National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Natchez Trace Parkway

Natural Resource Report NPS/NATR/NRR—2014/843

ON THE COVER
Lyreleaf sage blooms along the Natchez Trace Parkway
Photograph by: Marc Muench

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This report received formal peer review. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

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Executive Summary

This report provides an assessment of the condition of key natural resources at the Natchez Trace Parkway (NATR or Parkway). It discusses stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Gulf Coast Monitoring Network (GULN), and on other attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air quality, weather and climate, water quality, terrestrial vegetation, forest pests, animal communities, and landscape dynamics.

Data used in the assessment included NPS Inventory & Monitoring Program (I&M) reports and bio-inventories, spatial datasets, park-commissioned reports, unpublished park data, publicly-available data sets of various types, peer-reviewed publications, and personal communication with NATR and GULN staff. No new field data were collected for this report. When appropriate, data gaps and opportunities for improved data collection are identified.

The Natchez Trace Parkway corridor traverses numerous habitat types from the Mississippi River loess bluffs to the foothills of the southern Appalachian Mountains. It crosses or borders 16 watersheds (U S. Geological Survey 8-digit Hydrologic Units, HUCs). These systems flow into the Cumberland, Tennessee, and Mississippi Rivers, or directly into the Gulf of Mexico. The park includes long segments of three U.S. Environmental Protection Agency (EPA) Level III Ecoregions and segments of 12 physiographic regions. The Parkway is effectively a long transect representing many of the natural resources unique to the eastern interior Gulf of Mexico coastal plain.

The Parkway supports a rich diversity of plant and animal species. Approximately 1350 plant taxa have been found, including seven current federally threatened or endangered species (2 mussels, 1 fish, 1 butterfly, 1 bat, and 1 turtle, and the Louisiana black bear). The federally threatened Price's potato bean (*Apios priceana*) is suspected in the park, as are at least 65 plant species considered imperiled or critically imperiled at the state or province scale. Many of NATR's sensitive plant species are found in prairie and grassland habitats which occur throughout the park. Primary forest associations in the northern Parkway include white oak, oak, and pine-oak communities. Primary forest associations in the south and central park include oak, sweetgum, and pine-cedar communities. A great diversity of vertebrate animals is found in the park. The most recent fish inventory reported 92 species. Actual fish richness is probably significantly greater, with a maximum potential of over 170 species. A 1999-2000 bird inventory reported 134 species from the park, although, as with fishes, the actual richness is certainly greater. Two herpetofauna inventories (1999-2000 & 2011-2012) collectively reported 69 species of reptiles and amphibians. Anecdotal reports and other unpublished data suggest the actual richness is significantly greater with a maximum potential richness of around 100 species.

This report identifies and discusses threats or potential threats to natural resources. These include:

Decreased air quality—Observed ozone concentrations were in the range of moderate concern for human health. However, ozone levels appear to be declining in the region.

Impaired water quality—The Parkway crosses many streams and waterways. Water quality varies within the park, and some streams and watersheds were negatively impacted by anthropogenic activities. High bacterial levels were the most common stressors observed in the park, though low pH and low oxygen were also problems in some waterways.

Exotic plants—As non-native species of plants invade areas along the Parkway, native plants and wildlife habitat can be negatively impacted. Invasive exotic plants are common in the park, and one of the most important threats to NATR natural resources. Management of these plant pests is an ongoing issue at the Parkway.

Forest Pests—Forest pests and diseases occur along the Natchez Trace Parkway, although evidence suggests they are a relatively minor stressor. Dogwood anthracnose (*Discula destructive*), and fusiform rust (*Cronartium quercuum*) have been reported, although the effects of these diseases have apparently been negligible. Areas of the park are a relatively high risk from southern pine beetle (*Dendroctonus frontalis*) outbreaks. While the incidence of this pest in NATR is not known exactly, NATR staff estimate less than 12 areas with less than 20 trees per location, based on surveys to date.

Non-native wildlife—Non-native animals may alter habitat, compete with native species, or prey directly upon native species. In this report, non-native vertebrate animals were defined to include species or strains intentionally or accidentally introduced outside their native ranges by humans, and species spontaneously expanding their distributions to include areas never previously occupied. Non-native vertebrates were relatively rare in NATR inventory data. No herpetofaunal species, one fish, and six birds were considered non-native, and only the Brown-headed Cowbird (*Molothrus ater*) was relatively common. Feral hogs (*Sus scrofa*) occur in the park and are discussed below.

Wildlife Damage – Non-native or native animals can negatively impact natural areas, human infrastructure or agriculture, or human health and safety. On the Parkway, feral hogs and beaver (*Castor canadensis*) are known to cause these types of damage. Management plans and protocols exist for both species, and park staff actively work to mitigate negative impacts from these species.

Landscape change – An expansive category including negative impacts from development, human population increases, agricultural land uses, and habitat alteration and fragmentation. The Natchez Trace Parkway is especially vulnerable because it has a long linear configuration, with little interior area to protect from adjacent development influences.

Ten natural resource attributes were discussed and assessed for this report. Assessed attributes were within four broad categories: air and climate (two attributes), water quality (one attribute), biological integrity (six attributes), and landscape (one attribute). Several attributes were and assigned condition ranks for multiple reporting areas within the park. These included water quality (13 reporting areas), fish assemblages (13 reporting areas), bird assemblages (two reporting areas), and herpetofauna assemblages (two reporting areas). Other attributes were assessed and assigned conditions at the park level. Data quality was assessed by reporting area for fish, bird, and herpetofauna assemblages, and at the park scale for all other attributes. Trend was assigned to a few attributes for which sufficient data existed, and was assigned at the park scale in all cases, with the exception of a single water quality reporting area. To include multi-reporting area attribute conditions in a park-wide summary, the proportion of each reporting area within each condition rank was added to the appropriate category. For the entire park 26% of the attributes were ranked as good, 45% were ranked as fair, 4% were ranked as poor, and 25% were not assigned a rank. The assigned trend was improving for 11%, declining for 20%, and not determined for 69% of the attributes. Data quality was very good for 30%, good for 35%, fair for 13%, and marginal for 22% of the assessed attributes.

Acknowledgements

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Acronyms and Abbreviations

ANC – Acid Neutralizing Capacity
ARD – Air Resources Division (NPS)
BBS – Breeding Bird Survey
BLM – Bureau of Land Management
BOD – Biochemical Oxygen Demand
COOP - Cooperative Observer Program
CRI – Conservation Risk Index
DO – Dissolved Oxygen
EMF – Ecological Monitoring Framework
ENSO – El Nino Southern Oscillation
EPA – Environmental Protection Agency
FAQ – Fish and aquatic life
FAW – Fish and wildlife
FHTET – Forest Health Technology Enterprise Team
GAP – Gap Analysis Program
GIS – Geographic information system
GPMP – Gaseous Pollutant Monitoring Program
GULN – Gulf Coast Inventory and Monitoring Network
HUC – Hydrologic Unit Code
IBI – Index of Biotic Integrity
I&M – Inventory and Monitoring
IRR – Irrigation
IUCN – International Union for Conservation of Nature
LWW – Livestock watering and wildlife
MRLC – Multi-Resolution Land Characteristics Consortium
MDEQ – Mississippi Department of Environment Quality
MSPA – Morphological Spatial Pattern Analysis
NAAQS – National Ambient Air Quality Standards
NATC – Natchez National Historical Park
NATR – Natchez Trace Parkway
NLCD – National Landcover Dataset
NPS - National Park Service
NRCA – Natural Resource Condition Assessment
NRCS – Natural Resource Conservation Service
NTU – Nephelometric Turbidity Unit
PAD – Protected Areas Database
PIF – Partners in Flight
POMS – Portable Ozone Monitoring Station
RAWS – Remote Automated Weather Station
REC – Recreation
SEEPPC – Southeast Exotic Pest Plant Council
UGA – University of Georgia
USGS – United States Geological Survey

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…
Credible condition reporting for a subset of important park natural resources and indicators
Useful condition summaries by broader resource categories or topics, and by park areas

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources

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[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decisionmaking, planning, and partnership activities.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation and Park Significance

Natchez Trace Parkway (NATR or Parkway) was established in 1938 to commemorate the historical path used by Choctaw and Chickasaw Native Americans and later Europeans for trade and travel predominantly during the period 1790 to 1820 (Figure 1). This path contributed to development of the American Old Southwest bordered by the Mississippi River. The Trace received its heaviest use by traders, known as "Kaintucks", from the Ohio River Valley region who floated the Mississippi River to major trade areas in New Orleans and Natchez, MS, then returned north via The Trace. The route includes a memorial to Meriwether Lewis, who, following his trans-continental exploration with William Clark, died while traveling the Natchez Trace en route to Washington. Many other points of interest are found along the Parkway, including prehistoric mound sites, cemeteries, Native American villages, historic structures and other archeological sites (NPS 2012a). Construction of the Parkway, which begins in Natchez, MS and stretches for 715 km (444 miles) northeast to Nashville, TN, was completed in 2005.

Figure 1. The Natchez Trace Parkway follows closely the route of the original Trace path, which is visible in several locations (NPS 2012). [Photo courtesy of National Park Service]

2.1.2 Geographic Setting

Natchez Trace Parkway passes by or through several major urban areas along its route, including Jackson and Tupelo, MS, Florence, AL, and Nashville, TN (Figure 2). The Parkway boundary encompasses about 18,524 ha (45,774 acres), much of which is managed as undisturbed forest and open area. The average width of the Parkway land is 250 m (825 ft), though it varies, with notable exceptions being Meriwether Lewis, Rocky Springs, and Jeff Busby where there are campgrounds that cover a few hundred acres. It ranges in elevation from 21 m (70 ft) to 335 m (1,100 ft) while crossing four ecoregions as defined by The Nature Conservancy (Olson and Dinerstein 2002); it's upper ~25% falling primarily in the Interior Low Plateau, and its lower ~75% located primarily in the Upper East Gulf Coastal Plain. It briefly passes through the Cumberlands and Southern Ridge and Valley in the north, and also the East Gulf Coastal Plain in the south.

Figure 2. Natchez Trace Parkway passes through Mississippi, Alabama, and Tennessee. Following roughly the path of The Old Trace, it stretches for 715 km (444 miles), starting in Natchez, MS and ending in Nashville, TN.

2.1.3 Visitation Statistics

Data for annual number of visitors at NATR is available starting in 1953 (Figure 3). Visitation rose steadily until 1986, at which point it decreased and remained approximately at an annual mean of 6,000,000 visitors (NPS 2012a). While the reason for the decline is not known from available references, we speculate that because of the phased completion of the Parkway from 1938-2005, the location and methods for monitoring may have changed and affected counts of visitors. In 2012, NATR ranked 7 on the "top 10" list of most visited NPS units, attracting an estimated 5,560,668 recreational visitors.

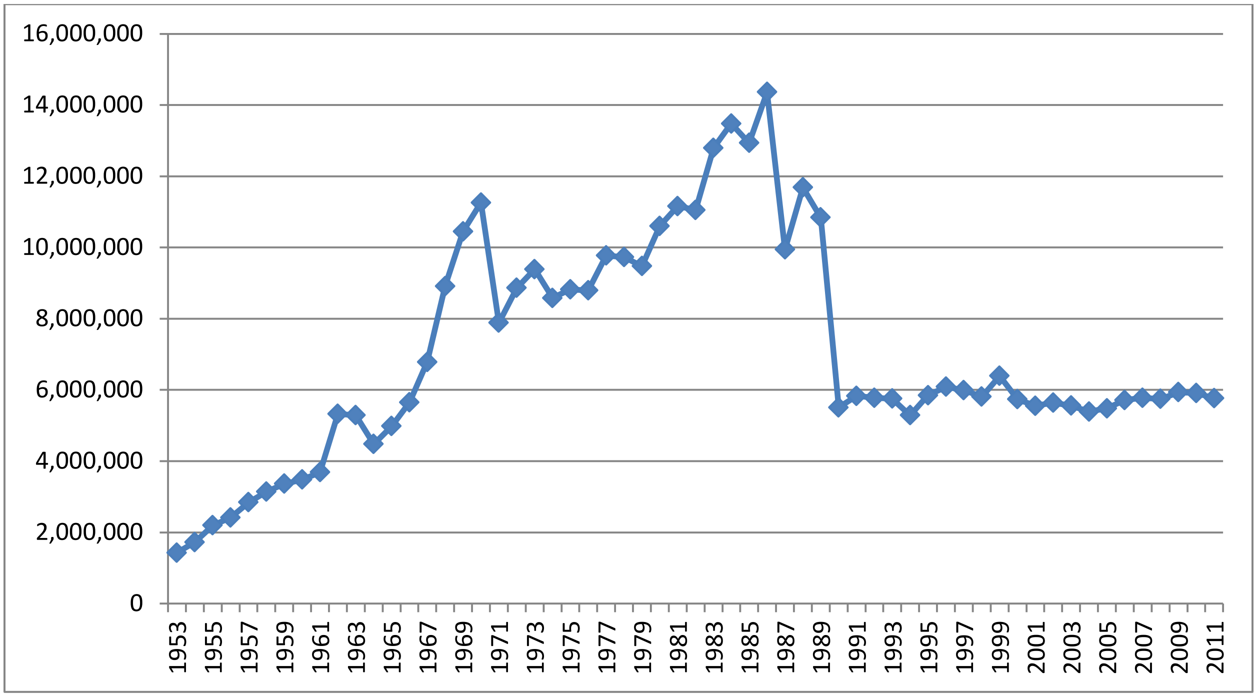

Figure 3. Annual visitation at NATR from 1953 to 2011.

2.2 Natural Resources

2.2.1 Soils and Geology

Terrain elevation along the parkway ranges from 21 m to 335 m, and the park covers over 50 main soil associations. The most common is the Natchez-Memphis association, which covers roughly 1,920 ha in the southern portion of the parkway. These soils are typically loess uplands with loose silty texture, and as a result are highly susceptible to erosion. Almost as predominant is the Sulphura-Dellrose-Bodine association covering 1,900 ha in the northern section of the parkway. These soils are typical of dissected uplands and can cover a range of slopes. They are derived from siltstone, limestone, chert, and shale, and may be found on uplands, hillsides, or footslopes. The next three most common soil associations are Mountview-Dickson-Baxter, Smithdale-Providence, and Memphis-Loring, which together comprise 3070 ha along the parkway. The remaining ~45 soil associations along the parkway represent about two-thirds of the area, with an average of 225 ha per association (NRCS 2012).

The southern section of the Parkway in AL and MS consists of soils derived from the Eutaw and Tuscaloosa geologic formations, which provide the underlying parent material that eventually weathers to surficial soil associations. Many of the mineral resources found in this region are commercially valuable, including limestone and sandstone deposits. The northern Tennessee section of the Parkway passes through the Highland Rim section surrounding Nashville, TN. This area has variable topography and consists mainly of Fort Payne chert overlying limestone formations. Much of the limestone in this region is mined for building material (Mangi Environmental Group 2008).

2.2.2 Hydrology

Natchez Trace Parkway crosses over four major hydrologic regions and six subregions (Figure 4). Around 1,300 flows of various sizes enter the park, and include major crossings such as Big Black River, Chuquatonchee Creek, Chiwapa Creek, the Tennessee River, and the Duck River. Because much of the watershed areas are located upstream of the Parkway, park streams are highly affected by runoff and land use occurring outside park boundaries. In addition, 26 streams listed as state 303(d) impaired waters cross the Parkway, many of which cross more than once. According to the U.S. Fish and Wildlife Service (USFWS), there are approximately 1,110 ha (2,750 acres) of wetlands within NATR, most of which is forested (Mangi Environmental Group 2008).

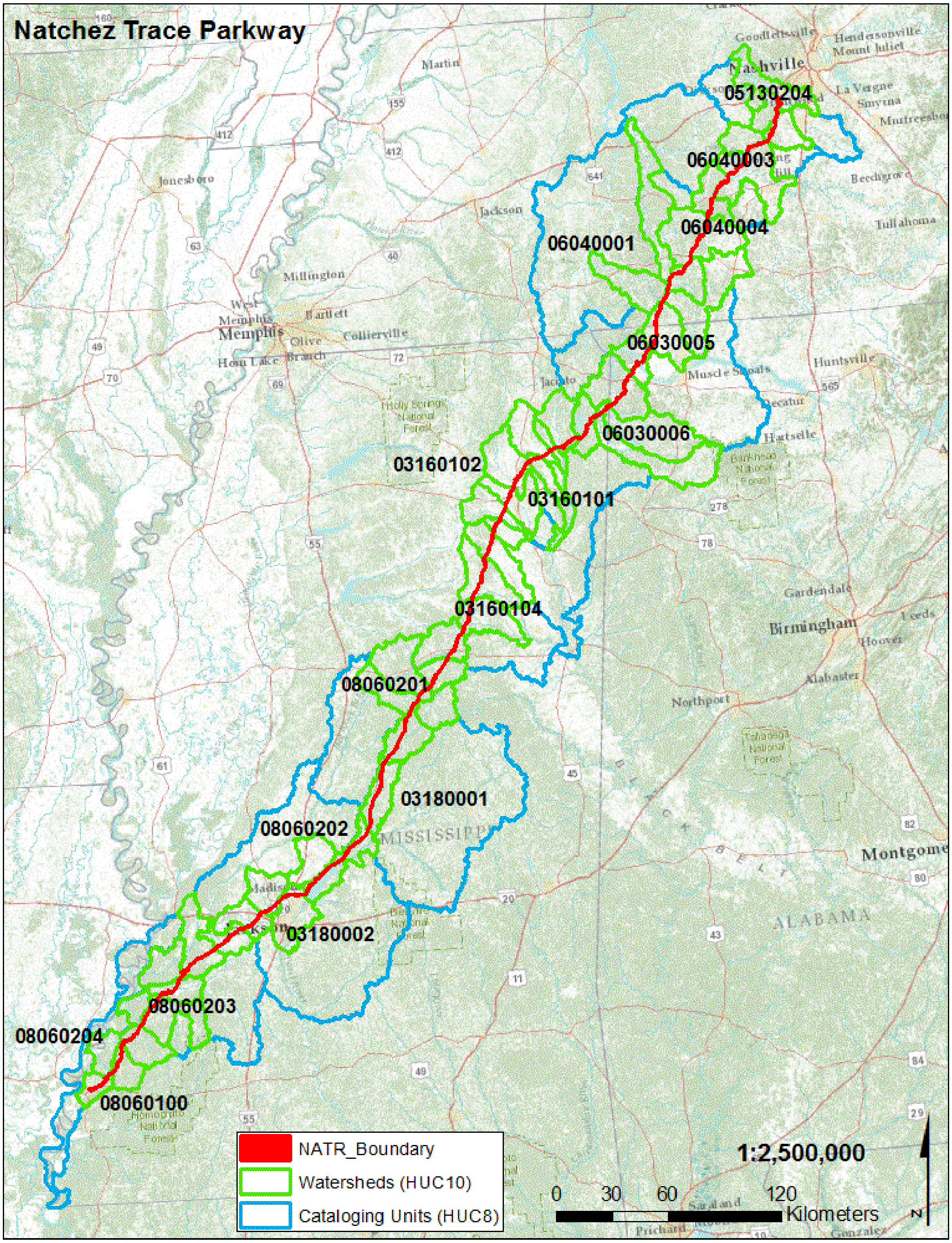

Figure 4. Natchez Trace Parkway crosses 16 cataloging units and 50 watersheds along its route from Natchez, MS to Nashville, TN.

2.2.3 Plants

The Parkway supports a great variety of plants, plant complexes, and forest associations. Approximately 1350 plant taxa are found in NATR, occurring in at least 61 unique vegetation associations (community types; Rangoonwala et al. 2011). The federally threatened Price's potato bean (*Apios priceana*) may be found in the park, as are 65 plant species considered imperiled or critically imperiled at the state or province scale. Approximately 20% of the Parkway's lands are grassland. Of particular significance are natural prairie areas, especially those of the Black Belt physiographic region of Mississippi and Alabama. Approximately 67% of park lands support some kind of forest cover. Mixed oak, sweetgum, and pine-cedar forest classes dominate the southern and central Parkway, and white oak, mixed oak, and pine-oak dominate the northern sections. Over 200 species, or around 15%, of all known NATR plant species are exotic.

2.2.4 Vertebrate Animal Assemblages

The Natchez Trace Parkway supports a great variety of vertebrate animals. The large drainages traversed by the Parkway support the richest fish assemblages in North America, and many communities are noted for high levels of endemism. From inventory data, 92 species of fish occur in NATR, and many more species are likely to be present (NPSpecies, NPS 2012c). The federally threatened slackwater darter (*Etheostoma boschungi*) occurs in the park, and the federally threatened bayou darter (*Etheostoma rubrum*) has been reported. Inventory efforts have reported 134 species of birds in NATR, and many more species certainly occur. No federally threatened or endangered bird species are known to occur, although at least 15 species of high conservation concern have been reported, including four state-listed species. A baseline inventory reported 67 species of reptiles and amphibians from the Parkway, including 25 snakes, 14 turtles, six lizards, one crocodilian, 15 anurans, and six salamanders. Results of other efforts in and around the park suggest that many more species likely are present. Salamanders, in particular, were probably under-represented in the herpetofauna inventory. The rainbow snake (*Farancia erytrogramma*) occurs in NATR and is listed as endangered in Mississippi. A variety of mammals occur in the park, although a basic inventory of this group has not been completed. In addition, because of the narrow nature of the Parkway, it would be difficult to quantify actual reliance on habitat within NATR. While mammals are not addressed in this report (with the exception of wildlife damage), a carefully designed occupancy survey in conjunction with habitat modeling for key species could begin to address the value of habitat in the Parkway relative to species' ranges.

2.2.5 Adjacent Landscapes

The Natchez Trace Parkway is surrounded by a mosaic of natural and human-altered landscapes. Because of the long, narrow configuration of NATR, impacts of adjacent land use are particularly acute on park resources. Much of the region surrounding the park is rural, although park lands abut several urban areas, including Tupelo and Jackson, Mississippi and Nashville, Tennessee. The dominant landcover class in the buffer area around the Parkway is forest, followed by pasture land. Core forest (>30 m from edge) accounts for around 40% of the landcover. Percent of impervious surface in this landscape is generally less than one percent. Road density in the region averages around 1.8 km per km^2. With the exception of several urban areas, surrounding regions are relatively sparsely populated. Roughly three percent of the surrounding landscape is classified as protected land (NPScape data, NPS 2012b).

2.2.6 Resource Issues and Management

A variety of factors actively affect natural resources at NATR. Some of these issues are addressed through monitoring and management actions. This section briefly discusses key resource issues and select monitoring and management programs that are ongoing in the Natchez Trace Parkway.

<u>Weather and Climate</u>

The purpose of weather monitoring is to develop a long-term record of meteorological data, which may in turn be used to track changes in climate and other vital signs. Five Cooperative Observer Program (COOP) weather stations with data from the 1890's through 2012 were selected to summarize weather and climate data (SERCC 2012). These stations were located along the Parkway, and have been monitoring for many decades. Two of the stations began monitoring in the 19th century (Natchez and Franklin Sewage Plant). All of these stations are still collecting data. Data was also available from three Remote Automated Weather stations (RAWS) one at Highway 41 near Tupelo, MS, one at the Meriwether Lewis site, and one at the Tupelo Maintenance compound (WRCC 2012). These stations were not used for this report, due to similarity of data the COOP stations, which were more numerous and representative of the areas at which RAWS stations occurred.

<u>Water Quality</u>

Quarterly water quality sampling began at NATR in summer 2007 at 52 sites along the Parkway (Earleywine 2010). Since that time, monitoring has been narrowed to 32 stations. Monitored parameters include temperature, specific conductance, pH, dissolved oxygen, acid neutralizing capacity, bacterial contamination, nitrate, and turbidity.

<u>Invasive Plants</u>

The linear nature of the Parkway leaves NATR highly susceptible to the incursion of exotic plant species. Currently, 210 exotic species have been documented at NATR, representative of roughly 15% of all taxa in the park unit (NPSpecies; NPS 2012c). Some of the main problem species include Chinese privet (Ligustrum sinese), kudzu (*Pueraria lobata*), Japanese honeysuckle (*Lonicera japonica*), mimosa (*Albizia julibrissin*), and tree-of-heaven (*Ailanthus altissima*). Ongoing treatments include mechanical reduction, prescribed fire, and pesticide application (Cooper et al. 2004).

<u>Fire Management</u>

Much of the land area surrounding the Parkway was historically burned by Native American inhabitants, after which it underwent a period of cultivation followed by abandonment and fire suppression (Cooper et al. 2004). The current Parkway policy is to use prescribed burning and mechanical treatments to reduce fuel buildup and mimic the historic cycle of fire throughout the landscape. Wildfires are suppressed along the Parkway, mainly due to the uncertainty of their behavior.

Prescribed fires can help decrease the encroachment of exotic species and in turn facilitate fire-dependent understory plants, in addition to increasing nutrient availability. In the Blackbelt prairie region of northern Mississippi, for instance, fires are used extensively to promote native species. The Parkway is divided into two main Fire Planning Units (FPU): the Northern Mississippi FPU, which encompasses the first 530 km (330 miles) of the Parkway from the sourthern terminous to the Tennessee River in Alabama, and the Tennessee/Green River FPU, which encompasses the remaining area (Figure 5). The Northern Mississippi FPU is in turn divided into three Fire Management Units (FMU): Natchez, Kosciusko, and Tupelo. The Tennessee/Green River FPU consists solely of the Meriwether Lewis FMU.

The northern Mississippi FPU is distinguished from the Tennessee/Green River FPU mainly based on vegetation. The MS unit is mostly forested, consisting of pine-hardwood and loblolly/shortleaf pine forests, with an overall estimated fire return interval of 4 to 8 years. The TN unit includes more rolling topography and fewer fire-adapted species due to an overall lower rate of natural fire occurrence. As a result, fuel buildup from years of fire suppression is typically less than in the MS unit.

Burning began at NATR in 1992, and currently personnel conduct prescribed burns on approximately 240 ha each year. In 2001, a fire effects monitoring team was established at the park to monitor vegetation before and after burns were conducted (NPS 2012a).

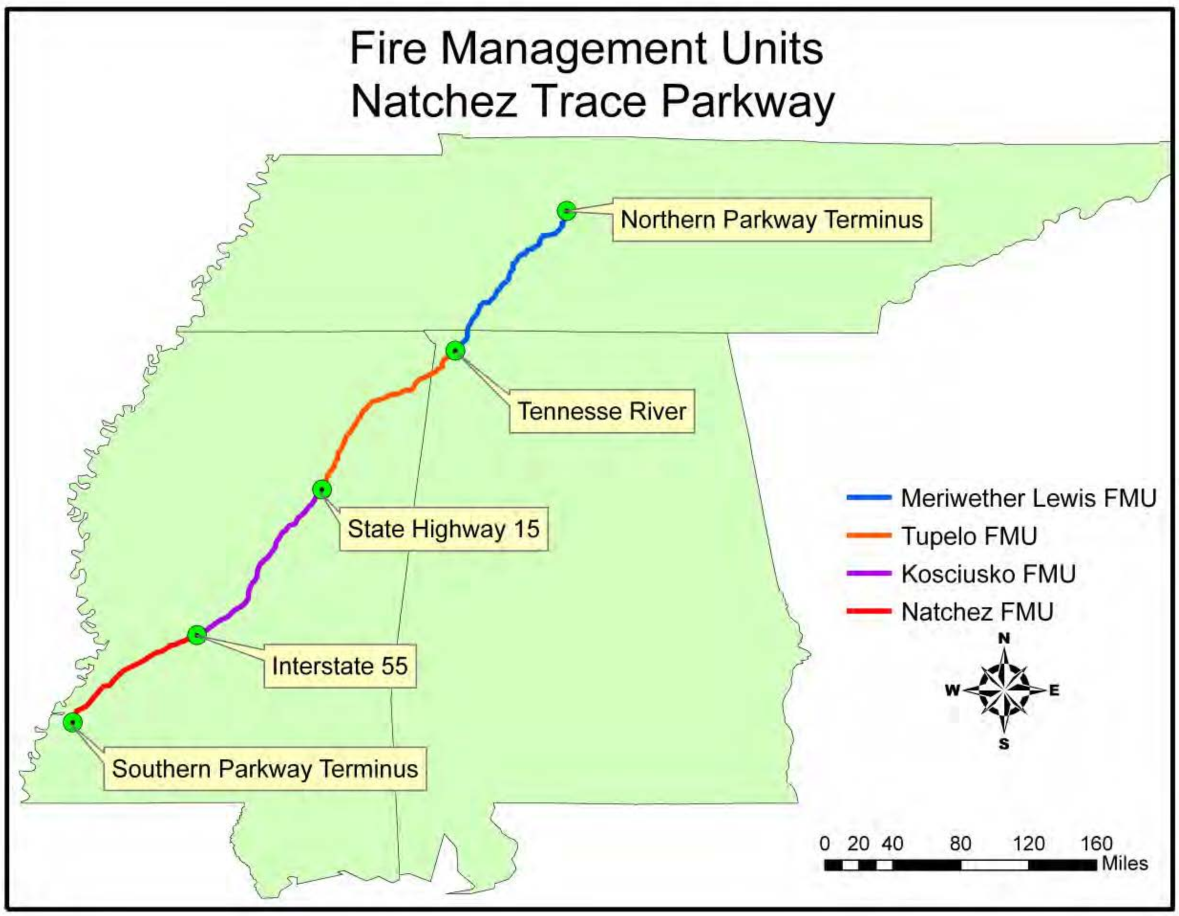

Figure 5. The Natchez Trace Parkway is divided into two main Fire Planning Units and four Fire Management Units. The Northern Mississippi FPU encompasses the first 530 km (330 miles) of the Parkway from the southern terminous to the Tennessee River in Alabama. The Tennessee/Green River FPU includes the remaining areas. [Figure taken from NPS (2010)]

Feral Hogs

Feral hogs occur in the park, where they cause damage to cultural and natural resources. Hogs are recognized as a persistent problem, and complete eradication is not considered a viable option. A feral hog management plan has been drafted by NATR. This plan outlines a monitoring and assessment regime to identify problem animals or areas. It calls for targeting and lethal disposal of specific problem animals.

Beavers

Beavers are abundant in NATR and are recognized as important and largely beneficial members of native animal assemblages. However, the timber cutting, digging, and damming activities of beavers pose threats to sensitive cultural resources and motor roadway integrity. A beaver management protocol has been developed for beavers on the Parkway. This plan calls for annual surveys of beaver colonies and beaver dams. Dams that pose risks to park resources or visitors are removed or mitigated.

Vertebrate Assemblages

The rich vertebrate animal assemblages found on the Parkway are understood to be key natural resources. As such, they can be monitored as indicators of park habitat condition and change. Baseline inventories of fishes, birds, and herpetofauna have been completed under the mandates of the Inventory and Monitoring program. Annual monitoring with standardized sampling techniques has been initiated for breeding birds and herpetofauna.

Landscape Change

Many of the other vital signs established for NATR interact and respond to changes of the landscape within and surrounding the park, including invasive species introductions, water quality issues, and air quality problems. At NATR, adjacent land-use impacts are particularly relevant due to the linear nature of the park. The Parkway boundary is roughly 1,600 km and the majority of directly adjacent land is farmland (Mangi Environmental Group 2008), though there is an overall trend towards development. This will undoubtedly continue to result in pressure along the Parkway including an increase in the fragmentation of forests near the park (within 5 km), which are currently less fragmented than forests within 30 km (NPS 2012b). These and other influences may affect not only the biological health of the park unit, but also the scenic integrity.

