The Southeastern Aquatic Biodiversity Conservation Strategy

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TENNESSEE AQUARIUM Conservation Institute

The Southeastern Aquatic Biodiversity Conservation Strategy

A report for The National Fish and Wildlife Foundation prepared by:

Duncan C. Elkins
Katie S. Hill
Seth J. Wenger
University of Georgia
River Basin Center
Athens, Georgia

Sarah C. Sweat
Bernard R. Kuhajda
Anna L. George
Tennessee Aquarium
Conservation Institute
Chattanooga, TN

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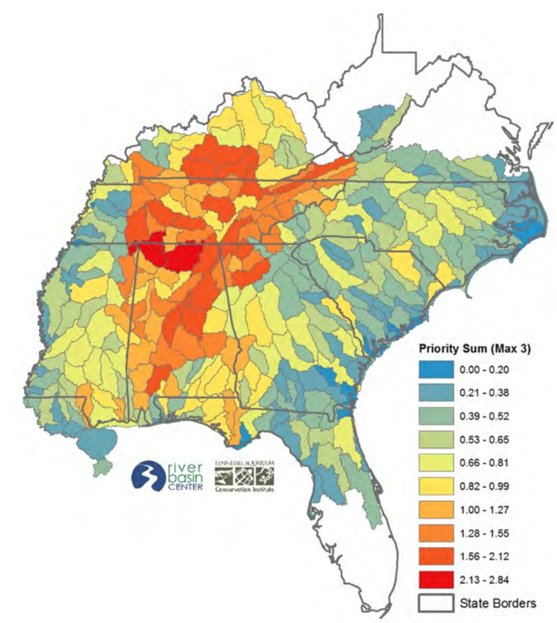
Cover Photo Credits:
Top: A wavy-rayed lampmussel, *Lampsillis fasciola*, nestled in the substrate uses its lure to bring fish close. Clinch River. Jeffrey Basinger, Freshwaters Illustrated.
Middle: A whitetail shiner, *Cyprinella galactura*, swims in the Hiwassee river. Jeffrey Basinger, Freshwaters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

CONTENTS

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).

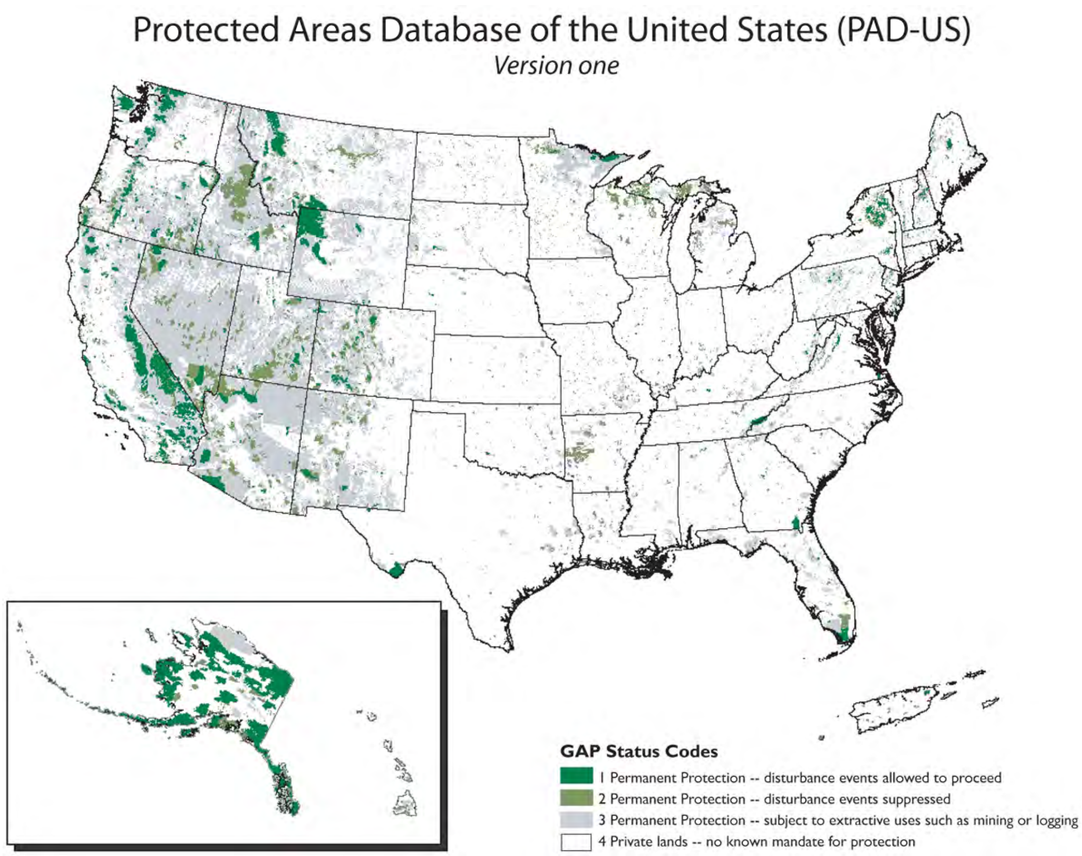


Figure 1. Protected Areas of the US. Source: USGS (http://gapanalysis.usgs.gov/)

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.

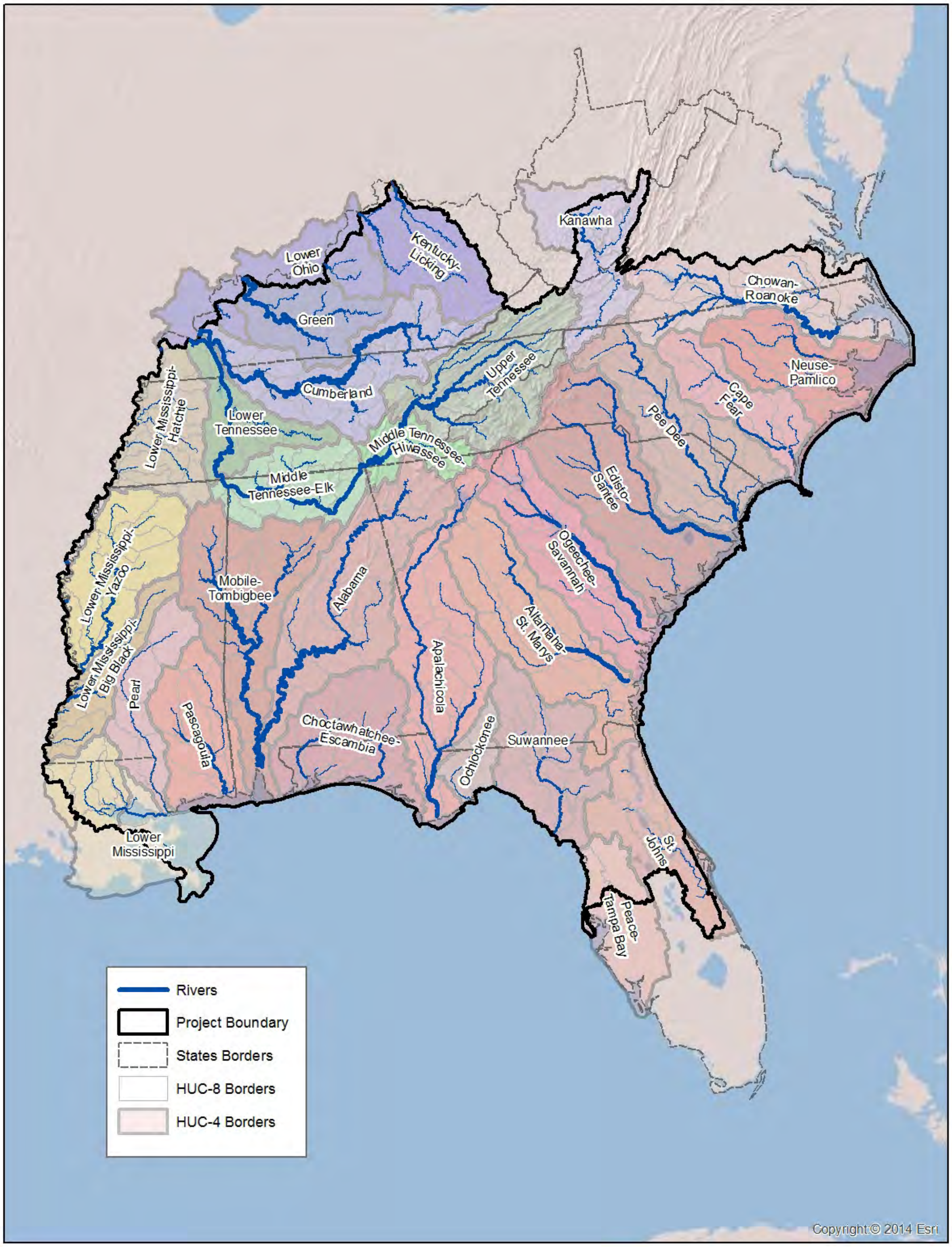


Figure 2 Project Area: "The Southeast." Additional maps of all HUC-8 sub-watersheds in the project area map be found in Appendix II.

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.

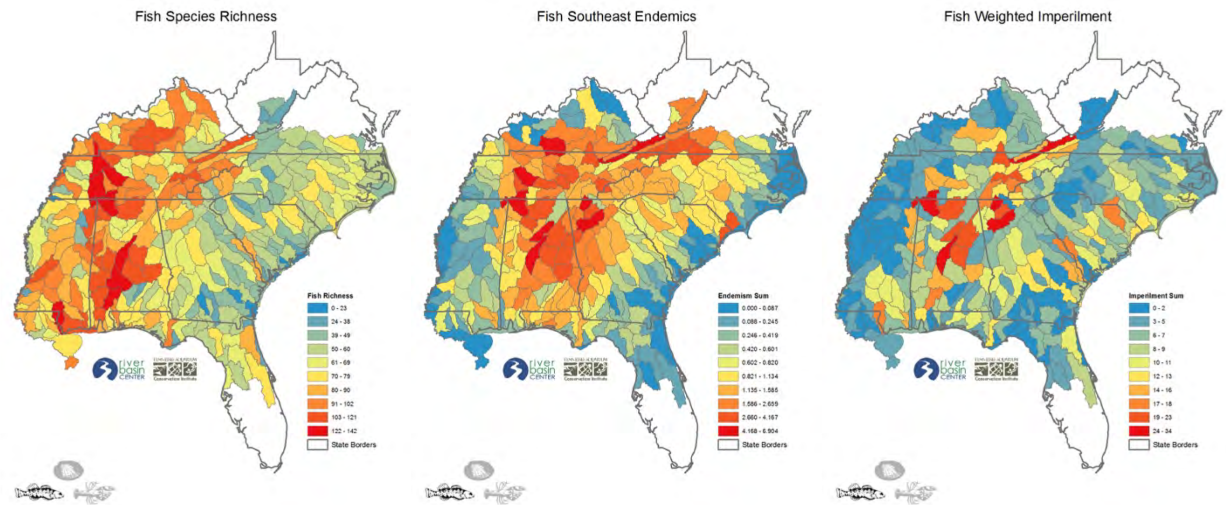


Figure 3 Richness, endemism, and imperilment scores for fishes. Note: large, high resolution versions are included in Appendix I.

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.

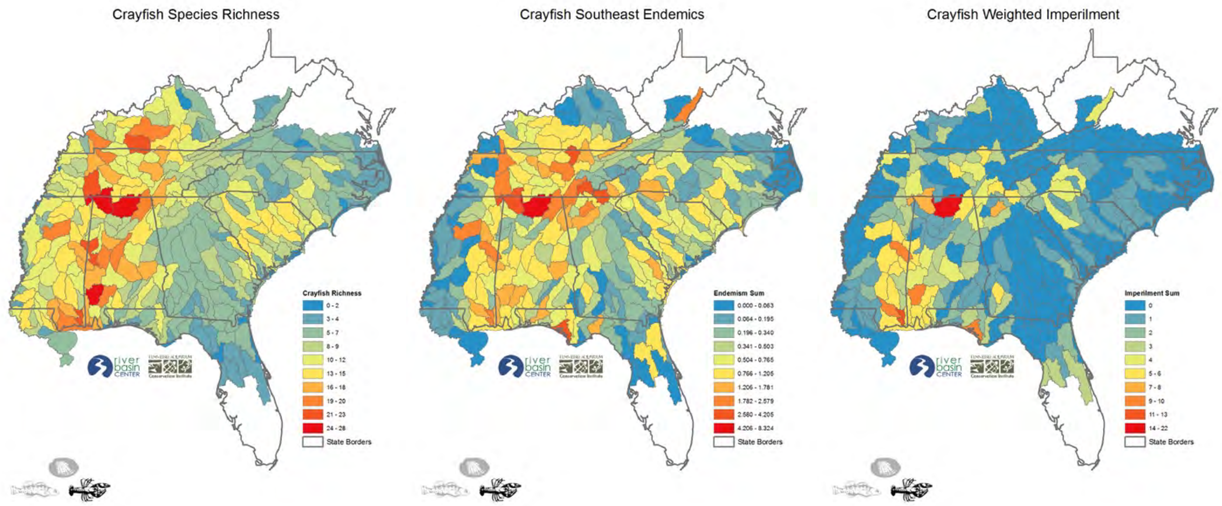


Figure 4 Richness, endemism, and imperilment scores for crayfishes. Note: large, high resolution versions are included in Appendix I.

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.

