

Mississippi SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
Tier description	Critical Conservation Need. Faces an extremely high risk of extinction or extirpation. Populations of these species are at critically low levels, face immediate threat(s), or occur within an extremely limited range. Intense and immediate management action is needed.	Very High Conservation Need. Has a high risk of extinction or extirpation. Populations of these species are at very low levels, face real threat(s), or occur within a very limited distribution. Immediate management is needed for stabilization and recovery.	High Conservation Need. Extinction or extirpation is possible. Populations of these species are in decline, have declined to low levels, or are restricted in range. Management action is needed to stabilize or increase populations.	Moderate Conservation Need. The species may be rare in parts of its range, particularly on the periphery. Populations of these species have demonstrated a declining trend or a declining trend is suspected which, if continued, is likely to qualify this species for a higher tier in the foreseeable future. Long-term planning is necessary to stabilize or increase populations.
Fishes	1 rock bass (*Ambloplites rupestris*)	19 fall-line sculpin (*Cottus carolinae*), blue sucker (*Cycleptus elongatus*), whitetail shiner (*Cyprinella galactura*), steelcolor shiner (*Cyprinella whipplei*), greenside darter (*Etheostoma blennioides blennioides*), black darter (*Etheostoma duryi*), stripetail darter (*Etheostoma kennicotti*), blackfin darter (*Etheostoma nigripinne*), bandfin darter (*Etheostoma zonistium*), chestnut lamprey (*Ichthyomyzon castaneus*), silver redhorse (*Moxostoma*	9 rosyside dace, (*Clinostomus funduloides funduloides*), spotfin shiner (*Cyprinella spiloptera*), fantail darter (*Etheostoma flabellare*), redline darter (*Etheostoma rufilineatum (Nothonotus rufilineatus)*), Alabama hog sucker (*Hypentelium etowanum*), black buffalo (*Ictiobus niger*), scarletfin shiner (*Lythrurus fasciolaris*), golden redhorse (*Moxostoma erythrurum*), paddlefish (*Polyodon spathula*)	1 slender madtom (*Noturus exilis*)

Mississippi SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 30		*anisurum*), river redhorse (*Moxostoma carinatum*), black redhorse (*Moxostoma duquesnei*), bigeye shiner (*Notropis boops*), highland shiner (*Notropis micropteryx*), stonecat (*Noturus flavus*), gilt darter (*Percina evides evides*), slenderhead darter (*Percina phoxocephala*), shovelnose sturgeon (*Scaphirhynchus platorynchus*)		
Mussels TOTAL: 21	13 mucket (*Actinonaias ligamentina*), purple wartyback (*Cyclonaias tuberculata*), spike (*Elliptio dilatata*), Cumberlandian combshell (*Epioblasma brevidens*), snuffbox (*Epioblasma triquetra*), orangenacre mucket (*Hamiota perovalis*), black sandshell (*Ligumia recta*), round hickorynut (*Obovaria subrotunda*), sheepnose (*Plethobasus cyphyus*), Tennessee pigtoe (*Pleuronaia barnesiana*), slabside pearlymussel (*Pleuronaia dolabelloides*), rabbitsfoot (*Quadrula*	2 butterfly (*Ellipsaria lineolata*), creeper (*Strophitus undulatus*)	5 rock pocketbook (*Arcidens confragosus*), white heelsplitter (*Lasmigona complanata*) pink heelsplitter (*Potamilus alatus*), kidneyshell (*Ptychobranchus fasciolaris*), deertoe (*Truncilla truncata*)	1 monkeyface (*Quadrula metanevra*)

Mississippi SWAP Species of Greatest Conservation Need in Pickwick Lake Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
	cylindrica cylindrica), Alabama creekmussel (*Strophitus connasaugaensis*)			
Crayfishes TOTAL: 6	0	2 Ets crayfish (*Orconectes etnieri*), Hatchie River crayfish (*Procambarus ablusus*)	4 tanback crayfish (*Cambarus girardianus*), depression crayfish (*Cambarus rusticiformis*), Coosa River spiny crayfish (*Orconectes spinosus*), powerful crayfish (*Orconectes validus*)	0
				TOTAL MS SCGN: 57

Management Actions to Address Threats in Pickwick Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Riparian and karst buffers	Agriculture, forestry, urbanization	The Conservation Reserve Program has been very successful at establishing riparian buffers in Mississippi, where incentives were first made available in 2000.
Livestock exclusion	Agriculture	
Livestock waste management	Agriculture	
Livestock production BMPs	Agriculture	The Mississippi State Water Quality Lab conducts research on freshwater nutrient issues, including projects concerning the efficacy of agricultural BMPs.[93]
Crop production BMPs	Agriculture	
Farmland restoration	Agriculture	
Aquatic restoration	Agriculture, forestry, urbanization	In 1999, NRCS highlighted Big Nance Creek, part of the Pickwick Lake Watershed in Northwestern Alabama, as a "National Showcase Watershed" for watershed restoration accomplishments.[94]

[93] MS State University, *Water Quality Lab*, http://www.fwrc.msstate.edu/water/index.asp.

[94] NRCS, *National Showcase Watersheds*, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026818.pdf.

Management Actions to Address Threats in Pickwick Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
		The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[95]
Land conservation	Agriculture, forestry, urbanization	The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[96]
Outreach and education	Agriculture, forestry, urbanization, landfills, coal ash ponds, groundwater withdrawals, invasive species	
Forestry BMPs	Forestry	A 2013 survey of forestry BMP implementation in Mississippi studied 254 random sites and found that 95 percent of BMPs applicable to the survey sites were implemented in accordance with the Mississippi forestry BMP handbook.[97]
Improvements in stormwater management (including green infrastructure)	Urbanization	
Conservation planning	Urbanization	
Water quality monitoring	Landfills, power plants (coal ash ponds)	
Invasive species control	Invasive species	
Conservation locking	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	
Impoundment removal	Impoundments and barriers	
Ecological flows	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	

[95] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.
[96] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.
[97] MS Forestry Comm'n., 2013 BMP IMPLEMENTATION SURVEY, *available at* http://www.mfc.ms.gov/sites/default/files/2014_BMP_%20Implementation_Survey_V5.pdf; MS Forestry Comm'n., MISSISSIPPI'S BMPS: BEST MANAGEMENT PRACTICES FOR FORESTRY IN MISSISSIPPI, *available at* http://www.mfc.ms.gov/sites/default/files/Entire_bmp_2008-7-24_2.pdf.

Pickwick Lake

Alabama, Mississippi, Tennessee

Management Actions to Address Threats in Pickwick Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Determining recharge areas for and specific habitats supplied by aquifers	Groundwater withdrawal	The Alabama SWAP recommends identifying recharge areas around ecologically significant caves.[98]
Monitoring spring and cave flows	Groundwater withdrawal	
Water conservation	Groundwater withdrawal	
Irrigation BMPs	Groundwater withdrawal	

General Management Actions to Support Species in Pickwick Lake Watershed	
Management Action	**Notes**
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	Comprehensive mussel surveys, fish IBI monitoring, and biotic and habitat monitoring have occurred at Bear Creek. The Alabama SWAP notes that permanent mussel sampling stations are needed at Bear Creek. The Alabama SWAP notes that a lot of basic life history and habitat research is needed for Tennessee River Basin species.[99] Identifying recharge areas of ecologically significant caves is recommended by the Alabama SWAP.
Captive propagation for reintroduction and augmentation	The *Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region* outlines opportunities for augmentation and reintroduction in the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.[100] To address mussel extinction and endangerment, the Alabama Dept. of Conservation and Natural Resources created the Alabama Aquatic Biodiversity Center (AABC) to lead recovery efforts through propagation and reintroduction. The AABC has augmented mussel populations in the Pickwick

[98] AL Dept. of Conservation & Natural Resources, ALABAMA WILDLIFE ACTION PLAN 183 (2015).
[99] AL Dept. of Conservation & Natural Resources, ALABAMA WILDLIFE ACTION PLAN 237 (2015).
[100] Cumberlandian Region Mollusk Restoration Committee, PLAN FOR THE POPULATION RESTORATION AND CONSERVATION OF IMPERILED FRESHWATER MOLLUSKS OF THE CUMBERLANDIAN REGION (2010), *available at* http://applcc.org/plan-design/aquatic-species-conservation-strategy/reports-documents/plan-for-the-population-restoration-and-conservation-of-imperiled-freshwater-mollusks-of-the-cumberland-region/view.

	Lake Watershed, including the 2011 release of 1,000 cultured Alabama Lampmussels into Bear Creek in Colbert County.

Upper Clinch

Virginia, Tennessee

Watershed Description

Within the Upper Clinch watershed, the Clinch River is unimpounded between its headwaters in Tazewell, Virginia, and Norris Lake (33,840 acres). This impoundment section of the Clinch River mainstem stretches 73 miles downstream to Norris Dam in Anderson and Campbell Counties in Tennessee. It drains approximately 1,944 square miles. The Upper Clinch is part of the Great Appalachian Valley (also known as the Shenandoah Valley), a gigantic trough of valley lowlands that marks the eastern edge of the Ridge and Valley physiographic province. It is characterized by roughly parallel, low rolling ridges and valleys and numerous springs and caves.

Most of the Upper Clinch Watershed is forested with forested classes making up just over 63% of the 2011 land cover map. The second leading land use is agriculture (18%), much of which occurs in floodplains due to the region's topography. Most of the agricultural areas are used for livestock pasture, primarily for cattle. Row crops are another common use, with tobacco production prevalent in some areas, mostly in Virginia. A large number of active and abandoned coal mines are scattered throughout the watershed, and the region's coal supply is expected to last for several decades. Urban areas are by no means common in the Upper Clinch Watershed, but are a significant land use in some subwatersheds.