The NPScape landscape dynamics program created an organized protocol for landscape scale assessment for all park units in the U.S. To achieve that goal, landscape analysis was divided into five main categories: (1) landcover, (2) roads, (3) population and housing, (4) pattern, and (5) conservation status. Each of these categories has an associated set of data sources and data products that provide the foundation for further analysis. For each section, the NPScape interpretative guide provides a literature review, including lists of thresholds that can serve as metric guidelines.

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Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

During November 2010, an initial scoping meeting was held to discuss natural resource issues at NATR (See Appendix A for list of attendees). The purpose of this meeting was to provide an introduction to the scope of the NRCA report and identify potential sources of data. Using the list of vital signs outlined by the GULN as a starting point, additional points of interest and important natural resource issues at the park unit were added as focal points to the assessment. Other discussion was devoted to how the report could maximize its utility at the park unit level.

3.2 Study Design

3.2.1 Indicator Framework

The ranking framework used for this natural resource condition assessment draws from the NPS ecological monitoring framework (EMF) (Fancy et al. 2009) (Table 1). Using an Environmental Protection Agency (EPA) ecological condition framework (Young and Sanzone 2002) as a model, the NPS framework divides monitoring into six general categories: air and climate, geology and soils, water, biological integrity, human use, and landscape pattern and processes. Each of these general categories, referred to as level-one, are further subdivided into level-two and level-three categories, with each park vital sign most closely associated with this fine-scale level-three division. Biological integrity, a level-one category for example, is divided into 4 level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Invasive species, in turn, includes two level-three categories: invasive/exotic plants and invasive/exotic animals. As the categories move from level-one to level-three, the resolution of the data involved also increases. Table 2 shows a general outline of the data sources used for identified categories of interest.

Table 1. NPS Ecological Monitoring Framework used to organize and identify natural resource areas of interest at NATR (Fancy et al. 2009). Blue highlighted categories represent relevant ecological attributes selected for Natchez Trace Parkway during initial scoping meeting using official vital signs identified by the GULN as guidance. Highlighted entries with a '†' are significant natural resources mentioned elsewhere or sampled as part of network inventory and monitoring efforts.

Ecological Monitoring Framework—Natchez Trace Parkway			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Air and Climate	Air Quality	Ozone†	Atmospheric ozone concentration; impact on native plants
		Wet and Dry Deposition	
		Visibility and Particulate Matter	
		Air Contaminants	
	Weather and Climate	Weather and Climate	Temperature, barometric pressure, humidity, precipitation
Geology and Soils	Geomorphology	Windblown Features and Processes	
		Glacial Features and Processes	
		Hillslope Features and Processes	
		Coastal/Ocean Features and Processes	
		Marine Features and Processes	
		Stream/River Channel Characteristics	
		Lake Features and Processes	
	Subsurface Geologic Processes	Geothermal Features and Processes	
		Cave/Karst Features and Processes	
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	
		Surface Water Dynamics	Discharge
		Marine Hydrology	

Table 1. (continued)

Ecological Monitoring Framework—Natchez Trace Parkway			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Water (continued)	Water Quality	Water Chemistry	Temperature, pH, specific conductivity, DO, ANC
		Nutrient Dynamics	
		Toxics	
		Microorganisms	*E. coli,* total/fecal coliforms
		Aquatic Macroinvertebrates and Algae	
Biological Integrity	Invasive Species	Invasive/Exotic Plants	New invasions (early-warning emphasis); occurrence, distribution models (I-ranks)
		Invasive/Exotic Animals	
	Infestations and Disease	Insect Pests	
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	
		Riparian Communities	
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	
		Desert Communities	
		Grassland/Herbaceous Communities	Soil stability, distribution, presence of invasives
		Shrubland Communities	
		Forest/Woodland Communities	Species composition, distribution, biological integrity, presence of invasives
		Marine Invertebrates	

Table 1. (continued)

Ecological Monitoring Framework—Natchez Trace Parkway			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Biological Integrity (continued)	Focal Species or Communities (continued)	Freshwater Invertebrates	
		Terrestrial Invertebrates	
		Fishes†	Species richness, diversity, biotic integrity
		Amphibians	Species richness, relative abundance, breeding site use
		Birds	Assemblage richness, indicator species/species of concern, biotic integrity
		Mammals†	Limited data available – not assessed
		Vegetation Complex	Threatened complexes (natural prairie) occurrence
		Terrestrial Complex	
	At-risk Biota	T&E Species and Communities	
Human Use	Point Source Human Effects	Point Source Human Effects	
	Non-point Source Human Effects	Non-point Source Human Effects	
	Consumptive Use	Consumptive Use	
	Visitor and Recreation Use	Visitor Use	
	Cultural Landscapes	Cultural Landscapes	
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	
	Landscape Dynamics	Land Cover and Use	NPScape areas of interest: landcover, population/housing, roads, pattern, and conservation status
	Extreme Disturbance Events	Extreme Disturbance Events	
	Soundscape	Soundscape	
	Viewscape	Viewscape/Dark Night Sky	
	Nutrient Dynamics	Nutrient Dynamics	
	Energy Flow	Primary Production	

Table 2. Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Natchez Trace Parkway.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	Portable Ozone Monitoring Systems (POMS) in NATR	Hourly measurements of ozone concentration within NATR at 2 ozone monitoring sites	2006 - 2009
		NPS Air Resources Division (NPS ARD)	Interpolated 5-year and 10-year estimates for NATR and NATC	Various periods between: 1996-2010
		MS Department of Environmental Quality (MDEQ)	Three year averages from stations in Tupelo, Jackson, and Natchez	2001-2010
		Gaseous Pollutant Monitoring Program (GPMP)	Summarized ozone data	Aug.-Sept., 2009
Weather and Climate	Temperature, precipitation, wind	Remote Automated Weather Station (RAWS) near Tupelo	Temperature, precipitation, wind speed/direction	1997-present
		Five Cooperative Observer Program (COOP) stations in NATR	*Same as above*	ca. 1900-present
Water Quality	Temperature, microorganisms, pH, specific conductance, dissolved oxygen, 303(d) impairment	Earleywine (2010)	Assessment of land use effects on NATR streams	2007-2009
		GULN	Unpublished water monitoring data	2009-present
Terrestrial Vegetation	Status of significant communities and rare species, presence and invasiveness of exotic species	Rangoonwala et al. (2011)	Vegetation map of NATR with associated narrative	2004-2010
		GULN (2010)	A summary of biological inventories in NATR	2010
		Hatch and Kruse (2008)	Report on the vascular flora of NATR	1997
		The Nature Conservancey (1996)	Assessment of rare, threatened, and endangered plant species in NATR	1996
		Waggoner (1986)	Unpublished list of NATR flora pulled from electronic database	1986

Table 2. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Forest Pests and Diseases	Presence and distribution of forest pests and disease	U.S. Forest Service Forest Health Technology Enterprise Team (FHTET)	Map of southern pine beetle risk for the NATR region	2011
		Walkinshaw and Barnett (1995)	Article on tolerance of pines to fusiform rust. Field work sampled several trees along NATR	1995
		Hess (1990)	Results of two driving surveys to detect dogwood anthracnose	1989
Fish Assemblages	Spp. richness, Simpson's Diversity Index, endemism, percentage of tolerant and intolerant spp.	Ross (1994)	Summary from academic database of fishes sampled within 10 km of NATR in MS	unknown - 1993
		Paxton et al. (2000)	Summary from several sources of fishes sampled within 10 km of NATR in TN	unknown - 1999
		Phillips and Johnston (2004)	Publication on long-term sampling of Bear Creek drainage in AL	1998-2000
		Johnston (2007)	Report and associated electronic data on comprehensive NATR fish inventory	2005-2006
		Earleywine (2010)	Thesis on effects of land use on aquatic resources in NATR	2007-2009
Bird Assemblages	Expected vs. observed richness, trait-based regional comparisons, PIF-base conservation ranks	U.S. Geologic Survey Breeding Bird Survey (BBS)	Data from roadside BBS point counts	1992-2011
		Audubon Society Christmas Bird Count (CBC)	Data from CBC counts	1989-2009
		Accipiter (2001)	Narrative report with included tables and graphics on a park-wide bird inventory	1999-2000
Herpetofauna Assemblages	Expected vs. observed richness	Accipiter (2001), Woodman (2013)	Narrative report and electronic data for all samples	1999-2000
		Ferguson (1961), Watson (1987), Scott (1991), Keisner (2002), Fogarty and Jones (2003), Scott and Davenport (2005), Edwards (2007), Niemeller et al. (2011), Posner (2012)	Inventory reports, peer reviewed publications, and academic theses on assemblage-scale sampling	Various

Table 2. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Wildlife Damage		NPS (undated)	Beaver management guidelines	
		NPS (2012)	Draft feral hog management plan	
		NPS (2012)	Spreadsheet of updated beaver dam inventory data	2012
Adjacent Land Use	NPScape main categories: landcover, roads, population and housing, pattern, and conservation status	NPScape dataset	Suite of GIS layers and associated data for each of the main categories, as well as resulting spatial analysis data products	Varies
		Gap Analysis Program Protected Areas Database (GAP PAD)	GIS database ranking the protection level of landscapes	Varies

3.2.2 Reporting Areas

Natchez Trace Parkway has a long, linear configuration, and natural resource conditions are expected to vary throughout the several ecological regions of the park. Therefore, some attribute conditions were reported separately for multiple discreet units within the park. These reporting areas were chosen for individual attributes, and were based upon ecological boundaries or observed differences in assemblage structure. Water quality and fish assemblage condition were reported at the USGS HUC 8 watershed boundary scale. For each of these attributes, 13 reporting areas were assessed. Bird assemblage and herpetofauna assemblage condition were each reported for two reporting areas, north and south. All other attributes discussed in this report were assessed at a park-wide scale.

3.2.3 General Approach and Methods

Condition and Trend Status Ranking Methodology

Data collected as part of the NPS Inventory and Monitoring (I&M) program typically is intended to assess the condition of the vital sign at level-3; therefore, we summarize at this level using the ranking status tables at the end of each natural resource section. These tables represent a subset of the EMF tables and show finest-scale division of the level 1 category to which the ranked attribute belongs. Individual attributes are assigned two individual rankings: condition and trend.

We used this hierarchical framework to choose assessment attributes and to organize the presentation of results. We developed a list of ecological attributes suitable for condition assessment using 1) level-three category attributes from the NPS framework described above, 2) the inventory and monitoring goals for the Gulf Coast Network (GULN) (Segura et al. 2007), and 3) input from NPS staff. We represented the condition of each attribute as a colored circle, where color indicated condition (Table 3). Condition rankings were comparable only within an attribute, consequently, identical rankings for different attributes may represent different levels of impairment or resource integrity. We used published metrics and established reference thresholds (e.g. IBI, NAAQS) to assign rankings whenever possible. When no quantitative metric was found, we used non-quantitative information from the scientific literature and expert opinion. When appropriate, we performed statistical tests using a 95% confidence standard (a = 0.05). Whenever possible, we also assigned a trend to each condition ranking based on time series data or data sources from multiple time periods. We represented condition trends with a directional arrow within the condition circle. Arrow orientation indicated improving condition (arrow points up), stable condition (arrow points right), or deteriorating condition (down).

Table 3. Example condition assessments. Attribute condition is as follows: dark green = excellent, light green = good, yellow = fair, red = poor, blue = no condition assigned. Condition trend is indicated by the arrow within the circle. Pointing up = improving condition, pointing right = stable condition, pointing down=declining/deteriorating condition, no arrow = no trend assigned. Checkmarks indicate whether data were appropriately thematic, spatial, or temporal for assessments, as described in the text. Colored bar indicates data quality score. Dark green = 6 of 6 possible checks (very good), light green = 5 of 6 possible checks (good), bright yellow = 4 of 6 possible checks (fair), light yellow = 3 of 6 possible checks (marginal), red = 2 of 6 possible checks (poor), dark red = 1 of 6 possible checks (very poor).

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal	Data Quality score	Interpretation
Example 1:		Relevancy ✓ Sufficiency ✓	Proximity ✓ Coverage ✓	Currency ✓ Coverage ✓	6 of 6: Very Good	Condition: Excellent Trend: Improving Data Quality: Very Good
Example 2:		Relevancy ✓ Sufficiency ✓	Proximity ✓ Coverage ✓	Currency Coverage ✓	5 of 6: Good	Condition: Good Trend: Stable Data Quality: Good
Example 3:		Relevancy ✓ Sufficiency ✓	Proximity Coverage ✓	Currency ✓ Coverage	4 of 6: Fair	Condition: Fair Trend: Declining Data Quality: Fair
Example 4:		Relevancy ✓ Sufficiency	Proximity Coverage ✓	Currency ✓ Coverage	3 of 6: Marginal	Condition: Poor Trend: None Assigned Data Quality: Marginal
Example 5:		Relevancy Sufficiency	Proximity Coverage ✓	Currency ✓ Coverage	2 of 3: Poor	Condition: Not Ranked Trend: None Assigned Data Quality: Poor
Example 6:		Relevancy ✓ Sufficiency	Proximity Coverage	Currency Coverage	1 of 6: Very Poor	Condition: Not Ranked Trend: None Assigned Data Quality: Very Poor

Data Quality

We assigned a data quality ranking to each attribute as an assessment tool for ranking reliability and to identify data gaps. This ranking is divided into three general categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al.'s (2008) NRCA report for Fort Pulaski National Monument. Each category is further subdivided into two sub-ranks, as shown in Table 4. The thematic category is divided into relevancy and sufficiency sub-ranks, answering the questions of whether the data are directly relevant to the category being assessed, and whether there were enough data or if data were sufficiently detailed. The spatial general category, which focuses on whether the data are spatially explicit, is divided into proximity and coverage sub-ranks. These sub-ranks address whether data are specific to the park and its boundaries, and whether the spatial coverage of the data includes the entire park unit. The temporal general category includes the currency and coverage sub-ranks. Respectively, these refer to whether data are recent (≤5 years) and whether they cover a sufficient breadth of time. To give an overall rank to the data quality, the number of sub-ranks fulfilled are summed and translated into a very good (6), good (5), fair (4), marginal (3), poor (2), or very poor (1) ranking and reported alongside the overall condition assessment (Table 3).

Table 4. Data quality ranking criteria showing six sub-ranks.

Data Category	Sub-Rank	Criteria
Thematic	Relevance	Are data directly relatable to assessment of the attribute?
	Sufficiency	Are data sufficient to conduct a thorough assessment?
Spatial	Proximity	Are data collected within or close to the park unit?
	Coverage	Is there sufficient areal coverage of the park unit?
Temporal	Currency	Were data sufficiently recent to reflect current conditions?
	Coverage	Do the data cover sufficient temporal breadth?

As continued monitoring adds to the available data for future condition assessments, it is likely that these data quality rankings will improve. In addition, implementation and refinement of monitoring protocols for the various natural resource categories is still underway. Data collection methods will likely also change as monitoring needs are fine-tuned to specific metrics and aspects of vital signs at each park unit.

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Chapter 4 Natural Resource Conditions

4.1 Ozone

4.1.1 Context and Standards

Ozone is a major air quality consideration in the GULN. The National Ambient Air Quality Standards (NAAQS) set by the EPA include two thresholds for primary and secondary pollutant limits. Primary limits are set with human health factors in mind, while secondary standards pertain to visibility, vegetation health, and building integrity. In the case of ozone, the NAAQS primary and secondary standard concentrations were lowered starting on May 27, 2008 from 0.080 ppm to 0.075 ppm for ozone over 8-hr periods. As a result, violations of this standard are defined as 3-year averages of the 4^{th} highest daily maximum 8-hour average ozone concentration (4^{th} Hi Max 8-hr means) that exceed 0.075 ppm (EPA 2012).

4.1.2 Data and Resource Knowledge

Portable Ozone Monitoring Stations

Ozone concentrations were collected at two Portable Ozone Monitoring Stations (POMS) along NATR—Dancy Ranger Station near Mantee, MS and Buzzard Roost Springs in Alabama near the Mississippi border (Figure 6). Respectively, data at these stations were available over the periods 2006 – 2008 and in 2009. These stations collected hourly ozone concentrations during the summer ozone season (April-September). The average 4^{th} Hi Max 8-hr mean over the three years of data at the Dancy Ranger Station POMS was 0.065 ppm, which is below the EPA NAAQS. At the Buzzard Roost Springs POMS, the 4^{th} Hi Max 8-hr mean for the single year of data was 0.053 ppm. The goal of these stations was to determine whether there was a need to monitor on the park between the larger metropolitan areas of Jackson and Tupelo, and to determine whether existing stations adequately reflected on-park conditions. After the initial moniring periods, the NPS Air Resources Division (ARD) determined there was no reason to continue monitoring (M. Segura, personal communication).

NPS Air Resources Division Assessments

In addition to monitoring from the POMS, the ARD produces interpolated estimates of ozone metrics for individual park units, averaged over five year periods. Estimates are available for both the overall Parkway, and at Natchez National Historical Park (NATC) at the southern terminus of the Parkway (Table 5).

Table 5. Five-year 4th Hi Max 8-hr annual mean estimates from POMS monitoring by the NPS ARD (NPS 2012).

Period of Estimate	**NATR**	**NATC**
	4^{th} Hi Max 8-hr mean (ppm)	
1999-2003.	--	0.081
2005-2009	0.071	0.075
2006-2010	0.070	0.074

The NPS ARD also assesses overall trends based on 10 year periods (NPS 2012). According to Air Quality Reports by the ARD in 2009 and 2008, significant decreases in 4th Hi max 8-hr metrics were observed at both NATC and NATR over the periods 1999-2008 and 1998-2007. The 2006 report observed no trend along the Parkway over the period 1996-2005.

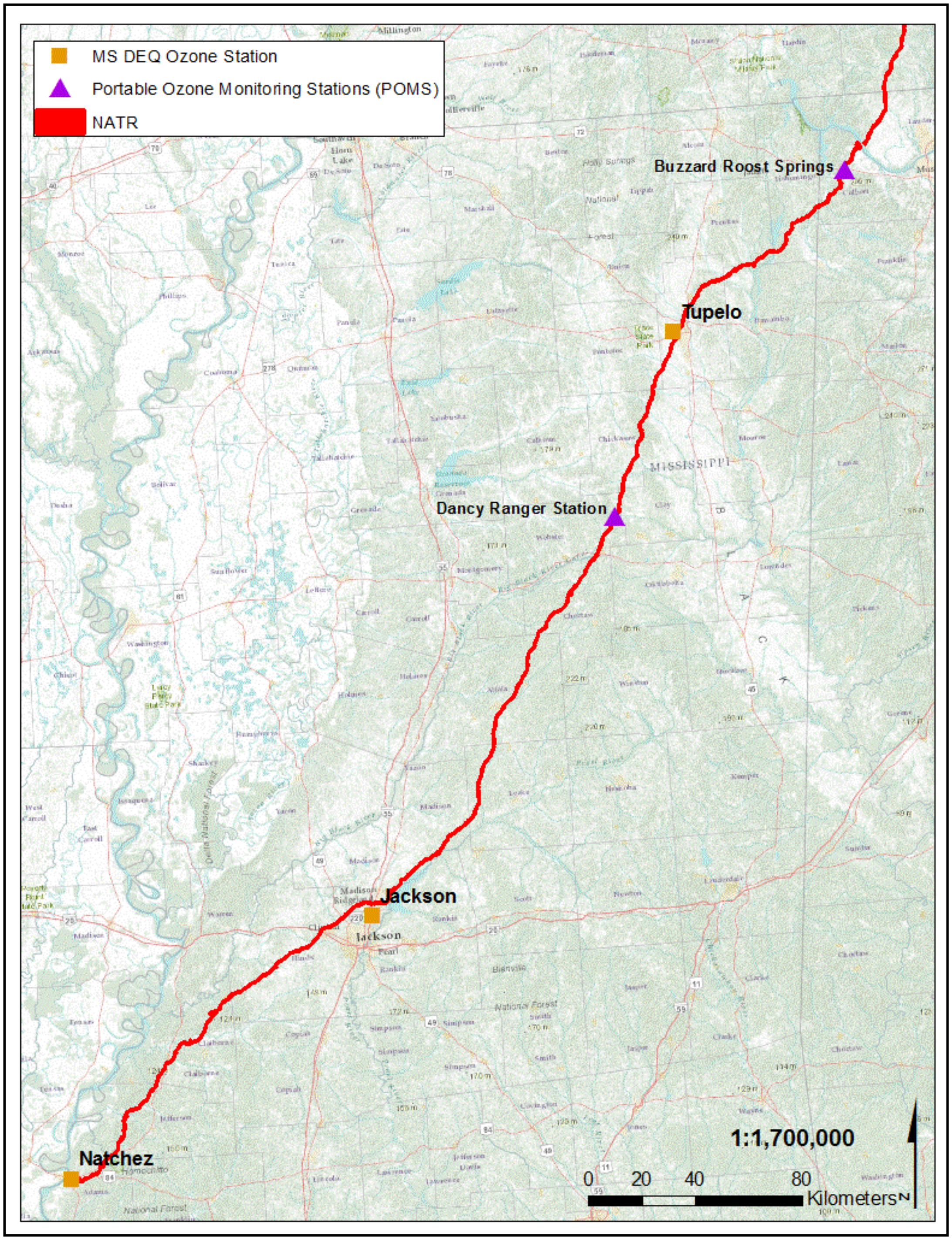

Figure 6. Two Portable Ozone Monitoring Stations (POMS) along NATR represent a combined data period of 2006 to 2009. The Mississippi Department of Environmental Quality collects ozone data at Tupelo, Jackson, and Natchez.

MS Department of Environmental Quality

The Mississippi Department of Environmental Quality (MDEQ) collects ozone data at several locations throughout the state, many of which are in metropolitan areas. Relevant to the Parkway are stations in Tupelo, Jackson, and Natchez (Figure 6). Three-year averages of the 4^{th} Hi Max 8-hr metrics are available at each station for the period 2001 to 2010 (1999-2001, 2000-2002, etc.), during which all stations showed a steady decrease. Beginning in 2006, all three stations reported 3-yr means within 0.002 ppm of one another. In 2010, the average 3-yr mean among all stations was 0.066 ppm.

Gaseous Pollutant and Monitoring Program

Gaseous Pollutant and Monitoring Program (GPMP) summaries are available for the park in August and September 2009, which report 4^{th} highest daily 8-hour maximum concentrations of 0.053 and 0.050 ppm, respectively.

4.1.3 Condition and Trend

Overall, the POMS measurements for ozone at NATR are reasonably low. The 3-yr 4^{th} Hi Max 8-hr mean from the Dancy Ranger Station falls within the range of moderate concern (0.061 – 0.075 ppm) for ozone condition, according to the ARD, while the single year metric from Buzzard Roost Springs falls within the good condition category (≤0.060 ppm). The MDEQ stations also averaged metrics in the range for moderate concern. The NPS ARD 3-year predictions were also just below the 0.075 ppm threshold for the latest two prediction periods. ARD five year estimates were in the moderate condition category for both NATR and NATC over the periods 2005-2009 and 2006-2010. GPMP summaries for the park in August and September, 2009 reported 4^{th} highest daily 8-hour maximum concentrations of 0.053 and 0.050 ppm, respectively. As a result of these findings, the condition status for ozone along NATR receives a rating of fair (Table 6). Ten year data periods assessed by NPS ARD (1999-2008 and 1998-2007) and all three MDEQ stations (2001-2010) showed significantly decreasing 3-yr mean metrics. As a result a trend of improving is also assigned for this condition status (Table 6). The quality of the data used to make the assessment was very good (Table 6).

Table 6. The condition of ozone concentration was fair. An improving trend was assigned to ozone condition. The quality of the data used for the assessment was very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Ozone		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

4.1.4 Literature Cited

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4.2 Weather & Climate

4.2.1 Context and Relevance

Climate patterns can provide insight into other processes and natural resource conditions such as water quality, vegetation dynamics, and animal communities. For the purposes of monitoring, "weather" generally refers to present and short-term conditions, whereas "climate" is the long-term trend, or norm, representing the entire distribution of atmospheric activity and its associated set of statistical descriptors. Datasets collected through weather and climate monitoring represent a primary mode of detecting how meteorology affects ecosystem processes. In the short-term, weather events drive multiple systems, including groundwater flow, species patterns, pollutant loads, and productivity. Longer-term records can reveal gradual and more permanent changes in climate, which may in turn cause fundamental alterations in the environment of the GULN region. One significant factor affecting short-term weather variation in the Gulf region is the El Niño Southern Oscillation (ENSO), which alternates between periods of warmer temperatures with intense thunderstorms and cooler periods that are overall wetter. Severe weather disturbances such as tropical storms and hurricanes also tend to be less frequent during the warm ENSO cycle (Davey et al. 2007).

4.2.2 Data

The GULN and other entities monitor long-term weather and climate patterns to help identify patterns, trends, and deviations for certain characteristics. Although the GULN does not maintain any weather stations, there are several weather monitoring stations in the vicinity of NATR that provide observations of temperature, precipitation, wind, and humidity, among other observations. Five Cooperative Observer Program (COOP) weather stations with data from the 1890's through 2012 were selected to summarize weather and climate data (SERCC 2012; Figure 7). These stations were located along the Parkway, and have been monitoring for many decades. Two of the stations began monitoring in the 19th century (Natchez and Franklin Sewage Plant). All of these stations are still collecting data. Data was also available from three Remote Automated Weather stations (RAWS) one at Highway 41 near Tupelo, MS, one at the Meriwether Lewis site, and one at the Tupelo Maintenance compound (WRCC 2012). These stations were not used for this report, due to similarity of data the COOP stations, which were more numerous and representative of the areas at which RAWS stations occurred.

4.2.3 Resource Knowledge

Precipitation

Precipitation is one of the most influential drivers for many ecosystem processes, through which it can affect fire regimes, primary production, stream flow, and pollutant deposition. The latest Weather and Climate Inventory Report for the GULN indicates that over the last century, precipitation has increased in most places in the GULN over the last century, particularly in fall (Davey et al. 2007, Figure 8).

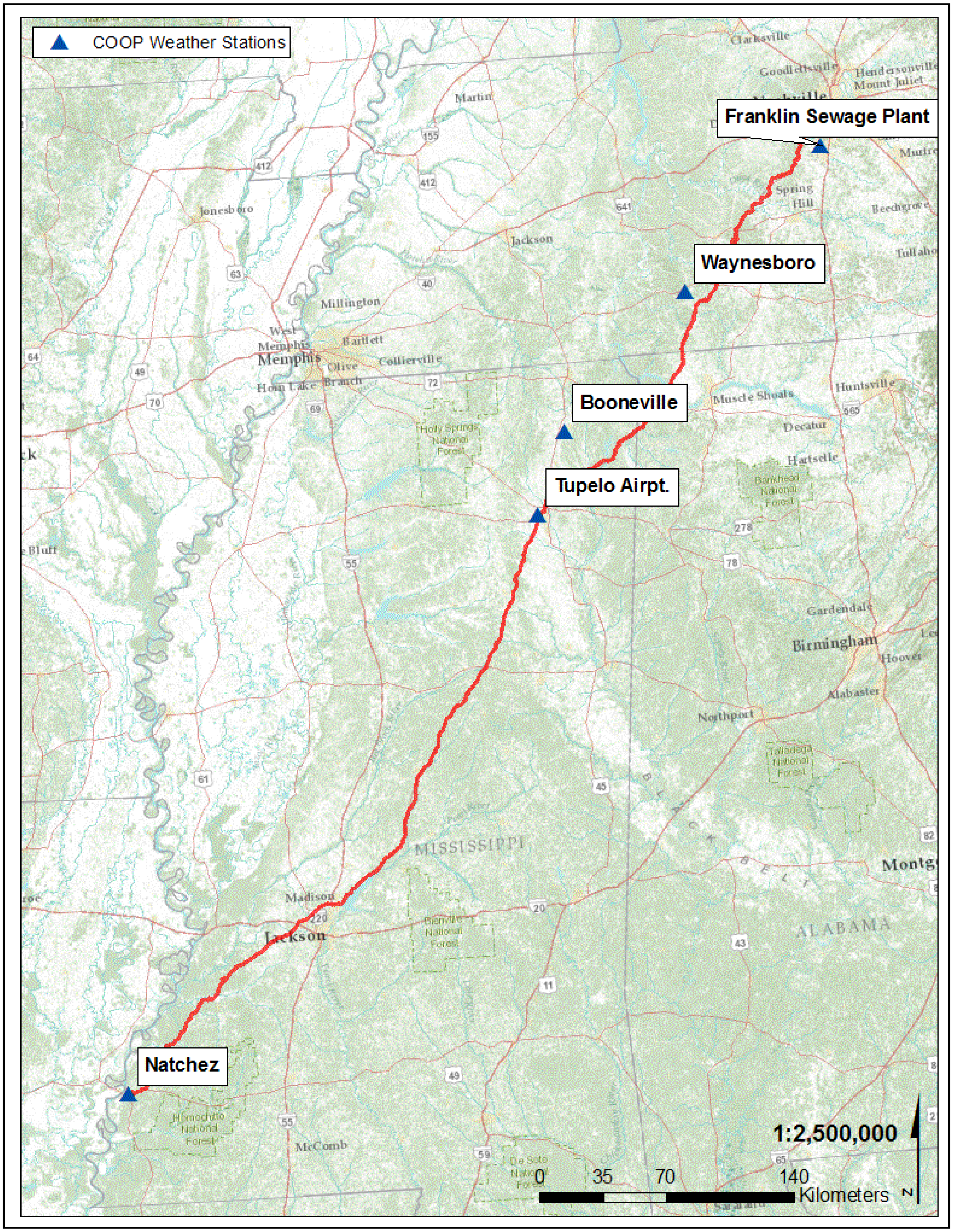

Figure 7. Five COOP stations along NATR were used in a summary of weather and climate data.

