



# The Southeastern Aquatic Biodiversity Conservation Strategy



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A draft 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. Hazzard  
Bernard R. Kuhajda  
Anna L. George  
*Tennessee Aquarium  
Conservation Institute  
Chattanooga, TN*

## Project Advisory Board

|                  |   |
|------------------|---|
| Susie Adams      | <i>US Forest Service</i>  |
| Paul Angermeier  | <i>Virginia Tech University</i>   |
| Katherine Baer   | <i>River Network</i>  |
| Art Bogan        | <i>North Carolina Museum of Natural Sciences</i>                              |
| Bob Butler       | <i>US Fish &amp; Wildlife Service</i>   |
| Stephanie Chance | <i>US Fish &amp; Wildlife Service</i>   |
| Tanya Darden     | <i>South Carolina Department of Natural Resources</i>                         |
| Jessica Graham   | <i>Southeastern Aquatic Resources Partnership</i>                             |
| Mike Harris      | <i>US Fish &amp; Wildlife Service</i>   |
| Michael LaVoie   | <i>Eastern Band Cherokee Indians</i>  |
| Pat O'Neil       | <i>Geological Survey of Alabama</i>   |
| Peggy Shute      | <i>US Fish &amp; Wildlife Service</i>   |
| Todd Slack       | <i>US Army Corps of Engineers- Engineer Research &amp; Development Center</i> |
| Matt Thomas      | <i>Kentucky Department of Fish &amp; Wildlife Resources</i>                   |

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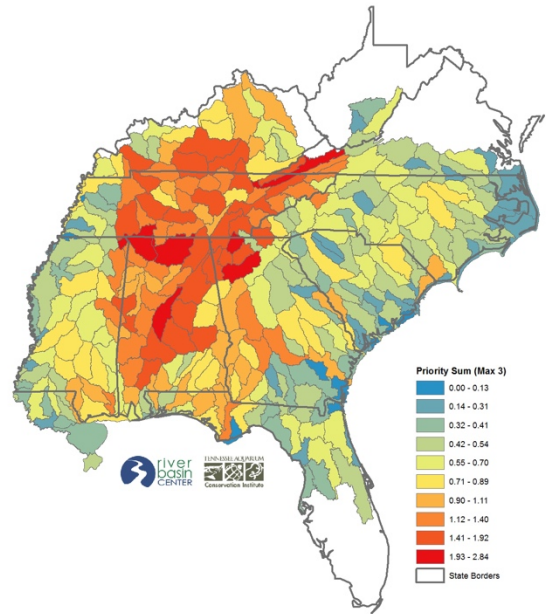
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## Executive Summary

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

This report summarizes an effort to prioritize watersheds within this region to support future conservation investments. We first describe the data sources and methods used to assemble a dataset of almost 1,050 species of fishes, mussels, and 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. Based on a decade of actions by several groups in Raccoon Creek in the Etowah River basin of Georgia, we estimate that approximately \$30 million 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. However, 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). 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 (Burkhead 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, the majority of protected lands are in the intermountain West (Figure 1), while priority areas for biodiversity conservation are in 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 Okefenokee 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).

Protected Areas Database of the United States (PAD-US)  
Version one

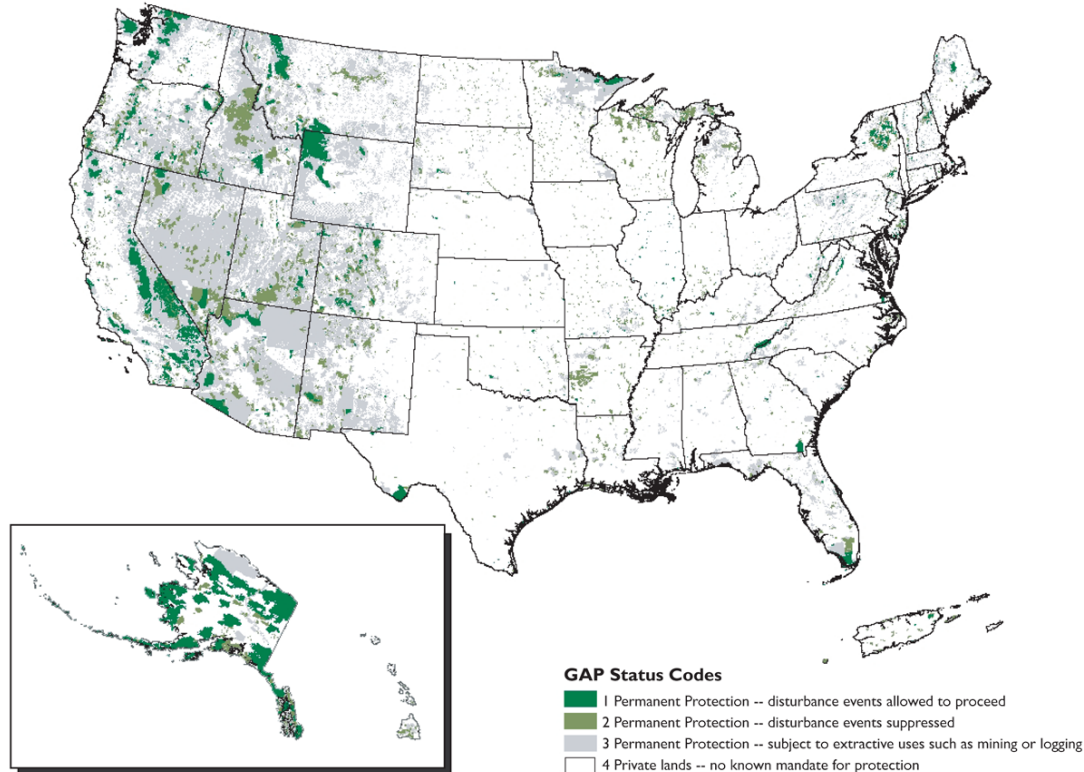


Figure 1. Protected Areas of the US. Source: USGS (<http://gapanalysis.usgs.gov/>)

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.

Despite notable federal initiatives such as the Partners Program, the primary responsibility for wildlife management has traditionally been 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, or “State Wildlife Grants,” 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 State and Tribal Wildlife Grants Program (SWG Program) in 2001 to addresses 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 a goal 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 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 Plans, and include such factors as habitat loss or fragmentation, competition from non-native species, and stressors related to climate change. The Plans identify their habitats, as well as 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*

| <b>Name</b>      | <b>Affiliation</b>   |
|------------------|--|
| 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 before 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.

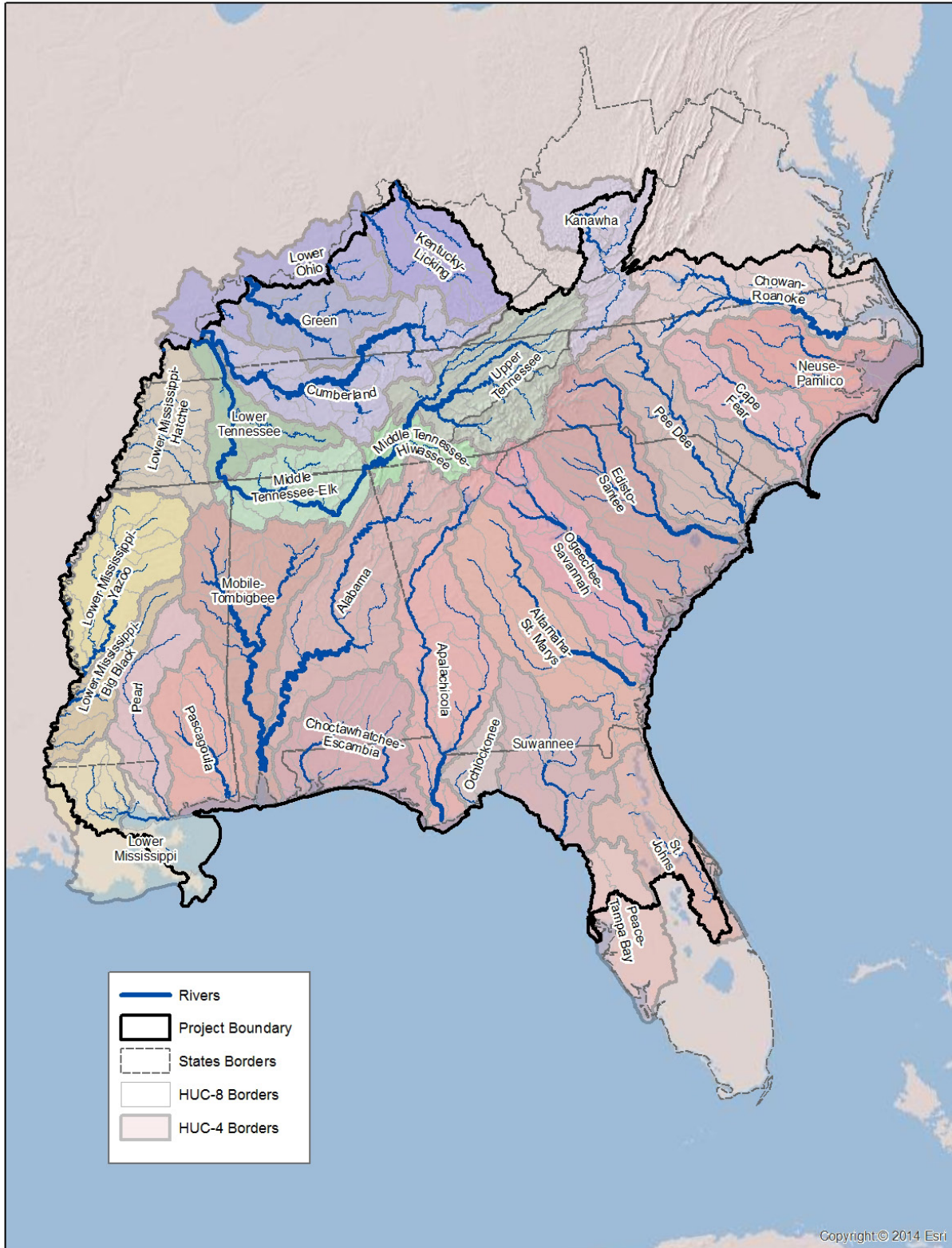


Figure 2 Project Area: "The Southeast." Additional maps of all HUC-8 sub-watersheds in the project area map be found in Appendix II.

## **Data Sources and Aggregation**

To identify the watersheds which, if protected and restored, would contain the highest biodiversity of 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 SGCN 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 SGCN tier specifically excluded ESA-listed species, while in Georgia aquatic species were added to the SGCN 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. 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 (see Citations for vetting of fish subhead within the References section for the references consulted). 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.

Table 2 Astacologists who contributed data or reviewed crayfish distribution maps

| Name                                       | Affiliation                                   | Provided Data | Map Review |           |
|--|---|---------------|------------|-----------|
|  |   |               | In-Person  | Via Email |
| 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         |
| 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         |
| 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          |           |

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 consisted of 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. 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).

*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      |
|                  | Kentucky Department of Fish and Wildlife             | X    |        |
|                  | Geological Survey of Alabama                         | X    |        |
|                  | Georgia 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 fish, mussels, and crayfish 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 mussels, 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.

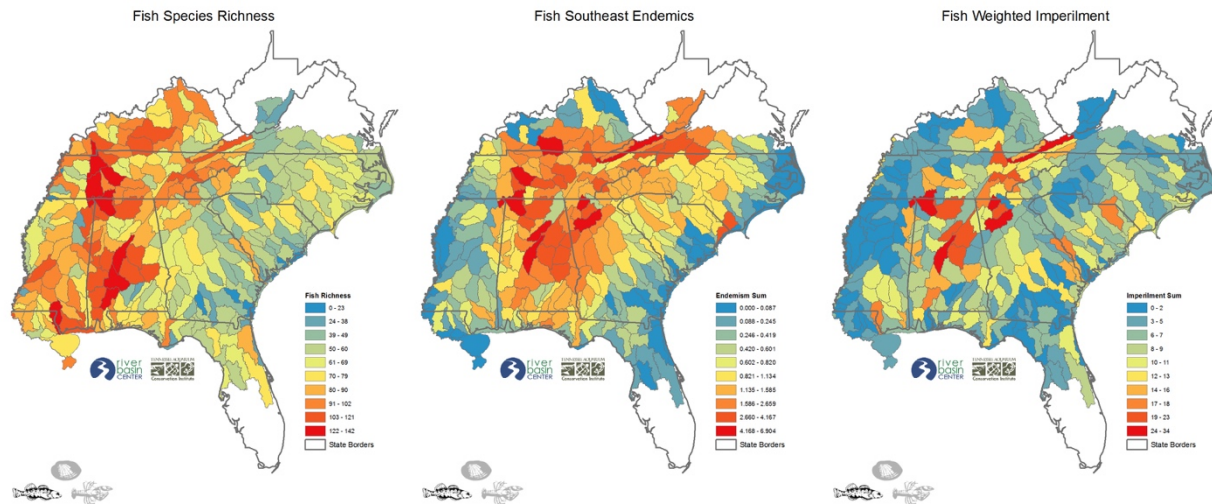


Figure 3 Richness, endemism, and imperilment scores for fishes. Note: large, high resolution versions are included in Appendix I.

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.

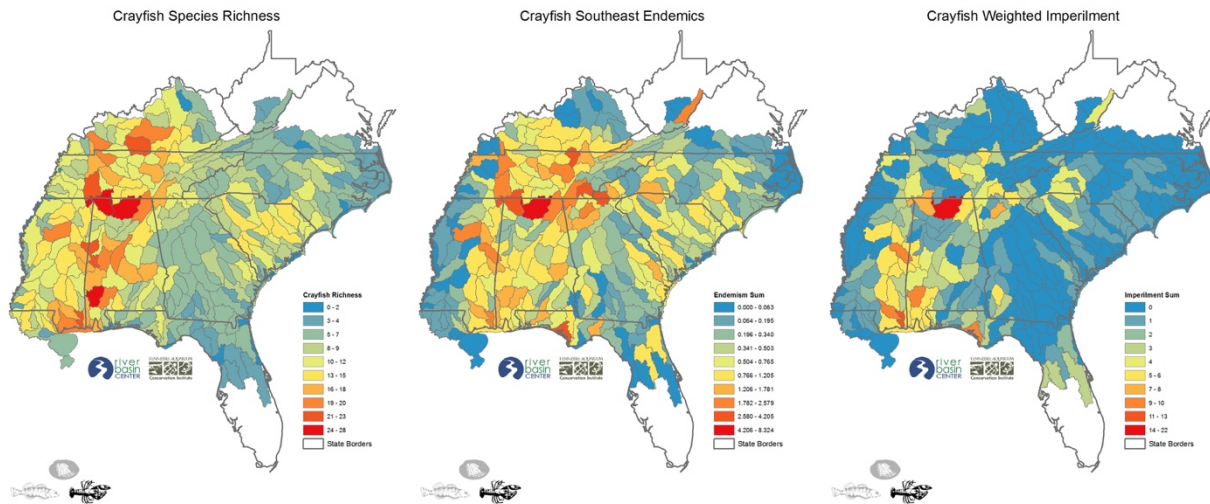


Figure 4 Richness, endemism, and imperilment scores for crayfishes. Note: large, high resolution versions are included in Appendix I.

These scores combine to give Wheeler Lake the highest overall priority for crayfish, with scores dropping off rapidly thereafter. Note that the majority of the top watersheds for crayfish 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), Gunter'sville 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.