The communities in the Upper Clinch Watershed are marked by high unemployment and economic disparity. Local economies in the region are primarily driven by coal mining and agriculture.

In the Virginia Wildlife Action Plan, the Upper Clinch is part of the Cumberland Plateau and Lenowisco Planning Regions. In the Tennessee State Wildlife Action Plan, the Upper Clinch is not part of any particular planning region, but is identified as being in the Ridge and Valley terrestrial ecoregion, the Tennessee River-Ridge and Valley Aquatic Subregion, and the Rolling Limestone Hills Subterranean Subregion.

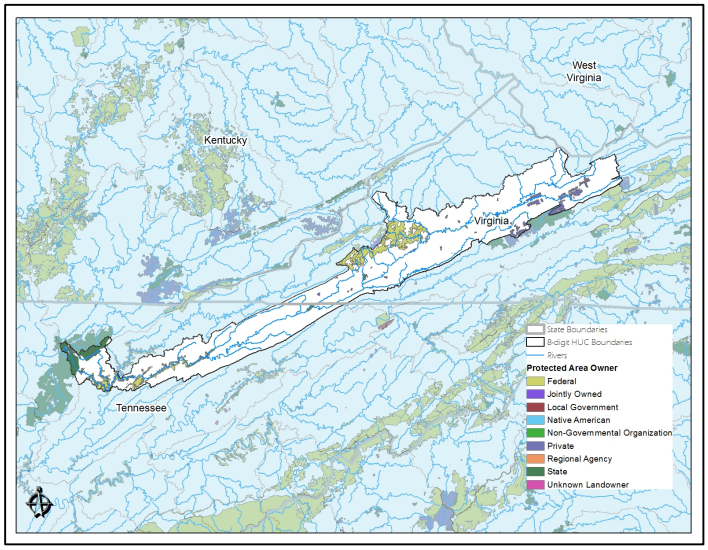
Species

The Upper Clinch is one of the most biodiverse freshwater systems in the nation. It contains a total of 173 species of fishes, mussels, and crayfishes, including 54 southeastern endemics (see table at the end of this section). Of these species, 18 are vulnerable, 10 are threatened, and 31 are endangered.[101] The Virginia and Tennessee State Wildlife Action Plans identify 58 and 59

[101] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

Species of Greatest Conservation Need (SCGN) in the watershed, respectively (see table at the end of this section).[102]

This rich biodiversity and endemism can be attributed to the fact that this narrow watershed is isolated from other waters and its karst geology with an abundance of sinkholes and caves (many species are karst-dependent).



Protected areas in the Upper Clinch.
Protected Areas Database of the U.S. v. 1.3, © USGS.

Potential Threats and Management Actions

This section describes primary and secondary potential threats to species and habitat in the Upper Clinch Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

[102] The total number of SGCN species in the watershed, as identified by both states, is less than the sum of these totals because many species listed as SGCN in Virginia are also listed as SCGN in Tennessee. State SWAPs, however, define what constitutes a SGCN differently, and providing a sum of total SCGN might incorrectly indicate that all of the SGCN species have similar conservation needs.

Although the watershed is mostly forested, the aquatic species in the Upper Clinch River face several potential threats. The primary potential threats to species are active and abandoned coal mines and agricultural practices. Secondary potential threats include urbanization, sinkhole dumping, and impoundments and barriers. Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

Primary Potential Threats and Associated Management Actions

Mines. Studies of fishes and mussels in the Upper Clinch suggest that population declines may be most attributable to coal mining. An ecological risk assessment of the Clinch and Powell Rivers found that the quality of fish communities decreased the most in areas dominated by forests. This finding would be surprising but for the fact that mining operations in the watersheds are found in forested areas.[103] A second study surveying mussels throughout the entire watershed in both states showed that, in general, populations in the upper reaches in Virginia are recovering, those in the middle reaches in Virginia are declining, and those in the lower reaches in Tennessee are stable and increasing. The researchers theorized that these impacts may be attributable to effects of inputs from tributary subwatersheds with mining sites.[104]

Management actions that address mines include:

- Mining site reclamation

[103] USEPA, CLINCH AND POWELL VALLEY WATERSHED ECOLOGICAL RISK ASSESSMENT (2002).

[104] Johnson, et al, *Influences of water and sediment quality and hydrologic processes on mussels in the Clinch River*, 50(4) JOUR. AMER. WATER RES. ASSOC. 878-897 (2014).

- Mine remediation activities

Agriculture. Poor agricultural practices are another potential leading threat to aquatic species in the Upper Clinch Watershed. The most common agricultural use is pasture for livestock (primarily cattle), followed by row crops (often tobacco). Because of the area's topography, most agricultural activities are located in floodplains, which can exacerbate impacts. Livestock operations have the potential to be particularly harmful if they occur without best management practices in areas with karst resources.

Management actions that address agricultural impacts include:

- Riparian and karst buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Crop production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Urbanization. Developed areas are not a widespread land use in the Upper Clinch, but likely cause impacts to species and habitat in areas where they are prevalent. Communities in the Upper Clinch region are typically rural, with low median income levels and limited local government budgets that do not provide for robust stormwater management, centralized sewer systems, or green infrastructure. Impacts from erosion and sedimentation, stormwater runoff, and septic systems are common. Stormwater runoff can be particularly problematic in karst areas, as pollutants can enter groundwater resources through fissures and other features with little to no treatment by soils. Impervious surfaces in aquifer recharge areas can also decrease the amount of groundwater available in karst habitat.

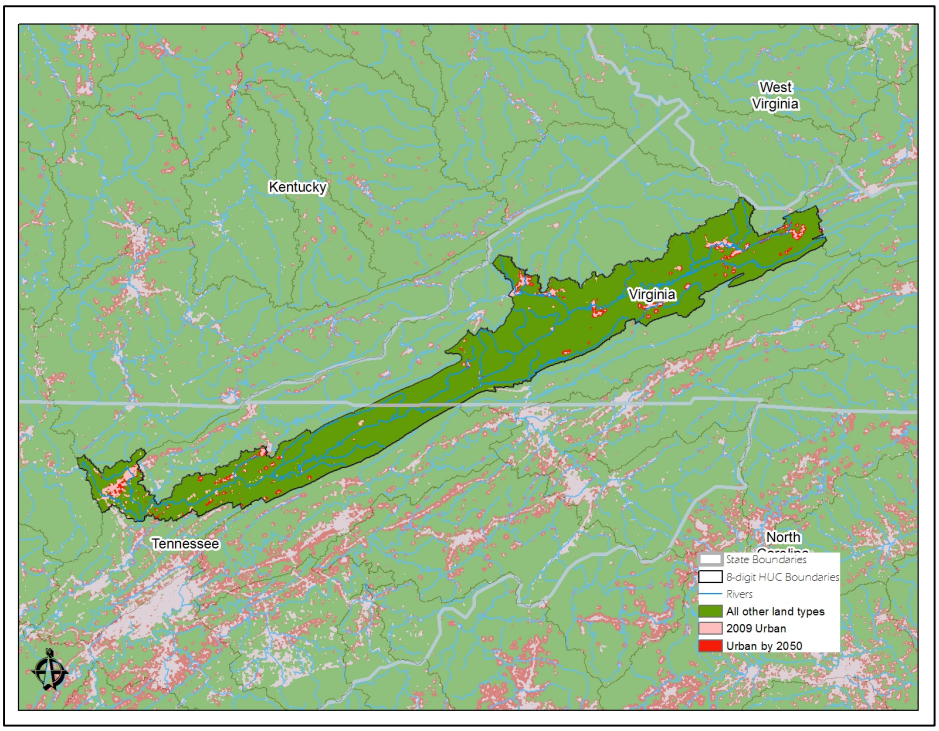


Figure 19. Upper Clinch urban growth projections to 2050 . © NC State.

Populations have been decreasing across much of the watershed in recent years, so new development should not pose much of a threat in the region. Investments in projects in Upper Clinch communities may, however, still be warranted. Such projects may generate support of aquatic protection other parts of the watershed. This is important in a region that has historically been wary of outsiders, particularly those associated with the federal government. For community projects, engaging a local partner that is trusted and respected by community members is advised.

Management actions that address urbanization include:

- Riparian and karst buffers
- Conservation planning
- Land conservation
- Aquatic restoration
- Improved stormwater management (including green infrastructure)
- Septic system remediation
- Outreach and education

Sinkhole dumping. Sinkholes, another component of karst geology, are often used by rural residents as dumping sites for garbage, dead livestock, and other materials that can impact water quality.

Management actions that address sinkhole dumping include:

- Alternative dump sites
- Outreach and education

Impoundments and barriers. One large reservoir (Norris Lake) exists on the upper Clinch River mainstem. Other small impoundments exist on the river's tributaries as well as an unknown number of potential barriers such hanging culverts. These structures alter hydrologic regimes, inundate lotic aquatic habitat, and lead to fragmentation of remaining lotic habitat, isolating populations.

Management actions to address impoundments and barriers include:

- Barrier modification for fish passage
- Impoundment removal
- Ecological flows
- Culvert replacement

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Upper Clinch Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

The Upper Clinch is a relatively small, narrow watershed without significant urban areas. It is, however, well-recognized as a biodiversity hotspot, and has adequate capacity for species conservation and management in terms of well-established programs and projects. The following programs and organizations are currently working to address some aspect of watershed or species health in the Upper Clinch.