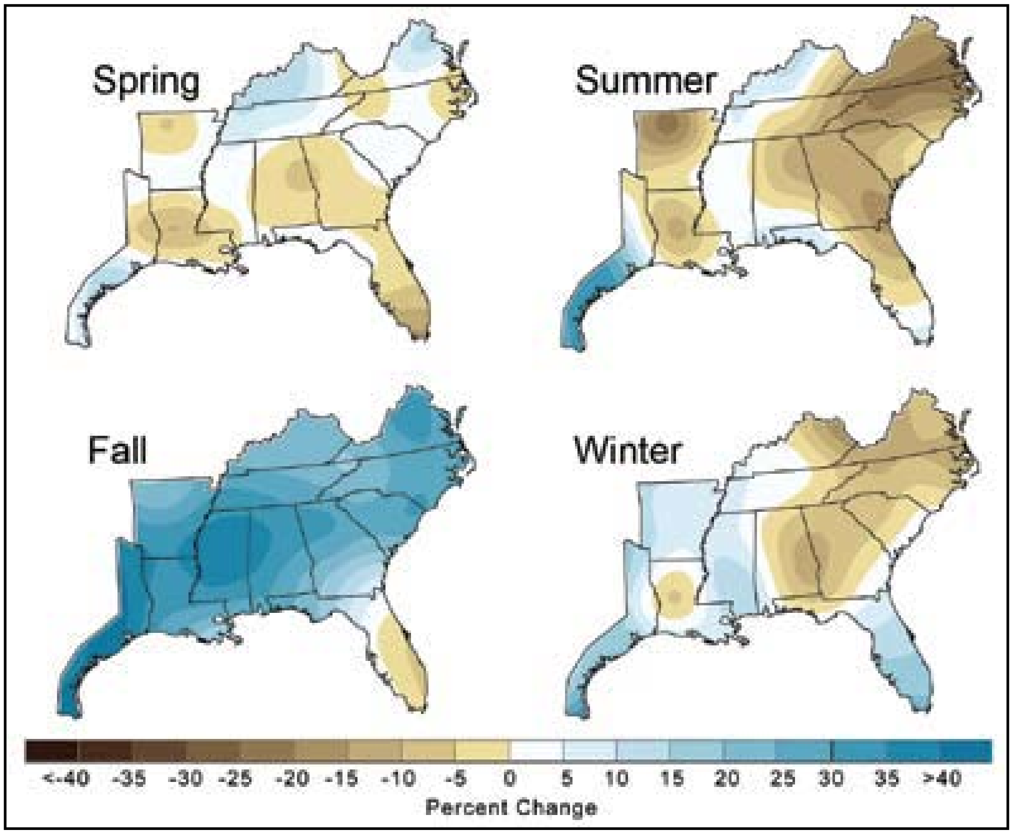

Figure 8. Changes in precipitation in the southeastern U.S. observed from 1901 to 2007. [Source: Karl et al. 2009]

Figure 9 shows annual precipitation levels at the COOP stations around NATR. The four stations with the longest monitoring periods showed increasing linear trends, while the Tupelo station with a dataset roughly half as extensive showed no apparent trend. ENSO cycles are evident in the precipitation data over a roughly 4-5 year cycle.

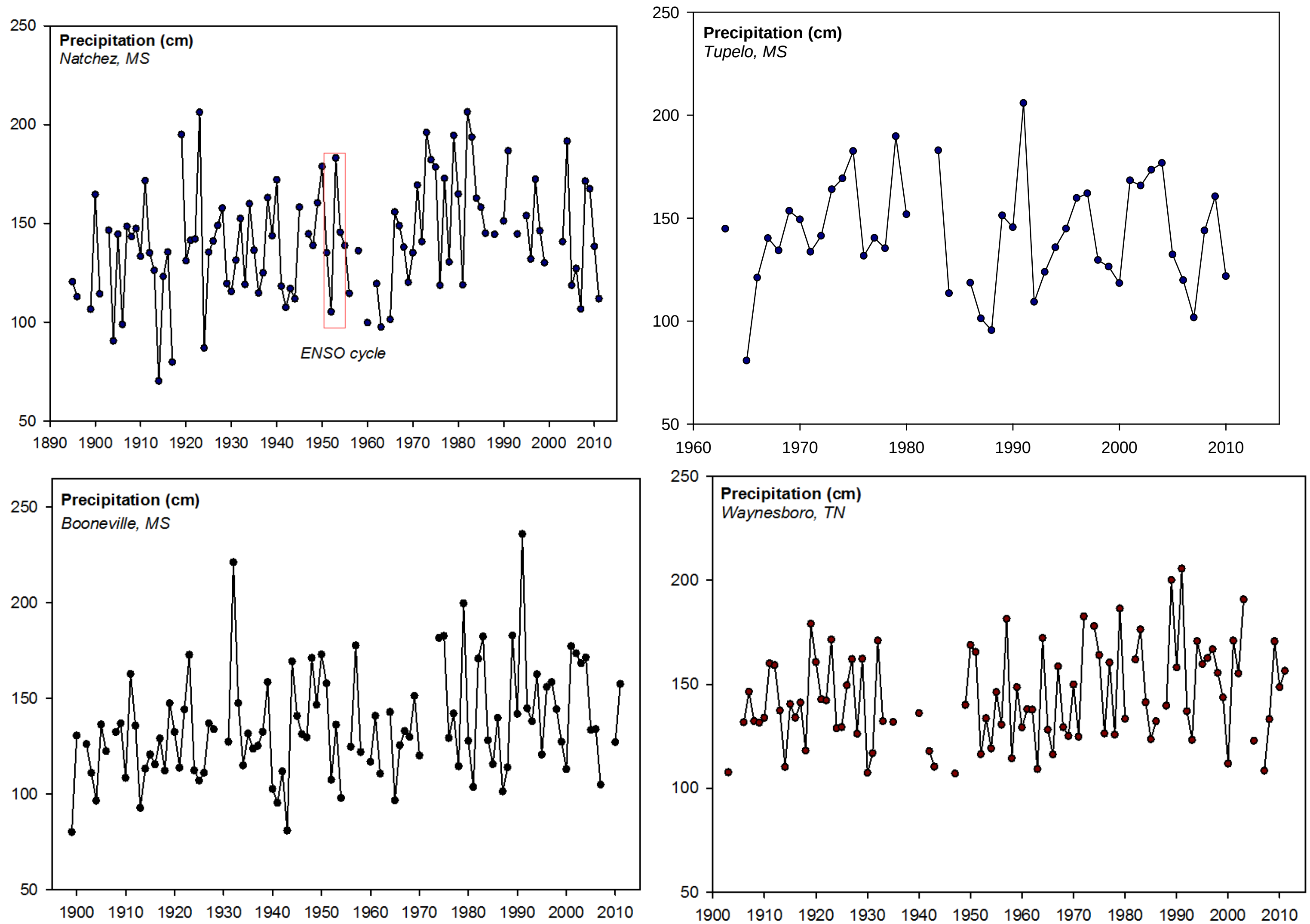

Figure 9. Average annual precipitation data at five COOP stations in the vicinity of NATR from the 1890's (variable by station) through 2012. Stations missing one month of data, or three months with a minimum of three days of data each, are not plotted for that year. Linear trends are plotted if significant.

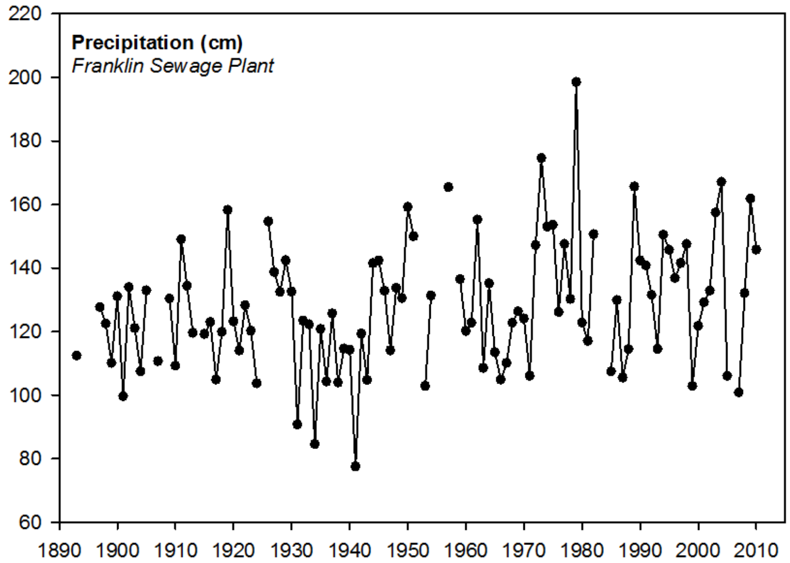

Figure 9. (continued)

Temperature

Long-term temperature monitoring in the GULN has also shown noticeable patterns over the past decades. Large-scale changes in temperature could be the result of climate change, as are changes in frequency of extreme weather events such as storms and droughts. These changes can also lead to ecosystem effects such as disease spread and susceptibility to invasive species (Davey et al. 2007).

Figure 10 shows average daily, maximum, and minimum annual temperatures at the COOP and RAWS monitoring locations at NATR. Years with insufficient data were not included in the plot. COOP stations appear to have relatively consistent temperature ranges over the monitoring periods. The Natchez and Booneville stations showed slight decreases for average daily and maximum temperatures over the monitoring periods. The Waynesboro station recorded modest declines for all three metrics. The Franklin Sewage Plant in TN appeared to decrease only for average annual minimum temperatures. At the Tupelo station, average annual and annual minimum temperatures showed an increase since monitoring began in 1963. Visually, it appears that from 1960 to present, Booneville and Waynesboro show slight increases despite the modest declines seen overall since the turn of the century.

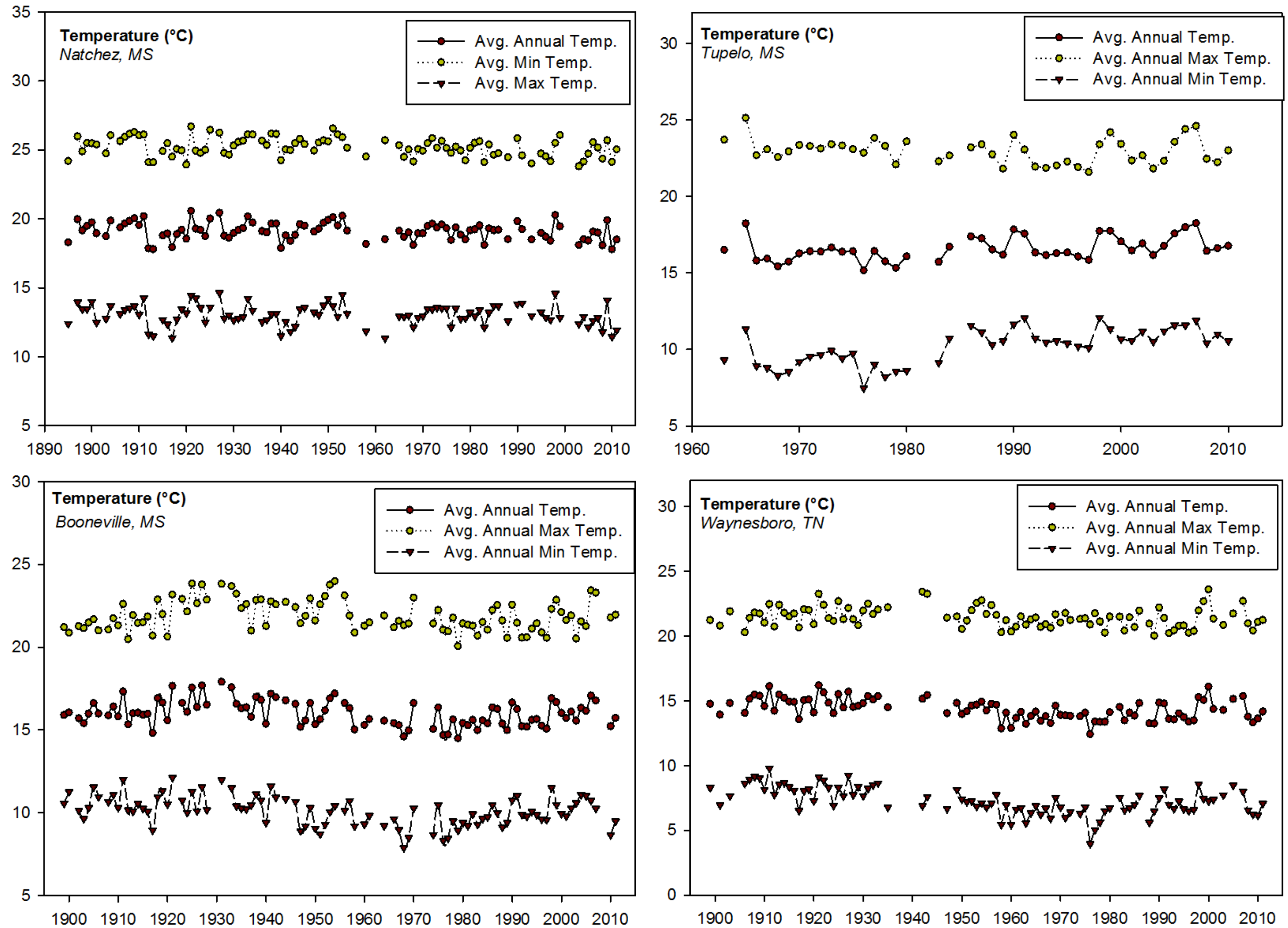

Figure 10. Average daily, maximum, and minimum annual temperatures at the five COOP stations in the vicinity of NATR from the 1890's (variable by station) through 2012. Stations missing one month of data, or three months with a minimum of three days of data each, are not plotted for that year. Linear trends are plotted if significant.

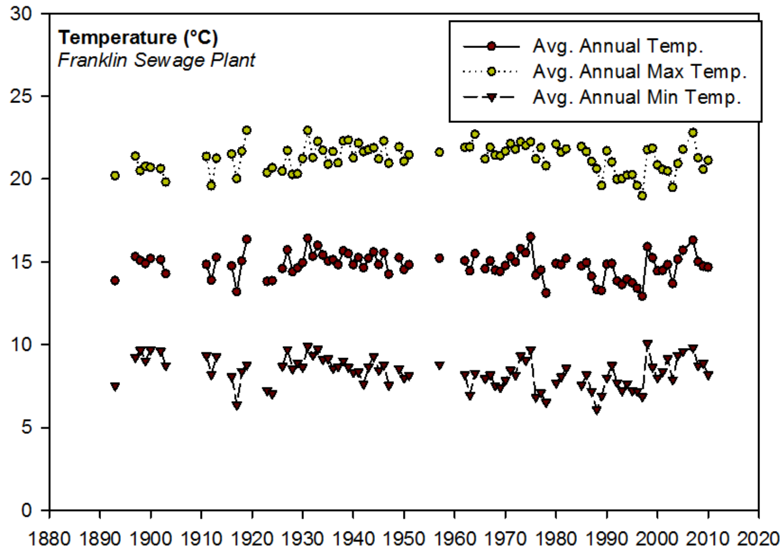

Figure 10. (continued)

Wind Speed and Direction

The Highway 41 RAWS near Tupelo, MS monitors wind speed and direction. Figure 11 shows a 16-point wind rose depicting cumulative wind speed and direction over the history of the station. At the RAWS, winds were calm (<1.3 m s^{-1}) approximately 90% of the time, and predominant directions of wind origin are from the northwest. However, with only one station on such a long linear park unit, we cannot draw conclusions about wind throughout NATR.

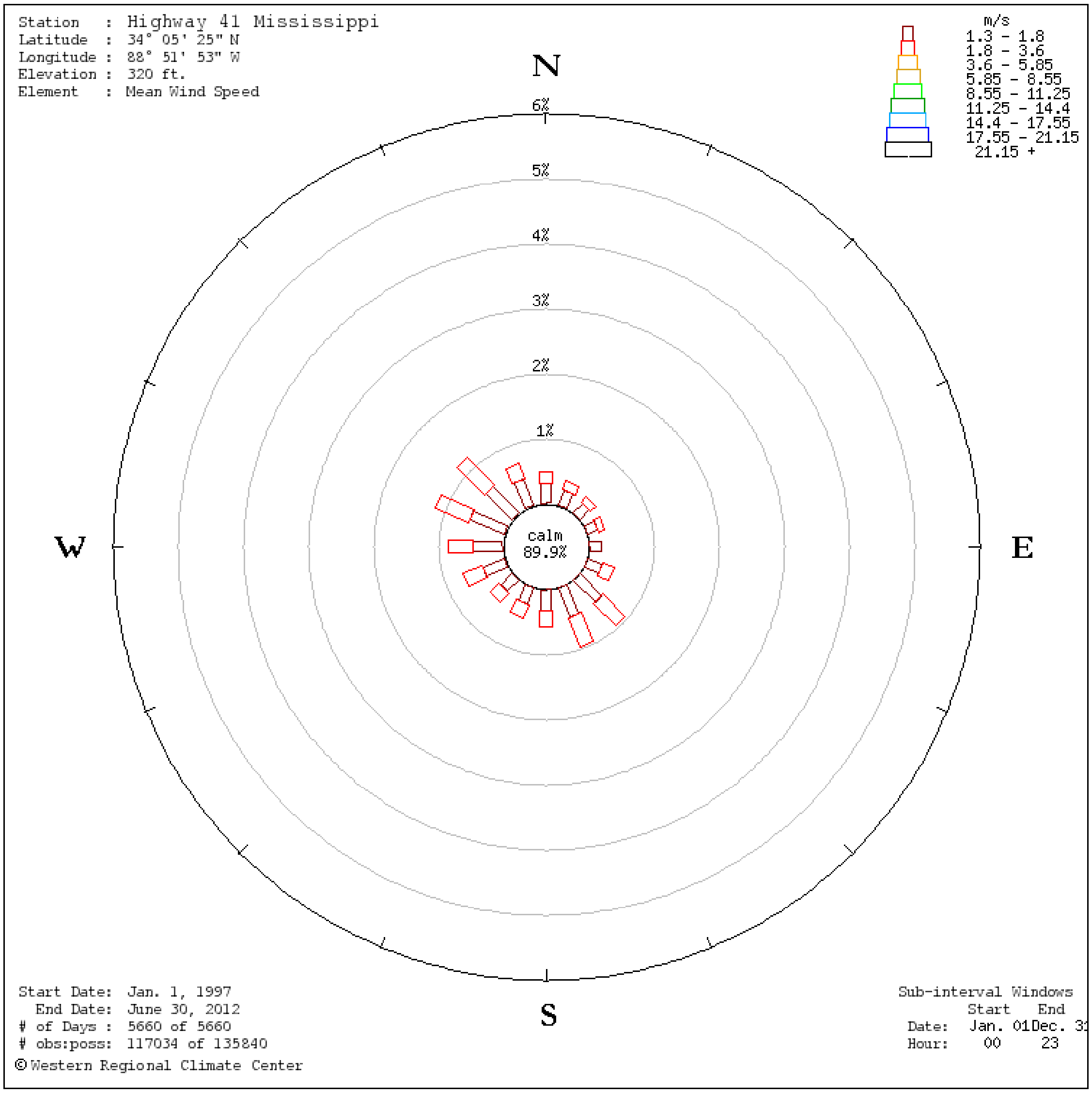

Figure 11. Directional wind rose for the Highway 41 RAWS monitor over the period 1997-2012. Colors represent wind speed classes, and length of individual colored bars represent proportion of wind in a given direction.

4.2.4 Condition and Trend

Overall, the five COOP stations and RAWS near NATR provide a reliable history of weather and climate monitoring at the park. As of this writing, all of the stations are still collecting data.

Of the five stations evaluated, the majority showed an increasing trend in precipitation. While a slight majority showed modest decreasing trends in annual temperature averages, almost as many stations showed either a lack of trend, or a slight increasing trend. These datasets, despite being extensive, are still not sufficient or inappropriate to assess climate change. Because there are no good literature-based mechanisms for assessing the quality of weather and climate, an assessment of condition untenable, even with relatively good data. Therefore, this attribute is not assigned a rank or trend (Table 7).

Table 7. The condition status for weather and climate at NATR was not assigned a rank or trend. The data quality for this attribute was very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Weather and Climate	(not assigned)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

4.2.5 Literature Cited

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and climate inventory, National Park Service, Gulf Coast Network. Natural Resource Technical Report NPS/GULN/NRTR—2007/011. National Park Service, Fort Collins, Colorado.

Karl, T. R., J. M. Melillo, and T. C. Peterson, editors. 2009. Global Climate Change Impacts in the United States. Cambridge University Press, New York, New York.

Southeast Regional Climate Center (SERCC). 2012. Historical climate summaries. Available at http://www.sercc.com/climateinfo/historical/historical.html (accessed May 2012).

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4.3 Water Quality

4.3.1 Relevance and Context

Throughout its 760 km course, NATR passes through 16 8-digit hydrologic cataloging units, and crosses over nearly 1,300 stream segments. In the northern section of the Parkway, streams traverse over rocky parent material before transitioning to loess banks in northern Mississippi, and cypress swamps in the lower section (NPS 2012). Some 43 of these segments are also listed on the EPA 303(d) list of impaired waters, while many others are unimpacted and relatively pristine. Two segments are also classified by the U.S. Fish and Wildlife Service as critical habitat for three federally listed organisms. Because of all of these factors, NATR is considered a category one park unit in regards to its hydrologic resources, meaning they are "central to the park establishment or mission" (NPS 2012). This classification also determines the sampling schedule used at the park unit.

4.3.2 Data and Standards

Beginning in 2007, Earleywine (2010) began water quality sampling at 44 streams along the Parkway. Sampling locations were stratified along the length of NATR and among hydrologic sub-regions. Water quality parameters collected included temperature, dissolved oxygen, specific conductivity, pH, nitrogen, phosphorous, turbidity, acid-neutralizing capacity (ANC), total suspended solids (TSS), and *Escherichia coli* concentration. Sampling for this project lasted until 2009, after which 32 sampling locations were maintained by the GULN for regular sampling. Parameters collected by GULN were the same with the exception of TSS and the nutrient suite was reduced to an indicator nutrient, nitrate. Figure 12 depicts all previous and current sampling stations along the Parkway.

<u>Use Classification</u>

Water quality standards are dictated by each of three states through which NATR passes. Streams are classified according to use, each of which carries a suite of water quality standards. Table 8 lists all sampling stations and designated uses, if available. When streams are not specifically classified into use categories, default classifications are often used. In Alabama, the default use classification is fish and wildlife (FAW), while in Tennessee, the default classification includes four uses: fish and aquatic life (FAQ), recreation (REC), livestock watering and wildlife (LWW), irrigation (IRR). The Mississippi Department of Environmental Quality (MDEQ) does not define a default classification, but instead poses minimum water quality standards (MDEQ 2012a). Despite the variety of use classifications, there is much overlap in water quality standards, depicted in Table 9.

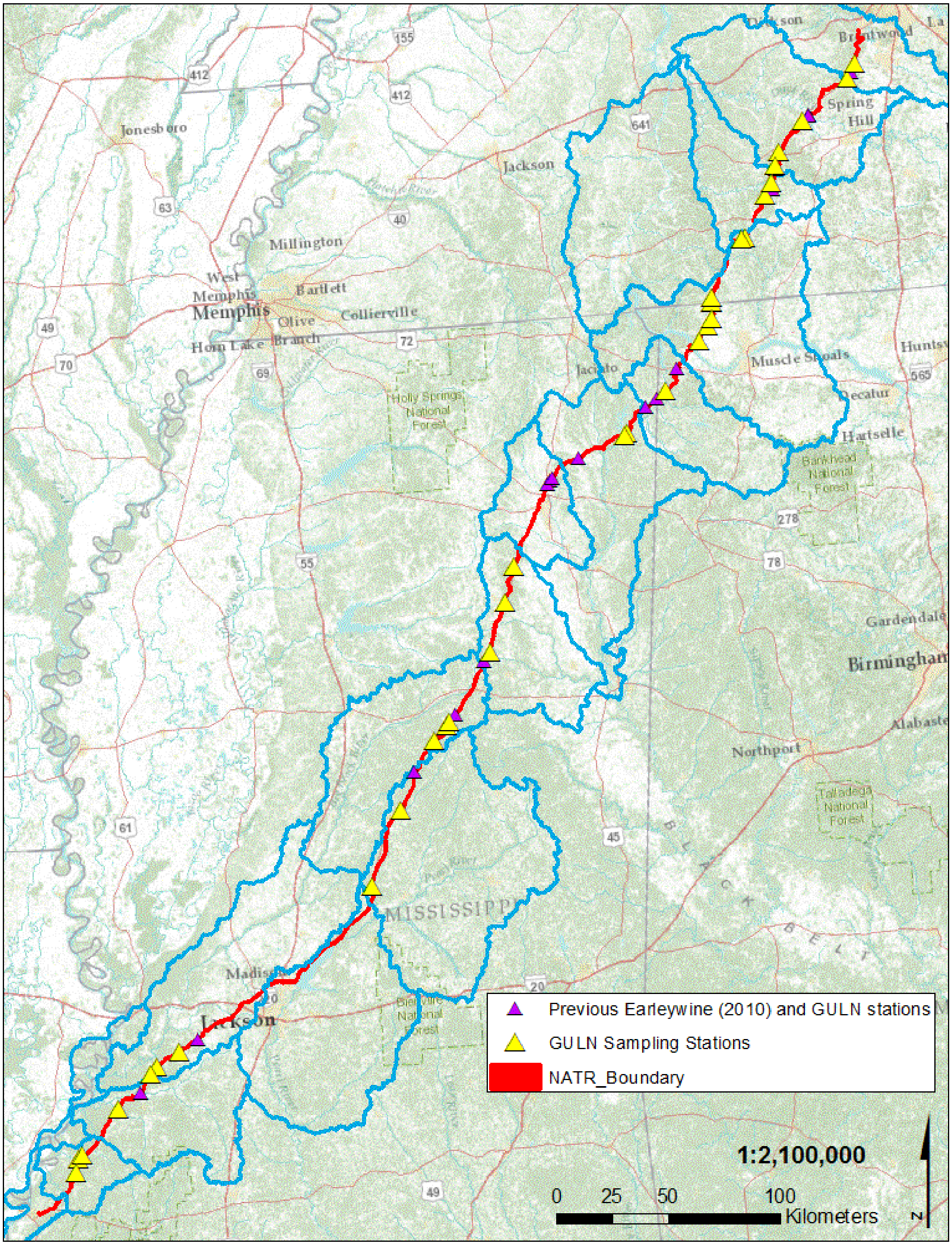

Figure 12. Quarterly water quality collections by GULN began along NATR in 2007 at 44 stations, 32 of which are still regularly sampled by GULN. Blue outlines indicate USGS 8-digit hydrologic unit boundaries.

Table 8. List of 50 sampling stations sampled by Earleywine (2010) and GULN. Quality designations are provided by GULN based on existing data in 2006.

Station ID	Waterbody	State	County	HUC-8	Use* - GULN Quality Designation
NATR_BCBC	Bear Creek	AL	Colbert	6030006	FAW; Potentially Degraded
NATR_BRBR	Burcham Branch	AL	Lauderdale	6030005	FAW
NATR_BRSP	Buzzards Roost Spring	AL	Colbert	6030006	FAW; Potentially Degraded
NATR_CECR	Cedar Creek	AL	Colbert	6030006	FAW
NATR_COCR	Colbert Creek	AL	Lauderdale	6030005	FAW; Potentially Degraded
NATR_LICR	Lindsey Creek	AL	Lauderdale	6030005	FAW
NATR_BAPI	Bayou Pierre	MS	Claiborne	8060203	REC
NATR_BBDI	Big Bywy Creek	MS	Choctaw	8060201	Not Classified - must meet minimum state standards
NATR_BSCR	Big Sand Creek	MS	Claiborne	8060202	Not Classified - must meet minimum state standards
NATR_CLCR	Cole Creek	MS	Attala	3180001	Not Classified - must meet minimum state standards
NATR_CQCR	Chuquatonchee Creek	MS	Chickasaw	3160104	Not Classified - must meet minimum state standards
NATR_FICR	Five Mile Creek	MS	Hinds	8060202	Not Classified - must meet minimum state standards
NATR_FOCR	Fourteen Mile Creek	MS	Hinds	8060202	Not Classified - must meet minimum state standards
NATR_HCCR	Hurricane Creek	MS	Attala	3180001	FAW; Potentially Degraded
NATR_HOCR	Houlka Creek	MS	Chickasaw	3160104	Not Classified - must meet minimum state standards
NATR_JOCR	Jourdan Creek	MS	Tishomingo	3160101	FAW; Potentially Degraded
NATR_LBCR	Little Bywy Creek	MS	Choctaw	8060201	FAW; Potentially Degraded
NATR_LBPI	Little Bayou Pierre	MS	Claiborne	8060203	REC
NATR_LNCR	Line Creek	MS	Webster	3160104	Not Classified - must meet minimum state standards
NATR_LSCR	Little Sand Creek	MS	Claiborne	8060202	FAW; Potentially Degraded
NATR_MBCR	Middle Bywy Creek	MS	Choctaw	8060201	FAW; Potentially Degraded
NATR_MCCR	McCurtain Creek	MS	Choctaw	8060201	Not Classified - must meet minimum state standards
NATR_MICR	Mud Island Creek	MS	Jefferson	8060204	FAW; Potentially Degraded
NATR_MUCR	NATR Mud Creek	MS	Lee	3160102	Not Classified - must meet minimum state standards
NATR_NFCR	North Fork Coles Creek	MS	Jefferson	8060204	FAW; Potentially Degraded
NATR_NICR	Nine Mile Creek	MS	Leake	3180001	Not Classified - must meet minimum state standards
NATR_OFCR	Old Field Creek	MS	Webster	3160104	Not Classified - must meet minimum state standards
NATR_ROCR	Rock Creek	MS	Tishomingo	3160101	Not Classified - must meet minimum state standards

Table 8. (continued)

Station ID	Waterbody	State	County	HUC-8	Use* - GULN Quality Designation
NATR_SFCR	South Fork Coles Creek	MS	Jefferson	8060204	Not Classified - must meet minimum state standards
NATR_TIBC	Bear Creek at Tishomingo	MS	Tishomingo	6030006	REC
NATR_TOCR	Town Creek	MS	Lee	3160102	Not Classified - must meet minimum state standards
NATR_TWCR	Twenty Mile Creek	MS	Lee	3160101	PWS
NATR_BRCR	Brock Creek	MS	Lee	3160102	Not Classified - must meet minimum state standards
NATR_TRRC	Tributary to Rock Creek	MS	Tishomingo	3160101	Not Classified - must meet minimum state standards
NATR_BUBR	Burns Branch	TN	Williamson	5130204	FAL, REC, LWW, IRR
NATR_CHCR	Chief Creek	TN	Lewis	6040004	FAL, REC, LWW, IRR
NATR_COBR	Cooper Branch	TN	Wayne	6030005	FAL, REC, LWW, IRR
NATR_CYCR	Cypress Creek	TN	Wayne	6030005	FAL; REC; LWW; IRR
NATR_DOBR	Dobbins Branch	TN	Williamson	5130204	FAL, REC, LWW, IRR
NATR_ECCR	English Camp Creek	TN	Lewis	6040003	FAL, REC, LWW, IRR
NATR_FAHO	Fall Hollow	TN	Lewis	6040003	FAL, REC, LWW, IRR
NATR_FBBR	Fattybread Branch	TN	Hickman	6040003	FAL, REC, LWW, IRR
NATR_GACR	Garrison Creek	TN	Williamson	5130204	FAL, REC, LWW, IRR
NATR_GHDR	Duck River	TN	Hickman	6040003	DOM, IWS, FAL, REC, LWW, IRR
NATR_GLBR	Glenrock Branch	TN	Wayne	6030005	FAL, REC, LWW, IRR
NATR_JABR	Jacks Branch	TN	Lawrence	6040004	FAL, REC, LWW, IRR
NATR_JAFA	Jackson Falls	TN	Hickman	6040003	FAL, REC, LWW, IRR
NATR_LISW	Little Swan Creek at Monument Road	TN	Lewis	6040003	FAL, REC, LWW, IRR
NATR_MFBR	Buffalo River	TN	Lewis	6040004	DOM, IWS, FAL, REC, LWW, IRR
NATR_PKLS	Little Swan Creek at Parkway	TN	Lewis	6040003	FAL, REC, LWW, IRR
NATR_SWBR	Sweetwater Branch	TN	Wayne	6030005	FAL, REC, LWW, IRR

AL: Fish and Wildlife (FAW)
MS: Recreation (REC), Fish and Wildlife (FAW), Public Water Supply (PWS)
TN: Fish and Aquatic Life (FAL), Recreation (REC), Livestock Watering and Wildlife (LWW), Irrigation (IRR), Domestic Water Supply (DOM), Industrial Water Supply (IWS)

Table 9. Water quality standards for streams at NATR according to all listed state uses in MS (MDEQ 2012a), AL (ADEM 2012), and TN (TDEC 2007).