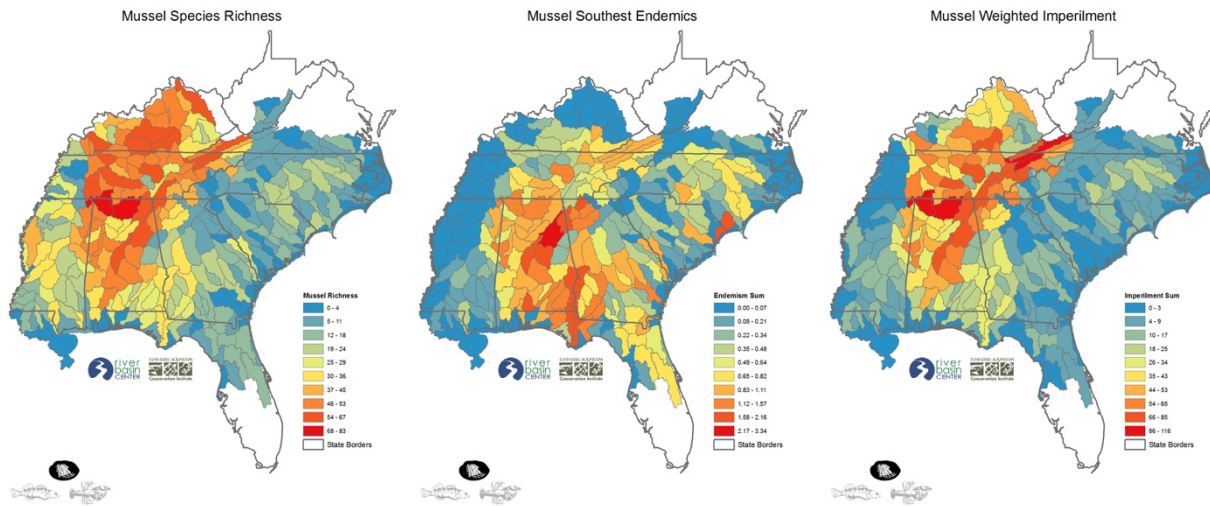


Figure 5 Richness, endemism, and imperilment scores for mussels. Note: large, high resolution versions are included in Appendix I.

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 fish, crayfish, 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 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 ends 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. The Atlantic coastal plain and Mississippi Valley score comparatively lower on this overall ranking.

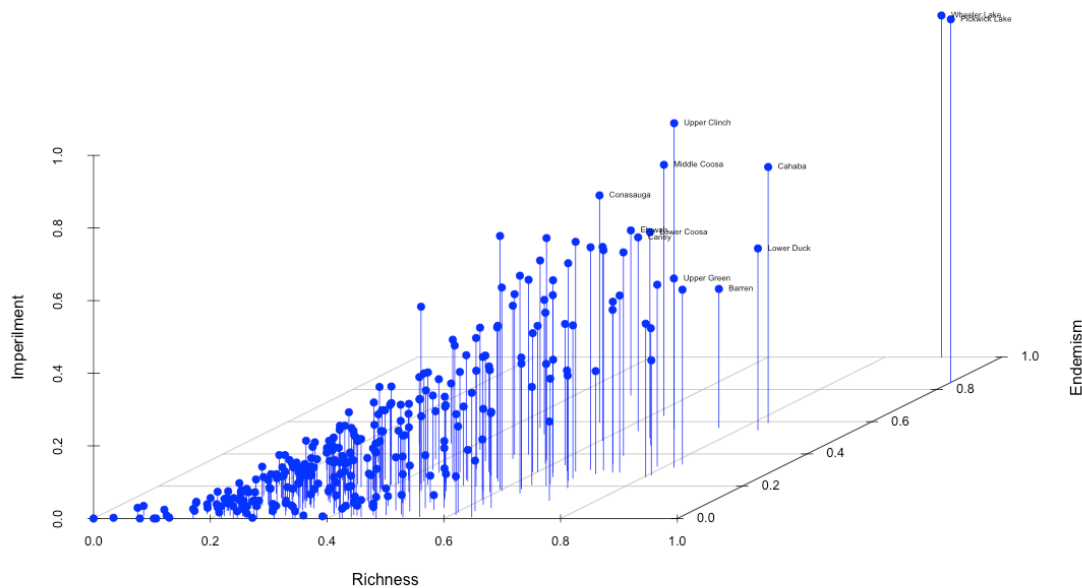


Figure 6 Scaled species richness, southeast endemism, and weighted imperilment for all taxa in 290 HUC-8 sub-basins. Labels indicate the top 12 sub-basins based on the combined priority ranking.

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 97<sup>th</sup> 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.

## Overall Priority Score

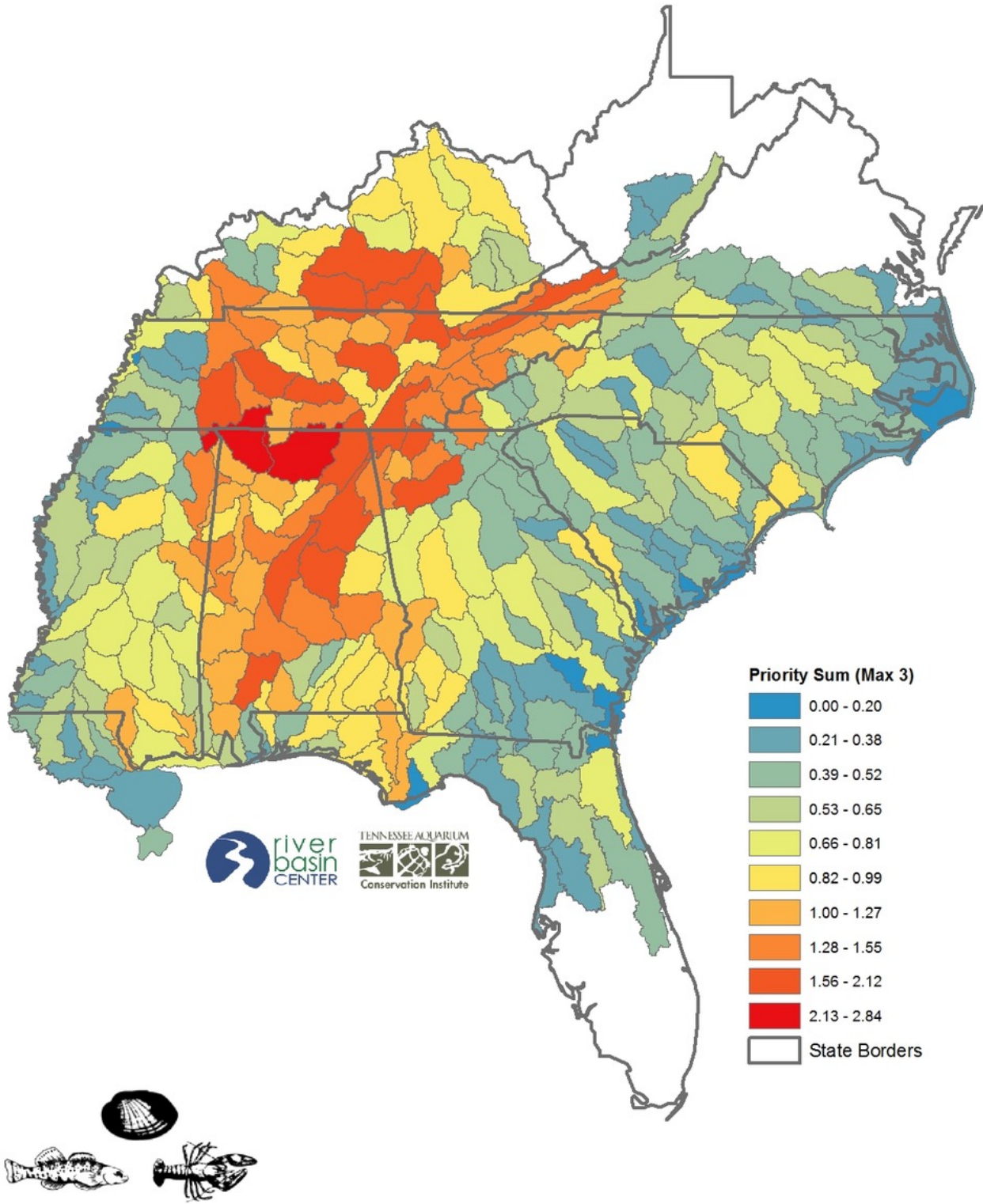


Figure 7 Overall priority score by sub-basin.

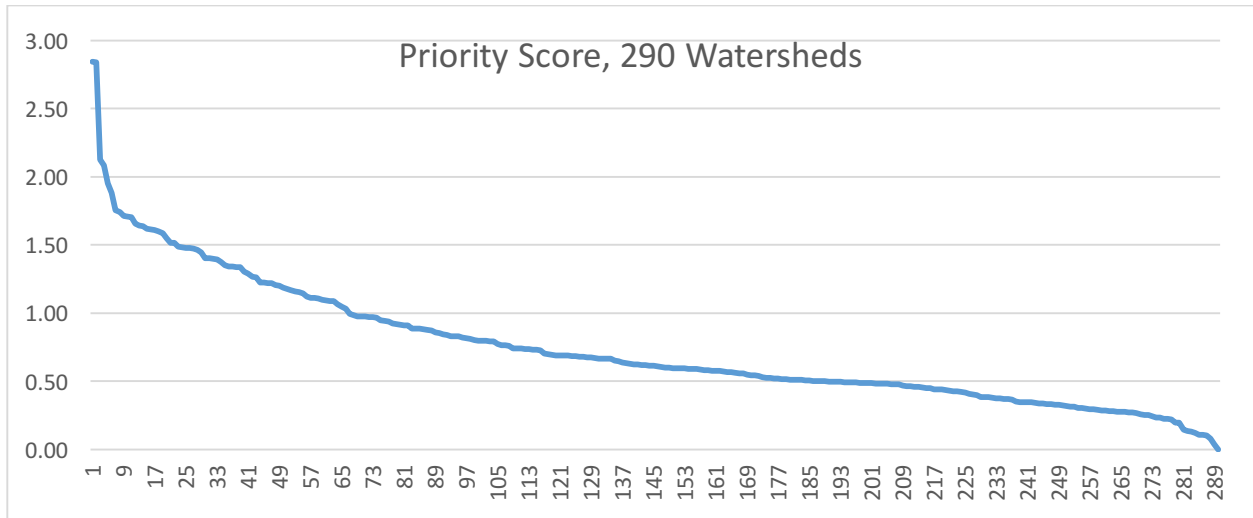


Figure 8 Sorted overall priority score by sub-basin

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 | 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             |
| 10            | 1.71           | Caney         | Cumberland     | 21             |

| Priority Rank | Priority Score | Sub-basin   | Major Drainage | Unique Species |
|---------------|----------------|-------------|----------------|----------------|
| 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.



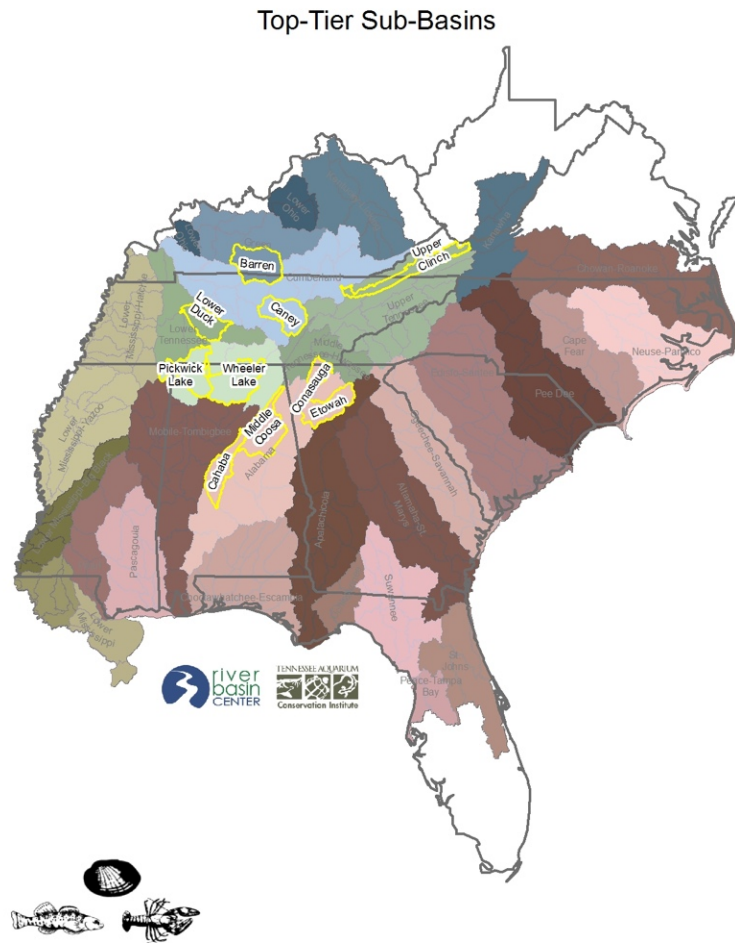


Figure 9. Ten highly biodiverse watersheds where management actions could have major conservation benefits. Shading reflects HUC-2 and HUC-4 boundaries, as in Figure 2.

### ***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.

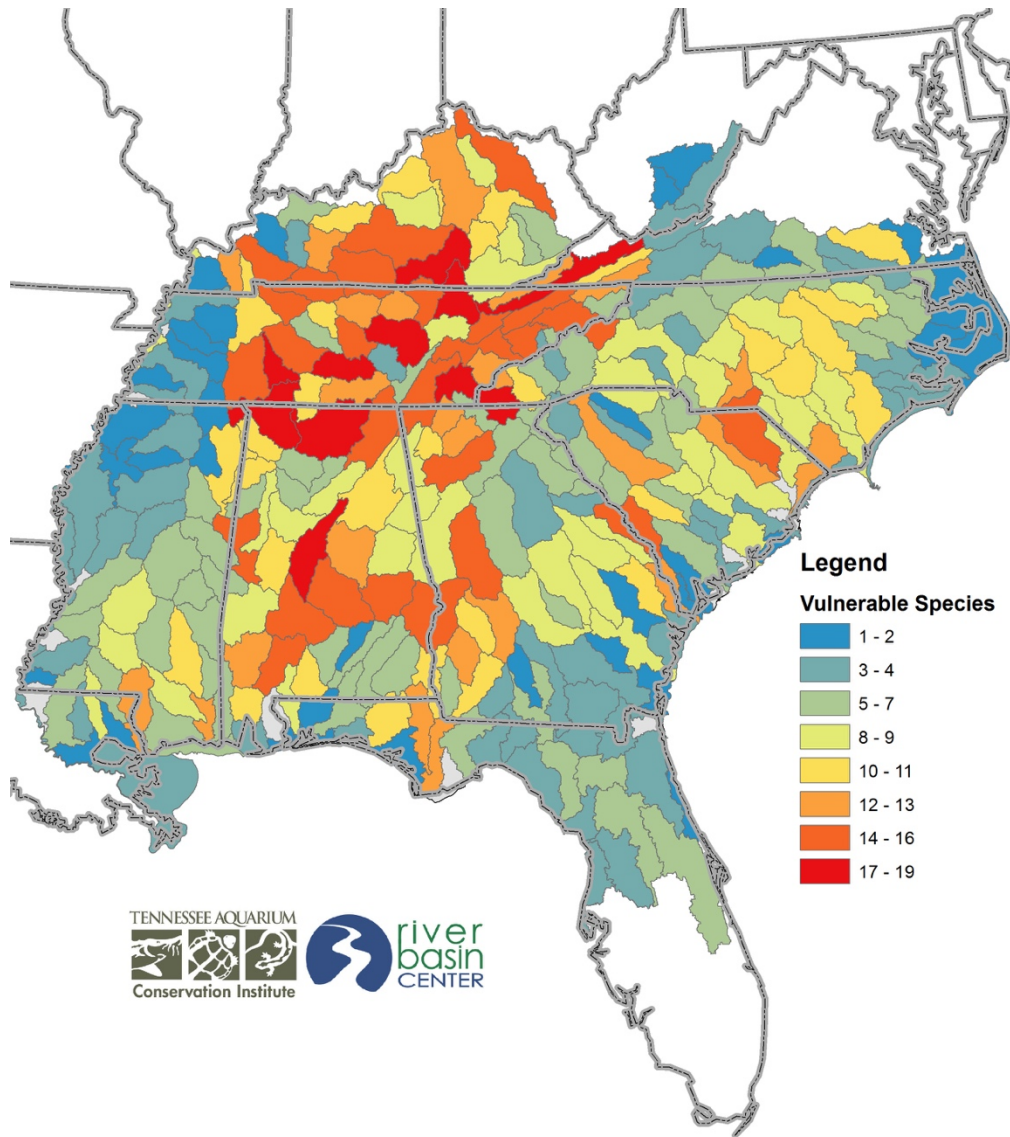


Figure 10 - Count of imperiled species (fishes, crayfishes, and mussels) with "Vulnerable" status by sub-basin.

