CHAPTER 4

PROBLEMS AFFECTING SPECIES AND HABITATS

4.1. Assessing Problems Affecting Species and Habitats

THE NEXT PHASE OF THE TN-SWAP REVISION EFFORT involved conducting a review and revision of the problems which may be adversely affecting species of Greatest Conservation Need (GCN) and their habitats in Tennessee. Although the problems differ across geography, flora, and faunal groups, all species designated as GCNs face one or more threats to their survival, including threats to habitat health and persistence and/or population stressors such as pollution and disease.

Certain issues, often related to human activities and management of lands and waters, pose threats to a range of habitat types and GCN species across the state. It is important to note, however, that in many cases people can make adjustments or implement "best practices" to mitigate or even eliminate the threats that these activities pose. In the past decade, conservation scientists and planners have become focused on understanding larger, or "landscape-scale" patterns of change to lands and waters as a means of evaluating challenges to habitat or population persistence. In addition, the negative impacts from climate change stressors increasingly are of concern to the short- and long-term health of GCN species and their habitats across the U.S. (NFWPCAP 2012).

Photo credit: Couchville Cedar Glades State Natural Area/prairie coneflower. Without proper management, grass and forb-dominated barrens often experience encroachment of woody species - Byron Jorjorian

4.1.1. Review and Update of Major Statewide Problems

Summary: 2015 process for identifying and prioritizing problems affecting GCN species and their habitats

1. Review and revise problems identified in 2005. The planning team determined 2005 SWAP problems are still representative of current problems for GCN species and habitats.
2. Categorize problems. Using the standardized Conservation Measures Partnership hierarchy, the team cross-walked 2005 problems to the most recent updated threats classification from 2015. Three additional problems were added: recreational area development , renewable energy development, and over-collection of plant species.
3. Prioritize threats. The team focused on the most consistently high-ranked problems from 2005 and, when possible for a particular problem, added a spatial assessment component to help identify the location of problem sources relative to priority GCN habitats. Problem rankings for individual species were not changed or updated from 2005.
4. Incorporate climate change as a major new source of stress. A separate climate change vulnerability assessment for Tennessee was prepared by the National Wildlife Federation and The Nature Conservancy, building on a SWAP update report on climate change issued by TWRA in 2009. The assessment examines data on species vulnerability, landscape resiliency, and potential vegetation change to gain a better understanding of the range of GCN vulnerabilities across the state.

The 2015 SWAP team used the Best Practices recommendations (AFWA 2012) to assist with the review of problems facing species and habitats (See Appendix A). In the 2005 planning effort, Tennessee followed a best practice, using a standardized process and hierarchy for identifying stresses and sources of stress aligned with broader categories defined by the Conservation Measures Partnership (CMP) (Salafsky et al. 2008). At the time, over 35 "sources" or problems, were identified and linked to 20 major ecological stress types, then the stress and source combinations linked to every GCN species and then evaluated for the scope, severity, timing, reversibility, and contribution to potential population declines in different regions of the state.

Both urban and rural development can have major impacts on the habitat of both terrestrial and aquatic species in Tennessee - Greg Wathen, TWRA

These evaluation assignments were captured in the SWAP database, then summarized to create cumulative ranking scores to identify the major problems facing GCN species distributed in the major terrestrial, aquatic, and subterranean regions of the state (see TWRA 2005, pp. 66-75). In 2005, TWRA lacked the planning time and resources to map the distribution of different problem sources, relying instead on an expert-derived estimate of the percentage of a species range that could potentially be affected by specific source-stress combinations. Therefore, the 2005 SWAP did not have the ability to spatially assess the intersection of problems with priority habitats to inform decision-making. Priority sources of stress were summarized in tabular format only and divided into terrestrial, aquatic, and subterranean regions.

The 2015 SWAP team reviewed the 2005 SWAP major stresses and potential sources of stress hierarchies and determined that they were still representative of current problems (Appendix E). The team also determined that the 2005 stresses to new GCNs identified as part of the update process remain the same, with the exception of plants, for which the 2005 stresses identified for fauna only do not completely apply.

Major statewide issues addressed in 2015 are urbanization; agricultural land management; forestry practices; water management; energy development; and transportation and utility corridors.

Three additional major problems were added during the 2015 revision process: potential issues with recreational area development, renewable energy sources, and over-collection of plant species. A crosswalk exercise was completed between the 2005 sources of stress hierarchy and the more recent CMP Open Standards threats classification (**Version 2, Beta – February 2015**). Appendix E provides the summary of the crosswalk exercise and shows the addition of the new potential sources of stress for 2015.

In reviewing the 2005 prioritization assessments for the terrestrial, subterranean, and aquatic regions, the 2015 planning team identified patterns in which sources of stress consistently emerged as top issues across all the regions, and grouped these sources by general category (for more details, see TWRA 2005, pp. 84-146). The team also documented which of these 2005 problems, and any emerging issues since 2005, warrant the greatest focus moving forward.

In assessing problems for the 2015 revision, the planning team chose to focus on the major sources of stress across the state, using new spatial information and analyses to understand where major problem sources intersect with priority GCN habitats rather than conducting new species-by-species rankings. Examining problems in this fashion allowed the team to focus on the highest priority issues and the major landscape-scale drivers of change in Tennessee to better inform conservation investments and collaborations with conservation partners.

As detailed in Section 3.2 and elaborated further in Section 4.2, the SWAP GIS database design allows for flexible assessments of habitat priorities and sources of stress to GCNs at a variety scales in Tennessee when spatially-relevant data are available. For example, urbanization issues were identified as a major problem in the 2005 SWAP, but the specificity of where on the landscape urbanization pressures intersected with GCN species and habitats was not identified. By utilizing spatial analyses for the 2015 update, the planning team has documented where in Tennessee urbanization pressures must be addressed to protect GCN species and habitats. In addition, the associated database features allow planners to identify which GCN species, how many occurrences, and which habitat types are under pressure at a given location when that type of information is needed for project-specific work.

The most frequently documented potential sources of stress in 2005, summarized as major issues for 2015, include urbanization (its associated infrastructure and water uses); agricultural land management; forestry practices; water management; energy development; and transportation and utility corridors. These land and water use issues typically have a landscape-level footprint across one or more regions of Tennessee, and effectively managing for better habitat outcomes requires education and active engagement of the private sector and government agencies involved in land and water management, transportation, and compensatory mitigation decisions (AFWA 2012).

Fire suppression is a significant issue for multiple grassland, forest, and woodland habitat types statewide, and managing certain recreational activities remains a challenge for protecting species and habitats in specific locations. The collection of particular plant and animal species in different regions of the state must be monitored, and regulations enforced, to prevent overharvest and species population declines. Additional areas receiving increased emphasis for the 2015 update are problems associated with the ongoing spread of several disease pathogens and invasive exotic species, particularly


Coal pile at Baldwin Plant in Anderson County; coal is a significant source of air pollution - Appalachian Voices


Pathogen infection: Snake fungal disease - Daniel Bryan - Cumberland University


Brown-headed Nuthatch, a species whose habitat is threatened by altered fire regimes - Allen Sparks

those affecting cave dwelling bat species, reptiles, amphibians, and forest habitats. Airborne pollutants also remain a challenge, as acid rain and deposition of bioaccumulative toxic metals such as mercury damage both terrestrial and aquatic habitats, particularly in the eastern two-thirds of Tennessee.

Topographical variation creates landscape diversity, which contributes to resilience. Southern Blue Ridge mountains - Greg Wathen, TWRA.

4.1.2. Climate Change Impacts Assessment

Like many SWAPs across the country, the 2005 version of Tennessee's plan did not explicitly address the potential impacts of climate change scenarios on GCN species and habitats. However, in 2009, TWRA published an update report for the SWAP entitled *Climate Change and Potential Impacts to Wildlife in Tennessee* (TWRA 2009). This report served as the first comprehensive review of the scientific literature on climate change at the time and the potential impacts on fish, wildlife, and habitats in Tennessee.

Understanding the synergies and linkages among multiple stresses affecting wildlife and plants, including climate change, is necessary for the development of successful conservation strategies. For the 2015 comprehensive update, TWRA built on the 2009 effort by contracting with the National Wildlife Federation to provide a Climate Change Vulnerability Assessment for Tennessee and to guide TWRA on the selection of appropriate adaptation strategies. (Glick et al. 2015).

Some amphibians may suffer disproportionately from climate change effects in TN. Southern Cricket Frog - Patrick Coin via Wikimedia

The primary emphasis of the assessment effort was to examine three major aspects of climate change impacts: species vulnerabilities, terrestrial and aquatic habitat changes, and landscape resiliency. Species vulnerability assessments using NatureServe's **Climate Change Vulnerability Index** (CCVI) (Young et al. 2011) were conducted by TWRA and academic experts for 189 GCN plant and animal species. Changes to terrestrial vegetation were identified using the U.S. Forest Service's Terrestrial Climate Stress Index (TCSI) methodology (Joyce et al. 2008). Data on landscape resiliency from The Nature Conservancy's *Resilient Sites for Terrestrial Conservation in the Southeast U.S.* (Anderson et al. 2014) were used in combination with the TCSI outputs and the SWAP terrestrial habitat priorities to gain a better understanding of the range of GCN habitat vulnerabilities across the state (Glick et al. 2015).

4.2. Updates to SWAP GIS and Database Information on Major Problems

In the decade since the 2005 SWAP was developed, through a variety of different project collaborations, TNC and TWRA have compiled a wide array of additional GIS data and spatial analyses to improve understanding of the major landscape-scale problems facing GCN species and habitats across the state. These efforts have focused on the aggregation and classification of state water quality and permit data managed by the Tennessee Department of Environment and Conservation (TDEC), the National Inventory of Dams, the USDA Cropland data coverage, urban growth boundary and population growth data from the State of Tennessee and University of Tennessee-Knoxville, and U.S. Office of Surface mining permitted lands. Field survey and planning efforts conducted by many partners to track the spread of pathogens, such as White-nose Syndrome in bats and Hemlock Woolly Adelgid in native hemlock forests, have also been used to map the current spatial extent of these problems.

Section 3.2.4. ***Updates to Habitat Mapping Units*** describes the basic unit of assessment for terrestrial, subterranean, and aquatic habitat priority maps (700-acre hexagon rosettes and NHDPlus v2 catchments, respectively). These same mapping units are used for assessments of potential problems. The GIS and relational database capacity makes it possible to look at the intersection of different types of land and water uses with the priority habitats identified for GCN species, and the mapping units allow for these data to be summarized at a variety of different spatial scales.

Understanding the current and potential spatial footprint of major land and water uses, as well as how these uses intersect with priority habitats, is critical to identifying habitat protection, restoration, and management needs and opportunities.

The maps and data summaries provided in this 2015 update document are intended to represent the scope and distribution of major potential problems including urbanization, agriculture, river and stream management, and non-renewable energy development. Also included are example distribution

Farmland in Tennessee - Joel Kramer

maps of White-nose Syndrome and the spread of Hemlock Woolly Adelgid. It is important to emphasize that these assessments are intended to direct attention to *potential* problems for habitats based on known issues with land and water management practices in general; they do not provide information on the presence or absence of best management practices in a given situation. The existence of actual problems always must be verified in the field with site specific knowledge and assessments.

For example, improving agricultural management practices in priority areas can improve outcomes for GCN freshwater species and overall water quality. These investments are being made by state and federal partners and private landowners across the state. The "potential" problem maps associated with agricultural land management do not contain information about where these actual on-the-ground practices are being used. Instead, these maps emphasize where best management practices may be targeted to achieve better outcomes for GCN species. In addition, the data associated with permitted activities are not intended to substitute for the standard reviews and decision-making performed in a regulatory context by both state and federal agencies. Rather, these data should be complementary to those reviews, as it can provide both a local- and a landscape-scale context of the associated activities with respect to important GCN habitats. In addition, the 2015 mapping assessments do not include potential issues with renewable energy, transportation corridors, and utility/service line development, all of which have the potential for large spatial footprints in certain sections of the state. Data on these activities are becoming increasingly available, and examinations in the context of habitat priorities will be an important data update need in the near future. A more detailed methods explanation for the landscape analyses of major problems is available in The Nature Conservancy's publication *Database Development and Spatial Analyses in Support of Tennessee's State Wildlife Action Plan* (Wisby and Palmer 2015).

Powerlines - Artondra Hall

Compared to 2005, the data development effort for the 2015 update allows TWRA and its many partners to conduct a variety of more detailed problem assessments to serve specific project needs. Examples of efforts already in progress include partnerships for specific agricultural watersheds to identify where riparian buffer improvements can help improve aquatic GCN habitats (see Elk River case study). GIS scientists with the Southeast Aquatic Resources Partnership are using the information and other applications they are developing to create more refined tools for prioritizing which stream barriers to remove for improved stream network and habitat connectivity (Granstaff et al. 2015).

TENNESSEE CASE STUDY: Fair market conservation incentives for private landowners in the Elk River Watershed Conservation Opportunity Area

Guided by Tennessee's State Wildlife Action Plan (SWAP) data, the Tennessee Wildlife Resources Agency identified the Elk River watershed as a priority for improving water quality. The elimination of riparian habitat along the Elk River and tributaries over the years has degraded water quality, so TWRA joined forces with the Tennessee Valley Authority (TVA), the National Fish and Wildlife Foundation (NFWF), the Natural Resources Conservation Service (NRCS), The Nature Conservancy (TNC), and other partners to develop increased conservation incentives for private landowners in the Elk River COA. The goal of this targeted program is to create 26 miles of stream buffer that will contribute to improved water quality.

> Agency partnerships and science-based conservation are the hallmarks of a new conservation program effort taking shape in the Elk River watershed of Tennessee.

The USDA's existing Conservation Reserve Program (CRP) continuous signup practices can pay farmers for contract periods of 10 to 15 years by reimbursing approximately 90% of the costs of establishing riparian buffers as well as annual payments to offset income losses from retired cropland or marginal pastureland, plus a one-time Signing Incentive Payment. The program also cost-shares mid-contract management practices, such as prescribed fire or herbicide applications.

However, agricultural producers in the Elk River area have been reluctant to enroll in CRP because the high price of corn and other crops has made incentive payments far less attractive. University of Tennessee Extension performed an analysis of crop pricing to arrive at a competitive CRP payment in the region. The TVA, TWRA, and NFWF then supplied additional funding for several CRP buffer practices, managed by the Farm Services Agency and NRCS, to create the new Elk River incentive program. In addition to the normal payments listed, the new effort offers an additional one-time payment of $1500 per acre for herbaceous buffers and $1700 per acre for forest buffers to be established through planting trees, creation of grass filter strips, and cattle fencing to protect creeks combined with alternative sources of water for livestock.

Top to bottom: Prothonotary Warbler - Noel Pennington; Gray Bats - USFWS; Snuffbox Mussel - USFWS; Ashy Darter - Conservation Fisheries/next page: Runoff from a farm in Tennessee - Tim McCabe, USDA NRCS; Clint Borum, TWRA with farmer Rich Koker-Chris Wolkonowski, NRCS

The agencies recognize that the public needs to compensate landowners for providing public benefits such as clean water. For this reason, these incentives are far higher than standard CRP rates to cover the higher opportunity costs associated with land retirement in this region. They are currently seeking leaders in the farming community to set an example by signing up for the program.

The hope in restoring 26 miles of buffer in selected subwatersheds is to make measurable benefits for water quality and aquatic species. The subwatersheds chosen provide habitat for a diversity of species of Greatest Conservation Need: songbirds such as the Prothonotary Warbler (*Protonotaria citrea*) and Yellow-billed Cuckoo (*Coccyzus americanus*); Gray Bats (*Myotis grisescens*) that rely on riparian and stream habitats for foraging; and a variety of aquatic organisms. The aquatics include the endangered mussel species Cracking Pearlymussel (*Hemistena lata*), Cumberland Monkeyface (*Quadrula intermedia*), Dromedary Pearlymussel (*Dromus dromas*), and Snuffbox mussel (*Epioblasma triquetra*), to name just a few.

In a state known for its freshwater mussel diversity, NRCS and Soil Conservation District personnel and TWRA private lands biologists are working side-by-side to achieve conservation objectives that benefit local streams and their wildlife, as well as downstream communities that rely on clean water from the Elk River.

4.3. Major Statewide Land and Water Uses

This section describes land and water uses that have large footprints in Tennessee and can result in widespread detrimental impacts to species and habitats.

4.3.1. Urbanization

Residential, commercial and industrial development can lead to a host of impacts to habitats, wildlife, and plants. This is particularly true in locations across the state where cities or towns are growing in ways that consume more land and put more pressure on surface and ground water resources to provide drinking water and dilute wastewater (Thurman and Terry 2011). These negative effects can include:

- direct loss of habitat through land conversion to other uses or stream habitat destruction;
- habitat fragmentation;
- increased runoff as a result of increasing levels of impervious surface, leading to erosion and/or water quality issues;
- increased flooding;

Box 5. How habitat fragmentation caused by development is affecting Streamside Salamanders in middle Tennessee

The Streamside Salamander (*Ambystoma barbouri*) uses both terrestrial and aquatic habitats throughout the year. During breeding season, these salamanders migrate from upland forests to first and second order streams where they attach their eggs to the underside of large rocks. The larvae develop in these streams until metamorphosis occurs, at which time they migrate into the surrounding upland habitat.

The majority of Streamside Salamander populations are located in middle Tennessee, just outside the current footprint of major cities. Habitat alteration as a result of urbanization leading to fragmented habitats is the main threat to this species in Tennessee (Niemiller et al. 2006). These salamanders are typically not found in streams where the surrounding forests have been removed (Lannoo 2005), and populations are thought to have been lost as a result of development (Mitchell et al. 1999). Development of conservation plans to protect terrestrial habitat surrounding first and second order streams is critical for this species (Niemiller et al. 2006).