Parameter	Standard
Temperature	AL,MS: ≤ 32.2˚C TN: ≤ 30.5˚C
Dissolved Oxygen	≥ 5.0 mg/L daily mean; ≥ 4.0 mg/L instantaneous
pH	AL: 6.0 to 8.5 SU MS, TN: 6.0 to 9.0 SU
Specific Conductance	≤ 1000 µS/cm (≤ 500 µS/cm for Public Water Supply – MS);
Turbidity	≤ 50 NTUs above natural conditions
Bacteria (*Escherichia coli*)	AL: Max 548 colonies/100 mL geometric mean (≥5 samples over 30-day period); 2,507 colonies/100 mL single sample; 487/100 mL single sample incidental contact June - September MS: Max 200 colonies/100 mL (≥5 samples over 30-day period); 400 colonies/100 mL for 10% of samples (May – October) Max 2000 colonies/100 mL (≥5 samples over 30-day period); 4000 colonies/100 mL for 10% of samples (November – April) TN: Max 126 colonies/100 mL geometric mean (≥5 samples over 30-day period); 941 colonies/100 mL single sample*

*Bacteria standards for TN are different for FAL and REC; streams sampled along NATR are classified as both, and thus the more stringent REC standards are listed

4.3.3 Reporting Areas

Because of the great variety and geographic separation of aquatic resources in NATR, water quality condition was reported by reporting areas based upon watershed boundaries. Water quality was reported for 13 USGS Hydrologic Unit Code (HUC) level 8 watersheds traversed by the Parkway. A park-wide summary of water quality is also provided, with an overall park condition rank.

4.3.4 Resource Knowledge Summary

Dissolved Oxygen

Dissolved oxygen (DO) is typically measured *in situ* using a sensor that adjusts for temperature and which is calibrated for atmospheric pressure at each site. The significance of this observation derives from its sensitivity to natural or anthropogenic alterations to the stream, as sensitive aquatic plants are one of the main sources of oxygen, along with aeration and mixing of atmospheric O_2. Sufficient concentrations of DO are also important to the survival of essentially all aquatic species (Palmer et al. 1997). Nutrient enriched runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (EPA 1997).

Standards are fairly consistent among the three states, specifying a minimum daily mean of 5.0 mg/l, or instantaneous minimum of 4.0 mg/l. Means of instantaneous values at all stations since monitoring began in 2007 were above or well above both thresholds, with the exception of Cole Creek (Figure 13). Cole Creek was sampled seven times between fall 2007 and winter 2009, during which four samples were below 4.0 mg/l. Cole Creek is not included in the current sampling schedule on NATR. Dissolved oxygen was also noticeably lower at the four stations below Cole Creek, wherein some samples fell below the 4 and 5 mg/l thresholds. Based on sampling during 2007 to 2009, Earleywine (2010) found a significant difference in dissolved oxygen concentrations among basins, with lowest mean values in the Mississippi (HUC 080602) and Pearl (HUC 031800) basins. The lower DO values may be the result of flatter topography in these Mississippi basins, resulting in slow-moving waters that lack aeration. Earleywine (2010) also attributes low DO concentrations to generally higher temperatures in the southern region. Streams and rivers with lower measured DO in these basins include Cole Creek, Hurricane Creek, Fourteen Mile Creek, Five Mile Creek, Big Sand Creek, and Little Sand Creek. Low DO was also measured on Line Creek and Old Field Creek in the Tombigbee basin, and on Lindsey Creek in the Tennessee basin.

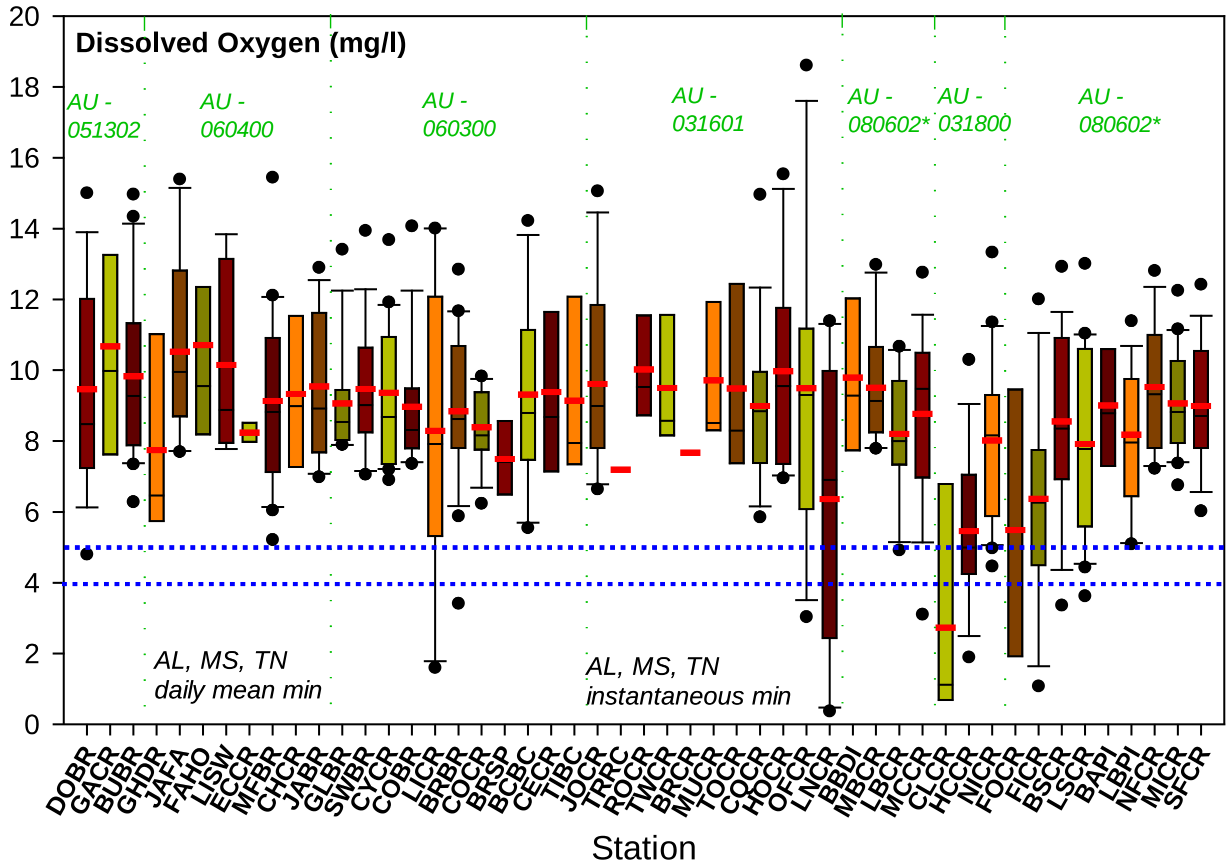

Figure 13. Summaries of instantaneous dissolved oxygen concentrations at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries.

pH

Measurement of pH is an important water quality attribute, because it affects almost all biological processes within aquatic systems. Low levels of pH (i.e. acidic) can potentially increase the mobility of toxic elements, and in turn, their uptake by aquatic plants and animals (EPA 1997). Even at only slightly acidic levels (6.0-6.5), species richness of phytoplankton, zooplankton, and benthic invertebrates can be inhibited, while levels between 5.0 and 6.0 can result in mortality of several fish species. In addition, algal growth increases at these acidic levels, which translates into an increased risk of mortality for macroinvertebrate species. Levels of pH below 5.0 can result in the loss of most fish species, decreased rate of nutrient cycling and organic matter decomposition, and can result in reproductive failure of certain sensitive amphibians (Driscoll et al. 2003).

State standards for pH specify a minimum of 6.0 standard units (SU), and a maximum of 8.5 SU in Alabama and 9.0 in Mississippi and Tennessee. Roughly nine percent of GULN observations fell below 6 SU, most of which were in the Tennessee and Pearl basins (Figure 14). The Pearl basin, as Earleywine (2010) points out, is more closely associated with evergreen forests, which can contribute to elevated acidity levels. Repeated low values for pH were observed on Cooper Branch and Lindsey Creek in the Tennessee basin and also on Rock Creek and Line Creek in the Tombigbee basin. No stations exceeded maximum limits for pH.

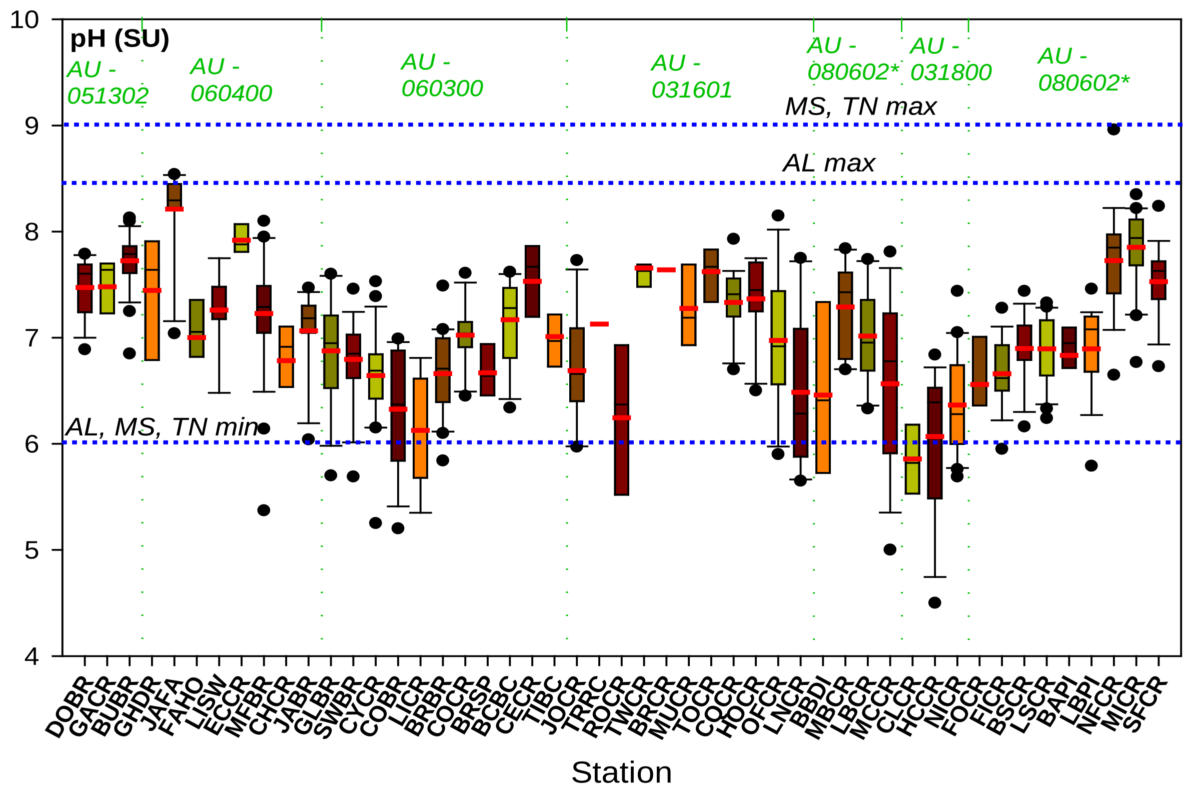

Figure 14. Values for pH at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries.

<u>Acid-neutralizing Capacity</u>

Acid-neutralizing capacity (ANC) is measured to assess the relative ability of the water to buffer acidic loading resulting from precipitation or other sources. It is the most common measurement used to assess sensitivity to acid deposition, wherein lower ANC values generally correspond to higher levels of aluminum ion (Al^{n+}), as well as a greater level of toxicity to aquatic biota such as fish, invertebrates, and periphyton (Sullivan et al. 2011). Although calcium carbonate is used as an equivalent standard for ANC values, it reflects the concentration of all substances that would tend to raise the water pH above approximately 4.5 (EPA 1986). Higher values of ANC are particularly influenced by concentrations of carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), phosphates (PO_4^{3-}), and hydroxides (OH^-). When referring to calcium carbonate concentrations, units of mg L^{-1} are used, while microequivalents per liter (μeq L^{-1}) are used to reflect concentrations of other compounds influencing alkalinity. Conversion between the two units is presented according to equation:

$$20*ANC\,(\mu eq\,L^{-1}) = ANC\,(mg\,L^{-1})\;\; 20*ANC\,(\mu eq\,L^{-1}) = ANC\,(mg\,L^{-1}) \qquad \text{(Eq. 1)}$$

Acid-neutralizing capacity is similar to alkalinity, another common measure of buffering capacity, but differs in that it is tested using an unfiltered sample. Particulate matter removed from samples tested for alkalinity can affect buffering capacity, resulting in different measurements for each of these parameters (Radtke et al. 1998).

Fewer samples for ANC were collected over the period of monitoring than for the other core water quality parameters; following the work of Earleywine, the GULN focused on continued ANC monitoring of streams shown to have low values. Although none of the state standards express target ranges for ANC, the EPA Goldbook (EPA 1986) specifies values greater than 20 mg/l for alkalinity to benefit aquatic life. Values observed on NATR vary widely (Figure 15) and are likely closely tied to local lithology. For the most part, stations near the border of the Lower Cumberland and Tennessee basins that observed low ANC values, for example, are the same ones that reported periodic low pH values. The same is true for stations bordering the Tombigbee and Pearl basins. The exceptions are samples taken on Cooper Branch and Lindsey Creek, which reported frequent low pH values (Figure 14) but relatively high ANC values (Figure 15). Both of these stations are located in major agricultural areas, the runoff of which may have contributed to the pH levels (McLeod and Hegg 1984).

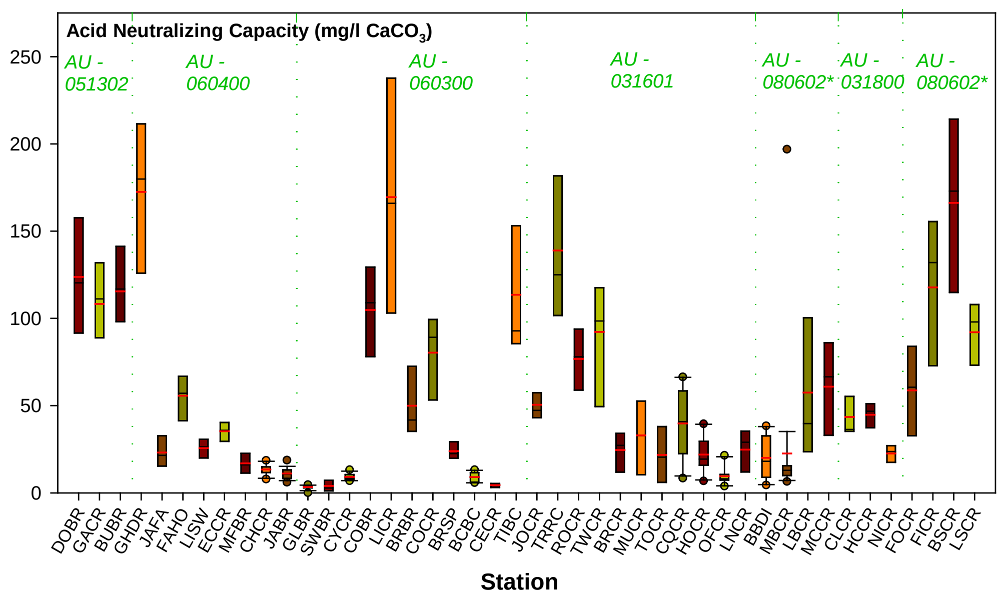

Figure 15. Acid-neutralizing capacity at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries.

Microorganisms

Bacterial contamination in water is usually determined through measurements of total coliform, fecal coliform, or *Escherichia coli* concentrations. Total coliform bacteria are a group of bacteria that live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated viruses and pathogens. Total coliform counts themselves, however, do not necessarily represent a health risk, as many types of coliform bacteria are harmless. Fecal coliform are a subset of total coliform bacteria that exist only in warm-blooded organisms, and may often originate in streams via wildlife feces. Because *E. coli* is a type of fecal coliform that is relatively easy to measure, it is commonly used to indicate fecal contamination.

Standards for different bacterial groups vary according to use, with more stringent values assigned to recreational waterbodies. Tennessee and Alabama specify geometric mean maximum *E. coli* concentrations for at least five samples collected within a 30-day period (Table 9). However, these thresholds are not shown in Figure 16 because sampling was not frequent enough at any station to test this requirement. Alabama specifies a maximum single sample concentration of 2,507 colonies/100 mL, which is higher than the detection limit of 2,419 colonies/100 mL used to collect the data. During the warmer months when incidental contact due to recreation is likely (June – September), a maximum of 487 colonies/100 mL is imposed. Tennessee specifies a single sample maximum of 941 colonies/100 mL statewide, but a 487/100 ml standard for NPS waters. Mississippi also divides limits by season, specifying a lower concentration during the period May – October, during which maximum concentration for 10% of all samples cannot exceed 400 colonies/100 mL. The maximum of 4,000 colonies/100 mL during the remainder of the year exceeds the detection limit.

In Tennessee, nine percent of I&M samples at seven stations exceeded the single sample maximum over the sampling period, while in Mississippi, nine stations exceeded 400 colonies/100 mL for at least 10% of samples during the warm months. A few elevated concentrations were also observed at Lindsey Creek and Buzzards Roost Spring in Alabama, though most occurred outside of defined warmer months. Many of these stations are located by agricultural land where runoff from grazed pasture areas during high flow may contribute to elevated concentrations.

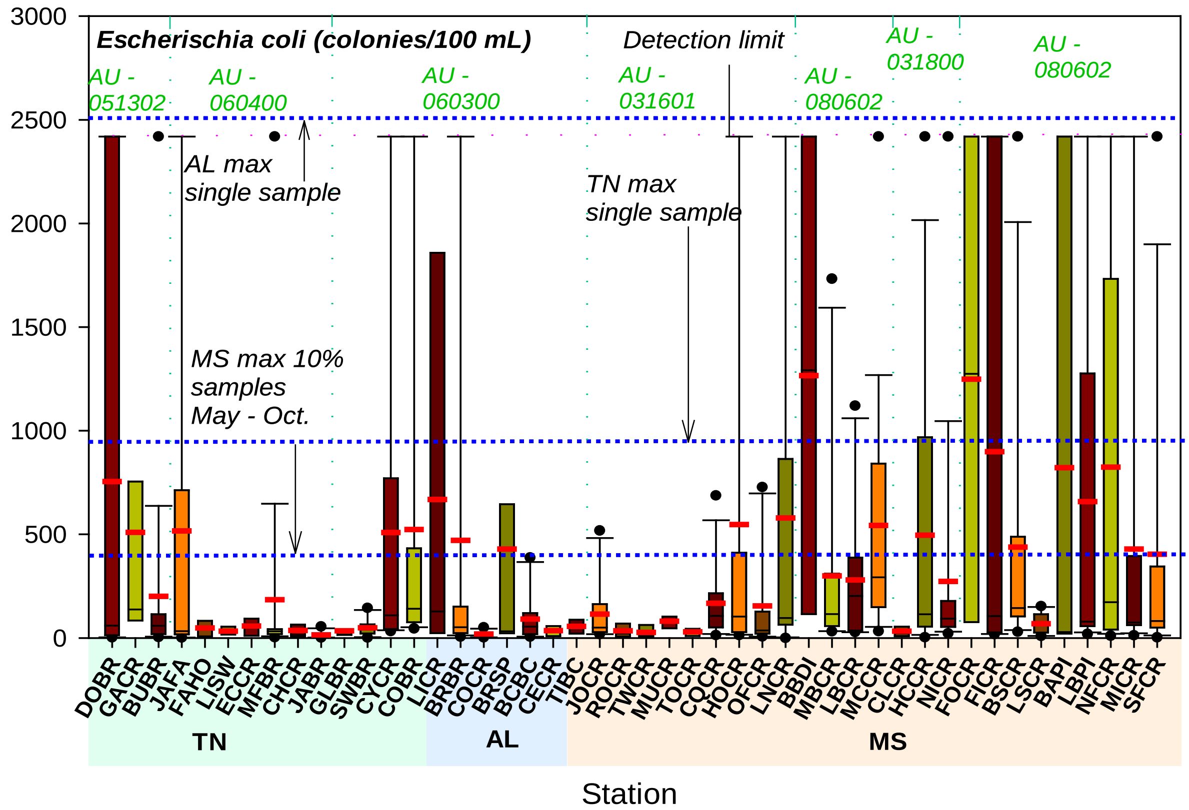

Figure 16. E. coli concentration at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries. Space was insufficient to list all state standards, though threshold lines are shown.

Temperature

Temperature is an important factor for water quality because it interacts with other parameters. As temperature increases, breakdown of organic material generally accelerates, which can lead to elevated oxygen demand through microbial activity. This, combined with lower solubility of oxygen at warmer temperatures, can quickly lead to oxygen depleted water and reduced survival of sensitive organisms. Higher temperatures also correspond to greater toxicity rates of certain substances (EPA 1986).

Temperature observations along NATR show a clear increase from north to south (Figure 17). Most all observations fall below state limits of 30.5°C (TN) and 32.2°C (AL, MS), with the exception of the four southernmost stations. These stations observed exceedances during summer months with the exception of early June sampling in 2008, which recorded high temperatures at both North and South Fork Coles Creek. Two sampling dates – one each in June and July of 2008 – recorded temperatures exceeding state standards on Twenty Mile Creek in northern Mississippi. Twenty Mile Creek is a large waterbody that flows adjacent to agricultural land before reaching NATR, which might explain the high temperature observations.

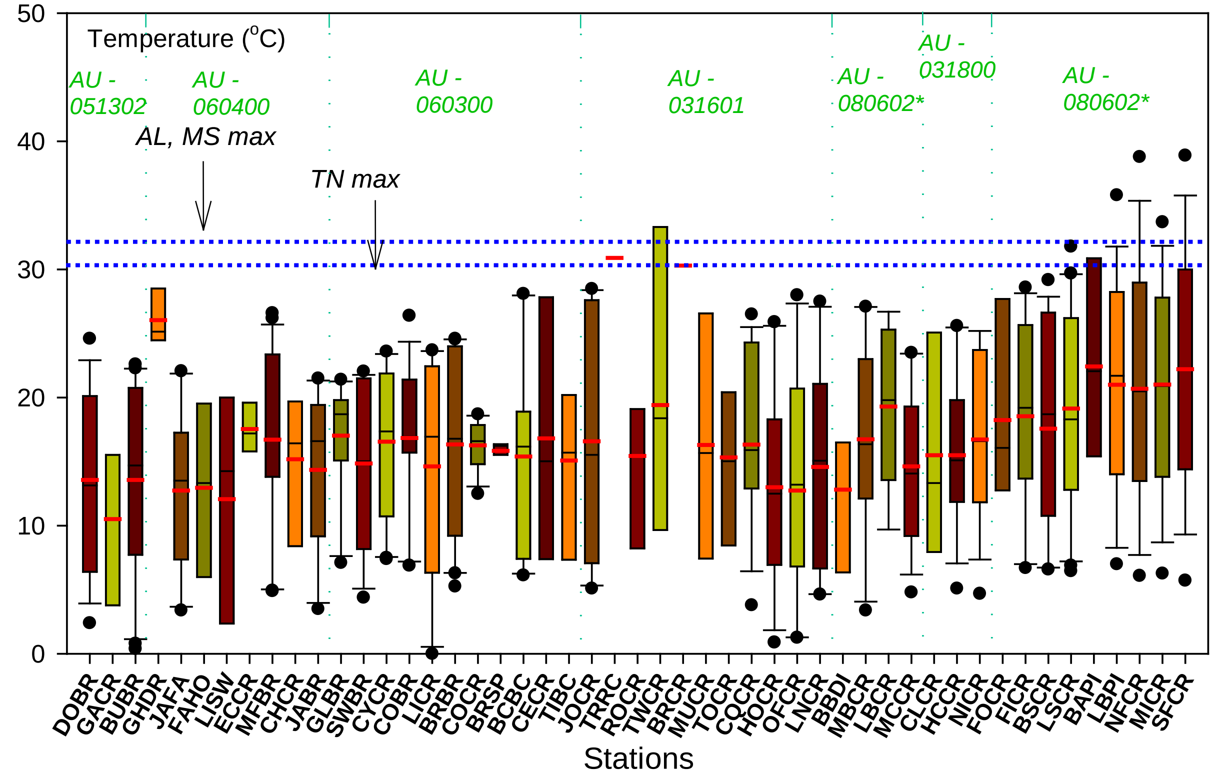

Figure 17. Temperature at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries.

<u>Specific Conductance</u>

Specific conductance gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Parent material is one of the main influences on conductance, because bedrock types that do not contribute many dissolved materials, such as granite, can result in a much lower conductivity than materials that freely contribute ionized components, such as limestone (EPA 1997). However, anthropogenic factors such as sewage discharge can also affect conductivity, which may raise or lower conductance from natural levels. As a result, it is difficult to discern the potential for pollution from conductance values alone, and is perhaps more useful to compare measurements to a baseline value.

Conductance is measured as the reciprocal of resistance and expressed in micro-Siemens per cm (µS/cm). Although no state standards exist for this parameter, the EPA (1997) sampling methods manual identifies 50 to 1,500 µS/cm as typical for waters in the US. It also outlines an ideal range of 150 to 500 µS/cm for “inland fresh waters…supporting good mixed fisheries,” and furthermore suggests that “conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates.” Generally, higher rates of conductivity are also associated with sources of pollution and indicate poor water quality (Wenner et al. 2003); the American Water Works Association (AWWA) recommends values below 400 µS/cm demonstrate the best water quality (Long and Plummer 2004).

Values for specific conductance were highly variable among sites, with the highest values observed on sites in the northern portion of the Mississippi basin (Figure 18). Although the EPA guidelines are very general, roughly two-thirds of I&M observations fell outside the recommended range of 150 to 500 µS/cm for specific conductance, the vast majority of which fell below it. Earleywine (2010) found significant differences in conductance among basins, with higher values observed in the Upper Cumberland (HUC 051302), Tombigbee (HUC 031601), and Mississippi (HUC 080602) basins. These differences are still observable in the current data. Naturally, depending on bedrock and other watershed minerals, some streams have higher natural dissolved ionic loads than others. In addition, SpC is higher during low flow conditions and lower during times of high flow. Steams that do not behave this way indicate potential issues. MBCR and LBCR at times behave oddly, and may be related to discharges or activities in the lignite mine upstream of the sampling sites (J. Meiman, personal communication).

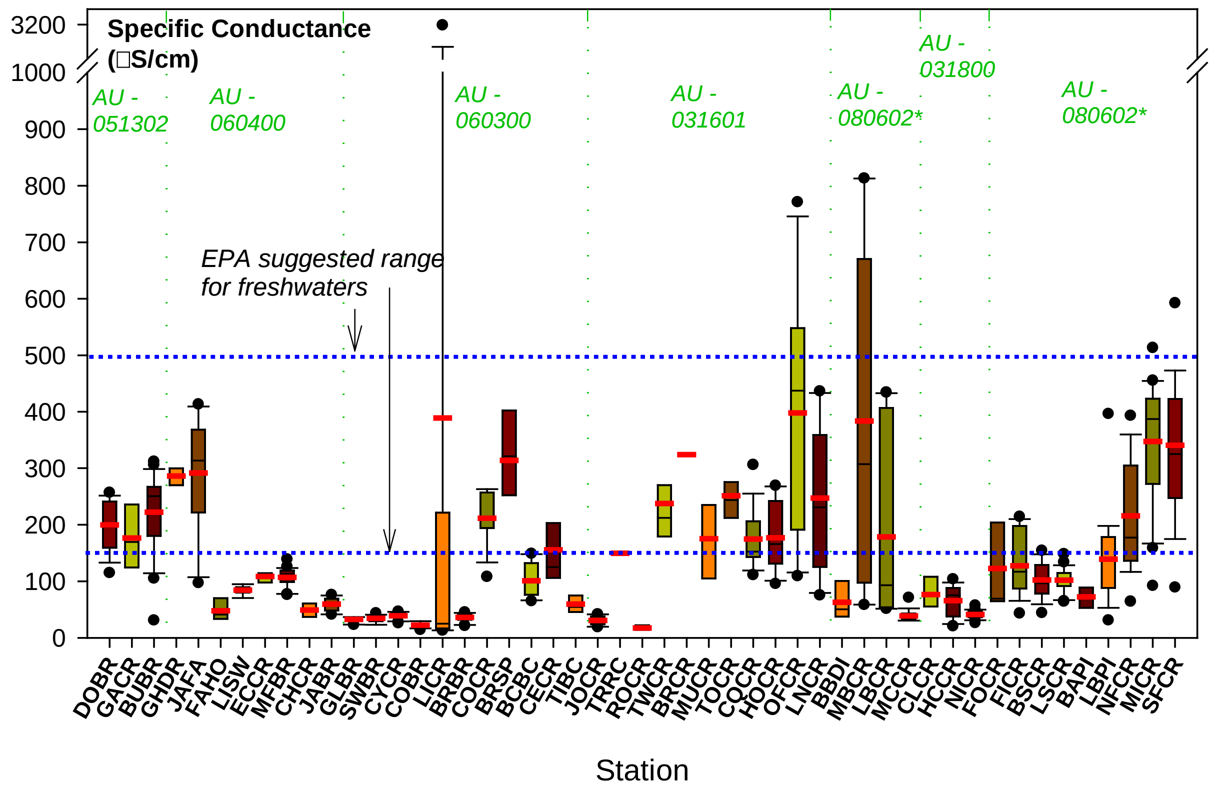

Figure 18. Specific conductance at stations along NATR over history of monitoring (Oct. 2007 - July 2012). Boxes represent quartiles with median; red line depicts mean. Whiskers depict 90th and 10th percentiles; points show outlying points. Stations are arranged from north to south; green lines depict hydrologic basin boundaries.

303(d) Impaired Waters

The Clean Water Act of 1972 requires each state to generate a list of its impaired waters bi-annually. Impaired waters are those which violate certain water quality parameters, which in turn depend on the use classification of the water body. Often, only certain sections are classified as impaired. In cases where the violation is due to a specific and identifiable pollutant, a Total Maximum Daily Load (TMDL) limit is assessed.

Along NATR, 20 streams are included on the most recent 2012 lists of 303(d) of impaired waters in Mississippi (MDEQ 2012b) and Tennessee (TDEC 2012) (Table 10). No currently listed 303(d) streams cross NATR in Alabama. Segments passing through the parkway total 16.9 km in length, and are mainly clustered around Jackson and Tupelo, MS (Figure 19). Reasons for listing vary, but most commonly include biological impairment due to sedimentation, hypoxia, nutrient loading, and fecal coliform contamination.