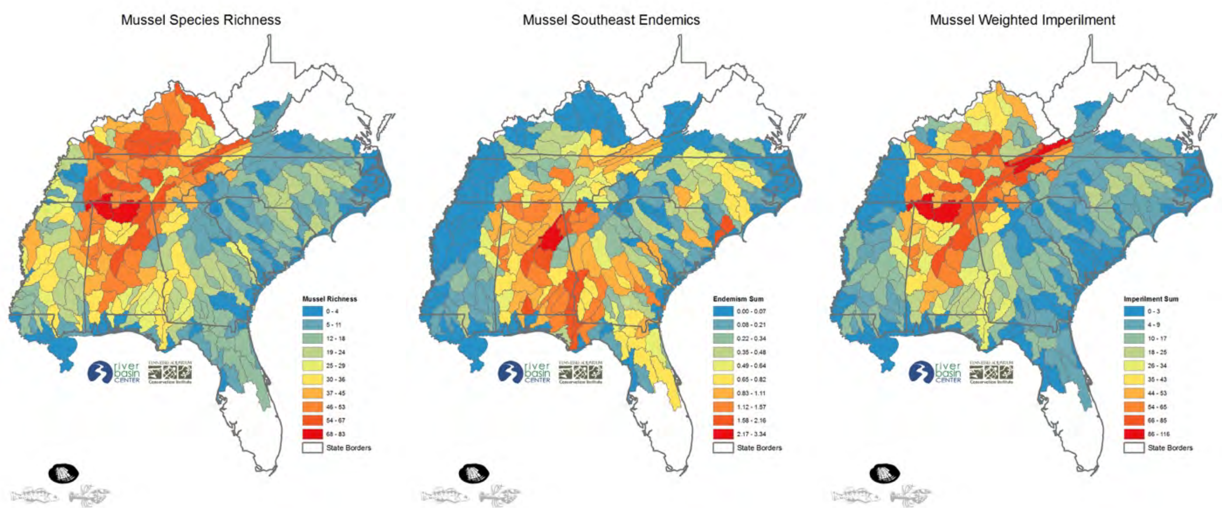


Figure 5 Richness, endemism, and imperilment scores for mussels. Note: large, high resolution versions are included in Appendix I.

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.

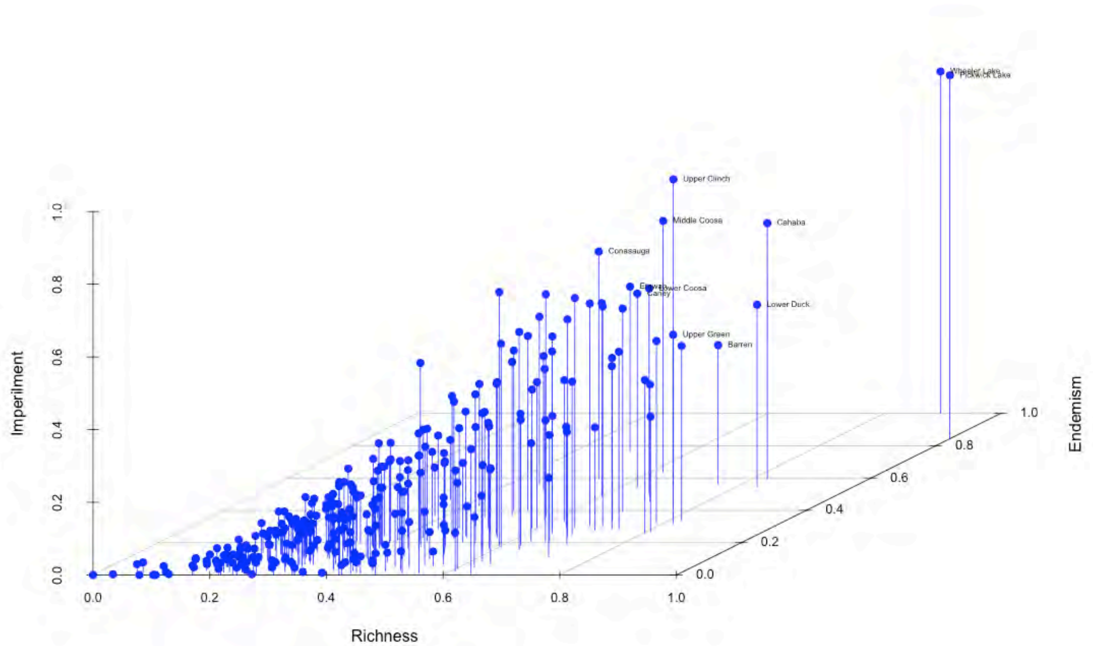


Figure 6 Scaled species richness, southeast endemism, and weighted imperilment for all taxa in 290 HUC-8 sub-basins. Labels indicate the top 12 sub-basins based on the combined priority ranking.

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.

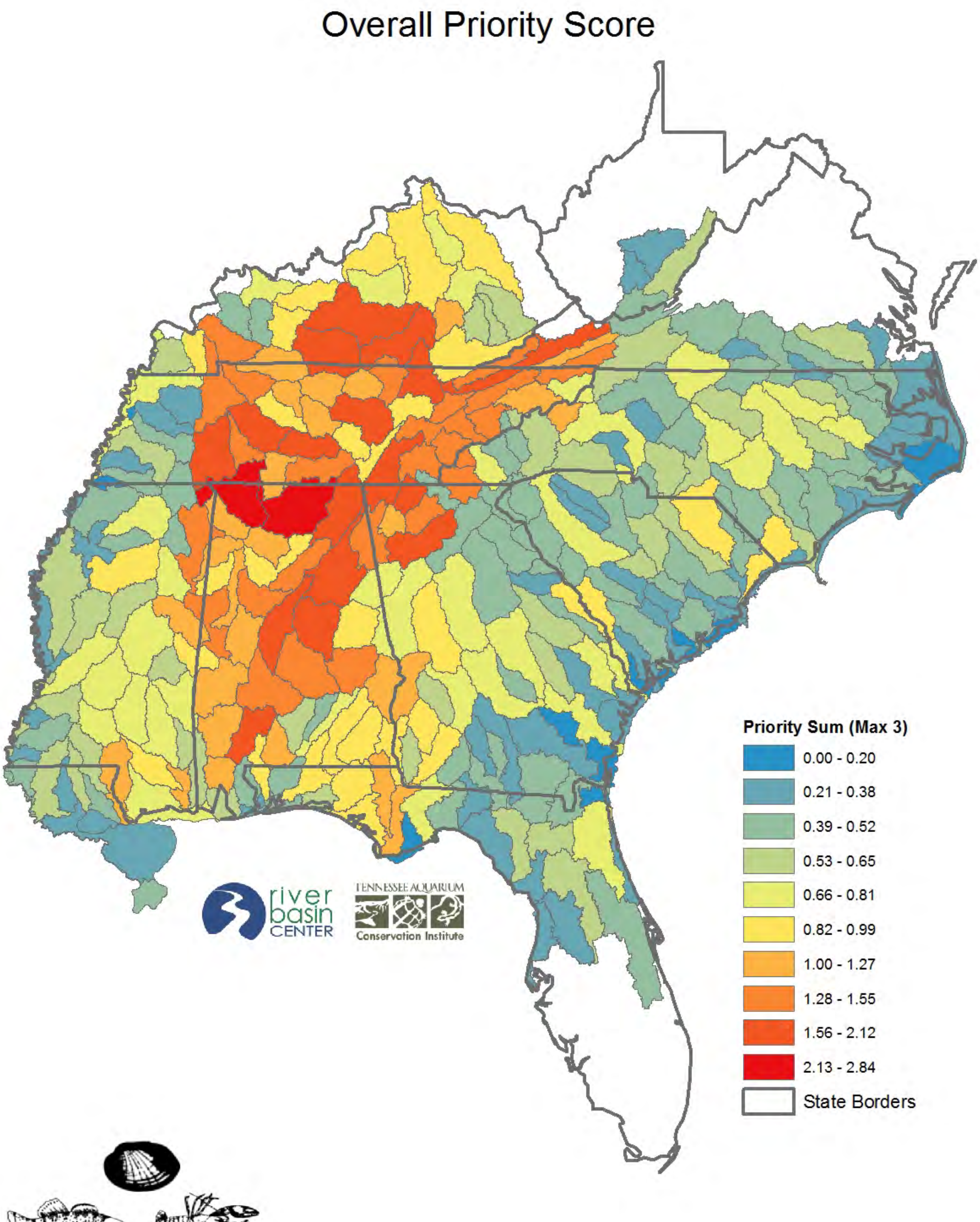


Figure 7 Overall priority score by sub-basin for the combined set of fishes, mussels, and crayfishes.

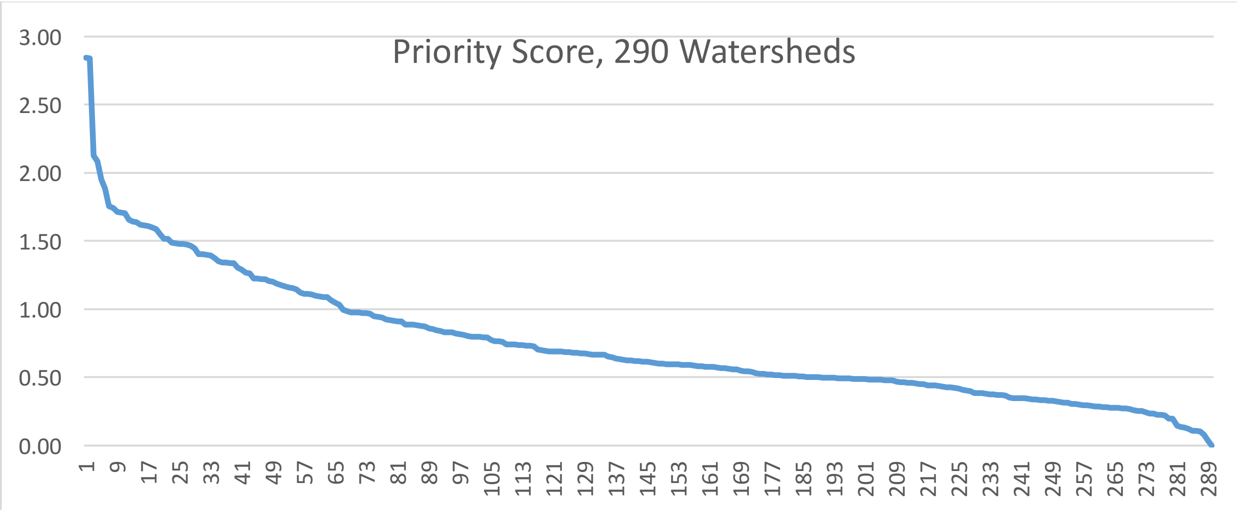


Figure 8 Sorted overall priority score by sub-basin

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.

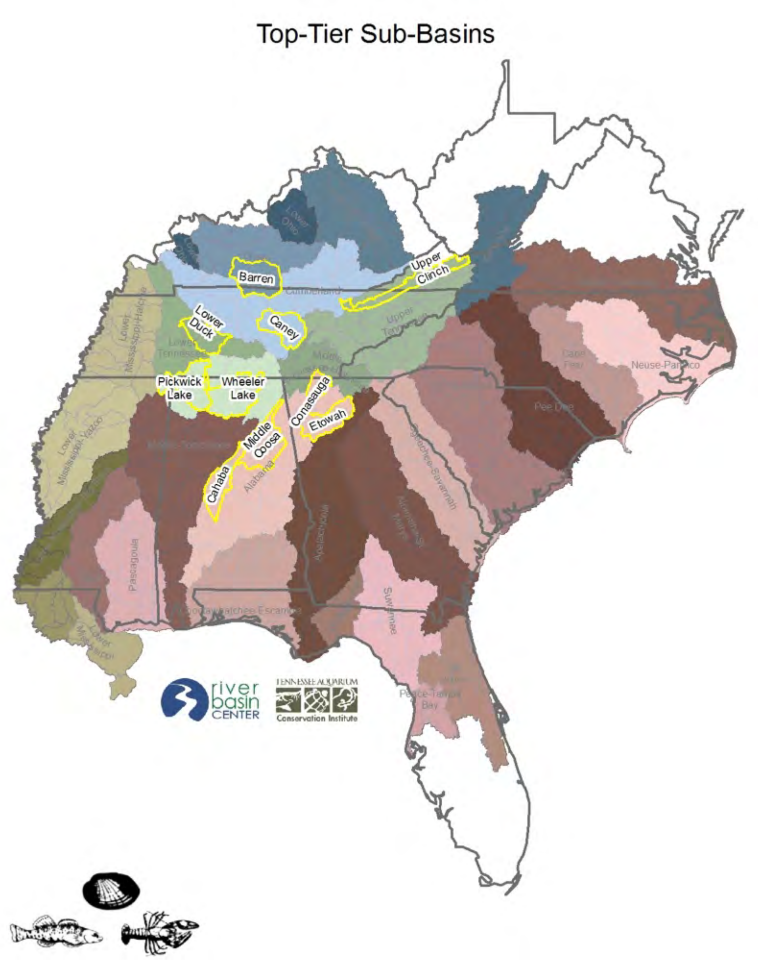


Figure 9. Ten highly biodiverse watersheds where management actions could have major conservation benefits. Shading reflects HUC-2 and HUC-4 boundaries, as in Figure 2.