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 Figure 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 |

### ***Sub-Basin Priority by State***

We recognize that many conservation decisions will not be made at the regional level. For instance, state wildlife agencies are 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 subset the overall 290 sub-basins 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*

| <b>Sub-basin Name</b>            | <b>HUC-8</b> | <b>Regional Rank</b> | <b>State Rank</b> | <b>% In State</b> |
|----------------------------------|--------------|----------------------|-------------------|-------------------|
| 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-<br>Chickamauga | 06020001     | 18                   | 7                 | 3%                |
| Guntersville Lake                | 06030001     | 19                   | 8                 | 83%               |

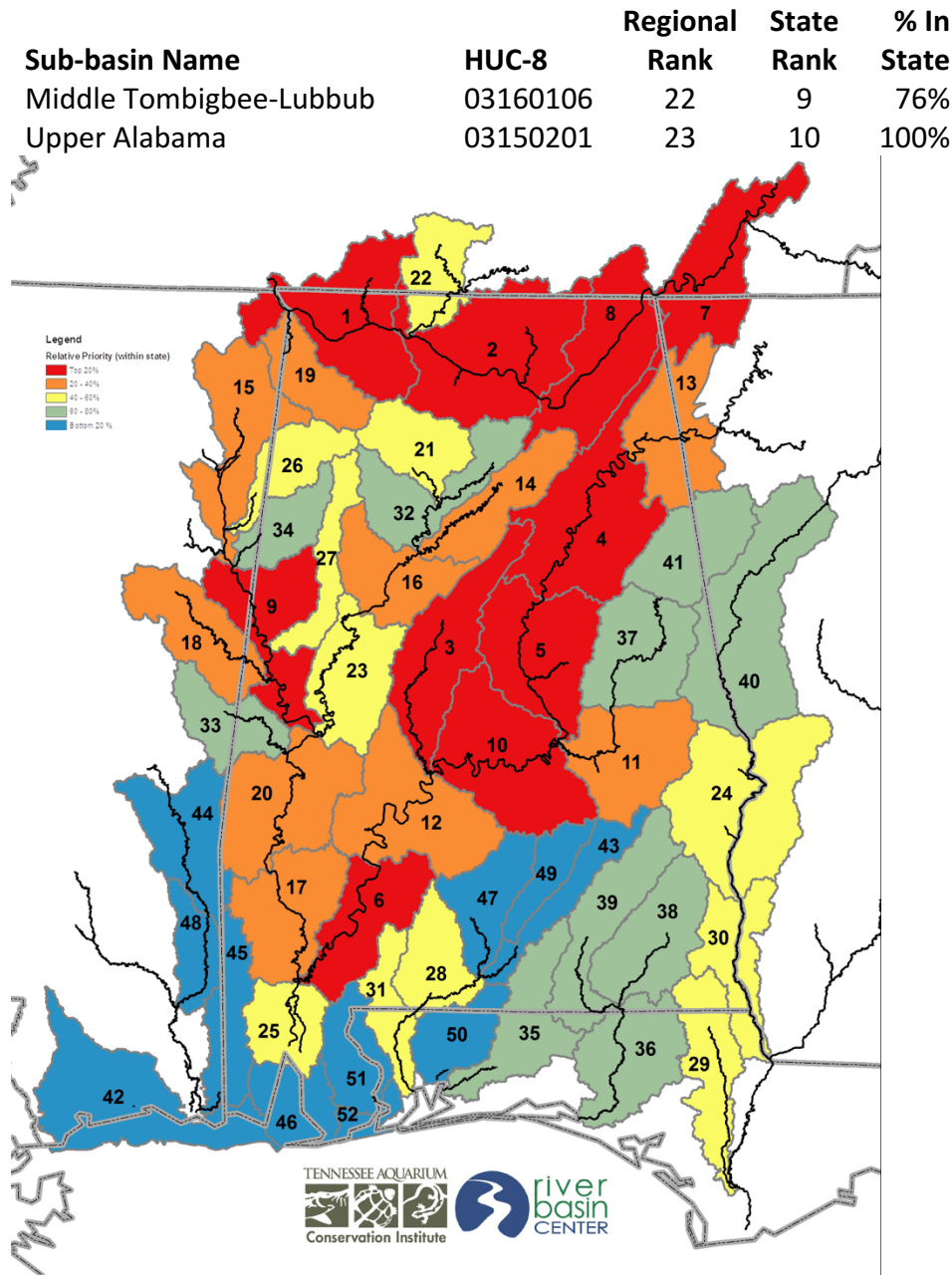


Figure 11 Within-state all-taxa priority rankings for sub-basins in Alabama

**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% |

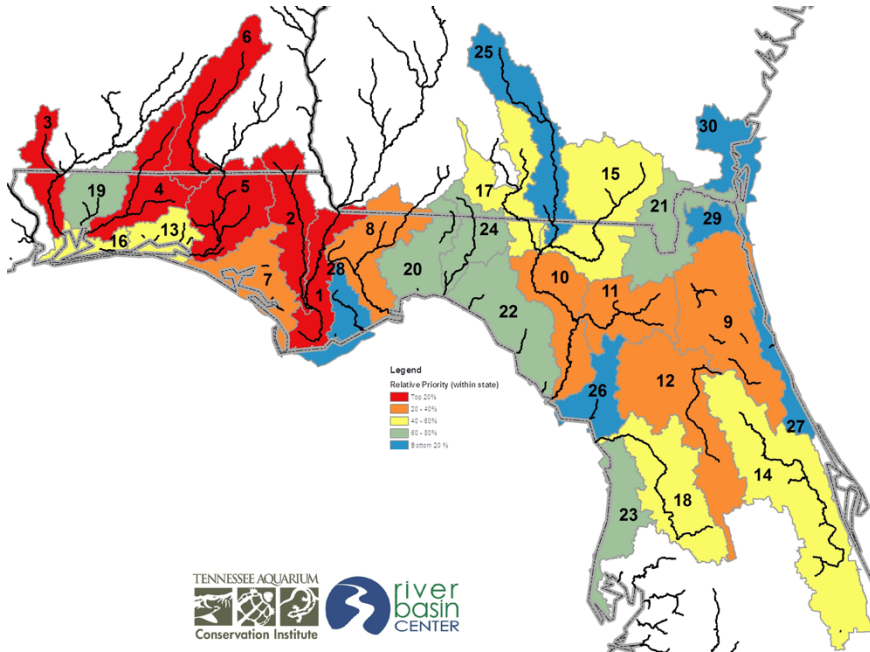


Figure 12 Within-state all-taxa priority rankings for sub-basins in Florida

### 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%        |
| Middle Chattahoochee-Walter F | 03130003 | 56            | 7          | 49%        |
| Oostanaula                    | 03150103 | 59            | 8          | 100%       |
| Apalachicola                  | 03130011 | 60            | 9          | 4%         |
| Upper Flint                   | 03130005 | 78            | 10         | 100%       |



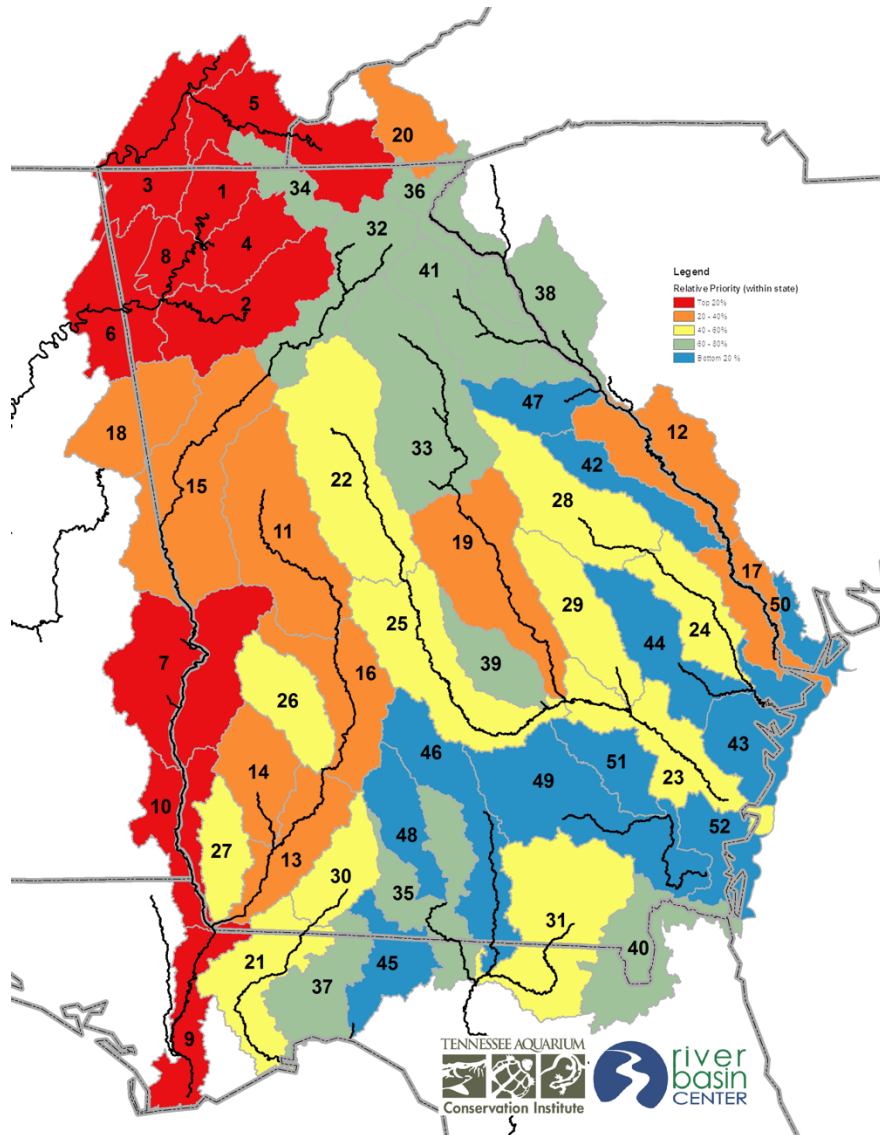


Figure 13 Within-state all-taxa priority rankings for sub-basins in Georgia

### 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%       |
| 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% |

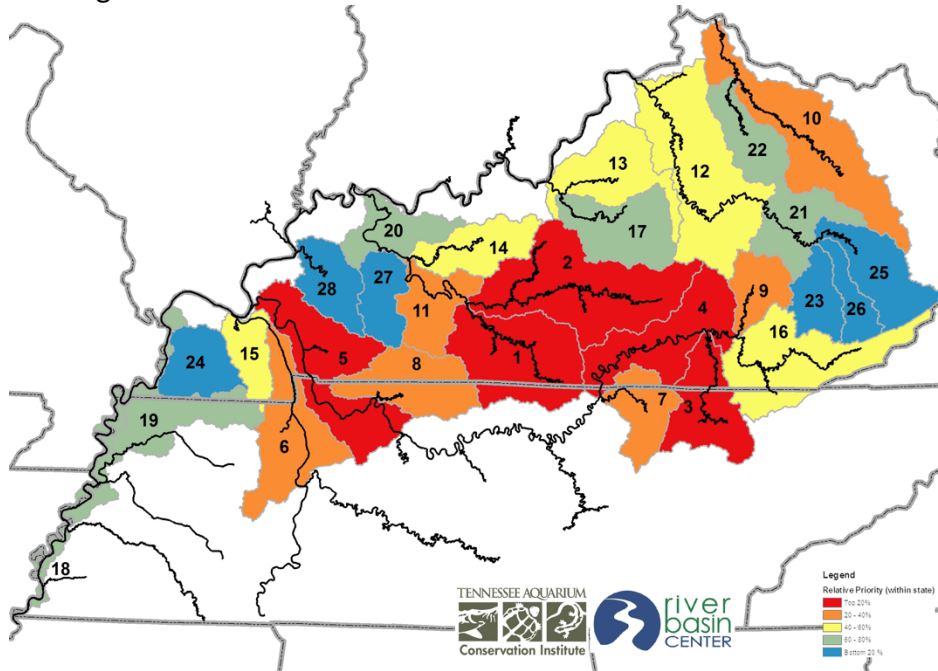


Figure 14 Within-state all-taxa priority rankings for sub-basins in Kentucky

## 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%        |
| Sucarnoochee            | 3160202 | 81            | 10         | 58%        |

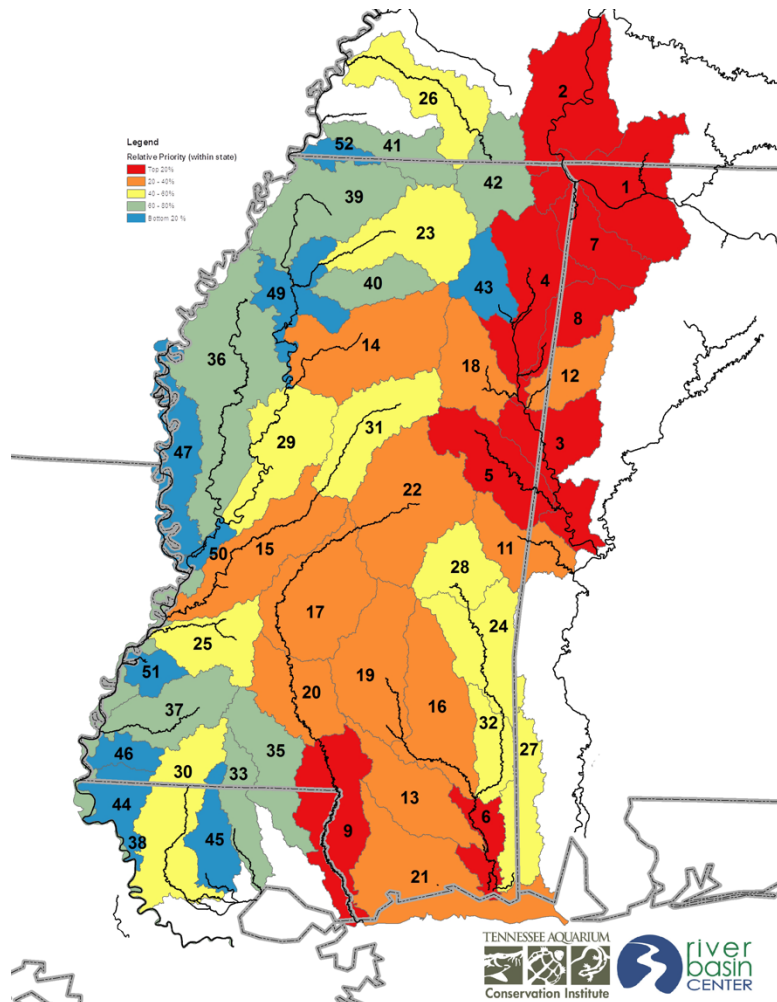


Figure 15 Within-state all-taxa priority rankings for sub-basins in Mississippi

### 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%         |
| Upper Tar              | 03020101 | 110           | 9          | 100%       |
| Upper Little Tennessee | 06010202 | 115           | 10         | 95%        |