Table 10. NATR intersects with 20 stream segments listed as state impaired 303(d) waters. Streams are listed north-to-south. *Indicates NPS monitoring station present on creek.

Stream	Length in Park (km)	Reason	Years Listed
Dog Creek	0.32	*E. coli* concentrations due to municipal point source and pasture grazing	2012
*Duck River	2.12	Atmospheric Mercury Deposition	2012
*Buffalo River	1.29	Atmospheric Mercury Deposition	2012
*Chief Creek	0.27	Flow Alteration due to Upstream Impoundment	2012
Squaw Branch	1.61	Hypoxia, Low Flow Alteration due to upstream impoundment	2006, 2008, 2010, 2012
*Rock Creek	2.05	Biological Impairment	2002, 2004, 2006, 2008, 2010, 2012
Little Brown Creek	0.20	Biological Impairment	2002, 2004, 2006, 2008, 2010, 2012
Sand Creek	0.40	Biological Impairment	2010, 2012
Tubbalubba Creek	0.18	Biological Impairment	2006, 2008, 2010, 2012
Chico Creek	0.24	Biological Impairment	2010, 2012
Cane Creek	0.49	Biological Impairment	2010, 2012
*Line Creek	0.23	Biological Impairment	1996, 1998, 2002, 2004, 2006, 2010, 2012
Dry Creek	0.80	Biological Impairment	2010, 2012
Turkey Creek	1.11	Biological Impairment	2010, 2012
*Five Mile Creek	0.33	Biological Impairment	2010, 2012
*Big Sand Creek	0.25	Biological Impairment	2010, 2012
*Bayou Pierre	0.64	Low pH	1996, 1998, 2002, 2004, 2012
*N. Fork Coles Creek	1.52	Biological Impairment	1996, 1998, 2002, 2004, 2006, 2008, 2010, 2012
*Mud Island Creek	1.03	Biological Impairment	2010, 2012
Saint Cathrine Creek	1.84	Biological Impairment	2002, 2004, 2006, 2008, 2010, 2012

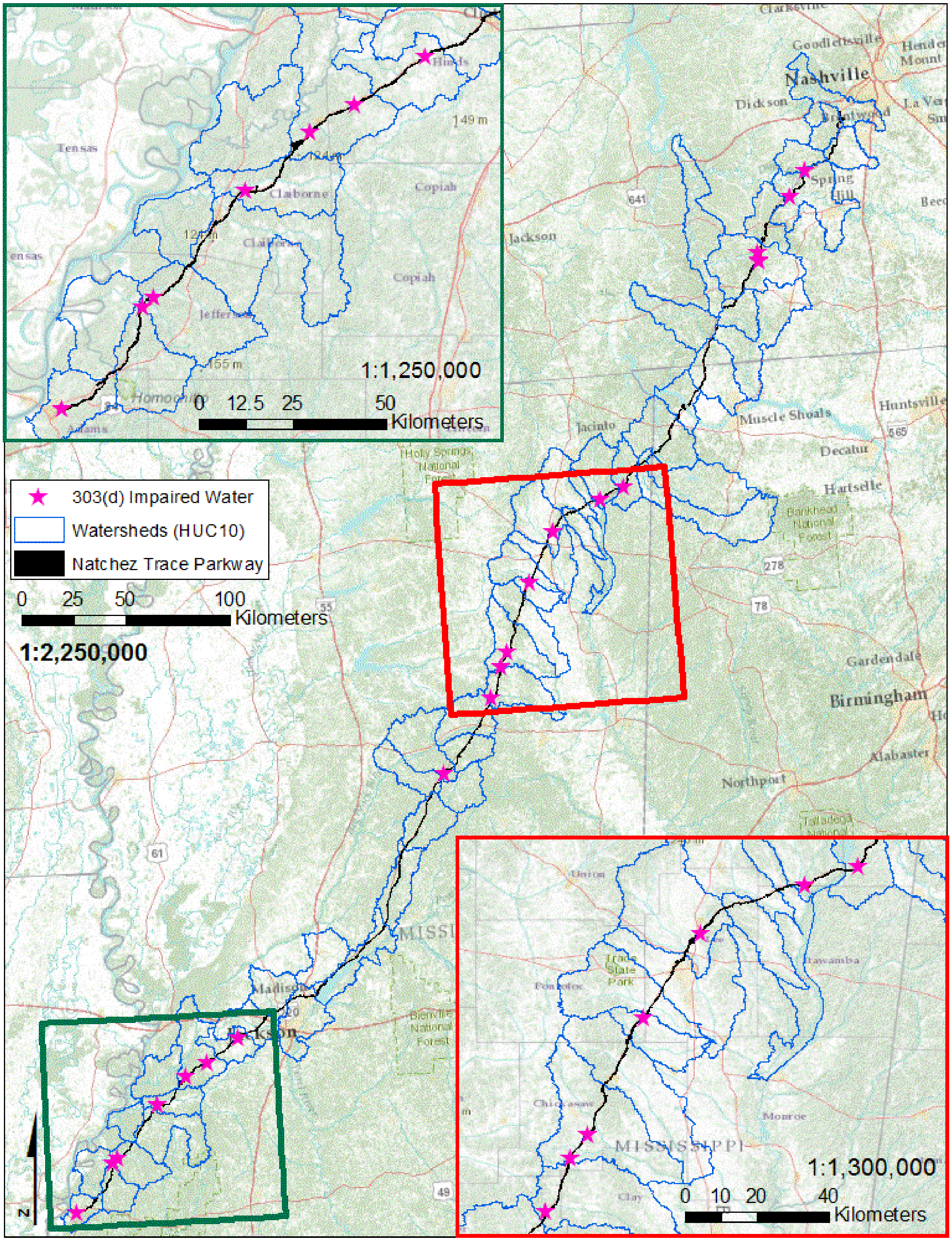

Figure 19. Twenty impaired 303(d) streams cross NATR, most of them near Jackson and Tupelo, MS.

4.3.5 Condition and Trend

<u>Lower Mississippi-Natchez (HUC 08060100)</u>
This southernmost cataloging unit through which NATR passes contains no sampling stations, past or present, but does contain the crossing of St. Catherine Creek, one of the twenty crossings of 303(d) impaired waters, which has been listed for biological impairment since 2002. Because of the lack of data, this unit is not ranked for water quality (Figure 20).

<u>Coles Creek (HUC 08060204)</u>
Data in this cataloging unit were included from three sampling locations, one each along N. Fork Coles Creek, Mud Island Creek, and S. Fork Coles Creek. These three stations, originally sampled by Earleywine (2010), are included in the GULN sampling schedule. Values observed at these stations showed mostly typical values. Temperature observations at these three stations were the highest recorded along the Parkway and regularly exceeded the state maximum during summer months. It is likely this is due to natural conditions, because these stations are the most southern and are likely shallow and slow-moving due to topography. Values for pH were also in the higher range of those observed on the Parkway, even though all fell within state standards. Dissolved oxygen and specific conductance also fell within a normal range, with values for ANC falling within the EPA recommended range. Concentrations at all sampling stations for *E. coli* were often high, though most such observations occurred during colder months, and only N. Fork Coles Creek exceeded the state limit.

North Fork Coles Creek and Mud Island Creek are both listed on the 2012 list of 303(d) impaired waters. North Fork Coles Creek has been listed for eight reporting years since 1996 – more often than any other impaired water on the Parkway. Mud Island Creek was originally listed in 2010. Both streams are currently listed due to biological impairment. While each parameter fell within mostly normal ranges with the exception of *E. coli* concentrations on N. Fork Cole Creek and temperature at all three stations, two of the three stations are located on currently 303(d) impaired waters. As a result, this cataloging unit is assigned a condition of fair, with no trend assigned (Figure 20).

<u>Bayou Pierre (HUC 08060203)</u>
Data in this cataloging unit are available from two sampling stations – Bayou Pierre and Little Bayou Pierre – the latter of which is still included in regular I&M sampling. Like the stations in the Coles Creek cataloging unit, Little Bayou Pierre exceeded the temperature limit, though only on a single occasion. Little Bayou Pierre also fell below the pH limit on a single occasion, and on Bayou Pierre, additional sampling by MDEQ showed repeated samples that fell below the minimum. Specific conductance and dissolved oxygen values fell within normal range. *E. coli* concentrations were elevated at both stations, though only exceeding state standards at Little Bayou Pierre.

Bayou Pierre was included as a 303(d) impaired water up until 2007, at which point it was removed due to improved water quality. It was relisted, however, in 2012 due to low pH. This is evident in available sampling data, wherein only 73% of observations were within state limits. Because of this listing as well as the *E. coli* concentration violation, a condition of fair is assigned to this unit (Figure 20).

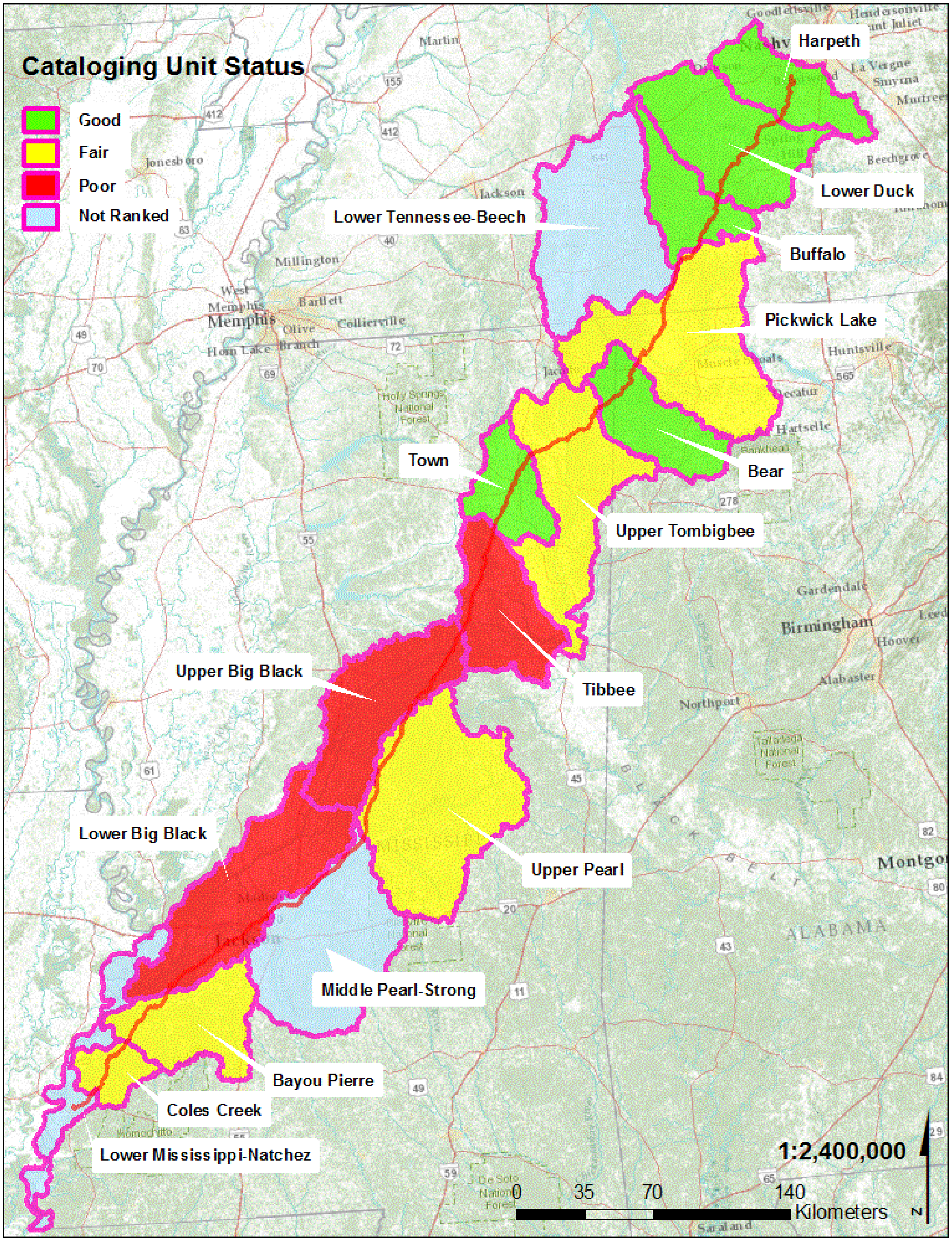

Figure 20. Cataloging units along NATR were ranked based on available sampling data from Earleywine (2010) and GULN efforts (2009 - 2012). Some additional data was available from state agency or previous NPS sampling. Thirteen cataloging units were ranked, while three were not due to lack of data.

Lower Big Black (HUC 08060202)
Four stations were sampled in this cataloging unit: Big Sand Creek, Five Mile Creek, a tributary to Fourteen Mile Creek, and Little Sand Creek. All except the Fourteen Mile Creek tributary are included in current I&M sampling. Parameters appeared mostly normal with the exception of some low DO values at all stations. At the Fourteen Mile Creek tributary, five of seven observations between 2007 and 2009 were below the state standard, resulting in a 29% compliance rate. Respective compliance rates for Five Mile Creek, Big Sand Creek, and Little Sand Creek, respectively, were 53, 88, and 68% - all of which are markedly low. *E. coli* concentrations during warm months also exceeded the state standard for the Fourteen Mile Creek tributary and Big Sand Creek. In addition to I&M sampling at these four stations, a single visit to Lindsey Creek by the MDEQ along the NATR in early 2006 reported normal values.

Big Sand Creek, Turkey Creek, and Five Mile Creek were all included on the state impaired waters list in 2012 for biological impairment and were originally listed in 2010. As a result of these listings, low DO, elevated *E. coli* concentrations, and numerous affected streams, this cataloging unit is assigned a condition status of poor (Figure 20).

Upper Pearl (HUC 03180001)
This cataloging unit was sampled regularly at three stations: Hurricane Creek, Nine Mile Creek, and Cole Creek. Most parameters among these stations were comparable, though dissolved oxygen concentrations were inconsistent. Cole Creek was only sampled as part of Earleywine's (2010) study, during which several samples were well below the minimum of 4 mg/l. Some early samples were also low on Hurricane Creek, though all I&M observations were normal. A quarter of pH samples on Hurricane Creek were also below the state minimum, though again all samples were normal after I&M sampling began. Hurricane Creek also exceeded the state standard for *E. coli* concentration.

Despite the low DO and pH values at Hurricane Creek, these values have fallen within state limits since I&M sampling began, and as a result a trend of improving is assigned. Because of the ongoing elevated *E. coli* concentrations, as well as the past history of very low DO on Cole Creek, a condition of fair is assigned (Figure 20). Renewed sampling on Cole Creek could verify whether conditions have improved. No 303(d) impaired waters are included in this cataloging unit.

Upper Big Black (HUC 08060201)
Four stations are located in the Upper Big Black cataloging unit: Big Bywy Creek, Little Bywy Creek, Middle Bywy Creek, and McCurtain Creek. Big Bywy is not included in current I&M sampling, while Middle Bywy Creek and McCurtain Creek were not sampled by Earleywine (2010). At Big Bywy Creek and McCurtain Creek, occasional low pH samples were observed, resulting in a 66% compliance rate (out of six samples) for the former and 71% for the latter. Values for ANC were relatively low at Big Bywy Creek and Middle Bywy Creek, though both means were slightly above the 20 mg/l EPA recommended minimum for aquatic life. These stations occur on the Urbo-Oaklimeter-Chenneby soil association, each series of which are strongly acidic.

Some of the highest values for specific conductance were observed on Middle and Little Bywy Creeks. This is most certainly strongly influenced by runoff high in dissolved solids from the nearby Red Hills Mine located less than 4 km from both sampling locations. The Red Hills Mine is a 2,350 ha lignite mine that began excavation in 2000 and supplies coal to the Red Hills Power Plant in Ackerman, MS. Additional NPS sampling on several dates in 1997 at the mine site showed normal conductance values prior to excavation (Figure 21). Most samples averaged below 50 µS/cm before 1997, while I&M sampling on Little Bywy and Middle Bywy Creeks averaged 178 and 383 µS/cm, respectively. This large difference between baseline and current levels strongly suggests the influence of pollutive inputs.

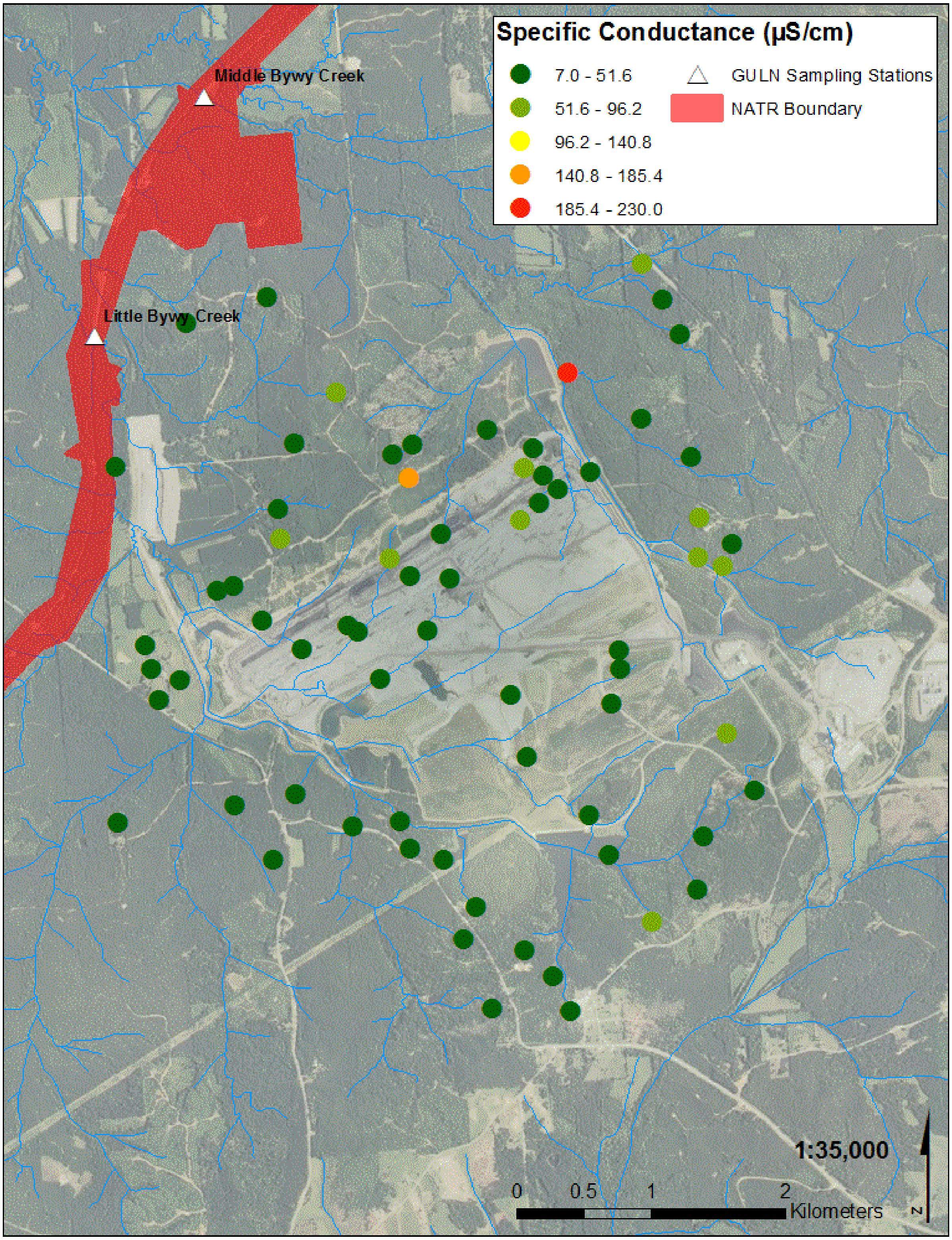

Figure 21. NPS sampling in 1997 showed low specific conductance values around the future site of the Red Hills Mine, which began lignite production in 2000.

Dry Creek is the only waterbody in this cataloging unit included on the 303(d) list of impaired waters. It was originally listed in 2010 and is currently listed due to biological impairment. Overall, assessment of this cataloging unit is based on sampling at Little, Big, and Middle Bywy Creeks. As a result of the low pH values and strong influence from the Red Hills Mine on two of these locations, water quality receives a condition status of poor (Figure 24). Sampling at additional large crossings further north, such as at Pigeon Roost Creek or Moores Creek, may result in a more positive depiction of water quality in this unit.

Tibbee (HUC 03160104)

In the Tibbee cataloging unit, sampling is available from four locations: Line Creek, Old Field Creek, Houlka Creek, and Chuquatonchee Creek. For the most part, Line Creek and Old Field Creek showed similar parameters, many of which were impacted, while Houlka and Chuquatonchee Creeks showed similar, unimpacted parameters.

Old Field Creek showed extremely variable DO, including some low values. Line Creek showed some of the lowest values for DO of any station; four of ten observations between 2007 and 2012 were below the state minimum. Values at the other two stations were all within normal range. On Line Creek, three of ten samples also fell below the state pH minimum. Specific conductance values were also high at both Line Creek and Old Field Creek, the latter of which had the highest mean value for specific conductance of 398 µS/cm. The mean at Line Creek over the same period was 247 µS/cm. ANC values at all four sampling sites were low, particularly at Old Field Creek. Finally, both Line Creek and Old Field Creek exceeded state standards for *E. coli* concentrations. Both Line Creek and Old Field Creek and upstream tributaries drain mostly pine plantations and agricultural land. Fertilizer runoff could result in the observed low DO levels or high *E. coli* concentrations.

Line Creek has a history of biological impairment, having been listed as an impaired water for seven cycles since 1996. Cane Creek and Chico Creek have also been listed as biologically impaired since 2010.

Based on available sampling data, observations at Line Creek and Old Field Creek reflect polluted waters, and as a result, this cataloging unit receives a condition status of poor (Figure 20). These creeks also dry during drought, resulting in disconnected pools (J. Meiman, pers communication), potentially adding to the biotic stress.

Town (HUC03160102)

This cataloging unit is informed by three sampling stations: Town, Mud, and Brock Creeks. These stations were only sampled by Earleywine (2010), and thus data is relatively sparse. Available data does show that water quality is in relatively good condition; no parameters violated state standards. Specific conductance values were somewhat elevated, but consistent, and thus may be related to lithology. A single sample collected in 2011 on Yonaba Creek also showed good water quality. Sand and Tubbalubba Creeks have been listed as 303(d) impaired waters for biological impairment since 2010 and 2006, respectively.

Based on available sampling data, water quality in this cataloging unit appears to be mostly free of problems, and thus a condition status of good is assigned (Figure 20).

Upper Tombigbee (HUC 03160101)
This cataloging unit is informed by three sampling stations: Twenty Mile Creek, Rock Creek, and Jourdan Creek. Each were sampled predominantly by Earleywine (2010), though Rock Creek was sampled once during spring 2012. Two samples on Twenty Mile Creek violated temperature limits, while on three of seven sampling dates pH values on Rock Creek fell below the state standard. ANC values were above the EPA recommended minimum, though specific conductance values were somewhat elevated over the sampling period, overall averaging 237 µS/cm. *E. coli* concentrations were consistently low.

Two streams in the Tombigbee were listed as 303(d) impaired waters – Rock Creek and Little Brown Creek. Both are listed for biological impairment and were originally included in 2002. As a result of the pH and temperature violations, in addition to the 303(d) listings, this unit receives a fair condition status rating (Figure 20).

Bear (HUC 06030006)
The Bear cataloging unit contains four main sampling stations. Regularly sampled stations by Earleywine (2010) and I&M include Bear Creek, Cedar Creek, Bear Creek at Tishomingo, and Buzzards Roost Spring. Observed values for these stations were mostly similar and within state standards. Bear Creek at Tishomingo showed greater ANC values than the other stations, while Buzzards Roost Spring reported the highest conductance values. Buzzards Roost Spring drains a large area, much of which flows through agricultural land. Fertilizer runoff from these areas may contribute to elevated specific conductance levels. This sampling location also reported some elevated *E. coli* concentrations, albeit only one exceeding the warm season recreation limit.

Extensive sampling was also conducted by the MDEQ at Bear Creek right along the Parkway (Figure 22). Samples showed parameters falling within state standards. Overall, samples showed normal water quality with the possibility of agriculturally influenced conductance values at Buzzards Roost Spring. As a result, this cataloging unit receives a condition of good (Figure 20). No 303(d) impaired waters fall within this cataloging unit.

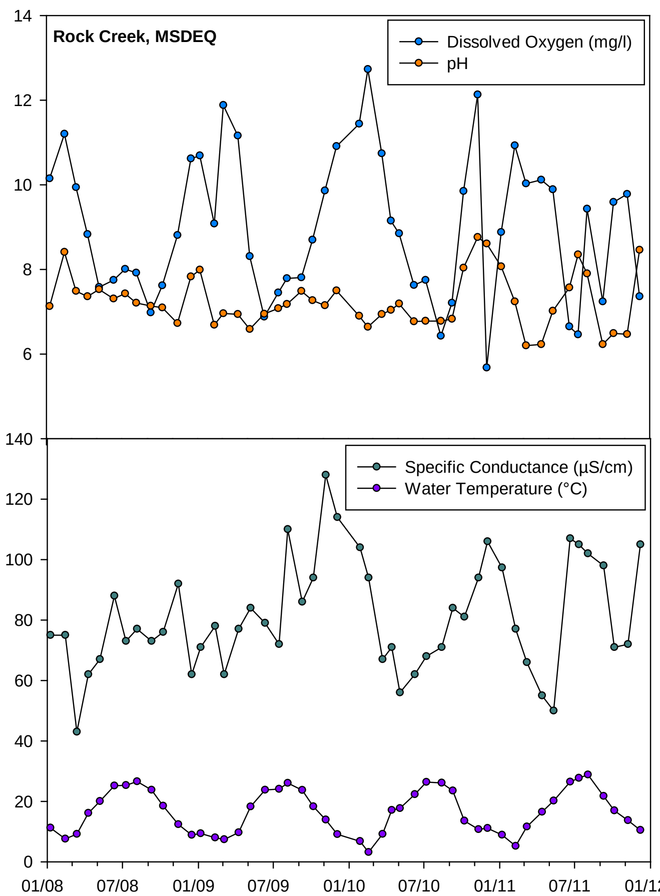

Figure 22. MDEQ sampling between 2008 and 2012 on Bear Creek, approximately 4 km up the Parkway from Bear Creek at Tishomingo.

Pickwick Lake (HUC 06030005)

The Pickwick Lake cataloging unit is informed by seven sampling stations: Colbert Creek, Burcham Branch, Lindsey Creek, Cooper Branch, Cypress Creek, Glenrock Branch, and Sweetwater Branch. The latter two stations are located in the northernmost section of the cataloging unit. Of these, Lindsey Creek showed occasional samples outside state standards, including low DO on two of ten samples and low pH on three of nine samples. Lindsey Creek also recorded the high values for specific conductance, particularly in comparison to the other stations. These values were somewhat sporadic, however, such that the mean conductance measurement was 388.8 µS/cm but the median was 25.0 µS/cm. Cypress Creek, Glenrock Branch (Figure 23), and Sweetwater Branch showed low ANC values, while the remaining stations exhibited high ANC values. All stations except Colbert Creek showed high levels of *E. coli* concentrations; Cooper Branch and Cypress Creek in Tennessee showed respective compliance rates of 78.6% (14 samples) and 84.2% (19 samples). Only Burcham Branch exceeded the Alabama warm season recreation limit once out of 17 samples. No waters in this cataloging unit were listed as impaired in 2012. Overall, water quality appears impaired on Lindsey Creek, though overall good at other stations with the exception of a few elevated *E. coli* concentrations. As a result this unit receives a condition status of fair (Figure 20).

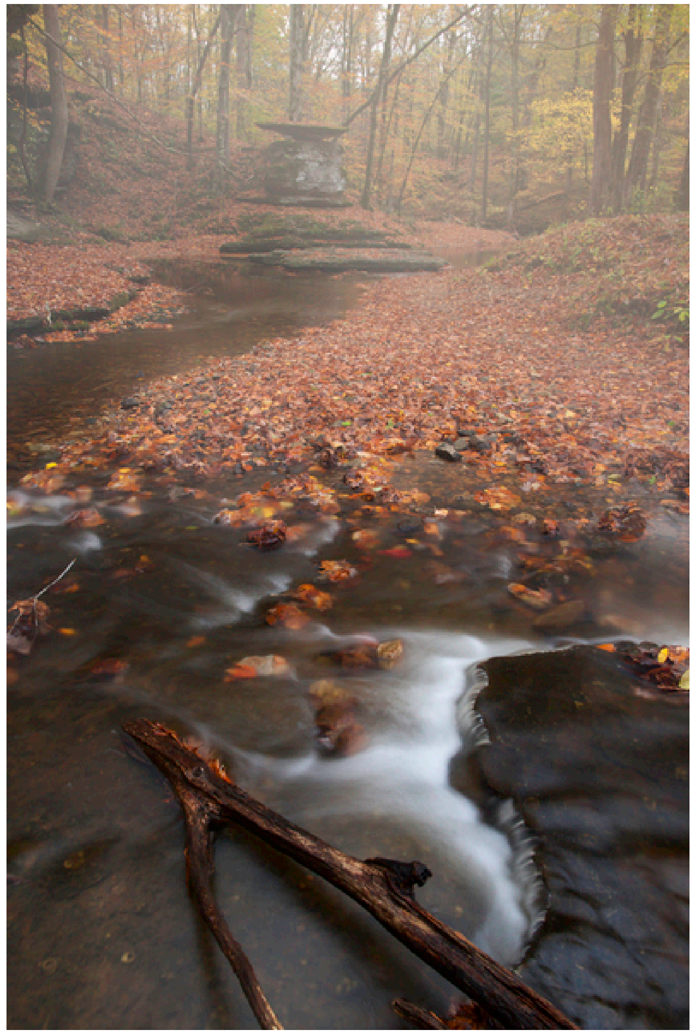

Figure 23. Glenrock Branch is one of seven sampling stations within the Pickwick Lake cataloging unit. [Source: M. Muench]

Buffalo (HUC 06040004)

The Buffalo cataloging unit includes three regular sampling stations at Buffalo River (Figure 24), Jacks Branch, and Chief Creek. Parameters were similar among stations for this unit, with no evident water quality issues. Despite this, Buffalo River and Chief Creek, in addition to Squaw Branch, were all listed on the 2012 list of 303(d) impaired waters, all for different reasons. Buffalo River was listed due to high levels of atmospheric mercury deposition, though it had not been listed as impaired prior to 2012. Chief Creek was also a new listing in 2012, but was listed due to flow alteration from the Dan Maddox dam less than a single kilometer upstream. Finally, Squaw Branch has been listed since 2006 due to hypoxia and low flow alteration due to the separate Dan Maddox Fishing Lake dam, which is also less than a single kilometer from the

Parkway. Water quality appears good based on I&M sampling, and despite the impaired waters resulting mainly from impoundments, this cataloging unit receives a condition status of good (Figure 20).

Figure 24. Buffalo River near the Natchez Trace crossing at Metal Ford. [Source: National Park Service]

Lower Duck (HUC 06040003)

The Lower Duck cataloging unit is informed by five sampling stations: Duck River, Jackson Falls, Fall Hollow, English Camp Creek, and Little Swan Creek. Only Little Swan Creek, Fall Hollow, and Jackson Falls are sampled regularly by GULN.