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

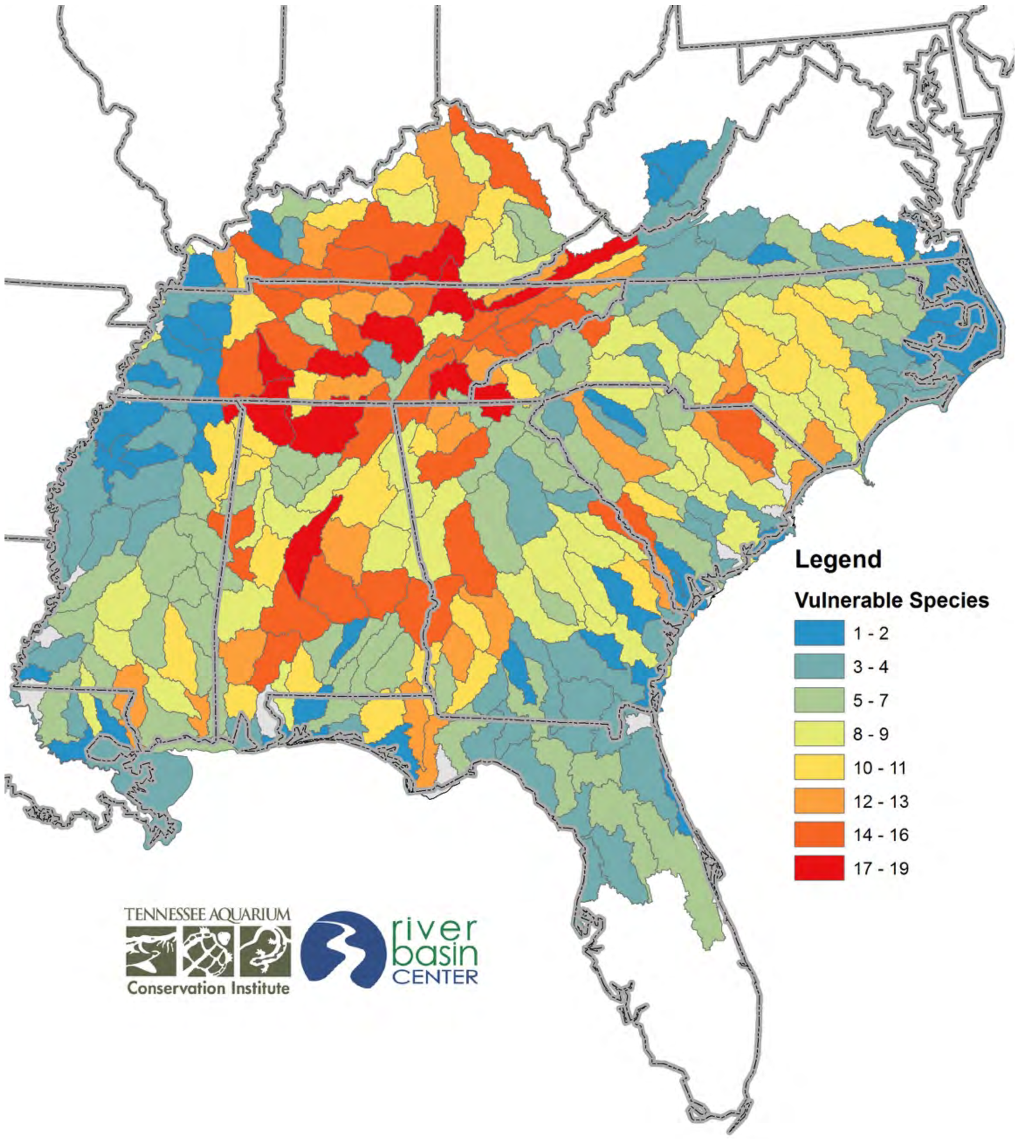


Figure 10 - Count of imperiled species (fishes, crayfishes, and mussels) with "Vulnerable" status by sub-basin.

