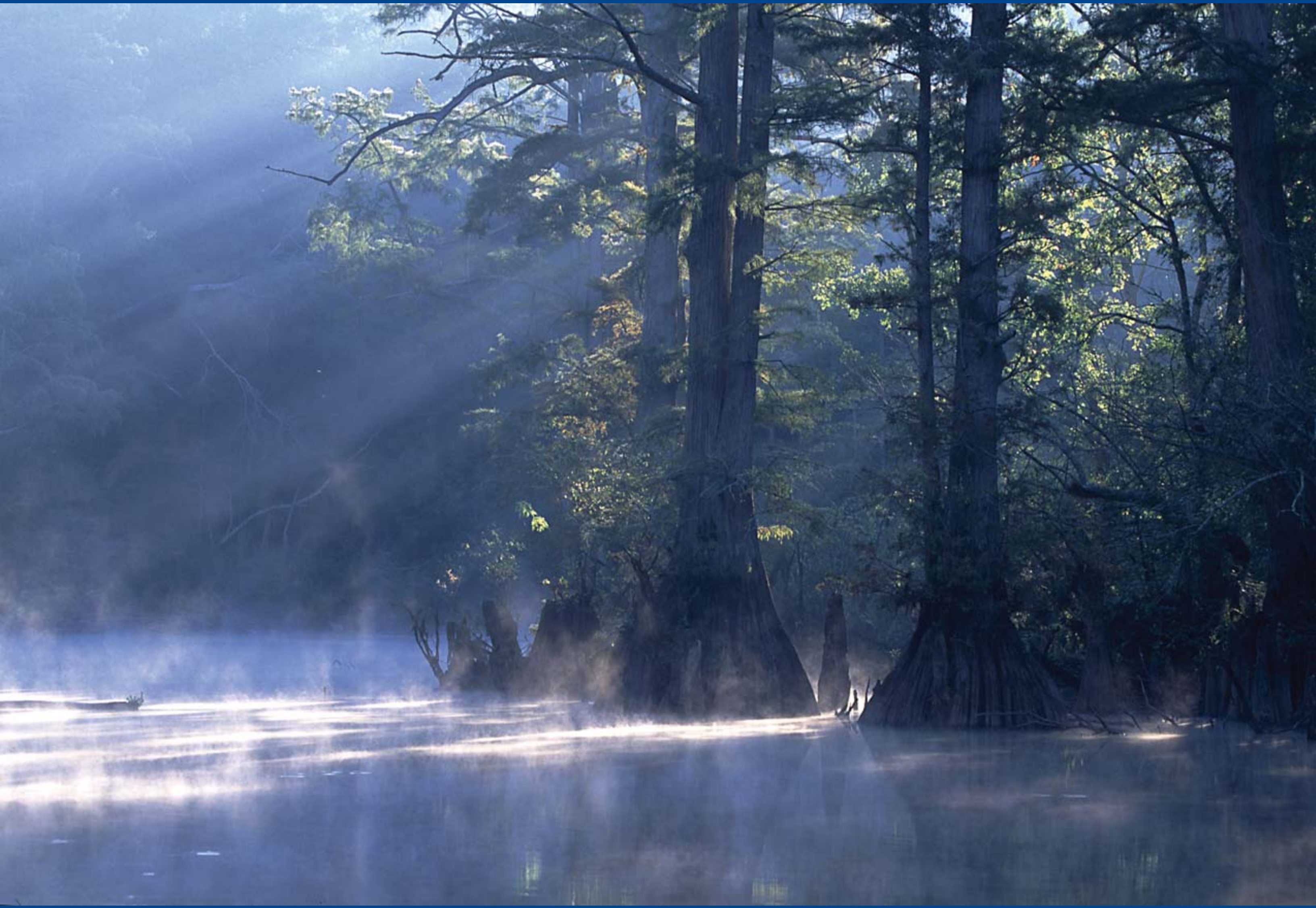

Priority Areas for Freshwater Conservation Action:

A Biodiversity Assessment of the Southeastern United States

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Funding for this project was generously provided by the Charles Stewart Mott Foundation.

CHARLES STEWART
MOTT FOUNDATION

On the cover: *the Hatchie River, Tennessee, photograph by Byron Jorjorian.*

Priority Areas for Freshwater Conservation Action:

A Biodiversity Assessment of the Southeastern United States

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EXECUTIVE SUMMARY

The southeastern United States harbors a spectacular diversity of freshwater species and ecosystems. Human uses of the region's land and water pose enormous threats to this natural treasure, and conservation organizations and government agencies are increasing their efforts to protect aquatic biodiversity within the region. Limitations on resources, however, require their actions be carefully targeted to ensure that they have the greatest possible impact.

This report summarizes The Nature Conservancy's efforts to identify the most important areas for freshwater biodiversity conservation in the southeastern United States. This suite of conservation areas, if adequately protected, would conserve the best remaining places that contain freshwater biodiversity representative of the Southeast. Many public agencies, academic institutions, conservation organizations, and other individuals provided data, expert opinion, and other assistance in this priority-setting process. The Charles Stewart Mott Foundation provided funding for this project.

World Wildlife Fund has identified four highly significant regions of freshwater biodiversity in the southeastern United States: Mississippi Embayment, South Atlantic, Tennessee-Cumberland, and Mobile Bay. This report takes the next step in conservation assessment by identifying the specific places that collectively meet the goals we set to represent the freshwater biodiversity of each of these regions.

Conservation scientists at The Nature Conservancy have developed a hierarchical classification of aquatic ecosystems to define and map the communities and ecosystems in the landscape. In analyzing priority areas for freshwater conservation in the Southeast, scientists from a wide range of organizations and government agencies used this classification in conjunction with data on a set of select species targets to assess patterns of freshwater biodiversity. A group of experts reviewed information on types and sources of threats and their impacts on the long-term survival and integrity of species and ecosystems.

This report presents the methods and conservation targets used to identify the freshwater conservation areas. These methods include identifying and mapping all of the distinct aquatic ecological systems within regions and compiling and analyzing the most up-to-date species data. In addition, the document provides species, ecosystems, threats, and quality attributes of each conservation area; the GIS data used in the analyses; and results of expert reviews of available data. A supplementary CD in the back pocket of this publication provides information for further analyses by conservation organizations and resource management agencies. This information, and the analyses described in this report, are intended to facilitate a coordinated approach to freshwater biodiversity protection by: identifying a suite of conservation areas around which groups can prioritize their work; supporting the development of multi-site strategies; and providing baseline data for future assessments of conservation actions and freshwater biodiversity status.

This assessment focuses on species and communities that are strictly aquatic and does not

Clinch River, Virginia. Photograph by Jon Golden.

address all wetland species and communities that are of conservation significance. Nor does our assessment identify waterways that are essential to the survival of high priority terrestrial plants and animals, including riparian species and native communities. While wetland and terrestrial species are not an explicit focus of this assessment, the Conservancy is conducting comprehensive planning addressing all biodiversity in a related effort. We expect that rivers, streams, and lakes that are high-priority here will also be priorities for conservation because of the wetland or terrestrial plants and animals those systems support.

ACKNOWLEDGEMENTS

Identification of priority areas for freshwater conservation in the southeastern United States would not have been possible without the support and participation of many people working on freshwater issues across the region. Contributors to this assessment included staff from federal and state agencies, academic institutions, industry, and conservation organizations.

Funding for this project was generously provided by the Charles Stewart Mott Foundation. In particular, we wish to thank Lois DeBacker, Ron Kroese, Rebecca Fedewa, and Cynthia Swineheart for their interest in and support of freshwater biodiversity conservation in the Southeast.

Input from participants with taxonomic, ecological, and programmatic expertise within and across the four basins in this study provided critical information on target species and system distribution, abundance, location and viability, and information on threats and opportunities at each of the identified conservation areas. The following experts graciously assisted in this process by attending an Experts' Workshop for the Mississippi Embayment, the Mobile Bay, the Tennessee-Cumberland, or the South Atlantic regions, and by providing additional information after the workshops:

Robin Abell, World Wildlife Fund
Ron Ahle, Division of Wildlife and Freshwater Fisheries, South Carolina Department of Natural Resources
Steve Ahlstedt, Water Resources Division, NAWQA, U.S. Geological Survey
Peter Aku, Department of Biology, University of Louisiana at Monroe
John Alderman, North Carolina Wildlife Resources Agency
Braven Beaty, Clinch River Program, Virginia Chapter of The Nature Conservancy
Steve Bennett, South Carolina Heritage Trust, South Carolina Department of Natural Resources
Richard Biggins, U.S. Fish and Wildlife Service
Arthur Bogan, North Carolina State Museum of Natural Sciences
Alvin Braswell, N.C. State Museum of Natural Sciences
Ken Brown, Department Biological Sciences, Louisiana State University
Noel Burkhead, Biological Resources Division, U.S. Geological Survey
Bob Butler, U.S. Fish and Wildlife Service
Bob Cashner, University of New Orleans
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Ron Cicerello, Kentucky Nature Preserves Commission
Shawn Clouse, Georgia Chapter of The Nature Conservancy
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Will Duncan, Alabama Rivers Alliance
David Etnier, Department of Ecology and Evolutionary Biology, University of Tennessee-Knoxville
John Fridell, Asheville Field Office, U.S. Fish and Wildlife Service
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Jim Godwin, Alabama Natural Heritage Program
Rick Guffey, Georgia Chapter of The Nature Conservancy
Wendell Haag, Center for Bottomland Hardwood Research, Southern Research Station, U.S. Forest Service

Randy Haddock, Cahaba River Society
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Peggy Shute, Tennessee Valley Authority Natural Heritage
Chris Skelton, Georgia Natural Heritage Program
Todd Slack, Mississippi Museum of Natural Science
Larry J. Smith, Wolf River Conservancy
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Naomi Van Tol, Wolf River Conservancy
Brian Wagner, Arkansas Game and Fish Commission
Amy Wales, Tennessee Valley Authority
Steve Walsh, Florida Caribbean Science Center, U.S. Geological Survey
Melvin L. Warren Jr., Forest Hydrology Laboratory, U.S. Forest Service
Andrew Whitehurst, Mississippi Department of Wildlife, Fisheries and Parks
Jim Williams, Florida Caribbean Science Center, U.S. Geological Survey
Paul Yokley Jr., Yokley Environmental Consulting

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SOUTHEASTERN FRESHWATER BIODIVERSITY & IMPERILMENT

The lakes, rivers, and streams of the southeastern United States are among the most biologically rich in the world. The region is geologically diverse and escaped recent glaciation, and as a result it has been fertile ground for the evolution of aquatic fauna. World Wildlife Fund (WWF) conducted a conservation assessment of freshwater ecoregions of North America (Abell et al. 2000) and found that streams and rivers in the southeastern United States contain the highest diversity of freshwater mussel and crayfish species in the world. The region contains the highest species diversity and levels of endemism for fishes, mussels, and crayfish in North America.

However, this rich natural heritage of the southeastern United States is greatly imperiled (Benz and Collins 1997). Over two-thirds of freshwater mussels and half the crayfish species are considered extinct, imperiled or vulnerable (Master et al. 1998; Neves et al. 1997; Allan and Flecker 1993; Williams et al. 1993; McAllister et al. 1997). In addition, more than one-third of freshwater fish species in the United States are at risk of extinction (Williams et al. 1989). With incomplete information about freshwater biodiversity, species and communities that are not monitored or even known are being lost before they are assessed (McAllister et al. 1997). Natural communities are potentially as threatened as aquatic species. Anthropogenic changes to freshwater habitats have caused catastrophic changes in fish communities (e.g., Trautman 1981; Cross and Moss 1987). Hackney et al. (1992) summarized the diversity of southeastern aquatic communities and their responses to anthropogenic impacts.

Based on a combination of species diversity, endemism, and level of threats, WWF highlighted the southeastern United States as containing some of the highest priority freshwater ecoregions for North American freshwater biodiversity conservation (Figure 1) (Abell et al. 2000). The scale of environmental degradation in the Southeast leaves us with few remaining opportunities to protect high quality aquatic ecosystems and their resident biodiversity. The conservation community must rapidly evaluate and protect the remaining freshwater species and communities before opportunities for conservation and restoration vanish.

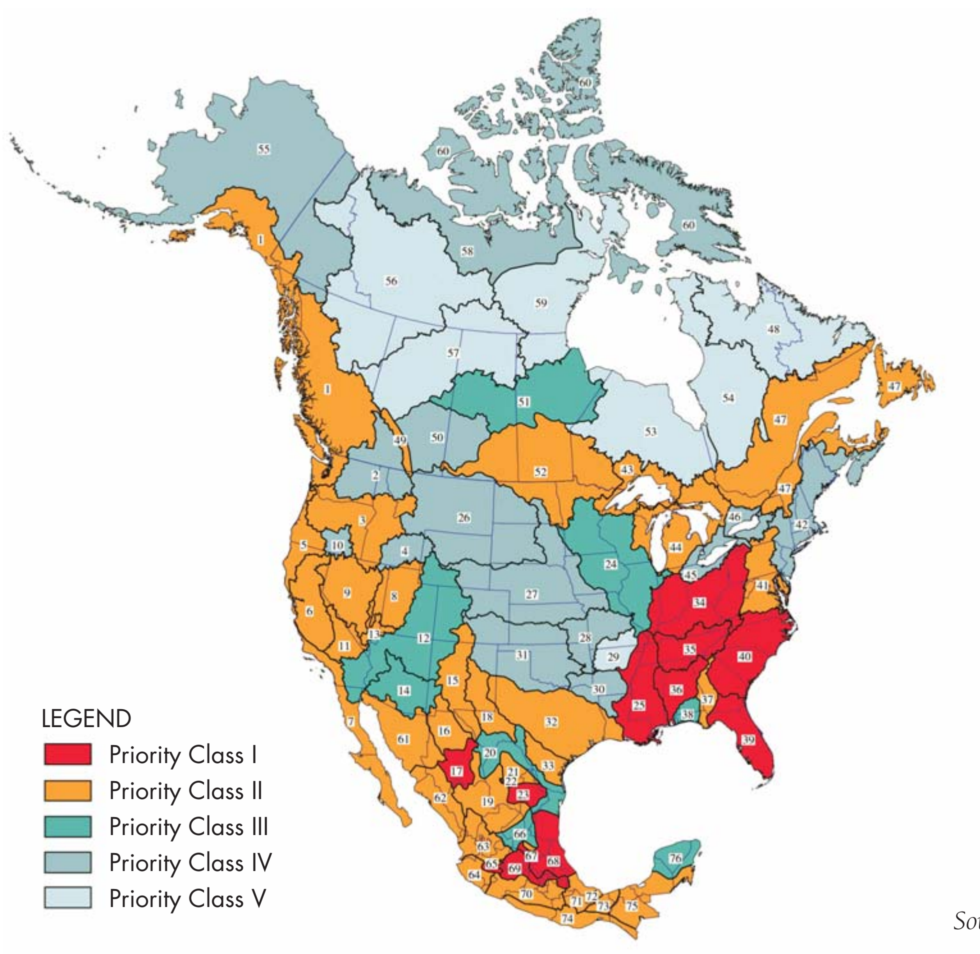
Crayfish Cambarus pristinus. *Photograph by Kevin S. Cummings and Christopher A. Taylor/ Illinois Natural History Survey.*

FRESHWATER CONSERVATION PRIORITIES IN THE SOUTHEAST

Conservation biologists have long recognized the importance of the southeastern United States for freshwater plants, animals, and natural communities. Until now, however, no one has conducted a comprehensive ecological assessment to identify the complete suite of places that we must conserve in order to protect this incredible biological diversity.

Abell et al. (2000) (Figure 1) and Master et al. (1998) (Figure 2) identified regional and watershed scale priorities for freshwater species conservation. The next step in conservation priority setting is to identify the specific areas on the ground that collectively contain the biodiversity of each region. Recognizing the unique and irreplaceable biodiversity of the southeastern United States, the Charles

Figure 1. The World Wildlife Fund's Priority Freshwater Ecoregions for Biodiversity Conservation



Source: Abell et al. 2000.

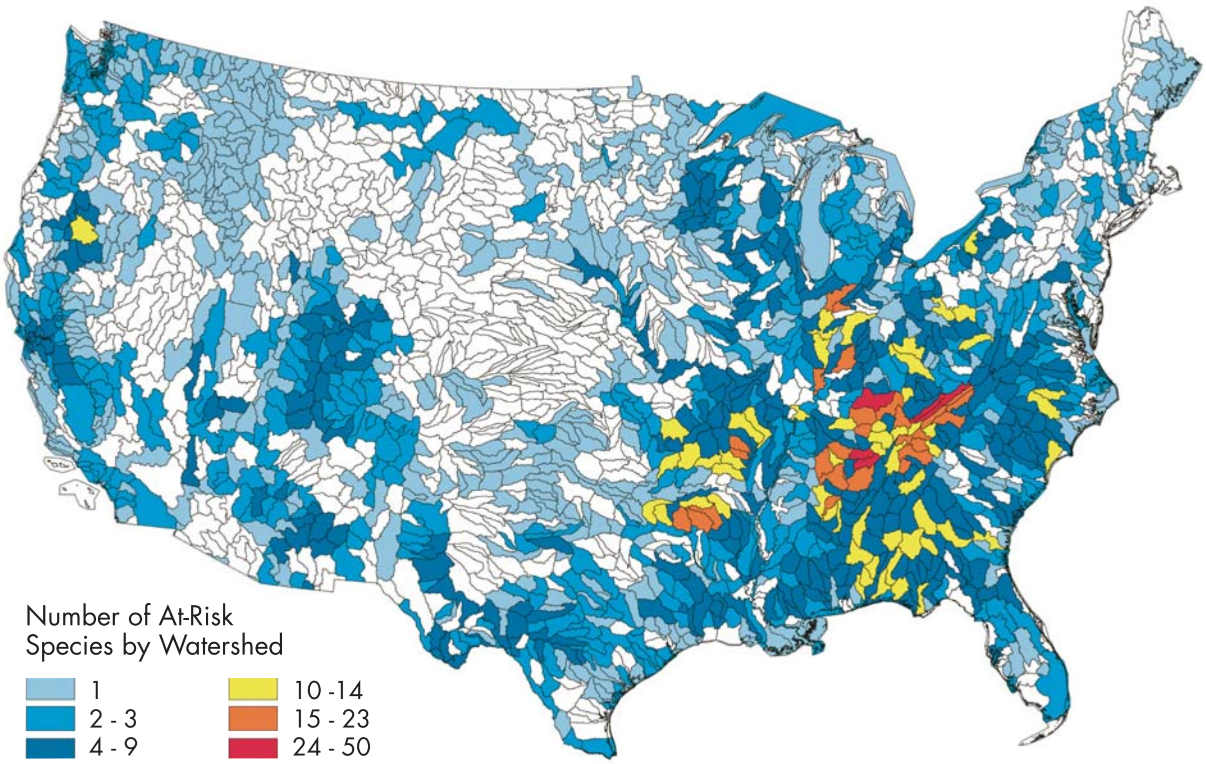


Figure 2. Hot Spots for At-Risk Fish and Mussel Species *Source: Master et al. 1998.*

Stewart Mott Foundation chose to support a detailed and comprehensive assessment of freshwater species and systems to identify a set of priority conservation areas in four specific aquatic regions, based on WWF's definition of freshwater ecoregions (Figure 3):

- Tennessee-Cumberland
- Mobile Bay
- South Atlantic
- Mississippi Embayment

Previous conservation planing efforts in the Southeast have focused on "hotspots" of rare and endangered species. While attention to these areas is essential to any comprehensive conservation effort, these hotspots do not encompass all species and ecosystems representative of the Southeast. Conservation planners need a framework that will guide conservation action for endangered species and communities, and facilitate conservation of species and communities before they become endangered and are in crisis. Such a framework must account for the common species, communities, and ecosystems that make up the majority of the region's biological resources and form the foundation of the region's ecological processes.