The English Camp Creek and Little Swan Creek sampling stations are located approximately two kilometers apart by stream distance, the latter being located 1.5 km below their confluence. Although sampling was sparse for English Camp Creek (it was recently added to the site list), paired sampling showed marked differences in pH, with values much lower on Little Swan Creek. The difference between the stations is that Little Swan Creek drains a much larger area that includes pine plantation, pasture, and an impounded tributary, whereas only a short distance of forested stream area exists upstream of English Camp Creek. Earlier sampling by TDEC during the period 1999 to 2004 at approximately the same location as the current I&M station on Little Swan Creek showed higher values for pH, suggesting that water quality has changed on Little Swan Creek between TDEC and GULN sampling periods. Linear regression on all available sampling data at this location does show a significant reduction ($p < 0.0001$). Additional sampling by TDEC in the upper drainage of Collier Branch, a main tributary of Little Swan Creek, exhibited pH values similar to the lower stations on Little Swan Creek. Although the waters appear altered, pH values do not violate state standards. However, if the alteration is due to anthropogenic disturbance, other stream quality issues may be present.

Further up the Parkway, regular sampling at Jackson Falls showed some of the highest values for pH at NATR, which may be largely due to limestone parent material in the region, though ANC values at this station were not observed to be very high (<50 mg/l $CaCO_3$). The station at Jackson Falls did show two elevated *E. coli* concentrations and relatively elevated and variable specific conductance values. Values further up the Parkway on Duck Creek were also normal and consistent.

Also within the cataloging unit are two 303(d) impaired waters: Dog Creek and Duck River. Both waterbodies were just added in 2012 - Duck River due to atmospheric mercury deposition, and Dog Creek due to high *E. coli* concentrations. Although samples were not collected at Dog Creek along the Parkway, its headwaters are located less than 500 m from the park boundary, and as a result, it is unlikely contamination is present within NATR waters at this site.

Overall, none of the stations showed repeat violations of state standards, although a decreasing trend in pH is observable based on sampling at Little Swan Creek. As a result, this cataloging unit receives a condition status of good (Figure 20).

<u>Harpeth (HUC 05130204)</u>
The northernmost cataloging unit through which NATR flows is sampled by three stations: Burns Branch, Garrison Creek, and Dobbins Branch. Garrison Creek was included only in Earleywine's (2010) sampling. Sampled parameters showed generally good water quality, though all stations recorded elevated *E. coli* concentrations. Dobbins Branch recorded the most exceedances, which included three out of ten samples. Dobbins Branch drains only a small area above the Parkway, most of which is lightly residential and forested slopes, so the source of microorganism concentrations is not immediately clear, and may include influence from wildlife. No 303(d) impaired waters cross NATR in this cataloging unit. Because of the lack of any overall water quality issues other than occasional microorganism contamination, this cataloging unit receives a condition rating of good (Figure 20).

4.3.6 Condition Summary
Of the 13 ranked cataloging units at NATR, five were ranked as good, five fair, and three poor. Only the Upper Pearl cataloging unit was assigned a trend due to improvements between sampling by Earleywine (2010) and GULN. Elevated concentrations of E. coli were the most common issue at sampling stations, followed by low pH and low DO values. Perhaps the most pressing concern along NATR regarding water quality is the effect from the Red Hills Mine located just 4 km from the Parkway in the Upper Big Black cataloging unit. Sampling prior to construction of the mine established a baseline level to which comparisons of current data clearly show a change in conductivity levels, which are indicative of the presence of mine runoff (Figure 21). This runoff could additionally affect other parameters, such as acidity, creating toxic conditions for certain aquatic species. Other metals such as manganese, copper, and zinc are also associated with mine drainages and may also be present. In addition to the Upper Big Black cataloging unit, the Lower Big Black and Tibbee units were also assigned poor condition statuses. Both units displayed low DO concentrations and contained repeatedly-listed 303(d) impaired waters, among other issues.

By weighting the individual cataloging unit scores, the overall condition status is fair, with no trend assigned (Table 11). The data quality was good, though a check for temporal coverage was not applied due to the relatively recent inception of I&M sampling. Although many stations were informed by additional sampling by Earleywine (2010), a longer dataset will be useful for identifying long-term trends.

Table 11. The condition status for water quality, at the park-wide scale, was fair. The data quality used to make this assessment was good. No trend was assigned to park-wide water quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Park-wide Water Quality		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	
		5 of 6: Good					

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4.4 Terrestrial Vegetation

4.4.1 Relevance and Context

Several vegetation types are present along the length of NATR, ranging from hardwood forests to open prairie. About 7% of the land in NATR is also agricultural. In addition, vegetation type clearly changes over the course of the Parkway, transitioning from areas of swamps and riverine forests in portions of southern Mississippi (Figure 25), to Appalachian foothills forests in Tennessee dominated by oak and hickory (NPS 2012). Vegetation also changes temporally along the Parkway, offering visitors abundant wildflowers beginning in the spring, and magnificent leaf colors in the fall (Figure 26).

Figure 25. Tupelo-Baldcypress swamp found along the southern portion of the Parkway in Mississippi. [Source: National Park Service]

Figure 26. Fall season colors along NATR. [Source: M. Muench]

4.4.2 Resource Knowledge

Vegetation Cover

Based on a combination of 2004 aerial image classification and field-site observations, the Parkway was classified into 61 USNVC vegetation alliances (vegetation communities) in six main physiognomic classes (Rangoonwala et al. 2011). The final map merged most of these alliances into 6 major classes and another 7 minor classes, and had an overall combined accuracy rate of 65%. Table 12 shows the division of landcover classes along three sections of the Parkway for each class with > 1% coverage. See Rangoonwala et al. (2011) for complete classification details. Whereas landcover proportions are similar in the southern and middle sections of the Parkway, proportion of white oak and pine-oak forests are higher for the northern section, while the pine-cedar class is lower.

Table 12. Division of landcover classes in three sections of NATR, ordered from largest to smallest fraction for the whole parkway. [Source: Rangoonwala et al. 2011]. Classes with fractional coverage of less than 1% are not shown.

Landcover class	Southern	Middle	Northern	All
Vegetation				
Oak	26%	20%	24%	24%
Grasslands	20%	27%	22%	22%
Pine-Cedar	23%	19%	11%	19%
Pine-Oak	8%	10%	13%	10%
Sweetgum	10%	11%	7%	9%
Scrub Shrub	6%	5%	4%	5%
White Oak	0%	0.2%	14%	4%
Plantation	3%	3%	1%	2%
Other				
Road-Developed	2%	3%	2%	3%
Water	1%	1%	0%	1%

Native Communities

One significant community type found along the Parkway is natural prairie, especially those associated with the Black Belt physiographic region, which stretches through Mississippi and Alabama. These prairies experienced frequent natural and anthropogenic fires, and were under cultivation from years of early settlement (Wieland 1994). Along the Parkway, the historic Chickasaw Village site, located north of Tupelo, MS, is maintained as a historic settlement area for the Chickasaw Native Americans, who remained at the site until the early 19^{th} century (Wieland 1994). Cultivation lasted at the site well into the 20^{th} century, at which point fields were planted with an exotic fescue grass (*Festuca* spp.). Recently, park management has introduced prescribed fire as a means of management at the site, in addition to mechanical vegetation removal to reduce exotic plants such as Chinese privet (*Ligustrum sinense*). The effectiveness of these management efforts remains unknown, pending further evaluation.

Sensitive Species

In 1996, The Nature Conservancy (TNC) completed an assessment of rare, threatened, and endangered species along NATR, which outlined the status of several sensitive plant species. From 2004-2006 a floristic inventory was completed by Hatch & Kruse (2008). A recent summary of available biological data at NATR compliled these and other available data in order to assess “Park Status” for each of the species (GULN 2010). The combined list is shown in Table 13, which is cross-referenced with NPSpecies. A few species including the hay-scented fern (*Dennstaedtia punctilobula*), Canada moonseed (*Menispermum canadense*), and Tennessee yellow-eyed grass (*Xyris tennesseensis*), were reported by TNC and Hatch & Kruse but are not listed as present at NATR in NPSpecies. It is unclear whether they are excluded for a specific reason (thought extirpated), or whether it was accidental. Tennessee yellow-eyed grass, which occurs in alkaline mesic areas and is federally endangered, was recently extirpated from at least three known locations in NATR (NatureServe 2012). Approximately 20 Xyris tenneseensis plants were outplanted adjacent to Little Swan Creek (where they had previously been known to occur prior to a large flood event in 1997). This population is monitored by TN Dept of Environment and Conservation (TDEC) annually (L. McInnis, personal communication). Field surveys in 1992 also documented the presence of a single rare species, white heath aster (*Symphyotrichum ericoides*), which is listed with a state conservation rank of S2 (imperiled) in Mississippi.

It does not appear that any differences between the two surveys can be attributed to actual differences in occurrence of any given species. The survey by Hatch & Kruse (2008) appears to have been very thorough, therefore could have legitimately detected more sensitive species than the earlier TNC survey. It is not clear whether or not Hatch & Kruse resampled any specific sites previously surveyed by TNC, therefore any non-detections of particular species in the more recent survey, are not likely to be sufficient to show extirpation. So, while the status of the three species mentioned above is unconfirmed, it indicates the possibility that they have been extirpated, and future surveys can be used to increase evidence one way or the other.

Table 13. Sensitive plant species at NATR (TNC 1996, Hatch and Kruse 2008, GULN 2010). For the 1996 and 2008 reports, “X” indicates the species was observed. Additionally, for the 2008 report, “S” indicates suspected but not confirmed, and “nv” indicates no voucher specimen was used/available. Park Status refers to current status of the species in the park: PIP=Present in Park, PP=Probably Present, U=Unconfirmed.

Species		State Conservation Rank*	Federal Status	1996	2008	Park Status
Agalinis heterophylla	Prairie False Foxglove	S1 - TN; S2 - AL; S3 - MS			Xnv	U
Amelanchier arborea	Downy Serviceberry	S1 - AL		X		PIP
Angelica atropurpurea	Great Angelica	S1 - TN			X	PIP
Apios priceana	Price's Potato-bean	MS - S1; TN - S2	T		S	PP
Arenaria lanuginosa	Spreading Sandwort	S1 - TN			X	PIP
Asarum canadense	Canada Wild Ginger	S2 - MS		X	X	PIP
Asclepias purpurascens	Purple Milkweed	S1 - TN, MS			X	PIP
Castanea dentata	American Chestnut	S1 - MS; S2S3		X	X	PIP
Chelone obliqua	Red Turtlehead	SH - MS; S1 - TN			X	PIP
Cotinus obovatus	American Smoketree	S2 - TN, AL			Xnv	U
Coreopsis auriculata	Lobed Tickseed	S2 - MS		X	X	PIP
Hypericum adpressum	Creeping St. John's-wort	S1 - TN			Xnv	PP
Cyperus plukenetii	Plukenet's Cyperus	SH - TN			Xnv	PP
Dalea candida	White Prairie-clover	S2 - TN			X	PIP
Dalea purpurea	Purple Prairie-clover	S1 - TN			Xnv	PIP
Dennstaedtia punctilobula	Hay-scented Fern	S3 - AL		X		
Dichanthelium aciculare	Needleleaf Witchgrass	S1 - TN			X	PIP
Drosera brevifolia	Dwarf Sundew	S2 – TN			X	PIP
Echinochloa walteri	Walter's Barnyard Grass	S1 - TN			X	PIP
Enemion biternatum	False Rue Anemone	S2 - AL		X	X	PIP
Festuca paradoxa	Cluster Fescue	S1 - TN			X	PIP
Frasera caroliniensis	Carolina Gentian	S2 - AL; S2S3 - MS		X	Xnv	PIP
Fuirena squarrosa	Hairy Umbrella-sedge	S1 - TN			X	PIP
Gelsemium sempervirens	Carolina Jessamine	S1S2 - TN			X	PIP
Gentiana saponaria	Harvestbells	S3 - AL		X	Xnv	PIP
Geum aleppicum	Yellow Avens	S1 - TN			Xnv	PP
Geum laciniatum	Rough Avens	S1 - AL, TN			X	PIP
Hieracium scabrum	Rough Hawkweed	S2 - TN			X	PIP
Hydrastis canadensis	Goldenseal	S1 – MS; S2 – AL, S1 - TN			Xnv	PIP
Hydrolea ovata	Ovate False Fiddleleaf	S1 - TN			X	PIP
Hydrophyllum virginianum	Shawnee Salad	S3 - TN			X	PIP
Juglans cinerea	Butternut	S1 – AL; S2 – MS; S3 - TN		X	Xnv	PIP
Lilium michiganense	Michigan Lily	S1 – MS, AL; S3 - TN		X	Xnv	PIP
Listera australis	Southern Twayblade	S1S2 - TN; S3 - AL		X	Xnv	PP
Ludwigia sphaerocarpa	Globefruit Primrose-willow	S1 - TN			X	PIP

Table 13. (continued)

Species		State Conservation Rank*	Federal Status	1996	2008	Park Status
Magnolia virginiana	Sweetbay Magnolia	S2 - TN		X	Xnv	PP
Marshallia trinervia	Broadleaf Barbara's Buttons	S2S3 – TN; S3 – MS, AL		X	Xnv	PIP
Melanthium virginicum	Virginia Bunchflower	S1 - TN; S2S3 - MS				PP
Menispermum canadense	Canada Moonseed	S3 - MS		X	Xnv	
Osmorhiza longistylis	Smoother Sweetroot	S3 - MS		X	Xnv	PIP
Pachysandra procumbens	Allegheny-spurge	S2 - AL; S3 - MS		X	Xnv	PIP
Panax quinquefolius	American Ginseng	S3 – MS, TN - S3		X	Xnv	PIP
Parnassia grandifolia	Largeleaf Grass-of-parnassus	S1 – AL; S2 – MS; S3 - TN		X	Xnv	PIP
Plantago cordata	Heartleaf Plantain	S1 - TN, AL, MS				PP
Polygala mariana	Maryland Milkwort	S1 - TN			Xnv	PIP
Polygala nana	Candyroot	S1 - TN			X	PIP
Polygonum cilinode	Fringed Black-bindweed	S1S2 - TN			Xnv	PIP
Prenanthes aspera	Rough Rattlesnake-root	S1 - TN; S2 - MS			Xnv	PP
Rhamnus alnifolia	Alderleaf Buckthorn	S1 - TN			X	PIP
Rhynchospora caduca	Falling Beakrush	S1 - TN			X	PIP
Rhynchospora rariflora	Few-flowered Beakrush	S1 - TN			X	PIP
Rosa virginiana	Virginia Rose	SH - TN			X	PIP
Rudbeckia subtomentosa	Sweet Coneflower	S1 - MS; S2 - TN			X	PIP
Sagittaria brevirostra	Shortbeak Arrowhead	S1 - TN			X	PIP
Smilax laurifolia	Laurel-leaf Greenbrier	S1 - TN			Xnv	PIP
Spiranthes lucida	Shining Lady's tresses	S1 – AL, TN			Xnv	PIP
Spiranthes ovalis	October Ladies' tresses	S2 – MS; S3 - TN			Xnv	PIP
Stylisma humistrata	Southern Dawnflower	S1 - TN		X	Xnv	PP
Symplocos tinctoria	Common Sweetleaf	S2 - TN			Xnv	PP
Symphyotrichum ericoides	White Heath Aster	S2 – MS; SH - TN			X	PIP
Trichomanes boschianum	Appalachian Bristle Fern	S1S2 – MS, TN; S3 – AL			X	PIP
Trillium sessile	Toadshade	S2 - AL		X	X	PIP
Vaccinium elliottii	Elliott's Blueberry	S1 - TN		X	X	PIP
Woodwardia virginica	Virginia Chainfern	S2 - TN			X	PIP
Xyris tennesseensis	Tennessee Yellow-eyed Grass	S2 – TN, AL		X	Xnv	
Zanthoxylum americanum	Common Pricklyash	S1 - AL; S2 - TN			Xnv	PIP

*Rounded NatureServe conservation status of a species from a state/province perspective, characterizing the relative imperilment of the species. S1=Critically Imperiled, S2=Imperiled, S3=Vulnerable, S4=Apparently Secure, S5=Secure, SH = Possibly Extirpated, H = Historic; Refer to <http://www.natureserve.org/explorer/nsranks.htm> for additional information on ranks.

†E: Endangered, T: Threatened

Exotics

Exotic plant species present a significant resource management concern in NATR, likely due to the fact that it is a narrow park and adjacent land use, both historical and current, could contribute to the introduction of exotics. In a checklist of species provided to NATR in 1986, Waggoner identified a total of 106 exotic plants along the Parkway. In a later survey conducted by The Nature Conservancy (1996), nineteen exotics were identified at 93 survey plots comprising 28 main vegetation communities along the Parkway. The NPSpecies database (accessed May 2014) reports that 215 exotic species are found at the park, or roughly 15% of the flora. This number includes the efforts of the floristic inventory at the park by Hatch and Kruse (2008).

Invasive species are exotic species that have the ability to be particularly damaging to an ecosystem and those which can be difficult to eradicate once established (Hatch and Kruse 2008). Phillips (2006) and Hatch and Kruse (2008) reported that 8% of all vegetation species at NATR are considered invasive according to the criteria used. Rangoonwala et al. (2011) classified 21.1 ha of total land area on the Parkway as dominated by invasive species based on aerial imagery classification. Much of this classification was kudzu vineland, though some sections of tree-of-heaven, water-hyacinth (*Eichhornia crassipes*), and Chinese privet were also identified. The largest concentration of patches of invasives was around Duck River, about 50 km southwest of Nashville, TN (Figure 27). Besides the monitoring by Hatch and Kruse (2008), NatureServe has also conducted monitoring in 2004, 2005, and 2009 at a total of 502 plots, which documented one or more of the following species at 285/502 plots: Chinese privet, Japanese honeysuckle and kudzu (Figure 28). Therefore, while at a coarse scale, a relatively small area of land is dominated by invasives (21.1 ha), the most common invasives are highly prevalent and occur at nearly 57% of sites surveyed.

Particular attention has been paid to the treatment of certain invasive exotics, including tree-of-heaven), mimosa, Chinese privet, Japanese honeysuckle, Johnsongrass (*Sorghum halepense*) and kudzu (NPS 1997, Cooper et al. 2004, Hatch and Kruse 2008, NPS 2012). Treatments by the Gulf Coast Exotic Plant Management Team and NATR staff have been important in reducing the occurrence of invasives. In addition to manual removal and herbicide application, prescribed fires help ease the proliferation of exotics. In 2010, approximately 30 ha were treated along the Parkway with herbicide.

Tree-of-heaven

Tree-of-heaven is already a widespread species and primarily invades habitat of low quality or disturbed areas. These disturbed areas may be the result of human activity or natural disturbance, such as a tree fall. It is able to tolerate extreme conditions including acidic soils, stony and thin topsoils, and high levels of air pollution (NatureServe 2012). This species is also allelopathic, meaning it secretes chemicals from its roots that can negatively impact the shrub layer or other competing species in its vicinity. Although seed production is high, persistent root sprouts also make this species particularly difficult to eradicate (NatureServe 2012).

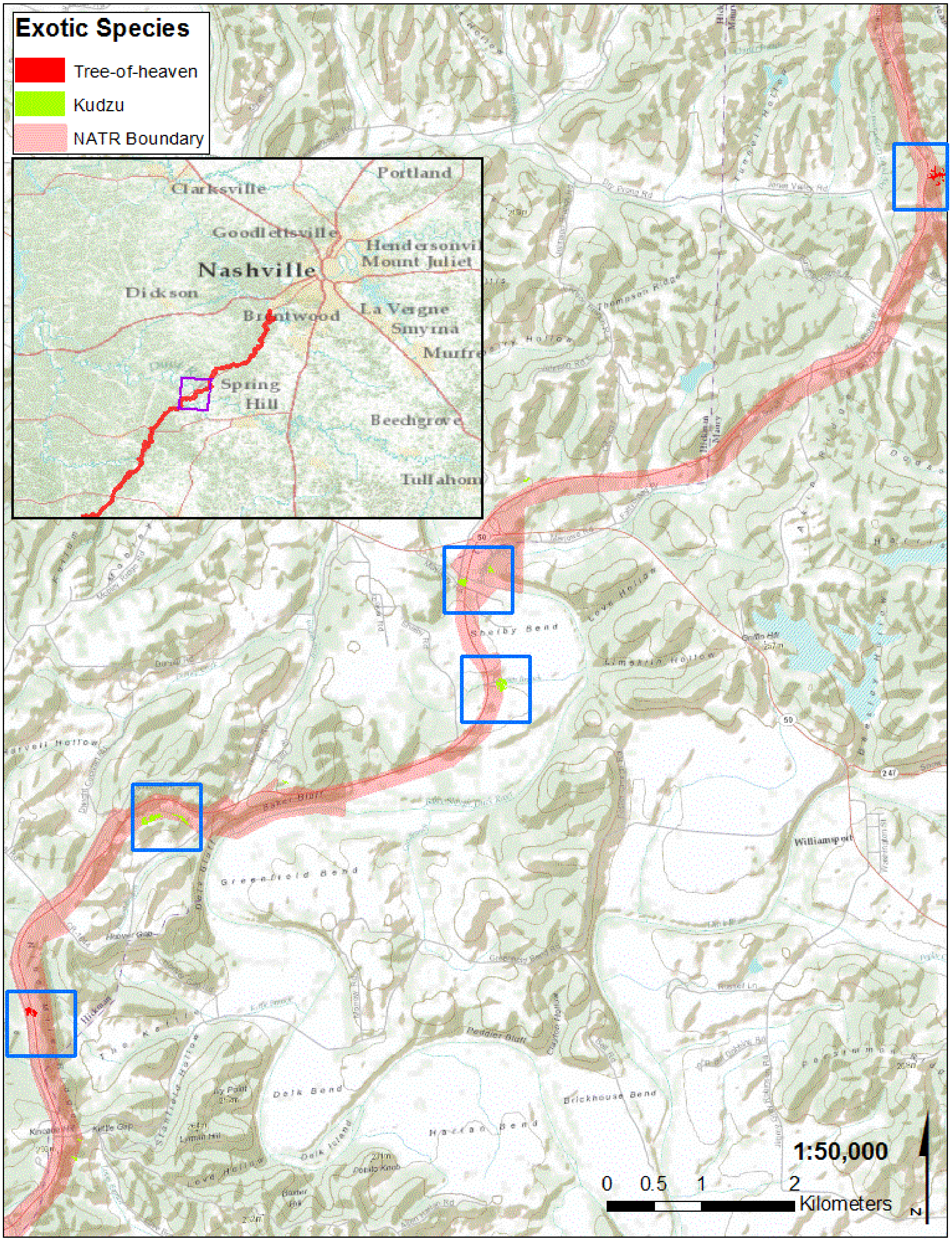


Figure 27. Several patches of tree-of-heaven and kudzu were mapped by Rangoonwala et al. (2010) around the Duck River on NATR.

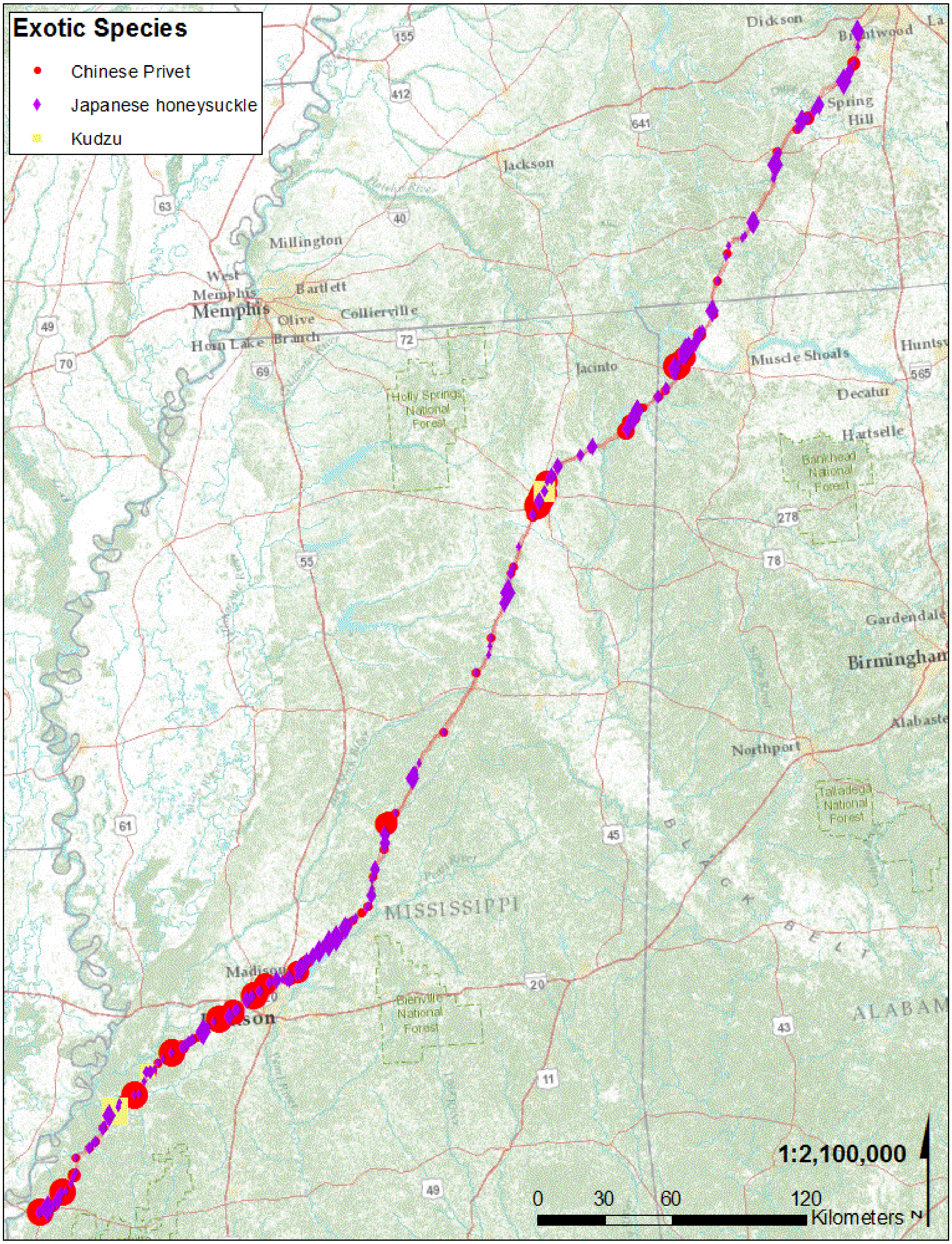


Figure 28. Along the entirety of NATR, NatureServe plots have documented the presence of Chinese privet, Japanese honeysuckle, or kudzu at a total of 285 plots. Symbol size is proportional to cover area.

Mimosa
Mimosa is a predominant invasive in the southern U.S., where it is planted frequently as an ornamental (Figure 29). It usually invades human-disturbed areas, though it can also grow in riparian areas and forest edges (extensive at NATR), adapting to several types of soil conditions. Because of its lasting seed viability, quick growth, and propensity for resprouting, treatment of this species proves difficult and usually necessitates herbicidal control in addition to mechanical reduction. Besides the ability to outcompete native vegetation, it also can alter the native growing environment by fixing nitrogen into the soil (SEEPPC 2011, NatureServe 2012).

Figure 29. Mimosa, a legume with a propensity for resprouting, is among the invasives treated at NATR. [Source: L. Ingram, USDA Forest Service, Bugwood.org]

Chinese Privet
One of the most troublesome characteristics of privet is that it easily invades multiple habitat types, including wetland forests, wet meadows, forest edges, prairies/old fields, and ravines. In these areas, it can create dense layers that shade out other native species (Munger 2003). It currently is distributed in the Southeast and most mid-Atlantic states, and usually requires a minimum of three to five years of repeated treatments for eradication (NatureServe 2012).

Mechanical and chemical control of Chinese privet at NATR is conducted on approximately 10 ha/year by the Gulf Coast EMPT and NATR staff. This acreage does not include areas treated with prescribed fire.

Japanese Honeysuckle
This species is an extremely prolific evergreen vine that can grow in a variety of habitats, mainly including those associated with a recent disturbance, such as old fields, prairies, and roadsides. It is also found in forest edge and interior areas, where it can twine around small trees and other vegetation. Birds spread the berries, and runners also aid in propagation. Japanese honeysuckle also has the ability to outcompete native plants, and in turn can result in a decrease in the number of native songbird populations (NatureServe 2012).

Johnsongrass
Johnsongrass, a frequently listed noxious weed throughout the U.S., also has the ability to invade a variety of habitats, most typically including disturbed areas, flooded bottomlands, forest edges, or roadsides. On roadsides in particular, it can establish quickly using rhizomatous movement to eventually outcompete native plants. Johnsongrass is easily spread via field cultivation and is difficult and expensive, though necessary, to control (NatureServe 2012).

Kudzu

Another significant problem in the park is kudzu, which is a fast-growing vine that can quickly form an impenetrable blanket over existing vegetation and fundamentally alter the existing community by outcompeting native species. Vines can grow up to 15m each season, while roots can penetrate to depths of 3m (SEEPPC 2011). Treating kudzu infestations can require considerable investment, including repeated mechanical reduction, digging, and herbicide application to prevent spread via runners. This species is the most actively-controlled of the exotic species at NATR, with the EPMT and NATR employees treating more than 25 ha annually.

I-Ranks

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics to native species and ecosystems, called the I-rank. The overall I-rank consists of 20 questions that cover four main subranks: ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty. Because imprecise ranks can occur (Morse et al. 2004), a range can also be assigned based on the highest and lowest scores assigned for each subrank category (e.g. High/Medium, High/Low). Table 14 shows species with an overall I-Rank of medium or higher, adapted from the list of exotic species by the GULN biological summary (2010). Species with the highest overall I-Ranks include giantreed (*Arundo donax*), Amur honeysuckle (*Lonicera maackii*), tallowtree (*Triadica sebifera*), crownvetch (*Coronilla varia*), Eurasian water-milfoil (*Myriophyllum spicatum*), common water-hyacinth, and autumn olive (*Elaeagnus umbellata*). Eurasian water-milfoil and common water-hyacinth are both aquatic species, while the remaining five are commonly encountered in wet bottomland areas, with the exception of Amur honeysuckle and autumn olive.

Because these I-Ranks are established based on generalized criteria, the local threat may be further determined by local prevalence, spread, and proximity to important native communities. For species on this list, but not currently targeted, treatment could be considered or monitoring could be employed to determine a significant change that would indicate a change to the local threat.

Table 14. Overall I-Ranks developed by Morse et al. (2004) shown for invasive exotics at NATR, adapted from GULN (2010). Habitat preferences from NatureServe (2012). I-Ranks with more than one ranking (e.g. High/Low) represent a range due to imperfect information for the species.