Streamside Salamander - Matthew Niemiller

- expanding transportation or service corridors that can fragment habitat or block the movement of smaller, less mobile species.

According to the National Wildlife Federation, for an estimated 85 percent of imperiled plant and animal species worldwide, habitat loss or degradation is the principal threat to their continued existence. Sixty percent of the rarest and most imperiled species in the U.S. occur in metropolitan areas, especially the 35 fastest growing large metro areas, which include both Memphis and Nashville. Though they comprise only 8 percent of the lower 48 states' land area, these metro areas are home to nearly one-third of the nation's declining species (Ewing et al. 2005).

Impacts to Terrestrial Habitats

Urbanizing land use patterns affect terrestrial species and habitats in a variety of ways. For example, urbanization can result in a shift in the types of species that live and thrive in a region, with non-native species often competing with or replacing native species. A review of 105 studies on the effects of urbanization found trends of increasing proportions of nonnative species toward urban cores in plants, birds, mammals, and insects. The effects of moderate urbanization (i.e. suburbs) varied significantly, with most studies indicating an increase in plant species richness, due in part to exotic species introductions, whereas most studies of invertebrates and non-avian vertebrates show decreasing species richness with increasingly intense urbanization (McKinney 2008).

Fragmentation

Terrestrial habitat fragmentation can affect the health and size of wildlife and plant populations by reducing the ability of organisms to migrate and/or disperse, which in turn can lead to inbreeding and loss of genetic diversity. Plants are intrinsically less mobile so may be more susceptible to habitat fragmentation and succession. Fragmentation can occur in a variety of settings across the state, including development in and around existing public lands. For example, development in the eastern mountains of Tennessee on steep mountainsides and ridge tops can damage viewsheds and decrease tree cover, which leads to erosion and habitat fragmentation. (Thurman and Terry 2011). Without greater attention to planning and proper management, the development of vacation and recreation sites can fragment significant conservation landscapes and public lands.

European Starlings, non-native species now widespread throughout North America in cities and countryside, displace and compete with many native bird species - Alden Chadwick

Land management patterns

An increased risk of land development can also be associated with forestland ownership. For example, on the Cumberland Plateau, much forestland held for decades by timber companies has been sold to institutional investors. These investor groups can be excellent land managers and conservation partners. However, depending on the income planning horizon and expectations, increased pressure may be placed on harvesting forest products and selling land assets for other types of development. Reduction of forestlands can also negatively impact water quality and quantity, the health and diversity of habitats, and other land values such as recreation, timber, and forest products. (Thurman and Terry 2011).

Parcelization
In addition, as development fans out into rural areas, a phenomenon known as parcelization can occur, in which larger landholdings are subdivided into smaller and smaller ownership units. Even in the absence of habitat fragmentation in terms of actual land use change, parcelization increases the difficulty of providing coordinated and coherent habitat management on a scale suitable for many wildlife and plant species. For example, when private lands with a history of conservation management using prescribed fire are subdivided, it will take far more effort and coordination among multiple landowners to conduct prescribed burns over the same acreage (EGCPJV 2014).

Unplanned development
Unplanned development patterns also have a high cost to local communities, their economies, and cultural heritage. A 2011 report of the Tennessee Advisory Commission on Inter-governmental Relations concluded that if Tennessee continues to adhere to sprawling development patterns, nearly 800,000 additional acres of open land will be developed by 2025. While developed land in Tennessee increased by more than 12% from 1982 to 2007, the percentage of cropland decreased by more than 25%, putting Tennessee among the top 8 states nationwide for loss of prime farmland. Local governments, tax payers, and utility rate payers often subsidize the real cost of sprawl through expensive and inefficient infrastructure expansions (Thurman and Terry 2011).

Impacts to Aquatic Habitats

The complex relationship between land use and stream health means that several aspects of the land urbanization process contribute to declines in the state's water resources. Urban development can alter the stream flows, habitat quality, and water chemistry of streams in both direct and indirect ways (USGS 2015).


Urban Drains carry pollutants; impervious road surfaces increase runoff and destabilize normal stream flow. - KOMU News

Urban development often results in direct alterations of streams, either to accommodate development of a specific site, improve site drainage, or access to a site. Direct stream alteration can degrade the physical habitat and contribute to downstream channel erosion, sedimentation, or lower stream flows. All of these changes reduce spawning, feeding, and living spaces of aquatic organisms (USGS 2015).

Faster and more frequent runoff from paved and built surfaces increases and destabilizes normal stream flow, which also alters streams and increases erosion. Rapid runoff carries surface pollutants directly to streams and reduces natural water infiltration through the ground back to groundwater and aquifer recharge. Lowered aquifers may then contribute to lower stream flows, particularly in summer months (USGS 2015). Flooding can be exacerbated by both development in the floodplain and the failure to plan for stormwater management and adequate water infiltration to the ground. For example, a study of 21 stream sites in the Ridge and Valley ecoregion of Tennessee and Georgia revealed that more urbanized watersheds were characterized by increased proportions of fine sediments and pool areas, coupled with reduced variation in stream channel complexity. Urbanized watersheds exhibited declines in biotic integrity, species diversity, richness, and evenness (Smith 2009).

Sources of pollution from developed areas commonly include fertilizers, pesticides, animal waste, septic tanks, sewage, erosion from construction, vehicular fluids, and industrial and commercial site runoff. These sources contribute to an increase in concentrations of contaminants in streams including nitrogen, chloride, insecticides, and polycyclic aromatic hydrocarbons (PAHs). A USGS study found that aquatic invertebrate communities begin to degrade from the onset of urban development, which indicates that some species are highly sensitive to physical and chemical changes associated with urban development. (USGS 2015).

The Tennessee Water Quality Assessment Report (TDEC 2012/EPA 2015) provides a comprehensive summary of water quality assessments for the state's waters (See Table 14). Urban-related storm-water, wastewater, and construction activities are three of the top five sources of impairment to Tennessee streams.

Table 14. Top 5 causes and sources of stream impairment in Tennessee (TDEC 2012/EPA 2015)

Sources of Stream Impairment	Stream miles
CAUSES OF STREAM POLLUTION	
Pathogens (mainly E. Coli)	7364.5
Habitat Alterations	6785.9
Sediment	6187.6
Nutrients (includes phosphorus and nitrogen)	3380.2
Organic Enrichment/Oxygen Depletion	1823.3
SOURCES OF STREAM POLLUTION	
Agriculture (includes grazing in riparian zones and non-irrigated crop production)	8,780.1
Hydromodification (includes channelization, upstream impoundments, and dredging)	4349.6
Urban-related Runoff/Stormwater	2786.6
Municipal Discharges/Sewage	1560.2
Construction (includes site clearing for development and transportation corridors)	1003.1

Impacts to Karst Habitats

Karst landscapes are characterized by caves, sinkholes, underground streams, and other features formed by the slow dissolving, rather than mechanical eroding, of bedrock (Veni et al. 2001). With more than 10,000 documented, Tennessee has the greatest number of caves in the country equalling about 20% of all known U.S. caves (Wisby and Palmer 2015). Most Tennessee caves are associated with karst composed of limestone in the central and eastern regions of Tennessee. Karst areas present unique challenges because so many of the processes key to their formation and stewardship are located underground, invisible from the surface. For this reason, the complex hydrologies of karst aquifers and other critical processes require specialized monitoring and assessment (Veni et al. 2001).

Hubbard's Cave: Tennessee has more caves than any other state in the U.S. Much of middle and eastern Tennessee is underlain by karst. - Byron Jorjorian

Karst regions are rich in water and mineral resources, providing unique habitats and spectacular recreational opportunities. Problems associated with living on karst can threaten both people and natural resources. Problems for people include sinkhole collapse, sinkhole flooding, and easily polluted groundwater that rapidly moves contaminants to wells and springs. Problems to the unique biota associated with caves and aquatic habitats include sediment and pollutants that infiltrate from the surface, as well as alteration of drainage conditions and the aquifer itself (Veni et al. 2001).

A variety of best management practices (BMPs) exist to help reduce these types of potential impacts. BMPs rely on knowledge of the location of karst and aquifers, combined with practices designed largely to avoid impacts from contamination or hydrological alteration. BMPs for living and working in karst regions cover the following activities:

- development and road construction
- wells and groundwater mining
- septic and sewage systems
- agriculture and livestock production
- timber harvest

(Veni et al. 2001)

Sinkholes are subject to flooding in response to precipitation; flood duration depends on the rate of water inflow, outflow, and degree of hydrologic connection to groundwater. Insufficient delineation of sinkholes and incomplete knowledge of their characteristics can result in development patterns that exacerbate sinkhole flooding (Bradley and Hileman 2006). Since many of Tennessee's growing urban areas are located in karst regions, the understanding and mapping of these habitats is critical.

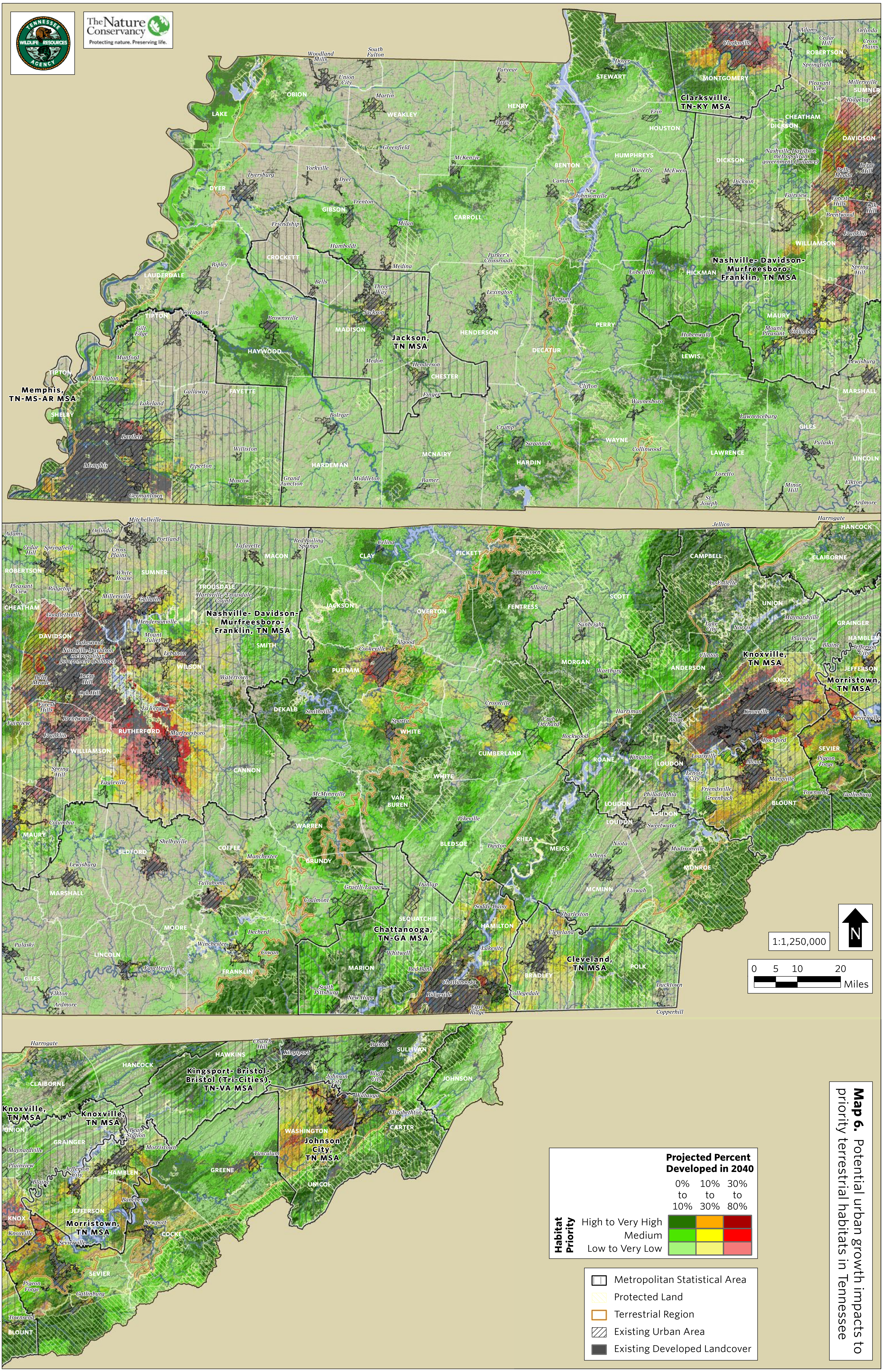
Mapping urbanization in Tennessee

While the population of Tennessee increased by 16.7% from 1990 to 2000, this rate subsequently declined. However, from 2000 to 2010, Tennessee's population still increased by 11.5% (US Census 2000 and 2010). The 2005 SWAP identified development-related issues as the most consistently high-ranked stressors to terrestrial, aquatic, and subterranean GCN species, and this assessment remains applicable in 2015.

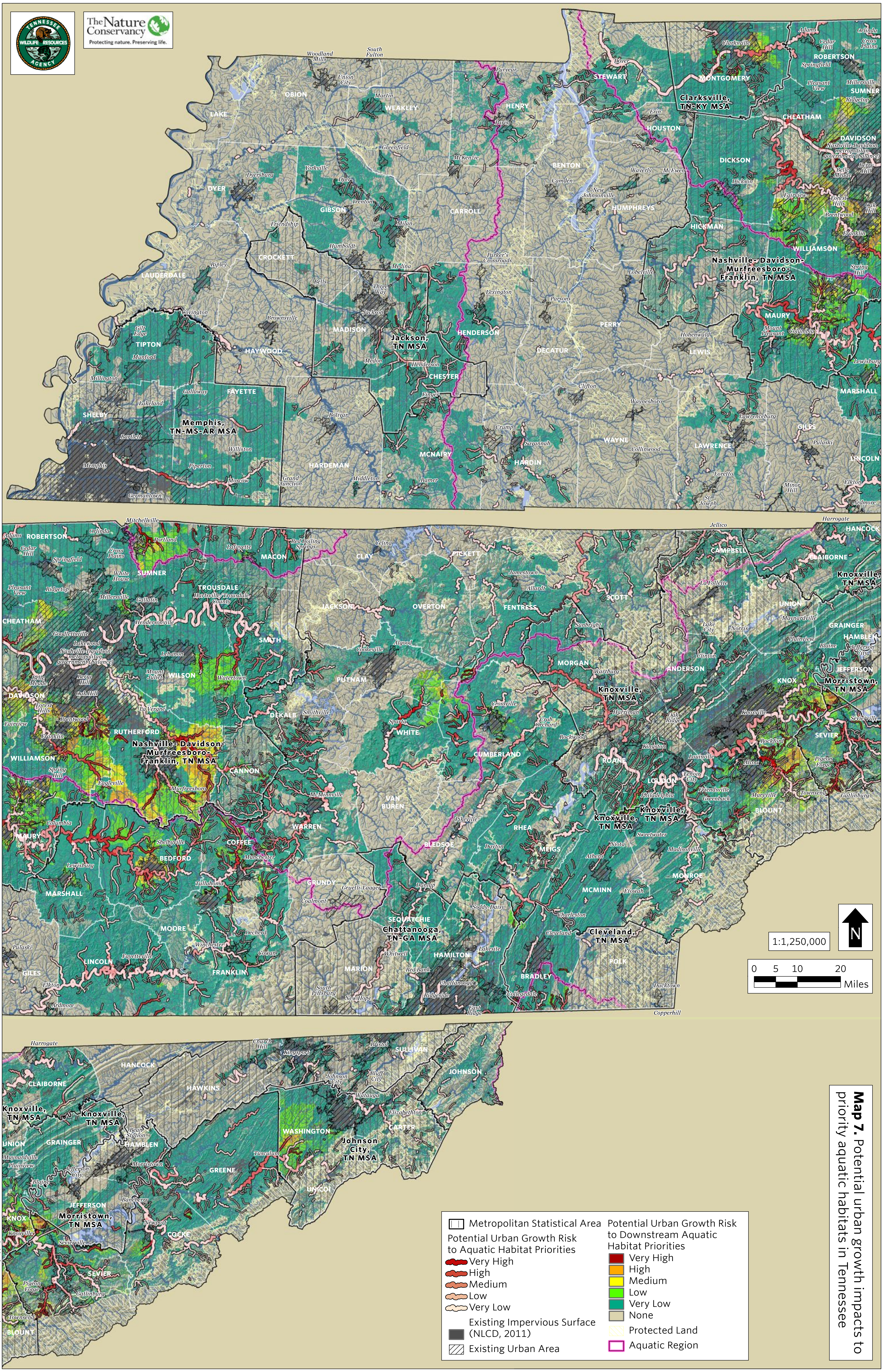
For the 2015 update, the SWAP team adopted a methodology developed by The Nature Conservancy (TNC) for examining the growth in urban land use footprints across Tennessee to accommodate our projected population through 2040 (Wisby and Palmer 2015). This methodology uses county-level population growth projections from the University of Tennessee's Center for Business and Economic Research; information on county and municipality urban growth and boundaries; and data on land features and proximity to infrastructure to determine which areas are likely to experience land conversion during the next 25 years.