Within each ecoregion in the United States (Figure 4), conservation planners at the Conservancy and cooperating organizations are engaged in a four-step conservation process (Figure 5) designed to create a framework for conservation success and provide a structure for making wise decisions about where to direct limited resources. In the Southeast, scientists from the Conservancy, other conservation organizations, federal and state agencies, academic institutions, and industry have used ecoregional planning methodologies to conduct the first comprehensive biodiversity assessment of freshwater species and systems in four freshwater regions. This report provides the

Figure 3. Aquatic Regions Included in This Assessment

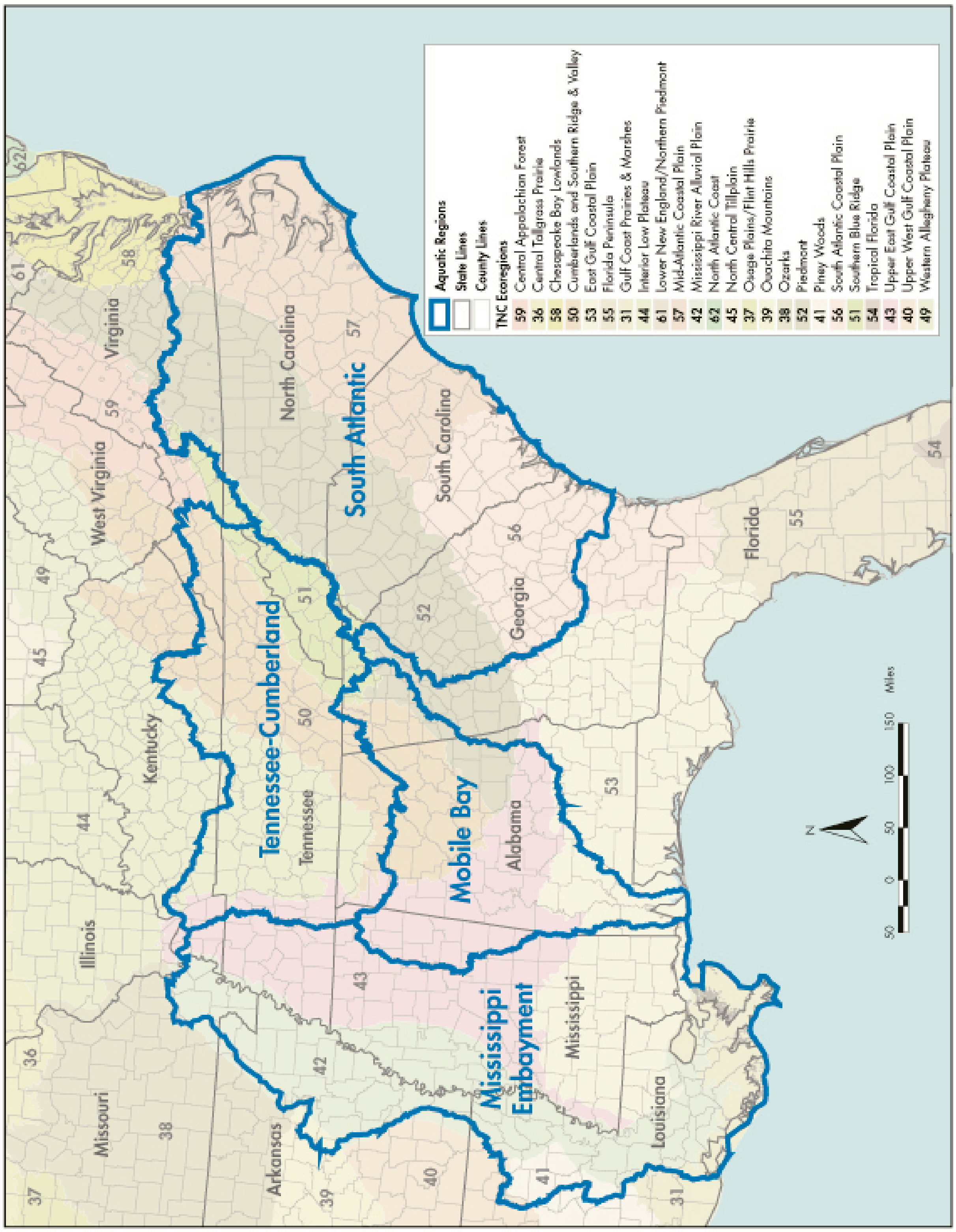


Figure 4. Ecoregions of the United States

The Nature Conservancy United States Ecoregions 2001, based on Bailey et al. 1994, modified for Conservancy Ecoregional Planning purposes. Canadian Ecological Zones developed by the Ecological Stratification Working Group 1995. Latin American and Caribbean Ecoregons based on World Wildlife Fund Ecoregions, Dinerstein et al. 1995, modified for Conservancy Ecoregional Planning purposes.

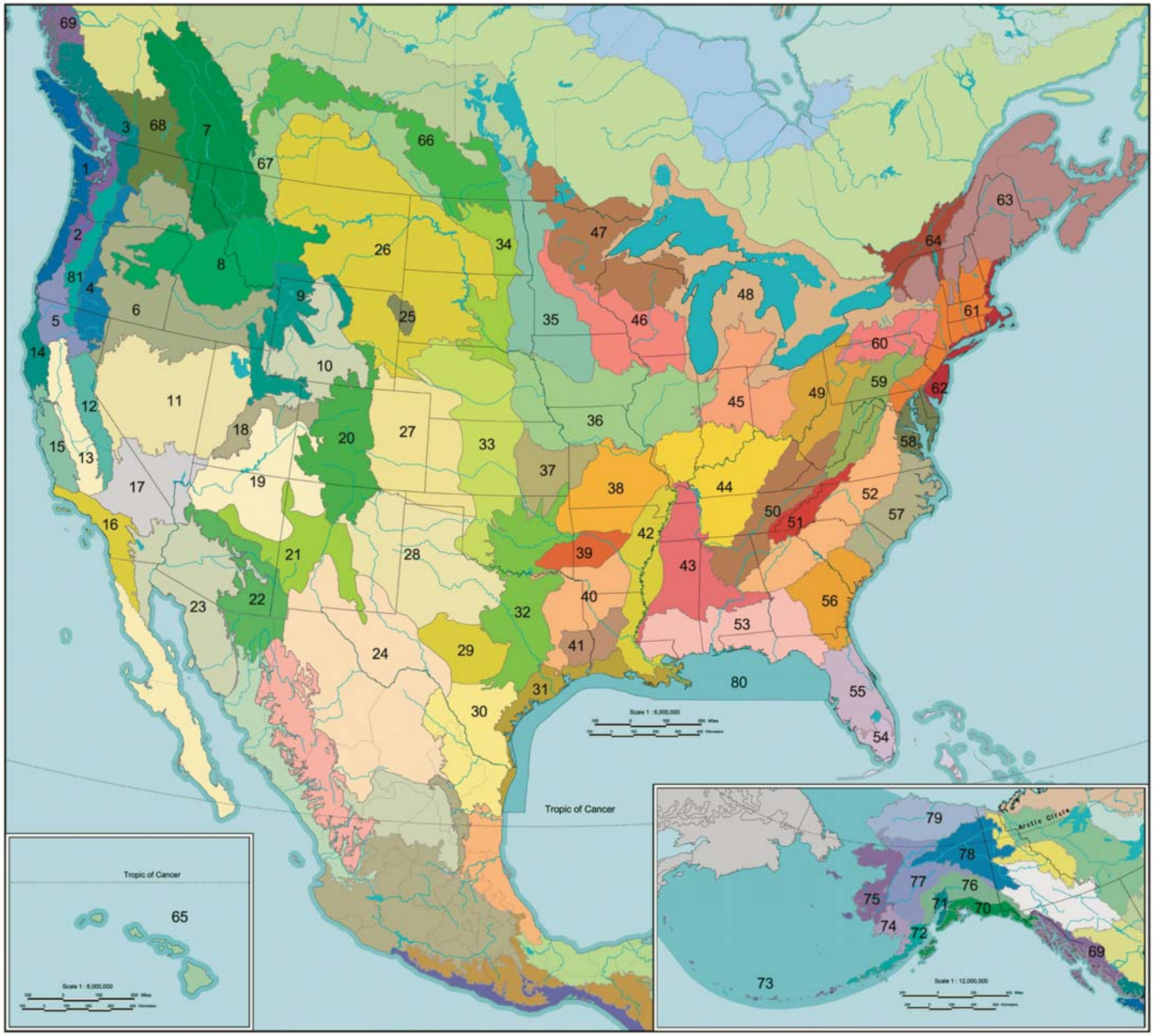


Figure 5. The Nature Conservancy's Conservation Approach

methodology and results of that assessment, which identifies the places that will conserve rare and endangered species while also capturing representative biodiversity from across the region.

A comprehensive biodiversity assessment process builds on, but goes beyond species inventories. No matter how detailed those inventories are—and in the Southeast scientists have gathered enormous amounts of data—conservation planners will never have complete or perfect information. They need a context for understanding patterns of ecological processes across large areas, and a way to identify the ecosystem types that contain common species and communities and should be the targets of conservation action.

The Nature Conservancy has developed a classification scheme to identify and map freshwater ecosystems for ecoregional planning efforts. The Conservancy has used this scheme extensively in the United States and Latin America but not previously in the Southeast. This classification helps planners identify "coarse filter" targets, which are large-scale ecosystems that capture multiple levels and types of biodiversity, including untracked common species, communities, and ecological processes. The classification systems does not replace

BOX 1. Using This Report as a Conservation Tool

Accompanying the text of this report is a CD including detailed information on conservation targets (species and freshwater ecosystems), target viability and integrity, conservation area attributes (target lists and threats), and geo-referenced data. Our intention is that this report and the accompanying data be used for further analysis and as a tool to implement conservation action. The conservation community can use the data to refine priorities, develop conservation strategies, address identified data gaps, and assess the efficacy of conservation actions and the status of freshwater biodiversity in the future.

Included on this CD are all tabular data and most GIS data sets used in this project. Components of the CD are:

- Report Text
- More detailed description of some methodologies
- GIS projects with key data layers
- Maps of conservation areas, geology, land use
- All tabular data including lists and descriptions of targets, Ecological Drainage Units, conservation areas, lists of targets in conservation areas, and details on target goals

In addition, all other large data layers used in this analysis will be available at gis.tnc.org. These include several large datasets (e.g., land use/land cover, digital elevation models, and surficial and bedrock geology coverages) not included on this CD. Details for login and download information can be found at the web-site.

Throughout the document, a CD  icon will be used to indicate that important related data are available on the CD. Please see the file <readme.doc> in the base directory on the CD for further instructions and software requirements for viewing the CD components.

detailed data on the distribution and status of species and communities, but provides conservation planners with a tool to help deal with incomplete information.

By identifying both high quality ecosystem types and areas supporting the best remaining populations of rare species, this report identifies the priority areas for freshwater conservation that collectively represent the freshwater biodiversity characteristic of each of the four aquatic regions. The result is a map and database that support setting priorities for conservation actions. The maps and data presented in this report, and accompanying CD, are intended to support action by a broad range of conservation groups and resource management agencies.

METHODS

We identified areas of freshwater biodiversity significance following the principles and methods developed for The Nature Conservancy's ecoregional planning process set forth in *Designing a Geography of Hope* (Groves et al. 2000). However, the areas that we identified are not a final product in the sense that they do not necessarily represent the limits or extent of where conservation action needs to take place. These boundaries may be larger than the areas that we highlighted.

Conservation areas were identified in each of the four freshwater regions following a six-step process:

1. Stratify regions into *Ecological Drainage Units* to create ecologically meaningful and manageable assessment units and to guide selection of conservation targets.
2. Select *conservation targets* (*aquatic species* and *systems*) as the focus of conservation assessment efforts.
3. Set *conservation goals* for targets
4. Identify *viable occurrences* of targets.
5. Delineate *conservation areas* within each freshwater ecoregion.
6. Identify *data gaps* and *research needs*.

BOX 2. Experts Workshops

Photograph by Paul Freeman/TNC

Regional experts provided detailed and up-to-date knowledge of the targets, their distribution and status, and the threats to their viability and persistence. Experts participated in at least one of four regional workshops, one in each aquatic region. These experts work with land or resource management agencies, academic institutions, private consulting firms, and/or non-profit organizations based in the region. As such, they not only represented the best expertise and knowledge of the targets, but also represented many potential partners in the application of conservation strategies to southeastern rivers.

At these meetings experts provided input on initial work conducted by Conservancy aquatic ecologists on selection of conservation targets, development of conservation goals, and delineation of conservation areas. The products of the workshops were a refined list of conservation targets, a set of specific areas with viable examples of targeted species and systems (and key information regarding threats and viability), and a list of data gaps for each region.

For each conservation area we also collected two types of information that will inform subsequent priority setting and local planning efforts in the Southeast. From the regional experts we compiled a list of threats, conservation contacts and strategies for each area. We also performed a GIS analysis that evaluated water quality in each area based on land use, point sources, road density, and other factors.

Ecological Drainage Units

Ecological Drainage Units (EDUs) are a set of ecologically based assessment units within aquatic regions. They facilitate evaluation of targets in the set of sub-regional ecological and evolutionary settings they occur. EDUs are groups of watersheds (8-digit U.S. Geological Survey Hydrologic Units) within aquatic ecoregions with similar patterns of zoogeographic sources and constraints, physiography, drainage density, hydrologic characteristics and connectivity. We delineated 48 Ecological Drainage Units in the four freshwater regions (Figure 6). Identifying and describing EDUs stratifies basins into smaller units for more accurate evaluation of patterns of freshwater biodiversity, promotes consideration of sub-regional differences in freshwater species pools, and guides conservation goals for targets across their environmental ranges.

Conservation Targets

Aquatic Species

The freshwater species targets in this assessment included imperiled, endemic, declining, and wide ranging species. To be included as target species taxa need to be federally or state listed as threatened, endangered, or special concern; have low global Heritage Program Network ranks (G1-G3); be endemic to a single ecoregion (though not all common endemic species were considered as targets); or be substantially declining in distribution. Species targets also were selected to represent diversity of ecological processes that occurs at multiple spatial scales (Figure 7) (Poiani et al. 2000, Groves et al. 2000).

We developed preliminary species target lists primarily from Natural Heritage Program databases and published imperiled species lists (Williams et al. 1989, Williams et al. 1993, Taylor et al. 1996). Regional experts reviewed these lists and provided information on additional declining species or newly described species. Final target lists included fishes, mussels, aquatic snails, crayfishes, and some aquatic insects and obligate aquatic amphibians and reptiles. We did not consider aquatic plants or amphibians and reptiles with adult phases of their life cycle primarily in terrestrial environments.

Aquatic Ecological Systems

Aquatic ecological systems are rivers, streams, and lakes with similar geomorphological patterns tied together by ecological processes (e.g., hydrologic and nutrient regimes, access to floodplains) or environmental gradients (e.g., temperature, chemical and habitat volume), and form a distinguishable unit on a hydrography map. Systems represent environmental gradients throughout ecoregions across which species occur. In addition, they are used as coarse filters to help ensure that conservation plans capture untracked common species and communities within those systems. To identify aquatic systems, we employed an approach developed by the Freshwater Initiative of The Nature Conservancy (Higgins et al. 1998, Groves et al. 2000) that uses a physically-based classification mapped in a Geographic Information System (GIS) to define the environmental patterns of freshwater ecosystems (Figure 8).

Aquatic systems are nested within EDUs and are unique to a given EDU (Figure 9). While the systems defined by the same set of attributes may occur in several EDUs, we identify these system types as distinct because the context of each EDU is distinct. We expect that the biological assemblages associated with these "mirror-image" systems will differ because of the zoogeographic and climatic differences among EDUs.

Aquatic system classification and delineation involved five steps:

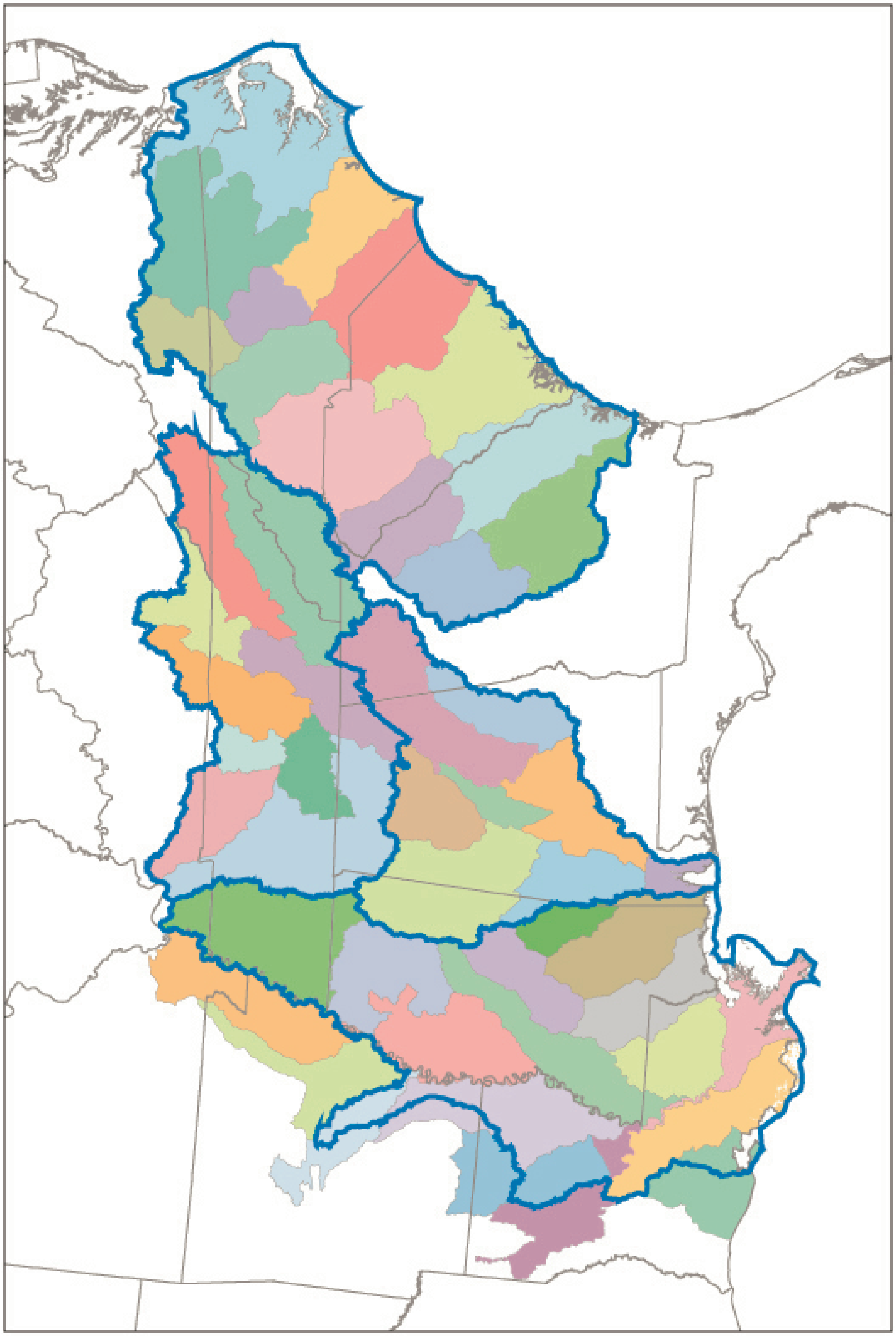
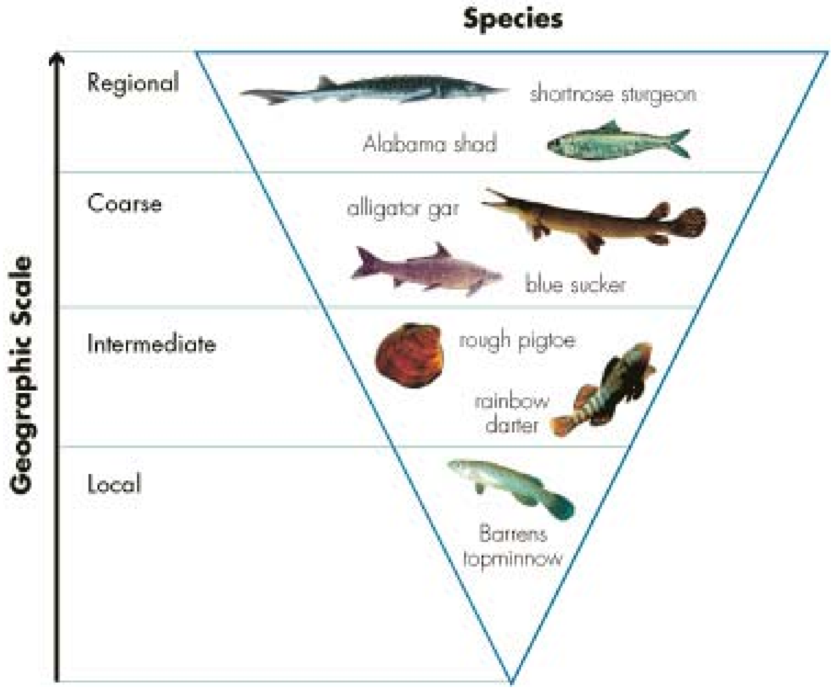


Figure 6. Ecological Drainage Units of Tennessee-Cumberland, Mobile Bay, South Atlantic, and Mississippi Embayment Aquatic Regions

Figure 7. Examples of Species Targets That Are Tied to Ecological Processes Operating at Different Spatial Scales



1. Determine physicochemical habitat variables that define environmental gradients and influence species distributions: stream size, gradient, elevation, downstream connectivity, and bedrock and surficial geologic characteristics (as they relate to hydrologic regime, water chemistry, stream and river geomorphology, and dominant substrate material; Seelbach et al. 1997).