TNC Clinch Valley Program: Established in 1990, The Nature Conservancy's Clinch Valley Program has helped protect more than 35,000 acres of critical natural habitat in the Clinch Valley. In the Clinch River, the program has protected seven shoals that collectively represent one of the world's most diverse assemblages of mussels. In 2016, in partnership with 5 local Natural Resources Conservation Service (NRCS) offices, the Conservancy was awarded $4.5 million by the USDA's Regional Conservation Partnership Program (RCPP) for a 5-year project that will target investment of agricultural Best Management Practices across five counties in the Clinch Watershed. As part of this grant, the Conservancy will chair a 5-county advisory board that will select BMP projects aimed to maximize benefits to rare species, water quality, and local farmers in the Clinch Valley.
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/virginia/placesweprotect/clinch-valley-program-1.xml

Clinch River Valley Initiative: The Clinch River Valley Initiative (CRVI) is a collaborative effort in Southwest Virginia focusing on the Clinch River Valley. Utilizing a consensus-based approach, project partners have developed goals for connecting downtown revitalization, outdoor recreation, water quality, entrepreneurship, and environmental education along the Clinch River, and are taking action to realize the prioritized goals. http://www.clinchriverva.com

Clinch-Powell Clean Rivers Initiative: To protect and sustain this region, The Nature Conservancy and partners formed the Clinch-Powell Clean Rivers Initiative (CPCRI) to document and address ecosystem stressors including excess sediments and nutrients, metals, dissolved solids, pesticides and persistent organics. This project is designed to improve water quality and aquatic habitat by developing a local working group for resource identification and BMP prioritization, designing a GIS-based ranking system to prioritize RCCP project investments, implementing agricultural and mining BMPs in biologically critical areas, and assessing the positive impacts of these BMPs on water quality. http://cpcri.net

Upper Tennessee River Roundtable: The Upper Tennessee River Roundtable is a non-profit organization with an overall interest in improving water quality in the Upper Tennessee River Watershed. It focuses its efforts on the Clinch, Holston, and Powell Rivers in Southwest Virginia. The Roundtable has been involved in a wide variety of projects, including streambank restoration, stormwater system upgrades, endangered species habitat restoration, pervious paver installation, rain garden installation, stream monitoring and training, outreach and education, and reclamation of coal mine tipple sites. http://www.uppertnriver.org

Guest River Restoration Project: Since 1998, the Guest River Restoration Project has been working to de-list the 303(d) listed waters of the Guest River, the most polluted tributary to the Clinch. The Project has engaged in a wide variety of initiatives, but its major current project focuses on reducing impacts from residential septic systems. It offers a 50-75% maintenance,

repair, or replacement cost-share incentive through a grant from the Virginia Department of Environmental Quality. http://guestriver.weebly.com

Emory, Clinch and Watts Bar Watersheds Habitat and Recreational Restoration Grant Program: As part of a settlement with the TVA concerning the Kingston Fossil Plant site, $750,000 will be available between 2016 and 2019 to fund habitat restoration and new or improved recreational opportunities in the Emory, Clinch, and Watts Bar Watersheds.[105] https://tn.gov/assets/entities/environment/attachments/grants_ecwb_application-manual.pdf

Plans and Other Resources

Lower Clinch River Watershed Water Quality Management Plan (TDEC 2005): A 2005 Tennessee document that describes the watershed approach to planning, gives a detailed description of the watershed, reviews water quality sampling and assessments, assesses point and nonpoint sources of impairments, highlights water quality partnerships, and provides point and nonpoint source approaches to water quality problems. https://www.tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-lower-clinch-2005.pdf

Upper Clinch River Watershed Water Quality Management Plan (TDEC 2007): A 2007 Tennessee document that describes the watershed approach to planning, gives a detailed description of the watershed, reviews water quality sampling and assessments, assesses point and nonpoint sources of impairments, highlights water quality partnerships, and provides point and nonpoint source approaches to water quality problems. https://www.tn.gov/assets/entities/environment/attachments/wr-ws_watershed-plan-upper-clinch-2007.pdf

Imperiled Aquatic Species Conservation Strategy for the Upper Tennessee River Basin: The purpose of this 2014 plan is to provide USFWS with a cost-effective approach to conserve and manage imperiled freshwater fish and mussels in the Upper Tennessee River Basin, which includes the Upper Clinch Watershed. Available at: http://applcc.org/plan-design/aquatic-species-conservation-strategy/the-strategy/copy_of_imperiled-aquatic-species-conservation-strategy

Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region (Cumberlandian Region Mollusk Restoration Committee 2010): This plan provides a framework for the restoration of freshwater mollusks and their ecological

[105] Emory, Clinch and Watts Bar Watersheds Habitat and Recreational Restoration Grant Program, TN Dept. of Environment and Conservation, *available at https://tn.gov/assets/entities/environment/attachments/grants_ecwb_application-manual.pdf*.

functions to reaches of the Cumberlandian Region (the Tennessee and Cumberland River systems) through reintroduction, augmentation, and controlled propagation. Available through the Appalachian Landscape Conservation Cooperative website at http://applcc.org.

Virginia Wetlands Catalog: An inventory of wetlands and potential wetlands with prioritization summaries for conservation and restoration purposes by parcel, subwatershed, and wetland boundaries. The Catalog can be used to prioritize wetlands, parcels, and subwatersheds for conservation or restoration purposes, to inform project-design processes to make them more efficient, to assess impacts of proposed projects, and to identify possible mitigation sites. http://www.dcr.virginia.gov/natural-heritage/wetlandscat

Appalachian LCC Energy Forecast Model: This mapping tool shows potential risk from different types of energy development in the Appalachian region. It shows risks to both watersheds and forest cores. It may be useful in prioritizing land conservation projects to avoid future impacts from energy development. http://applcc.org/plan-design/gis-planning/gis-tools-resources/web-map-viewers/energy%20forcast%20model

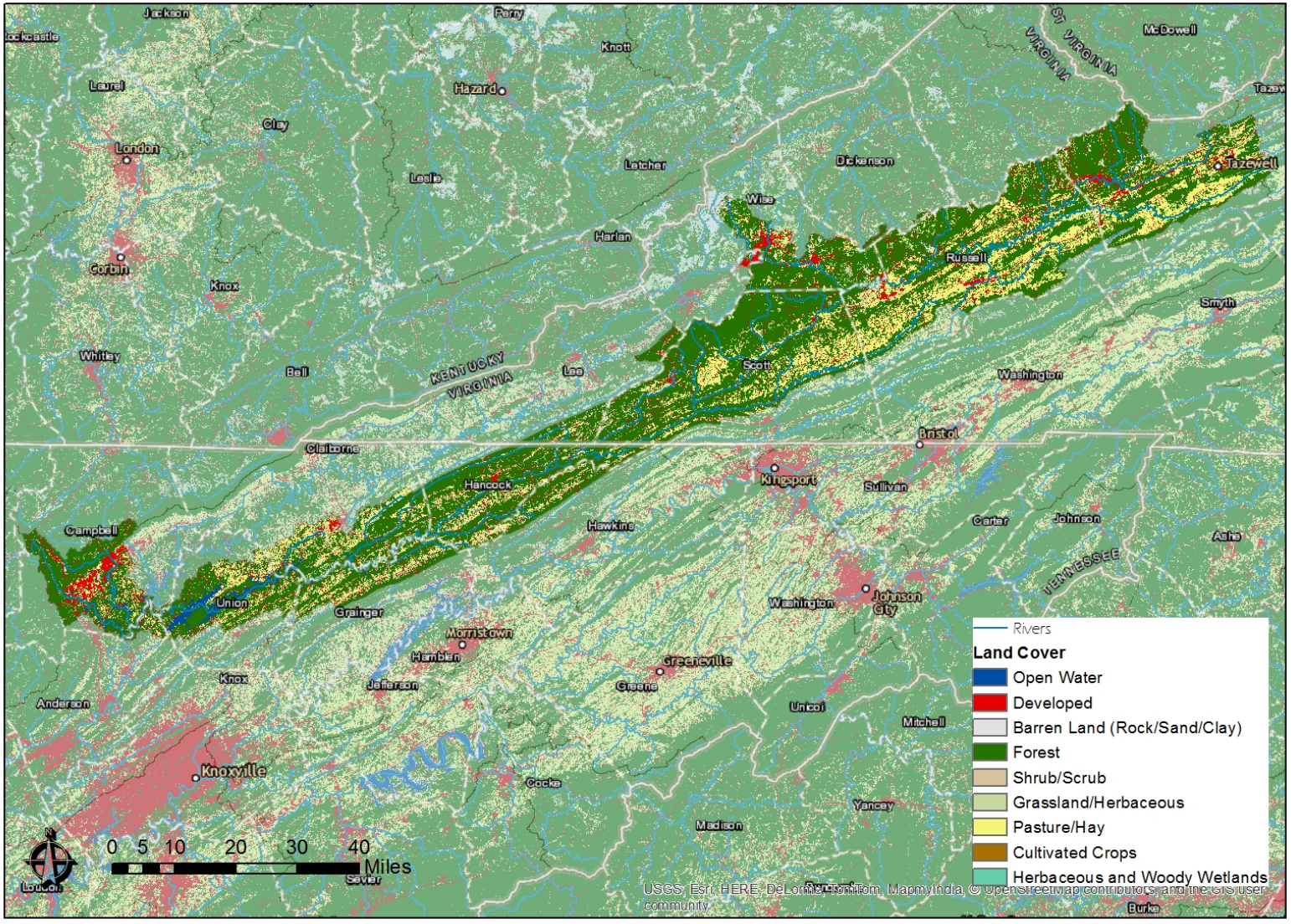


Figure 20. Land Use / Land Cover in the Upper Clinch River Watershed

Upper Clinch

Virginia, Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Upper Clinch River Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	110	29	6	5	6
Mussels	55	18	24	5	12
Crayfishes	8	7	0	0	0
TOTAL	173	54	30	10	18

Please note the differences between Tier descriptions for Virginia and Tennessee.