Nashville riverfront and skyline - Brad Montgomery

The results show the specific locations across the state where GCN habitats and species may be at risk without proper planning for habitat protection (Maps 6 and 7). These maps, and the underlying species and habitat data, can help inform decision-making so that natural resource considerations can be made in advance. While the potential expansion footprint may not appear visually large in some places, such as far eastern Tennessee, urbanization can result in localized habitat fragmentation effects that can interrupt habitat connectivity at larger scales. Maps 6 and 7 also show the boundaries of Metropolitan Statistical Areas (MSAs) of Tennessee (Figure 3). The maps group the ten MSAs of Tennessee into a smaller subset of 5 combined areas. For planning collaborations with SWAP conservation partners, the data can be analyzed and presented for

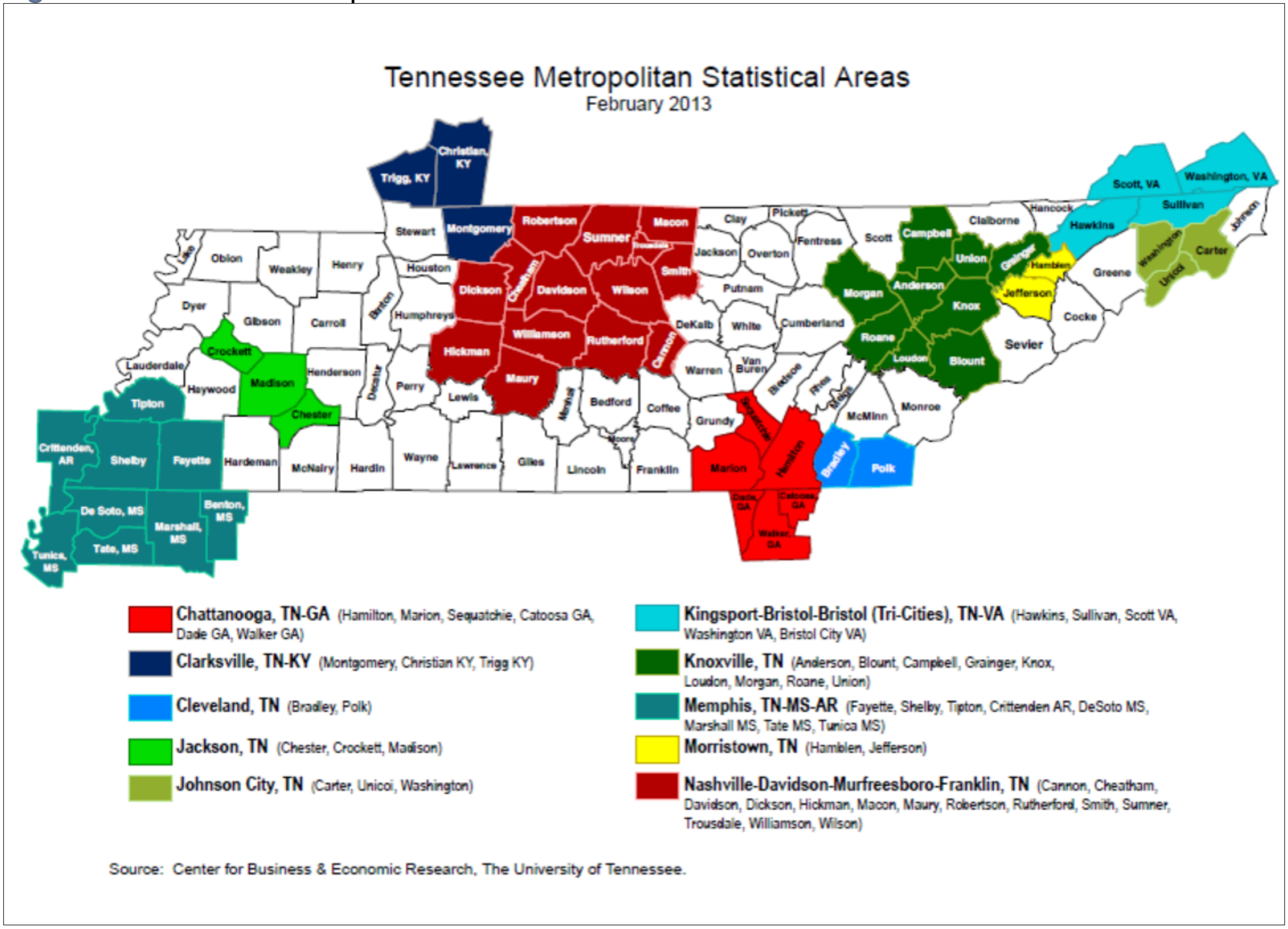


Map 6. Potential urban growth impacts to priority terrestrial habitats in Tennessee



Map 7. Potential urban growth impacts to priority aquatic habitats in Tennessee

Figure 3. Tennessee Metropolitan Statistical Areas



any specific MSA or combination of MSAs at the desired spatial scale.

4.3.2. Agriculture

Agricultural conversion and incompatible agricultural management practices can, in some cases, pose challenges to sustaining certain wildlife and plant species in Tennessee. However, it is important to note that not all agriculture poses a threat to wildlife and plants. In fact, certain forms of agricultural management can be beneficial for wildlife and plant conservation or can be managed to lessen negative impacts. Many such practices are promoted through incentive programs for landowners administered by the U.S. Department of Agriculture, Natural Resources Conservation Service, and the Tennessee Department of Agriculture.

Impacts to Terrestrial Habitats

Agricultural land use can pose a threat to terrestrial species when important grasslands or forests are converted to cropland or pasture, contributing to overall loss or fragmentation of habitat. Loss of riparian habitat impacts GCN bird species such as Prothonotary Warblers, Swainson's Warblers, and many others.

Wetland habitats provide important services such as water filtration and groundwater recharge, and they provide critical habitat to many species at various points in their life cycle as well. As with so many wetland areas of the United States, these highly localized habitats have been vastly reduced, often as a result of drainage and clearing for agriculture (USGS 1997). Tennessee lost 59% of its wetlands from the 1780's to the 1980's, according to estimates by the U.S. Fish and Wildlife Service (Dahl 1990).

Contemporary estimates of Tennessee's wetland area range from 640,000 to 1,400,000 acres. Wetlands are ecologically and economically valuable to Tennessee, despite making up a relatively small percentage of the state. Bottomland forests are the state's most common type of wetland, located primarily in the flood plains of rivers in west Tennessee. Major causes of wetland loss or degradation in Tennessee include

- agricultural conversions,
- logging,
- reservoir construction,
- channelization,
- sedimentation,
- urbanization

(USGS 1997).


Prothonotary Warbler, a species that depends on riparian and bottomland habitats. Cynthia Routledge

Beginning with the introduction of genetically modified herbicide-resistant (HR) crops, herbicide use increased in the U.S. by 527 million pounds from 1996 to 2011 (Benbrook 2012). These increases occurred in states such as Tennessee, where the HR crops soybeans, corn, or cotton are grown. The use of herbicides on HR crops increased 31% nationwide from 2007 to 2008, to a large degree due to the spread of weeds resistant to these same herbicides (Benbrook 2009).

Milkweed and many other flowering herbs and shrubs that serve as sources of seed and nectar for birds and other pollinators have suffered collateral damage from the widespread use of herbicides, with one study in 2012 showing a direct correlation between declining Monarch Butterfly numbers and increasing adoption of herbicide tolerant soybeans and corn (Monarch Joint Venture 2015). Also, studies by Purdue University have shown that herbicides making their way into streams have the potential to adversely affect GCN species such as Hellbenders by altering growth and development of larval stages (Solis et al. 2007).

Impacts to Aquatic Habitats

Incompatible agricultural management practices are the number one source of damage to streams across

Water flows off a farm in Tennessee following a storm.
- Tim McCabe, USDA NRCS

Tennessee (see Table 14). One reason for this ranking is that Tennessee's overall landscape remains largely in some form of agricultural use or forest type. Management practices that can contribute to stream health impairments include removal of streamside vegetation; grazing livestock along stream banks with unrestrained access to the stream; poor farm nutrient, waste, and herbicide management; channelizing and dredging streams; and creating impoundments on streams or withdrawing excess amounts of water.

Poor farm nutrient and waste management practices can contribute to pollution by Escherichia coli (E. coli) pathogens, and nitrogen and phosphorus inputs to streams and rivers. An excess of nutrients results in a problem known as eutrophication in streams, which lowers the dissolved oxygen in water available for freshwater animals, including insects.

Of all the effects associated with incompatible agricultural practices, excess sedimentation from farm fields and eroding stream banks may well be the single most deleterious for freshwater GCN species in Tennessee. According to a USGS study of 20 streams in Tennessee's Eastern Highland Rim ecoregion, nutrient concentrations, stream gradient, width, and substrate embeddedness (the degree to which fine particles surround coarse substrates) were all related to cropland density in a particular watershed. However, results suggest that fish communities respond primarily, and negatively, to the cumulative effects of sedimentation (Powell 2003). Channelization of streams and rivers to increase land

A channelized stream in west Tennessee, South Fork of the Forked Deer River - Rob Colvin, TWRA available for agricultural production is a major contributor to habitat impairments in western Tennessee.

Impacts to Karst Habitats

Tennessee is among a handful of states with the greatest number of springs (3000), most of which are associated with karst composed of limestone in middle and eastern Tennessee. Enhanced interactions between surface and groundwater processes occur in karst. The hydrological cycle begins with precipitation and surface water drainage into the aquifer, which can occur over the entire karst surface area. Caves are considered subsurface extensions of karst landscapes, with most caves forming at or just below the water table. Caves above the water table are tributaries to caves below the water table. Water percolating downward passes through caves, which serve as “natural pipes” and the water can often re-emerge at the surface as springs or seeps (Veni et al. 2001).

Water flows over steps into Arch Rock at Alum Cave in Great Smoky Mountains National Park - Patrick Mueller

In rural and agricultural areas, karst aquifers are subject to contamination from a number of sources. Chemical fertilizers, pesticides, herbicides, and elevated pathogen concentrations can be flushed through soils into aquifers beneath farmland, pastures, and feedlots. In addition to the impacts of sedimentation listed previously, sediments can affect the flow of groundwater through karst and may also carry contaminants, making programs to minimize soil loss critically important for many karst areas.

Another practice common in rural areas is dumping of refuse, construction materials, and dead livestock into sinkholes. “Common harmful products include bacteria from dead animals; used motor oil and antifreeze; and empty herbicide, solvent, and paint containers. These substances readily enter the aquifer and rapidly travel to nearby water wells and springs. Few people would throw a dead cow into a sinkhole if they realized that the water flowing over the carcass might be coming out of their kitchen faucet a few days later.” (Veni et al. 2001).

Mapping agricultural land use and priority freshwater habitats

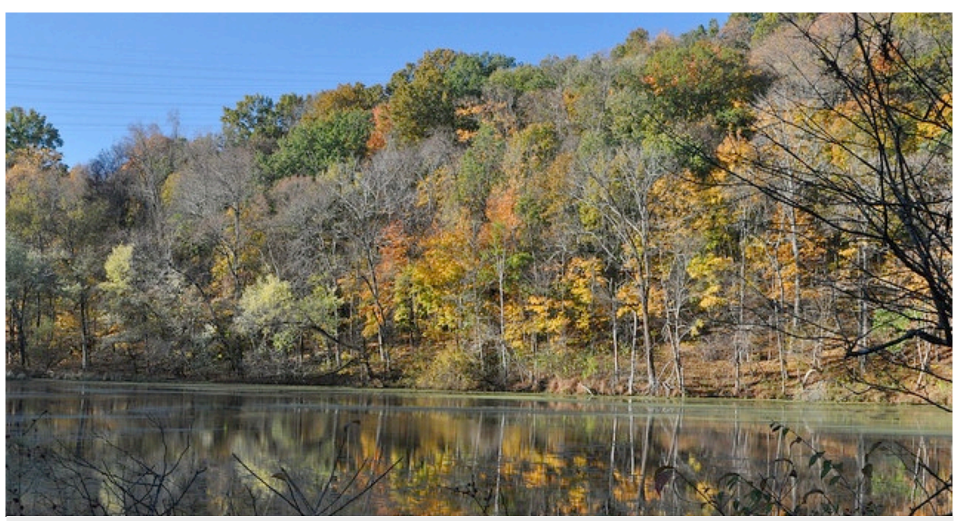
Improving agricultural management practices in priority areas can improve outcomes for freshwater species of greatest conservation need and overall water quality across Tennessee. To better understand the scope of the challenges and opportunities, for the 2015 update the SWAP team used an approach developed by TNC (Wisby and Palmer 2015) to examine where across the state important watersheds for freshwater species conservation intersect with different agricultural land uses that may contribute to habitat or water quality degradation, if not managed to prevent such problems (see Map 8). The results show specific locations across the state where GCN habitats and species may be at risk without the use of agricultural best management practices, including sound management of Combined Animal Feeding Operations (CAFOs). It is important to note that these maps do not take into consideration where best management practices may already be in place; therefore, they are not representative of actual site-specific habitat conditions.

4.3.3. Forestry

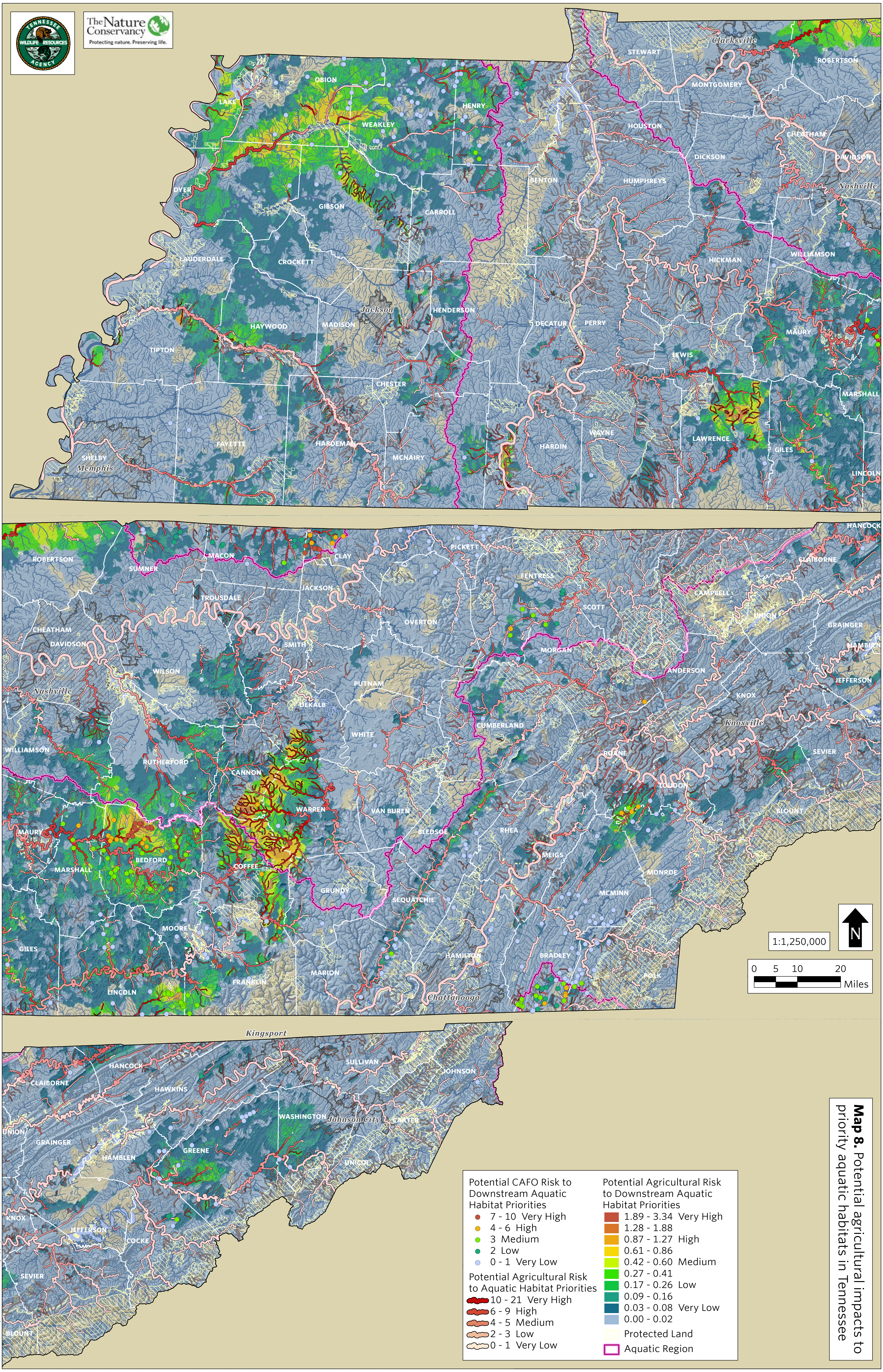
The Tennessee Division of Forestry developed its first Forest Resource Assessment and Strategy, also called the Forest Action Plan, in 2010. Where possible, it complements other state plans including the 2005 SWAP. Both plans identify problems facing Tennessee forests in the form of incompatible forestry practices that decrease forest habitat extent, alter habitat structure, and contribute sediment and nutrients to streams. All of these problems can negatively impact GCN species populations. Changing forestland ownership and increased parcelization present additional challenges to coordinated management and protection activities in many regions of the state (TDF 2010).

In terms of specific management practices, the lack of vertical structure in forests (i.e. understory, mid-story, and canopy development) is a threat to wildlife because a hardwood forest with structure supports a far greater diversity of wildlife than one without. This lack of structure is the result of little or no natural disturbance or intermediate management action, such as burning or thinning, over the life of a forest (TDF 2010).