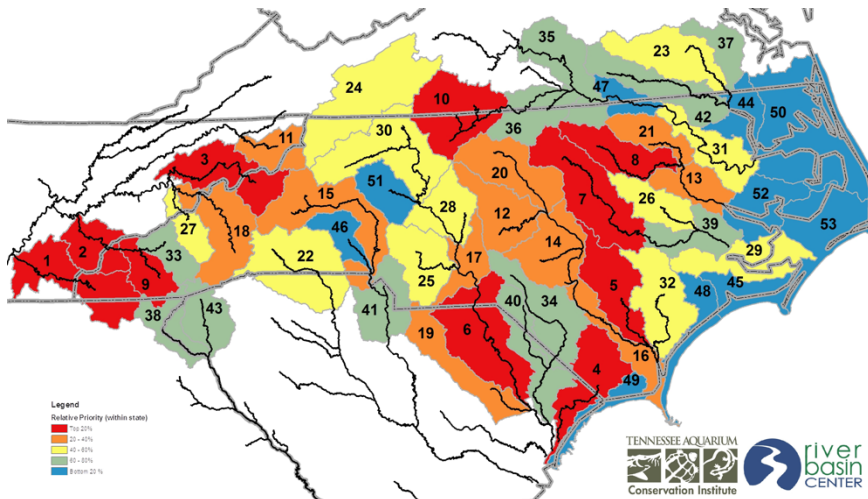


Figure 16 Within-state all-taxa priority rankings for sub-basins in North Carolina

### 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%       |

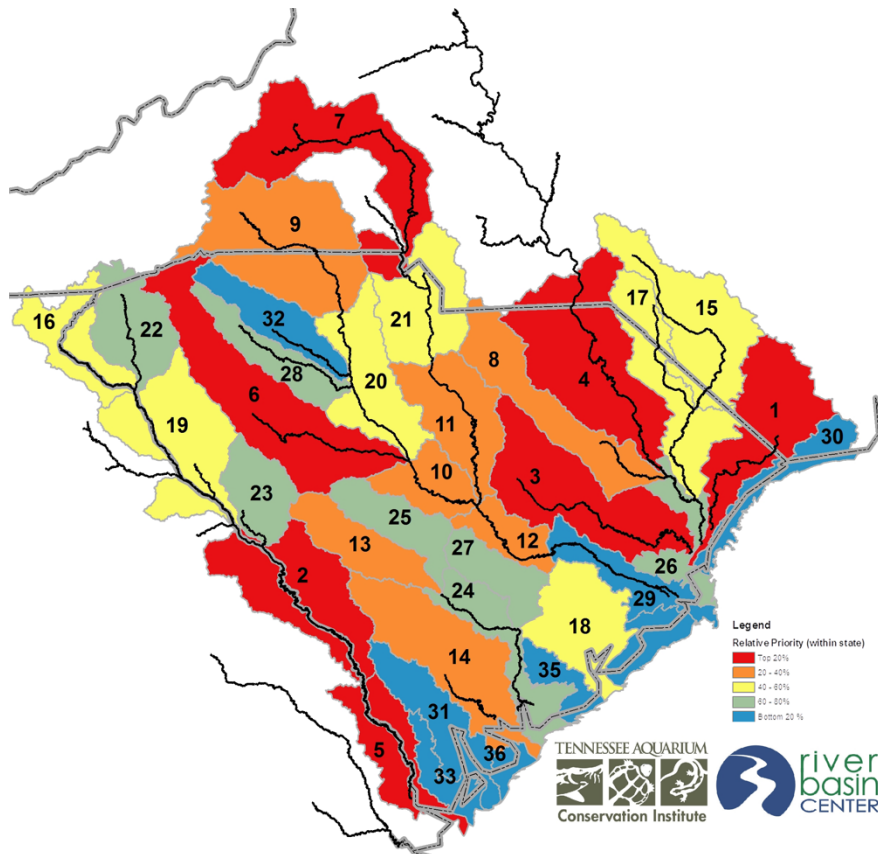


Figure 17 Within-state all-taxa priority rankings for sub-basins in South Carolina

## 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%       |

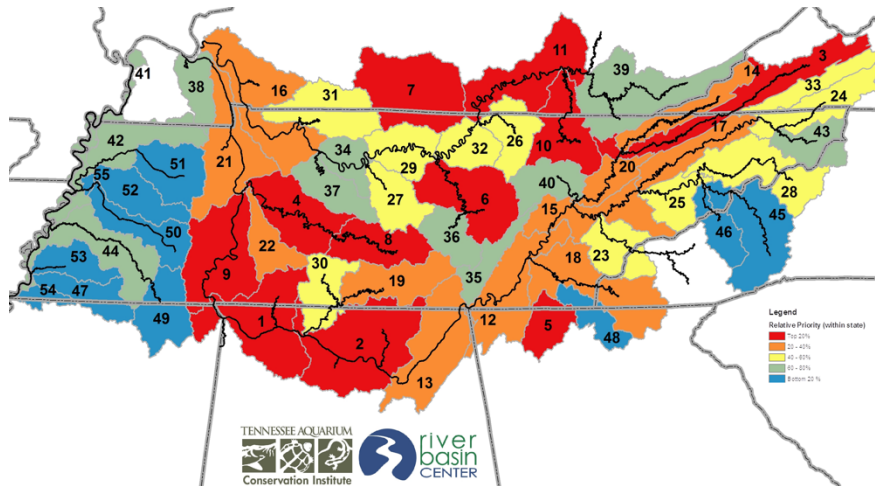


Figure 18 Within-state all-taxa priority rankings for sub-basins in Tennessee

### 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%        |

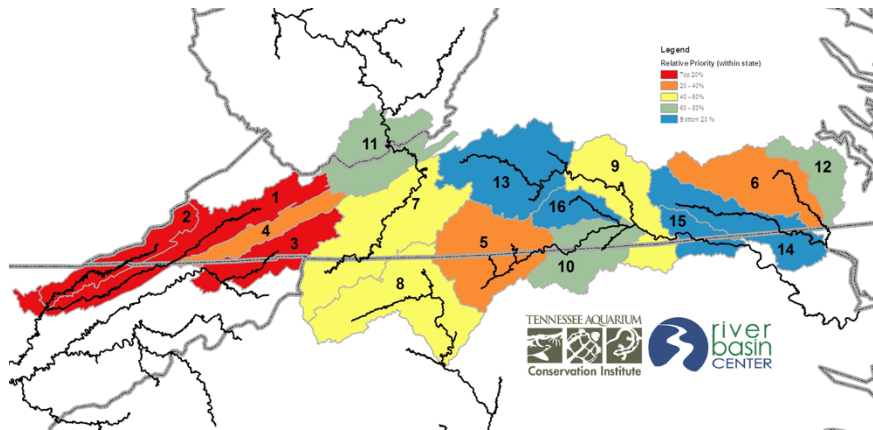


Figure 19 Within-state all-taxa priority rankings for sub-basins in southern Virginia

### 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              |

| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b>     | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|------------------------------------|--------------------------|-----------------------|
| 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                     |
| 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                    |

| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b>          | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|---|--------------------------|-----------------------|
| 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                     |
| 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)      | Ohoopie (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                          | 155                      | 1                     |

| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b>                  | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|---|--------------------------|-----------------------|
| Suwannee (0311)                | (03110205)<br>Santa Fe (03110206)               | 162                      | 2                     |
| Suwannee (0311)                | Upper Suwannee<br>(03110201)                    | 189                      | 3                     |
| Suwannee (0311)                | Withlacoochee (03110203)                        | 204                      | 4                     |
| Suwannee (0311)                | Econfina-Steinhatchee<br>(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<br>(03120003)                 | 117                      | 1                     |
| Ochlockonee (0312)             | Upper Ochlockonee<br>(03120002)                 | 186                      | 2                     |
| Ochlockonee (0312)             | Apalachee Bay-St. Marks<br>(03120001)           | 216                      | 3                     |
| Apalachicola (0313)            | Middle Chattahoochee-<br>Walter F (03130003)    | 56                       | 1                     |
| Apalachicola (0313)            | Apalachicola (03130011)                         | 60                       | 2                     |
| Apalachicola (0313)            | Chipola (03130012)                              | 66                       | 3                     |
| Apalachicola (0313)            | Lower Chattahoochee<br>(03130004)               | 70                       | 4                     |
| Apalachicola (0313)            | Upper Flint (03130005)                          | 78                       | 5                     |
| Apalachicola (0313)            | Lower Flint (03130008)                          | 88                       | 6                     |
| Apalachicola (0313)            | Ichawaynochaway<br>(03130009)                   | 90                       | 7                     |
| Apalachicola (0313)            | Middle Chattahoochee-Lake<br>Harding (03130002) | 100                      | 8                     |
| Apalachicola (0313)            | Middle Flint (03130006)                         | 103                      | 9                     |
| Apalachicola (0313)            | Kinchafoonee-Muckalee<br>(03130007)             | 138                      | 10                    |
| Apalachicola (0313)            | Spring (03130010)                               | 144                      | 11                    |
| Apalachicola (0313)            | Upper Chattahoochee<br>(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<br>(03140203)              | 81                       | 4                     |

| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b>        | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|---------------------------------------|--------------------------|-----------------------|
| 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                    |
| 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-                     | 49                       | 7                     |



| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b> | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|--------------------------------|--------------------------|-----------------------|
|                                | Chickasaw (03160201)           |                          |                       |
| 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                    |
| 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             | 132                      | 4                     |

| <b>Huc-4 Name (HUC-4 Code)</b> | <b>HUC-8 Name (HUC-8 Code)</b>                        | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--------------------------------|---|--------------------------|-----------------------|
| Kentucky-Licking (0510)        | (05100102)<br>South Fork Kentucky                     | 147                      | 5                     |
| Kentucky-Licking (0510)        | (05100203)<br>North Fork Kentucky                     | 165                      | 6                     |
| Kentucky-Licking (0510)        | (05100201)<br>Middle Fork Kentucky                    | 174                      | 7                     |
| Green (0511)                   | (05100202)<br>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                     |
| Cumberland (0513)              | Caney (05130108)                                      | 10                       | 1                     |
| Cumberland (0513)              | South Fork Cumberland<br>(05130104)                   | 15                       | 2                     |
| Cumberland (0513)              | Upper Cumberland-Lake<br>Cumberland (05130103)        | 16                       | 3                     |
| Cumberland (0513)              | Lower Cumberland<br>(05130205)                        | 24                       | 4                     |
| Cumberland (0513)              | Obey (05130105)                                       | 40                       | 5                     |
| Cumberland (0513)              | Stones (05130203)                                     | 43                       | 6                     |
| Cumberland (0513)              | Lower Cumberland-Old<br>Hickory Lake (05130201)       | 47                       | 7                     |
| Cumberland (0513)              | Red (05130206)  | 53                       | 8                     |
| Cumberland (0513)              | Upper Cumberland-Cordell<br>Hull Reservoir (05130106) | 54                       | 9                     |
| Cumberland (0513)              | Lower Cumberland-<br>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<br>(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,<br>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                     |

| <b>Huc-4 Name (HUC-4 Code)</b>   | <b>HUC-8 Name (HUC-8 Code)</b>                | <b>Regional Priority</b> | <b>Basin Priority</b> |
|----------------------------------|---|--------------------------|-----------------------|
| 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                    |
| 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                     |

| <b>Huc-4 Name (HUC-4 Code)</b>         | <b>HUC-8 Name (HUC-8 Code)</b>          | <b>Regional Priority</b> | <b>Basin Priority</b> |
|--|---|--------------------------|-----------------------|
| 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 (08010211)          | 285                      | 11                    |
| 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        | Lower Mississippi-Baton                 | 183                      | 3                     |

| Huc-4 Name (HUC-4 Code)                | HUC-8 Name (HUC-8 Code)                  | Regional Priority | Basin Priority |
|--|--|-------------------|----------------|
| (0807)                                 | Rouge (08070100)                         |                   |                |
| 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              |
| 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                  |
|              | <i>Acipsenser oxirynchus desotoi</i> | dams                            |
|              | <i>Alosa alabamae</i>                | dams                            |
|              | <i>Cyprinella caerulea</i>           | sedimentation                   |
|              | <i>Hybognathus nuchalis</i>          | dams                            |
|              | <i>Fundulus stellifer</i>            | unknown                         |
|              | <i>Mugil cephalus</i>                | dams                            |
|              | <i>Sander sp. cf. vitreus</i>        | unknown, possibly hybridization |
| Lower Coosa  | 107 total species, 3 extirpated      | (2.8%)                          |
|              | Species                              | Putative cause                  |
|              | <i>Acipsenser oxirynchus desotoi</i> | dams                            |
|              | <i>Scaphirhynchus suttkusi</i>       | dams                            |
| Middle Coosa | 87 total species, 1 extirpated       | (1.1%)                          |
|              | Species                              | Putative cause                  |
|              | <i>Percina brevicauda</i>            | dams                            |
| Etowah       | 81 total species, 1 extirpated       | (1.2%)                          |
|              | Species                              | Putative cause                  |
| Conasauga    | <i>Cyprinella caerulea</i>           | sedimentation                   |
|              | 80 total species, 2 extirpated       | (2.5%)                          |
|              | Species                              | Putative cause                  |
| Lower Duck   | <i>Noturus sp. cf. munitus</i>       | Sedimentation & water quality   |
|              | <i>Percina shumardi</i>              | unknown                         |
| Pick wick    | 133 total species, none extirpated   | (0%)                            |
|              | 142 total species, 10 extirpated     | (7%)                            |
|              | Species                              | Putative cause                  |