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%

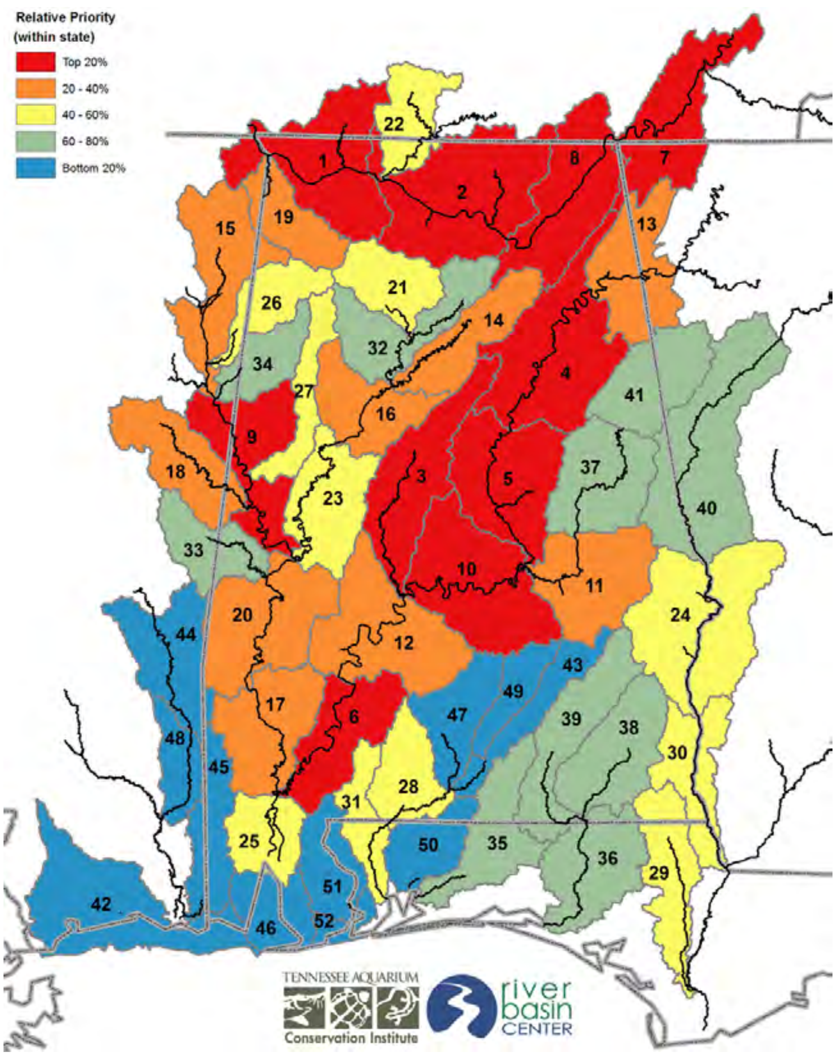


Figure 11 Within-state all-taxa priority rankings for sub-basins in Alabama

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%

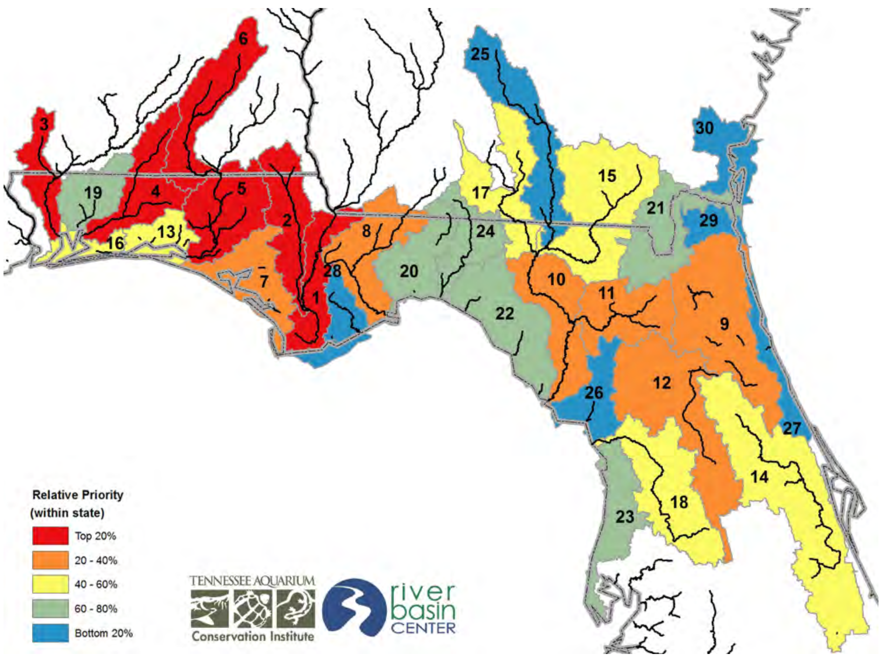


Figure 12 Within-state all-taxa priority rankings for sub-basins in Florida

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%

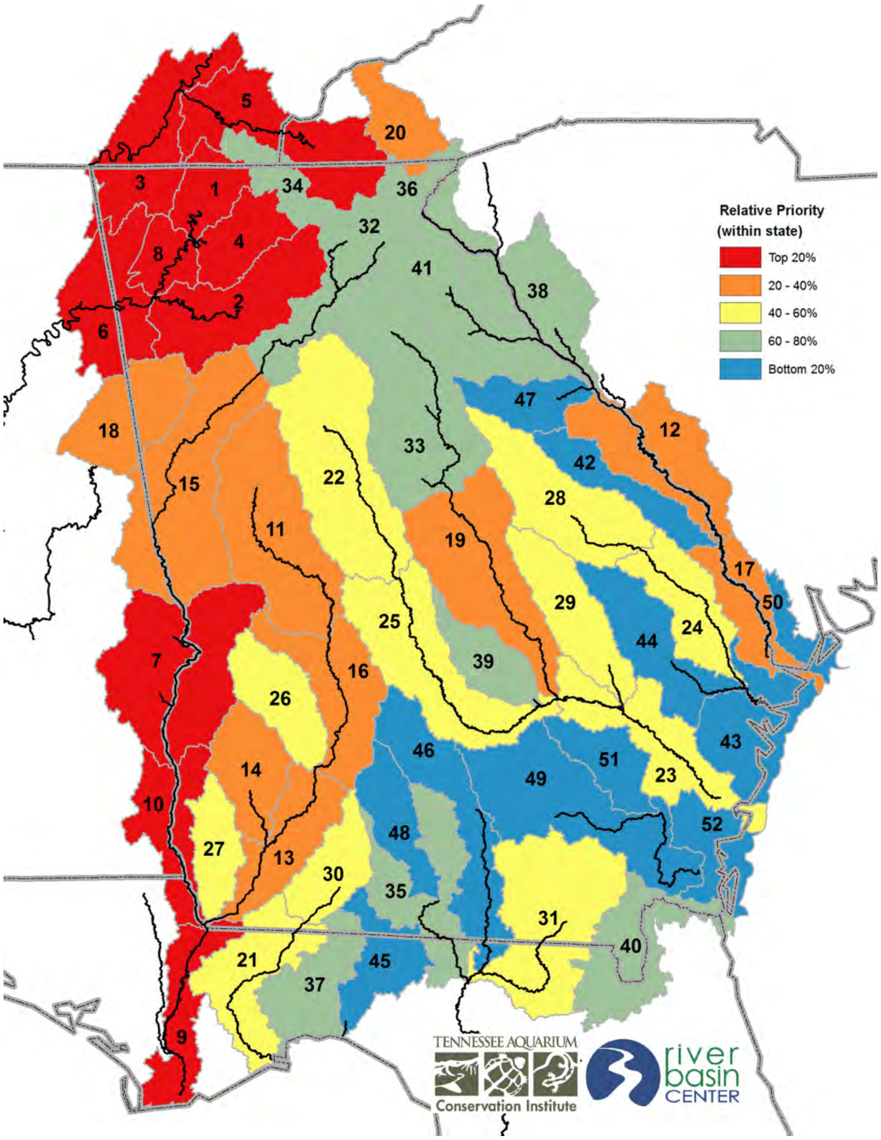


Figure 13 Within-state all-taxa priority rankings for sub-basins in Georgia

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%

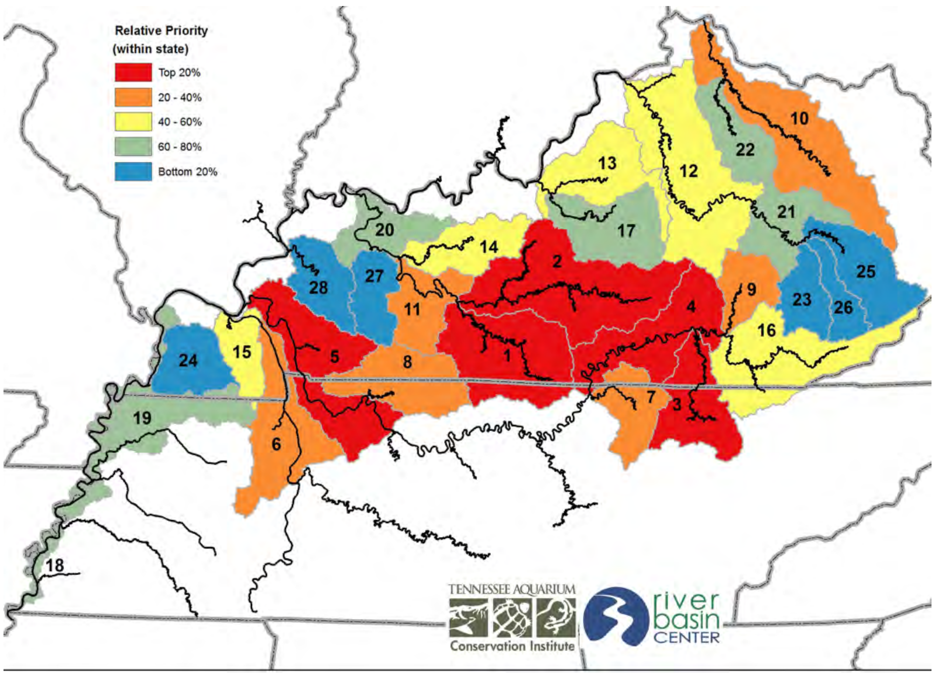


Figure 14 Within-state all-taxa priority rankings for sub-basins in Kentucky

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%

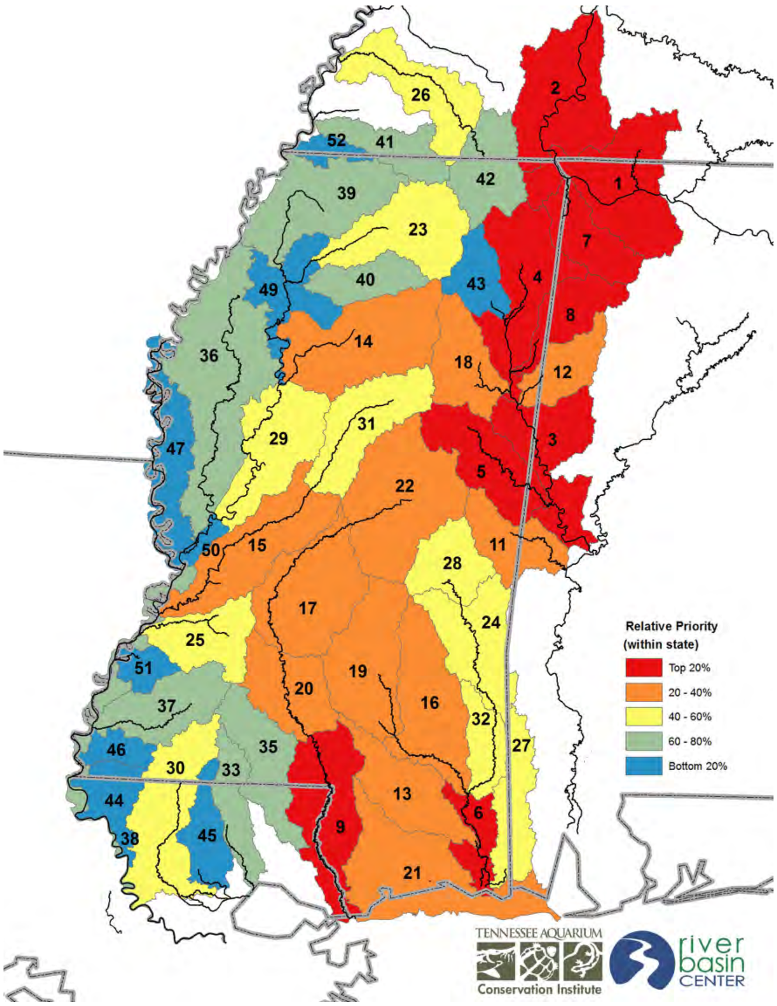


Figure 15 Within-state all-taxa priority rankings for sub-basins in Mississippi

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%

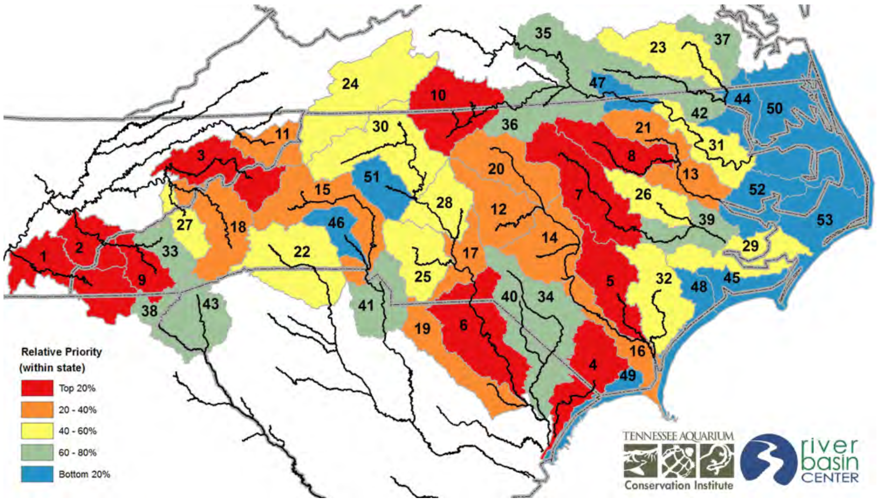


Figure 16 Within-state all-taxa priority rankings for sub-basins in North Carolina

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%

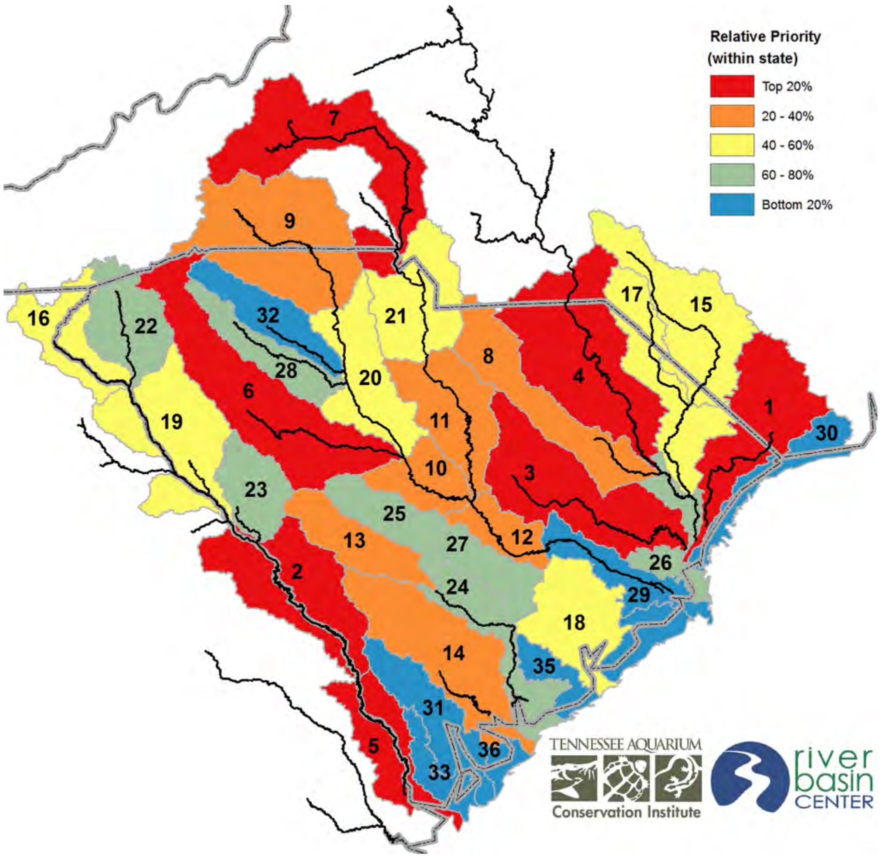


Figure 17 Within-state all-taxa priority rankings for sub-basins in South Carolina

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%

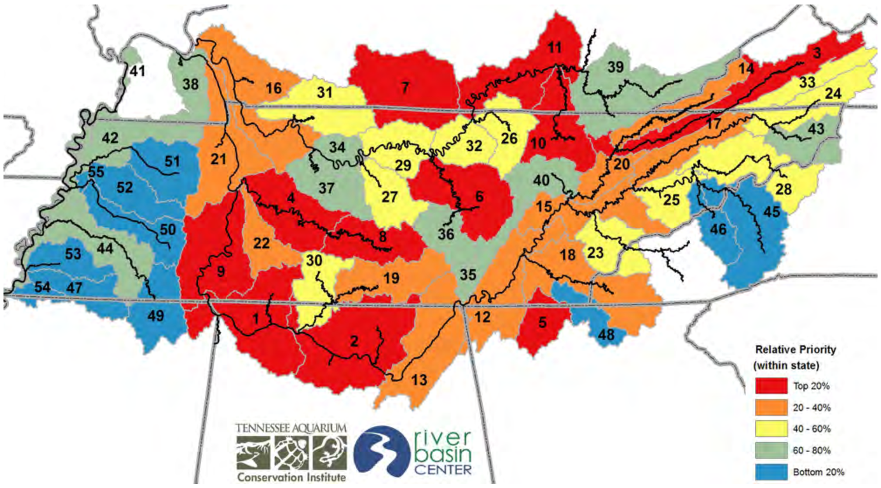


Figure 18 Within-state all-taxa priority rankings for sub-basins in Tennessee

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%

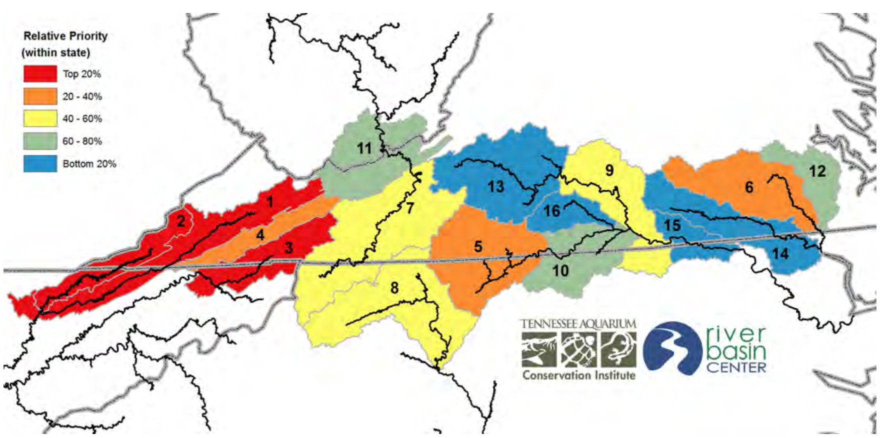


Figure 19 Within-state all-taxa priority rankings for sub-basins in southern Virginia

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%).

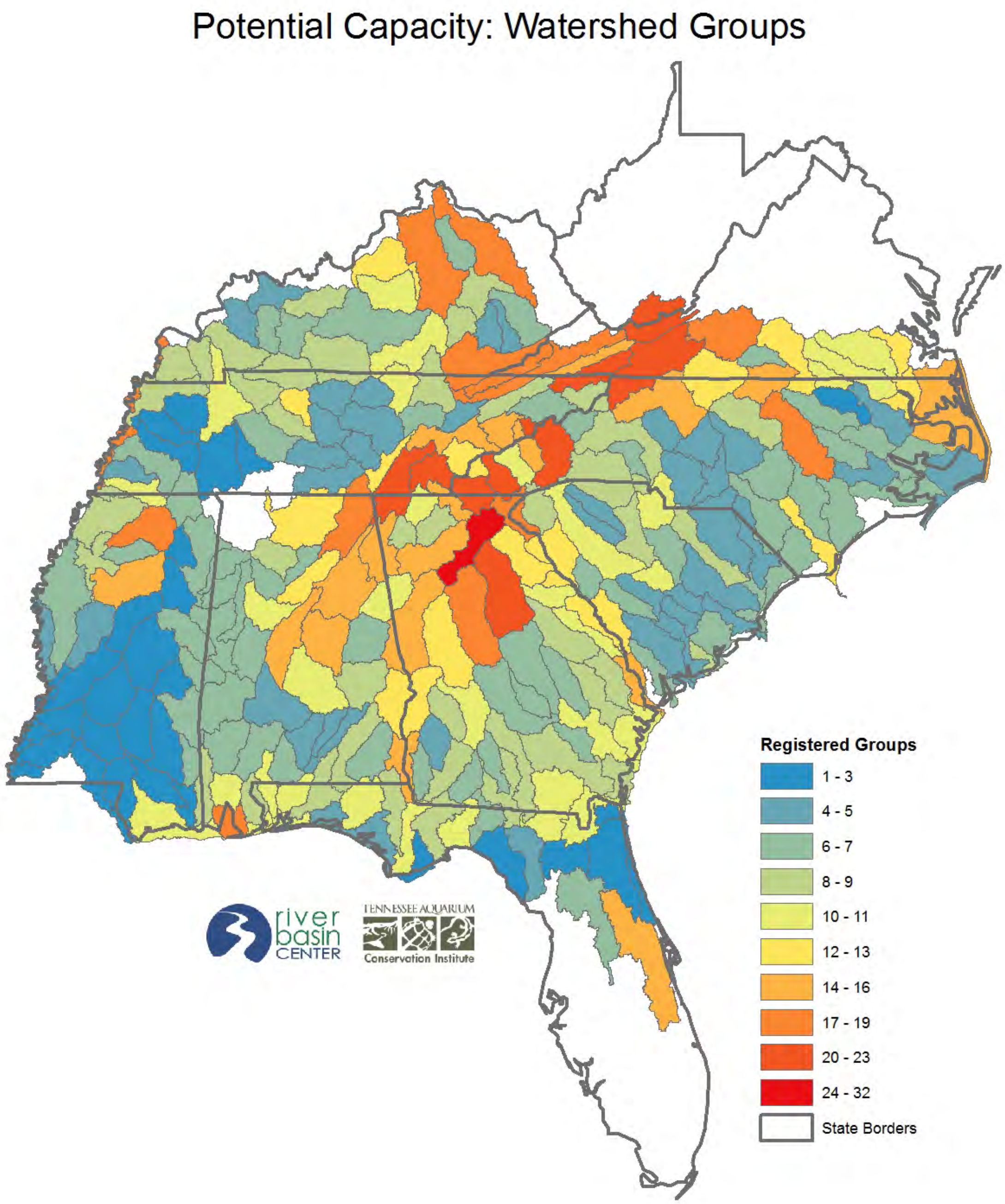


Figure 20 Total number of watershed groups registered in EPA database, per sub-basin, in August 2015. Blank areas within the project region reflect sub-basins where no groups were registered.

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).

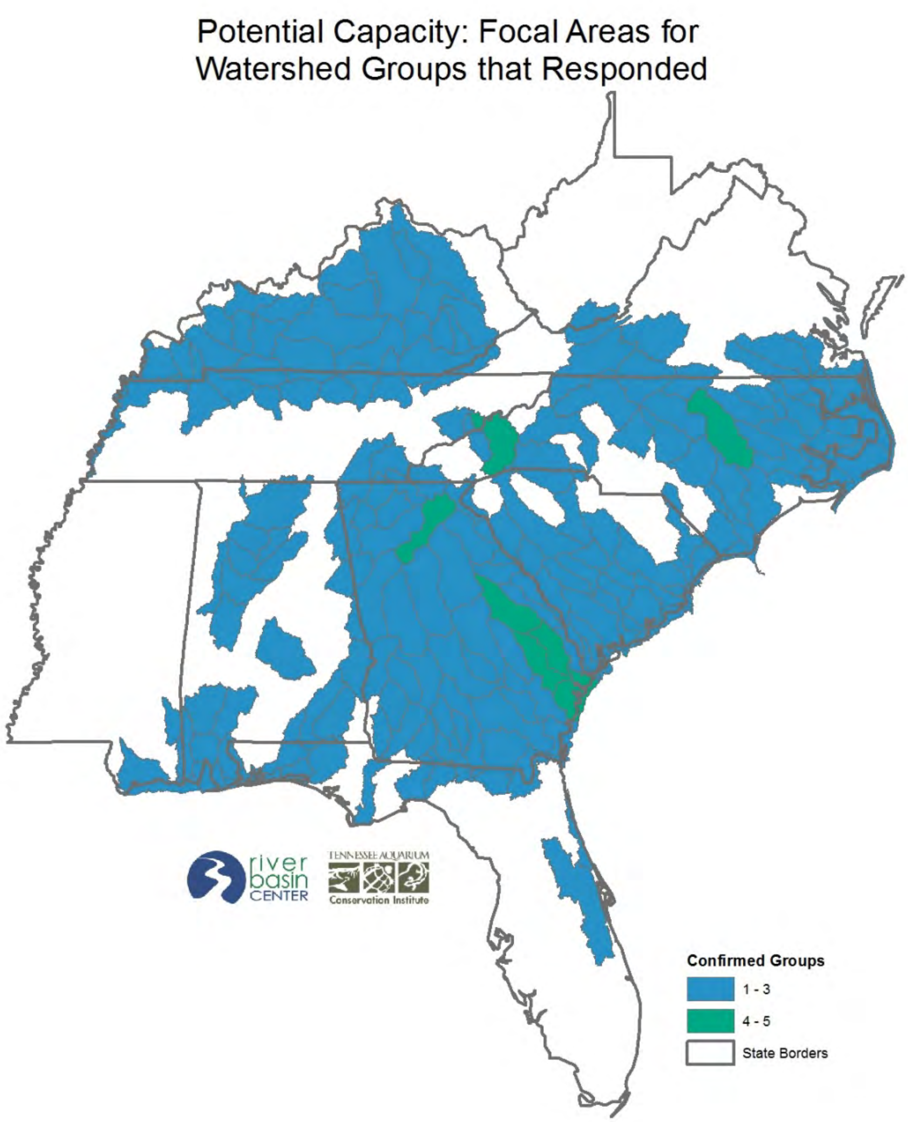


Figure 21 Total number of watershed groups registered, per sub-basin, among survey respondents. Blank areas of the map within the project area were not associated with any group that responded.