Virginia SWAP Species of Greatest Conservation Need in the Upper Clinch River Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
Tier description	Critical Conservation Need. Faces an extremely high risk of extinction or extirpation. Populations of these species are at critically low levels, face immediate threat(s), or occur within an extremely limited range. Intense and immediate management action is needed.	Very High Conservation Need. Has a high risk of extinction or extirpation. Populations of these species are at very low levels, face real threat(s), or occur within a very limited distribution. Immediate management is needed for stabilization and recovery.	High Conservation Need. Extinction or extirpation is possible. Populations of these species are in decline, have declined to low levels, or are restricted in range. Management action is needed to stabilize or increase populations.	Moderate Conservation Need. The species may be rare in parts of its range, particularly on the periphery. Populations of these species have demonstrated a declining trend or a declining trend is suspected which, if continued, is likely to qualify this species for a higher tier in the foreseeable future. Long-term planning is necessary to stabilize or increase populations.
Fishes	4 slender chub (*Erimystax cahni*), ashy darter (*Etheostoma cinereum*), duskytail darter (*Etheostoma percnurum*), yellowfin madtom (*Noturus flavipinnis*)	4 Western sand darter (*Ammocrypta clara*) popeye shiner (*Notropis ariommus*) blotchside logperch (*Percina burtoni*) paddlefish (*Polyodon spathula*)	8 steelcolor shiner (*Cyprinella whipplei*), bluebreast darter (*Etheostoma camurum* (*Nothonotus camurus*)), wounded darter (*Etheostoma (Nothonotus) vulneratus*), Ohio lamprey (*Ichthyomyzon bdellium*),	20 freshwater drum (*Aplodinotus grunniens*), black sculpin (*Cottus baileyi*), streamline chub (*Erimystax dissimilis*), blotched chub (*Erimystax insignis insignis*), rainbow darter (*Etheostoma caeruleum caeruleum*),

Virginia SWAP Species of Greatest Conservation Need in the Upper Clinch River Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 36			mountain brook lamprey (*Ichthyomyzon greeleyi*), river redhorse (*Moxostoma carinatum*), emerald shiner (*Notropis atherinoides*), channel darter (*Percina copelandi*)	Swannanoa darter (*Etheostoma swannanoa*), banded darter (*Etheostoma zonale*), Northern studfish (*Fundulus catenatus*), brook silverside (*Labidesthes sicculus*), mountain shiner (*Lythrurus lirus*), mirror shiner (*Notropis spectrunculus*), mountain madtom (*Noturus eleutherus*), stonecat (*Noturus flavus*), tangerine darter (*Percina aurantiaca*), logperch (*Percina caprodes*), gilt darter (*Percina evides evides*), blackside darter (*Percina maculata*), dusky darter (*Percina sciera sciera*), stargazing minnow (*Phenacobius uranops*), bullhead minnow (*Pimephales vigilax*)
Mussels	9 shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), cracking pearlymussel (*Hemistena lata*), pink mucket (*Lampsilis abrupta*), littlewing pearlymussel (*Pegias fabula*), rough pigtoe (*Pleurobema plenum*), Cumberland	3 slippershell mussel (*Alasmidonta viridis*), spectaclecase (*Cumberlandia monodonta*), snuffbox (*Epioblasma triquetra*)	3 black sandshell (*Ligumia recta*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*)	4 elephantear (*Elliptio crassidens*), fragile papershell (*Leptodea fragilis*), deertoe (*Truncilla truncata*), mountain creekshell (*Villosa vanuxemensis*)

Virginia SWAP Species of Greatest Conservation Need in the Upper Clinch River Watershed				
	Tier I.	Tier II.	Tier III.	Tier IV.
TOTAL: 19	monkeyface (Quadrula i*ntermedia*), Appalachian monkeyface (*Quadrula sparsa*), Cumberland bean (*Villosa trabalis*)			
Crayfishes TOTAL: 3	0	0	0	3 angled crayfish (*Cambarus angularis*), reticulate crayfish (*Orconectes erichsonianus*), surgeon crayfish (*Orconectes forceps*)
				TOTAL VA SCGN: 58

Tennessee SWAP Species of Greatest Conservation Need in the Upper Clinch River Watershed		
	Tier I	Tier III
Tier description[106]	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes	11 Western sand darter (*Ammocrypta clara*), highfin carpsucker (*Carpiodes velifer*), blue sucker (*Cycleptus elongatus*), streamline chub (*Erimystax dissimilis*), blotched chub (*Erimystax insignis insignis*), ashy darter (*Etheostoma cinereum*), spotted darter (*Etheostoma (Nothonotus) maculatum*), wounded darter (*Etheostoma (Nothonotus)*	7 spotfin chub (*Erimonax monachus*), slender chub (*Erimystax cahni*), duskytail darter (*Etheostoma percnurum*), palezone shiner (*Notropis albizonatus*), yellowfin madtom (*Noturus flavipinnis*), pygmy madtom (*Noturus stanauli*), paddlefish (*Polyodon spathula*)

[106] Tennessee's Tier II covers "All other fauna not defined as wildlife under Tennessee law (i.e., insects and other invertebrates)." Tier IV covers "Plant species of Greatest Conservation Need." Tennessee describes its Tier system as follows: "The Congressional mandate to states regarding the creation of State Wildlife Action Plans is to invest in conservation activities that assist in the prevention of future federal listings (e.g. Federally Endangered or Federally Threatened). Different state agencies also maintain separate jurisdictional authorities over species and habitat management. For these reasons, the 2005 SWAP designated 'tiers' to track the legal status and jurisdictional authorities associated with all GCN species (TWRA 2005, p. 43). The 2015 core planning team decided to maintain the original tier designation system and add a fourth tier for plants."

Tennessee SWAP Species of Greatest Conservation Need in the Upper Clinch River Watershed		
	Tier I	Tier III
TOTAL: 18	*vulneratus*), tangerine darter (*Percina aurantiaca*), blotchside logperch (*Percina burtoni*), sickle darter (*Percina williamsi*)	
Mussels TOTAL: 39	17 mucket (*Actinonaias ligamentina*), pheasantshell (*Actinonaias pectorosa*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), longsolid (*Fusconaia subrotunda*), Tennessee heelsplitter (*Lasmigona holstonia*), black sandshell (Ligumia *recta*), Cumberland moccasinshell (*Medionidus conradicus*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), Tennessee pigtoe (*Pleuronaia barnesiana*), creeper (*Strophitus undulatus*), purple lilliput (*Toxolasma lividum*), rainbow (*Villosa iris*), mountain creekshell (*Villosa vanuxemensis*)	22 spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), dromedary pearlymussel (*Dromus dromas*), Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), snuffbox (*Epioblasma triquetra*), shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), cracking pearlymussel (*Hemistena lata*), pink mucket (*Lampsilis abrupta*), birdwing pearlymussel (*Lemiox rimosus*), scaleshell (*Leptodea leptodon*), littlewing pearlymussel (*Pegias fabula*), white wartyback (*Plethobasus cicatricosus*), sheepnose (*Plethobasus cyphyus*), rough pigtoe (*Pleurobema plenum*), slabside pearlymussel (*Pleuronaia dolabelloides*), rough rabbitsfoot (*Quadrula cylindrica strigillata*), Cumberland monkeyface (*Quadrula intermedia*), Appalachian monkeyface (*Quadrula sparsa*), rayed bean (*Villosa fabalis*), Cumberland bean (*Villosa trabalis*)
Crayfishes TOTAL: 2	2 angled crayfish (*Cambarus angularis*), surgeon crayfish (*Orconectes forceps*)	0
		TOTAL TN SGCN: 59

Management Actions to Address Threats in the Upper Clinch River Watershed		
Management Action	**Threats Addressed**	**Notes**
Mine site reclamation	Coal mining	The Upper Tennessee Roundtable has engaged in coal mine tipple site reclamation. The Tennessee Dept. of Environment and Conservation's Land Reclamation Section receives state and federal funding to reclaim abandoned mine sites. Staff identify potential reclamation project sites, design reclamation plans and specifications for those sites, award reclamation contracts, and inspect the reclamation work as it progresses.[107]
Mine remediation activities	Coal mining	
Aquatic restoration	Agriculture, urbanization	The Virginia Wetlands Catalog is an inventory of wetlands and potential wetlands with prioritization summaries for conservation and restoration purposes by parcel, subwatershed, and wetland boundaries.[108]
Riparian and karst buffers	Agriculture, urbanization	Buffers may use up sizable portion of farmable land in narrow valleys, so sufficient incentives may be needed. Extensive (long) buffers may be needed to provide water quality benefits.[109] The Tennessee Urban Riparian Buffer Handbook contains information on establishing buffers in a range of urban settings, a set-by-set guide on how to complete buffer projects, handouts for volunteers, and a regionalized buffer plant list.[110]
Livestock exclusion	Agriculture	Cattle fencing programs in the Upper Clinch Watershed should rely on personnel familiar to farmers and provide flexible options to encourage participation. A very successful Shenandoah Resource Conservation and Development Council program used one on one contact between well-known Soil and Water Conservation District and Natural Resource Conservation District staff and farmers to encourage participation. It also

[107] *See more at* TN Dept. of Env. & Conservation, *Mining Information and Permits,* https://tn.gov/environment/topic/wr-mining-information-permits#sthash.m7geASeZ.dpuf.