|              |                                     |                               |
|--------------|-------------------------------------|-------------------------------|
|              | <i>Scaphirhynchus platyrhynchus</i> | dams                          |
|              | <i>Hiodon alosoides</i>             | dams                          |
|              | <i>Hybognathus hayi</i>             | drainage of wetlands          |
|              | <i>Hybognathus nuchalis</i>         | dams                          |
|              | <i>Notropis albizonatus</i>         | dams                          |
|              | <i>Notropis ariommus</i>            | dams                          |
|              | <i>Noturus miurus</i>               | sedimentation & water quality |
|              | <i>Etheostoma cinereum</i>          | dams                          |
|              | <i>Percina vigil</i>                | dams                          |
|              | <i>Elassoma alabamae</i>            | dams                          |
|              | 120 total species, 7 extirpated     | (5.8%)                        |
|              | Species                             | Putative cause                |
| Wheeler      | <i>Scaphirhynchus platyrhynchus</i> | dams                          |
|              | <i>Lepisosteus platostomus</i>      | dams                          |
|              | <i>Hiodon alosoides</i>             | dams                          |
|              | <i>Hybognathus hayi</i>             | drainage of wetlands          |
|              | <i>Hybognathus nuchalis</i>         | dams                          |
|              | <i>Phenacobius uranops</i>          | dams                          |
|              | <i>Noturus crypticus</i>            | sedimentation & water quality |
|              |                                     |                               |
|              | 110 total species, 4 extirpated     | (3.6%)                        |
|              | Species                             | Putative cause                |
| Upper Clinch | <i>Macrhybopsis hyostoma</i>        | dams                          |
|              | <i>Notropis albizonatus</i>         | dams                          |
|              | <i>Notropis buchanani</i>           | dams                          |
|              | <i>Cycleptus elongatus</i>          | dams                          |
|              |                                     |                               |
| Caney Fork   | 86 total species, no extirpations   | (0%)                          |
|              | 109 total species, 4 extirpations   | (3.7%)                        |
|              | Species                             | Putative cause                |
| Barren       | <i>Hybognathus nuchalis</i>         | dams                          |
|              | <i>Notropis amnis</i>               | unknown                       |
|              | <i>Noturus exilis</i>               | unknown                       |
|              | <i>Percina evides</i>               | 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%)<br>Species<br><i>Elliptio arca</i><br><i>Epioblasma penita</i><br><i>Lasmigona etowaensis</i><br><i>Ligumia recta</i><br><i>Medionidus parvulus</i><br><i>Obovaria arkansasensis</i><br><i>Obovaria unicolor</i><br><i>Pleurobema hanleyianum</i><br><i>Pleurobema hartmanianum</i><br><i>Pleurobema stabile</i><br><i>Pleurobema taitianum</i> |
| Lower Coosa  | 52 total species, 9 extirpations (17%)<br>Species<br><i>Elliptio arca</i><br><i>Epioblasma penita</i><br><i>Lasmigona etowaensis</i><br><i>Ligumia recta</i><br><i>Medionidus parvulus</i><br><i>Obovaria unicolor</i><br><i>Pleurobema hanleyianum</i><br><i>Pleurobema hartmanianum</i><br><i>Pleurobema stabile</i>  |

|               |   |
|---------------|---|
| Cahaba        | <p>58 total species, 6 extirpations (10%)<br/>                 Species<br/> <i>Elliptio arca</i><br/> <i>Medionidus parvulus</i><br/> <i>Obovaria arkansasensis</i><br/> <i>Obovaria unicolor</i><br/> <i>Pleurobema georgianum</i><br/> <i>Pleurobema perovatum</i></p>  |
| Pickwick Lake | <p>83 total species, 29 extirpations (35%)<br/>                 Species<br/> <i>Actinonaias ligamentina</i><br/> <i>Actinonaias pectorosa</i><br/> <i>Alasmidonta marginata</i><br/> <i>Alasmidonta viridis</i><br/> <i>Dromus dromas</i><br/> <i>Epioblasma ahlstedti</i><br/> <i>Epioblasma brevidens</i><br/> <i>Epioblasma capsaeformis</i><br/> <i>Epioblasma obliquata obliquata</i><br/> <i>Epioblasma triquetra</i><br/> <i>Fusconaia cor</i><br/> <i>Fusconaia cuneolus</i><br/> <i>Hemistena lata</i><br/> <i>Lasmigona costata</i><br/> <i>Leptodea leptodon</i><br/> <i>Medionidus conradicus</i><br/> <i>Obovaria olivaria</i><br/> <i>Obovaria retusa</i><br/> <i>Obovaria subrotunda</i><br/> <i>Plethobasus cooperianus</i><br/> <i>Pleurobema clava</i><br/> <i>Pleurobema oviforme</i><br/> <i>Pleurobema dolabelloides</i><br/> <i>Ptychobranthus subtentus</i><br/> <i>Quadrula intermedia</i><br/> <i>Quadrula sparsa</i><br/> <i>Strophitus undulatus</i><br/> <i>Toxolasma cylindrellus</i><br/> <i>Villosa trabalis</i></p> |
| Wheeler Lake  | <p>78 total species, 15 extirpations (19%)<br/>                 Species<br/> <i>Actinonaias ligamentina</i></p>   |

*Cyprogenia stegaria*  
*Dromus dromas*  
*Epioblasma brevidens*  
*Epioblasma capsaeformis*  
*Epioblasma florentina aureola*  
*Lemiox rimosus*  
*Obovaria olivaria*  
*Obovaria retusa*  
*Plethobasus cicatricosus*  
*Plethobasus cooperianus*  
*Pleurobema clava*  
*Ptychobranhus 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 of 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 fish and crayfish, 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 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.

### Potential Capacity: Watershed Groups

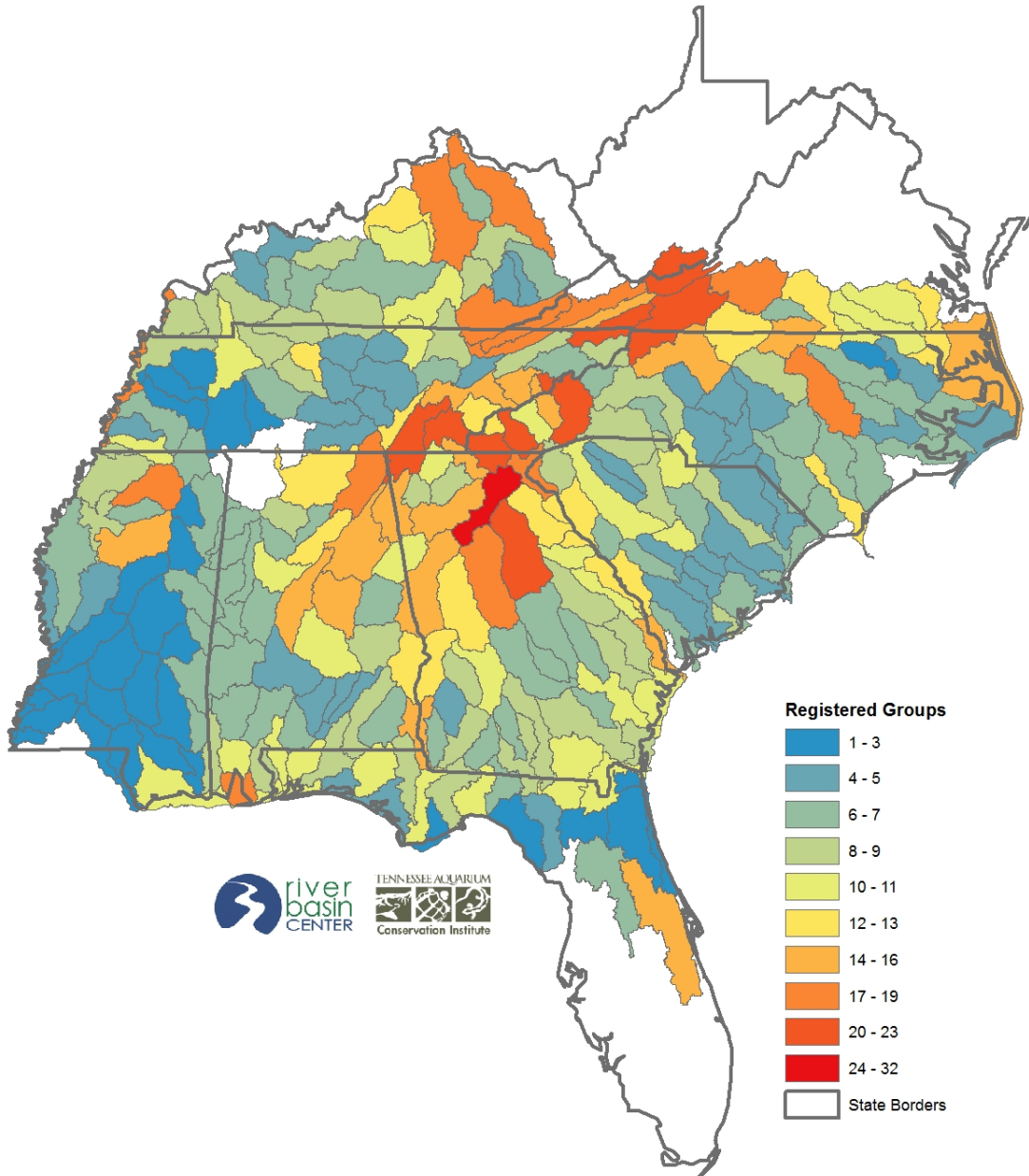


Figure 20 Total number of watershed groups registered in EPA database, per sub-basin, in August 2015

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%).

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

| <b>Activity Category</b>   | <b># Groups/Projects</b> |
|--|--------------------------|
| 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                        |
| <b>Grand Total</b>   | <b>2229</b>              |

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 only nine did not update either their name, email, website, zip, or geographic focus, and 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).

### Potential Capacity: Focal Areas for Watershed Groups that Responded

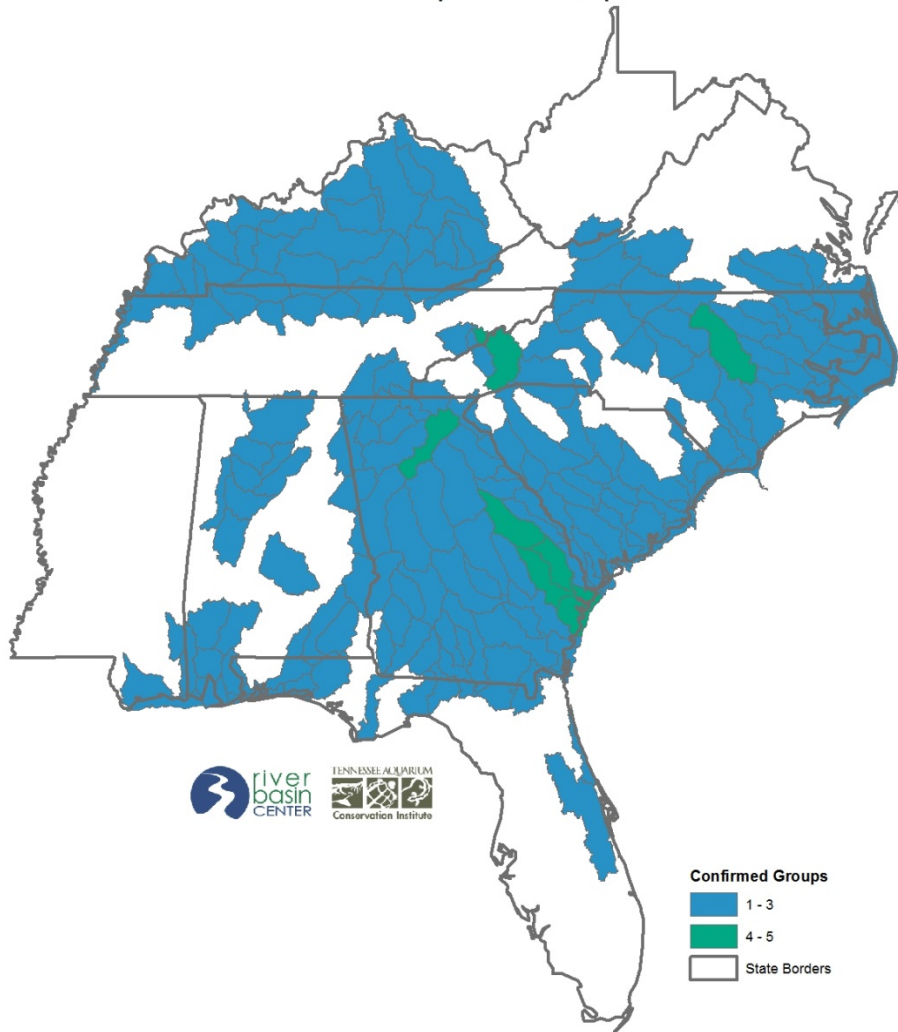


Figure 21 Total number of watershed groups registered, per sub-basin, among survey respondents

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%).



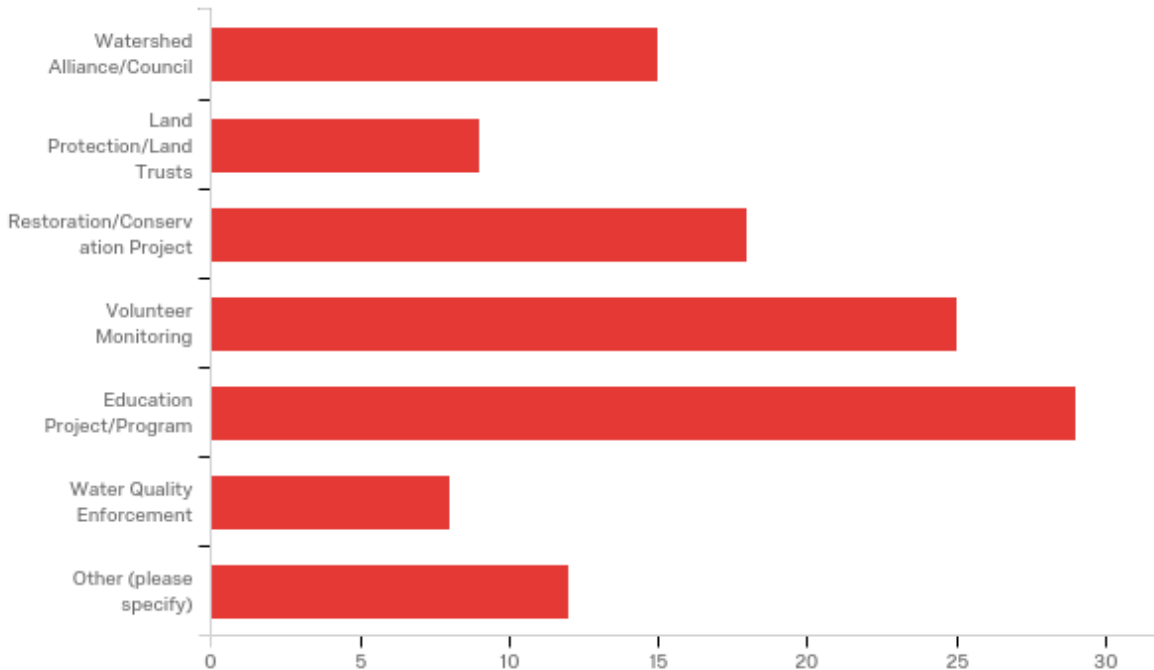


Figure 22- Frequency of group or project objectives on the responses of 51 watershed groups completing surveys. (Respondents were allowed to select more than one response.)

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 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, by examining a multi-faceted, long-term conservation campaign 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 could have benefits out of proportion to the low cost, particularly given the increasing attention and support being given at the federal and state level to the removal of derelict dams and the efforts 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. Another model is the successful implementation of landowner incentives for the planting of herbaceous and vegetative buffers in the Elk River watershed of Tennessee. This 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, supplements the payments already available through NRCS in an area where high commodity process had made buffer implementation unattractive, resulting 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. This project has resulted in almost 200 acres of buffer planting in trees or native warm-season grasses at a cost of just over \$315,000. 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*. Combined with costs due to altered operations to benefit salmon, BPA spends nearly 20% of its budget managing for salmon. The main energy companies of the Southeast that operate hydropower facilities (Duke Energy, Southern Company and the Tennessee Valley Authority) collectively have much greater revenue than BPA, taking in over \$50 billion per year. If they devoted just two tenths of one percent of this to aquatic conservation (equivalent to ten cents out of a \$50 electric bill), that would provide \$100 million in annual funding. This is just an illustration, but the unavoidable conclusion is this: as a society we have the resources to easily achieve major conservation goals for this global biodiversity hotspot, if we only decide to do so.