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%).

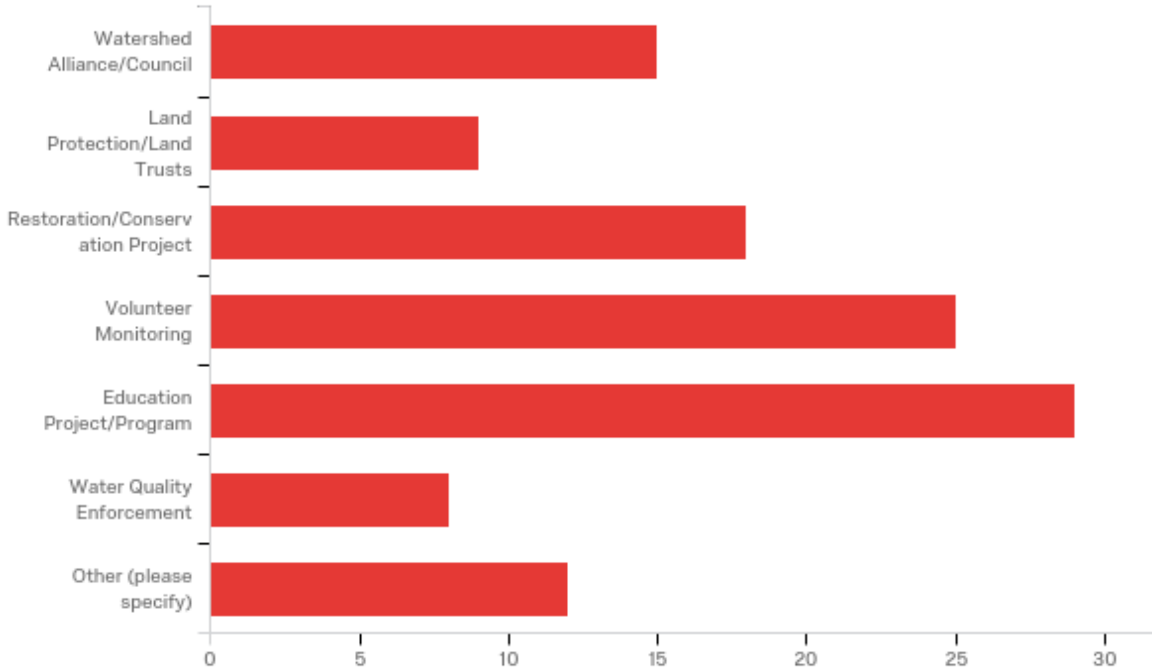


Figure 22- Frequency of group or project objectives on the responses of 51 watershed groups completing surveys. (Respondents were allowed to select more than one response.)

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).

Data provided by Alabama Department of Conservation and Natural Resources, Alabama Department of Environmental Management, Auburn University Museum Fish Collection, Florida Fish and Wildlife Conservation Commission, Geologic Survey of Alabama, Geologic Survey of Alabama and Alabama Department of Environmental Management, Geologic Survey of Alabama and Tennessee Valley Authority, Georgia Department of Natural Resources, Kentucky DEQ, Division of Water Quality, Louisiana Department of Environmental Quality, Louisiana Department of Wildlife and Fisheries, Mississippi Museum of Natural Science, North Carolina Department of Environment and Natural Resources, North Carolina Wildlife Resources Commission, South Carolina Department of Natural Resources, Tennessee Wildlife Resources Agency, Troy University, University of Alabama Ichthyological Collection, Virginia Department of Environmental Quality, and West Virginia Department of Environmental Protection-Division of Water and Waste Management via www.marisdata.org December 15, 2015

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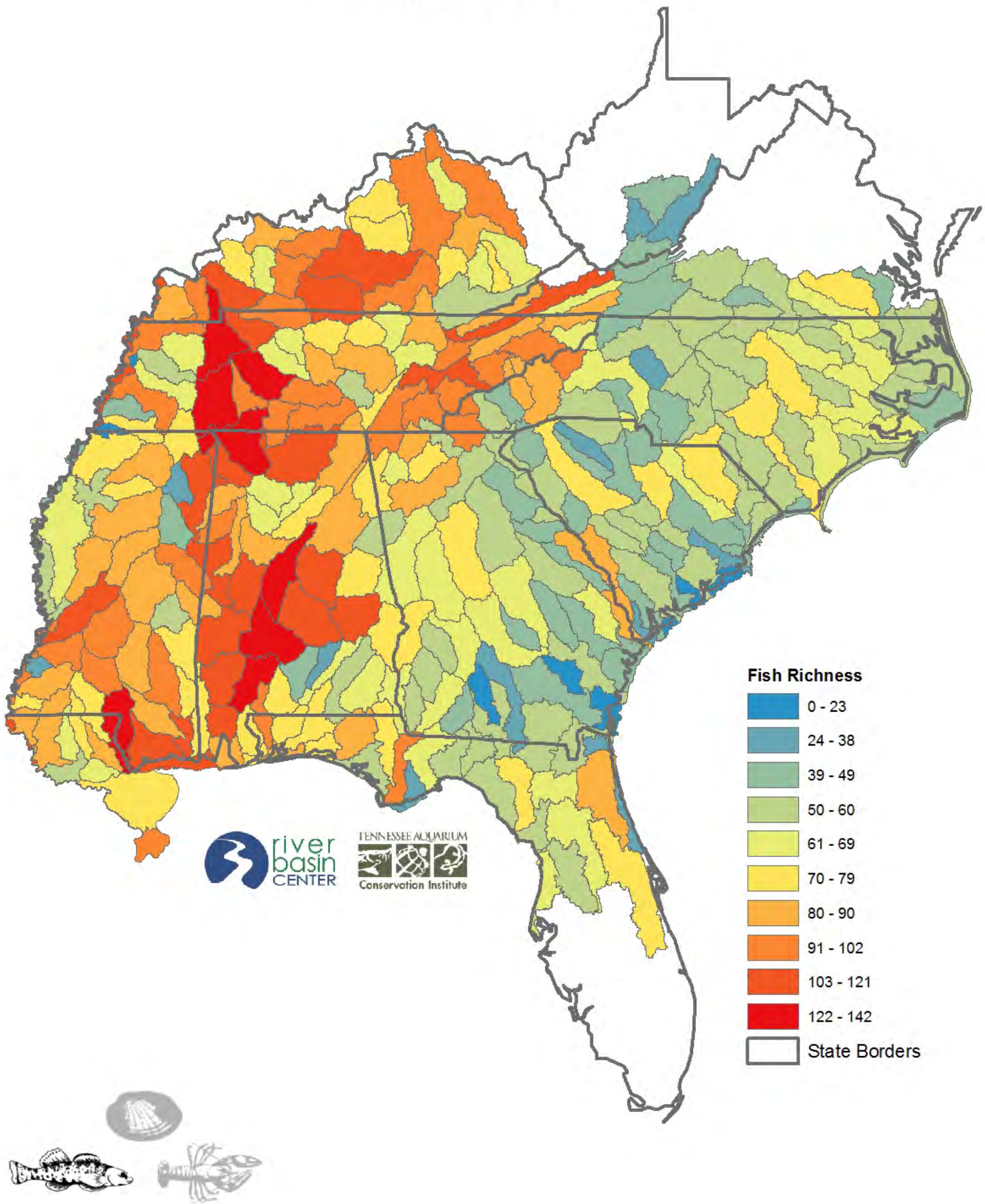
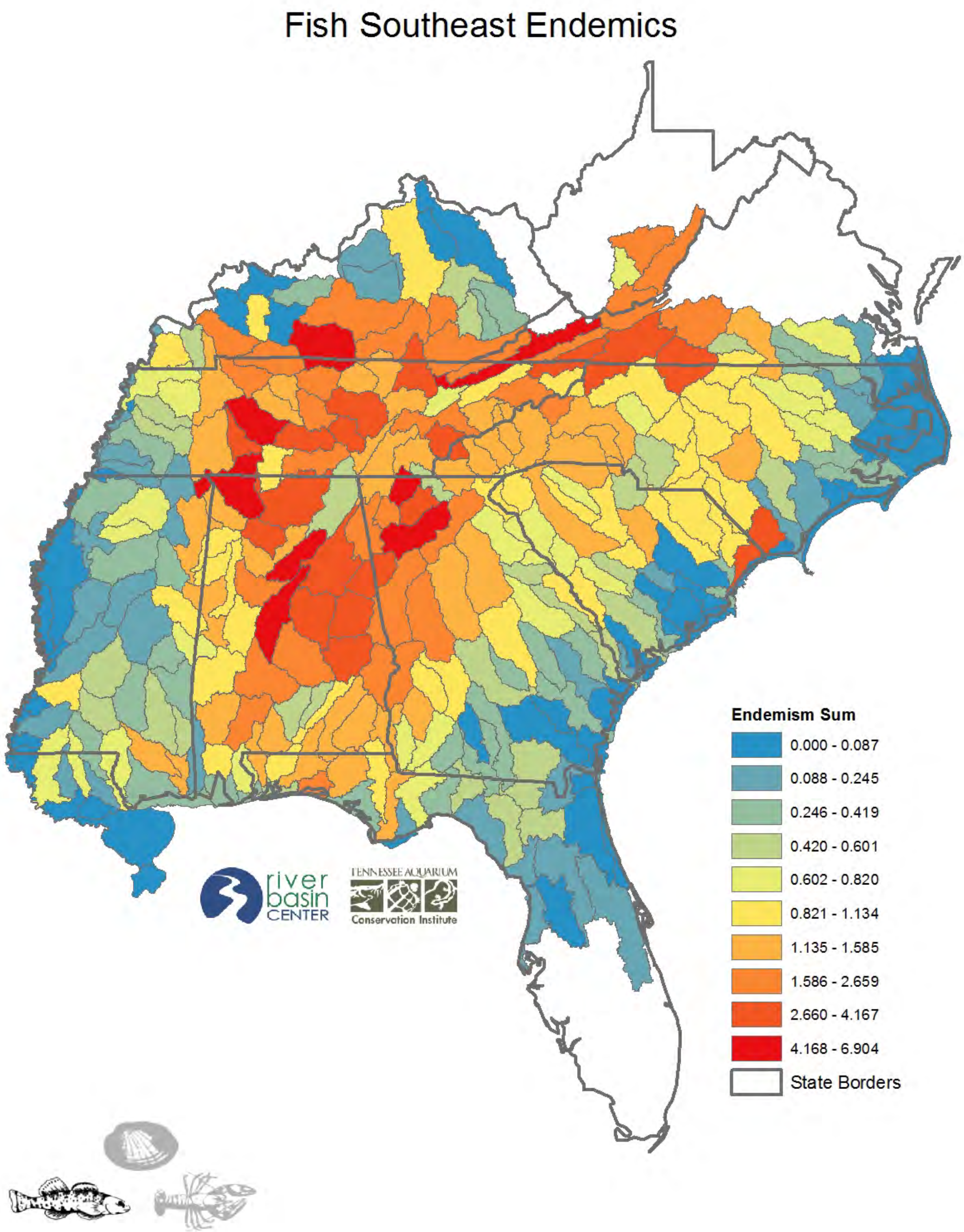
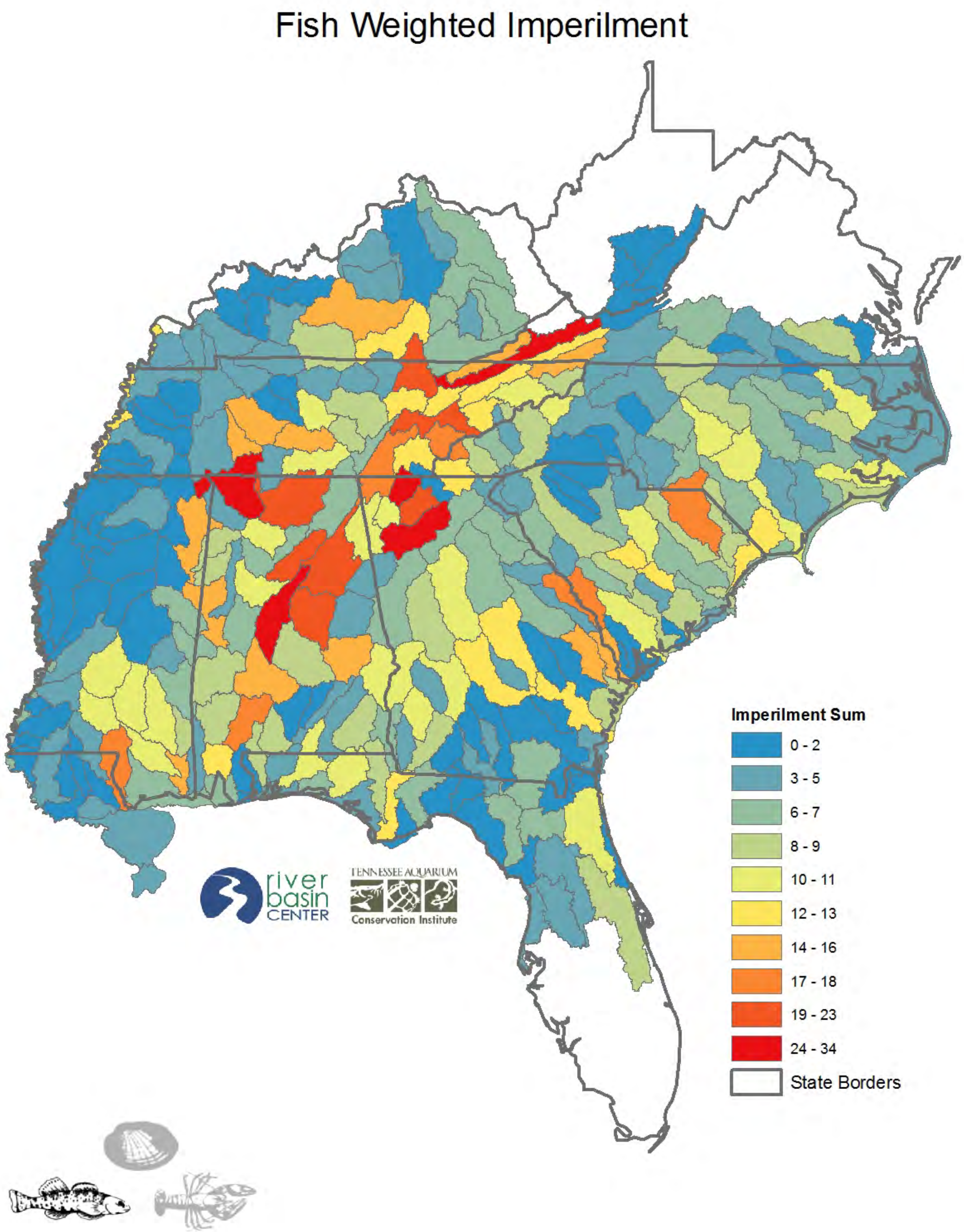
APPENDIX I: FISH, CRAYFISH, AND MUSSEL MAPS