[108] VA Dept. of Conservation and Recreation, *Virginia Wetlands Catalog, available at* http://www.dcr.virginia.gov/natural-heritage/wetlandscat.

[109] *See* J. Diamond, et al, *Assessing relationships between human land uses and the decline of native mussels, fish, and macroinvertebrates in the Clinch and Powell River Watershed, USA* 21 ENVIRON. TOXICOL. CHEM. 1147, 1154 (2002).

[110] TN Dept. of Agriculture, TENNESSEE URBAN RIPARIAN BUFFER HANDBOOK (2015), *available at* http://www.tn.gov/agriculture/topic/ag-forests-turb.

Management Actions to Address Threats in the Upper Clinch River Watershed		
Management Action	**Threats Addressed**	**Notes**
		allowed farmers to design a system that fit their land and needs. Instead of requiring minimum buffers, it based fence post positions on the topography of the site.[111]
Livestock production BMPs	Agriculture	
Land conservation	Agriculture, urbanization	Land conservation in headwaters is particularly beneficial to protecting downstream habitat and biodiversity. According to the Tennessee SWAP, the upper reaches of the Upper Clinch in Tennessee have high terrestrial habitat priority in addition to aquatic habitat priority. This may provide opportunities for land conservation projects with multiple benefits.
Livestock waste management	Agriculture	
Crop production BMPs	Agriculture	
Farmland restoration	Agriculture	The 2007 Upper Clinch River Sediment Total Maximum Daily Load Implementation Plan (Virginia) recommended putting permanent vegetative cover on 288 acres of cropland, and reforesting 387 acres of erodible crop and pastureland.
Streambank restoration	Agriculture, urbanization	
Improved stormwater management (including green infrastructure)	Urbanization	Rain gardens and bioswales are two of the more common and relatively easy to install types of green infrastructure that will likely be appropriate in rural Upper Clinch communities. They may be particularly appropriate in areas where development on steeper topographies has resulted in a decrease in floodwater attenuation. Since 2008, the Tennessee Stormwater Association (TNSA), the Tennessee Valley Authority (TVA), and the Tennessee Department of Transportation (TDOT) have partnered together with the Tennessee Department of Environment & Conservation (TDEC) to offer a Green Development Grant program that was developed as an effort to encourage the advancement of green infrastructure projects across the state.[112]
Conservation planning	Urbanization	

[111] Chesapeake Bay Funders Network, *Adaptive Streambank Fencing Program* (describing Shenandoah Resource Conservation and Development Council program), *available at* http://blogs.ext.vt.edu/farm-to-table/files/2012/05/Shenandoah_v5_Final.pdf.

[112] TN Dept. of Environment & Conservation, *Green Development*, http://www.tennessee.gov/environment/topic/wr-green-development.

Upper Clinch

Virginia, Tennessee

Management Actions to Address Threats in the Upper Clinch River Watershed		
Management Action	**Threats Addressed**	**Notes**
Septic system remediation	Urbanization	
Outreach and education	Agriculture, urbanization, invasive species, sinkhole dumping	
Alternative dump sites	Sinkhole dumping	
Invasive species control	Invasive species	
Impoundment removal	Impoundments and barriers	
Ecological flows	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	

General Management Actions to Support Species in the Upper Clinch River Watershed	
Management Action	**Notes**
Land conservation	
Aquatic restoration	
Genetic research	
Basic research	
Captive propagation for reintroduction and augmentation	A multi-partner project in the Clinch and Powell Rivers has re-established numerous species to several river sections where they were previously extirpated.[113] The *Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region* outlines opportunities for augmentation and reintroduction in the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.[114]

[113] *See* VA Dept. of Game and Inland Fisheries, *Freshwater Mussel Restoration*, https://www.dgif.virginia.gov/wildlife/freshwater-mussels/restoration/.

[114] Cumberlandian Region Mollusk Restoration Committee, PLAN FOR THE POPULATION RESTORATION AND CONSERVATION OF IMPERILED FRESHWATER MOLLUSKS OF THE CUMBERLANDIAN REGION (2010), available at http://applcc.org/plan-design/aquatic-species-conservation-strategy/reports-documents/plan-for-the-population-restoration-and-conservation-of-imperiled-freshwater-mollusks-of-the-cumberland-region/view.

Wheeler Lake

Alabama, Tennessee

Watershed Description

Wheeler Lake Watershed is located primarily in north central Alabama, with small portions in south central Tennessee. It drains almost 3,000 square miles, a little over 200 of which are in Tennessee. It is named after Wheeler Lake, a 60-mile long, 68,300 acre Tennessee River reservoir stretching from Wheeler Dam to Guntersville Dam, both of which are Tennessee Valley Authority facilities. The busiest port on the Tennessee River, the Port of Decatur, is found on Wheeler Lake. Wheeler Lake is also a major recreational destination, garnering around 4 million visitors a year. The Wheeler Lake Watershed contains the Huntsville-Decatur Combined Statistical Area, which includes the Huntsville and Decatur Metropolitan Areas and houses a population of around 680,000.

Most of the Wheeler Lake Watershed is part of the Interior Plateau ecoregion (also known as the Highland Rim), which extends northward from Alabama's Tennessee River to Indiana's Pleistocene glacial boundary. Highly erodible limestone is common in the region, and valleys, basins, and karst resources such as springs, sinkholes and caves are prevalent. The Huntsville area has a particularly large number of caves. Portions of the watershed are in the Southwestern Appalachians ecoregion, which mostly consists of open low mountains.

Just over 35% of the 2011 land cover was forested and most of the non-forested land in the Wheeler Lake watershed is in agricultural uses; pasture (25% of total) is the most common agricultural use, followed by cropland (13%). The watershed has a prolific poultry industry: a 2003 Alabama Tennessee Basin Watershed Plan estimated it contained over 12 million broilers. Urban or developed land uses cover just over 12% of the watershed area.

The Alabama SWAP lists Limestone, Piney, and Beaverdam Creeks and the Flint and Paint Rock Rivers as Strategic Habitat Units that are Priority Areas for Conservation Action.[115]

Species

Wheeler Lake Watershed is biologically important in part due to the species diversity found in its tributary watersheds. The Tennessee River itself is impounded and consequently has lost native species richness, but tail waters below dams still harbor a substantial number of species that are large-river specialists. Many of these subwatersheds and areas along Wheeler Lake contain karst geology and associated springs and caves, which form habitat that is important to many fishes and crustaceans.These watersheds contain a total of 226 species of fishes, mussels, and crayfishes, including 63 endemics (see table at the end of this section). Of these species, 19

[115] Alabama Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION 247 (2015).

are vulnerable, 11 are threatened, and 34 are endangered.[116] The Alabama State Wildlife Action Plan (SWAP) identifies 65 Species of Greatest Conservation Need (SGCN) in the watershed, and the Tennessee SWAP identifies 62.[117]

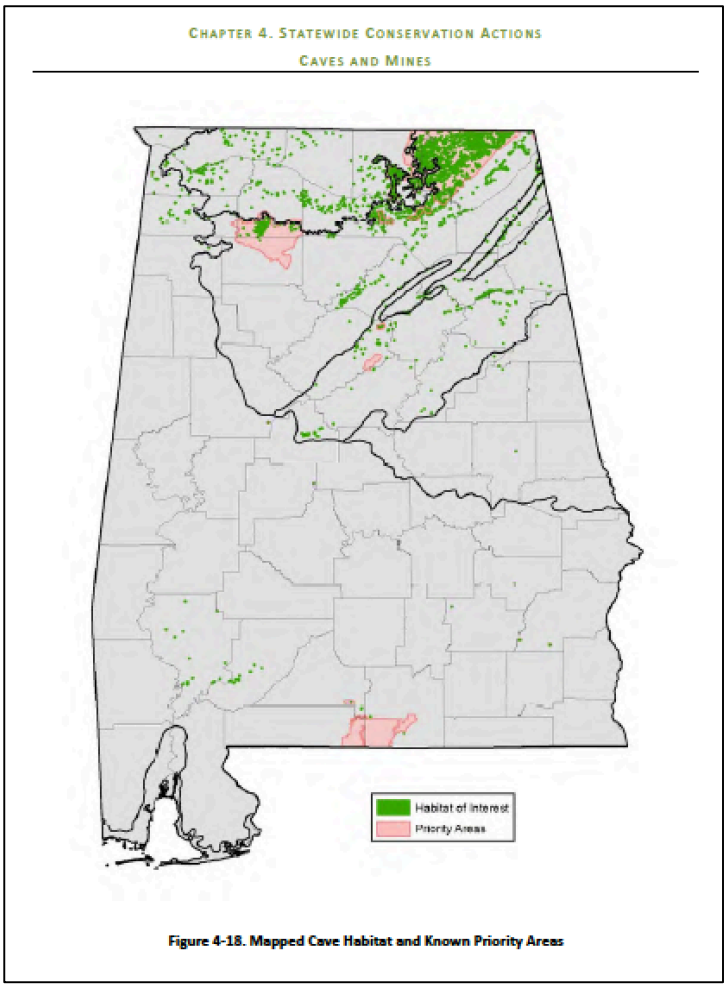


Figure 21. A map depicting caves from the July 2015 draft of the Alabama SWAP.

Potential Threats and Management Actions

[116] The imperilment statistics used in this analysis are based on the most recent peer-reviewed assessments from the American Fisheries Society or the Freshwater Mussel Conservation Society, updated with new surveys or assessments, if available. Federal listings were not used because there are hundreds of species listing petitions currently undergoing review, so the federal program does not accurately reflect the current state of imperilment for many species.