2. Acquire and develop GIS data layers of these habitat variables or other data layers that can be used to model these variables.

3. Determine classes for these variables that correspond to ecologically meaningful breaks in environmental gradients and attribute each stream reach with a value for the variables (Table 1).

4. Classify the types of ecosystems by identifying all distinct combinations of physico-chemical attributes.

5. Map aquatic systems by assigning system types to stream reaches at the small watershed scale.

We used stream size class (Table 1) as an initial variable to distinguish lotic system types. The result is four categories of lotic systems: headwaters/creeks, small, medium, and large rivers. Aquatic systems of each size category were then further distinguished by patterns in the other classification variables (Tables 1). An example of an aquatic system type composed of small streams is: moderate elevation, moderate gradient headwaters and creeks in sandstone bedrock geology. This system type may connect downstream to another system type composed of large rivers with origins in the Cumberland Mountains of Kentucky and Tennessee. We also classified natural lentic systems according to their geomorphology, size, salinity, and connectivity. Springs, caves, and wetlands were not classified as explicit system target types, but are nested within various system types; several spring or cave complexes with imperiled snails, fishes, amphibians, or insects are addressed

Figure 8. GIS Overlay Process Used in Aquatic Systems Classification

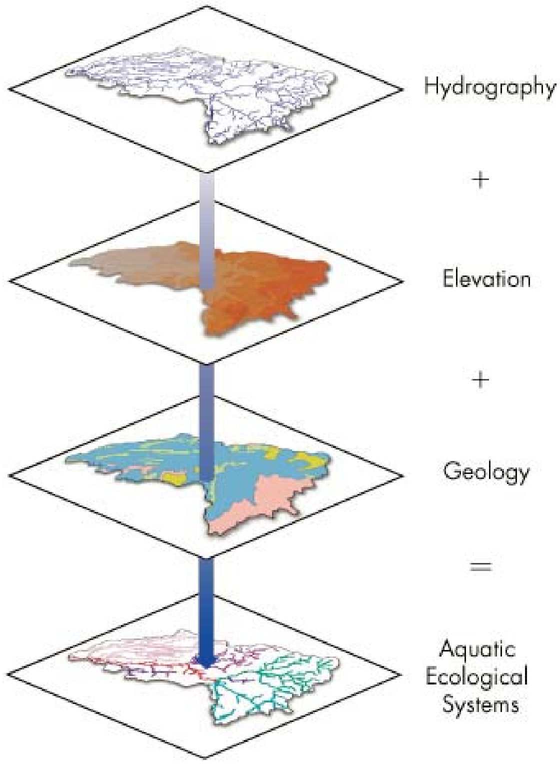


Figure 9. Hierarchical Nature of Aquatic Systems Delineation Within Ecoregions and EDUs

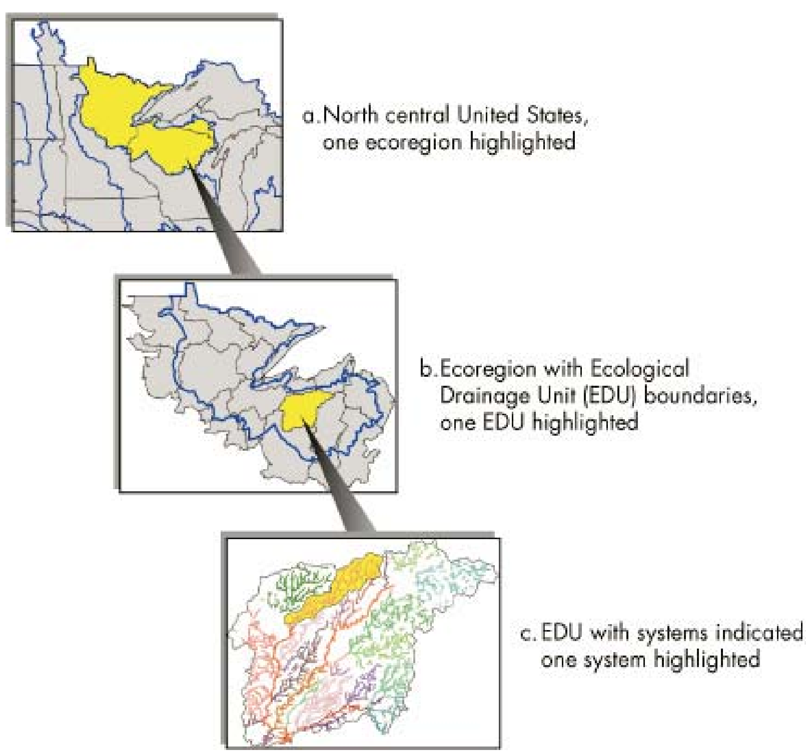


Figure 10. Some Examples of Aquatic Systems Occurring in the Four Aquatic Regions

Large, low gradient rivers, in unconsolidated sands, with floodplain wetlands. Photograph by Brian Richter/TNC.

Small, moderate gradient rivers, with acidic water chemistry, in Cumberland Plateau sandstones. Photograph by Harold E. Malde.

Creeks and headwaters, high gradient in acidic granites, with flashy hydrologic regime. Photograph by Ben Muskin/TNC Photo Contest.

through species targeting. Pictures of other examples of aquatic systems are in illustrated in Figure 10. Aquatic systems were mapped using the Environmental Protection Agency's Reach File 3 hydrography data (e.g., Figure 11).

Conservation Goals

Conservation goals in ecoregional planning define the number and spatial distribution of on-the-ground occurrences of targets that are needed to adequately conserve them in an ecoregion for at least 100 years or 10 generations (whichever is longer). Setting such goals also enables planners to measure how successful a portfolio of conservation areas is at representing and conserving targets in an ecoregion. For instance, if goals are not met in an ecoregional plan, the shortfall of occurrences represents a set of restoration goals. A key aspect of defining conservation goals is that planners seek to represent high quality occurrences of each target stratified across its geographic range. This stratification captures the necessary number of replicates and the genetic and landscape variation that will ensure persistence of the targets in the face of environmental stochasticity, anthropogenic impacts and the likely effects of climate change.

The principles guiding initial definition of goals for each species target (Table 2) were threefold:

1) EDUs are the fundamental sub-regional units of environment, zoogeographic, genetic, and evolutionary process variation within the range of a species or community.

2) Goals must be feasible based upon an assessment of the prevalence of historically occurring habitat for each target within EDUs. For example, there may only be one or two large rivers in an EDU

Table 1. Elevation, Stream Size, Gradient, Downstream Connection, and Bedrock and Surficial Geology Classes Used in Stream Reach Attribution for Aquatic System Classification

Elevation (Meters)	Stream Size (Link)	Gradient	Downstream Connection	Bedrock and Surficial Geology Characteristics
Low (<300)	Headwater (1-10)	Low (<0.01)	Streams, Small Rivers	Recent river alluvium
Moderate (301-900)	Creek (11-100)	Moderate (0.01-0.05)	Large Rivers	Gravels
High (>900)	Sm. River (101-1000)	High (>0.05)	Lakes	Sands
	Md. River (1001-2500)		Ocean	Mixed sands, silts, clays
	Lg. River (>2500)		Embayments	Noncalcareous clays
				Calcareous clays
				Pleistocene terrace
				Pleistocene valley-train
				Loess
				Marsh deposits
				Loose limestone, shell
				Alkaline sedimentary
				Moderately alkaline mixture
				Fissile shales
				Erodible acidic sedimentary, meta-sedimentary
				Resistant acidic sedimentary, meta-sedimentary
				Erodible acidic, intermediate igneous, meta-igneous
				Resistant acidic, intermediate igneous, meta-igneous
				Erodible mafic igneous, meta-igneous
				Resistant mafic igneous, meta-igneous

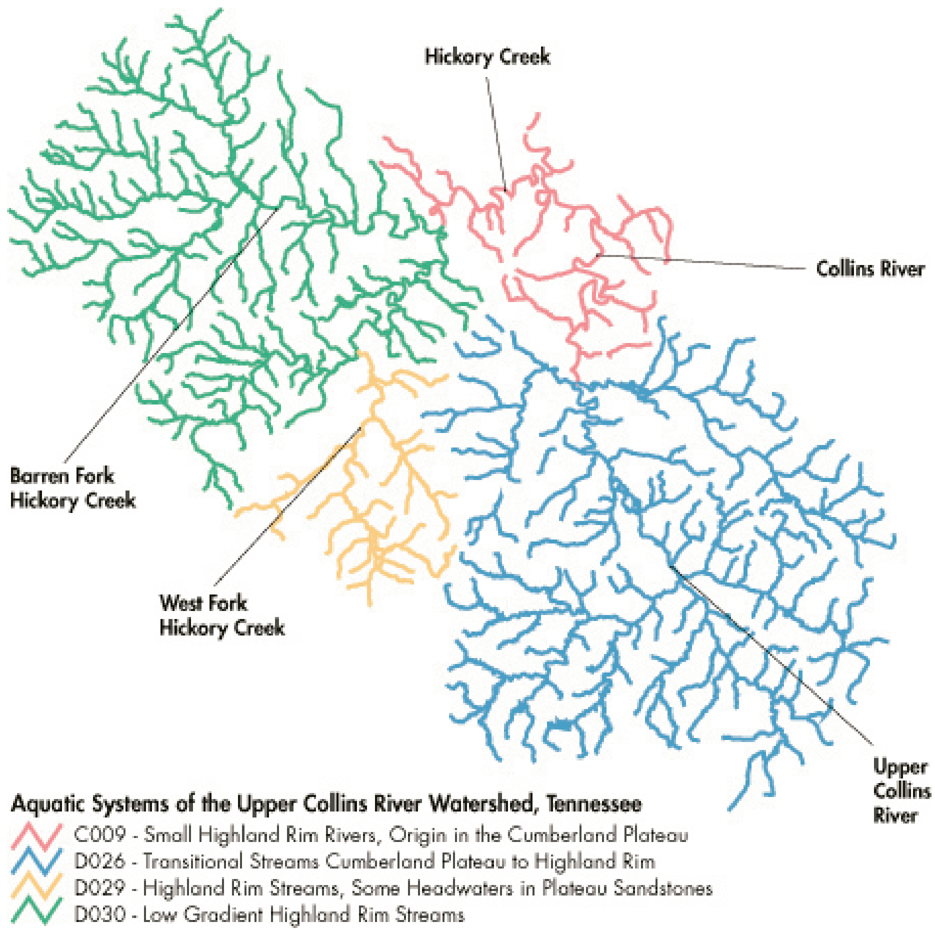
affording sufficient habitat for one population of a large river target, but a single river system may support sufficient habitat for several populations of targets inhabiting small streams. Thus, a target goal such as number of populations desired per EDU should be lower for large river species targets than small stream targets.

3) More populations are needed to ensure persistence of species that are prone to local extirpation based on their life history or habitat preferences. Wherever possible, we assessed susceptibility to extirpation for each species and increased the goal for vulnerable species.

In some cases, the final goal was increased or decreased according to specific circumstances. For example, for species targets known with a high degree of certainty to have only a small number of historic populations, goals were decreased from the initial to the maximum number of populations known historically for the species.

The goal for aquatic systems targets was to protect occurrences that appear to be functioning within an historic range of variation and demonstrating a high level of ecological integrity. Goals included one occurrence of each medium and large sized river system, two occurrences of each small river system, and three occurrences of each creek/headwater system in each EDU (Table 3). Systems peripheral to a basin (i.e., systems occurring primarily outside of the focus basins) had goals of one occurrence per EDU for all sizes. There was a minimum stream/river length required for inclusion

Figure 11. Example of an Aquatic Systems Map — Aquatic Systems of the Upper Collins River Watershed, Tennessee



of occurrences of lotic aquatic system targets as viable examples. This was based on the assumed requirements of the biotic components of the communities contained in the system. Thus, the minimum length is greater for large rivers than for creeks and small rivers (Table 3).

Target Occurrences and Conservation Area Delineation

Aquatic target occurrences were delineated in two steps. First, experts identified areas supporting viable populations (i.e., occurrences) of species targets. The specific reaches of streams or lakes that contained these targets were delineated in a GIS. The experts then identified high quality stream reaches to represent aquatic systems not "captured" by the species occurrences.

We delineated conservation areas around occurrences of target species and ecological systems that experts identified as conservation priorities (Figure 12). A fine-scale assessment of any conservation area is needed to determine the exact boundaries of the ecological processes that maintain the conservation targets. This fine-scale assessment is beyond the scope of this project and is best addressed when developing single-area strategies.

Table 2. Goals for Representation of Species Targets in Conservation Areas

Global Rank	Distribution Relative to Aquatic Region	Stream/River Size Inhabited by Species Target	Number of Populations Required in Each EDU
G1-G2	Endemic (>90% of range in aquatic region)	Large Rivers	1
		Small Rivers	2
		Creeks, Headwaters	3
	Widespread	Large Rivers	1
		Small Rivers	2
		Creeks, Headwaters	3
G3-G5	Endemic (>90% of range in aquatic region)	Large Rivers	1
		Small Rivers	1
		Creeks, Headwaters	2
	Widespread	Large Rivers	1
		Small Rivers	1
		Creeks, Headwaters	2

Table 3. Goals for Representation of Aquatic System Targets in Conservation Areas

Category of Target	Number of Occurrences Required in Each EDU	Minimum Length for Viable System Occurrence
Large, Medium Rivers	1	40 km
Small Rivers	2	15 km
Headwaters, Creeks	3	5 km

We represented conservation areas in three ways:

1) For conservation areas that were simply creeks or small rivers we highlighted the entire watershed area.

2) For medium and large rivers we buffered the stream lines to 1 kilometer. This spatial representation represents a compromise between the need for conservation areas to be easily distinguishable on a map but to not constitute too large a portion of the region (e.g., if all of the watershed area affecting target occurrences in the Mobile River Basin was represented it would potentially comprise the entire region), even if all of the area must eventually be considered for activities to some extent to conserve the target occurrences.

3) We used polygons encompassing spring complexes or important caves supporting aquatic

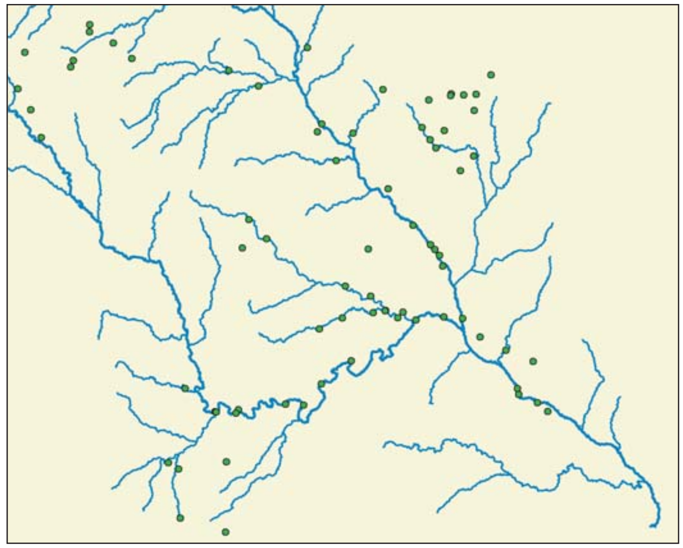
BOX 3. Target Viability and Ecological Integrity

We define viability as the ability of an individual species population or system occurrence to persist for at least 100 years. Ecological integrity is a valuation of the dominant processes necessary to maintain the biological components of ecosystems. Viability is a function of the size, condition, and landscape context o the target population. Ecological integrity is assessed from expert opinion about the extent to which processes necessary to maintain the biotic targets in ecosystems are functioning, and indirectly through landscape-scale GIS analysis of threats to freshwater ecosystems.

Figure 12. Delineating Conservation Areas from Target Occurrences

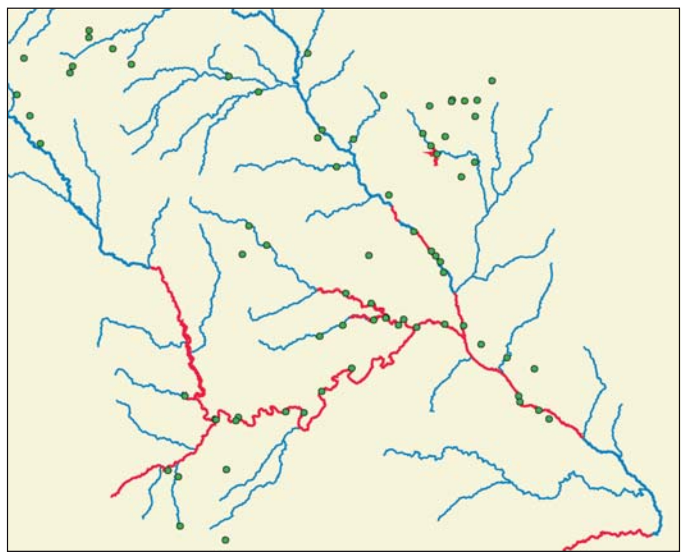
Step 1

Assembled readily available sources of data on target distributions. Most of these were point collections or observations. Sources included Natural Heritage Program databases, experts survey data, and published reports.



Step 2

Delineated species populations by attributing the point collection data to GIS reaches that represent the spatial extent of the species populations.



targets, or a natural lake with or without upstream or downstream connected tributaries.

In some cases, we kept adjacent or connecting reaches as separate conservation areas if the targets captured in them were distinct in life history and/or size of stream occupied from adjacent ones. We also maintained separation among conservation areas occurring in separate EDUs.

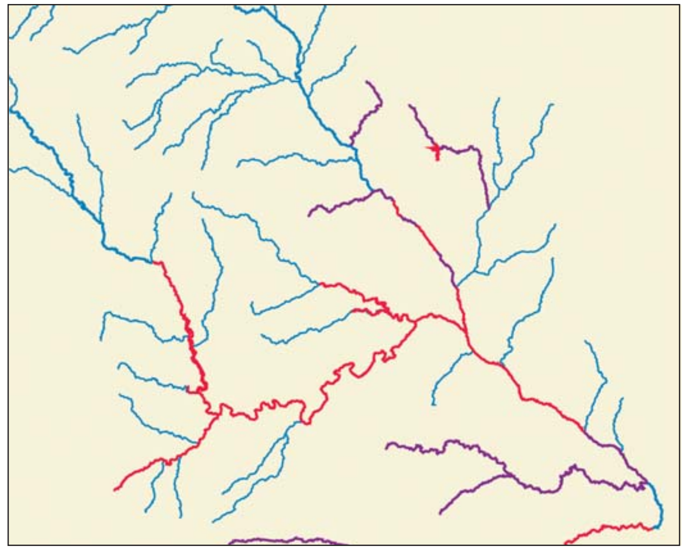
Data Collected for Subsequent Analysis

In addition to data on target occurrences and viability, we compiled information on the threats to biodiversity (stresses and sources of stress), urgency of need for conservation effort, the probability of success of conservation efforts, existing conservation partners and managed areas, and initial suggestions

Figure 12 continued

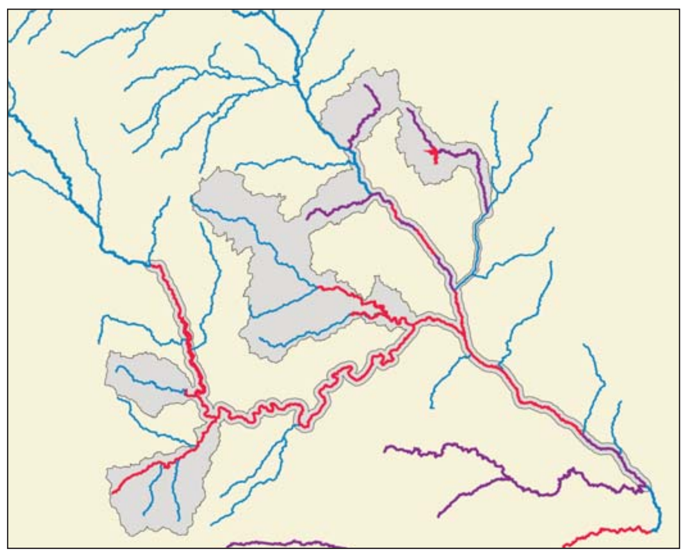
Step 3

Compiled the resulting set of reach occurrences for all target species and aquatic systems and combined the different taxa group maps. In many cases, several species occurred in the same reaches.



Step 4

Delineated conservation areas around the species populations according to the mapping guidelines outlined in the text.



for conservation strategies. This data, when combined with information on number of targets, rarity of targets, and viability, can be used to set priorities or evaluate funding applications based on an objective assessment of level of threat and urgency of action. The data will also be useful to teams responsible for developing local conservation plans for each of these conservation areas. In some areas, this will be the best information available to identify threats and strategies for abating those threats.