Species	Common Name	I-Rank	Habitat
Arundo donax	Giantreed	High	Riparian areas, ditches
Lonicera maackii	Amur Honeysuckle	High	Forests, recently disturbed areas
Triadica sebifera	Tallowtree	High	Marshes, bottomlands
Coronilla varia	Crownvetch	High	Prairies, open woodlands
Myriophyllum spicatum	Eurasian Water-milfoil	High	Slow-moving or stagnant water
Eichhornia crassipes	Common Water-hyacinth	High	Wetlands, slow-moving or stagnant water
Elaeagnus umbellata	Autumn Olive	High	Prairies, wetlands
Holcus lanatus	Velvetgrass	High/Medium	Disturbed areas, roadsides, ditch banks
Lolium arundinaceum	Tall Fescue	High/Medium	Prairies
Sorghum halepense	Johnsongrass	High/Medium	Old fields, some undisturbed open areas
Lonicera japonica	Japanese Honeysuckle	High/Medium	
Dioscorea oppositifolia	Chinese Yam	High/Medium	Disturbed areas, riparian areas, mesic forest
Lygodium japonicum	Japanese Climbing Fern	High/Medium	Mesic forest, swamps, riparian areas
Potentilla recta	Sulfur Cinquefoil	High/Medium	Old fields, roadsides, open forest, grasslands
Acer platanoides	Norway Maple	High/Medium	Forested natural areas
Ligustrum sinense	Chinese Privet	High/Medium	Floodplains, riparian areas, woodlands
Ligustrum vulgare	European Privet	High/Medium	River bottoms, forest interiors, barrens
Morus alba	White Mulberry	High/Medium	Forest edges, grasslands, waste areas
Carduus nutans	Musk Thistle	High/Low	Prairies, grasslands, disturbed areas
Brassica nigra	Black Mustard	High/Low	Disturbed areas, ditches, roadsides
Albizia julibrissin	Mimosa	High/Low	Human-disturbed areas, roadsides, forest edges
Plantago lanceolata	Narrowleaf Plantain	High/Low	Disturbed areas, roadsides, grasslands
Linaria vulgaris	Butter and Eggs	High/Low	Disturbed areas, prairie
Datura stramonium	Jimsonweed	High/Low	Disturbed areas
Alternanthera philoxeroides	Alligatorweed	Medium	Slow-moving or stagnant water, adjacent terrestrial sites
Lolium perenne	Perennial Ryegrass	Medium	Roadsides, disturbed areas
Phleum pratense	Common Timothy	Medium	Grasslands,roadsides
Lespedeza cuneata	Chinese Lespedeza	Medium	Open forests, grasslands, prairies
Wisteria sinensis	Chinese Wisteria	Medium	Disturbed areas, forest edges, roadsides
Ailanthus altissima	Tree-of-heaven	Medium	Disturbed areas, urban areas, roadsides
Verbascum thapsus	Common Mullein	Medium	Grasslands, riparian areas, disturbed areas

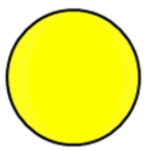
4.4.3 Summary

Because NATR transverses such a large latitudinal gradient, it encompasses several vegetation types and provides habitat for numerous sensitive plant species. For some of these sensitive species, current status is unknown. A single federally threatened species is thought to be hanging on (Price's Potato-bean (*Apios priceana*)). Additionally, important opportunities for conservation of the remaining 65 state-listed species still remain. Continued monitoring at previously sampled locations could help determine population status.

Another important vegetation management concern at NATR is exotic species, which can displace native species and alter vegetation types. The most recent list of plants on NPSpecies (NPS 2007) includes 212 exotics, or roughly one-sixth of the plants found along the Parkway. Among these, tree-of-heaven, mimosa, Chinese privet, Japanese honeysuckle, Johnsongrass, and kudzu have proven to be important targets for control. With help from the Exotic Plant Management Team, efforts by NATR staff will be important to prevent exotics from invading and altering previously undisturbed areas. Techniques such as Early Detection and Rapid Response (EDRR) are efficient and effective ways to minimize new infestations of exotics.

Overall, due to the presence of exotics at NATR, combined with the number of sensitive plant species found along the Parkway, terrestrial vegetation receives a condition status of fair (Table 15). Sparse information exists to inform the assignment of a trend as well. Although there is an apparent increase in the number of exotics found along NATR since Waggoner's 1986 inventory, it is not known whether a true increase has occurred, or simply an increase in detection due to additional surveys, a well-known sampling effect on species detection. Therefore, no trend is assigned. A rare plants monitoring protocol would assist in identifying specific conservation needs and trends, as would additional information on the prevalence of exotics and the efficacy of management efforts. For these reasons, the thematic sufficiency data quality check is withheld; the overall data quality is good.

Table 15. The condition of terrestrial vegetation at NATR is fair with a degrading trend. The data quality is good.

Attribute	Condition & Trend	Data Quality					
		Thematic		**Spatial**		**Temporal**	
Terrestrial Vegetation		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	✓
		5 of 6: Good					

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4.5 Forest Pests and Diseases

4.5.1 Relevance and Context

Dogwood Anthracnose

Dogwood anthracnose (*Discula destructiva*) is a fungal disease that infects flowering dogwood (*Cornus florida*). Originally detected in the northeast, the disease has spread to the south and has been reported in some western states, where it infects Pacific dogwood (*Cornus nuttallii*). Contributing factors include cold and wet spring and fall weather, and over time the disease may kill the tree. Symptoms include necrotic leaf blotches (Figure 30) and retained dead leaves in the fall. Eventually symptoms may spread to the

Figure 30. Leaf blotches from dogwood anthracnose. [Source: USFS]

twigs and main trunk, where cankers and split bark may result. Watering trees in high-value areas during periods of drought may help prevent infection, as well as mulching and avoiding mechanical injuries which can leave the tree more susceptible (Hess 1990). Fungicides may also be effective after infection (Mielke and Daughtrey 2012).

Figure 31. Tree showing pitch tubes from southern pine beetle infestation. [Source: R. Billings, TX Forest Service, Bugwood.org]

Southern Pine Beetle

Several pine species are susceptible to attack from southern pine beetle, wherein the beetle enters the tree forming a pitch tube (Figure 31), after which newly hatched beetles exit the tree. The risk of mortality to each tree varies depending on its health, but generally a moving front of beetles can cause widespread mortality (USFS 2011).

Fire also plays an important role in pine beetle outbreaks. While some evidence suggests that fire can stress trees and increase their susceptibility to an infestation (Santoro et al. 2001), others maintain that increased oleoresin production in pines, such as what follows a period of fire, can boost their resistance to southern pine beetle attack (Knebel and Wentworth 2007, Strom et al. 2002). This is especially true for low to moderate intensity fires, like those of a prescribed burn, whereas intense fires associated with crown damage may predispose trees to an attack (McHugh et al. 2003). Knebel and Wentworth (2007) observed elevated oleoresin levels in pine-dominated experimental plots for up to 18 months after low to moderate intensity fires.

Fusiform Rust

A native fungus, fusiform rust (*Cronartium quercuum*) affects loblolly (*Pinus taeda*) and slash pine (*P. elliottii*), ultimately causing rust galls along the tree bole.

4.5.2 Resource Knowledge

Dogwood Anthracnose

Two driving surveys were conducted by the U.S. Forest Service along the Parkway in 1989 to search for signs of dogwood anthracnose infection (Hess 1990). The first survey included 33 miles between milesposts 337 and 370, which is mostly the southernmost portion of the Parkway in Tennessee and a small portion in Alabama, while the second survey included the section of the Parkway between the Tennessee Tombigbee Waterway and the northern terminus – roughly 149 miles. The first survey found a single infected swamp dogwood (*Cornus stricta*), which was removed. The second survey resulted in seven sites sampled and investigated for infection due to dead or dying trees, though none tested positive for the pathogen. Hess (1990) suggested that observed dogwood mortality could be due to other factors such as dogwood borer (*Synanthedon scitula*), club-gall midge (*Resseliella clavula*), crown canker (*Phytophthora cactorum*), or environmental factors such as drought or excessive moisture, and that monitoring should continue specifically from MP 337 to MP 398 where these mortalities occurred.

Southern Pine Beetle

To assess the risk of southern pine beetle infestation in this region, the Forest Health Technology Enterprise Team (FHTET) of the U.S. Forest Service constructed a southern pine beetle vulnerability map for the entire southeastern region using 8 separate models over 15 different ecoregions. Each model adopted a set of parameters to assess infestation risk in that region, resulting in a southern pine beetle infestation risk map at 30-m resolution. The parameters of the two ecoregional models that included NATR were tree diameter, basal area, proportion host trees, slope, aspect, and soil drainage index. Of the pine species present at NATR, species susceptible to southern pine beetle include shortleaf (*Pinus echinata*), spruce (*Pinus glabra*), loblolly, and Virginia pine (*Pinus virginiana*).

Using a 3-mile (5 km) buffer along NATR, the FHTET model was mapped along the Parkway. In general, overall risk was greatest in the central areas of the Parkway, between Jackson, MS and the Alabama state line. According to the model, the area with the most concentrated risk included a roughly 90 km stretch adjacent to the Tombigbee National Forest (Figure 32). This swath contained several bands of susceptible pine forest areas that intersected with the Parkway.

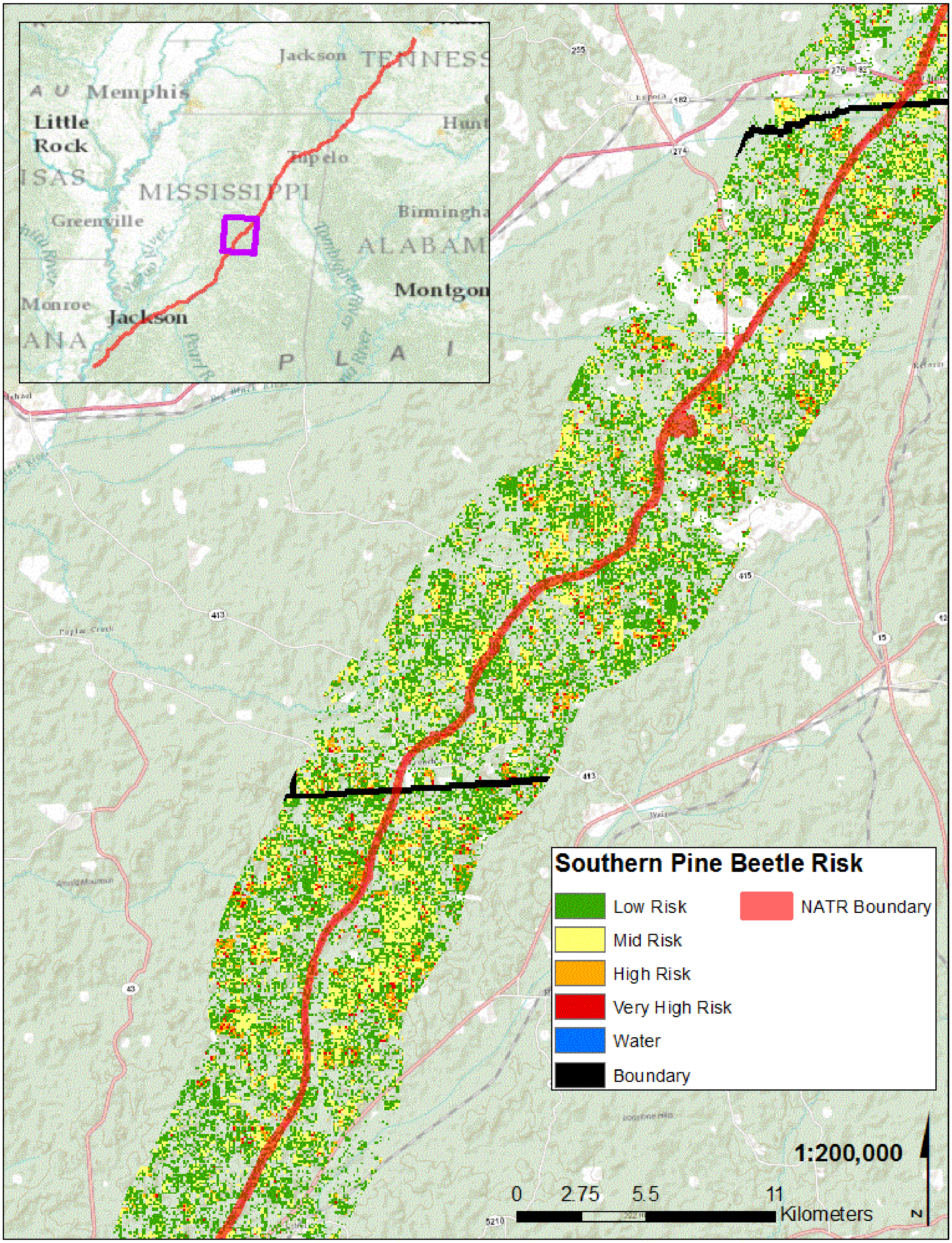

Figure 32. Southern pine beetle risk prediction map for NATR produced by the Forest Health Technology Enterprise Team (FHTET) of the U.S. Forest Service. Black boundary is Choctaw County, MS.

Fusiform Rust

As part of a U.S. Forest Service study to determine tolerance of loblolly pines to fusiform rust, several mature trees along 180 km of NATR were assessed by observing infection rate and tree size (Walkinshaw and Barnett 1995). Measurements showed that growth of infected trees along NATR was not inhibited by rust infection, as determined by size measurements. Infected trees usually had one to two galls, though likelihood of tree mortality was associated with number of galls present. Walkinshaw and Barnett (1995) suggested a threshold of four galls before rust-associated mortality was usually observed.

4.5.3 Summary

Of the three main pests highlighted in this section, two are native, while dogwood anthracnose was introduced to the U.S. in the 1970s from Asia. The single study by Hess (1990) focusing on dogwood anthracnose found on a single infected tree, while another study by Walkinshaw and Barnett (1995) observed that fusiform rust did not appear to be affecting the health of trees along the Parkway. Although southern pine beetle is a native southern pest species and thus trees display some adapted resistance, outbreaks are not unexpected, and many trees along the southern portion of the Parkway may serve as potential hosts. U.S. Forest Service models predicted some areas along the Parkway with elevated risk of a pine beetle outbreak, though most areas along the Parkway had low or no risk. Outbreaks still occur, however, and necessitate management attention from park staff.

4.5.4 Condition and Trend

Overall, the status of forest pests and diseases at NATR appears to be in good condition (Table 16), though no trend is assigned. Data quality was only marginal, however, receiving three out of six potential checks. Because only a single survey was available for both dogwood anthracnose and fusiform rust, both of which were conducted two decades ago, data was considered insufficient and not current, and thus neither temporal check was assigned. Thematic sufficiency was lacking because no on-the-ground data for southern pine beetle was available.

Table 16. The condition status for vegetation communities at NATR is good. The data quality is marginal.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Forest Pests and Diseases		Relevancy	✓	Proximity	✓	Currency	
		Sufficiency		Coverage	✓	Coverage	
		3 of 6: Marginal					

4.5.5 Literature Cited

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4.6 Fish Assemblages

4.6.1 Context and Relevance

The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000). Major southeastern river drainages are characterized by high richness and endemism of fish species (Sheldon 1988, Warren et al. 1997). Furthermore, southeastern fish assemblages face multiple anthropogenic threats and contain many imperiled species. Among southeastern states, Tennessee and Alabama have the greatest known fish richness and the greatest percentage of imperiled fishes, with 15.6% and 11.7% of native species imperiled, respectively (Warren et al. 1997).

Natchez Trace Parkway lands extend across a large swath of diverse southeastern fish habitat, and include waters from multiple ecoregions (Figure 33). From north to south, the NATR crosses the Interior Plateau, Southeastern Plains, and Mississippi Valley Loess Plains ecoregions (Figure 33). The interior plateau region is characterized by rocky substrates, open hills, and tablelands drained by relatively high-gradient streams (EPA 2010). The Southeastern Plains and Loess Plains ecoregions have lower elevations, flatter topography and low-gradient streams over primarily sandy and silt substrates (EPA 2010). Streams in the plains ecoregions are prone to channel incisement due to the highly erosional soils (EPA 2010).

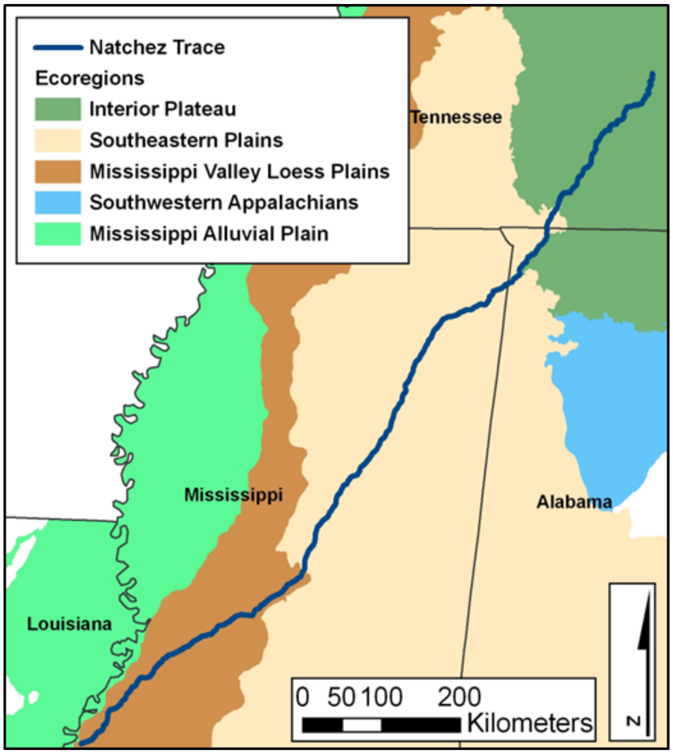

Figure 33. EPA Level III Ecoregions in the Natchez Trace area.

The NATR is located within several major watersheds (Figure 34). From north the south, Parkway streams drain into the Cumberland, Tennessee, Tombigbee, Lower Mississippi (Big Black), and Pearl River drainages (Figure 34). A relatively small segment (30 km) of the NATR is located in the Cumberland River basin which drains into the Tennessee River. About 195 km of the Parkway's length is located in the Lower Tennessee drainage. The Tennessee River basin (including the Cumberland basin) contains the richest known assemblage of native freshwater fishes of any basin in North America (Sheldon 1988, Warren et al. 1997), and drains ultimately into the Mississippi. Approximately 150 km of the NATR is located in the Tombigbee River basin. The Tombigbee drains to the Mobile River and eventually into the Gulf of Mexico. The Mobile River basin (including the Tombigbee), probably contains the second richest fish assemblage of any river basin in North America (Sheldon 1988). Approximately 206 km of the NATR is located in the Lower Mississippi River drainage. The major river in this section, the Big Black, drains directly to the Mississippi. The Pearl River drainage roughly parallels the Big Black along the southern portion of the NATR and 137 km of the Parkway is located in the Pearl Basin. The Pearl River empties directly into the Gulf of Mexico. The Big Black and Pearl basins have lower fish richness and lower endemism than the Cumberland, Tennessee, and Tombigbee river basins. Nonetheless, these drainages have a notably rich fauna relative to drainages of similar area on the Atlantic and western Gulf Coasts of the United States (Sheldon 1988, Warren et al. 1997).

The Natchez Trace Parkway has the potential to harbor a fish fauna that is uniquely rich among NPS units. It represents a long transect crossing multiple geographic regions and multiple drainages of renowned fish diversity. This expectation is tempered by the fact that the NATR is narrow, containing only short reaches of individual streams and waterways. The watersheds of waterways crossing the Parkway lie primarily outside of NPS boundaries and experience inputs and land use practices not subject to park management.

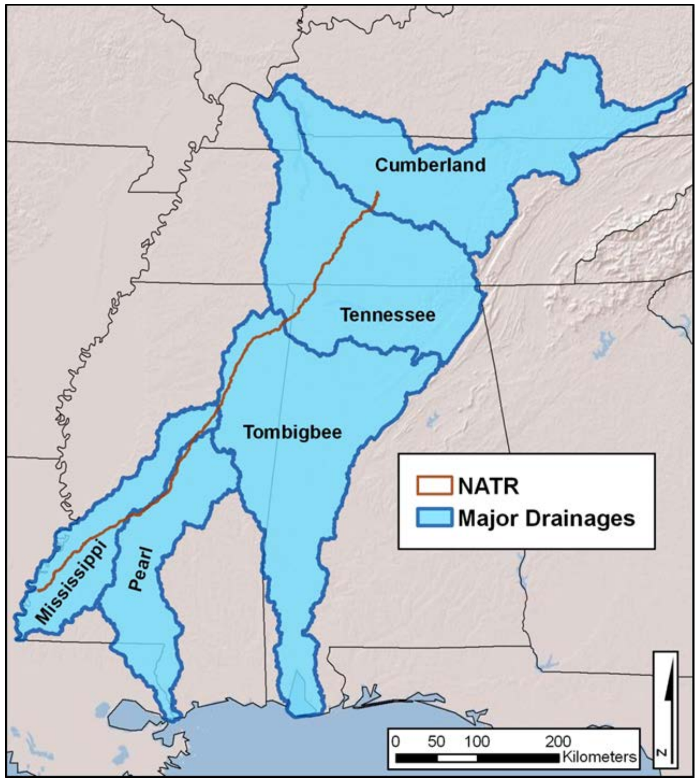

Figure 34. Major river drainages on the Natchez Trace Parkway.

4.6.2 Resource Knowledge

Multiple researchers have sampled fishes in the watersheds crossed by the NATR. Most of these efforts were independent of NPS goals and few historical samples have been collected within park boundaries. However, researchers have summarized the subset of available fish sampling data collected near or within park boundaries. Paxton et al. (2000) compiled a summary of fishes reported from within 10 km of NATR boundaries in Tennessee. Paxton et al. (2000) used multiple sources including: a database maintained by the University of Tennessee, museum records housed at other state and academic institutions, unpublished records from the University of Tennessee and from state government agencies, and published records. This summary resulted in 82 species reported from the NATR region in Tennessee, excluding 13 additional species potentially occurring in the 10 km corridor but for which specific detailed records could not be located (Paxton et al. 2000). Paxton et al. (2000) stated that the northernmost section of the NATR in the Cumberland basin had received relatively lower sampling effort than other Tennessee sections of the park.

Ross (1994) compiled a summary of fishes reported from within 10 km of NATR boundaries in Mississippi. Ross (1994) used a database of fish distributions maintained by the University of Southern Mississippi's Museum of Ichthyology. This database included an exhaustive list of Mississippi museum records from fish samples collected throughout the state (Ross 1994). This summary resulted in 121 species reported from the NATR region in Mississippi.

Phillips and Johnston (2004) reported on fish assemblages in the Bear Creek basin in Alabama. Bear Creek is a tributary to the Tennessee River and its watershed contains a uniquely rich fish assemblage including species typical to the lower Tennessee system and the Upper Tombigbee system (Phillips and Johnston 2004). Phillips and Johnston (2004) sampled throughout the watershed from 1998-2000 and reported 48 species from within approximately 10 km of NATR boundaries. Unlike the reports by Paxton et al. (2000) and Ross (1994), the Phillips and Johnston

(2004) study was not conducted for NPS purposes. Approximate locations relative to NATR were determined using GIS and a hardcopy of the site map included in the publication. Also unlike the previous NPS data reports, the Phillips and Johnston (2004) results are exclusively from relatively recent sampling.

Johnston (2007) conducted a comprehensive survey of park fishes from 2005 – 2006. This inventory included a literature and museum record search and a field survey. Researchers used backpack electrofishing, seining, and dipnets to collect samples from 59 sites along the length of the Parkway (Johnston 2007). Samples were collected in 13 of the 16 USGS HUC 8 watersheds located on the Parkway (Figure 35). Watersheds where samples were not collected were: Lower Tennessee—Beech (06040003), Bayou Pierre (08060203), and Lower Mississippi—Natchez (08060100) (Figure 35). Time of sampling at each site was longer for larger streams, and sampling continued until three to five efforts were completed without collecting unique species (Johnston 2007). All non-imperiled fishes were collected and preserved for verification of ID (Johnston 2007). Johnston (2007) reported 92 species from her own sampling efforts.

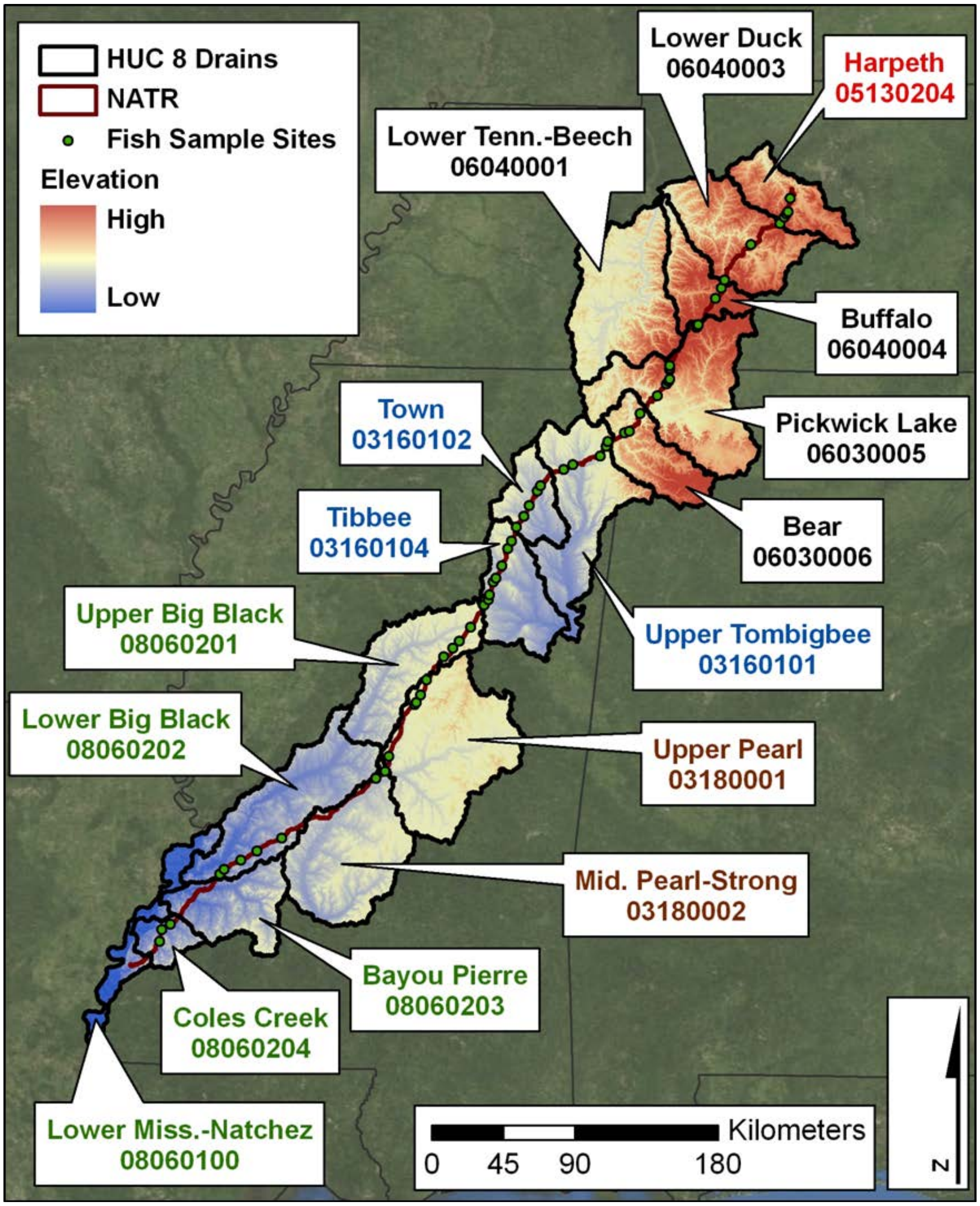

Figure 35. USGS HUC 8 watersheds located on the Natchez Trace Parkway, with sites sampled during a 2005-2006 fish inventory by Johnston (2007). Text color indicates the major drainages in which the HUC 8 watersheds are located with: **red** = Cumberland, **black** = Tennessee, **blue** = Tombigbee, **brown** = Pearl, and **green** = Lower Mississippi.

Earleywine (2010) conducted fish sampling in NATR as part of broader effort to study the effects of land use on aquatic resources. She sampled 18 streams in nine of the 16 HUC 8 watersheds of the park (Earleywine 2010). Fish were collected using timed 25-30 minute backpack electroshocking samples (Earleywine 2010). One reported species, the flat bullhead (*Ameiurus platycephalus*), reported from the Big Black watershed, was considered a probable misidentification. This species is not native to any Gulf Coast drainages and has not been reported as introduced in the lower Big Black watershed (Warren et al. 2000). Excluding this record and records not identified to species level, Earleywine (2010) reported 61 species from park streams. These included 11 species not reported by Johnston (2007) (Appendix B).

The sources discussed above report a total of 175 species from the NATR region (Ross 1994, Paxton et al. 2000, Phillips and Johnston 2004, Johnston 2007, Earleywine 2010) in Tennessee, Alabama, and Mississippi (Appendix B). This list included 82 species reported by Paxton et al. (2000), 121 reported by Ross (1994), 48 reported by Phillips and Johnston (2004), 92 reported by Johnston (2007), and 61 reported by Earleywine (2010). All these data were sufficiently spatially explicit to place all species within the USGS HUC 8 watersheds from which they were reported. Some of these data were not collected recently. In some cases, the amount and type of effort was not known. Because some data were collected outside park boundaries, it is uncertain whether all these species have ever had suitable habitat within NATR. Furthermore, the sources discussed above are not an exhaustive record of all sampling from the NATR region. For these reasons, this list should be considered a rough estimate of NATR potential fish richness. However, this list resulted from literature searches and sampling efforts conducted specifically for NATR and was compiled from records collected near park boundaries. Therefore, it is expected to be a more accurate list of NATR expected fish species than could be derived at a courser geographic scale (e.g. watershed, county, or state level). We consider it a valuable starting place for understanding fish richness and distribution in the park.

The most comprehensive current understanding of fishes within NATR was derived from Johnston (2007). This study was relatively recent, and was conducted within park boundaries specifically as a comprehensive fish survey. Earleywine (2010) provided further useful data on current park fish assemblages. This effort was recent and within park boundaries, but was not fish specific and included significantly less fish sampling effort than did the Johnston (2007) inventory. We primarily used the Johnston (2007) inventory data when describing current or recent fish assemblage status in NATR. The Johnston (2007) inventory was comprehensive, NATR fish specific, and conducted by a knowledgeable published local fisheries researcher. Furthermore, fishes collected by the Johnston (2007) survey were collected and verified for certain species ID. Except where otherwise noted, the following summaries of fish assemblages use data from the field samples collected by Johnston (2007).

The most abundant and common fish species sampled by Johnston (2007) included primarily members of the families Cyprinidae (minnows) and Centrarchidae (sunfish and bass) (Table 17). Mosquitofish (*Gambusia affinis*) and blackspotted topminnows (*Fundulus olivaceus*) were also common species in the park (Table 17). The most abundant species, by total number of individuals, was the blacktail shiner (*Cyprinella venusta*), which comprised 18% of the overall individuals sampled by Johnston (2007). The creek chub (*Semotilus atromaculatus*) was the most commonly found species among samples, occurring in 46% of all samples collected. The bluegill (*Lepomis macrochirus*) was the most common species by HUC 8 watershed occurrence, and occurred in 12 (92%) of 13 HUC 8 watersheds sampled by Johnston (2007). Four species were among the top 10 in total individuals, sample occurrence, and HUC 8 occurrence. They were the blacktail shiner, creek chub, striped shiner (*Luxilus chrysocephalus*), and mosquitofish. Combined, these species represented 32% of the total sample collected by Johnston (2007).