Across the southern Appalachians, early successional habitats have been declining over several decades due to farm abandonment, changes in farming practices, urban



Diverse forest structure: wildlife generally respond to diversity - Greg Wathen, TWRA



Map 8. Potential agricultural impacts to priority aquatic habitats in Tennessee

The Yellow-breasted Chat is a GCN species that depends on early successional habitat. - Chris Sloan

encroachment, and the suppression of natural disturbances such as fire, flooding, and beaver activity. Species like the Golden-winged Warbler that depend on these habitats have declined over time, and their habitat restoration has become a priority (USFSb 2015).

Other potentially incompatible practices include high grading, clearcutting, pine monoculture, and use of exotic plants. In addition, high density, even aged, short rotation pine stands provide few wildlife or native plant benefits (TDF 2010; D. Lincicome, personal communication, Sep. 4, 2015).

Large timber harvests implemented without attending to BMPs designed to protect water quality, snags, and ground cover can directly impact wildlife, native plant populations, and habitats. In recent years, clearcutting and harvesting of the largest, highest quality trees (known as high grading) has occurred on both public and private lands. Maintaining the structure and diversity of old growth forest habitats and their connectivity across the landscape is critical to conservation of many GCN plants and animals. Without proper planning with respect to landscape-level habitat requirements for multiple species, including those dependent on different types of habitat, high grading practices can be detrimental as they lessen diversity in forest structure.

Logging road in Tennessee: best management practices help to mitigate erosion, concentrated flows, and sedimentation. - Chris M. Morris

Other negative effects of certain types of forest management include the following:

- Soil compaction and erosion;
- Impaired water quality from erosion, altered drainage patterns, and concentrated flows;
- Conditions that promote the establishment and spread of invasive species or insect pests (USFS 2015c).

Proper management of forest resources, including the promotion of landscape-level forest habitat health, helps protect a diversity of habitats for GCN species. It also promotes many other beneficial forest uses, such as protection of public drinking water supplies, recreation opportunities, and local forest-product related economic activities (TDF 2010).

4.3.4. Water Management

Tennessee's rivers and streams provide habitat for some of the greatest diversity of aquatic species in North America (Smith et al. 2002, Master et al. 1998). For the last century, government agencies and private businesses have developed the state's water resources to provide flood control, river navigation, electricity, drinking water, agricultural improvements, and recreation benefits to Tennesseans as well as residents of neighboring states. While transforming state and local economic opportunities, the construction of dams and other water infrastructure has also fundamentally changed Tennessee's rivers and tributaries from their original interconnected, free-flowing conditions. Currently the best estimate for number of dams in Tennessee is 1, 721 (E. Granstaff 2015, personal communication, Aug. 11).

The flow regime of a stream or river system and the connection of a river to its tributaries is a highly significant factor in determining both the structure and function of aquatic and riparian

Streamflow: one of the key factors that determine the species composition and health of a stream. - Greg Wathen, TWRA

ecosystems. An ongoing USGS study on stream flow and ecology in the Tennessee river basin has identified specific aspects of streamflow that influence fish community health and abundance (USGS 2013).

Dam construction can alter flow by turning river systems into a series of large pool reservoirs. Flow alteration as a result of dams both large and small has significant impacts on aquatic species, fragmenting the river network, impeding the movement of resident and diadromous fish species, and eliminating or altering in-stream habitat. By preventing many species of fish and invertebrates from accessing river reaches upstream and downstream of the structures, dams essentially disconnect populations from large sections of their habitat. In addition, dams pose threats to native aquatic systems by changing several key characteristics of the streams that occur downstream of reservoirs: natural flow patterns, dissolved oxygen, temperature, nutrient loads, and water chemistry.

Water withdrawals are also a concern if the timing or amount of withdrawal is sufficient to alter basic flow patterns and affect ecological responses, posing a threat to aquatic wildlife and plants. Both channelization and upstream impoundments, which can affect flow patterns, are listed among the top ten sources of impairment to Tennessee river and stream health (TDEC 2012/EPA 2015) (See Table 14). In addition to reducing habitat for aquatic species, flow alteration can also affect water quality, water temperature, and water availability (USGS 2013).

Resource management challenges of large dams and reservoirs

Rivers below dams are commonly referred to as tailwaters or tailraces. Many hydropower and flood control dams, operated by the Tennessee Valley Authority (TVA) in the Tennessee River system and the U.S. Army Corps of Engineers (USACE) in the Cumberland River system, release cold water into the tailwaters. The cold water can degrade or reduce habitat for native fishes and mussels.

Likewise, some tailwaters are low in oxygen, especially by the end of the summer, because decaying organic matter in reservoirs uses up oxygen at the bottom of the reservoir, and the heavier, colder water does not mix with the surface. It is also these waters that are discharged from the dam. These are issues that TVA, USACE, TWRA, and the U.S. Fish and Wildlife Service (USFWS) have worked to address in recent decades, by creating flow regimes and improving downstream water quality to benefit at-risk and endangered species in key river reaches.

Since 1991, TVA has spent more than $60 million constructing capital projects to address the problem of low oxygen, installing a variety of equipment and technologies designed to increase dissolved oxygen concentrations below 16 dams. TVA also monitors key aspects of ecological health in the tailwater sections to achieve biological and recreation objectives (TVA 2015b).

In recognition of the importance of stream flows, TVA also changed their policy for operating the Tennessee River and reservoir system in May 2004. The policy now focuses on managing the flow of water through the system rather than storage. It specifies flow requirements for individual reservoirs, to prevent riverbeds below dams from drying out, and for the system as a whole. (TVA 2015b). Their operations

Lake Sturgeon below Douglas Dam on the French Broad River. Once extirpated from the Tennessee River, in part due to hydroelectric dams, Lake Sturgeon are making a comeback due to TVA's Reservoir Releases Improvement program. - Bart Carter, TWRA now maintain wetted habitat in 180 miles of river that previously were intermittently dry (Yarbrough 2013).

Similarly, the USACE has conducted watershed assessments in key watersheds where they operate. These are collaborative processes with state, federal, tribal, interstate, local government, and stakeholder organizations that produce watershed plans to balance needs for water supply, public safety (flood control), wildlife habitat, and aquatic diversity (USACE 2015).

In some cases, agencies recognize that cold tailwaters are inevitable and present an opportunity to provide a sport fishery. Because cold water released into the tailwaters below dams creates a new type of habitat, TWRA stocks trout to diversify the state's angling opportunities. TVA's monitoring program on the Elk River allows the agency to adjust the operation of Tims Ford Dam to protect the variety of life in the river, including a cold-water trout fishery, endangered species, and sport fish that require warm water (TVA 2015b).

Resource management challenges of small dams and stream barriers

Even small impoundments, which are constructed on smaller or headwater streams for various reasons, have the potential to adversely affect aquatic life. Such impoundments eliminate flowing stream habitat in the flooded pool zone, making habitat unsuitable for native stream species. These dams also may alter the physical, chemical, and biological components of downstream reaches. They create barriers that can result in isolated populations, and with no provision for minimum flows, they may result in insufficient flow downstream, particularly during summer months (Arnwine et al. 2006).

Even small dams create barriers and can alter the flow, chemistry, and biology of areas both up and downstream. - Chris Simpson, TWRA

All of these factors combined are a recipe for reduced biotic integrity, altered flows, and negative impacts on water quality downstream of the impoundment. Results from one study indicate that small impoundments affect the biological community for at least one-quarter mile downstream (Arnwine et al. 2006). As recognition of these impacts has grown, momentum has increased among a variety of constituents across the country to remove dams, particularly those that no longer serve their original purpose or that pose significant threats to public safety.

Negative impacts of stream and river channelization

Channelization of rivers and the use of levees and dikes to prevent flooding in former natural floodplains are two major contributing factors to the imperilment of many GCN fish species, particularly within the Mississippi River and its tributaries in western Tennessee. Straightening streams means removing the meanders that produce habitat structure in the form of pools and riffles, which are essential to a diversity of fish and other aquatic life. Channelization can also lead to greater erosion and sedimentation (TWRA and USFWS 2002).

Channelization has hurt the following species in west Tennessee:

•Alligator Snapping Turtle
•Alligator Gar
•Lesser Siren
•Smallmouth Salamander
•Piebald Madtom
•Pink Mucket Mussel
•Orangefoot Pimpleback Mussel

Disconnecting streams from their floodplains through channelization, levees, or dike construction can cause the following problems (TWRA and USFWS 2002):

- loss of sediment;
- deposition outside of the streambed;
- decrease in groundwater recharge;
- elimination of spawning and nursery habitat for fish and amphibians.

Channelization and associated silt load in the Forked Deer River system in Madison County - TWRA staff

4.3.5. Energy Development

Non-renewable energy development

Resource extraction for non-renewable energy sources includes mining for coal as well as drilling for oil and natural gas. These activities can involve significant impacts to natural habitats. Without proper advance planning, management, and mitigation, they can cause long-term and even irreversible damage.

Coal Mining

Coal mining activities, from site preparation to post-mining impacts, can introduce a spectrum of problems for GCN species and their habitats. A 2002 Clinch and Powell Valley Watershed Ecological Risk Assessment conducted by the EPA analyzed associations between land use and in-stream habitat and their effects on fish and mussels. Their findings show that coal mining activities can cause "unacceptable losses of valuable and rare native fish and mussels." (EPA 2002).

Forest loss can fragment habitat and severely affect interior forest-dwelling birds and other species. A current threat facing the region is that of mountaintop removal coal mining, which even with reclamation leaves landforms permanently altered (SELC 2015).

The Cumberland Plateau and Mountain region of Tennessee has experienced decades of long term environmental impacts from coal mining, including problems associated with contour mining, deep mining, cross-ridge mining, and re-mining of areas. Such activities destroy terrestrial habitats and permanently disrupt and degrade the hydrologic and ecologic function of surrounding forests, spring seeps, streams and riparian zones. These activities also disrupt and degrade the ecological function and connectivity of ridgeline habitat corridors.

Coal mining conducted prior to the passage of the 1977 Surface Mining Control and Reclamation Act (SMCRA), which required post-mining site repair activities to take place, left clear cuts, polluted rivers, and unstable slopes in their wake. Issues from older abandoned mines that were either never reclaimed or improperly reclaimed have degraded both water quality and aquatic wildlife diversity. (EPA 2014c).

For example, in the Big South Fork National River and Recreation Area, numerous abandoned coal mine sites are found throughout the park. These sites have become sources of contaminated water affecting the river and its tributaries (NPS 2014). The Office of Surface Mining, Reclamation and Enforcement's **Abandoned Mine Land Inventory System** lists 290 problem areas in their database for Tennessee.

Big South Fork acid mine drainage - NPS

An additional land management challenge in Tennessee comes from the "split estate" ownership status separating subsurface mineral rights from surface rights. Even in many cases where the state or federal government protects and manages the land surface, the mineral rights may be privately owned. According to the U.S. Bureau of Land Management, in these situations, "the mineral owner must show due regard for the interests of the surface estate owner and occupy only those portions of the surface that are reasonably necessary to develop the mineral estate." (BLM 2015). Maps 9 and 10 demonstrate where currently permitted coal mining activity intersects with priority GCN species habitats in Tennessee. Collaborative planning and management at site and regional scales may help reduce the potential for negative impacts.

Oil and Gas

Both public and private lands in the Northern Cumberland Mountains and Plateau region have experienced historic impacts from oil wells and are now facing new challenges from natural gas developments. Big South

Fork National River and Recreation Area and Obed Wild and Scenic River have over 300 private oil and gas operations. "Many of the past and existing oil and gas operations in these NPS units are adversely impacting resources and values, human health and safety, and visitor use and experience; most are not in compliance with federal and state regulations." (NPS 2012).

In 1994, 82 percent of Tennessee's total oil production, and 60 percent of its total gas production,

Big South Fork acid mine runoff into a stream-National Park Service

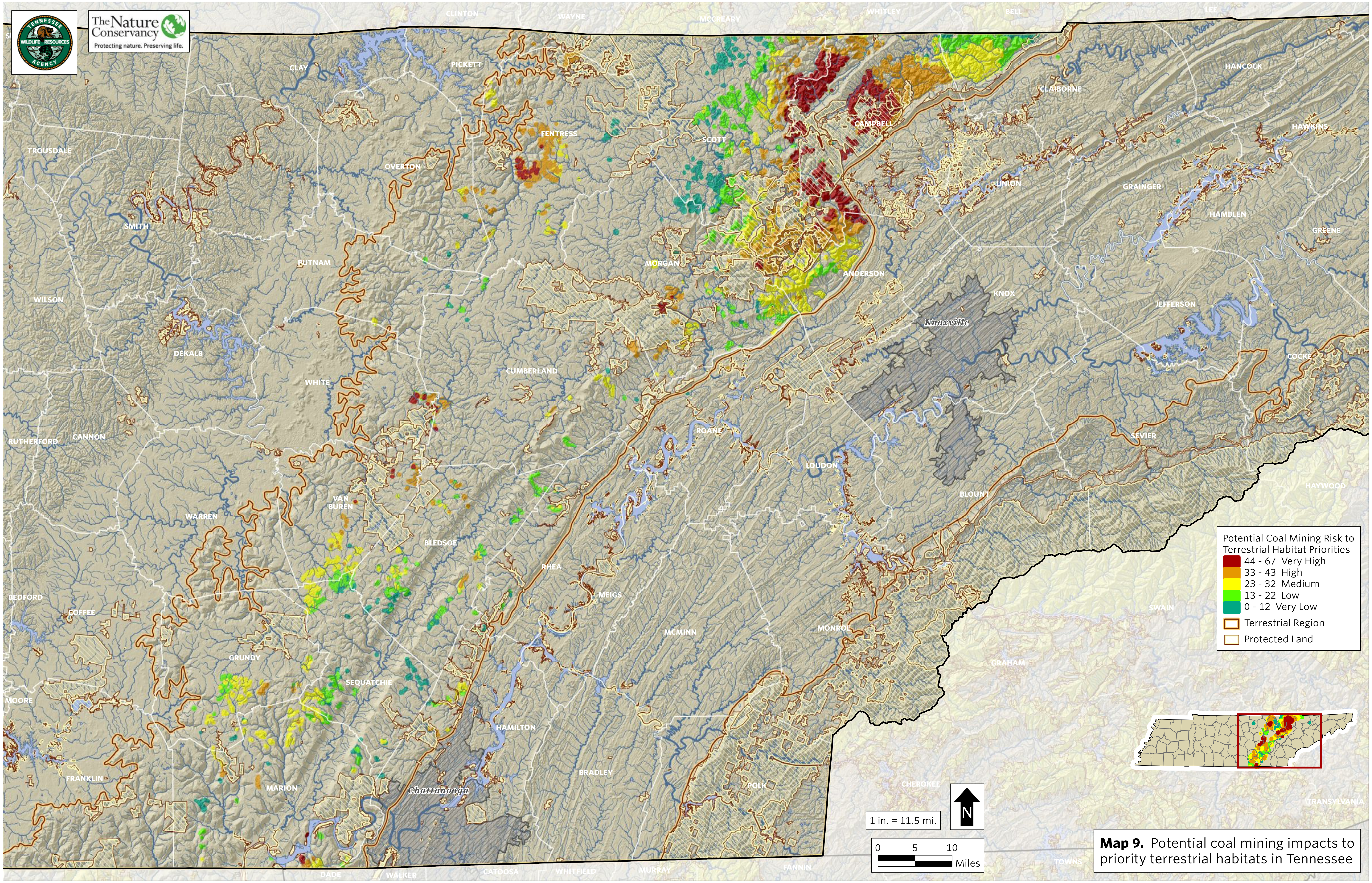
came from counties within the watershed of the Big South Fork River. By 2006, 50% of Tennessee's total oil production and 99% of its gas production came from these same watershed counties (NPS 2012).

The National Park System's Oil and Gas Management Plan for these areas states that many of these operations are not in compliance with federal and state regulations. The plan is a strategy to help park managers ensure their park units are protected from current as well as potential future threats from new development. The plan provides park-specific guidance for oil and gas owners and operators who wish to establish new oil and gas extraction sites (NPS 2012).