For each conservation area, we also calculated a series of potential habitat quality indicators. We chose these indicators based on a literature review of research on the relationship between watershed characteristics and aquatic biological integrity (FitzHugh 2001). Most of these indicators have been found in previous research to influence stream biological integrity. The quality indicators are:

- Percent land cover distribution in the following classes:
  - Water
  - Urban area
  - Barren
  - Forest
  - Agriculture
  - Wetlands
- Percent impervious surface (calculated from the land cover data)
- Road density (road length/watershed area)
- Road-stream crossing density (crossings/stream length in watershed)
- Dam density (dams/length of stream watershed)
- Point source density (point sources/length of stream in watershed)

We calculated these indicators using a set of customized GIS tools that The Nature Conservancy employs in its ecoregional planning process. These tools allow the user to calculate, for each conservation area, the aggregate characteristics of the upstream watershed. Indicators were calculated using the entire watershed with the exception of small conservation areas such as swamps, where entire-watershed indicators may not be meaningful.

Most research to date on the relationship between these indicators and biological integrity has been conducted using small watersheds (Scheuler 1994), so entire-watershed indicators also may not be meaningful for mainstem river conservation areas, due to the great flow distances involved. For areas containing large rivers, the same indicators were also calculated for the local area immediately surrounding the mainstem defined by a one kilometer buffer.

ECOREGION DESCRIPTIONS AND RESULTS

Tennessee-Cumberland

The Clinch River, Tennessee. Photograph by Byron Jorjorian.

The Tennessee-Cumberland aquatic region spans 152,292 km^2, draining the Appalachian Highlands, Cumberland Mountains and Plateaus, Ridge and Valley, Highland Rim/Nashville Basin, and Coastal Plain (Figure 13). It is geologically complex (Figure 14) and contains a high diversity of stream types (Abell et al. 2000). This region contains the highest number of fish, mussel and crayfish species, and the highest number of endemic freshwater fauna in North America, with 231 species of fish (67 endemic), 125 species of mussels (20 endemic) and 65 species of crayfish (40 endemic). More than 57 species of fish and 47 species of mussels are classified as at-risk (Master et al. 1998, Abell et al. 2000). The primary impacts to this region are hydrologic alteration from impoundments, channelization and land use; pollution from industrial, urban and agricultural runoff; excessive sedimentation; and rapid urban expansion (Abell et al. 2000). Nearly 70% of the region is forest and nearly 25% is agriculture, with small percentages urban, water, and wetlands (USGS 1992; see Figure 15).

This aquatic region is divided into the Cumberland River and Tennessee River Basins. To delineate Ecological Drainage Units (EDUs), we broke up the two river basins according to physiographic distinctions, primarily reflecting the conclusions of Etnier and Starnes (1986) and the section level ecoregions of the U.S. Forest Service (McNab and Avers 1994). We identified nine EDUs in the Tennessee-Cumberland region (Table 4, see Figure 6), distinguished primarily by zoogeography and physiography.

Conservation Targets and Conservation Areas

We considered 135 species targets in the Tennessee-Cumberland aquatic region, most of which inhabit streams and small rivers (Table 5). The targets include 52 of the 231 fish species known to occur in the region, 46 of the 125 known mussel species, 22 snail species, 10 crayfish species, 2 amphibian species, and 3 insect species. Many of these targets are endemic to this aquatic region, and 38 have viable populations known from only one EDU.

We identified 120 aquatic systems targets in the Tennessee-Cumberland (Table 7). Eight of these aquatic system targets are large rivers, 10 were medium rivers, 20 were small rivers, and 82 were headwaters/creeks. There were no natural lake system targets in the Tennessee-Cumberland aquatic region.

Experts delineated 70 conservation areas in the Tennessee-Cumberland Basin (Figure 16). Of these, 28 occur primarily in the Highland Rim/Nashville Basin, 20 in the Cumberland Mountains and Plateau and Ridge and Valley, 19 in the Southern Blue Ridge, and 3 in the Coastal Plain. Twenty of these conservation areas have only one species target, many of which are localized endemic species with one or two known occurrences.

Table 4. Ecological Drainage Units of the Tennessee-Cumberland Aquatic Region

EDU Name
Tennessee River - Ridge and Valley
Tennessee River - Blue Ridge
Tennessee River - Cumberland Plateau
Tennessee River - Nashville Basin
Lower Tennessee River
Cumberland Mountain
Upper Cumberland River
Cumberland River - Nashville Basin
Lower Cumberland River

Conservation Goals

In Tennessee-Cumberland conservation areas we captured at least one population of all species targets and 76 of 120 aquatic system targets. Lists of targets and progress toward conservation goals are detailed on the CD. Some key observations about goals are:

- We met the highest number of goals for mussels and amphibian species, but met few goals for crayfishes and snails (Table 6).
- Approximately 50% of species target goals were met in most EDUs (Table 8).
- The lowest number of species goals were met in the Nashville Basin EDUs.
- The highest number of goals were met for species in the upper Ridge and Valley portions of the Tennessee River drainage and the uppermost portions of the Cumberland River drainage.
- Endemic species that have only one or two known populations reached few conservation goals, while goals were met for more than 50% of widespread species.
- We met a higher number of goals for aquatic systems composed of small rivers and creeks/

Figure 13. Locator Map of the Tennessee-Cumberland Aquatic Region

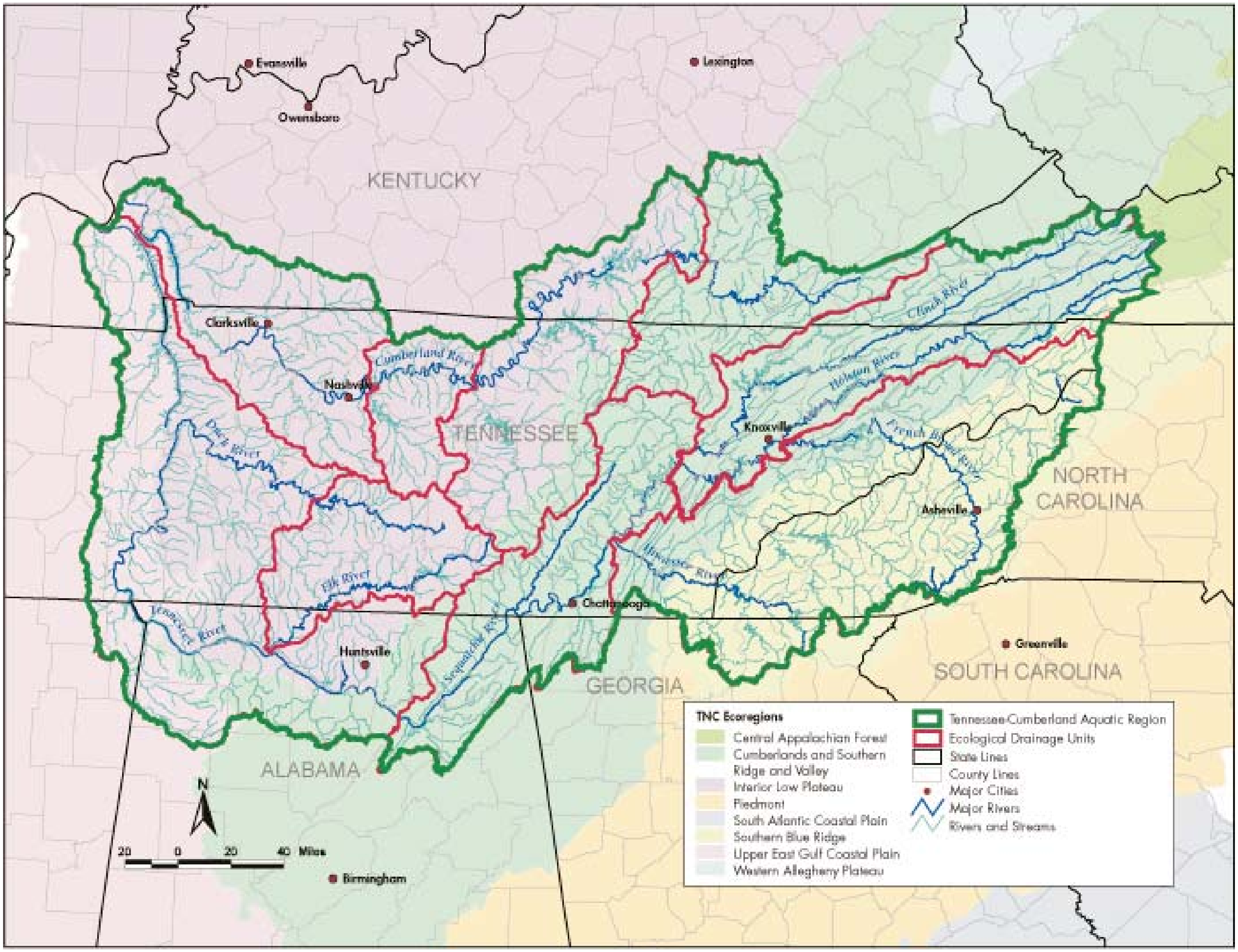


Table 5. Global Ranks, Distributions, and Preferred Habitat Groups of Tennessee-Cumberland Aquatic Region Species Targets

Global Rank	Distribution	Habitat Group	Number of Targets
G1-G2	Endemic	Large Rivers	0
		Small Rivers	41
		Streams	39
	Widespread	Large Rivers	2
		Small Rivers	11
		Streams	2
G3-G5	Endemic	Large Rivers	0
		Small Rivers	11
		Streams	7
	Widespread	Large Rivers	5
		Small Rivers	14
		Streams	3

headwaters than for medium and large river systems (Table 7).

- Approximately 50% of the conservation goals were met for aquatic systems targets in most EDUs (Table 8).
- However, few goals were met for creek and headwater size targets in the Ridge and Valley portions of the Tennessee River drainage.
- Few conservation goals were met for systems occurring in the Coastal Plain portions of the Tennessee River drainage and the Interior Low Plateau portions of the lower Cumberland River and Cumberland River-Nashville Basin EDUs.

Small rivers and larger creeks were best represented in Tennessee-Cumberland conservation areas because they have the most examples of least impacted landscapes. There are few sections of high quality, medium or large rivers with ecological integrity remaining in the Tennessee-Cumberland region since most of the main channel rivers have been dammed and have regulated flows.

Table 6. Species Target Representation in Tennessee-Cumberland Aquatic Region Conservation Areas

Target Category	Number of Species Targets	Number and (%) of Species Targets with All EDU Goals Met
Taxonomic Group		
amphibian	2	1 (50%)
insect	3	1 (33%)
crayfish	10	1 (10%)
snail	22	3 (14%)
mussel	46	18 (39%)
fish	52	15 (29%)
G-Rank		
GU	2	0 (0%)
G4	6	6 (100%)
G3	33	23 (70%)
G2	30	3 (10%)
G1	64	7 (11%)
Distribution		
Endemic	98	16 (16%)
Widespread	33	22 (67%)
Peripheral	4	1 (25%)

The few represented river targets are sections below reservoirs with relatively stable flows that have been identified for recovery of some large river mussels, fishes, and snails. However, the ability of even these larger river sections to support long-term viable

Figure 14. Physiography of the Tennessee-Cumberland Aquatic Region

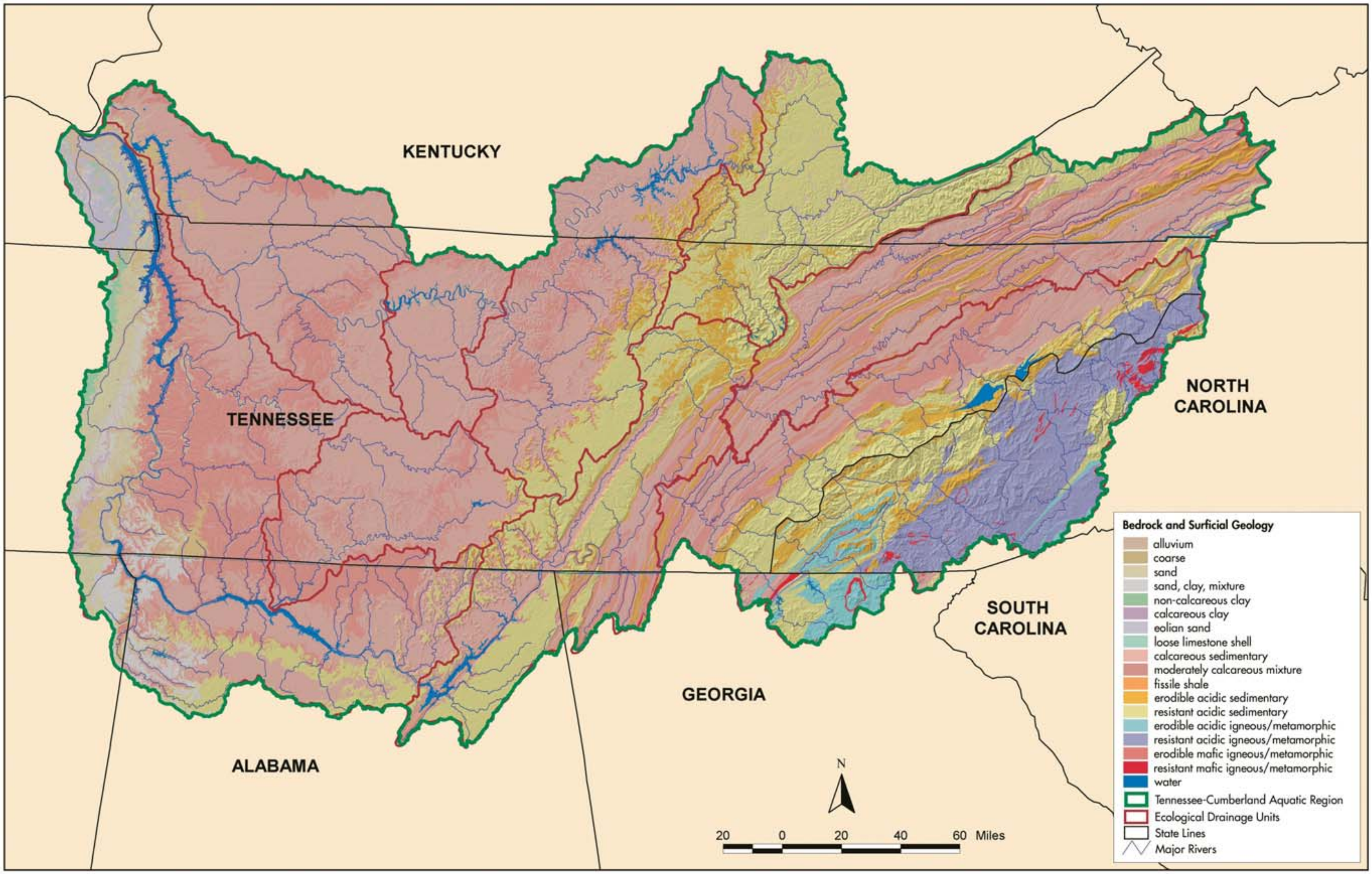


Figure 15. Land Use/Land Cover of the Tennessee-Cumberland Aquatic Region

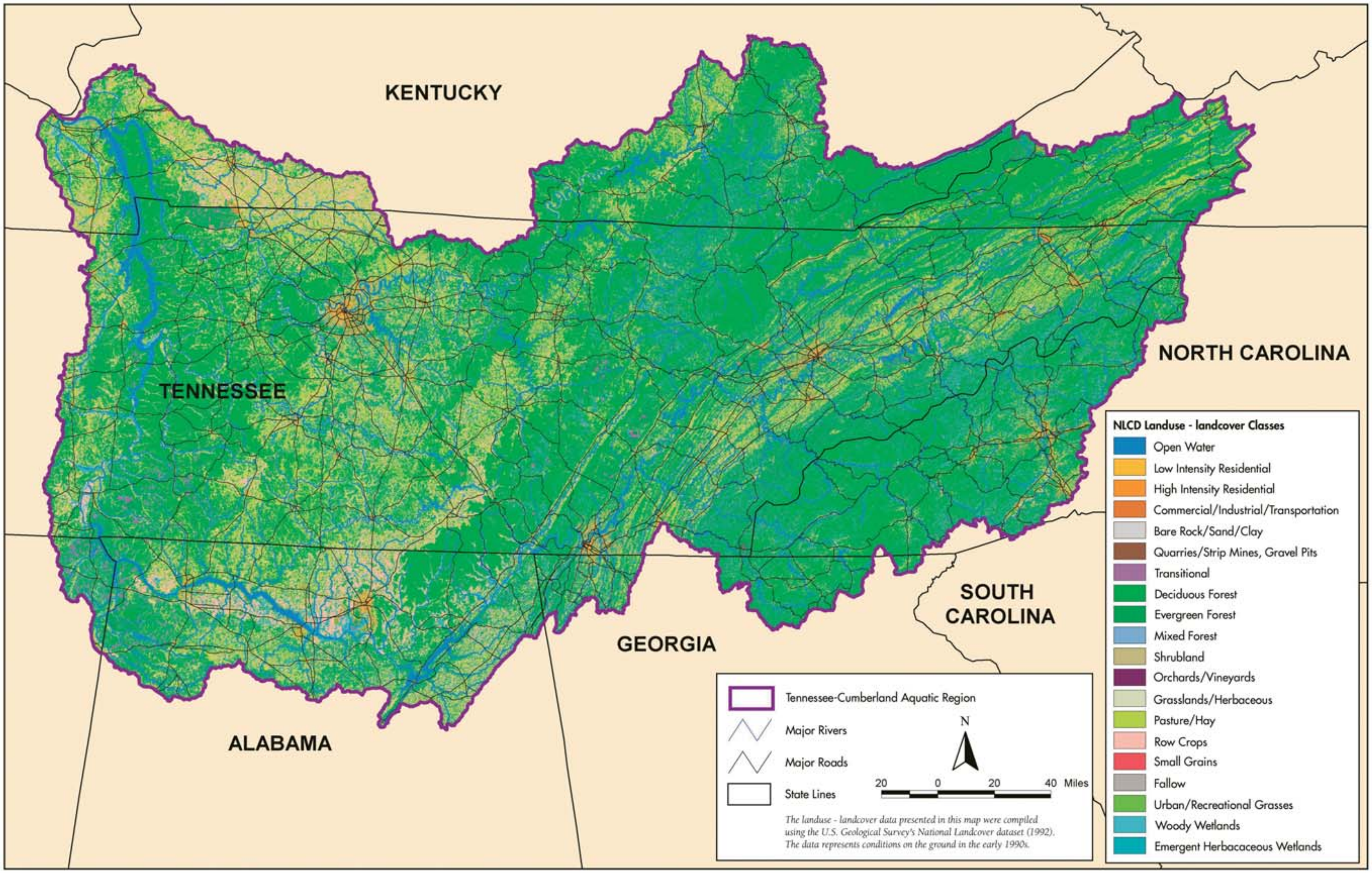


Figure 16. Freshwater Conservation Areas of the Tennessee-Cumberland Aquatic Region