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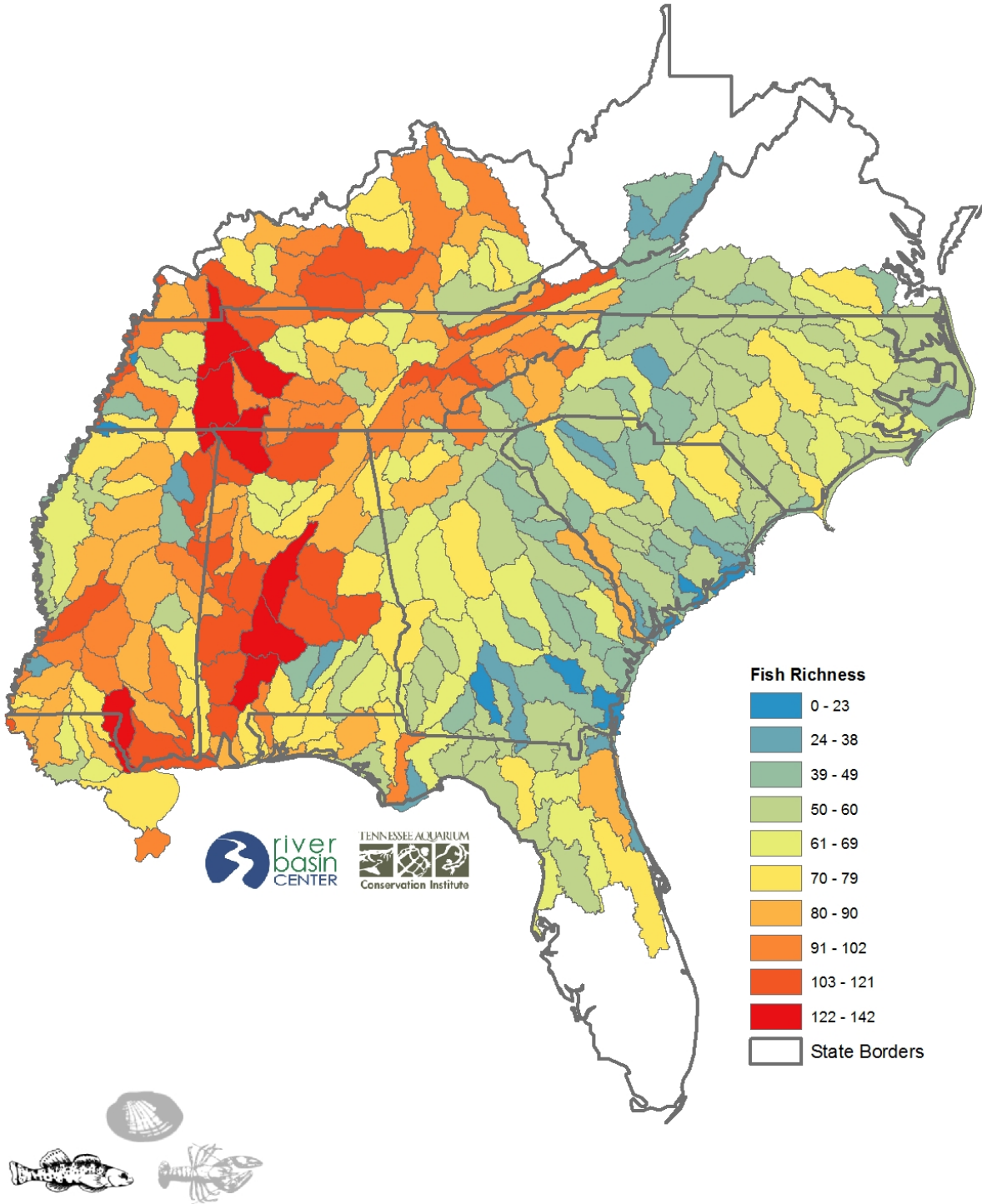
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## Appendix I. Fish, Crayfish, and Mussel Maps

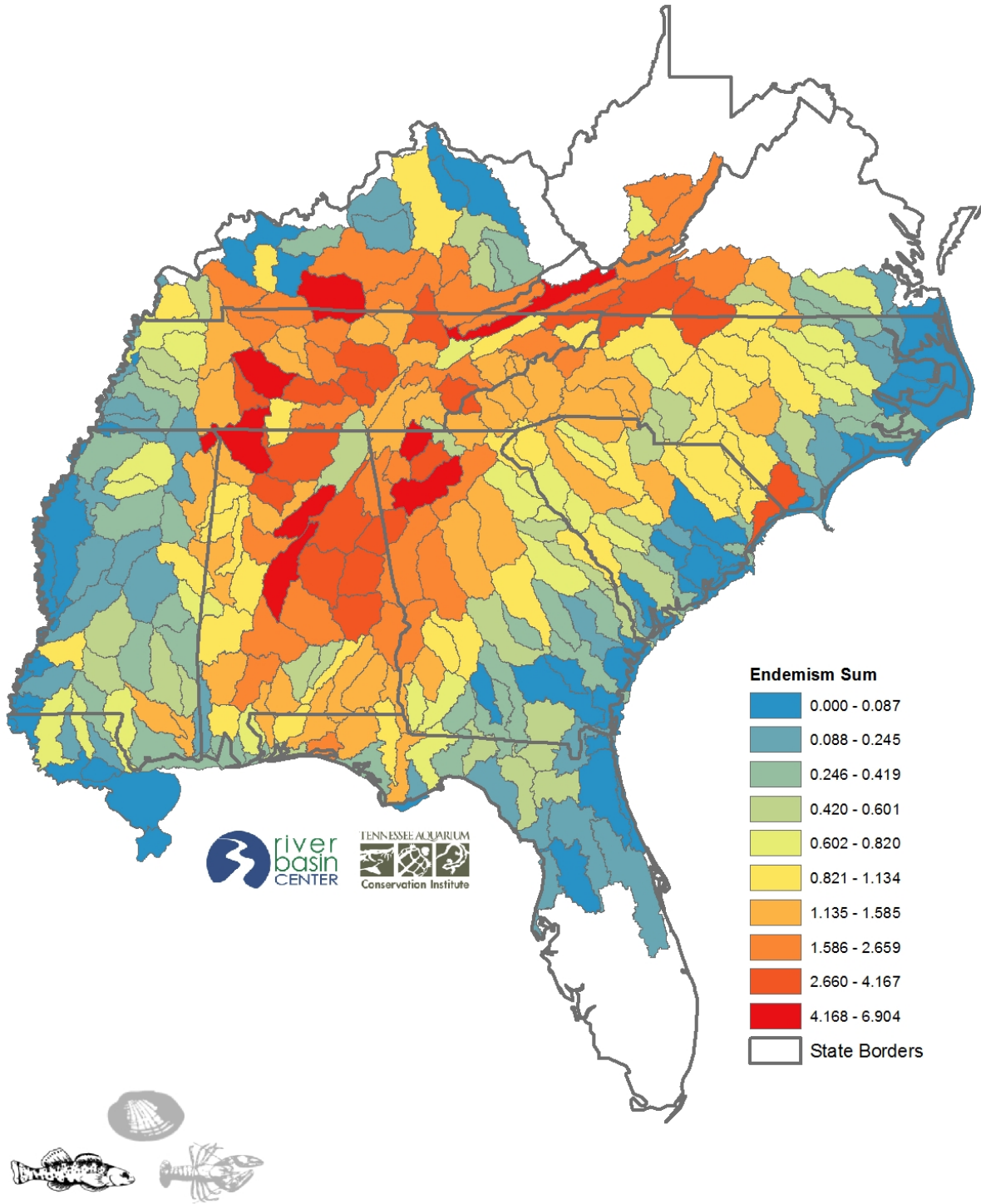
### Appendix I

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](http://www.southeastfreshwater.org)