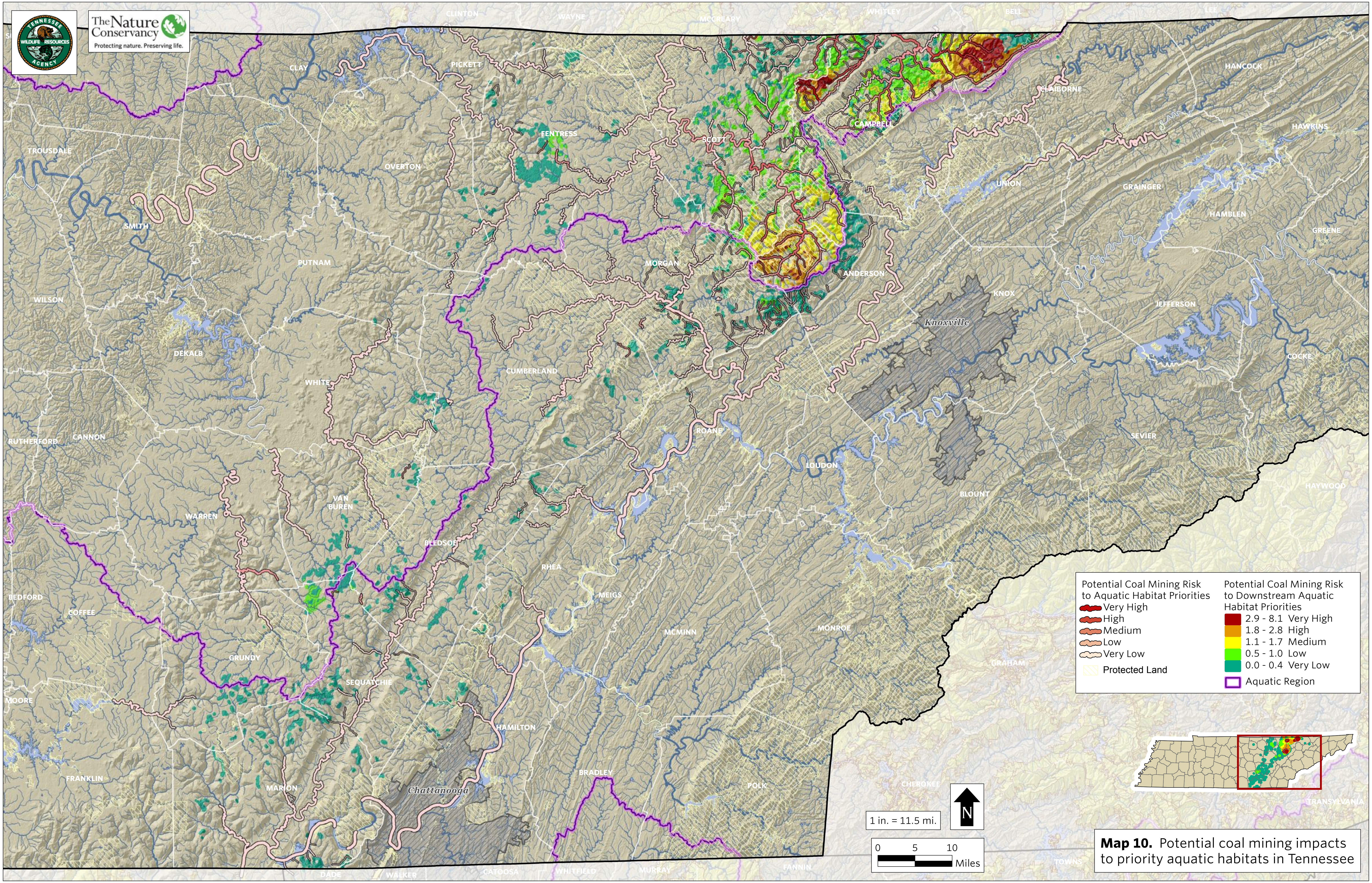
Different processes for extracting natural gas have raised concerns about potential negative impacts to both surface streams and groundwater affecting both freshwater species and overall water quality (Entrekin et al. 2011). In addition to the drilling process itself, the infrastructure development associated with production -- particularly new well pads, pipelines, and roads -- poses a major challenge to long term forest habitat integrity, both locally and across broader landscapes where production is increasing (Drohan et al. 2012, Fisher 2012). Tennessee has yet to experience the landscape-scale level of development similar to other states such as Pennsylvania; however, Tennessee does retain natural gas resources that are currently being developed and may be developed more in the future. Maps 11 and 12 demonstrate where permitted oil and natural gas activity intersects with priority GCN species habitats. As with potential coal mining impacts, use of these data in a collaborative planning framework may help reduce negative outcomes for species.

Renewable energy development

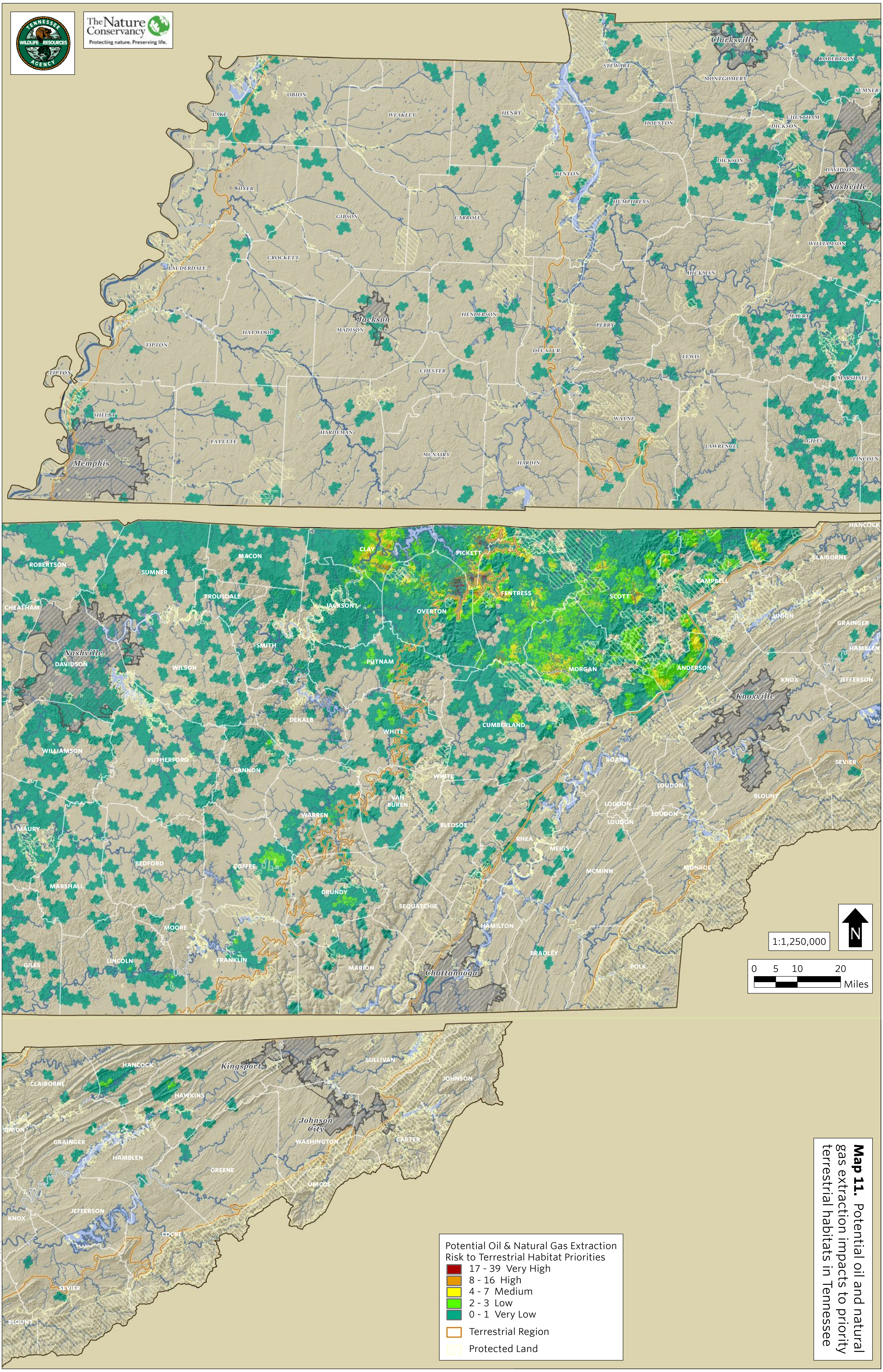
The development of renewable energy resources is receiving increased attention and study across the U.S. Renewable sources such as wind, solar, and biofuels/biomass, are currently being developed at smaller scales across Tennessee. Hydropower, also considered a renewable source, has been a significant provider of peak electrical power for many decades.



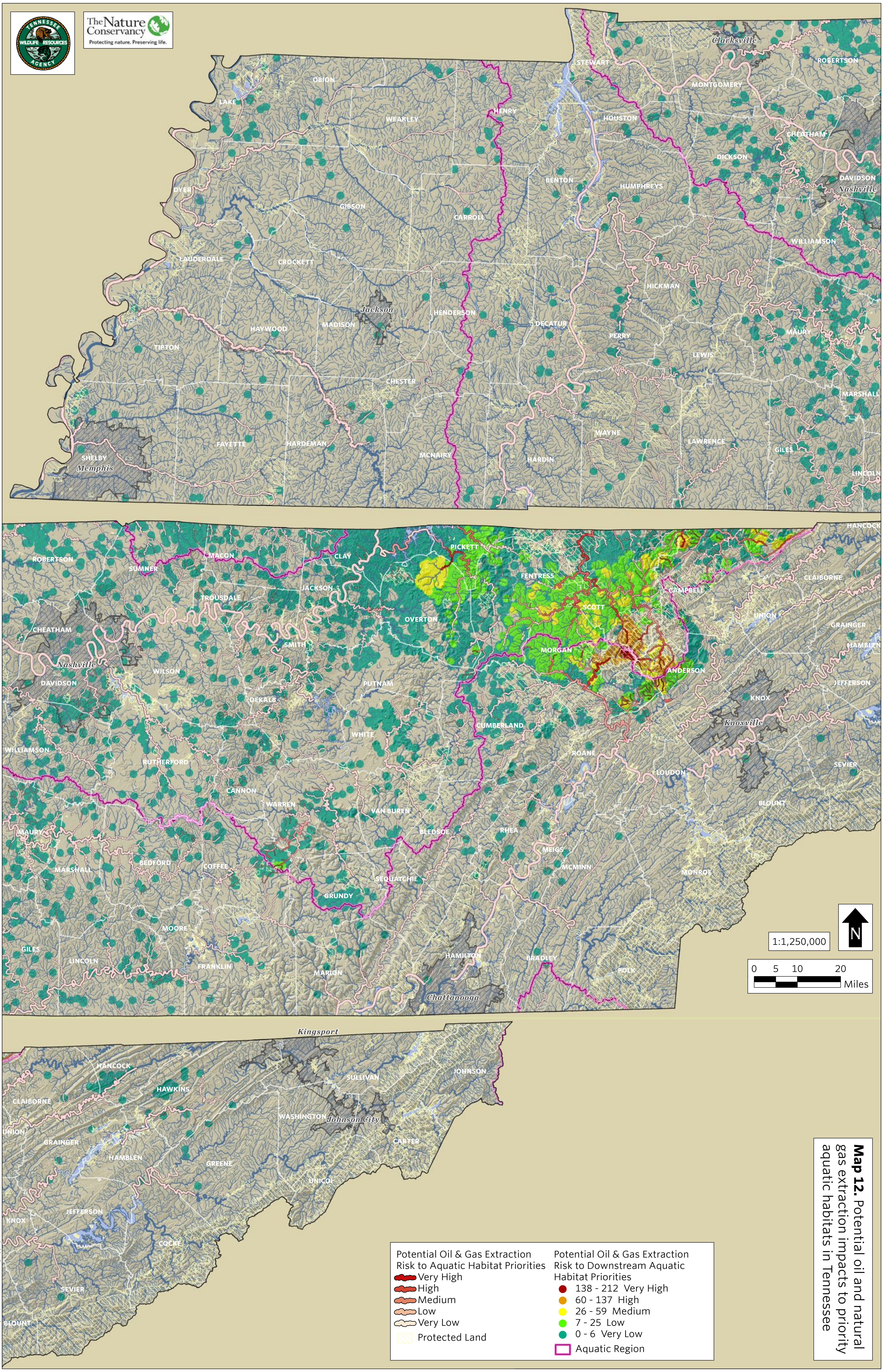
Map 9. Potential coal mining impacts to priority terrestrial habitats in Tennessee



Map 10. Potential coal mining impacts to priority aquatic habitats in Tennessee



Map 11. Potential oil and natural gas extraction impacts to priority terrestrial habitats in Tennessee



Map 12. Potential oil and natural gas extraction impacts to priority aquatic habitats in Tennessee


Switchgrass grown at the Power Plant Garden of the National Arboretum - USDA

Each type of renewable source has its own potential conflicts with species and habitat conservation needs. Well-designed approaches for overall land uses need to consider the potential of the land for all human needs as well as for biodiversity protection, placing each use in its most suitable location. Primary considerations for all renewable energy development types include eliminating or reducing direct species impacts, habitat losses, and fragmentation of habitat across the landscape.

Bioenergy

Biofuels (liquid fuels) and biomass (solid fuels) are both forms of renewable energy derived from biological materials, such as plants, vegetable oils, forest products, or waste materials. A 2010 analysis of the implications of biofuels for land use and biodiversity points out that perennial bioenergy crops could be considered an appropriate component of conservation farming systems when their use is integrated with land use planning along with rotations that improve soil quality, reduce erosion, and minimize runoff of agricultural inputs (Dale et al. 2010). Several species of perennial warm season grasses, such as switchgrass (native to the North American prairie from the Gulf of Mexico to Canada) provide excellent wildlife habitat.

Continued crop breeding innovations will almost certainly expand the range of growing conditions for bioenergy feedstocks, making even more areas that are important habitats for wildlife suitable for agriculture. Also, while native warm season grasses do provide excellent habitat, the design of production fields for biofuels may not be structured to provide the spacing and pattern of habitat needed on the ground. Thus, the risk of conversion to cropland in such areas merits special attention, protection, and planning (Dale et al. 2010).

Within the last decade, more research and development projects have been directed toward understanding the potential of forest biomass to supply alternative energy sources. The U.S. Forest Service anticipates that woody biomass can help replace up to 30 percent of petroleum consumption by the year 2030 (USFS 2010). Harvesting of forest products is also seen as a positive mechanism for improving overall forest health while


TVA windmills atop Buffalo Mountain-Michael Hodge

providing woody biomass for fuels (USDA 2014). Proper planning and utilization of these management practices in forests will be important for conserving terrestrial and freshwater habitats at both local and landscape scales

Wind

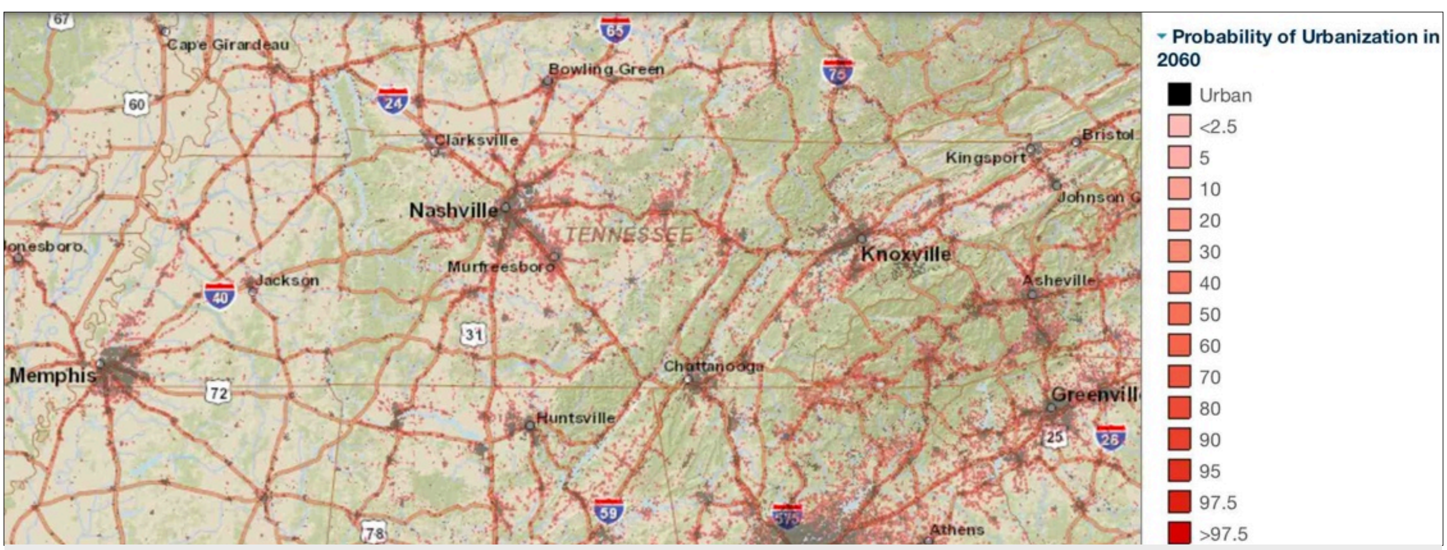
Improperly sited or operated wind turbines can directly affect native plant populations and wildlife, particularly birds and bats, especially during aerial migration at distinct geographic locations (Fiedler 2004, Nicholson et al. 2005). Negative effects can include direct mortality of animals, habitat loss, and habitat fragmentation. Birds and bats can be attracted to wind turbines by different lighting or operational features, and management attention to such features is warranted (Nicholson et al 2005). At present, wind production does not provide a significant portion of Tennessee's alternative energy portfolio. If facilities are to expand, considerations of cumulative impacts on population sizes and species ranges should be made (Fiedler 2004).

Hydropower

Finally, increasing the capacity of hydropower is believed to be a significant source of renewable energy across the U.S. (National Hydropower Association 2010). However, as previously discussed, dam construction and operations, including hydropower and other water management practices, have already significantly degraded natural river habitats in Tennessee. Alteration of existing dam structures to produce hydropower or the construction of new hydropower facilities must be considered in the context of these historic resource losses and with an eye to preventing further species and habitat declines (Grimm 2002).

4.3.6. Transportation and Service Corridors

Roads and other forms of transport, whether for people, utilities, energy, or goods, can directly impact habitats by damaging sensitive ecosystems, fragmenting habitat, and creating barriers to movement of both species



Projected development to the year 2060 (shown in red) clearly shows linear branch development along roads in Tennessee-SLEUTH Projected Urban Growth dataset, GCPO LCC Conservation Planning Atlas

Perched culvert, impassable to small aquatic organisms. - Sam Beebe

differences in local abundance and species richness could serve as indicators of problem barriers. Consideration of these problems can lead to better advance planning to avoid streams, improve engineering designs, and promote the use of less problematic materials (Warren and Pardew 1998, USDOT-FHA 2007). The USFWS, TWRA, and TDEC have begun looking at this issue in-depth, with the intention of working with state, county, and municipal departments during scheduled road maintenance to replace barriers with **passage-friendly culverts** and crossings across the Tennessee landscape.

and the natural flow of water in wetlands and riverine habitats. Transportation routes are responsible for linear branch development, and the construction of highways and roads can cause rapid outgrowth from urban cores. For these reasons they are commonly considered in forecasting urban sprawl (Bhatta 2010).