[117] The total number of SGCN species in the watershed, as identified by all three states, is less than the sum of these totals because many species listed as SGCN in Alabama are also listed as SCGN in Tennessee. State SWAPs, however, define what constitutes a SGCN differently, and providing a sum of total SCGN might incorrectly indicate that all of the SGCN species have similar conservation needs.

This section describes primary and secondary potential threats to species and habitat in Wheeler Lake Watershed. Potential threats are activities that tend to cause impacts in places where they are prevalent. Primary potential threats are activities that are pervasive throughout or in sizable or important parts of the watershed, and/or activities that have been significantly linked to declines in species or watershed health in previous research. Secondary potential threats may also be significant, but they are either less prevalent throughout the watershed or they have been identified as contributing smaller, but non-negligible, impacts. Additional research may be necessary to confirm if potential threats are indeed affecting species.

Primary potential threats to species in the Wheeler Lake Watershed are agriculture, urbanization, and groundwater withdrawals. Secondary potential threats include impoundments and barriers, industry, septic systems, forestry, and invasive species. Many management actions appropriate in the watershed address multiple threats and will benefit multiple species. More information on individual management actions, including watershed-specific information when available, is found in tables at the end of this section.

Karst

Karst refers to lands created by the dissolution of soluble rocks such as limestone and dolomite. Karst is characterized by sinkholes, sinking streams, springs, and caves, all of which are connected to groundwater resources that are highly susceptible to hydrologic alterations and pollution. Karst also provides ecosystems where unique species often occur; indeed, many of the species in priority watersheds addressed in the Southeastern Aquatic Biodiversity Conservation Strategy are dependent on some aspect of karst, or the groundwater systems connected to it. Because of the sensitivity of karst resources and their importance for aquatic species, potential threats that occur in areas underlain by karst in the Barren River Watershed can be particularly damaging. This should be kept in mind when determining which threats or management actions to prioritize in any particular situation.

Primary Potential Threats and Associated Management Actions

Agriculture. Over a third of the Wheeler Lake Watershed is in agricultural uses, and these activities are the cause of most of its reported water quality impairments. The watershed contains significant livestock operations, including many poultry feeding operations. It also has many thousands of acres of row crops. Sedimentation and nutrient enrichment from poorly managed livestock operations and crop production can degrade water quality and are likely impacting species and habitat in the watershed. Agricultural activities may be particularly harmful to species and habitat in the Wheeler Lake Watershed when they occur in karst areas without the use of appropriate best management practices such as buffers and livestock exclusion fencing around springs, sinkholes, and caves.

One of the largest potential agricultural threats in the Wheeler Lake Watershed is poorly managed poultry operations. North Alabama has an exceptionally robust poultry producing industry,[118] and the Wheeler Lake Watershed contains portions of two counties, Cullman and Marshall, that rank first and third in the state for broiler production, respectively.[119] The industry supports over 5,000 jobs in these communities. Chicken litter contains nitrogen, phosphorus, and pathogens that can impair waterways, and it is routinely spread on fields as fertilizer. When appropriate management measures are not in place, chicken litter used as fertilizer can enter surface and groundwater, causing impairments such as nutrient enrichment and low dissolved oxygen.

Management actions to address agriculture include:

- Riparian and karst buffers
- Livestock exclusion
- Livestock waste management
- Livestock production BMPs
- Crop production BMPs
- Farmland restoration
- Aquatic restoration
- Land conservation
- Outreach and education

Urbanization. As noted above, the Wheeler Lake Watershed contains the Huntsville-Decatur Combined Statistical Area, which has a population of about 680,000. Huntsville is the fastest growing city in Alabama, adding more than 10,000 residents since 2010.[120] Its population has grown over 25% since 1980.[121] Much of this growth is occurring along I-565 and other highways.

This urbanization has likely impacted aquatic species and habitat through hydrologic changes, runoff, and other impacts. Impervious surfaces in aquifer recharge areas decrease the amount of groundwater available in karst habitat. A 2003 Alabama Tennessee River Basin Watershed Plan listed reducing nonpoint source pollution from urban development activities and from

[118] *See* Brian Lawson, *One million tons of chicken waste in Alabama every year. Where does it all go?* AL.COM, March 22, 2015, http://www.al.com/news/index.ssf/2015/03/alabama_farmers_have_to_deal_w.html.
[119] Alabama Cooperative Extension System, CULLMAN COUNTY AGRICULTURE, FORESTRY, AND RELATED INDUSTRIES, *available at* http://www.aces.edu/pubs/docs/A/ANR-1486/ANR-1486.pdf; Alabama Cooperative Extension System, MARSHALL COUNTY AGRICULTURE, FORESTRY, AND RELATED INDUSTRIES, *available at* http://www.aces.edu/pubs/docs/A/ANR-1501/ANR-1501.pdf.
[120] Challen Stephens, *Census: Huntsville and Auburn growing rapidly, Montgomery shrinking*, AL.COM May 19, 2016, http://www.al.com/news/index.ssf/2016/05/census_huntsville_and_auburn_g.html.
[121] U.S. Census Bureau, 2010.

residential sources (lawns, etc.) as the first and third priority objectives for the Wheeler Lake Watershed.[122]

Management Actions to address urbanization include:

- Riparian buffers
- Improved stormwater management (including green infrastructure)
- Conservation planning
- Land conservation
- Aquatic restoration
- Outreach and education

Groundwater withdrawal. Aquifers in the Interior Plateau provide cool, consistent, high quality water for springs, spring-fed creek, and caves. Groundwater habitats are one of the major drivers for the endemic biodiversity found in this watershed. Use of groundwater for agricultural irrigation and municipal/industrial use, especially during drought conditions, can cause severe stress on many of these specialized habitats, and this stress will likely increase with climate change.

Management actions to address groundwater withdrawal include:

- Determining recharge areas for and specific habitats supplied by aquifers
- Monitoring spring and cave flows
- Outreach and education

Secondary Potential Threats and Associated Management Actions

Impoundments and barriers. The Tennessee River Basin is heavily impounded, and Wheeler Lake Watershed is no exception. In addition to Wheeler Lake on the Tennessee mainstem, which inundates lotic aquatic habitat, alters hydrologic regimes, and fragments remaining local habitat causing isolation of populations, the watershed also has an "undetermined number of low water crossings and culverts [that] also impede or prevent migration, resulting in fragmented populations, restricted gene flow, and local extirpations."[123]

Management actions that address impoundments and barriers include:

- Conservation locking

[122] Alabama Clean Water Partnership, TENNESSEE RIVER BASIN WATERSHED MANAGEMENT PLAN 3.3, Table 3.1 (2003), *available at* http://www.adem.state.al.us/programs/water/nps/files/TennesseeBMP.pdf.
[123] Alabama Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 233 (2015).

- Ecological flows
- Impoundment removal
- Culvert replacement
- Barrier modification for fish passage

Industry. There are a large number of industrial facilities in the Wheeler Lake Watershed, with a particularly high concentration near the City of Decatur. Industrial discharges have been listed as a contributing source for some water quality impairments in the watershed, and in 2016 the Tennessee Riverkeeper filed a lawsuit against 3M, the city of Decatur, and others over chemicals found in the Wheeler Reservoir.[124] The Tennessee River and Wheeler Reservoir have been contaminated with, among other things, chemicals including PFOS (perfluorooctane sulfonate).

Most management actions that would directly mitigate industrial impacts on aquatic resources in the Wheeler Lake Watershed are business or regulatory decisions. There are, however, some management actions covered by this project that could help ameliorate some impacts. These include:

- Water quality monitoring
- Outreach and education

Figure 22. Kinder Morgan facility, located on a tributary of the Wheeler Lake Watershed.

[124] *See* Eric Fleischauer, *Environmental group serves notice of intent to sue 3M, Decatur*, DECATURDAILY.COM, Sept. 24, 2015, http://www.decaturdaily.com/news/lawrence_county/environmental-group-serves-notice-of-intent-to-sue-m-decatur/article_2add3585-e514-5500-8953-254c3cf7d4e1.html.

Invasive species. Invasive species can displace native species by, among other things, depredation and competition for resources. They can also, in some instances, impact water quality. Aquatic invasive species are present in Wheeler Lake Watershed, including bighead carp, silver carp, and zebra mussels. The Alabama SWAP notes that introduction of, or a failure to eradicate or control these species is a problem in the greater Tennessee River Basin.[125]

Management actions that address invasive species include:

- Outreach and education
- Invasive species control

Management Actions to Support Species

There are several management actions that are not direct responses to specific threats, but are used to directly support species survival. These actions would be beneficial for a number of species in the Wheeler Lake Watershed. They include:

- Land conservation
- Aquatic restoration
- Genetic research
- Basic life history and ecological research
- Captive propagation for reintroduction and augmentation

Programs and Organizations (Capacity)

Tennessee Riverkeeper: The Tennessee Riverkeeper is an advocacy organization dedicated to protecting the river and its tributaries by enforcing environmental laws and educating the public. http://www.tennesseeriver.org/staff.html

Flint River Conservation Association: A group of volunteers working to preserve the Flint River, a tributary of the Tennessee in the Wheeler Lake Watershed. http://flintriverconservation-al.org

Flint Creek Conservancy District: A soil and water conservation district that has been involved in planning and restoration projects in the Wheeler Lake Watershed.

Piney Creek Watershed Association: Founded in 2004, the Piney Creek Watershed Association educates the community about water pollution issues and performs service projects, including trails, pet waste stations, and rain gardens. http://pineycreekwatershed.org

[125] Alabama Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 237 (2015).