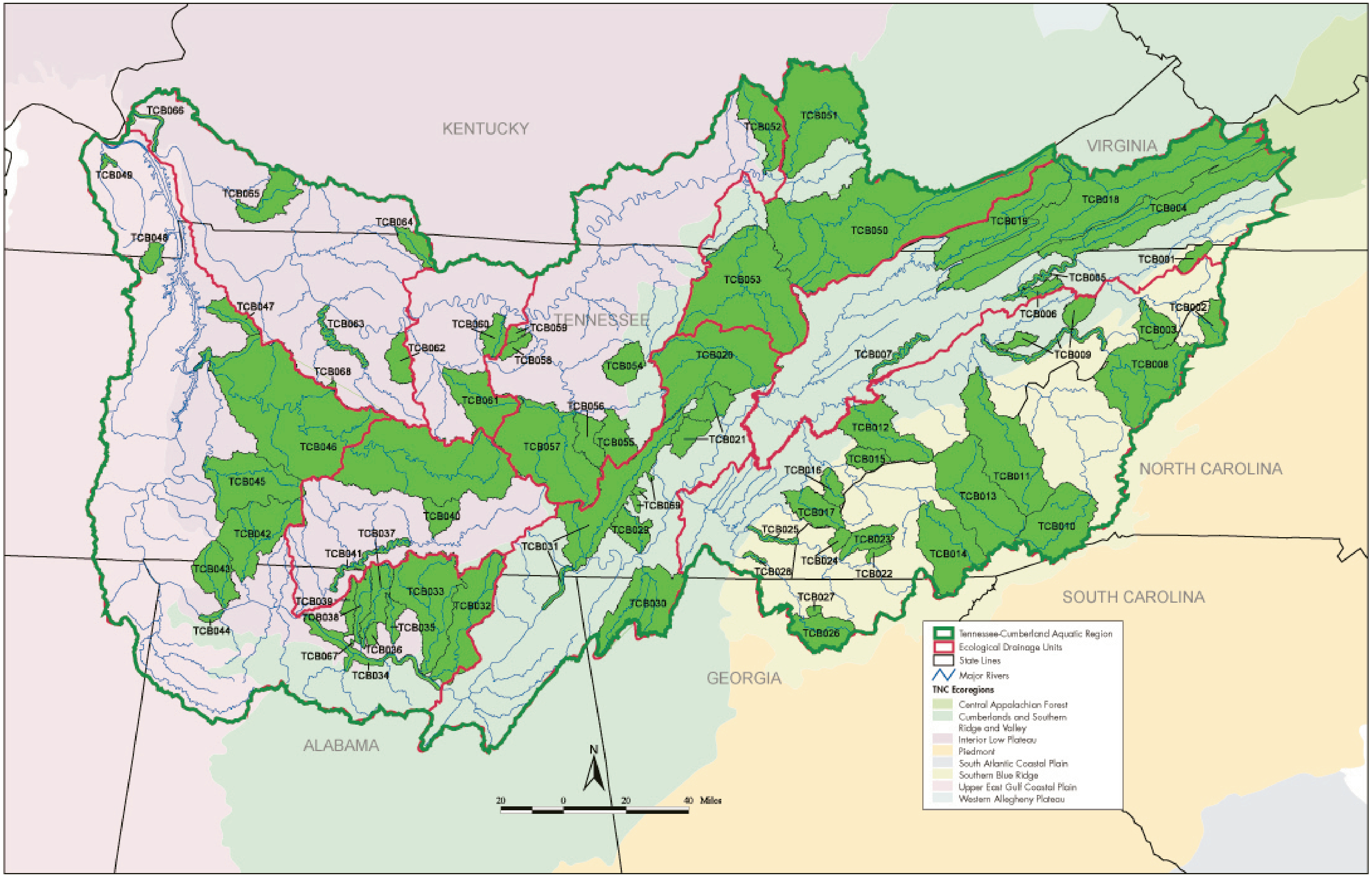


Table 7. Aquatic System Target Representation in Tennessee-Cumberland Aquatic Region Conservation Areas

Aquatic System Target Category	Number of System Targets in Category	Number and (%) of System Targets Represented in at Least One Conservation Area	Number and (%) of System Targets with Goal Met
Large Rivers	8	4 (50%)	4 (50%)
Medium Rivers	10	3 (30%)	3 (30%)
Small Rivers	20	18 (90%)	10 (50%)
Creeks, Headwaters	82	51 (62%)	35 (43%)

Table 8. Goals Met for Tennessee-Cumberland Species and Aquatic System Targets in Each Ecological Drainage Unit

EDU #	EDU Name	Number of Species Targets in EDU	Number and (%) of Species Goals Met	Number of Aquatic Systems Targets in EDU	Number and (%) of Aquatic Systems Goals Met
1.01	Tennessee River - Ridge and Valley	64	44 (69%)	22	10 (45%)
1.02	Tennessee River - Blue Ridge	44	25 (57%)	23	10 (43%)
1.03	Tennessee River - Cumberland Plateau	32	14 (44%)	15	8 (53%)
1.04	Tennessee River - Nashville Basin	10	2 (20%)	6	3 (50%)
1.05	Lower Tennessee River	76	32 (42%)	18	10 (56%)
1.06	Cumberland Mountain	28	14 (50%)	8	5 (63%)
1.07	Upper Cumberland River	26	12 (46%)	11	4 (36%)
1.08	Cumberland River - Nashville Basin	3	0 (0%)	9	1 (11%)
1.09	Lower Cumberland River	11	3 (27%)	8	1 (13%)

populations of diadromous species that once occupied the Tennessee and Cumberland rivers is questionable.

Coastal Plain portions of the Tennessee River drainage and the lower Cumberland River drainage constitute a data gap because we were not able to identify many high quality examples of these systems types. The Coastal Plain portions of the Tennessee River drainage also have been heavily altered from agriculture, and few system types with high degrees of ecological integrity remain.

The federeally endangered fanshell (Cypr ogenia stegaria), photograph by Kevin S. Cummings/Illinois Natural History Survey.

Mississippi Embayment

The Hatchie River, Tennessee. Photograph by Byron Jorjorian

Large temperate rivers, defined by the mainstem of the Mississippi River and lowermost reaches of the White, Arkansas, Ouachita, and Red Rivers characterize this 258,675 km^2 region (Abell et al. 2000) (Figure 17). The region lies entirely within the Gulf Coastal Plain and Mississippi River Alluvial Plain (Figure 18), and historically was dominated by swamps, marshes, and bottomland forests. It served as a center for fish distribution and as a refuge for fishes during glacial periods (Abell et al. 2000). As a result, there are many species of fish with few being endemic: of 206 fish species, only 11 are endemic to the region, and these are found in tributary drainages. The characteristic larger river biota include ancient river fishes such as five lamprey species, four sturgeon, four gar, bowfin and paddlefish (Abell et al. (2000). There are 63 species of mussels, 57 species of crayfish (of which 23 are endemic to the Mississippi Embayment) and 68 species of amphibians and aquatic reptiles.

Major impacts to the region include hydrologic alteration from over 4,000 dams, channelization, levees and land use, nearly 4,000 non-point sources of sedimentation and pesticides from agriculture, poor water quality discharges from urban centers, and conversion of natural vegetation such as floodplain forest and other wetlands to agriculture (Abell et al. 2000). Just under half of the region is forest, and approximately one-third is agriculture, with the rest water, urban, barren, and wetlands (Figure 19).

We aggregated the 87 eight-digit USGS hydrologic units of the Mississippi Embayment into 18 ecological drainage units (Table 9). Several EDUs (Lower Red, Arkansas, Mississippi, Mississippi Delta) represent portions of major drainage systems that terminate in Coastal Plain and Alluvial Plain portions of the region. Other EDUs represent the entire watershed of a single coastal drainage system (e.g., Atchafalaya River) or a lumping of several small drainages (e.g., smaller systems of western Tennessee). In other cases, we divided drainage systems into those portions occurring in different physiographic domains (e.g., alluvial vs. Coastal Plain portions of the Yazoo River drainage).

Table 9. Ecological Drainage Units of the Mississippi Embayment Aquatic Region

EDU Name
Chickasawhay River
Pascagoula, Escatawpa Rivers
Pearl River- Upper Coastal Plain
Lower Pearl River, Coastal Drainages
Lake Pontchartrain
Coastal Plain - Tennessee
Yazoo River - Coastal Plain
Yazoo River - Mississippi Alluvial Plain
Big Black, Lower Coastal Plain - Mississippi
St. Francis River
White River
Arkansas River
Ouachita River - Coastal Plain
Ouachita River - Mississippi Alluvial Plain
Lower Red River
Atchafalaya River
Lower Mississippi Delta
Mermentau, Vermilion Rivers

Conservation Targets and Conservation Areas

We selected 82 species targets considered in the Mississippi Embayment (Table 10). Overall, the Mississippi Embayment contains fewer targets and species endemic to the region than the other three aquatic regions. The most notable exception to this is a high number of endemic crayfishes that are restricted to the Mississippi Embayment, each with less than four known occurrences.

We identified 160 aquatic systems targets in the Mississippi Embayment (Table 12). The high number of system types is a result of the higher number of EDUs in the region. There is also a higher diversity of downstream connectivity in the region, with aquatic systems connecting to large rivers, embayments, and the Gulf of Mexico.

Experts delineated 79 conservation areas in the Mississippi Embayment (Figure 20). Of these, 37 have only one target, many of which are endemic with one or two known occurrences. Forty-nine of these conservation areas occur primarily on the eastern Gulf Coastal Plain, 14 in the Mississippi River alluvial plain, 14 in the western Gulf Coastal Plain, and 2 in coastal marshes. Thirteen of these conservation areas occur partially out of the region, but were included in the analyses because they fell within the EDU boundaries.[1]

Conservation Goals

In Mississippi Embayment conservation areas we "captured" at least one population of all species targets

[1] EDUs extend beyond the boundaries of this region because the drainage boundaries of the tributaries to the Mississippi do not correspond to the regional boundaries.

Figure 17. Locator Map of the Mississippi Embayment Aquatic Region

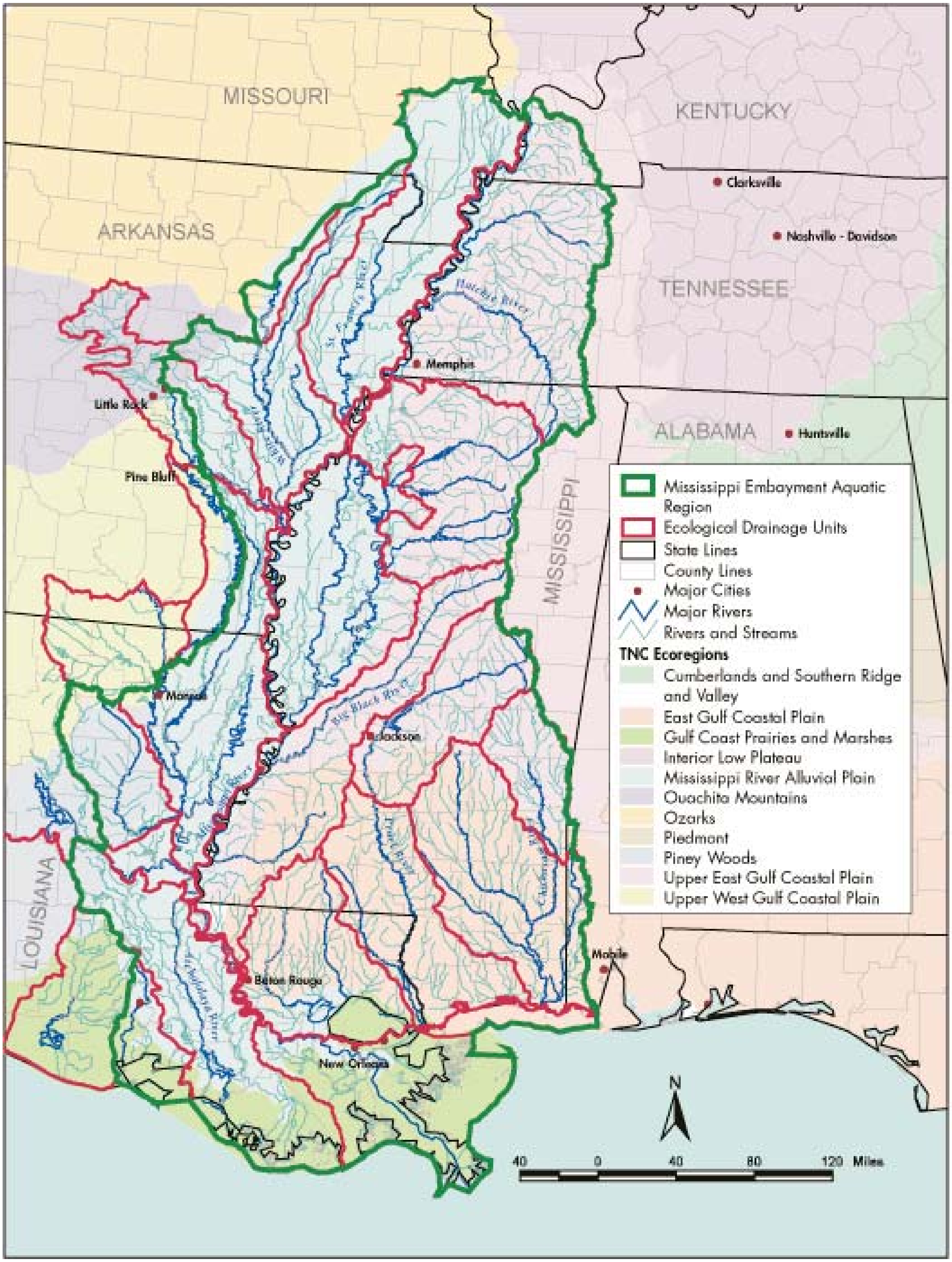


Figure 18. Physiography of the Mississippi Embayment Aquatic Region

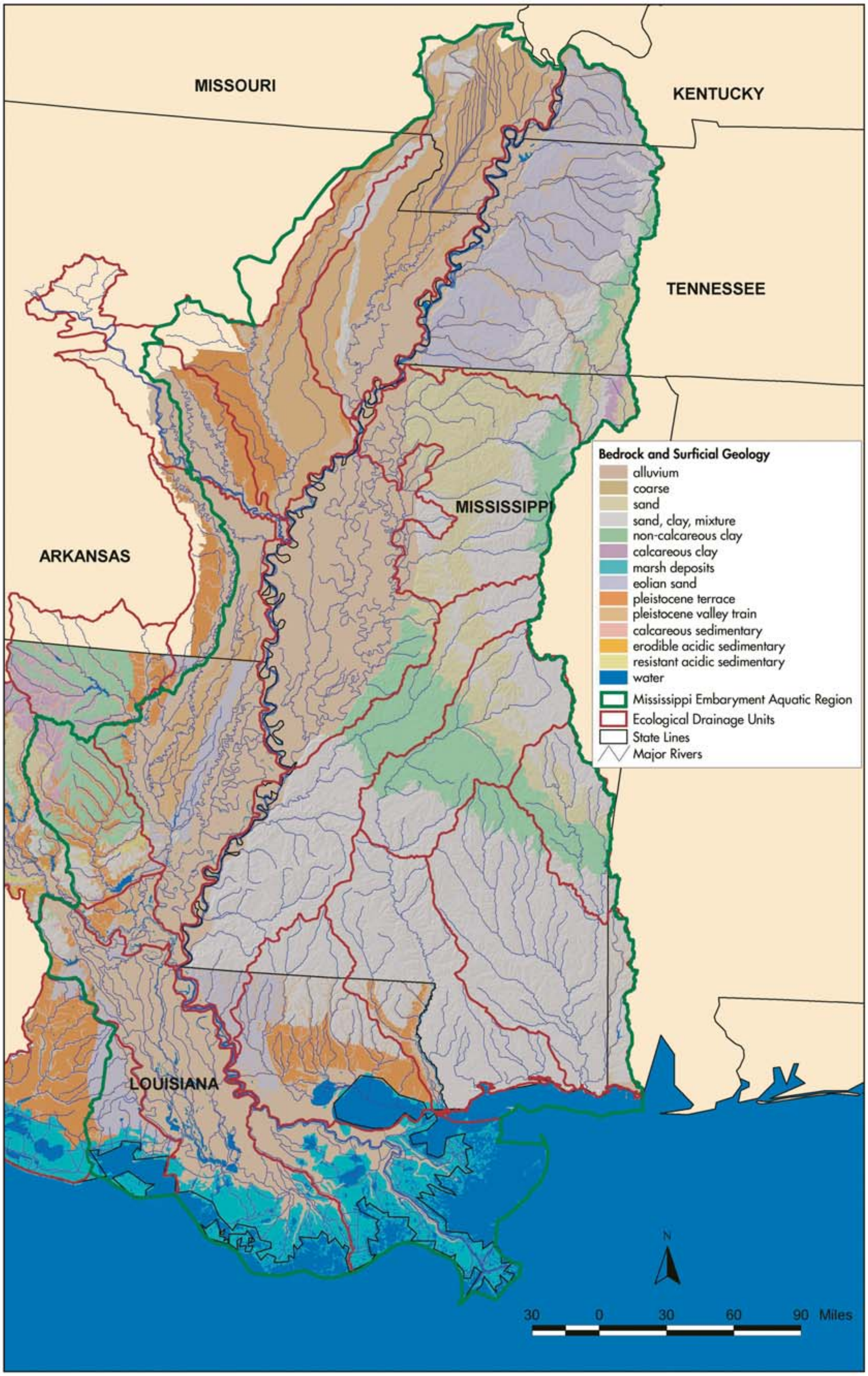


Figure 19. Land Use/Land Cover of the Mississippi Embayment Aquatic Region

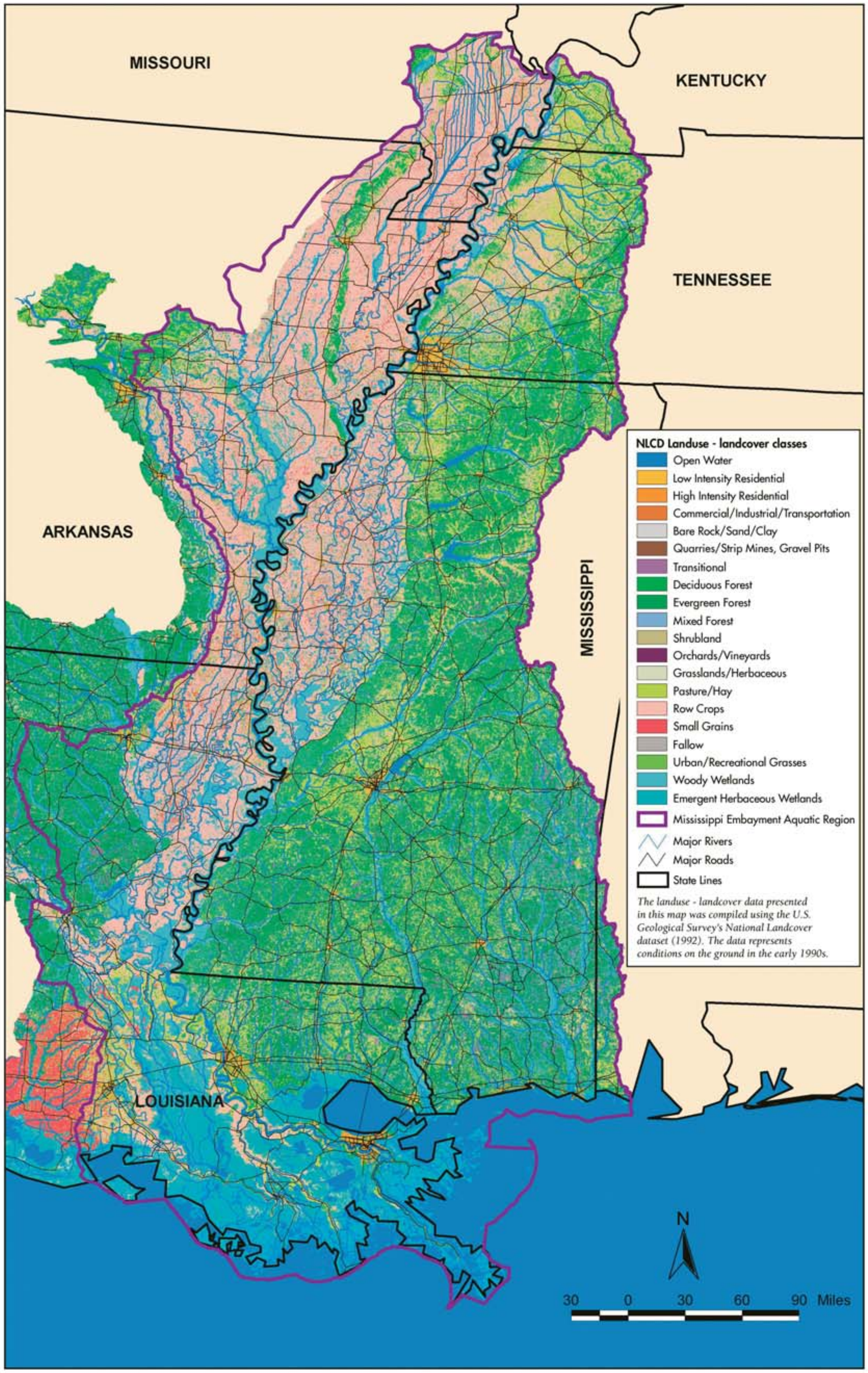


Figure 20. Conservation Areas of the Mississippi Embayment Aquatic Region

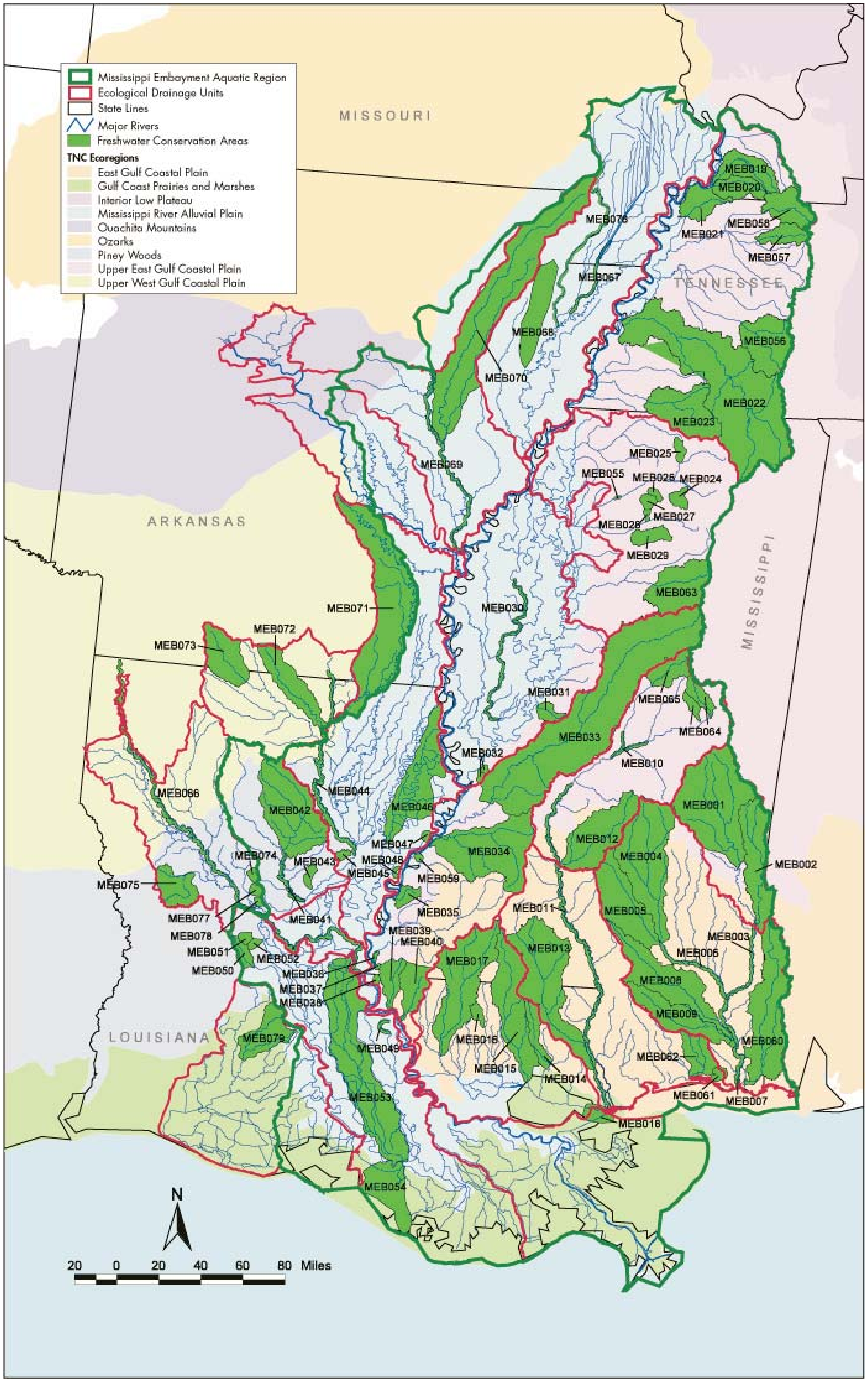


Table 10. Global Ranks, Distributions, and Preferred Habitat Groups of Mississippi Embayment Aquatic Region Species Targets