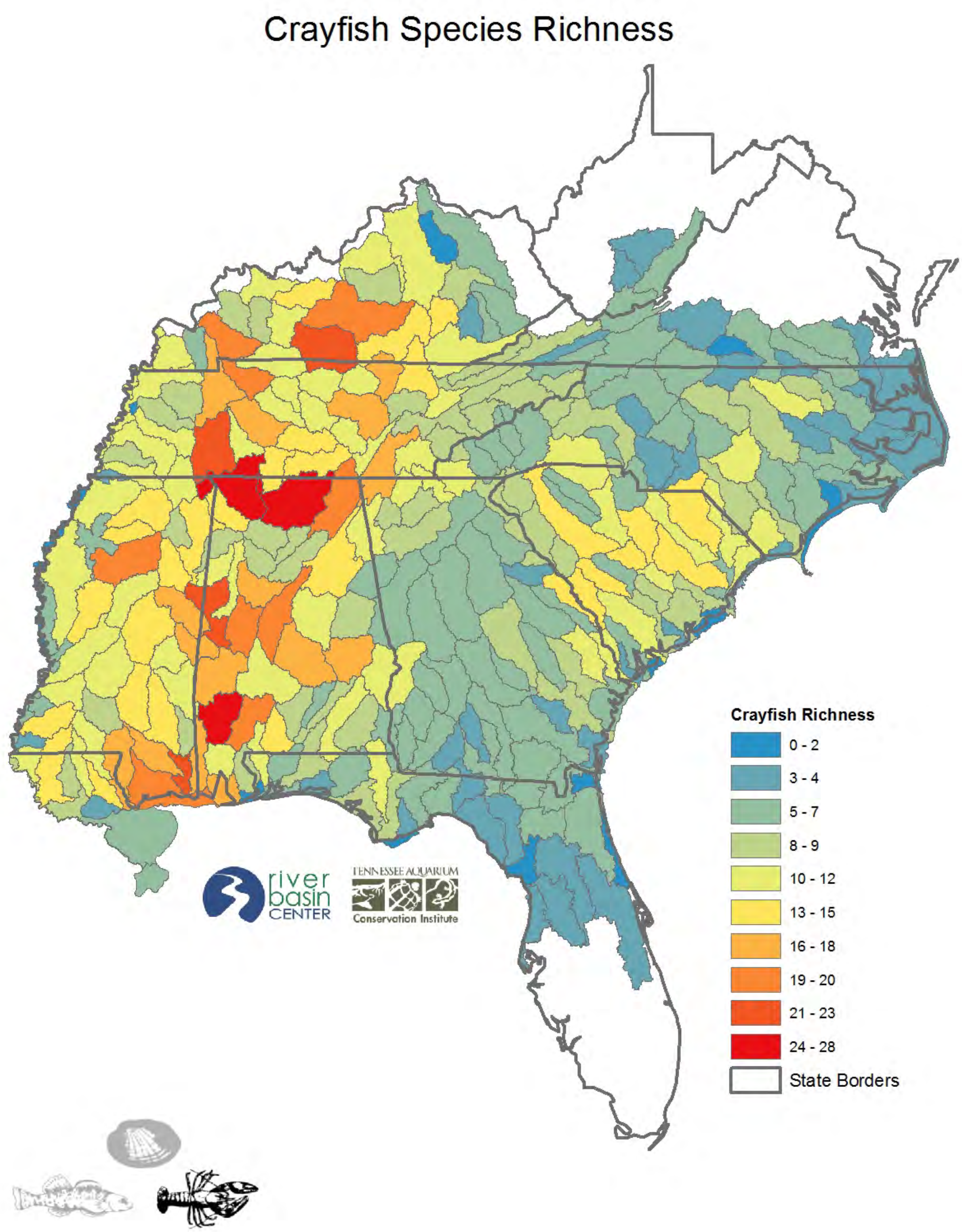
The maps in this section duplicate the inset maps from the results section at a larger size, for better on-screen viewing. Digital versions will be available at www.southeastfreshwater.org

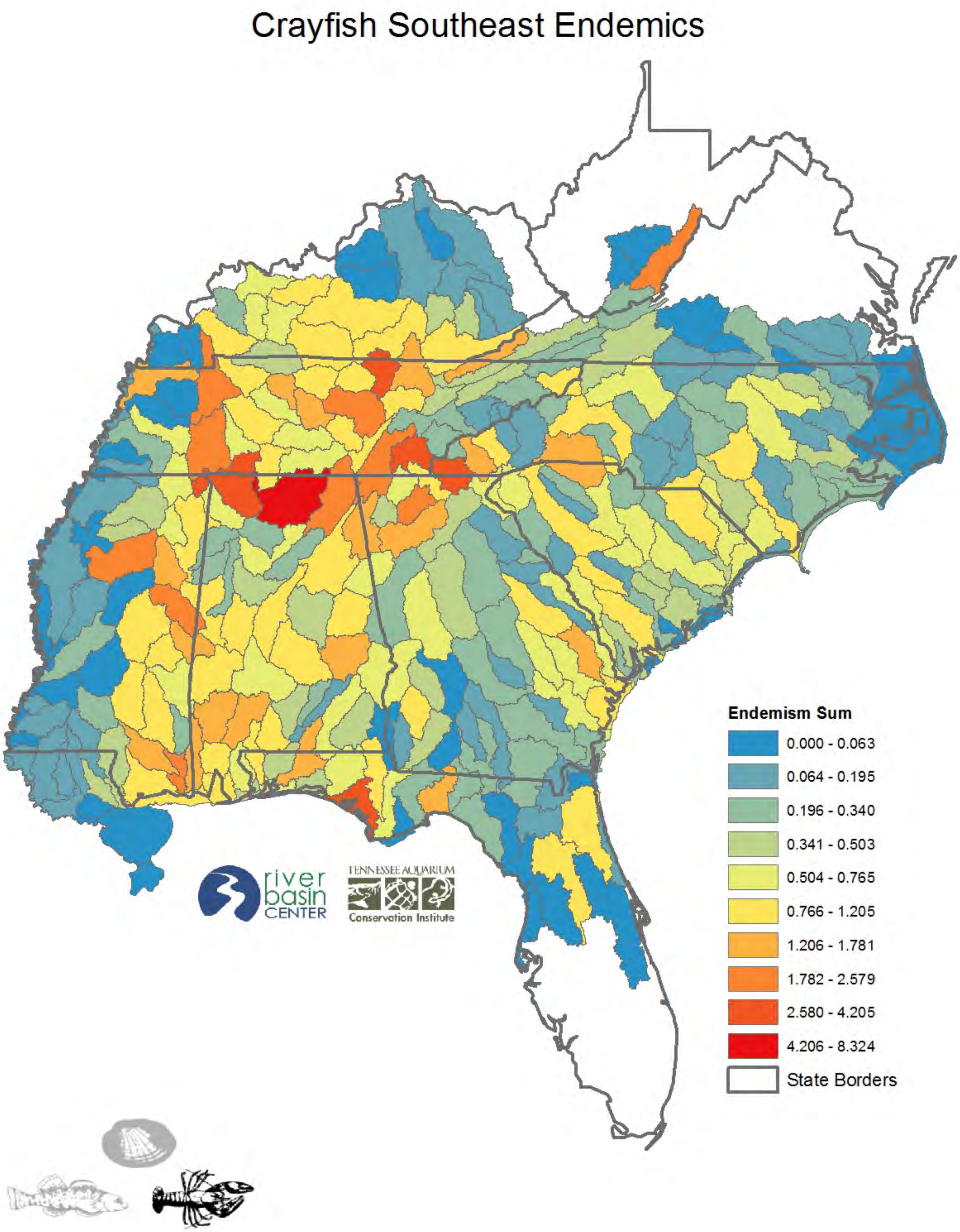
Fish Species Richness

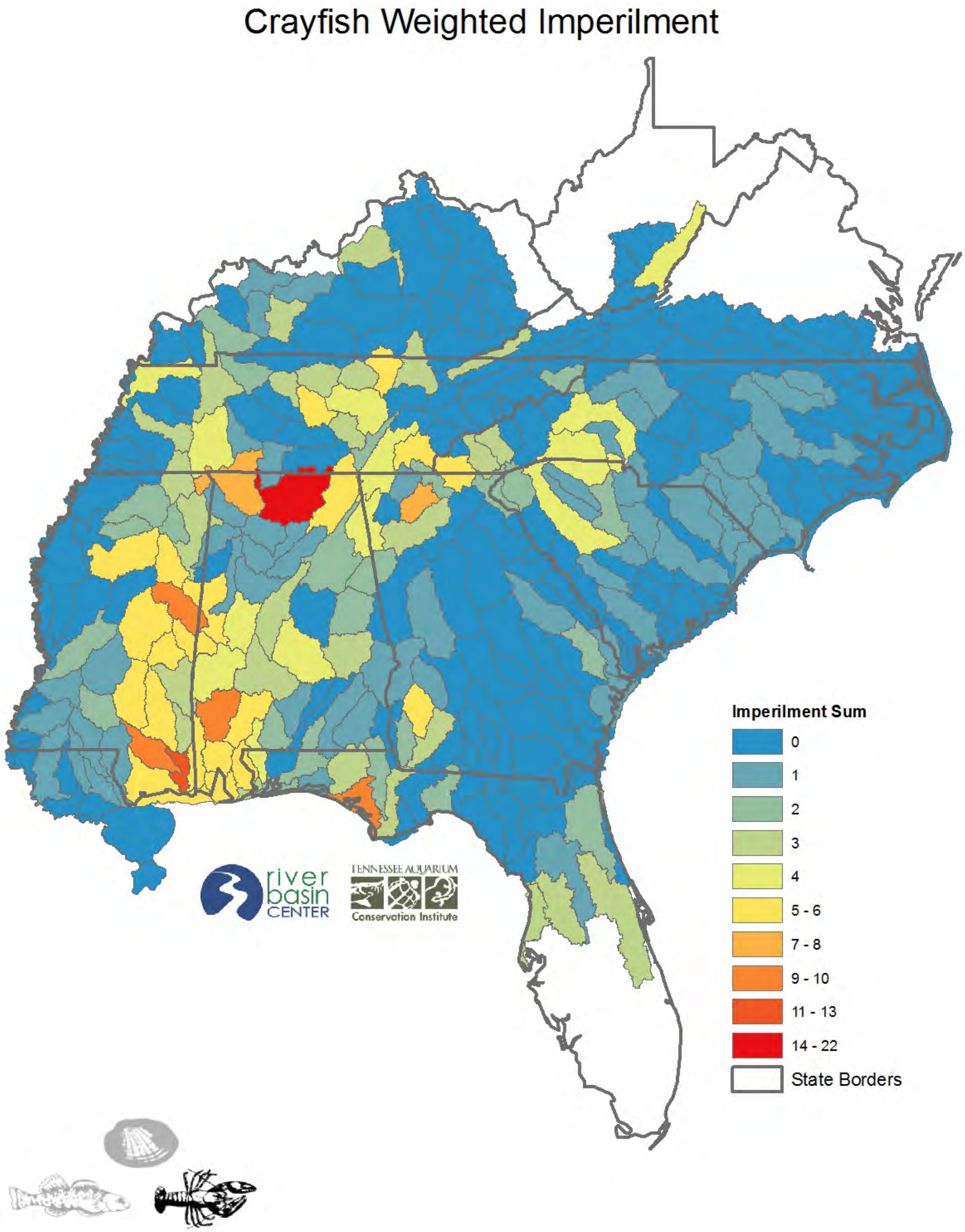



Fish Southeast Endemics
Endemism Sum
0.000 - 0.087
0.088 - 0.245
0.246 - 0.419
0.420 - 0.601
0.602 - 0.820
0.821 - 1.134
1.135 - 1.585
1.586 - 2.659
2.660 - 4.167
4.168 - 6.904
State Borders
river basin CENTER
TENNESSEE AQUARIUM
Conservation Institute