Sierra Club North Alabama Group: The northern Alabama division of the Alabama Sierra Club. http://www.sierraclub.org/alabama/north-alabama

Huntsville Grotto of the National Speleological Society: The Huntsville Grotto is an official club of the National Speleological Society, an organization dedicated to the study, protection, and exploration of caves. http://caves.org/grotto/huntsville/

Jackson County Grotto of the National Speleological Society: The Jackson County Grotto is an official club of the National Speleological Society, an organization dedicated to the study, protection, and exploration of caves.

Plans and Other Resources

Tennessee River Basin Watershed Management Plan (ADEM 2003): The goal of this plan is to "initiate, revitalize, and encourage local restoration efforts to improve, maintain, and protect the waters of the Tennessee River basin to the intended goals of the original Clean Water Act of 1972, 'fishable and swimmable waters for all Americans.'" http://www.adem.state.al.us/programs/water/nps/files/TennesseeBMP.pdf

Protecting our Waters: The Tennessee River Basin (AL Clean Water Partnership): An educational document regarding the Tennessee River Basin. http://www.cleanwaterpartnership.org/uploadedFiles/File/ACWP_Tennessee_FINAL_Web.pdf.

Plan for the Population Restoration and Conservation of Imperiled Freshwater Mollusks of the Cumberlandian Region (Cumberlandian Region Mollusk Restoration Committee 2010): This plan provides a framework for the restoration of freshwater mollusks and their ecological functions to reaches of the Cumberlandian Region (the Tennessee and Cumberland River systems) through reintroduction, augmentation, and controlled propagation. Available through the Appalachian Landscape Conservation Cooperative website at http://applcc.org.

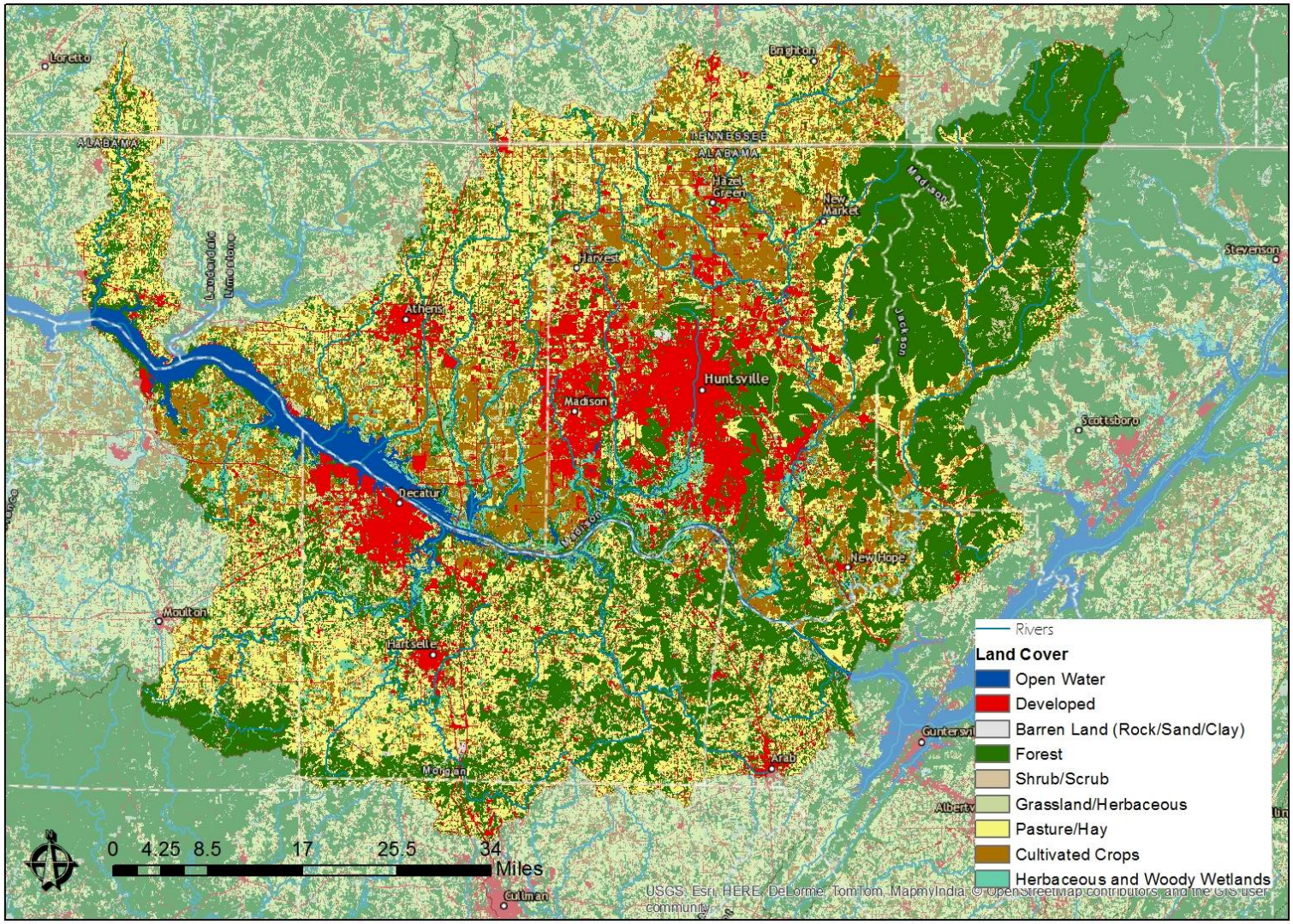


Figure 23. Land Use / Land Cover in the Wheeler Lake Watershed

Wheeler Lake

Alabama, Tennessee

Total Species, Endemics, and Endangered, Threatened, and Vulnerable Species in the Wheeler Lake Watershed					
	Total Species	SE Endemics	Endangered	Threatened	Vulnerable
Fishes	121	20	4	3	3
Mussels	78	20	24	7	14
Crayfishes	28	24	6	1	2
TOTAL	227	64	34	11	19

Tennessee SWAP Species of Greatest Conservation Need in the Wheeler Lake Watershed		
	Tier I	Tier II
Tier description	Species defined as wildlife under Tennessee Code Annotated 70-8-101, (i.e., amphibians, birds, fish, mammals, reptiles, crustaceans & mollusks), excluding federally listed and game species.	Federally listed or game species which have alternative conservation funding.
Fishes TOTAL: 13	8 lake sturgeon (*Acipenser fulvescens*), highfin carpsuckers (*Carpiodes velifer complex*), streamline chub (*Erimystax dissimilis*), blotched chub (*Erimystax insignis insignis*), tuscumbia darter (*Etheostoma tuscumbia*), flame chub (*Hemitremia flammea*), blotchside logperch (*Percina burtoni*), Southern cavefish (*Typhlichthys subterraneus*)	5 slackwater darter (*Etheostoma boschungi*), palezone shiner (*Notropis albizonatus*), chucky madtom (*Noturus crypticus*), snail darter (*Percina tanasi*), paddlefish (*Polyodon spathula*)
Mussels TOTAL: 44	22 mucket (*Actinonaias ligamentina*), pheasantshell (*Actinonaias pectorosa*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), longsolid (*Fusconaia subrotunda*), Tennessee heelsplitter (*Lasmigona holstonia*), Cumberland moccasinshell (*Medionidus conradicus*), hickorynut (*Obovaria olivaria*), round hickorynut (*Obovaria subrotunda*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (Pleurobema *oviforme*), pyramid pigtoe (*Pleurobema rubrum*), round pigtoe (*Pleurobema sintoxia*), Tennessee pigtoe (*Pleuronaia barnesiana*), Alabama creekmussel (*Strophitus connasaugaensis*), creeper (*Strophitus undulatus*), purple lilliput (*Toxolasma lividum*)	22 spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), dromedary pearlymussel (*Dromus dromas*), Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), snuffbox (*Epioblasma triquetra*), shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), pink mucket (*Lampsilis abrupta*), Alabama lampmussel (*Lampsilis virescens*), birdwing pearlymussel (*Lemiox rimosus*), ring pink (*Obovaria retusa*), white wartyback (*Plethobasus cicatricosus*), orangefoot pimpleback (*Plethobasus cooperianus*), sheepnose (*Plethobasus cyphyus*), clubshell (*Pleurobema clava*), rough pigtoe (*Pleurobema plenum*), slabside pearlymussel (*Pleuronaia dolabelloides*), rabbitsfoot (*Quadrula cylindrica cylindrica*), Cumberland monkeyface (*Quadrula intermedia*), pale

Wheeler Lake

Alabama, Tennessee

Tennessee SWAP Species of Greatest Conservation Need in the Wheeler Lake Watershed		
	Tier I	Tier II
	rainbow (*Villosa iris*), little spectaclecase (*Villosa lienosa*), painted creekshell (*Villosa taeniata*), mountain creekshell (*Villosa vanuxemensis*), Southern rainbow (*Villosa vibex*)	lilliput (*Toxolasma cylindrellus*), Cumberland bean (*Villosa trabalis*)
Crayfishes TOTAL: 5	5 cavespring crayfish (*Cambarus tenebrosus*), Alabama crayfish (*Orconectes alabamensis*), Southern cave crayfish (*Orconectes australis*), Flint River crayfish (*Orconectes cooperi*), surgeon crayfish (*Orconectes forceps*)	0
		TOTAL TN SGCN: 62