Global Rank	Distribution	Habitat Group	Number of Targets
G1-G2	Endemic	Large Rivers	0
		Small Rivers	4
		Streams	15
	Widespread	Large Rivers	1
		Small Rivers	9
		Streams	4
G3-G5	Endemic	Large Rivers	0
		Small Rivers	1
		Streams	5
	Widespread	Large Rivers	6
		Small Rivers	27
		Streams	10

and 80 of 163 aquatic system targets. Lists of targets and progress toward conservation goals are in the CD. Some key observations about goals are:

• We met a high percentage of goals for widespread species with high global ranks, while less than 30% of more globally rare endemic species had goals met (Table 11).

• In 13 of the 18 EDUs we met goals for more than 50% of species targets (Table 13).

• No goals were completely met for target species in the Lower Mississippi Delta, Arkansas, Mermentau, Vermilion River EDUs.

• Large and medium river systems had the highest percentage of goals met (Table 12).

• The highest number of aquatic systems goals were met in the Pascagoula and Pearl River EDUs (Table 13).

• We met a small number of goals in most other EDUs.

• We met the highest number of goals for aquatic systems occurring primarily in the Coastal Plain.

Table 11. Species Target Representation in Mississippi Embayment Aquatic Region Conservation Areas

Target Category	Number of Species Targets	Number and (%) of Species Targets with All EDU Goals Met
Taxonomic Group		
reptiles	1	1 (100%)
crayfishes	20	7 (35%)
snails	1	0 (0%)
mussels	31	17 (55%)
fishes	29	13 (45%)
G-Rank		
G5	17	12 (71%)
G4	8	4 (50%)
G3	24	13 (54%)
G2	18	5 (28%)
G1	15	4 (27%)
Distribution		
Endemic	25	7 (28%)
Widespread	52	28 (54%)
Peripheral	5	3 (60%)

• Several of the systems in the western portions of the Coastal Plain for which we did not meet goals occur primarily out of the basin and we did not ask experts to look out of the basin.

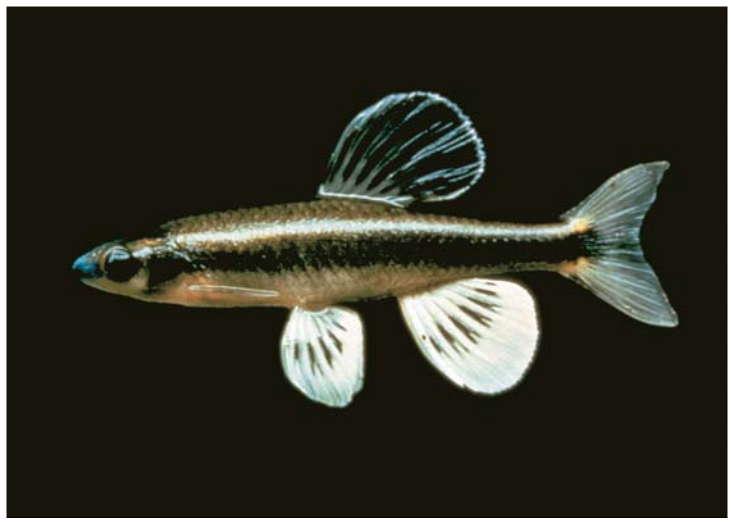
• We met few conservation goals for stream

Table 12. Aquatic System Target Representation in Mississippi Embayment Aquatic Region Conservation Areas

Aquatic System Target Category	Number of System Targets in Category	Number and (%) of System Targets Represented in at Least One Conservation Area	Number and (%) of System Targets with Goal Met
Large Rivers	14	6 (43%)	6 (43%)
Medium Rivers	11	5 (45%)	5 (45%)
Small Rivers	38	20 (53%)	8 (21%)
Creeks, Headwaters	88	47 (53%)	19 (22%)
Lakes	9	2 (22%)	1 (11%)

systems occurring in the Alluvial Plain.

Few conservation goals were met in the Mississippi Embayment, even for areas that experts know well, because of the intense alteration of the regional landscape. Experts could identify few sections of high quality, medium or large rivers in the region with high levels of ecological integrity since most of the main channel rivers have been dammed, leveed and have regulated flows. The few river ecosystem targets that are the best remaining examples of these systems are still subject to intense dredging, channel maintenance, and alteration of flow regime. However, these large river sections still support diadromous species that have access to many tributary drainages, and still serve as important migratory corridors. Alluvial plain stream systems met few conservation goals because these regions have been heavily altered for agriculture and flood control. Experts determined many of these systems not to be worthy of conservation attention. Restoration should be considered one of the primary strategies in this region.



Bluenose shiner (Pteronotropis welaka). *Photograph by Malcolm Pierson.*

We also did not well represent coastal brackish marsh and tidal systems of the Atchafalaya River, Mississippi Delta, and Mermentau/Vermillion Rivers EDUs. These areas have also been heavily altered. However, engagement of other groups of expert and practitioners could easily identify the most restorable portions of such habitats.

Table 13. Goals Met for Mississippi Embayment Species and Aquatic System Targets in Each Ecological Drainage Unit

EDU #	EDU Name	Number of Species Targets in EDU	Number and (%) of Species Goals Met	Number of Aquatic Systems Targets in EDU	Number and (%) of Aquatic Systems Goals Met
2.01	Chickasawhay River	4	0 (0%)	4	3 (75%)
2.02	Pascagoula, Escatawpa Rivers	22	14 (64%)	8	4 (50%)
2.03	Pearl River - Upper Coastal Plain	23	15 (65%)	6	4 (67%)
2.04	Lower Pearl River, Coastal Drainages	14	9 (64%)	8	2 (25%)
2.05	Lake Pontchartrain	12	7 (58%)	10	3 (30%)
2.06	Coastal Plain - Tennessee	19	12 (63%)	13	5 (38%)
2.07	Yazoo River - Coastal Plain	9	7 (78%)	10	2 (20%)
2.08	Yazoo River - MS Alluvial Plain	11	6 (55%)	16	0 (0%)
2.09	Big Black, Mississippi Lower Coastal Plain	21	16 (76%)	10	5 (50%)
2.10	St. Francis River	16	13 (81%)	9	1 (11%)
2.11	White River	4	4 (100%)	10	1 (10%)
2.12	Arkansas River	1	0 (0%)	4	0 (0%)
2.13	Ouachita River - Coastal Plain	4	3 (75%)	9	3 (33%)
2.14	Ouachita River - MS Alluvial Plain	23	19 (83%)	11	3 (27%)
2.15	Lower Red River	7	5 (71%)	9	1 (11%)
2.16	Atchafalaya River	7	5 (71%)	11	2 (18%)
2.17	Lower Mississippi Delta	0	0 (0%)	6	0 (0%)
2.18	Mermentau, Vermilion Rivers	1	0 (0%)	6	0 (0%)

South Atlantic

The Altamaha River, Georgia. Photograph by Harold E. Malde.

This aquatic region is 296,608 km^2, draining the Blue Ridge Mountains, the Piedmont Plateau and the Atlantic Coastal Plain (Figures 21, 22). These three major physiographic provinces account for the region's variety of freshwater ecosystem types. Major river systems include the Altamaha, Savannah, Cooper-Santee, Pee Dee, Cape Fear, Neuse, Tar, and Roanoke. In addition, there are numerous Piedmont and Coastal Plain rivers and wetlands (Abell et al. 2000). The South Atlantic is diverse for a temperate region, historically containing 177 species of fish (48 endemic), 59 species of freshwater mussels (19 endemic) and 56 crayfish species (39 endemic), and a number of endemic amphibians. Forty-seven of the species of fish and mussels are at risk of extinction (Master et al. 1998, Abell et al. 2000).

Primary impacts to this region include urban development—this is the most urban of the four aquatic regions and contains the most roads—channelization, agricultural runoff, dams, and non-native species. Most of the native forest cover has been replaced with agriculture or silviculture (Abell et al. 2000). Slightly more than half of the region is forested, roughly one-fifth is agriculture, and the remainder is water, urban, barren, and wetlands (Figure 23).

We delineated 13 EDUs (Table 14) in the South Atlantic region according to major drainage systems and physiographic zones. We divided each major Atlantic drainage into at least two EDUs, one representing the Piedmont and Blue Ridge portions of the drainages and the other the Coastal Plain portions. The exception was the Roanoke drainage which had a third EDU delineated to represent the areas of the drainage that have penetrated the Blue Ridge into the Ridge and Valley province. Due to zoogeographic similarities, we lumped together the Albemarle and Pamlico drainages, the lower Santee and Edisto drainages, and the lower Savannah and Ogeechee drainages.

Conservation Targets and Conservation Areas

We considered 176 aquatic systems and 118 species targets in the South Atlantic aquatic region (Tables 15, 17). There are three notable centers of endemism in the region: Lake Waccamaw, the Altamaha River, and the Upper Tar River. In addition, a number of species (e.g., several mussel species) are limited in their distribution to an area stretching from the Roanoke River south to the Altamaha River.

The South Atlantic region was the only region where we were able to address a high number of aquatic insect targets. Many of these are previously undescribed species known from five or fewer locations. Because the distribution of these undescribed forms is not well known, we set goals for these targets as the number of currently known occurrences. Several insect targets also have widespread but sparse populations and are locally rare.

Experts delineated 107 conservation areas in the South Atlantic region (Figure 24). Fifty-eight of these conservation areas are in the Piedmont and Blue Ridge foothills, while 49 are in the Atlantic Coastal Plain. Thirty-three of these conservation areas have only one species target, many of which are localized endemic species with one or two known occurrences.

Table 14. Ecological Drainage Units of the South Atlantic Aquatic Region

EDU Name
Upper Roanoke River
Albermarle, Pamlico - Piedmont, Fall Zone
Albermarle, Pamlico - Coastal Plain
Cape Fear River - Piedmont
Cape Fear River - Coastal Plain
Upper Pee Dee River
Pee Dee River - Coastal Plain, Waccamaw
Upper Santee River
Santee River - Coastal Plain, ACE Basin
Upper Savannah River
Savannah River - Coastal Plain, Ogeechee River
Altamaha River - Piedmont
Altamaha River - Coastal Plain

Cape Fear shiner (Notropis mekistocholas). *Photograph courtesy of the U.S. Fish and Wildlife Service.*

Conservation Goals

South Atlantic conservation areas captured at least one population of all species targets and 103 of 176 aquatic system targets. Lists of targets and progress toward conservation goals are in the CD. Some key observations about goals are:

Table 15. Global Ranks, Distributions, and Preferred Habitat Groups of South Atlantic Aquatic Region Species Targets

Global Rank	Distribution	Habitat Group	Number of Targets
G1-G2	Endemic	Large Rivers	4
		Small Rivers	9
		Streams	10
		Lakes/Ponds	5
	Widespread	Large Rivers	0
		Small Rivers	7
		Streams	5
G3-G5	Endemic	Large Rivers	3
		Small Rivers	4
		Streams	4
	Widespread	Large Rivers	3
		Small Rivers	20
		Streams	5
GU	Endemic	Small Rivers	30
	Widespread	Small Rivers	9

• We met goals for all insects and amphibians, about half of fishes and mussels, but very low numbers of snails and crayfishes (Table 16).

• Goals were met for greater than 60% of species targets in all EDUs, except in the Cape Fear-Piedmont, Upper Savannah River, and Altamaha-Piedmont EDUs (Table 18).

• Large and small river systems had the highest number of goals met (Table 17).

• The fewest goals were met for lake system targets.

• Goals were met for less than 50% of system targets in all EDUs, except for the Albemarle, Pamlico-Piedmont, Fall Zone and Cape Fear-Coastal Plain (Table 18).

• Aquatic systems occurring primarily in North Carolina met the highest number of goals.

Table 16. Species Target Representation in South Atlantic Aquatic Region Conservation Areas

Target Category	Number of Species Targets	Number and (%) of Species Targets with All EDU Goals Met
Taxonomic Group		
amphibians	1	1 (100%)
crayfishes	4	0 (0%)
insects	57	57 (100%)
snails	6	2 (33%)
mussels	28	13 (46%)
fishes	22	10 (45%)
G-Rank		
GU	39	37 (95%)
G5	10	9 (90%)
G4	9	8 (89%)
G3	20	11 (55%)
G2	21	8 (38%)
G1	19	10 (53%)
Distribution		
Endemic	69	45 (65%)
Widespread	48	39 (81%)
Peripheral	1	0 (0%)

Table 17. Aquatic System Target Representation in South Atlantic Aquatic Region Conservation Areas

Aquatic System Target Category	Number of System Targets in Category	Number and (%) of System Targets Represented in at Least One Conservation Area	Number and (%) of System Targets with Goal Met
Large Rivers	10	8 (80%)	8 (80%)
Medium Rivers	19	8 (42%)	8 (42%)
Small Rivers	26	18 (69%)	11 (42%)
Creeks, Headwaters	115	67 (58%)	30 (26%)
Lakes	6	2 (33%)	2 (33%)

Table 18. Goals Met for South Atlantic Species and Aquatic System Targets in Each Ecological Drainage Unit

EDU #	EDU Name	Number of Species Targets in EDU	Number and (%) of Species Goals Met	Number of Aquatic Systems Targets in EDU	Number and (%) of Aquatic Systems Goals Met
3.01	Upper Roanoke River	10	6 (60%)	16	3 (19%)
3.02	Albermarle, Pamlico - Piedmont, Fall Zone	29	24 (83%)	16	9 (56%)
3.03	Albermarle, Pamlico - Coastal Plain	22	18 (82%)	12	5 (42%)
3.04	Cape Fear River - Piedmont	15	6 (40%)	8	4 (50%)
3.05	Cape Fear River - Coastal Plain	25	21 (84%)	17	9 (53%)
3.06	Upper Pee Dee River	15	13 (87%)	15	5 (33%)
3.07	Pee Dee River - Coastal Plain, Waccamaw	35	27 (77%)	14	4 (29%)
3.08	Upper Santee River	8	5 (63%)	13	3 (23%)
3.09	Santee River - Coastal Plain, ACE Basin	9	6 (67%)	15	5 (33%)
3.10	Upper Savannah River	7	2 (29%)	13	2 (15%)
3.11	Savannah River - Coastal Plain, Ogeechee River	11	7 (64%)	11	4 (36%)
3.12	Altamaha River - Piedmont	1	0 (0%)	11	3 (27%)
3.13	Altamaha River - Coastal Plain	9	7 (78%)	11	3 (27%)

Few EDU goals were met for widespread species that have declined in much of their range and have been extirpated from one or more EDUs in the region. This is particularly the case in the Piedmont, where several targets, especially mussels and fishes, had formerly much more extensive ranges within the basin and have experienced several extirpations.

We met a higher number of goals for large and small rivers systems in the South Atlantic. This does not represent a trend in patterns of aquatic system integrity, but is an artifact of incomplete geographic inclusion of high quality aquatic system examples. We met very few goals in EDUs occurring in the Coastal Plain and Piedmont of South Carolina. This points out both major survey needs (South Carolina systems) and gaps that can be filled in with further efforts of site practitioners (e.g., Coastal Plain systems of Georgia). The highest number of goals were met for aquatic systems occurring primarily in North Carolina because we had the most extensive expertise for North Carolina at the workshop.