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
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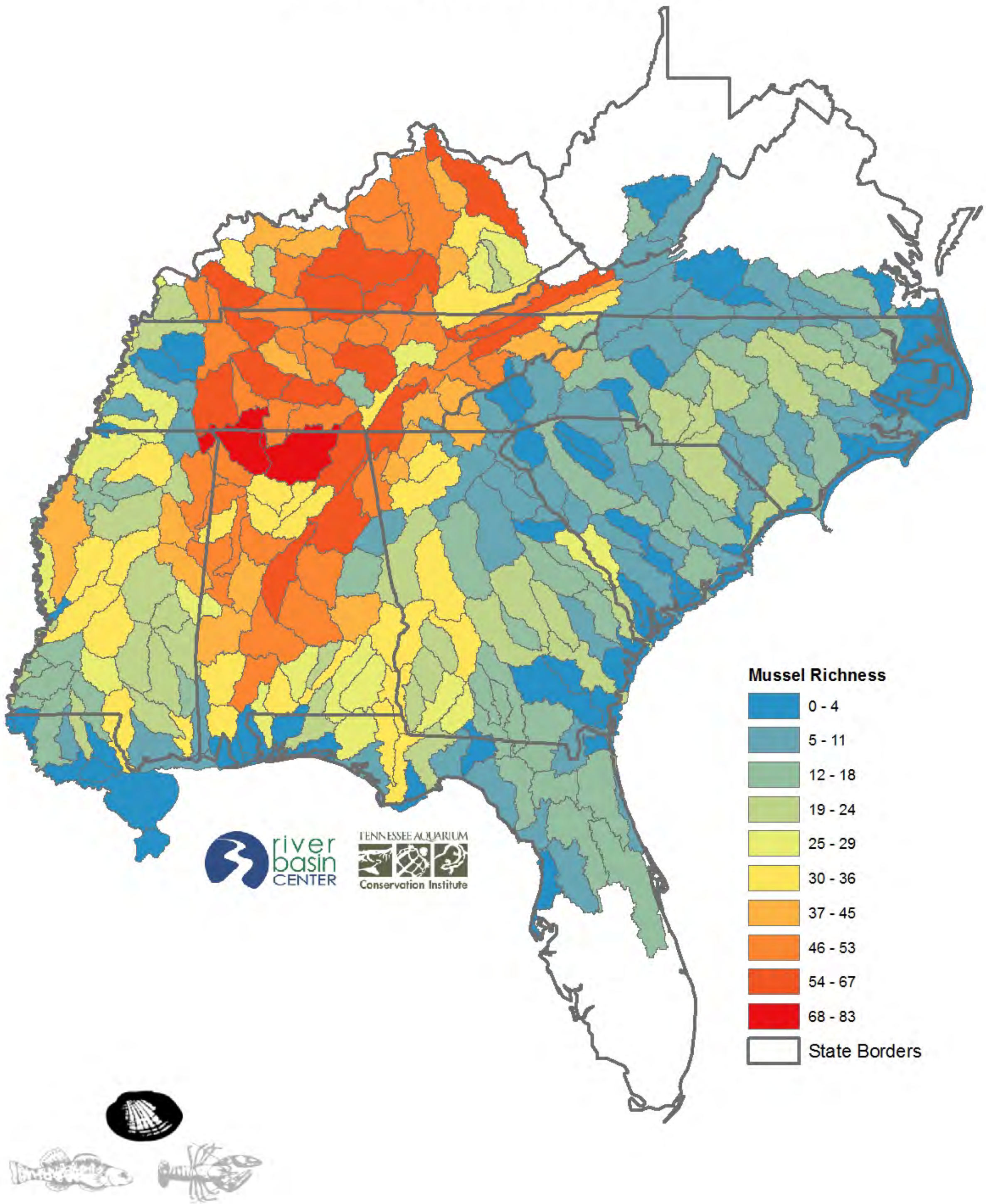
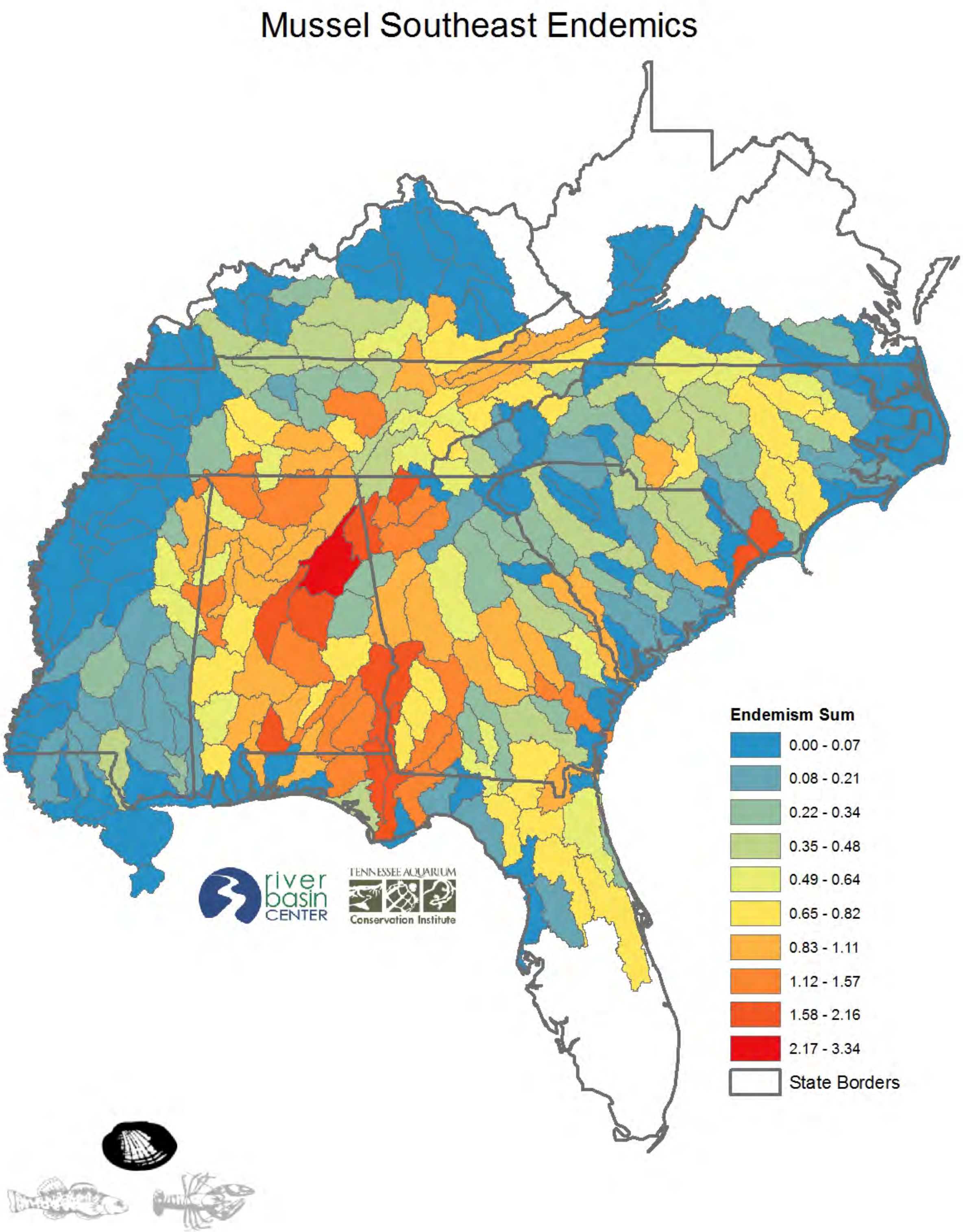
Mussel Species Richness




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
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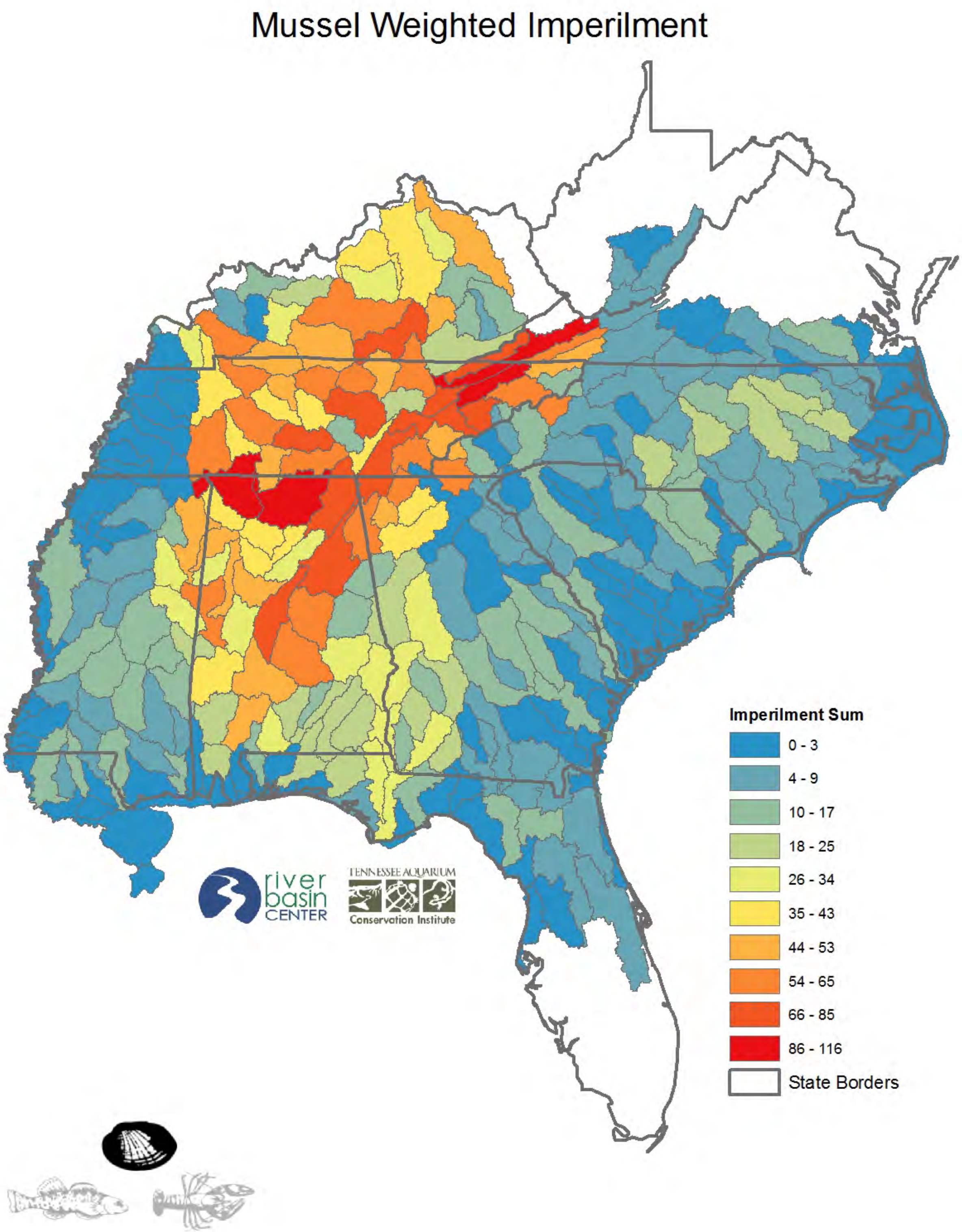
Mussel Weighted Imperilment
Imperilment Sum
0 - 3
4 - 9
10 - 17
18 - 25
26 - 34
35 - 43
44 - 53
54 - 65
66 - 85
86 - 116
State Borders
river basin CENTER
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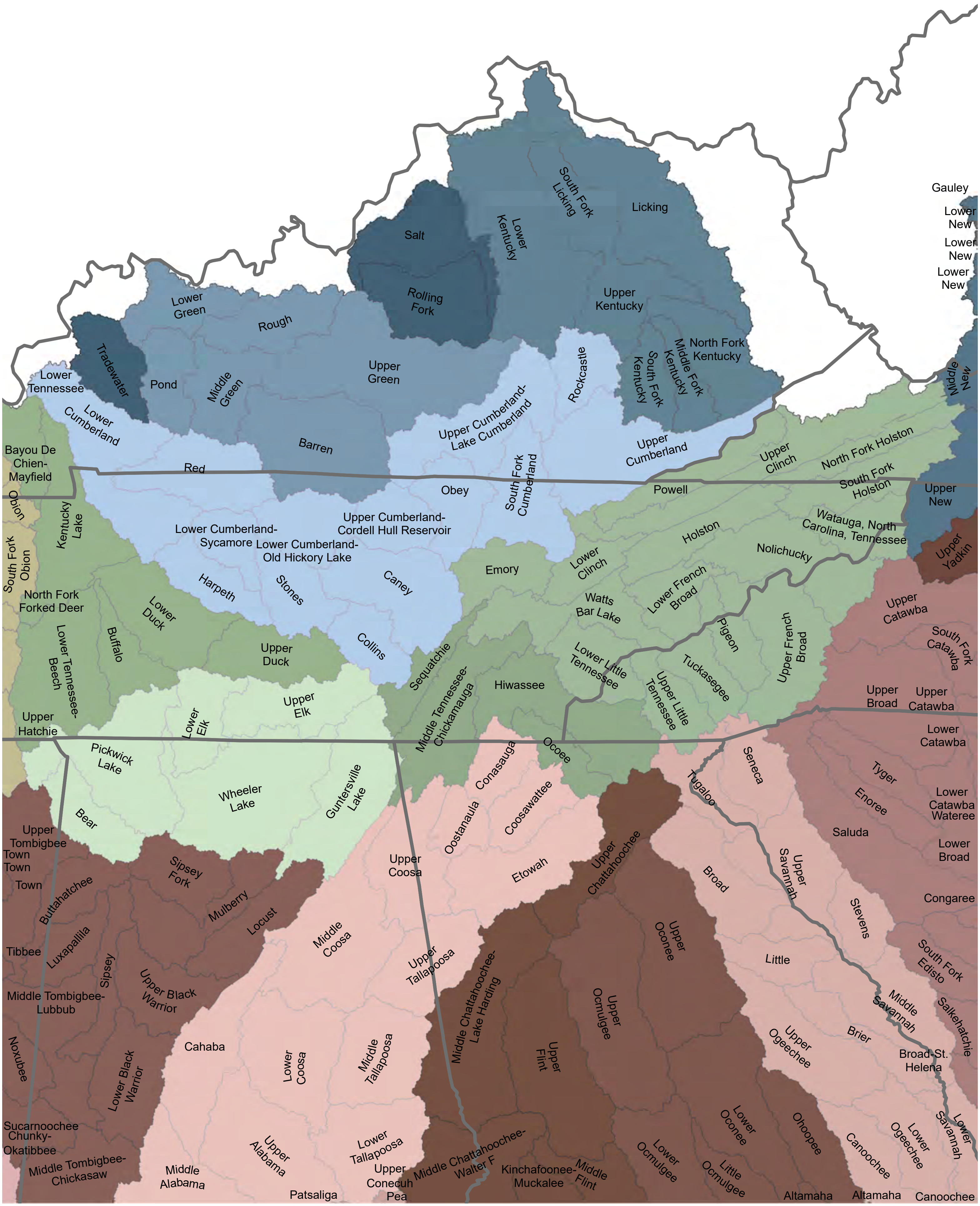
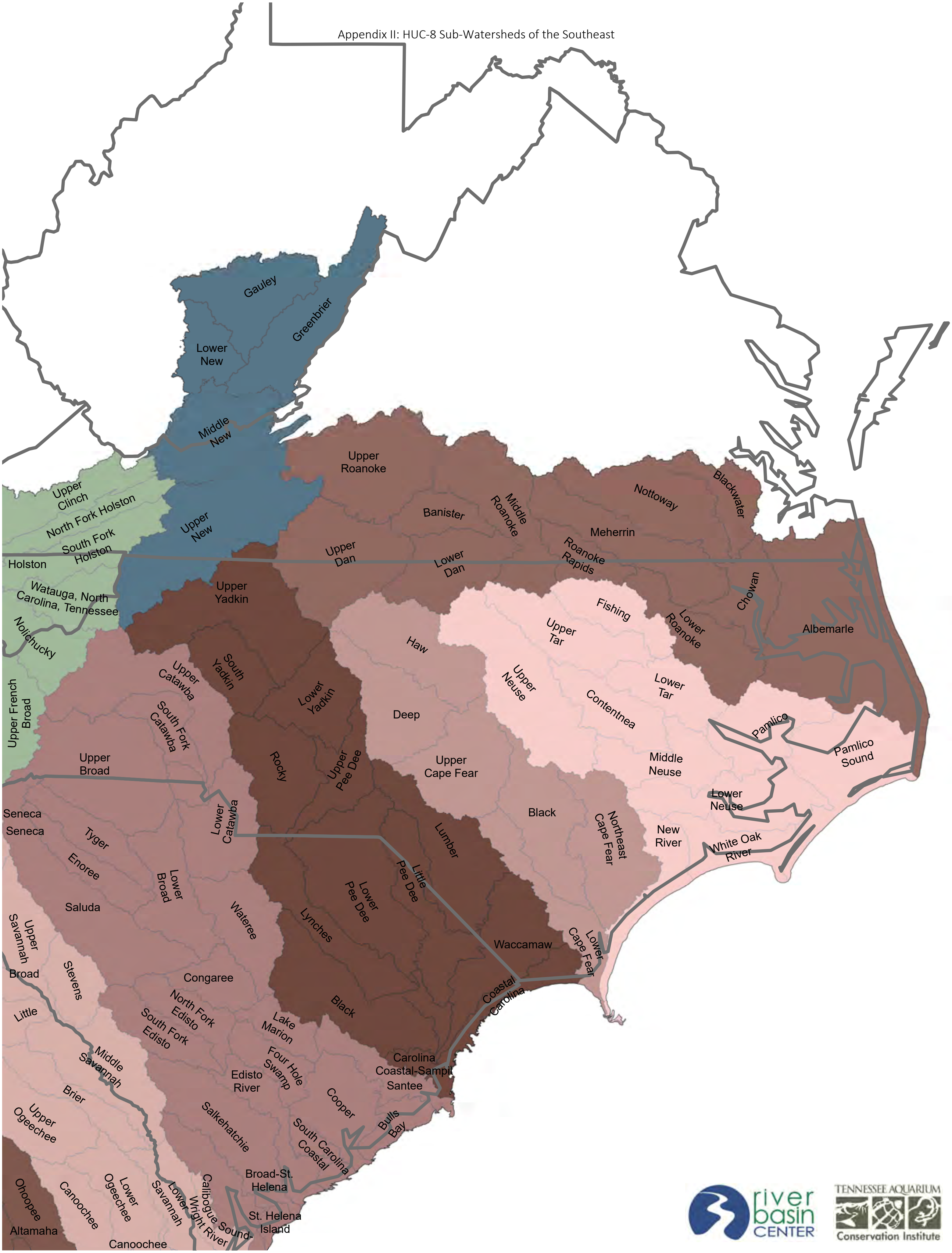
APPENDIX II. NAMES OF HUC-8 SUB-BASINS IN THE SOUTHEAST