Improperly designed road crossings such as bridges and culverts can fragment stream habitats, cause erosion, prevent the migration of species throughout a watershed, and impact local abundance and species richness of fishes in a stream. For example, one study in West Virginia found that in stream sections located above impassable culverts, fewer than half the number of species and less than half the total fish abundance occurred when compared with sections upstream of passable culverts (Nislow et al. 2011). This suggests that simple monitoring protocols to detect

Small fish, such as the Chucky Madtom, can be affected by lack of connectivity and dredging. - Conservation Fisheries, Inc.

In river environments, dredging for navigational channel maintenance is a key issue, particularly on the Tennessee and Cumberland River mainstems. Dredging destroys or degrades river bottom habitats and bottom-dwelling species; it also stirs up sediment, affecting downstream habitats. For these reasons, both the U.S. Fish and Wildlife Service and TWRA have management oversight requirements relative to dredging, monitoring, and relocating species to protect them from channel dredging on a regular basis.

4.4. Habitat Management and Biological Resource Use Challenges

4.4.1. Fire suppression

Many of Tennessee's upland systems, as well as some types of wetlands, have been shaped and maintained by periodic fire – a process that was historically maintained to a large degree by Native Americans. Decades of fire suppression have degraded these systems and have changed the human perception of fire and its role on the landscape. Many species of wildlife depend on the plant communities that develop following a fire, in particular birds dependent upon grasslands and woodlands (EGCPJV 2014).

In the Great Smoky Mountains National Park (GSMNP) fire suppression has occurred over the past 60 to 70 years; this is exacerbated by the construction of homes and cabins in the vicinity of the park. Lack of fire leads to fuel buildups in the form of heavy accumulations of dead wood and brush. Under drought conditions, this fuel can contribute to catastrophic wildfires that are bad for people, their property, and natural forest systems (NPS 2015d).

Prescribed fire (the controlled application of fire in selected habitat areas) is a management practice that can directly address the problem of altered fire regimes. Prescribed fire reduces the risk of wildfire and costs much less than wildfire. However, prescribed fire is not widely and publicly recognized, embraced, or supported as a beneficial practice. (EGCPJV 2014, TNPFC 2015). In Tennessee, restoration of oak and pine savannas and woodlands, native grasslands, and high-quality early successional habitat requires fire, although the application, timing, and intensity of fire needed differs depending on the natural system (Harper and Birckhead 2012).

Prescribed fire as a management practice is more practical and less controversial in some areas versus others. For example, at Arnold Air Force Base in the Barrens region of Tennessee's Eastern Highland Rim, prescribed fire has been incorporated into the management regime to benefit natural communities while also accomplishing a highly complex military mission. The prescribed fires are

Prescribed burn at Catoosa Wildlife Management Area - Clarence Coffey, TWRA (retired) used to restore barrens habitat – Tennessee's prairie ecosystems – and to manage fuel loads in the Tennessee Army National Guard's weapons firing area as a means of preventing wildfire that interrupts training (DOD 2006).

4.4.2. Recreation

Tennessee's landscapes provide a wonderful array of recreational activities that contribute to the quality of life of both citizens and visitors, and which promote the state and local economies. Proper management of recreational activities in many situations


ATV, All Terrain Vehicle-Jassen

can be critical to promoting the protection of habitat and species, which in many cases are themselves one of the prime draws for visitors. A variety of recreational activities in natural area habitats can be detrimental, usually through the impacts of overuse.

One example is the growing concern that rock climbing, which has exploded in popularity in recent decades, could adversely affect the diversity of plant species that grow in specialized environments. The Obed River Gorge is a popular rock climbing destination, yet its vascular plants, bryophytes, and lichens make up one of the richest floras in the southeastern U.S. (Walker et al. 2009). Research on this topic indicated some impacts of foot traffic on vascular and non-vascular species, with a slight shift in lichen species composition on the cliff faces in response to climbing (Walker et al. 2009).

Another example is the importance of proper planning and management of horse riding trails. Studies have shown that damage to vegetation and stream water quality can occur when trails are not located properly, have maintenance issues, or are not properly followed by riders (Marion and Olive 2006). Good planning and maintenance can reduce potential damage and keep horse trails safe and enjoyable for the public.

The impacts of all-terrain vehicles (ATVs) and other recreational vehicles (RVs) can be significant in certain cases, but they are highly localized. TWRA allows restricted use on dedicated trails on some WMAs; however, the demand for trail access is growing. Without sufficient resources for signage and enforcement, this type of use in areas set aside for wildlife could pose a more significant threat. In addition, while most riders are responsible, as the number of riders coming from out-of-state is increasing, pressure on public and private lands will likely increase if greater density of use occurs.

Generally, people may not realize the extent to which ATVs and OHVs can damage the environment (TVA 2006). Mangled vegetation, destroyed wildlife habitats, severe soil erosion, and sedimentation of streams are the main impacts of ATVs and OHVs in sensitive or inappropriate areas, particularly when users blaze new trails; do not use designated stream crossings; or even ride within streambeds. The damage caused to wildlife and water quality by riding in streams has caused some states like Missouri and Georgia to outlaw the activity.

Eastern Box Turtle, a species that is sometimes taken from the wild as a pet. - Ezra Freelove

4.4.3. Overuse of Biological Resources

The collection of particular plant and animal species in different regions of the state must be monitored, and regulations enforced, to prevent overharvest and species population declines. Illegal poaching of desirable plants, particularly medicinal species, from both public and private lands is an issue in Tennessee.

According to the Tennessee Department of Environment and Conservation, ginseng is the number one poached plant (Lincicome 2015). This species has historically been used for medicine by Native Americans and is still valued for this purpose, particularly for use in Asian products. Goldenseal and orchids also are highly popular species.

The trade of ginseng and many other plant species is regulated under CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora. TDEC administers a licensing program to regulate and monitor the harvest and export of American ginseng from Tennessee, and collection of ginseng on the Cherokee National Forest requires a permit from the U.S. Forest Service.

In some cases, such as the collection of turtles as pets, the problem is part of a web of interrelated issues. For example, as development fragments habitat, Box Turtles near urban areas increasingly encounter humans, domestic pets, and automobiles -- all of which can lead to direct mortality, impacts to overall health, and removal of reproductive individuals from wild populations (Andrews et al. 2013). This is significant, as loss of adults can cause declines in turtle populations regardless of reproductive rates (Bowen et al. 2004).

4.5. Pathogens and Invasive/Exotic Species

4.5.1. Pathogens

Novel pathogens are a continuing and growing problem in Tennessee as well as other parts of the U.S. Emerging infectious diseases pose a growing threat to wildlife, yet appropriate actions to manage outbreaks before, during, and after invasion are only in the beginning stages. Researchers active in this field have proposed definitions for recognizable stages of pathogen invasion and means for control or treatment appropriate to each stage. However, one of the best means of addressing this threat will be prevention

Pathogen infection: Little Brown Bat with White-nose Syndrome - Dustin Thames, TWRA

at the federal level, through quarantine and trade restrictions on common vectors for the introduction of new pathogens (Langwig et al. 2015).

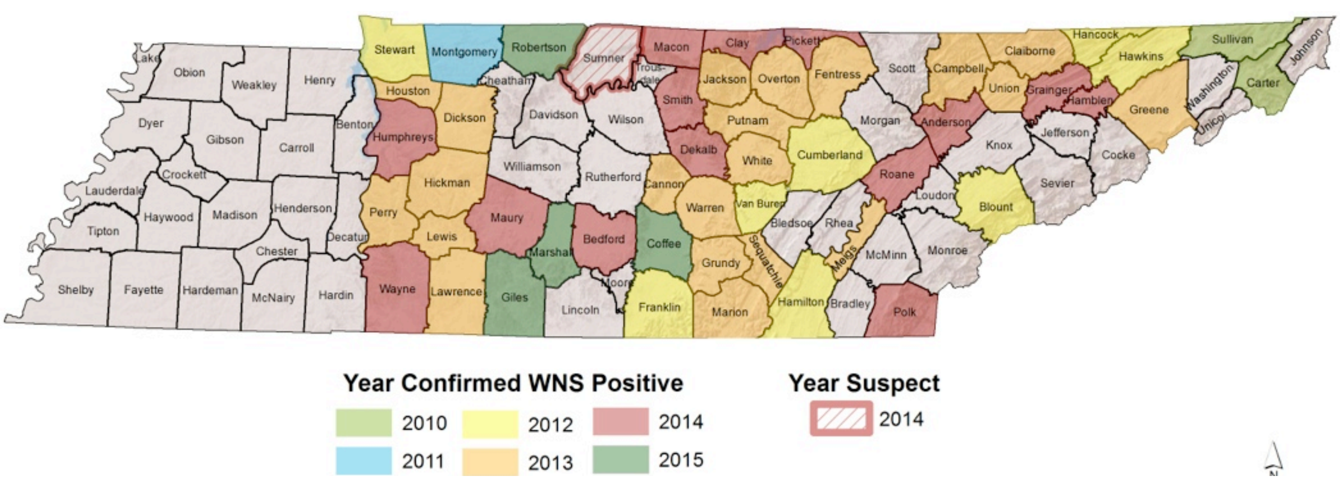
White-nose Syndrome

The challenge of White-nose Syndrome (WNS) in bats clearly illustrates how rapid, and devastating, pathogens can be. This disease had not even been considered a major problem in 2005, the date of first publication for State Wildlife Action Plans. WNS was first documented in New York in 2006-07 and has since spread across the eastern U.S. and Canada to more than 25 states and 5 Canadian provinces. TWRA confirmed the first case of WNS in Tennessee in February 2010.

Seven of the sixteen bat species that occur within Tennessee have been documented as having histologically confirmed cases. The syndrome is named for the characteristic white fungus (*Pseudogymnoascus destructans)* that causes white spots on the muzzle, ears, and wings of affected bats. Although it is not fully understood how WNS kills bats, the leading hypothesis is that infections arouse the bats during hibernation, causing them to exhaust their fat reserves prior to emergence in the spring. Essentially, they starve to death. Mortality rates differ among bat species (TNBWG 2014).

By 2014, WNS had killed more than 5.5 million bats in the U.S., and nothing has yet been effective in halting its spread. According to the Tennessee Bat Working Group, human transport of the fungus is probable, thus in 2009, the USFWS issued a cave advisory urging the closure of all caves and the implementation of a cave gear disinfection protocol to limit its spread between caves. In Tennessee, the National Park Service, The Nature Conservancy, Tennessee Wildlife Resources Agency, Tennessee Valley

Figure 4. Progress of White-nose Syndrome in Tennessee 2010 through 2015



Authority, Tennessee Department of Environment and Conservation, and the Tennessee Division of Forestry all had closed access to caves on their properties at the time (Lamb and Wyckoff 2010). Figure 4 shows the current distribution of WNS in Tennessee.

Chytrid Fungus

Another highly publicized threat is that of chytrid fungus (*Batrachochytrium dendrobatidis)* to amphibian species worldwide, including in Tennessee. Chytrid affects Hellbender salamanders (see Hellbender case study, Ch. 5). Both WNS and chytrid have caused mass mortality events and extinctions or extirpations in multiple species (Langwig et al. 2015).

Ranavirus

Ranaviruses are emerging pathogens of amphibians, reptiles, and fish, which have been associated with die-offs in the Americas, Europe, and Asia. With death rates often 90% or greater during an outbreak, as well as mounting evidence that some ranaviruses can be transmitted among all three of these vertebrate classes, these pathogens pose a substantial risk to Tennessee's biodiversity (Global Ranavirus Consortium, 2015).

Snake Fungal Disease

Snake fungal disease causes swelling, crusty scabs, or open wounds in snakes - Danny Bryan, Cumberland University

Another prime example of the pathogen threat is Snake Fungal Disease, an infection that has afflicted populations of snakes, primarily venomous species, from the northeast through the Midwest, and was recently discovered in Tennessee. This disease appears to be triggered by the fungus *Ophidiomyces ophiodiicola*, which is relatively new to science. At this time, it is not known whether this fungus has always been present in the environment, if it was introduced, or if perhaps it has recently mutated allowing it to cause more severe disease (NEPARC 2013). Researchers at University of Tennessee at Knoxville, Cumberland University, and Middle Tennessee State University have been working to document the spread of fungal infection in Timber rattlesnakes and other reptile species.

4.5.2. Invasive and Exotic Species

Invasive species, including both plants and animals, are a management concern across the state, along with the level of financial support and labor required to manage them. Invasive plants alter the composition, structure, and function of native ecosystems, while invasive animals can directly destroy habitat and reduce species populations through predation or competition. Intensive and extensive management is often required to prevent these undesirable ecosystem changes. Most invasive species are introduced non-natives (i.e. exotic), though not all.

Invasive and exotic plants

According to a survey and research conducted by the Tennessee Exotic Pest Plant Council, invasive plants cost the state of Tennessee at least $2.6 million annually. This figure only includes direct costs of control, mapping, and outreach. It does not include indirect costs associated with:

- ✦ Decreased agricultural yields;
- ✦ Lower property values;
- ✦ Diminished recreational opportunity; or
- ✦ Decreased diversity and wildlife habitat.

(TN-EPPC 2015).

While there are many invasive plant species in Tennessee, the following examples illustrate some of the current threats they pose:

✦*Lespedeza cuneata* and *Lespedeza bicolor* are particularly difficult to deal with when using fire as a management tool, as they are tolerant of fire and may even respond positively. These introduced species replace

Lespedeza bicolor - Miya.m Wikimedia

native vegetation, alter wildlife habitat, reduce diversity, and can limit restoration options because they can prevent grass growth and tree establishment. (USFS 2015a).

✦*Microstegium,* a grass species introduced from Asia, and *Ligustrum sinense*, or Chinese privet, are both insidious invasive species problems. Once established, they can be resource intensive to remove or control.

Tree of heaven, kudzu, and multiflora rose also are examples of species categorized as severe threats that spread easily into native plant communities, displacing native vegetation. Of growing concern are Callery pear trees invading natural habitats, particularly in Middle Tennessee. The seeds of the parent – the cultivated variety Bradford pear tree - are not sterile, and when distributed by birds and other wildlife revert back to the more aggressively growing Callery pear.

Invasive and exotic insects

A number of invasive insect pests threaten Tennessee forests annually. These include the following, all of which are introduced with the exception of pine beetles:

- ✦ Hemlock Woolly Adelgid
- ✦ Emerald Ash Borer
- ✦ Southern Pine Beetle
- ✦ Gypsy Moth
- ✦ Asian Longhorned Beetle

(TDF 2015)