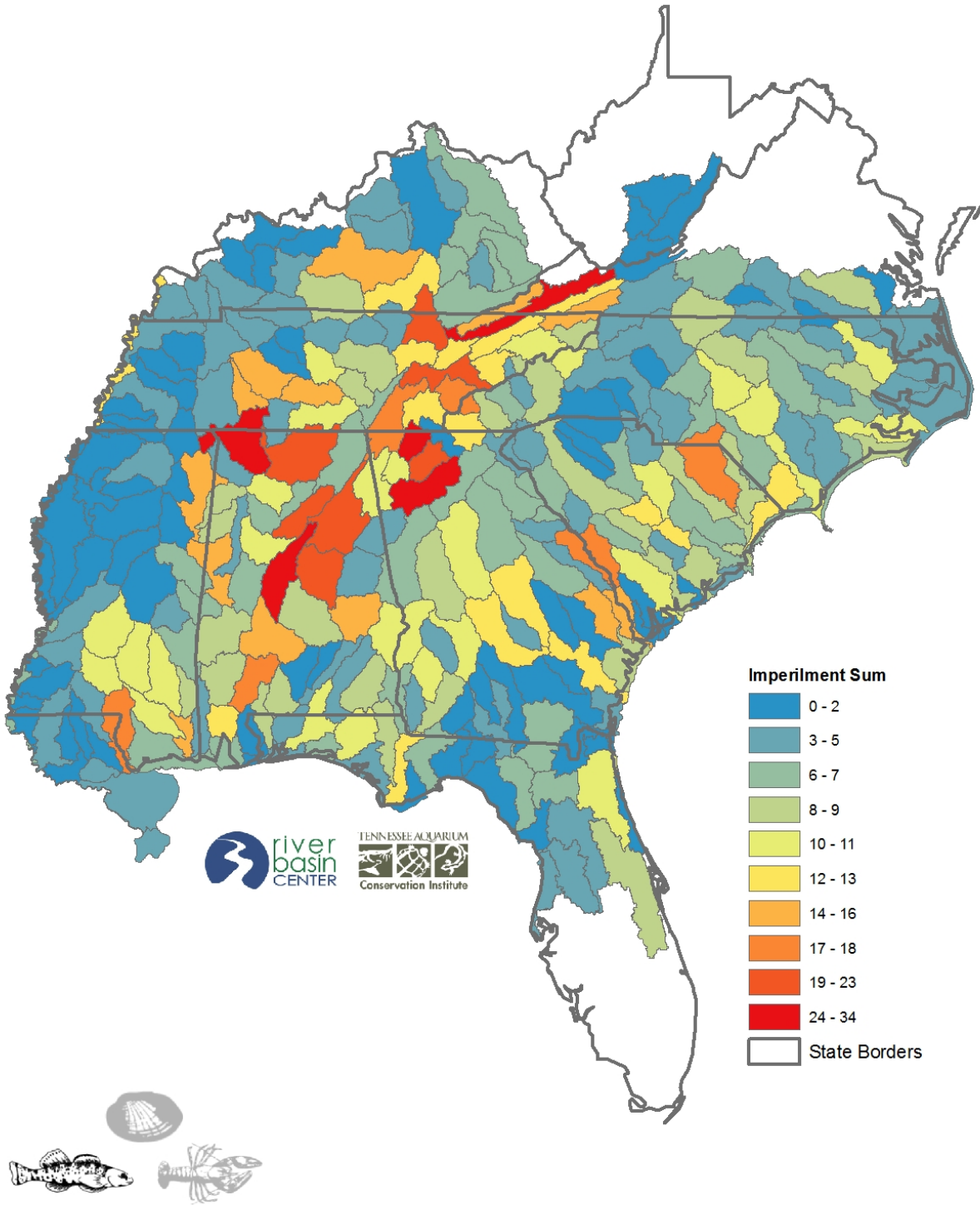
### Fish Species Richness



### Fish Southeast Endemics

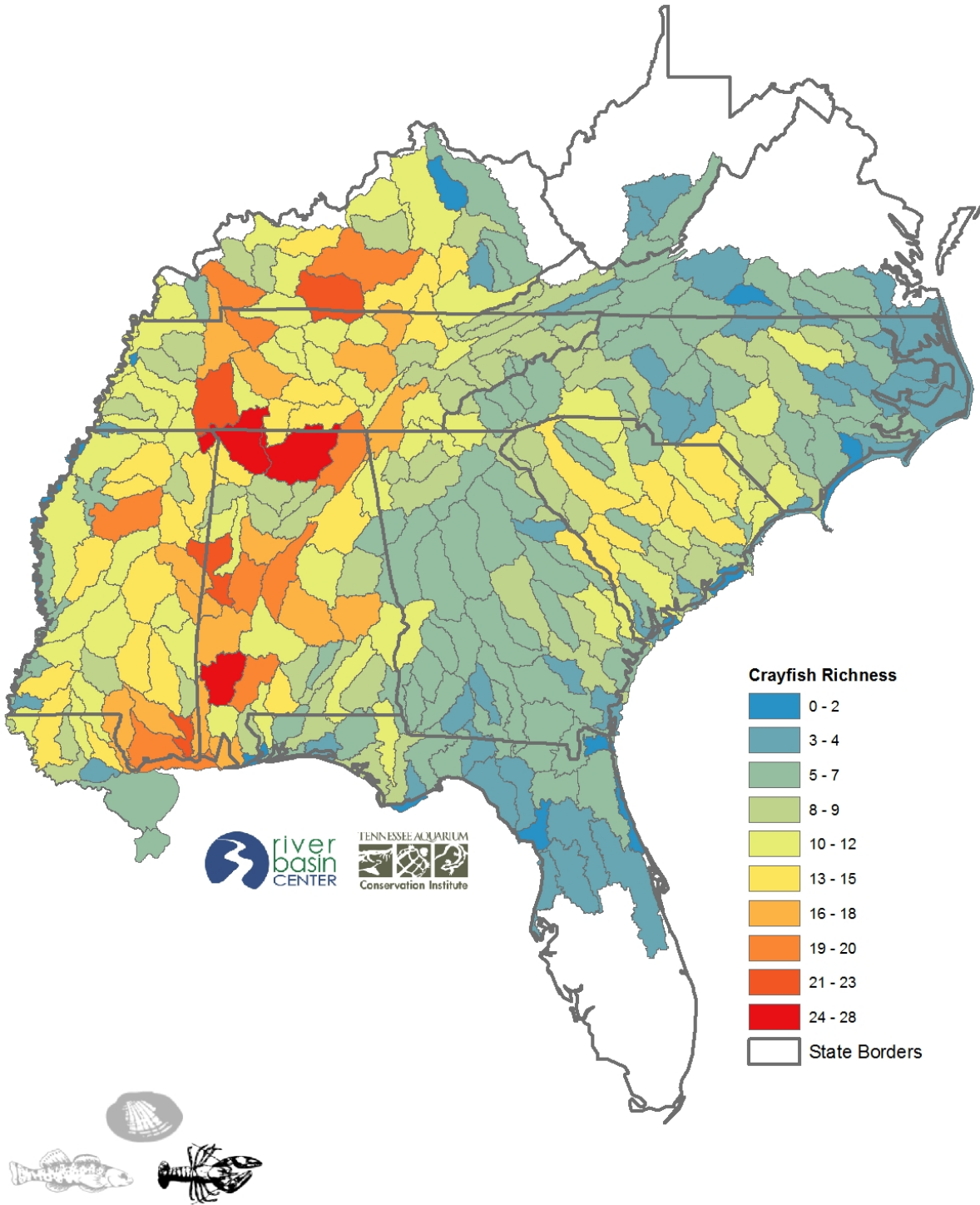


## Fish Weighted Imperilment

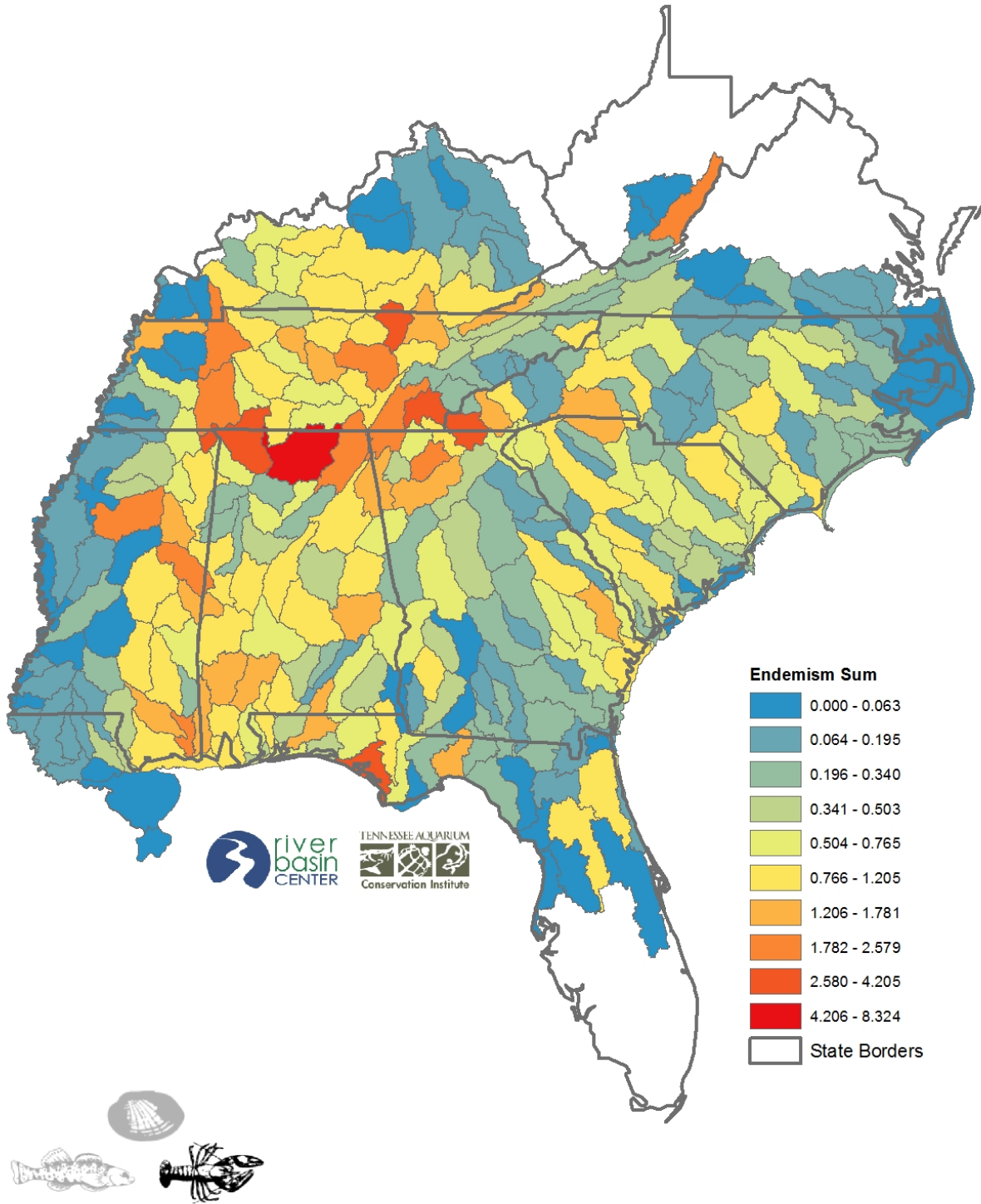




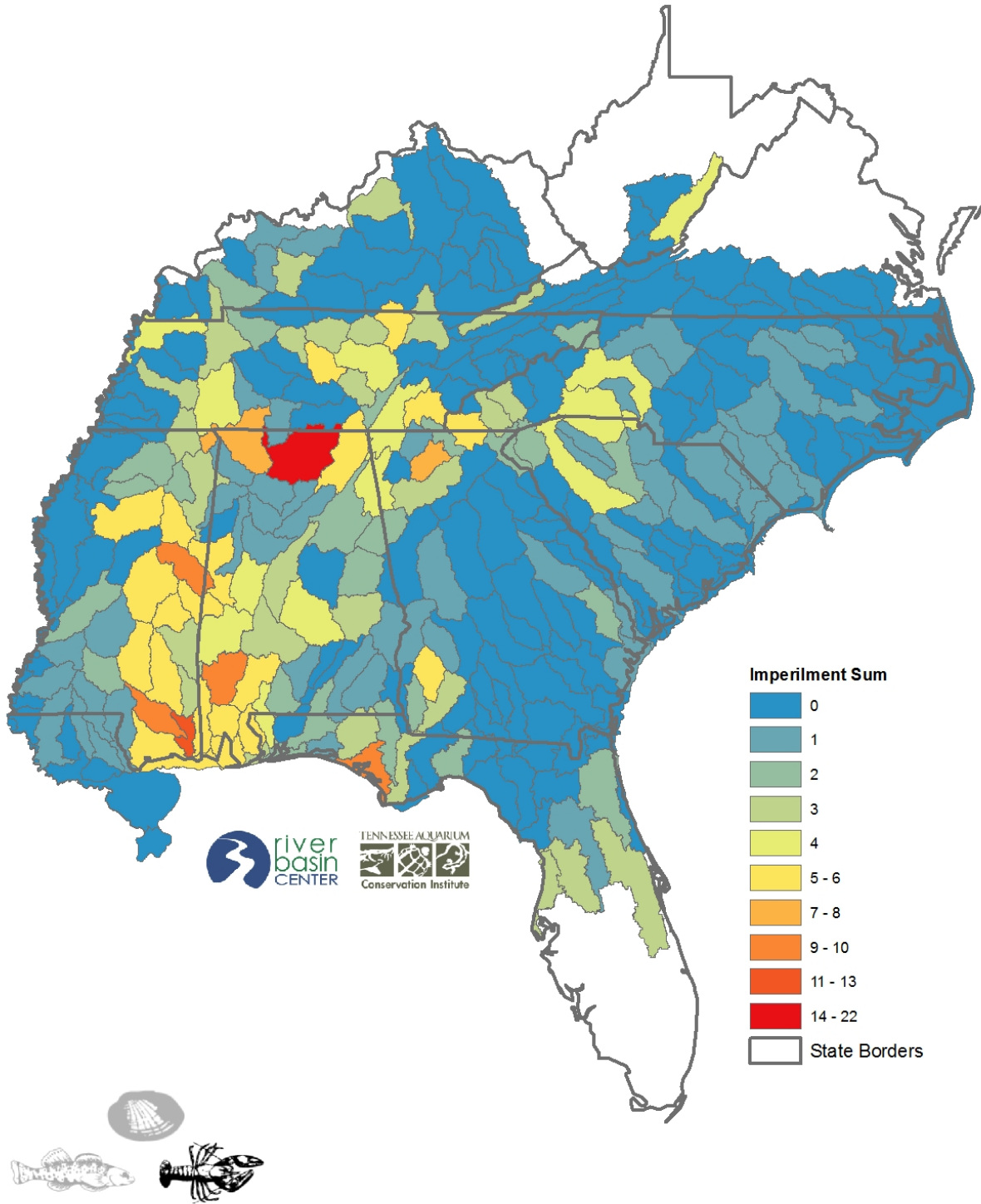
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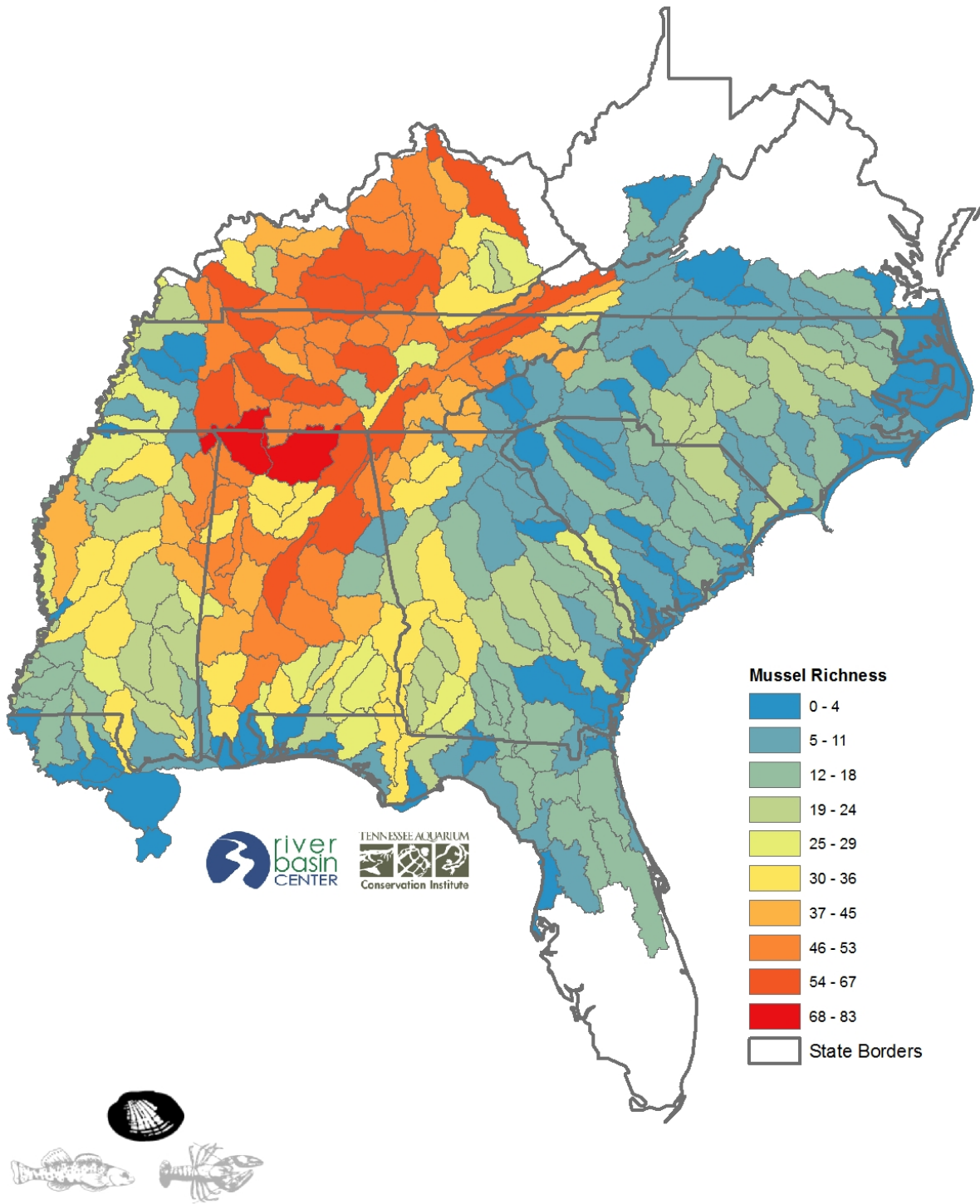
### Crayfish Southeast Endemics