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.

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




Gauley
Greenbrier
Lower New
Middle New
Upper New
Upper Clinch
North Fork Holston
South Fork Holston
Holston
Watauga, North Carolina, Tennessee
Nolichucky
Upper French Broad
Upper Roanoke
Banister
Middle Roanoke
Nottoway
Blackwater
Meherrin
Upper Dan
Lower Dan
Roanoke Rapids
Chowan
Lower Roanoke
Albemarle
Fishing
Upper Tar
Lower Tar
Upper Yadkin
South Yadkin
Lower Yadkin
Haw
Deep
Upper Neuse
Contentnea
Pamlico
Pamlico Sound
Upper Catawba
South Fork Catawba
Upper Broad
Rocky
Upper Pee Dee
Upper Cape Fear
Middle Neuse
Lower Neuse
Black
Northeast Cape Fear
New River
White Oak River
Seneca
Seneca
Tyger
Enoree
Lower Catawba
Lower Broad
Lumber
Little Pee Dee
Lower Pee Dee
Saluda
Wateree
Lynches
Waccamaw
Lower Cape Fear
Upper Savannah
Broad
Stevens
Congaree
Coastal Carolina
Little
North Fork Edisto
South Fork Edisto
Lake Marion
Black
Middle Savannah
Four Hole Swamp
Edisto River
Carolina Coastal-Sampit
Santee
Brier
Cooper
Upper Ogeechee
Salkehatchie
Bulls Bay
South Carolina Coastal
Broad-St. Helena
Ohoopee
Canoochee
Lower Ogeechee
Lower Savannah
Calibogue Sound-Wright River
St. Helena Island
Altamaha
Canoochee
river basin CENTER
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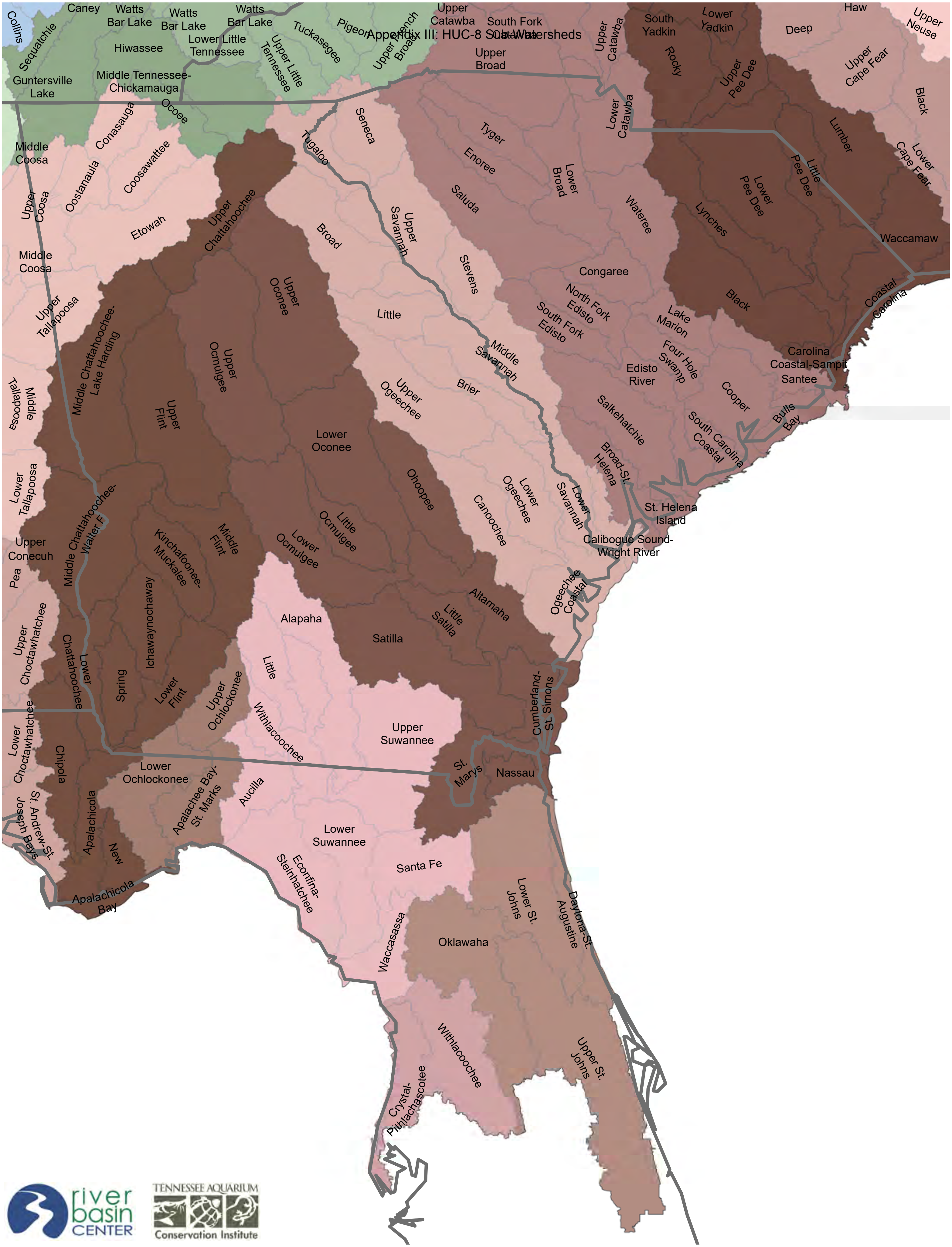
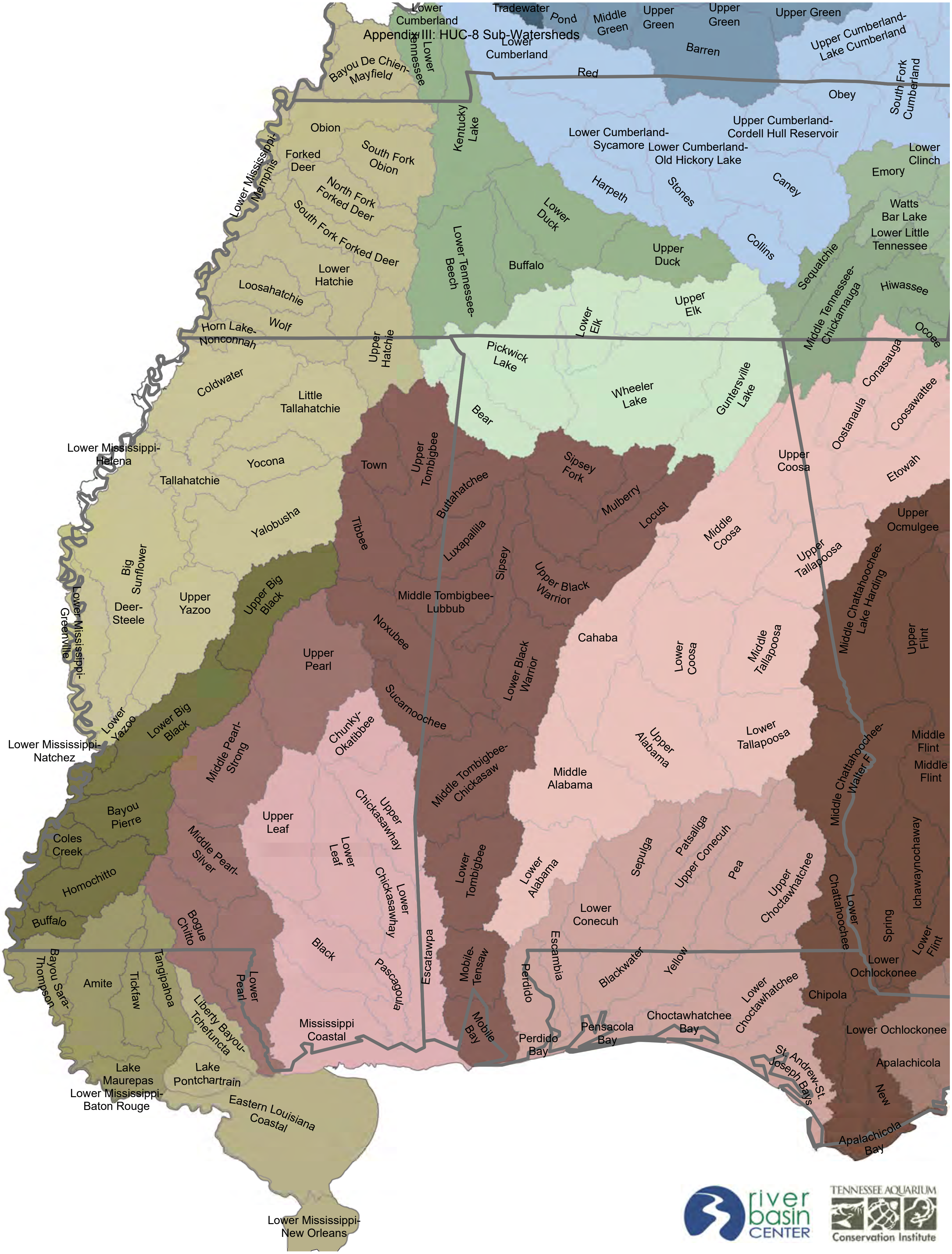
Appendix III: HUC-8 Subwatersheds



Appendix III: HUC-8 Sub-Watersheds



river basin CENTER

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