Figure 21. Locator Map of the South Atlantic Aquatic Region

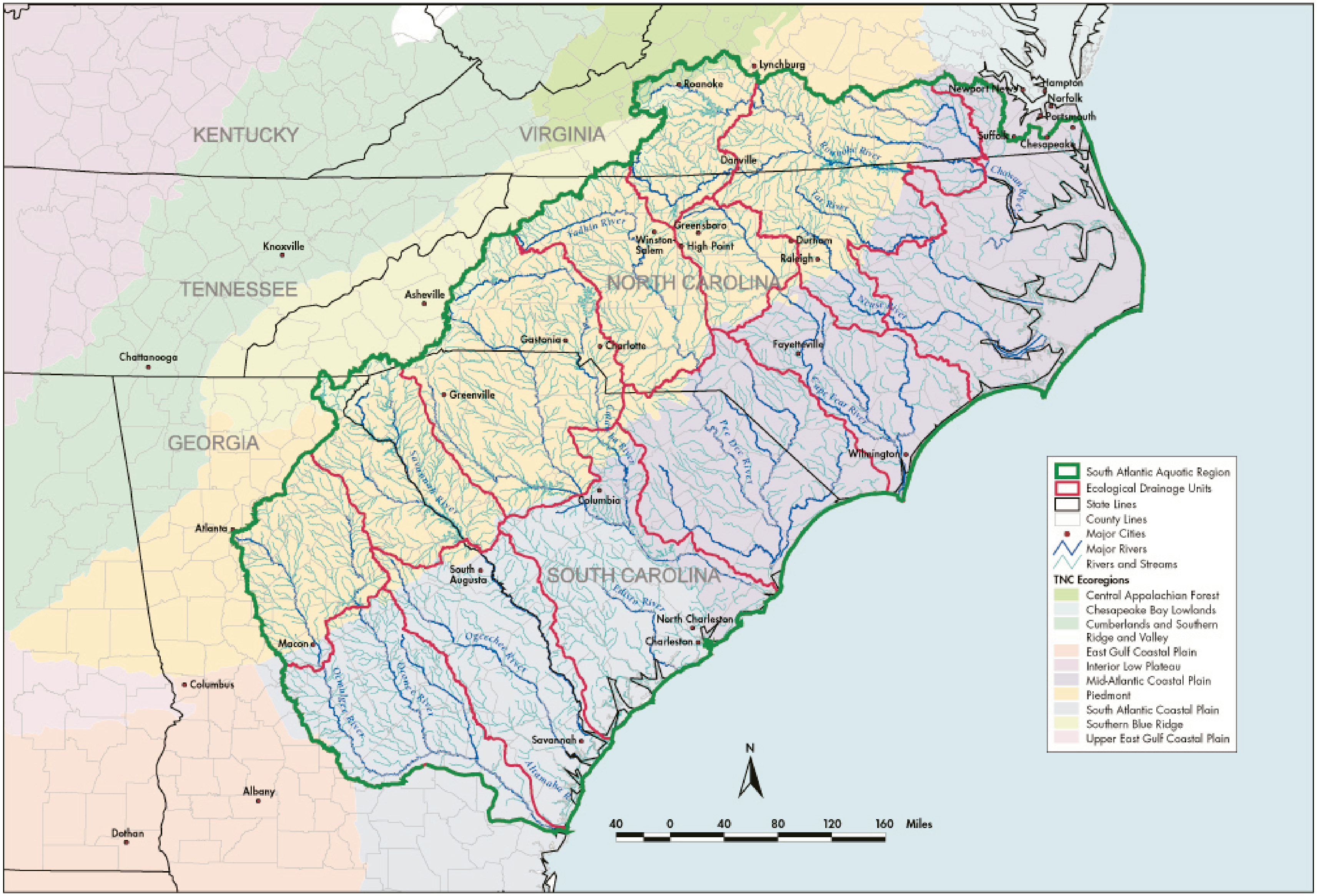


Figure 22. Physiography of the South Atlantic Aquatic Region

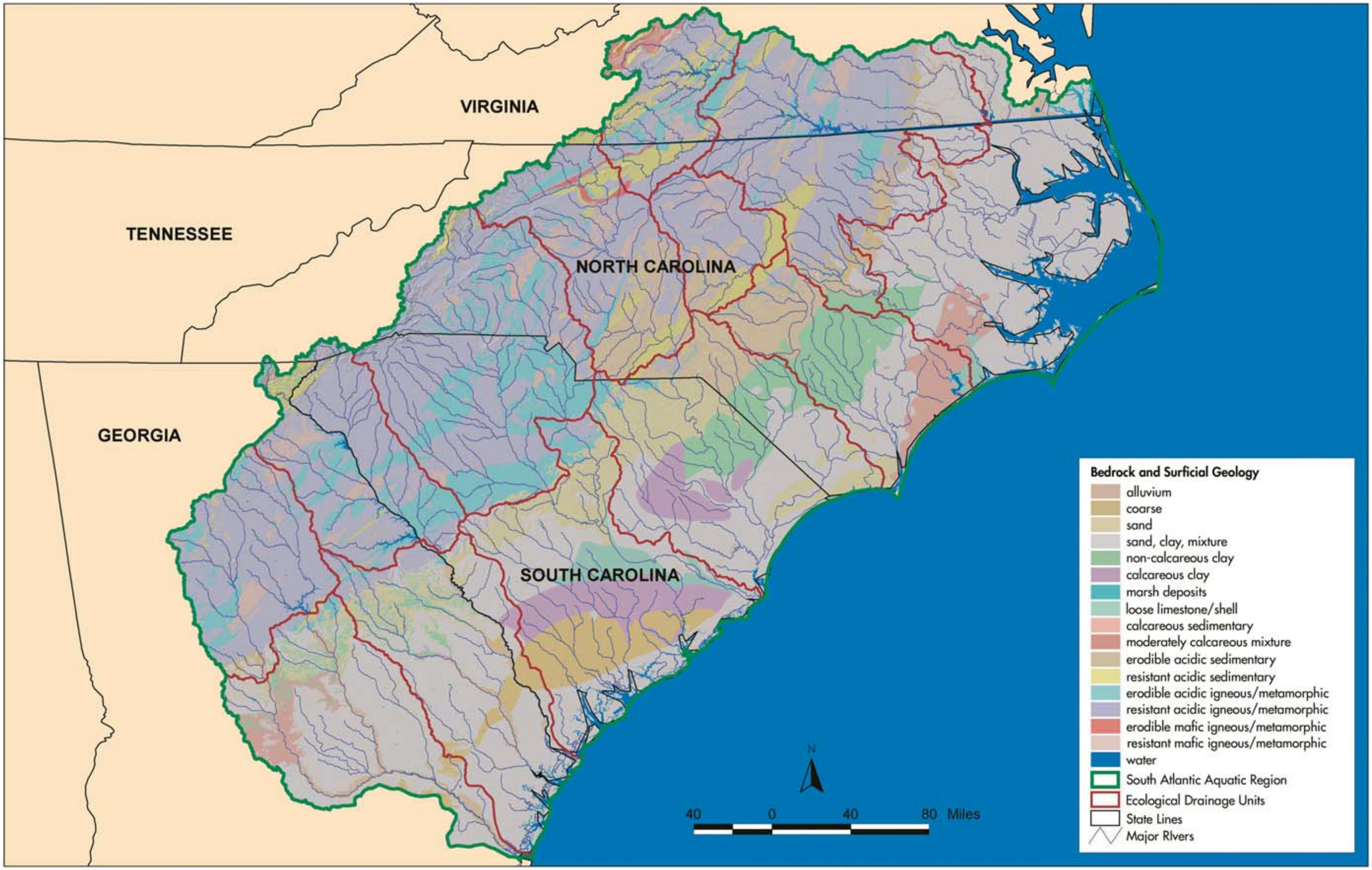


Figure 23. Land Use/Land Cover of the South Atlantic Aquatic Region

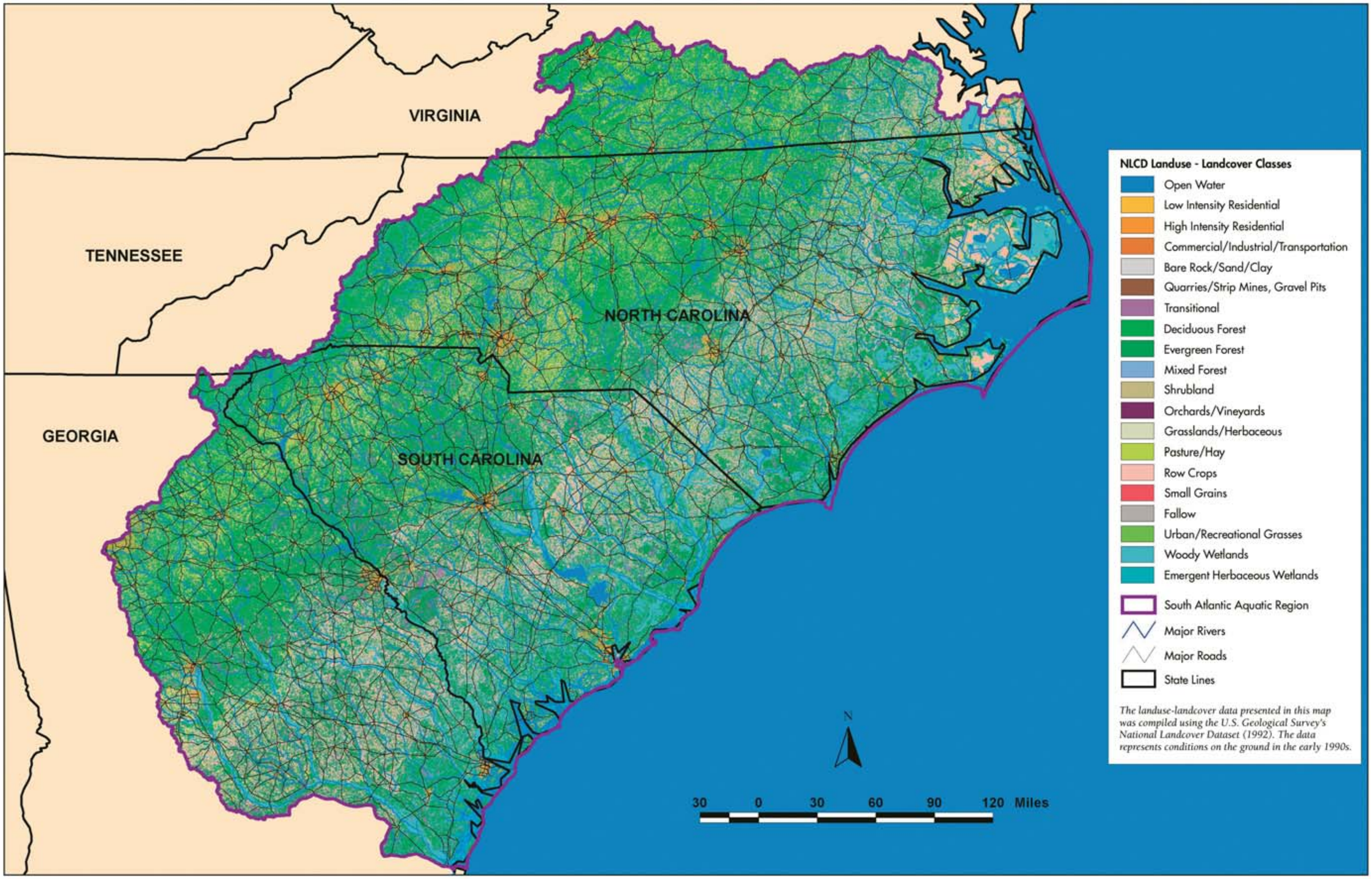
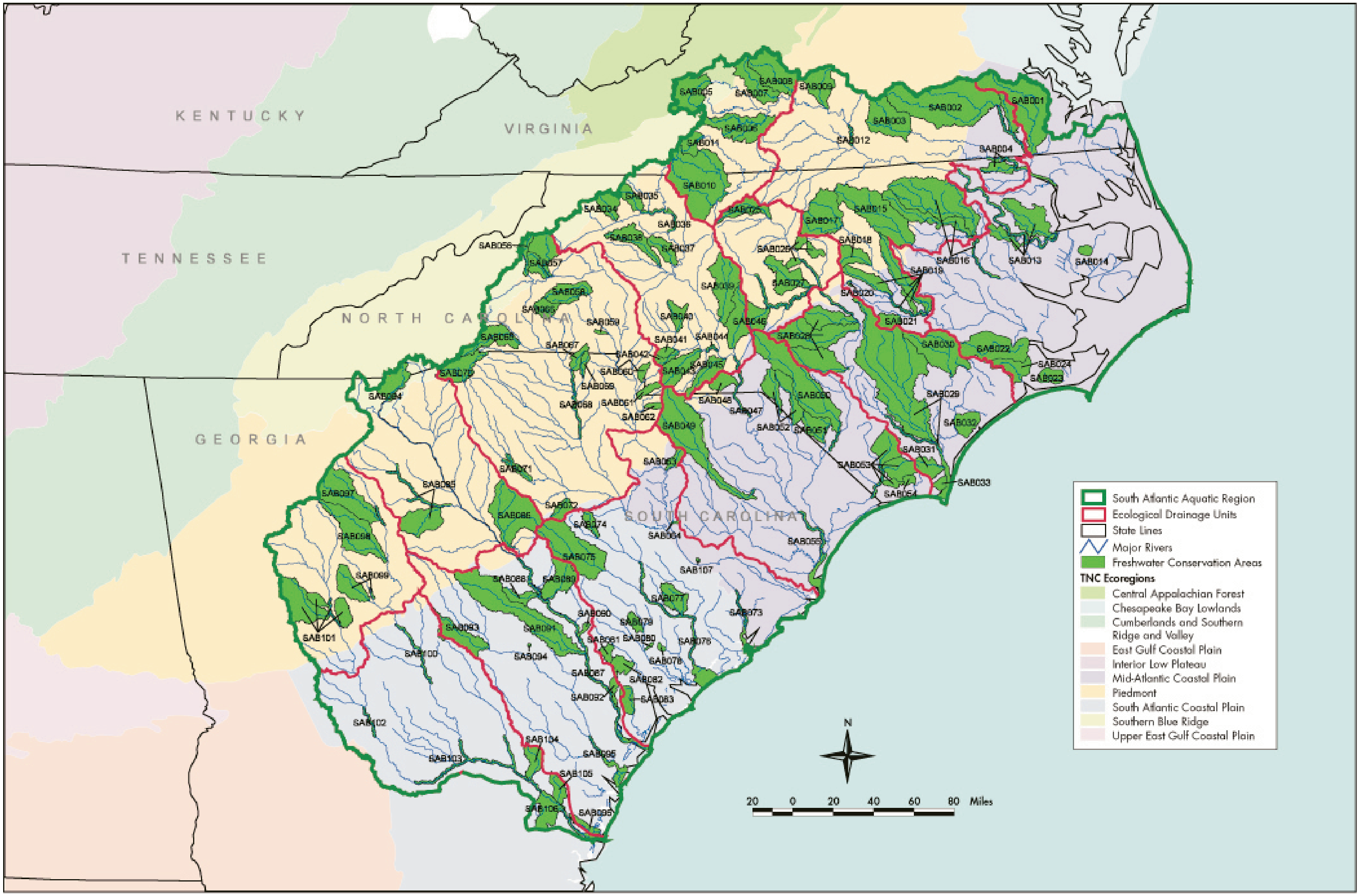


Figure 24. Freshwater Conservation Areas of the South Atlantic Aquatic Region



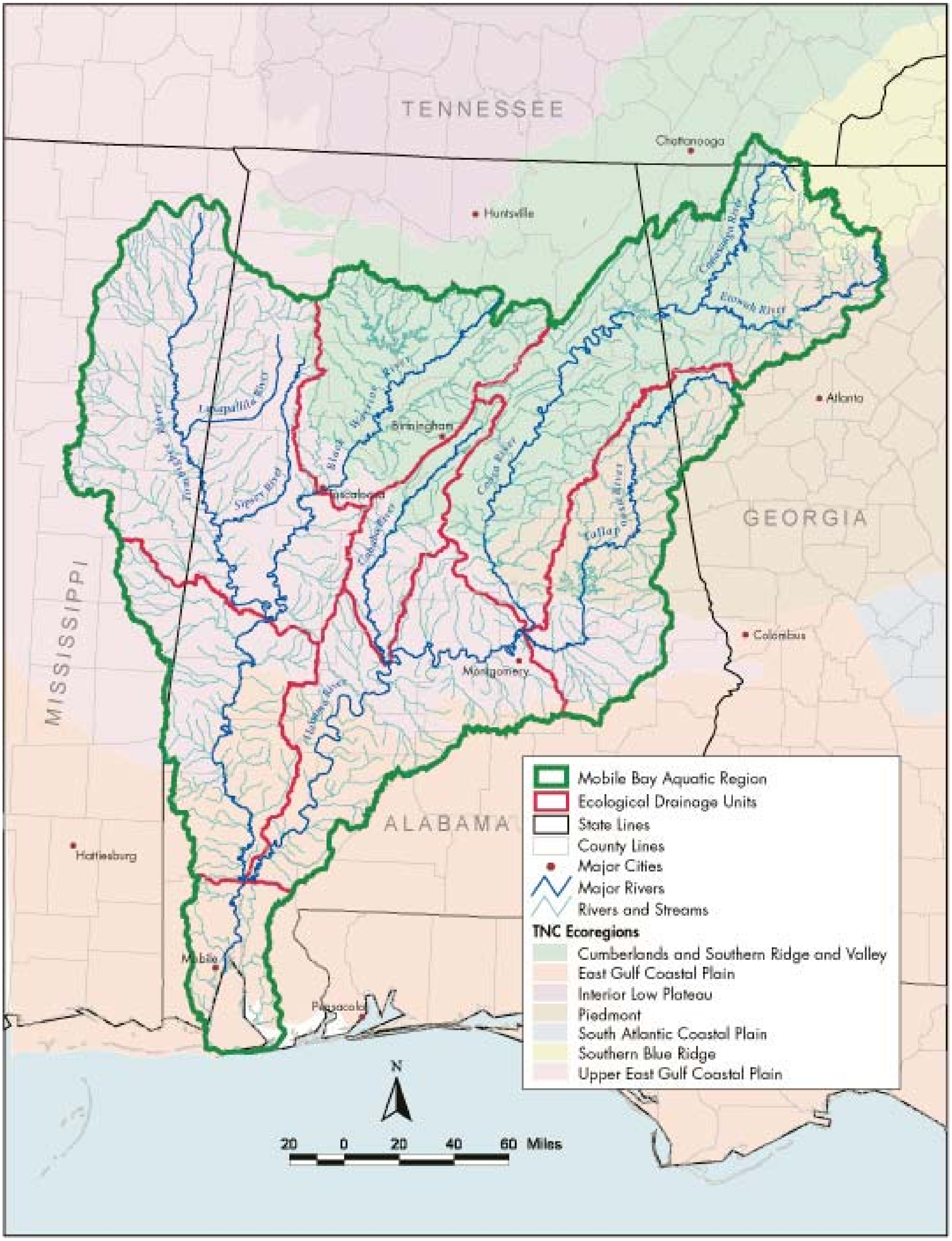
Mobile Bay

Little Cahaba River, Alabama. Photograph by Edward Orth.

This region drains 115,514 km^2 of the Cumberland Ridge and Valley, Piedmont Uplands, Appalachian Plateau and the Coastal Plain physiographic regions (Figures 25, 26). Major river complexes include the Mobile, Tombigbee-Black Warrior, and Alabama-Coosa-Tallapoosa. Because of its physiographic complexity and geologic history, this ecoregion has the highest species diversity and endemism in the eastern Gulf (Abell et al. 2000). There are 187 species of fish, including 47 endemic species. The Cahaba River itself contains 131 fish species. The Etowah, Oostanaula and Coosa River complexes once supported the most diverse freshwater mollusk assemblage in the world (Abell et al. 2000). Major threats to this ecoregion include dams, channelization, channel clearing, in-stream gravel mining, water withdrawls, transformation from natural vegetation to agriculture and silviculture, point discharges and runoff, and exotic species (Figure 27) (Abell et al. 2000).

We delineated nine EDUs (Table 19) in the region. Zoogeography is one determining factor, as patterns of species endemism within the region result in different community structure in the same physical stream type. For this reason, the Coosa, Cahaba, Tallapoosa, and Upper Black Warrior watersheds were separate EDUs. Coastal Plain portions of the region were placed in two EDUs: the lower Alabama River and the Tombigbee River drainage. Also, the Mobile River/delta area was a

Figure 25. Locator Map of the Mobile Bay Aquatic Region



separate EDU because of the connection to the Gulf of Mexico.

The second factor considered was physiographic distinctions, primarily reflecting the section level ecoregionalization by the U.S. Forest Service. This factor resulted in breaking out the Coastal Plain portions of the Tombigbee drainage into two EDUs, an upper and a lower. The upper EDU includes primarily sandhills and complex prairies with much habitat heterogeneity. The lower EDU is composed of primarily flat plains.

Conservation Targets and Conservation Areas

We considered 115 aquatic systems and 142 species targets in the Mobile Bay region (Tables 20, 22). Over 80% of these species targets are endemic to the Mobile Bay Basin, and 36 species have viable populations known from only one EDU. Fourteen species targets inhabit medium or large rivers, 23 inhabit small rivers, and 77 inhabit headwaters and creeks.

We delineated 100 conservation areas in the Mobile Bay aquatic region (Figure 28). Of these, 36 occur primarily in the Cumberland Plateau and Ridge and Valley, 12 in the Piedmont, 3 in the Blue Ridge, and 49 in the Gulf Coastal Plain.

Thirty-five conservation areas have only one target, many of which are localized endemic species with one or two known occurrences.

Conservation Goals

Mobile Bay conservation areas captured at least one population of all species targets and 82 of 115 aquatic system targets. Lists of targets and progress toward conservation goals are in the CD. Some key observations about goals are:

• We met the highest percentage of goals for fishes, mussels, and amphibians (Table 21).

• We met a high number of goals for widespread targets, but fewer for globally rare endemic species.

• 50% or higher of species goals were met for all EDUs except the Upper Black Warrior River and Cahaba Rivers (Table 23).

• Large and medium rivers were the best represented in Mobile Bay conservation areas (Table 22).

• We met goals for less than 50% of aquatic systems targets in all EDUs except the Upper Tombigbee and Black Warrior river systems (Table 23).

Table 19. Ecological Drainage Units of the Mobile Bay Aquatic Region

EDU Name
Tallapoosa River
Coosa River
Cahaba River
Alabama River
Upper Black Warrior River
Upper Tombigbee, Lower Black Warrior Rivers
Lower Tombigbee River
Mobile Delta

An assortment of snails from the Mobile Bay Aquatic Region. Photograph by Chris Oberholster/TNC.

Table 20. Global Ranks, Distributions, and Preferred Habitat Groups of Mobile Bay Aquatic Region Species Targets

Global Rank	Distribution	Habitat Group	Number of Targets
G1-G2	Endemic	Large Rivers	10
		Small Rivers	28
		Streams	39
	Widespread	Large Rivers	0
		Small Rivers	4
		Streams	1
G3-G5	Endemic	Large Rivers	1
		Small Rivers	9
		Streams	9
	Widespread	Large Rivers	8
		Small Rivers	6
		Streams	6
GU	Endemic	Large Rivers	3
		Small Rivers	6
		Streams	12

Few goals were reached for the localized endemic species that have only one or two known populations. However, a relatively high proportion of goals were met for the species considered widespread, but that have experienced declines in much of their ranges and have been extirpated from one or more EDUs in the region.