HWA infestation on hemlock-Nicholas A. Tonelli

Beetles that prey on HWA-Chris Simpson, TWRA

Figure 5. Hemlock Wooly Adelgid rate of spread

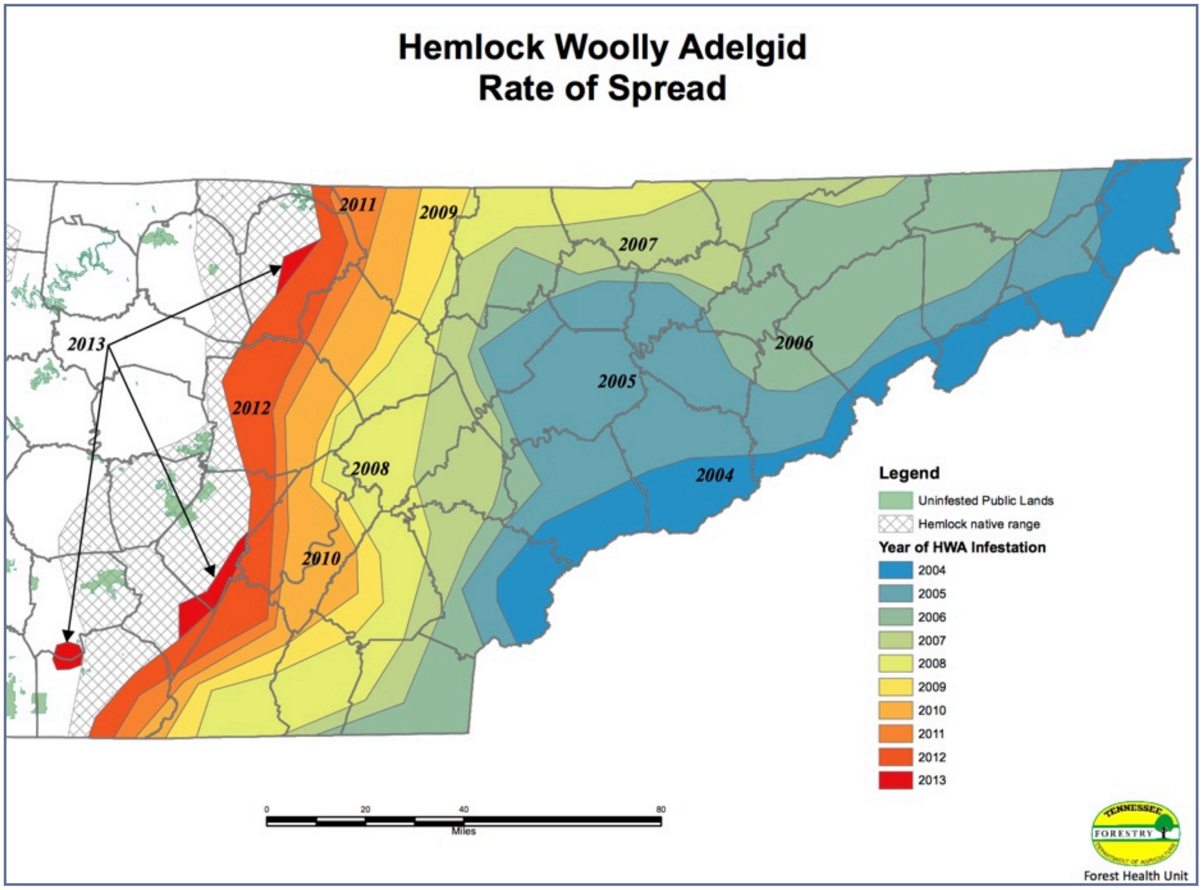
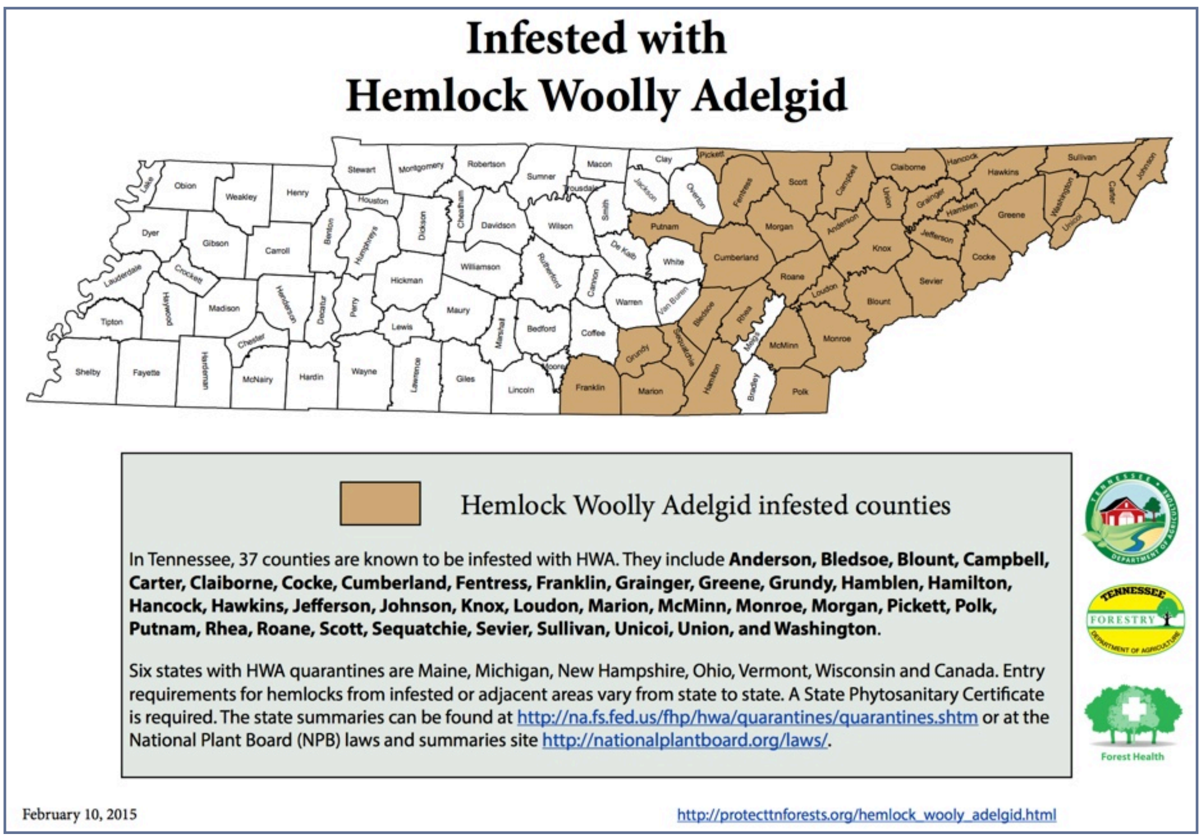


Figure 6. Tennessee Counties Infested with Hemlock Wooly Adelgid



The example of Hemlock Woolly Adelgid (HWA) serves to illustrate the issues surrounding invasive insects. Hemlocks are slow-growing, long-lived evergreens critical to the ecosystems in which they occur because they provide dense shade that helps to keep forest streams cool throughout the hot summer months. Since 2002, adelgids have been causing hemlock mortality, killing trees that are hundreds of years old in as little as three years. The HWA has caused extensive hemlock mortality in the Great Smoky Mountains National Park and the Cherokee National Forest. As of 2015, almost all counties in Tennessee with native hemlocks have these infestations (NPS 2015c) (See Figures 5 and 6).

While effective chemical treatments for these pests are available to individual landowners, they are cost prohibitive and impractical to address the problem on a landscape scale. Researchers and natural resource managers are working to find an effective mix of chemical and biological controls that can help protect some populations of hemlocks or slow down infestations (Wisby and Palmer 2015).

Invasive and exotic animals

Exotic animals pose similar problems to invasive plants and insects, and in addition they can directly impact native animal populations. Examples of current threats posed by exotic animals include:

✦Invasive crayfish are an issue in many areas of the state, as noted in the Tennessee Aquatic Nuisance Species (ANS) Management Plan (TANSTF 2008). Competition from both native crayfish (which are often transported across drainages in bait buckets and released into new areas of the state) and nonnative crayfish can displace or contribute to the decline of native species and overall diversity. Some species may hybridize with natives, and some also impact habitat through their burrowing activities or destruction of aquatic vegetation.

Crayfish burrow - Carl Williams, TWRA

Surgeon Crayfish - Carl Williams, TWRA

The non-native Kentucky Crayfish is invading Surgeon Crayfish habitat and negatively affecting their populations. - Carl Williams, TWRA

✦Silver Carp, also noted in Tennessee's ANS Plan, may be a problem for big river GCN species. Wild populations were probably originally the result of escape from aquaculture facilities or shipments mixed with grass carp. Silver carp compete for food with native plankton-eating species including Paddlefish, Bigmouth Buffalo, Gizzard Shad, the larval fishes of many species, and freshwater mussels. The noise of boat motors induce Silver Carp to leap out of the water, creating the potential for human injury or fatality. Commercial fishermen have abandoned fishing sites on the Missouri River due to the high numbers of Asian carp in their nets (TANSTF 2008).

✦Although Mosquitofish are widely introduced as mosquito control agents, according to the Tennessee ANS Plan, critical reviews of the literature do not support the view that they are very effective in reducing either mosquito populations or mosquito borne diseases. Depending on what they choose to eat, Mosquitofish introductions can lead to algal blooms or even cause an increase in mosquitoes. Mosquitofish are extremely aggressive and can affect native fishes through direct competition and often attack, kill, or eat other fishes. In Tennessee, they pose a threat to imperiled Barren's Topminnow (*Fundulus julisia*) populations in the few springheads where this species occurs (TANSTF 2008).

Damage caused by Wild Hogs, Bush Farm, Jefferson County - Scott Dykes, TWRA

✦Wild Hogs cause extensive damage to crops, wildlife habitat, and plant populations; contribute to erosion and water pollution; and carry diseases harmful to livestock and other animals as well as humans. Wild Hogs are prolific reproducers and do massive damage to the land through feeding and wallowing. They are also omnivorous, and will eat just about anything they can find. Wild Hog depredation can cause turkeys, ground-nesting birds, amphibians, and reptiles to suffer population decreases (Cox 2014). Wild Hogs also root up acres of land, including native plant populations, which requires significant time and money to repair. The damage that Wild Hogs cause has become more common and widespread, as they have gone from being present in 15 counties in 1992 (~16%) to nearly 84% of Tennessee's 95 counties in 2015.

4.6. Air Pollution

4.6.1. Acid Rain

Acid precipitation is caused by air pollution, primarily nitrogen oxides and sulfur dioxide from the burning of fossil fuels for electricity production and, to a lesser degree, nitrogen oxides in automobile exhaust. These chemicals react in the atmosphere to form nitric and sulfuric acids, which fall to earth as both wet and dry deposition (EPA 2012).

Decades of research have made it clear that acid rain causes slower growth, injury, or death of forests by:

- damaging leaves
- limiting the nutrients available to plants
- exposing plants to toxic substances that are slowly released from the soil.

(EPA 2012, USFS 2013)

Acid rain has contributed to forest and soil degradation in many areas of the eastern U.S., particularly high elevation forests of the Appalachian Mountains that include areas such as the Great Smoky Mountains National Park (EPA 2012). Acid rain, coupled with other problems such as invasive exotic species, pathogens, and climate change, has decimated Tennessee's high elevation spruce-fir forest. These forests provide important habitat for several rare and endangered species, such as the Spruce-fir Moss Spider (Gunnarsson and Johnson 1989, TWRA 2005).

Red Salamander (left) and Mud Salamander (right): amphibian and aquatic species are especially sensitive to acid precipitation. - Chris Simpson, TWRA

The effects of acid deposition in aquatic systems are no less severe. It causes a cascade of effects that harm or kill individual fish, reduce populations, extirpate fish species from a waterbody, and decrease biodiversity. In watersheds where soils do not have a buffering capacity, acid rain releases aluminum from the ground into lakes and streams, thus as acidity in a lake or stream increases, so does aluminum. Both increased acidity and aluminum are toxic to fish (EPA 2012).

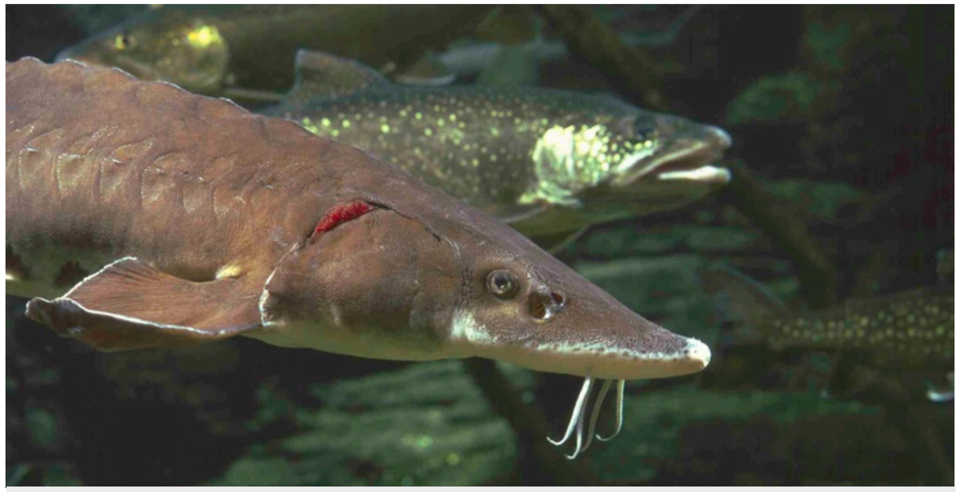
According to TDEC, 41 miles of streams in Great Smoky Mountains National Park have very low pH (i.e. are very acidic). While all streams in the park are more acidic than they were 20 years ago, air quality is improving. Acidic streams are suspected to be the main cause for the decline of the native brook trout population in the park (NPS 2015a).

4.6.2. Ozone Pollution

Ground level ozone pollution (as opposed to the protective stratospheric layer) is a problem in GSMNP and other regions of the state, and it derives from sources similar to those that create acid rain. Ozone exposure levels on park ridge tops are up to twice as high as those in Knoxville and Atlanta. These levels are sufficient not only to injure trees and plants, but also to threaten human health. Research has found that the following plants show signs of ozone damage in GSMNP: black cherry, milkweed, tuliptree, sassafras, winged sumac, blackberry, and cutleaf coneflower (NPS 2015b).

Auto exhaust contributes to ozone pollution - “biofriendly”

4.6.3. Mercury



Concentration of toxins through biomagnification is most likely to occur in large long-lived fish, such as Lake Sturgeon, which can affect fish development and pose a threat to people who consume them. - Todd Stailey, Tennessee Aquarium

Fish sampling surveys in the U.S. have shown widespread mercury contamination in streams, wetlands, reservoirs, and lakes, with 33 states -- including Tennessee -- having issued fish consumption advisories due to mercury contamination. Mercury is second only to PCBs as a pollutant impairing Tennessee ponds and lakes (TDEC 2012/EPA 2015). According to the USGS, the continental to global scale of mercury contamination is due to widespread air pollution (USGS 1997).

Levels of mercury measured in air and surface water are low. Nevertheless, they pose a threat because living organisms do not quickly excrete mercury, and it undergoes both bioaccumulation and biomagnification.

Bioaccumulation is the process by which organisms (including humans) can take up contaminants more rapidly than their bodies can eliminate them, causing mercury levels in their bodies to accumulate over time. Biomagnification is the buildup of contaminants through the food chain.

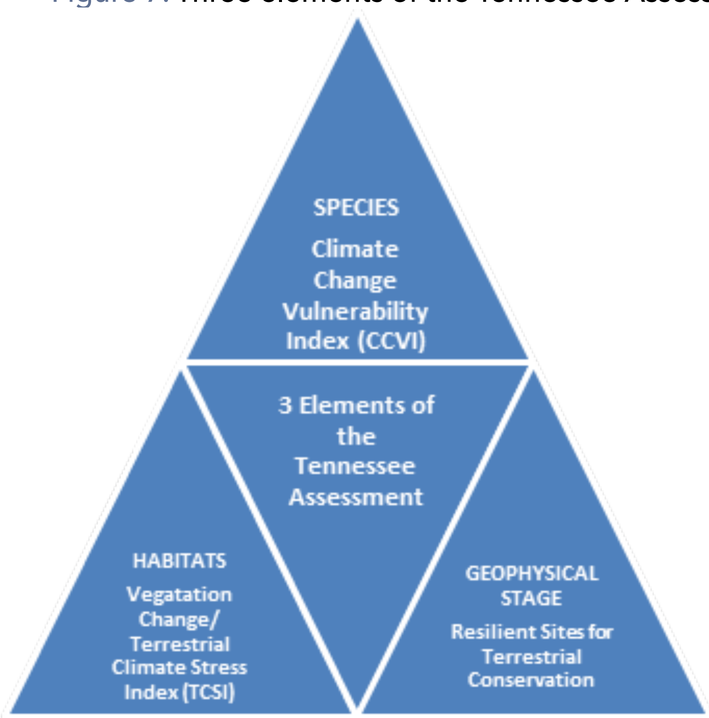
Coal-burning power plants are the largest human-caused source of mercury emissions to the air in the U.S., accounting for over 50 percent of domestically generated emissions; however, less than half of all mercury deposition within the country comes from U.S. sources (EPA 2014b).

4.7. Climate Change Vulnerabilities

The primary emphasis of Tennessee's updated climate vulnerability assessment was to use a multi-faceted approach and examine three major aspects of climate change impacts: species vulnerabilities, terrestrial and aquatic habitat changes, and landscape resiliency. Figure 7 summarizes these three major elements: assessment of *species* vulnerability using NatureServe's **Climate Change Vulnerability Index** (CCVI) (Young et al. 2011); assessment of terrestrial *habitat* vulnerability to climate stress including vegetation change; and evaluation of relative landscape resilience based on *geophysical settings* (Anderson et al 2014.) The focus on these elements together is intended to provide managers with a more comprehensive picture of climate change vulnerability by incorporating factors relevant to both species and habitats. The three-element approach is adapted from ideas piloted by the North Atlantic Landscape Conservation Cooperative for the Connecticut River watershed (NALCC 2014).

Details of the technical methods used in the assessment and results are provided in a 2015 SWAP companion report, *Climate Change Vulnerability Assessment for Tennessee Wildlife and Habitats* (Glick et al. 2015). The text and maps in the following sections are excerpted from this companion report to serve as a general overview of the results and application of the assessment work for informing further prioritization and strategy development during the 2015 SWAP update.

Figure 7. Three elements of the Tennessee Assessment



4.7.1. Species and Habitat Vulnerability Summaries

State fish and wildlife experts used NatureServe's **Climate Change Vulnerability Index** (CCVI) (Young et al. 2011) to assess a total of 189 GCN plant and animal species, including 15 mammals, 51 birds, 17 reptiles, 26 amphibians, 19 fish, 27 freshwater mussels, 8 crayfish, and 26 plants. Sixty-three percent (119) of the 189 species assessed scored as "Presumed Stable" or "Increase Likely," and 37% (70 species) were considered at least Moderately Vulnerable (see Glick et al. 2015 for detailed species scores).

Mammals, birds, and reptiles comprise most of the species ranked as Presumed Stable or Increase Likely due, in part, to their mobility and

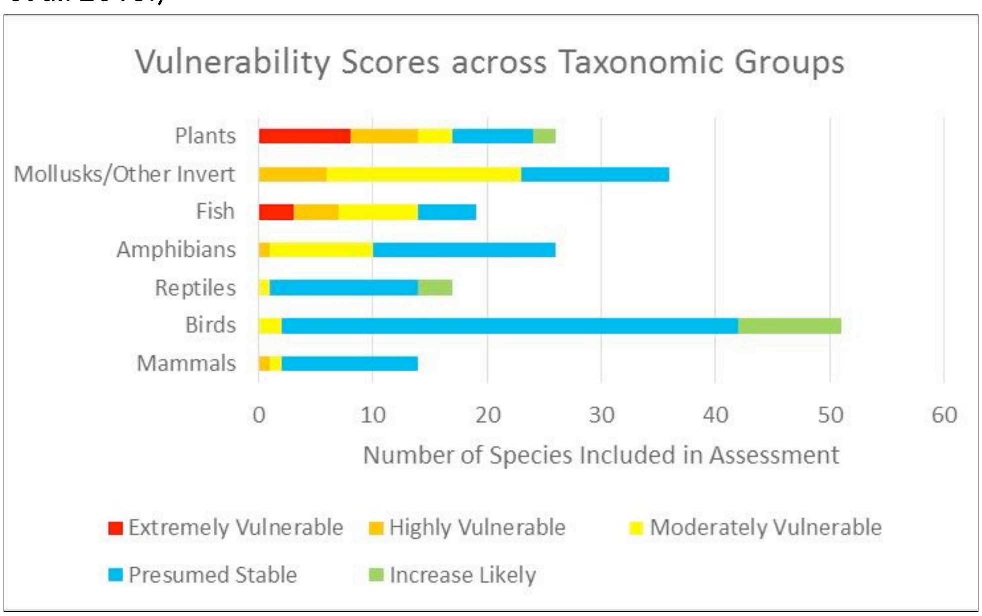
Brook Trout are coldwater species in Tennessee that may be impacted by warming waters. - Dave Herasimtschuk, Freshwaters Illustrated

other factors that enhance their adaptive capacity. Plants, fish, and mussels comprised the greatest number of species that ranked as Moderately, Highly, or Extremely Vulnerable for a variety of reasons, including the presence of natural and anthropogenic barriers to dispersal, restricted habitat range, and high levels of sensitivity to changes in temperature and moisture. Figure 8 provides a comparison of the CCVI vulnerability scores summarized across taxonomic groups. For more specific information on the scoring process and results, see Glick et al. 2015.