### Crayfish Weighted Imperilment

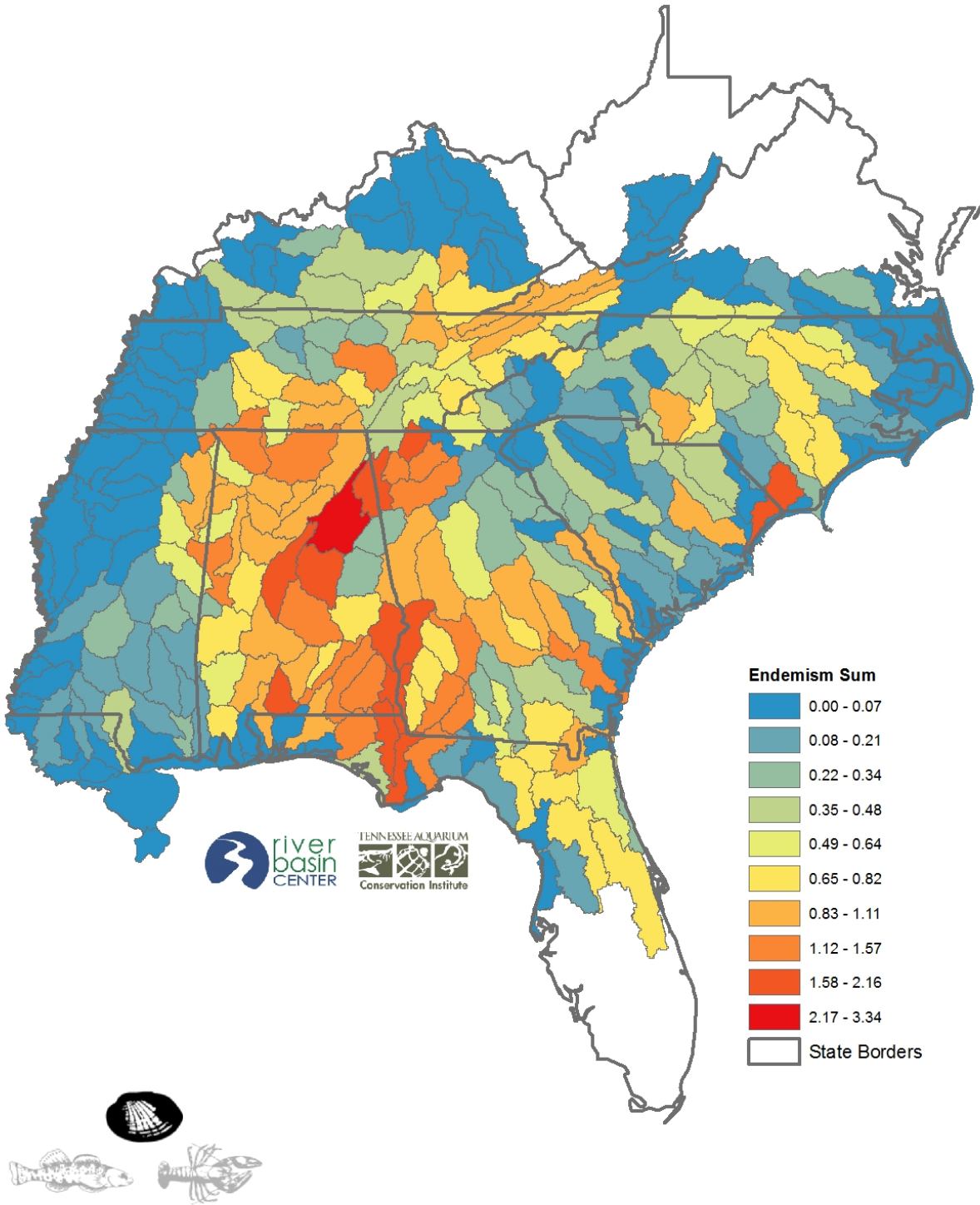


### Mussel Species Richness

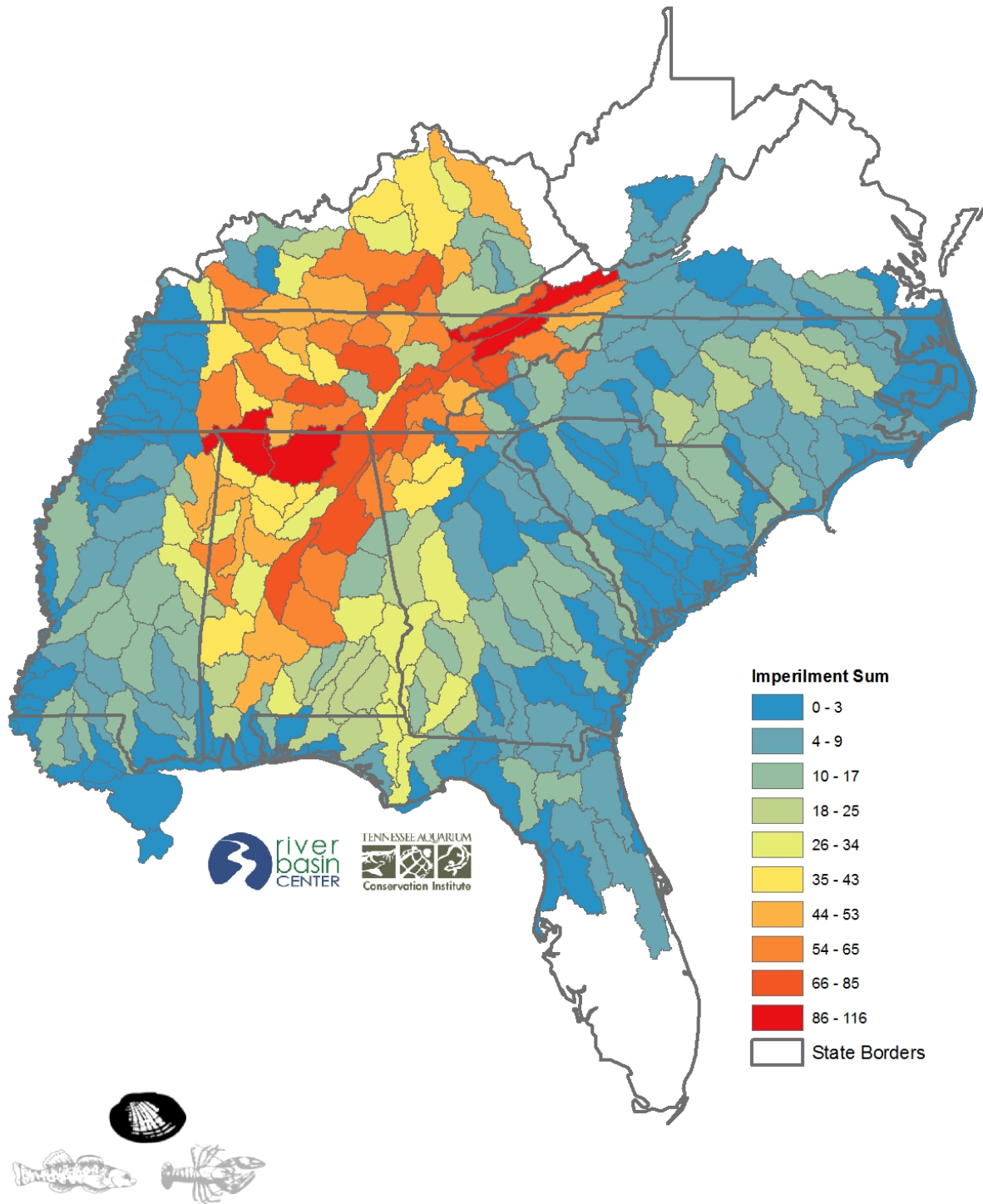




### Mussel Southeast Endemics



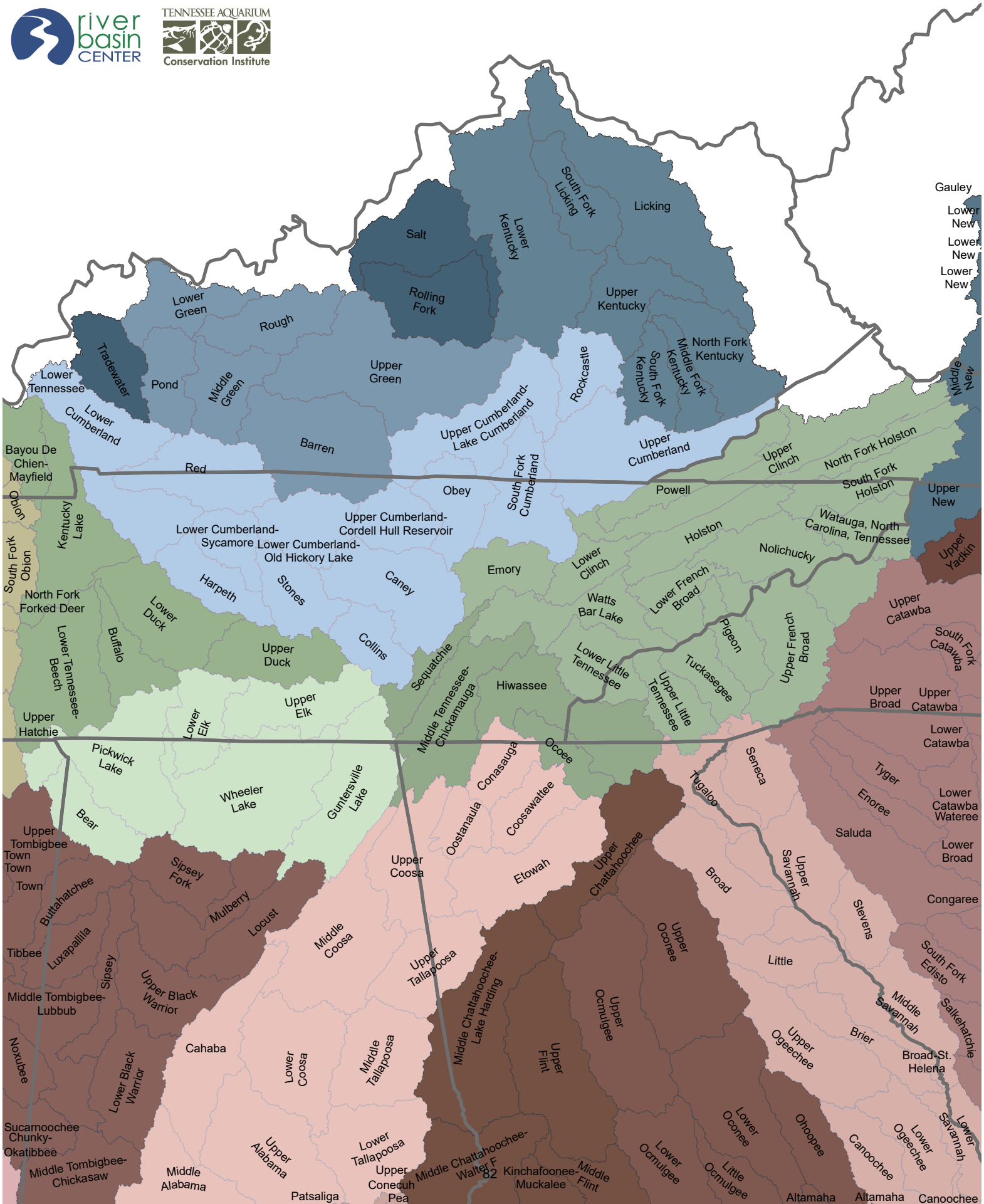
### Mussel Weighted Imperilment



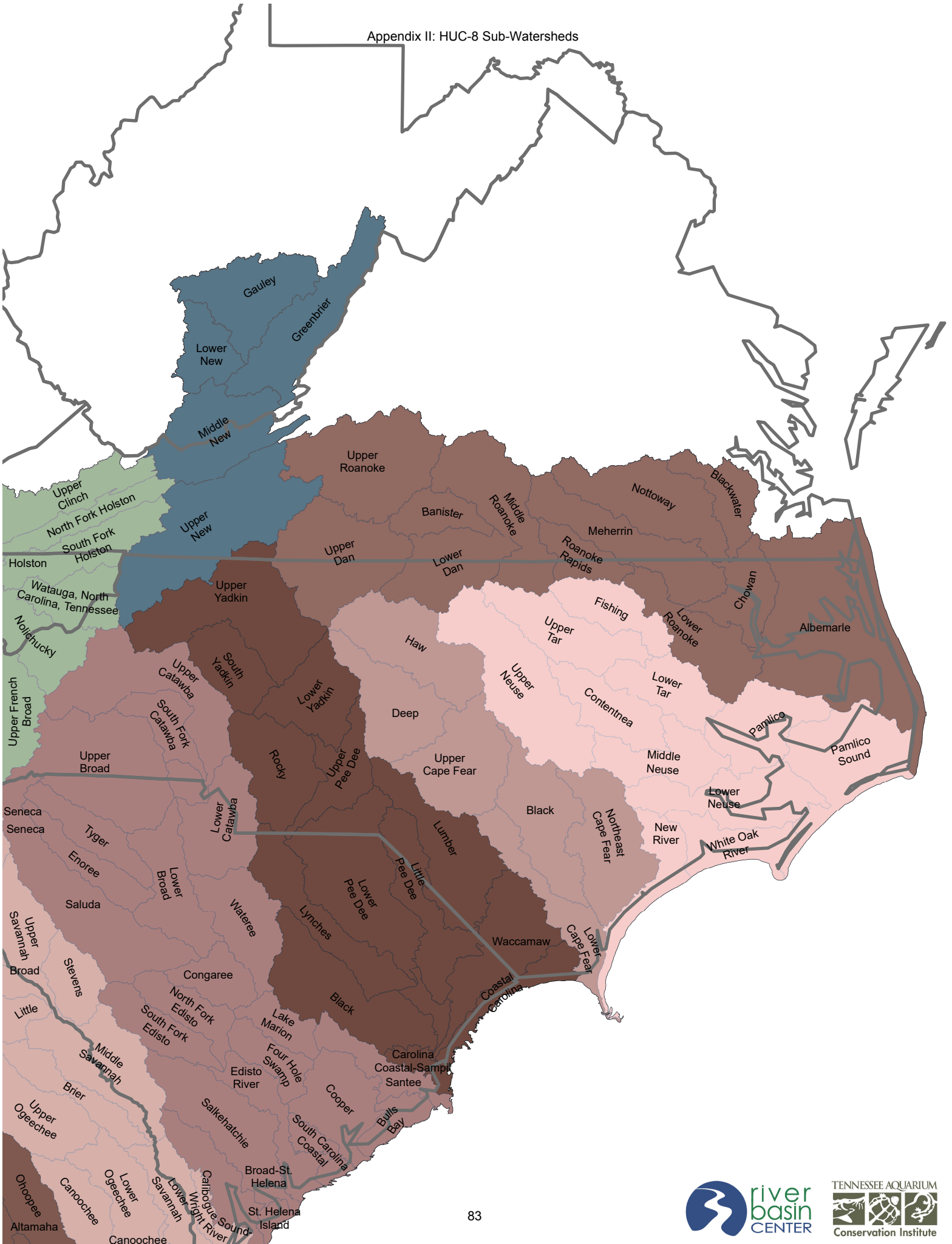
## Appendix II. Names of HUC-8 Sub-basins

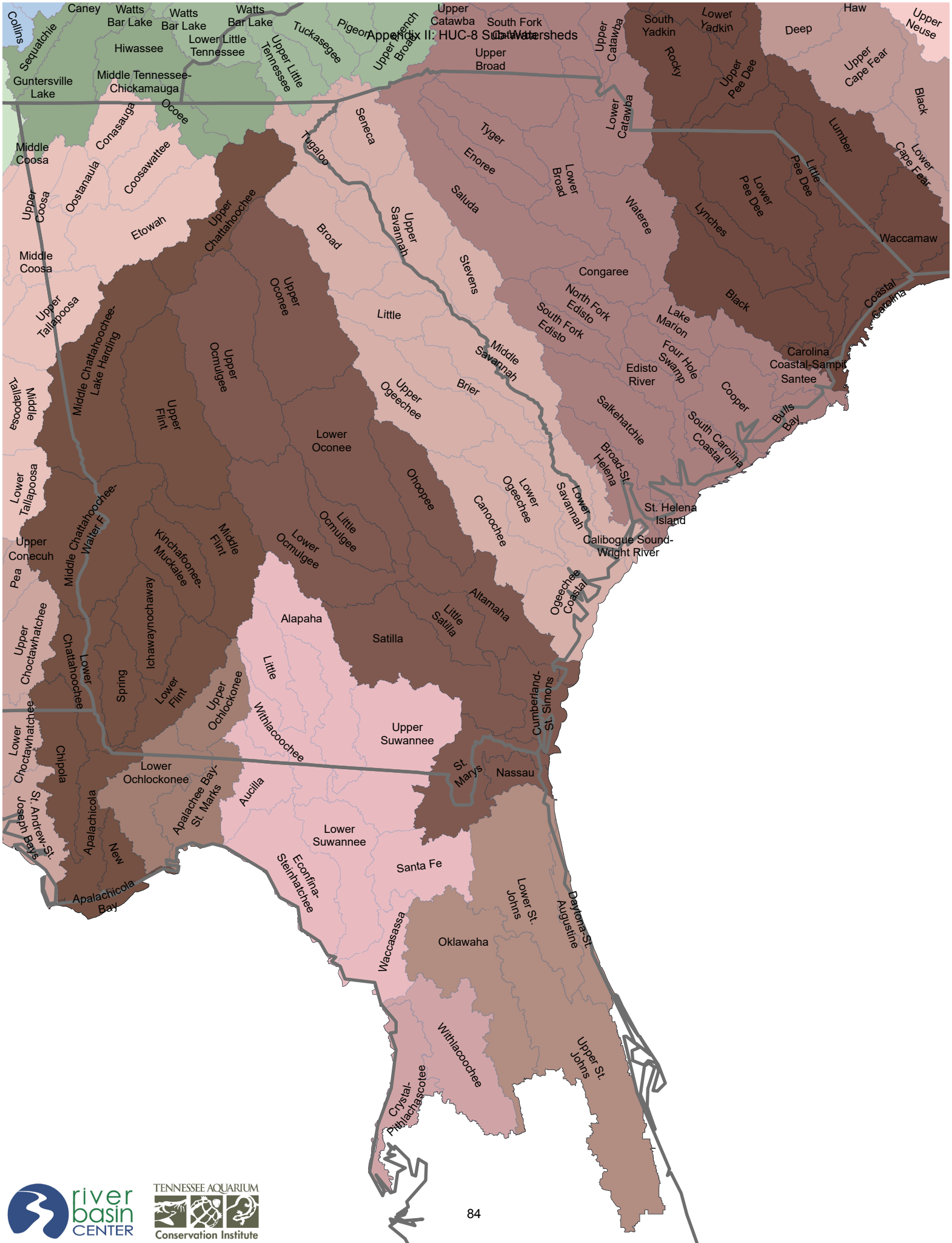
The maps in this section show the 270 HUC-8 Sub-basins in the project area, with names. HUC boundaries and names data drawn from the USGS National Watershed Boundary Dataset (<http://nhd.usgs.gov/wbd.html>). Colors reflect HUC-2 and shading reflects HUC-4 boundaries.

Appendix II: HUC-8 Sub-Watersheds









# Appendix II: HUC-8 Sub-Watersheds