	Alabama SWAP Species of Greatest Conservation Need in the Wheeler Lake Watershed			
	Tier I.	Tier II.	Tier III.	Tier IV.
	Extirpated (EX). Taxa that historically occurred in Alabama, but are now absent, may be rediscovered or be reintroduced from populations existing outside the state.	Extirpated/Conservation Action Underway (EXCAU). Taxa that historically occurred in Alabama, were absent for a period of time, and currently are being reintroduced, or have a plan for being reintroduced, into the state from populations outside the state.	Critical Conservation Need (P1). Faces an extremely high risk of extinction or extirpation. Populations of these species are at critically low levels, face immediate threat(s), or occur within an extremely limited range. Intense and immediate management action is needed.	Very High Conservation Need (P2). Has a high risk of extinction or extirpation. Populations of these species are at very low levels, face real threat(s), or occur within a very limited distribution. Immediate management is needed for stabilization and recovery.
Fishes TOTAL: 14	4 goldeye (*Hiodon alosoides*), shortnose gar (*Lepisosteus platostomus*), chucky madtom (*Noturus crypticus*), shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1 lake sturgeon (*Acipenser fulvescens*)	5 Spring pygmy sunfish (*Elassoma alabamae*), slackwater darter (*Etheostoma boschungi*), palezone shiner (*Notropis albizonatus*), blotchside logperch (*Percina burtoni*), snail darter (*Percina tanasi*)	4 streamline chub (*Erimystax dissimilis*), tuscumbia darter (*Etheostoma tuscumbia*), ghost shiner (*Notropis buchanani*), stargazing minnow (*Phenacobius uranops*)

Mussels TOTAL: 42	9 pheasantshell (*Actinonaias pectorosa*), dromedary pearlymussel (*Dromus dromas*), birdwing pearlymussel (*Lemiox rimosus*), hickorynut (*Obovaria olivaria*), ring pink (*Obovaria retusa*), orangefoot pimpleback (*Plethobasus cooperianus*), clubshell (*Pleurobema clava*), fluted kidneyshell (*Ptychobranchus subtentus*), Cumberland monkeyface (*Quadrula intermedia*)	2 oyster mussel (*Epioblasma capsaeformis*), Cumberland bean (*Villosa trabalis*)	26 mucket (*Actinonaias ligamentina*), elktoe (*Alasmidonta marginata*), slippershell mussel (*Alasmidonta viridis*), spectaclecase (*Cumberlandia monodonta*), fanshell (*Cyprogenia stegaria*), spike (*Elliptio dilatata*), Cumberlandian combshell (*Epioblasma brevidens*), snuffbox (*Epioblasma triquetra*), shiny pigtoe (*Fusconaia cor*), finerayed pigtoe (*Fusconaia cuneolus*), longsolid (*Fusconaia subrotunda*), pink mucket (*Lampsilis abrupta*), Alabama lampmussel (*Lampsilis virescens*), Cumberland moccasinshell (*Medionidus conradicus*), round hickorynut (*Obovaria subrotunda*), white wartyback (*Plethobasus cicatricosus*) sheepnose (*Plethobasus cyphyus*), Ohio pigtoe (*Pleurobema cordatum*), Tennessee clubshell (*Pleurobema oviforme*), rough pigtoe (*Pleurobema plenum*), pyramid pigtoe (*Pleurobema rubrum*), round	5 Tennessee heelsplitter (*Lasmigona holstonia*), Tennessee pigtoe (*Pleuronaia barnesiana*), monkeyface (*Quadrula metanevra*), Alabama creekmussel (*Strophitus connasaugaensis*), painted creekshell (*Villosa taeniata*)

			pigtoe (*Pleurobema sintoxia*), slabside pearlymussel (*Pleuronaia dolabelloides*), kidneyshell (*Ptychobranchus fasciolaris*), creeper (*Strophitus undulatus*), pale lilliput (*Toxolasma cylindrellus*)	
Crayfishes TOTAL: 9	0	0	4 Lacon Exit Cave crayfish (*Cambarus laconensis*), phantom cave crayfish (*Cambarus pecki*), White Spring Cave crayfish (*Cambarus veitchorum*), Shelta Cave crayfish (*Orconectes sheltae*)	5 Alabama cave crayfish (*Cambarus jonesi*), depression crayfish (*Cambarus rusticiformis*), Sweet Home Alabama, crayfish (*Cambarus speleocoopi*), Flint River crayfish (*Orconectes cooperi*), saddle crayfish (*Orconectes durelli*)
				TOTAL AL SGCN: 65

Management Actions to Address Threats in the Wheeler Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Riparian and karst buffers	Agriculture, urbanization	Restoring forested buffers around cave entrances is a High Priority Conservation Action in the Alabama SWAP. The Tennessee Urban Riparian Buffer Handbook contains information on establishing buffers in a range of urban settings, a set-by-set guide on how to complete buffer projects, handouts for volunteers, and a regionalized buffer plant list.[126]
Livestock exclusion	Agriculture	

[126] TN Dept. of Agriculture, TENNESSEE URBAN RIPARIAN BUFFER HANDBOOK (2015), *available at* http://www.tn.gov/agriculture/topic/ag-forests-turb.

Wheeler Lake

Alabama, Tennessee

Management Actions to Address Threats in the Wheeler Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Land conservation	Agriculture, urbanization	The Alabama SWAP lists acquiring high priority caves and surface habitats and watersheds of caves supporting sensitive species as Highest Priority Conservation Actions. The Alabama SWAP lists supporting expansion of the Wheeler National Wildlife Refuge to include the lower reaches of Limestone and Piney Creeks as a Highest Priority Conservation Action. The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[127]
Livestock production BMPs	Agriculture	
Livestock waste management	Agriculture	
Farmland restoration	Agriculture	
Crop production BMPs	Agriculture	The Alabama SWAP recommends reducing persistent pesticides, sediments, and other pollutants in groundwater recharge areas.[128] The Agricultural Resources Conservation Fund provides cost-share assistance to Tennessee landowners to install Best Management Practices (BMPs) that reduce agricultural water pollution. This assistance is facilitated primarily through Soil Conservation Districts although Resource Conservation and Development Councils, universities, and other agricultural associations may participate. A wide range of BMPs are available for cost-share, from those that curtail soil erosion to ones that help to remove pollutants from water runoff from agricultural operations. Landowners may be eligible to receive up to 75% of the cost of a BMP installation. Part of the fund is available for educational projects which raise awareness of soil erosion/water quality problems and promote BMP use.[129]

[127] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

[128] AL Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 184 (2015).

[129] TN Dept. of Agriculture, *Guidelines for the Agricultural Resources Conservation Fund* (FY 2017), *available at* https://tn.gov/assets/entities/agriculture/attachments/AgFarARCFguidelines.pdf.

Management Actions to Address Threats in the Wheeler Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Aquatic restoration	Agriculture, urbanization	The Alabama Clean Water Partnership is currently working with NRCS on updating the Service's list of prioritized Alabama streams for restoration or protection.[130]
Improved stormwater management (including green infrastructure)	Urbanization	Since 2008, the Tennessee Stormwater Association (TNSA), the Tennessee Valley Authority (TVA), and the Tennessee Department of Transportation (TDOT) have partnered together with the Tennessee Department of Environment & Conservation (TDEC) to offer a Green Development Grant program that was developed as an effort to encourage the advancement of green infrastructure projects across the state.[131]
Conservation planning	Urbanization	
Septic system remediation	Urbanization	
Outreach and education	Agriculture, urbanization, invasive species, groundwater withdrawal, industry	
Determining recharge areas for and specific habitats supplied by aquifers	Groundwater withdrawal	The Alabama SWAP recommends identifying recharge areas around ecologically significant caves.[132]
Monitoring spring and cave flows	Groundwater withdrawal	
Irrigation BMPs	Groundwater withdrawal	
Water conservation	Groundwater withdrawal	
Invasive species control	Invasive species	
Water quality monitoring	Industry	
Conservation locking	Impoundments and barriers	
Barrier modification for fish passage	Impoundments and barriers	
Culvert replacement	Impoundments and barriers	
Impoundment removal	Impoundments and barriers	

[130] Alabama Clean Water Partnership, *ACWP Stream Prioritization Project*, http://www.cleanwaterpartnership.org/current-projects/?portfolioID=59.

[131] TN Dept. of Environment and Conservation, *Green Development*, http://www.tennessee.gov/environment/topic/wr-green-development.

[132] AL Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 183 (2015).

Wheeler Lake

Alabama, Tennessee

Management Actions to Address Threats in the Wheeler Lake Watershed		
Management Action	**Threats Addressed**	**Notes**
Ecological flows	Impoundments and barriers	The Alabama SWAP includes supporting implementation of more natural flow regimes in dams on the Tennessee River and in the Bear Creek Watershed as a Highest Priority Conservation Action.[133]

General Management Actions to Support Species in the Wheeler Lake Watershed	
Management Action	**Notes**
Land conservation	The Alabama SWAP includes supporting expansion of the Wheeler National Wildlife Refuge to include lower reaches of Limestone and Piney creeks as a High Priority Conservation Action (at 244).
Aquatic restoration	
Genetic research	
Basic research	Current distribution and status, as well as knowledge of various aspects of life history and biology, are poorly known for many species.[134] Monitoring is recommended for many individual species in the Alabama SWAP, particularly crayfish.
Captive propagation for reintroduction and augmentation	To address mussel extinction and endangerment, the Alabama Dept. of Conservation and Natural Resources created the Alabama Aquatic Biodiversity Center to lead recovery efforts through propagation and reintroduction. The Alabama SWAP states that SGCN mussels in the Tennessee River Basin "may require population augmentation and/or reintroduction to suitable habitats to maintain their viability. …The genetic integrity of populations among drainages should be maintained." (at 244). Among other places, reintroduction efforts for some mussels are underway in the Paint Rock River.

[133] AL Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 244 (2015).

[134] AL Dept. of Conservation and Natural Resources, ALABAMA WILDLIFE ACTION PLAN 237 (2015).