In the Mobile Bay region, a high number of goals were met for aquatic systems composed of small rivers and creeks/headwaters. This is because there are still examples of these small system types that exist within patches of relatively intact landscape, as opposed to the few sections of high quality medium or large rivers with high levels

Table 21. Species Target Representation in Mobile Bay Aquatic Region Conservation Areas

Target Category	Number of Species Targets	Number and (%) of Species Targets with All EDU Goals Met
Taxonomic Gpoup		
amphibians	1	0(0%)
reptiles	2	1 (50%)
crayfishes	11	0 (0%)
snails	32	15 (47%)
mussels	41	22 (54%)
fishes	55	18 (33%)
G-Rank		
GU	22	8 (36%)
G5	4	3 (75%)
G4	8	6 (75%)
G3	26	11 (42%)
G2	20	7 (35%)
G1, GH	62	21 (34%)
Distribution		
Endemic	117	38 (32%)
Widespread	24	17 (71%)
Peripheral	1	1 (100%)

Figure 26. Physiography of the Mobile Bay Aquatic Region

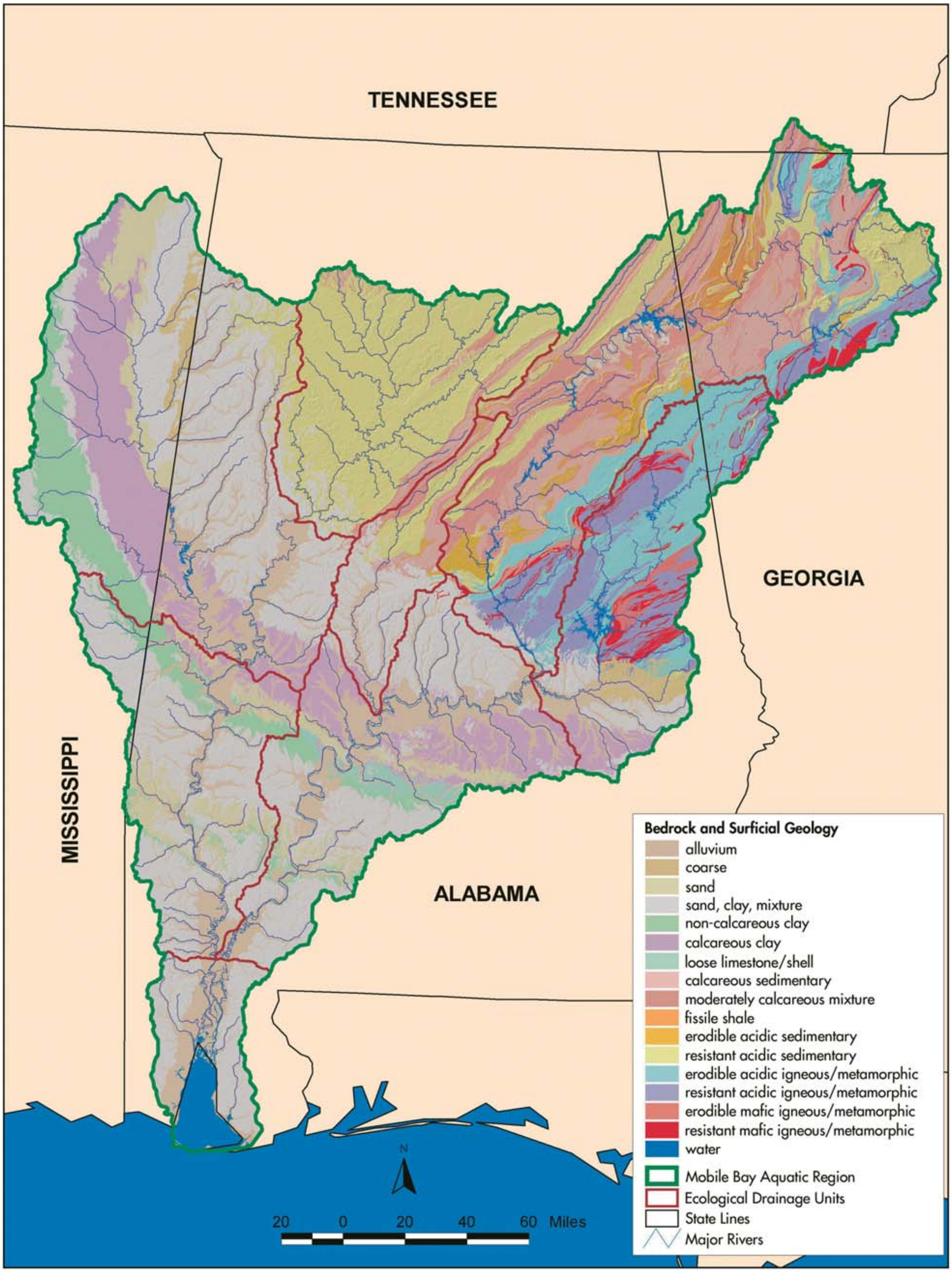


Figure 27. Land Use/Land Cover of the Mobile Bay Aquatic Region

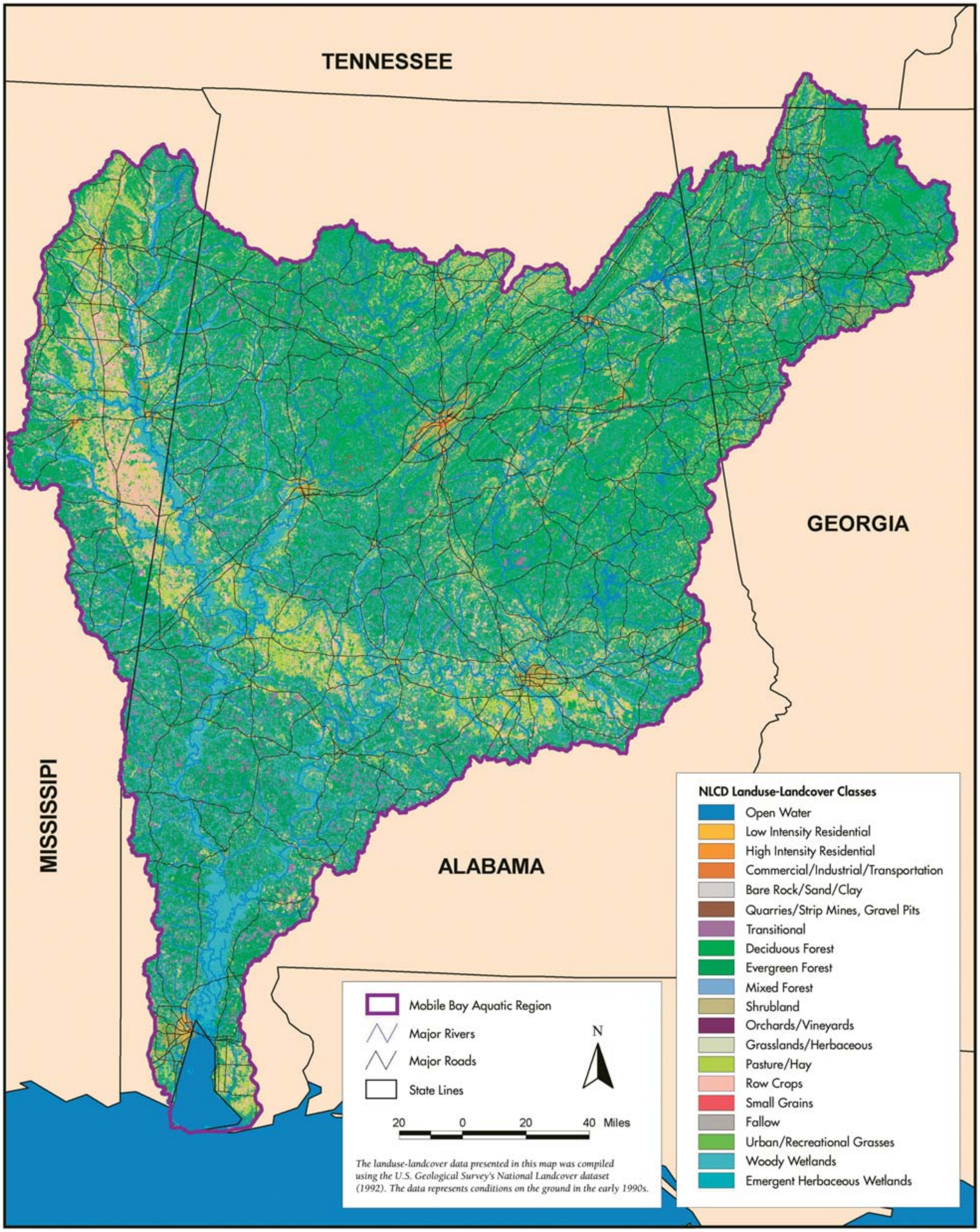


Figure 28. Freshwater Conservation Areas of the Mobile Bay Aquatic Region

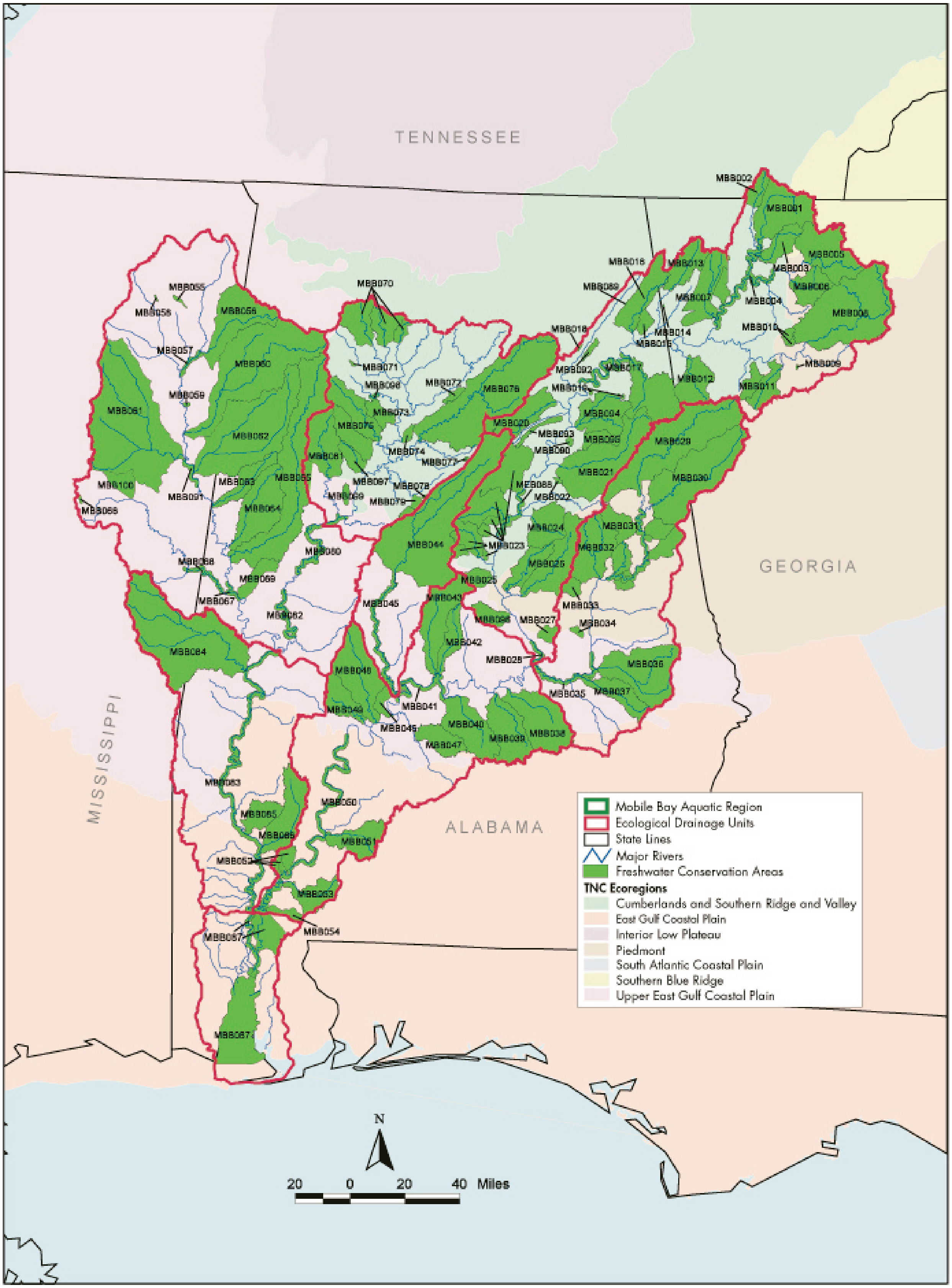


Table 22. Aquatic System Target Representation in Mobile Bay Aquatic Region Conservation Areas

Aquatic System Target Category	Number of System Targets in Category	Number and (%) of System Targets Represented in at Least One Conservation Area	Number and (%) of System Targets with Goal Met
Large Rivers	8	7 (88%)	7 (88%)
Medium Rivers	7	4 (57%)	4 (57%)
Small Rivers	23	18 (78%)	9 (39%)
Creeks, Headwaters	77	53 (69%)	28 (36%)

Table 23. Goals Met for Mobile Bay Species and Aquatic System Targets in Each Ecological Drainage Unit (EDU)

EDU #	EDU Name	Number of Species Targets in EDU	Number and (%) of Species Goals Met	Number of Aquatic Systems Targets in EDU	Number and (%) of Aquatic Systems Goals Met
4.01	Tallapoosa River	17	15 (88%)	18	6 (33%)
4.02	Coosa River	69	35 (51%)	32	14 (44%)
4.03	Cahaba River	34	16 (47%)	11	3 (27%)
4.04	Alabama River	21	16 (76%)	12	5 (42%)
4.05	Upper Black Warrior River	33	9 (27%)	8	4 (50%)
4.06	Upper Tombigbee, Lower Black Warrior Rivers	32	23 (72%)	19	11 (58%)
4.07	Lower Tombigbee River	13	8 (62%)	10	4 (40%)
4.08	Mobile Delta	6	3 (50%)	5	1 (20%)

of ecological integrity remaining in the region since most of the main channel rivers have been dammed and have regulated flows.

More large river targets were well represented in the Mobile Bay than in the other three regions. This is because the mainstem Mobile River and lower Tombigbee and Alabama Rivers remain undammed. However, several river targets that were represented are sections below reservoirs with relatively stable flows that have been identified for recovery of some large river mussels, fishes and snails. These large river sections still support diadromous species that have been extirpated from the upper portions of the Coosa and Black Warrior Rivers.

GENERAL FINDINGS ACROSS REGIONS

Data Gaps

Data gathered for this project significantly advanced the understanding of freshwater species, systems, and conservation areas in the southeastern U.S., yet many knowledge gaps remain that are common across all four aquatic regions. Data gaps beyond the scope of this report include inventory, classification, and assessment needs; spatial analysis thresholds; and species life history research. A complete list of identified data gaps is included on the data CD.

Some of these gaps can be filled through further consultation with experts, particularly by teams responsible for site-level planning at individual conservation areas. For example, a prominent data gap is the lack of knowledge of high quality occurrences of aquatic system targets in some portions of these aquatic regions. Because it was difficult to assemble experts who could identify example systems in all EDUs for all four regions, several system types were not well-represented in conservation areas. These system types may be better included through further consultation with additional experts. Areas especially lacking high quality examples include the lower portions of the Tennessee and Cumberland River systems, the Mississippi Delta, the lower Arkansas, Red, Ouachita, and Yazoo River systems, the Piedmont of South Carolina, and tidal marsh systems of the Gulf of Mexico and Atlantic drainages.

Another information need is a standardized method of aquatic system classification, inventory, and assessment. The classification work developed through this project represents first regional GIS-based classification of aquatic ecosystems in the southeastern United States and should be the beginning of a standardized method for inventory of biological communities, development of prioritization approaches, and conservation strategies for these elements of biodiversity.

The GIS methods used in this report for

The Altamaha River, Georgia. Photograph by Kathryn Kolb.

potential habitat quality modeling highlight conservation areas in the most intact landscapes and those that are in varying degrees of altered landscapes. However, the specific thresholds of landscape-scale alterations that result in in-stream freshwater habitat degradation are not yet known.

We also identified several taxonomic description, life history research, and inventory needs for species. Common to all four regions is a strong need for research on taxonomic groups such as snails, insects, crayfishes, and even some fish and mussel genera. In addition there is need for more extensive inventory of all taxa. In many cases, we did not meet conservation goals for species targets because there were not enough known viable populations. For example, we were not able to adequately address the incredible diversity of aquatic insects in any of the four regions. There is a need for taxonomic attention and extensive survey work for this group even in the South Atlantic region where we were able to identify some of the areas known to support high quality examples.

Conservation Areas

We identified a total of 352 priority freshwater conservation areas across the four aquatic regions addressed in this report. These conservation areas are well distributed across most river drainages and physiographic provinces and represent the best remaining examples of the Southeast's characteristic biotic assemblages and viable populations of the numerous highly imperiled species.

This blueprint also clearly indicates the areas presenting the greatest challenges for aquatic biodiversity conservation. We did not identify many high quality aquatic systems in landscapes that have been exceedingly altered for agriculture or river systems that have been extensively channelized for navigation or dammed for hydro-power or flood control. In particular, few priority aquatic conservation areas were identified in the Mississippi River alluvial plain, the lower Tennessee Valley, portions of the Gulf and Atlantic Coastal Plains, and portions of the Piedmont. Some of these areas do represent areas that require more extensive survey work and data cataloguing. However, the failure to meet goals in some areas will require a shift toward identifying aquatic systems with high potential for restoration.

Many of these conservation areas represent currently well-known centers of biodiversity. Other conservation areas contain high quality examples of representative systems and the best populations of freshwater taxa that are less well-known (e.g., crayfishes, snails, and some insects). The high degree of species endemism in the aquatic regions resulted in many conservation areas that each captured few target populations. We consider the entire suite of identified areas to be conservation priorities because they represent the full biodiversity and range of environmental gradients across the four aquatic regions based on the best available data. However, we realize that resource management agencies and conservation organizations may wish to focus their actions on a subset of the conservation areas. We intend for agencies and organizations to use the supplementary conservation area data on the enclosed CD to refine their priorities, develop strategies, and take action as best fits the programmatic direction of each conservation group.

Goals

The suite of priority conservation areas identified in this project represent the current state of knowledge of occurrences of many types of conservation targets. Included are nearly all representative aquatic systems and imperiled species targets. If protected, these conservation areas would represent a significant first step toward long-term persistence of the aquatic biodiversity of the Southeast.

However, these conservation areas alone do not represent an adequate number of occurrences of many species and system targets to ensure their long-term persistence across their entire range. Few species targets in any of the four aquatic regions have enough viable occurrences in all EDUs to meet conservation goals. This is clear evidence of the highly altered nature of certain portions of these aquatic regions. Heavy alteration of certain portions of these aquatic regions has resulted in extensive extirpation of target groups in some EDUs (e.g., snails in the lower Alabama River and mussels in the lower Tennessee and Cumberland Rivers). Thus, we did not meet representation goals for these groups because our goal was to represent a certain number of occurrences of each target in each EDU in which it historically occurred. This indicates a great need to restore populations of many species to ensure their long-term persistence.

For several targets, the number of known extant populations represented in this suite of conservation areas is below the number thought to be required to persist in the current and future landscape. In particular, many locally endemic species have only one or two known populations and are in danger of extinction. It is important to note that while most of these species historically had many more populations, some may have been naturally very rare and goals for these species may have been inflated. As we learn more about the historic distribution and abundance of species targets, and population dynamics necessary to maintain viability, we can re-visit and establish more meaningful goals.

Many aquatic systems across the four regions also do not meet conservation goals. This is also due to the heavy alteration of certain portions of these aquatic regions. Many of the system targets for which goals were not met represent systems in highly altered EDUs. These areas are the Mississippi Delta, lower Cumberland and Tennessee River systems, and some portions of the Piedmont. Following the pattern for localized endemic species targets, we also did not meet goals for several system types that are extremely rare and had few historic examples. For example, there are few examples of some Ridge and Valley systems and creek/headwater systems in unique Coastal Plain limestone formations, and others connecting to Atlantic embayments. We also did not meet many goals for large river system types, which tend to be highly altered, with few remaining viable examples.

Representation of many aquatic systems is poor because we directed experts only to identify areas that they knew to be high quality, viable examples of these system types. We only included in conservation areas and counted toward goals those examples of aquatic systems that were confirmed as viable by experts. Thus, many systems that do not meet conservation goals represent gaps in our ability to identify or verify aquatic system condition and viability. The lack of viable examples of a range of targets emphasizes the need for more survey work, viability assessments, conservation of remaining viable occurrences, and system-level restoration across all four aquatic regions.

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