Some of the most significant impacts of climate change on Tennessee's fish and wildlife species will be associated with potential changes to their habitats. Notable impacts include the following:

✦Changes in the composition of plant communities in both forest and grassland systems, particularly in the western portion of the state;
✦An increase in the frequency and severity of disturbances such as wildfires and outbreaks of already-problematic species such as Southern Pine Beetle (*Dendroctonus frontalis*) and Hemlock Wooly Adelgid (*Adelges tsugae*);
✦Shifts in the location and extent of suitable habitat for fish and other aquatic species due to higher water temperatures and altered water quality, with areas of coldwater habitat in mountain streams likely to decline and warmwater habitat projected to expand;
✦Changes in the timing and magnitude of streamflows and other hydrological conditions, including increased drying of ephemeral pools important to amphibians and other

Figure 8. **Comparison of CCVI vulnerability scores across taxonomic groups. (For more specifics on the scoring process and results, see Glick et al. 2015.)**



wildlife. Appendix F provides a summary factsheet of potential climate change impacts and strategies for Tennessee.

Given the complexities and uncertainties in climate projections and associated impacts, the general challenge for managers may be to consider how to transition Tennessee from its current mix of terrestrial habitats to a different mix without losing biodiversity (Joyce et al. 2008). The state's upland forest systems, for instance, support a great diversity of wildlife due in part to the variety of different habitats and niches found within a structurally diverse forest system (TWRA 2014). Managing for a diversity of habitat types, even if the composition of associated vegetation changes, may still support desired conditions for valued fish and wildlife.

With many of Tennessee's highly diverse aquatic species already considered at-risk for a variety of reasons, the additional threat from climate change is likely to exacerbate conservation concerns (TWRA 2009). Indeed, it is the combination of climate change and other stressors such as polluted runoff and barriers to stream connectivity that will have the greatest impact on aquatic habitats and the species that depend on them (Sun et al. 2013). An integrated approach to managing aquatic species and habitats that takes into account multiple stressors, including climate change, will be important to help the state meet its short- and long-term wildlife conservation goals.

Fish kill associated with drought in September 2012 on the Chickasaw National Wildlife Refuge - USFWS

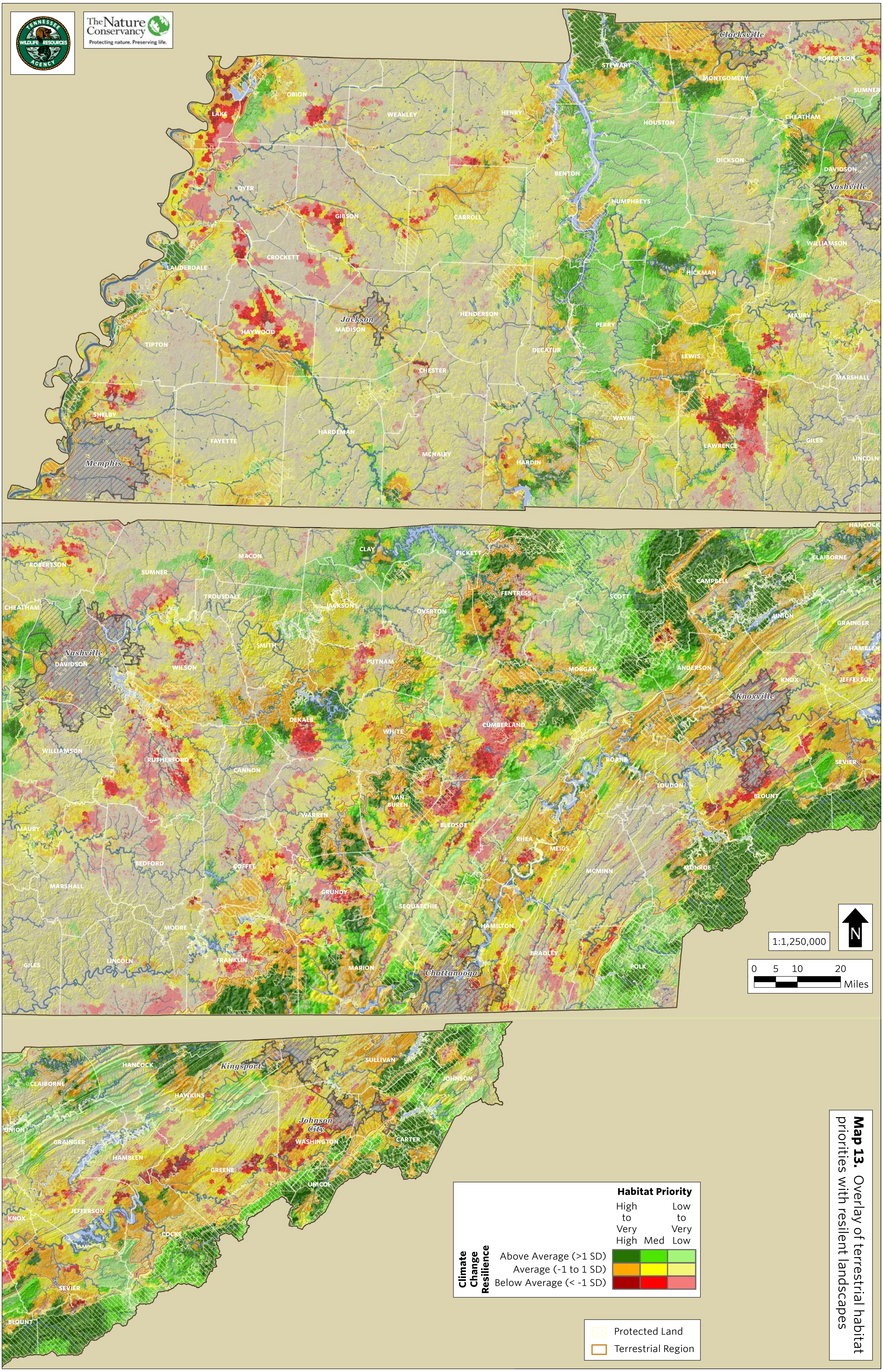
4.7.2. Spatial Vulnerability Assessment Maps

Tennessee's vulnerability assessment also includes a spatial analysis of climate change vulnerability across terrestrial habitats to help inform a landscape level understanding of potential issues across the state. The landscape vulnerability assessment draws from the approaches used by Joyce et al. (2008), Kershner and Mielbrecht (2012), and Anderson et al. (2014), with a focus on terrestrial habitat priorities updated by the 2015 SWAP (Glick et al. 2015). Several existing datasets and maps from these approaches are synthesized in the assessment, including:

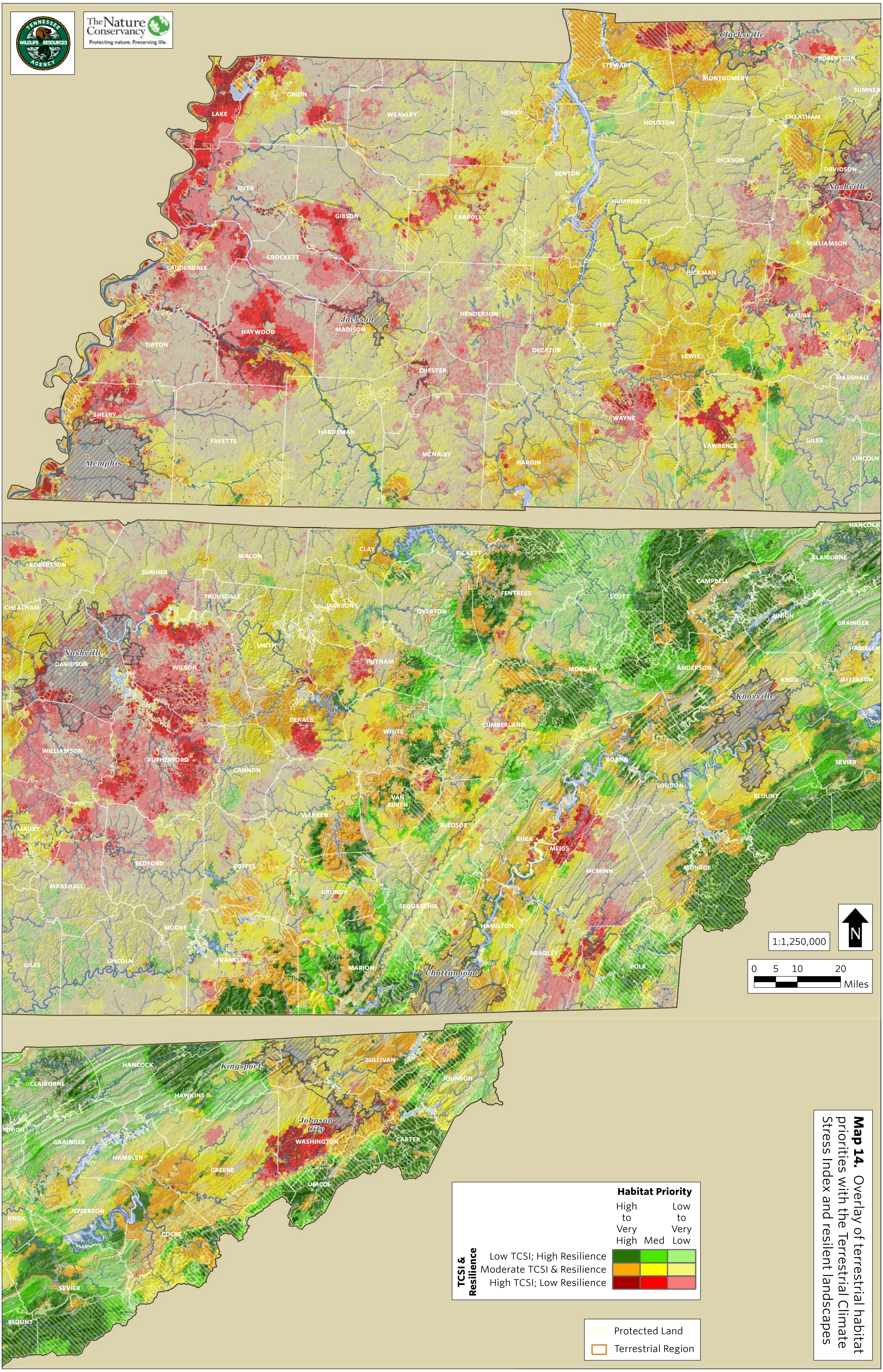
- Terrestrial GCN Habitat Priority areas in Tennessee;
- Potential vegetation change using a Terrestrial Climate Stress Index; and
- Resilient Sites for Terrestrial Conservation in Tennessee.

Two of the statewide vulnerability maps are provided below to illustrate the interplay between species, habitat, and resiliency in assessing climate vulnerability.

Map 13 shows an overlay of the landscape resilience to climate change scores and



Map 13. Overlay of terrestrial habitat priorities with resilient landscapes



Map 14. Overlay of terrestrial habitat priorities with the Terrestrial Climate Stress Index and resilient landscapes

the terrestrial habitat priority areas for Tennessee. Recall that both map inputs are stratified by ecoregion, meaning that sites within each ecoregion are compared only to other sites within the same ecoregion. Areas highlighted in darker green are high habitat priorities that coincide with relatively high landscape resiliency scores. Areas in yellow to light orange are high priority habitats within average locations of average landscape resiliency. Areas in darker red indicate places of high habitat priority but less than average resilience (i.e., higher potential climate change vulnerability). There are a number of areas across Tennessee that are identified as both high habitat priorities and resilient sites (the darkest green), which suggests that those particular resilient sites are likely to be important areas to maintain for biodiversity.

Map 14 combines information on the SWAP terrestrial habitat priorities with both landscape resilience and the terrestrial climate stress index (which incorporates potential vegetation change).

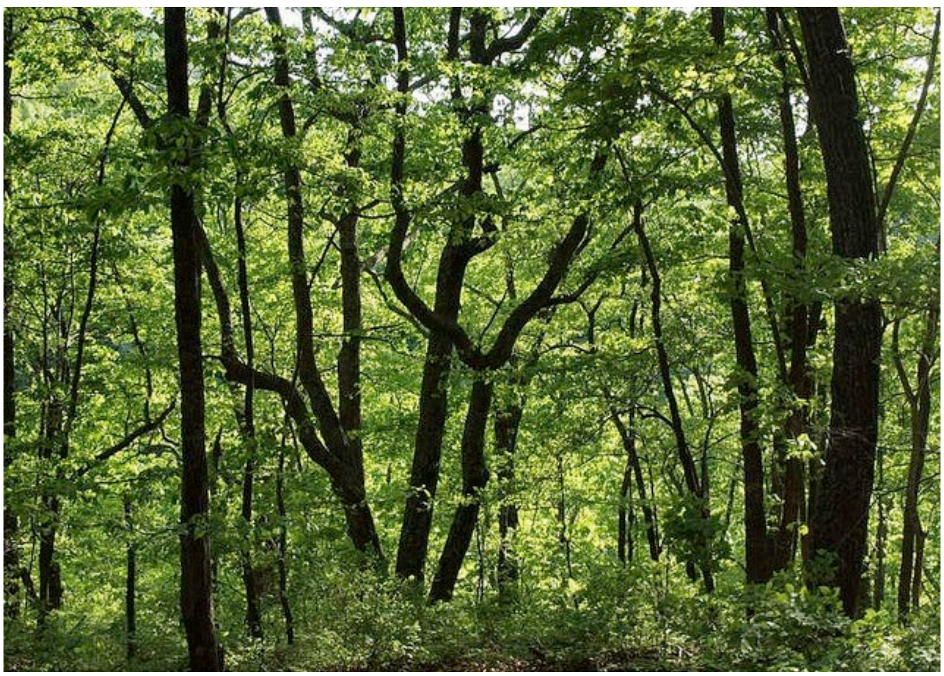
Examining these data collectively makes it possible to identify those places of high habitat importance for terrestrial GCN species in 2015 that are in locations of comparatively low landscape resilience and facing higher climate stress, indicating overall vegetation types within those areas also may be changing.

Mississippi Alluvial Plain habitats may be vulnerable to climate change. - Rob Colvin, TWRA

In Map 14, the darker green areas are current (2015) high priority habitats for terrestrial species and are also showing higher degrees of overall resilience to potential climate stressors including vegetation change. The darker red areas are also current (2015) high priority habitats, but those which are showing greater vulnerability to climate change due to lower landscape resilience and higher potential for major vegetation changes.

While there is a fair amount of complexity in results across the state depending on the various factors considered, current habitat priority areas in certain regions -- such as the Mississippi Alluvial Plain, Upper East Gulf Coastal Plain, and the Nashville Basin subregion of the Interior Low Plateau -- appear especially vulnerable to climate change compared to other areas, such as the Cumberland Plateau and Mountains and portions of the Southern Blue Ridge (Map 14).

Management strategies for these areas will need to take into consideration the potential for dominant vegetation type changes as well as the lower capacity of the surrounding landscapes to provide niche refugia or connectivity to other areas with natural vegetation cover.



Forest of the Cumberland Plateau: relatively intact natural vegetation cover is one characteristic of these forests, which appear promising as habitat refugia. - Hunter Desportes

Places that are identified as resilient and face relatively low terrestrial climate stress, such as the forests of the Cumberland and Smoky Mountains, appear especially promising as habitat refugia. These eastern Tennessee landscapes have more complex topography and geology, more intact natural vegetation cover, and are less likely to experience major vegetation type shifts. Other areas, including the Western Highland Rim forests of the Interior Low Plateau in middle Tennessee and some higher elevation sections of the Southern Blue Ridge, are identified as resilient from a landscape feature perspective, but face higher terrestrial climate-stress.

The Terrestrial Climate Stress Index (TCSI) rating identifies those areas more likely to undergo changes in terrestrial vegetation types. Also, the species CCVI results indicate that certain individual species may be vulnerable regardless of the potential for overall stability in their current surrounding landscapes. Therefore, management strategies for sites otherwise in resilient landscape settings will have to consider the potential trajectory of overall vegetation change as well as potential stresses on individual species of concern.

Climate change does not occur in a vacuum but rather acts synergistically with many other factors affecting Tennessee's GCN species. In some cases, climate change may not pose a major risk for a species, but that does not necessarily mean that the species is not otherwise imperiled. For example, a species assessed as Presumed Stable under the CCVI may still be impacted by other stressors unrelated to climate change, such as overharvest. Ultimately, managers will need to consider the broad context of conditions in which species and associated habitats exist, both now and in the future, in order to develop effective conservation strategies.