Table 17. Common fish species in from the Natchez Trace Parkway sampled during a 2005 – 2006 fish inventory (Johnston 2007). The three listed categories include 10 most abundant by total individuals sampled (of 2,372 total), 10 most common by number of sample locations (of 59 total), and 10 most common by number of HUC 8 watersheds where species was found (of 13 possible). An "*" indicates species common to all categories and "†" indicates species unique to a single category.

Scientific Name	Common Name	Total Individuals	Sample Locations	HUC 8s
10 Most Abundant by Total Individuals				
*Cyprinella venusta**	Blacktail Shiner	426	20	8
*Semotilus atromaculatus**	Creek Chub	153	27	10
Lythrurus roseipinnis†	Cherryfin Shiner	152	9	4
Lythrurus bellus†	Pretty Shiner	140	11	3
*Luxilus chrysocephalus**	Striped Shiner	108	17	8
Clinostomus funduloides	Rosyside Dace	96	14	4
Notemigonus crysoleucas†	Golden Shiner	84	5	3
Lythrurus ardens†	Rosefin Shiner	82	8	3
*Gambusia affinis**	Mosquitofish	77	20	9
Notropis ammophilus†	Orangefin Shiner	76	8	3
10 Most Common by Sample Locations				
*Semotilus atromaculatus**	Creek Chub	153	27	10
Lepomis megalotis	Longear Sunfish	70	23	9
Lepomis macrochirus	Bluegill	60	22	12
Fundulus olivaceus	Blackspotted Topminnow	56	22	8
*Gambusia affinis**	Mosquitofish	77	20	9
*Cyprinella venusta**	Blacktail Shiner	426	20	8
*Luxilus chrysocephalus**	Striped Shiner	108	17	8
Campostoma oligolepis†	Largescale Stoneroller	43	15	5
Pimephales notatus	Bluntnose Minnow	75	14	7
Clinostomus funduloides	Rosyside Dace	96	14	4
10 Most Common by HUC 8 Occurrence				
Lepomis macrochirus	Bluegill	60	22	12
*Semotilus atromaculatus**	Creek Chub	153	27	10
Lepomis megalotis	Longear Sunfish	70	23	9
*Gambusia affinis**	Mosquitofish	77	20	9
Fundulus olivaceus	Blackspotted Topminnow	56	22	8
*Cyprinella venusta**	Blacktail Shiner	426	20	8
*Luxilus chrysocephalus**	Striped Shiner	108	17	8
Micropterus punctulatus†	Spotted Bass	28	13	8
Pimephales notatus	Bluntnose Minnow	75	14	7
Micropterus salmoides†	Largemouth Bass	23	13	7

Several species of concern at the state or federal level were reported from the Parkway by Johnston (2007). Two species listed as endangered in Mississippi occurred in the sample, but were not reported from Mississippi. These were the southern redbelly dace (*Phoxinus erythrogaster*) and the greenside darter (*Etheostoma blennioides*). The highfin carpsucker (*Carpiodes velifer*) was listed by Tennessee as "deemed in need of management" but was only reported from Mississippi. The crown darter (*Etheostoma corona*) and the flame chub (*Hemitremia flammea*) were listed by Tennessee as endangered and "deemed in need of management", respectively. These species were not reported from Tennessee but occurred near the border in watersheds extending into Tennessee. The slackwater darter (*Etheostoma boschungi*) occurred in Tennessee and is listed as threatened federally and by the state of Tennessee. Johnston (2007) reported that the federally listed bayou darter (*Etheostoma rubrum*) has been reported from NATR in the literature, but this species was not found in the recent inventory.

Non-native species were rare in the data collected in the recent inventory (Johnston 2007). The weed shiner (*Notropis texanus*) reported from Buzzard Roost Creek in the Bear Creek drainage in Alabama was considered non-native. This species is native to the Upper Tombigbee watershed (Mettee et al.1996) and is considered an introduced species in the Tennessee drainage (Etnier and Starnes 1993, Warren et al. 2000). Ross (1994) reported the species occurring in samples from the Mississippi portion of the Bear Creek watershed, and Mettee et al. (1996) reported that a record of the species from the Pickwick Lake HUC 8 watershed north of Bear Creek was the first record of the species from the Tennessee basin in Alabama. Phillips and Johnston (2004) did not find the species in the watershed. Etnier and Starnes (1993) reported new records of the species in Tennessee and suggested that it may have entered the Tennessee watershed via the artificial Tennessee-Tombigbee Waterway. To our knowledge, the report by Johnston (2007) is the first report of this species from the Bear Creek drainage in Alabama. The weed shiner is the only species considered non-native for this report. It is difficult to rule out the possibility that "native" species found at individual sites are not present as the result of anthropogenic activity. Species found in the park that potentially fit this category include the red shiner (*Cyprinella lutrensis*), mosquitofish, green sunfish (*Lepomis cyanellus*), and golden shiner (*Notemigonus crysoleucas*). These species are environmentally tolerant and have been frequently introduced outside their native range. However, in the NATR fish inventory, these species only occurred in watersheds where they were considered native. In general, the NATR fish assemblages as evidenced in the recent inventory show a low incidence of non-native species.

4.6.3 Threats and Stressors

Southeastern stream fishes face many anthropogenic threats and many native taxa are imperiled (Warren et al. 1997). General threats to southeastern fishes include deforestation and urbanization, impoundment and channelization of rivers, and competition from invasive species (Warren et al. 2000). The long, linear shape of the park, and the presence of relatively unprotected lands along much of its boundary, suggest that land use activities adjacent to park lands probably have a significant effect on park ichthyofauna. Impoundments are common in the watersheds traversed by the Parkway, and can cause the loss of the lotic fish habitat, alter flow regimes, create barriers to fish passage, and create potential reservoirs for the spread of non-native species. Recent inventory data suggests that invasive species are not a primary existing threat among NATR fish assemblages. However, the potential threat may be considerable. The artificial Tennessee-Tombigbee Waterway connects the Tennessee and Tombigbee (Mobile) River basins, increasing the risk of homogenization of the diverse and highly endemic fish faunas of these two systems. Feral hog (*Sus scrofa*) rooting activities may alter habitat critical to the survival of the threatened slackwater darter (NPS 2012). In general, these threats are recognized as having the potential to affect NATR fishes, but few specific threats have been identified and monitored.

4.6.4 Reporting Areas

Because Natchez Trace covers a large geographic extent including habitat in many watersheds, we chose to assess fish assemblages by watershed-based reporting areas. We reported fish condition using USGS HUC 8 cataloging units. We defined a reporting area as the area within a HUC 8 unit that was within 10 km of park boundaries. The 10 km buffer was used because it matched the area defined by past researchers (Ross 1994, Paxton et al. 2000), because it corresponded to a realistic region of influence for NATR fish assemblages, and because it facilitated graphic representation. Assessments were made based on data collected within park boundaries. NATR boundaries contain portions of 16 HUC 8 polygons (Figure 35; Table 18). Of these, three were not assessed in this report because of lack of recent field data (Table 18). The Lower Tennessee-Beech and Lower Mississippi-Natchez HUC 8s have limited or no fish habitat within NATR boundaries and are therefore of limited importance to park fishes.

Table 18. Surface area and total stream length within USGS HUC 8 watersheds, fish reporting areas, and NATR boundaries. An "*" indicates areas that were not assessed in this report due to lack of data.

		Area (km^2)			Total Stream Length (km)		
HUC 8 Code	**HUC 8 Name**	**HUC 8**	**Reporting Area**	**NATR**	**HUC 8**	**Reporting Area**	**NATR**
03160101	Upper Tombigbee	4652.8	956.0	11.6	8962.2	1931.3	31.3
03160102	Town	1769.1	849.0	11.2	3543.7	1687.8	20.2
03160104	Tibbee	2894.0	1077.7	15.3	5789.5	2326.0	32.1
03180001	Upper Pearl	6381.0	1144.0	15.1	11854.2	2189.7	27.8
03180002	Middle Pearl-Strong	5125.7	922.6	16.5	9048.7	1392.8	20.0
05130204	Harpeth	2243.9	651.0	8.7	3529.0	1139.3	10.4
06030005	Pickwick Lake	5907.4	1191.6	17.1	9897.8	2124.9	39.1
06030006	Bear	2442.8	669.5	8.7	3996.6	1186.3	19.9
06040001	Lower Tennessee-Beech*	5400.6	198.7	0.7	9832.6	373.0	0.0
06040003	Lower Duck	4002.7	1144.7	15.8	7949.2	2322.3	22.8
06040004	Buffalo	1973.8	656.6	9.5	3891.6	1259.9	20.4
08060100	Lower Mississippi-Natchez*	1798.9	369.5	5.2	2285.3	598.6	7.6
08060201	Upper Big Black	3834.3	1228.7	12.4	11708.7	3596.4	38.4
08060202	Lower Big Black	4942.7	1806.7	19.5	9624.6	3440.9	43.8
08060203	Bayou Pierre*	2778.4	739.7	9.3	5040.3	1254.2	20.3
08060204	Coles Creek	953.0	649.8	8.7	1733.2	1210.1	11.9

4.6.5 Data

Several data sources were used in this summary and assessment of NATR fish assemblages. Ross (1994), Paxton et al. (2000), and Phillips and Johnston (2004), Johnston (2007), and Earleywine (2010) were used to establish a baseline understanding of potential species richness in NATR. Primarily, we relied upon Johnston (2007) to assess fish assemblage condition because this was deemed the most reliable and comprehensive data on current fish condition. The Johnston (2007) data were digital records provided by the GULN. These data were spatially explicit and identifications had been verified with voucher specimens collected in the field. Unless otherwise stated, the following analyses and summaries are based on this analysis dataset.

4.6.6 Methods

General Approaches
GIS software was used to determine the approximate catchments defined by individual samples collected by Johnston (2007). Specific methods are described in metadata associated with GIS data provided with this report. Percentage of land cover within each HUC8 catchment was calculated from the 2010 NLCD landcover dataset.

Comparative Ranks
We used three basic metrics of diversity and species endemism to compare NATR fish assemblages among reporting areas. For each metric, the 13 reporting areas were divided into three categories, and assigned scores to the top, middle, and lowest third categories (Table 19). Scores for the three metrics were summed for each reporting area and the total score was used to determine a relative rank (Table 20). These ranks are strictly relative and rely on the assumption that higher values indicate better condition. They are presented primarily to assist in comparing reporting areas, and as baseline values for future reference.

Table 19. Scores corresponding to percentile ranges for values of metrics used compare fish assemblages among NATR fish reporting areas.

Score	Percentile
5	> 66.7
3	33.3 - 66.7
1	< 33.3

Table 20. Possible total scores and their ranks used to compare and assess NATR fish assemblages.

Possible Total Scores	Rank
3, 5	**Poor**
7, 9	**Fair**
11, 13, 15	**Good**

To derive comparative rankings we used the metrics: species richness, Simpson's Diversity Index (D), and endemism. Species richness was determined for individual samples and mean sample richness was used to determine scores for each reporting area. We calculated Simpson's D for individual samples using the equation:

$$D = 1 - \sum_{i=1}^{R} \left[\frac{n_i(n_i-1)}{N(N-1)}\right] \quad \text{(Eq. 2)}$$

where n_i is the number of individuals of the ith species and N is the total number of individuals in the sample. We used the mean of this index to determine scores for each reporting area. This index is adjusted for small samples without replacement and estimates the probability that two random draws from the population will be different species (Peet 1974, Kwak and Peterson 2007). Simpson's D is influenced by both species richness and evenness, but especially evenness (Huston 1994). The endemism metric was the percentage of species occurring in each reporting area that were unique to that reporting area. This metric was calculated at the reporting area scale and was not a mean of samples.

Biotic Integrity Ranks

Three metrics of assemblage diversity and composition were used to explore the condition of NATR fish assemblages. The metrics included measures commonly used in fish-based indices of biotic integrity (IBIs). Fish-based IBIs evaluate freshwater aquatic resources based upon relative density, diversity, and ecological attributes of sampled species (Karr 1981). Quality rankings are developed by analyzing assemblages from sites with known and independently-assessed levels of anthropogenic disturbance (Karr 1981). Generally, good conditions are indicated when communities contain a wide diversity of trophic specialists and relatively high proportions of specialists and sensitive species. IBIs are developed and empirically tested for specific geographic regions. To our knowledge, no regionally specific fish IBIs have been developed for most of the NATR region. We chose metrics that were calculable from the available data and which were common among multiple regional IBIs developed for southeastern fishes (Killgore et al. 2008, O'Neil and Shepard 2010, O'Neil and Shepard 2011). These metrics are not presented as complete and calibrated IBIs, but rather as generally common indicators of fish assemblage condition.

To assess fish assemblage and assign condition ranks, we used the following metrics: mean native species richness, mean number of intolerant species, and mean percentage of tolerant species. These metrics were calculated for each sample, and the mean sample value of each metric was calculated by reporting area. The scores corresponding to metric values were approximated from IBIs for regions of Alabama and Mississippi (Killgore et al. 2008, O'Neil and Shepard 2010, O'Neil and Shepard 2011) (Table 21). For each reporting area, the three scores were summed and assigned condition ranks (Table 20). Species richness or native species richness is nearly universally included in IBIs and is expected to vary with watershed area. The ability of this metric to differentiate among quality categories performed better in Alabama for watersheds larger than 25 square miles (O'Neil and Shepard 2010, O'Neil and Shepard 2011). We selected value ranges for this metric that were conservative in that they were expected values for small watersheds. Tolerant and intolerant species designations were assigned using IBI literature. The number of intolerant species and the percentage of tolerant species are common IBI metrics.

Table 21. Scores corresponding to value ranges for biotic integrity metrics used to assess the condition of NATR fish assemblages.

Score	Mn. Sp. Richness	Mn. # Intolerant Spp.	Mn. % Tolerant Spp.
5	> 11.0	> 1.0	≤ 15.0
3	8.1 - 11.0	0.1 - 1.0	15.1 - 35.0
1	≤ 8.0	0	> 35.0

Due to the several caveats mentioned, caution is warranted when interpreting these metrics. These metrics are taken from several sources and do not represent a complete and regionally calibrated IBI. However, efforts were made to apply the most useful, general, and regionally-applicable metrics. We believe these metrics will provide a useful context for NATR fish assemblages and will provide a baseline for understanding fish diversity in the reporting areas.

4.6.7 Condition and Trend

Summary

Fish sampling efforts by Johnston (2007) were distributed among 13 reporting areas, with effort ranging from two to 10 samples for individual reporting areas (Table 22). Percentage of forest within sample catchments ranged from 32.2 to 86.9% among HUC 8 units, with the Town HUC 8 having the lowest and the Harpeth HUC 8 having the greatest percent of forest cover (Table 22). Conversely, percentage of agriculture and development within sample catchments ranged from 2.5 to 25.8% with Town having the highest and Harpeth having the lowest (Table 22).

Table 22. Summary of total sample catchment area, catchment landcover, number of samples, number of individuals (N), and species richness, from a fish inventory conducted in NATR by Johnston (2007). Max. Spp. Rich. is the total number of species reported from the reporting area by five researchers (see Appendix B). Total catchments were watersheds areas upstream of individual samples locations, combined for the reporting area. Forest, agricultural, and developed landcover represent combined classes for those types defined by 2010 NLCD data.

HUC 8 Code	HUC 8 Name	Total Catch. Area (km^2)	% Forest Catch. Area	% Ag. & Dev. Catch Area	# Samps.	N	Spp. Rich.	Max. Spp. Rich.
03160101	Upper Tombigbee	181	48.6	16.9	5	209	20	69
03160102	Town	422.6	32.2	25.8	5	395	18	35
03160104	Tibbee	351.7	47.4	14.1	8	389	22	41
03180001	Upper Pearl	95.3	56.9	6.4	5	152	19	61
03180002	Middle Pearl-Strong	41.6	41.0	7.8	2	76	15	19
05130204	Harpeth	29.5	86.9	2.5	5	94	16	30
06030005	Pickwick Lake	148.4	46.5	20.8	10	277	27	49
06030006	Bear	1,002.6	58.5	6.6	3	154	21	84
06040003	Lower Duck	56.8	60.9	6.3	2	72	21	57
06040004	Buffalo	100.4	69.0	8.1	2	64	19	66
08060201	Upper Big Black	250	55.6	8.2	4	104	14	45
08060202	Lower Big Black	360.5	46.3	14.6	5	302	25	56
08060204	Coles Creek	353.5	71.8	5.7	3	84	14	44

Comparative

A comparative examination showed that fish reporting areas in the northern Tennessee River watershed section of the Parkway generally tended to have greater mean richness, higher mean Simpson's D, and greater percentages of endemic fish species, relative to more southern reporting areas (Figure 36). There were exceptions to this pattern. The Lower Big Black reporting area had high relative mean species richness (Figure 36-A). The Upper Pearl and the Coles Creek reporting areas had relatively high percentages of species unique to those reporting areas (Figure 36-C). The highest third of reporting areas by mean Simpson's D were all located in the northernmost portions of the Parkway (Figure 36-B). This resulted because samples from these regions tended to have greater evenness, with less dominance by a few species. The central reporting areas located along the Tombigbee River watershed tended to have the lowest ranks relative to other NATR fish reporting areas. Although there was variance among the reporting areas, the Tombigbee watershed reporting areas tended to have low forest and high development relative to fish sample catchments along NATR generally (Table 22). This may contributed to the relatively lower ranks observed for these reporting areas.

Relative ranks for the NATR fish reporting areas were created to assist in understanding variance in fish assemblage composition along the Parkway. Species richness, Simpson's Diversity Index, and species endemism are metrics of potential interest to managers. The relationship of these metrics to condition is not fully understood and is expected to vary among regions. For this report, these metrics were broadly interpreted as "larger is better". Within NATR, Tennessee watershed fish resources stand out for having relatively high values of these metrics, and Tombigbee fish resources are notable for low values.

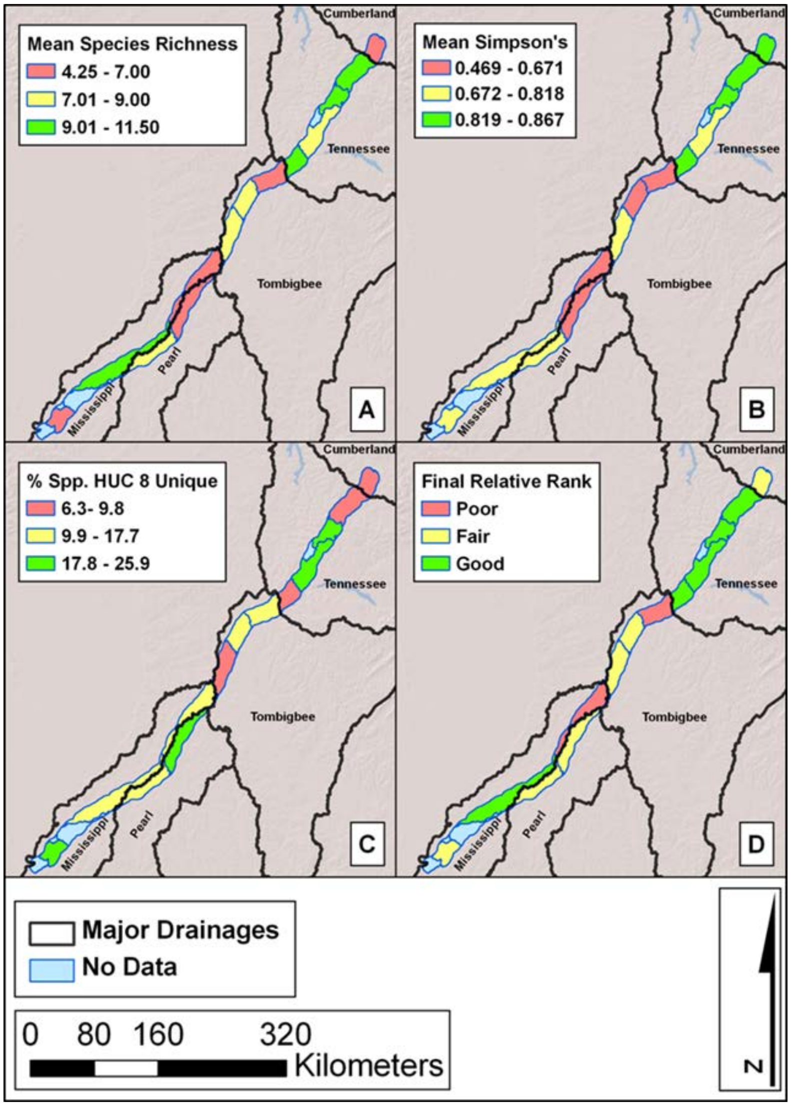

Figure 36. Relative ranks of fish reporting areas from NATR fish inventory data (Johnson 2007), showing the approximate lowest third (red), middle third (yellow), and highest third (green) of reporting areas (A – C) for three assemblage metrics, and a combined relative rank (D). See methods for a description of metrics and scoring.

<u>Biotic Integrity</u>

Harpeth

The Harpeth was the northernmost fish reporting area in the park. Five samples were collected in this reporting area. Mean sample catchment area was 5.9 km^2, the smallest among NATR reporting areas, indicating that samples were collected from small streams. Mean sample species richness was 7.0, mean number of intolerant species was 2.2, and mean percentage of tolerant species was 19.4. For the reference ranges used, mean richness was low and mean number of intolerant species was high. The condition of the Harpeth fish reporting area was ranked as fair (Table 23, Figure 37). The data quality was ranked as fair (Table 23). The data was collected within the park and adequately covered the available habitat. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling of the same area; therefore, the data did not receive a check for thematic sufficiency.

Table 23. Fish assemblage condition for the Harpeth (HUC 8 05130204) fish reporting area was fair, but no trend was assigned. Data quality for fish condition assemblage was fair.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Harpeth		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Lower Duck

The Lower Duck fish reporting area lies directly south of the Harpeth. Two samples were collected in this reporting area. Mean sample catchment area was 28.4 km^2. Mean sample species richness was 11.5, mean number of intolerant species was 3.0, and mean percentage of tolerant species was 27.0. The condition of the Lower Duck fish reporting area was ranked as good (Table 24) (Figure 37). The data quality was ranked as marginal (Table 24). The data were collected within the park but only two samples were collected within the reporting area. Therefore, the data did not receive a spatial coverage check. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same area; therefore, the data did not receive a check for thematic sufficiency.

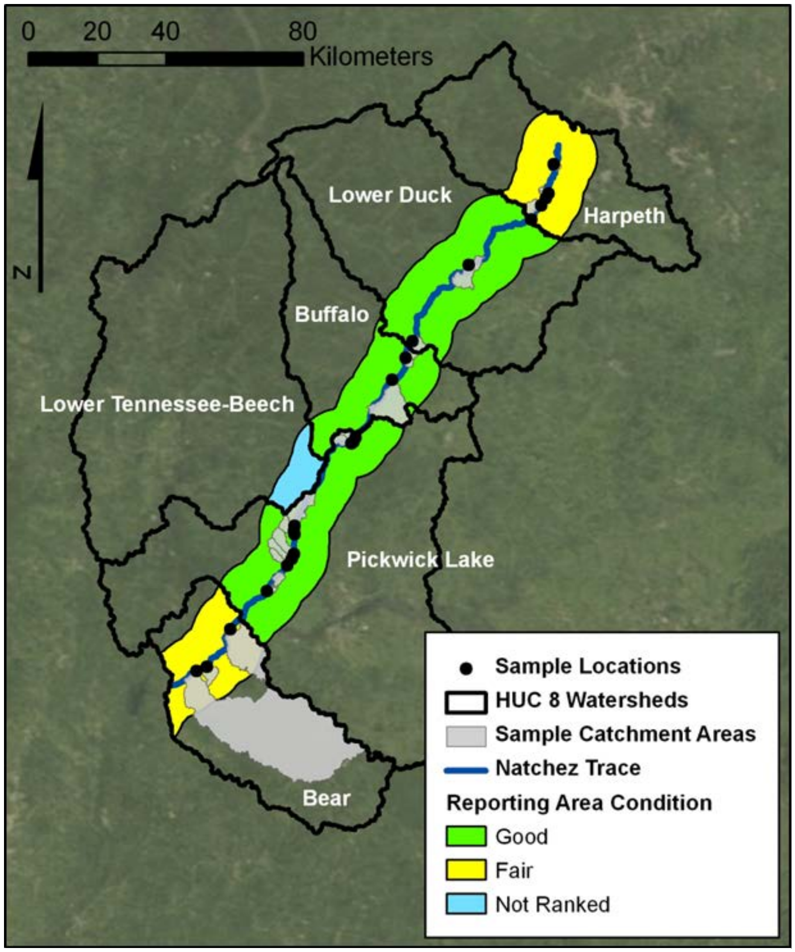

Figure 37. Biotic integrity condition ranks of fish reporting areas, and sample catchment areas of the northern portion of NATR. Based on samples collected by Johnston (2007).

Table 24. Fish assemblage condition for the Lower Duck (HUC 8 06040003) fish reporting area was good. Data quality for fish condition assemblage was marginal. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Lower Duck	Good (green circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage		Coverage	
		3 of 6: Marginal					

Buffalo

The Buffalo fish reporting area lies directly south of the Lower Duck (Figure 37). Two samples were collected in this reporting area. Mean sample catchment area was 50.2 km^2. Mean sample species richness was 11.5, mean number of intolerant species was 6.0, and mean percentage of tolerant species was 13.0. The condition of the Buffalo fish reporting area was ranked as good (Table 25, Figure 37). The data quality was ranked as marginal (Table 25). The data were collected within the park but only two samples were collected within the reporting area. Therefore, the data did not receive a spatial coverage check. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same area. Therefore, the data did not receive a check for thematic sufficiency. Although sampling effort was low for this reporting area, results suggest it is one of the highest quality regions of the park in terms of fish assemblage condition.

Table 25. Fish assemblage condition for the Buffalo (HUC 8 06040004) fish reporting area was good. Data quality for fish condition assemblage was marginal. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Buffalo	Good (green circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage		Coverage	
		3 of 6: Marginal					

Pickwick Lake

The Pickwick Lake fish reporting area lies directly south of the Buffalo and is part of the Tennessee River drainage (Figure 37). Ten samples were collected in this reporting area. Mean sample catchment area was 14.8 km^2. Mean sample species richness was 8.4, mean number of intolerant species was 1.7, and mean percentage of tolerant species was 22.8. The condition of the Pickwick Lake fish reporting area was ranked as good (Table 26, Figure 37). The data quality was ranked as fair (Table 26). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer.

Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 26. Fish assemblage condition for the Pickwick Lake (HUC 8 06030005) fish reporting area was good. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Pickwick Lake		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Bear

The Bear fish reporting area lies directly south of the Pickwick Lake reporting area and is part of the Tennessee River drainage (Figure 37). Three samples were collected in this reporting area. Mean sample catchment area was 334.2 km^2, the largest among the fish reporting areas in this report. This resulted primarily because a sample collected in Cedar Creek (southernmost sample within the reporting area) had a relatively large catchment area of 854.0 km^2 (Figure 37). Mean sample species richness was 10.0, mean number of intolerant species was 0.67, and mean percentage of tolerant species was 27.0. The condition of the Bear fish reporting area was ranked as fair (Table 27, Figure 37). The data quality was ranked as fair (Table 27). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 27. Fish assemblage condition for the Bear (HUC 8 06030006) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Bear		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Upper Tombigbee

The Upper Tombigbee fish reporting area lies directly south of the Bear reporting area and is the northernmost reporting area within the Tombigbee Drainage (Figure 38). Five samples were collected in this reporting area. Mean sample catchment area was 36.2 km^2. Mean sample species richness was 6.4, mean number of intolerant species was 0.2, and mean percentage of tolerant species was 33.4. The condition of the Upper Tombigbee fish reporting area was ranked as fair (Table 28, Figure 38). The data quality was ranked as fair (Table 28). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 28. Fish assemblage condition for the Upper Tombigbee (HUC 8 03160101) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Fish Assemblages: Upper Tombigbee		Relevancy ✓	Proximity ✓	Currency ✓
		Sufficiency	Coverage ✓	Coverage
		4 of 6: Fair		

Town

The Town fish reporting area lies south of the Upper Tombigbee reporting area and within the Tombigbee River Drainage (Figure 38). Five samples were collected in this reporting area. Mean sample catchment area was 84.5 km2. Mean sample species richness was 7.2, no intolerant species were found, and mean percentage of tolerant species was 29.8. The condition of the Town fish reporting area was ranked as poor (Table 29, Figure 38). The data quality was ranked as fair (Table 29). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

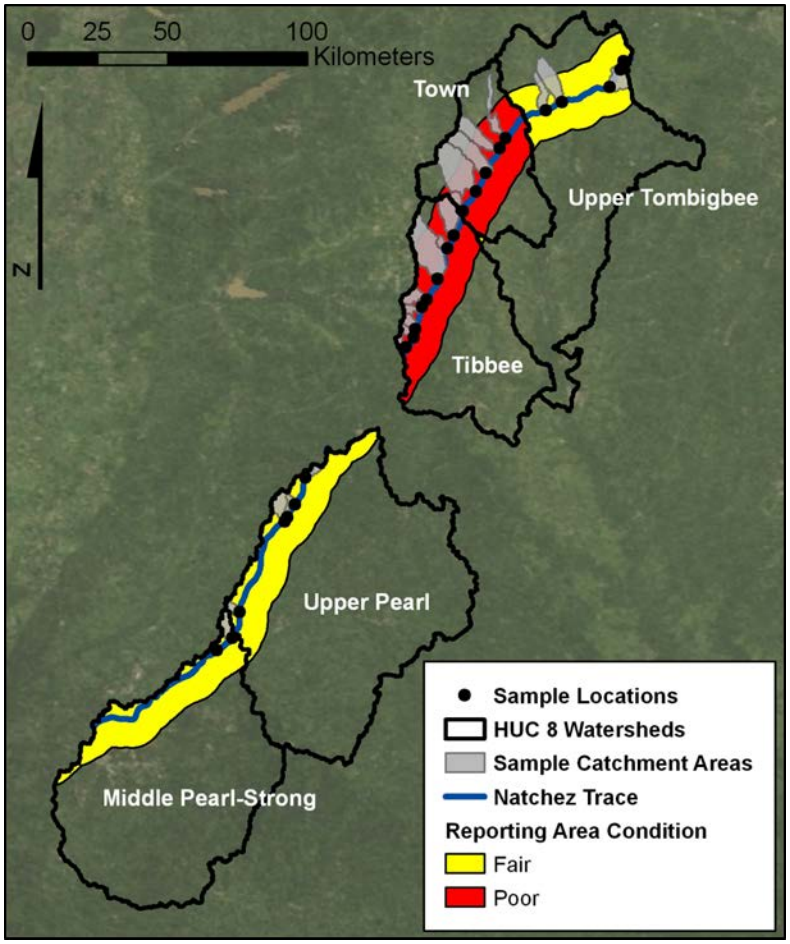

Figure 38. Biotic integrity condition ranks of fish reporting areas, and sample catchment areas of the central portion of NATR. Based on samples collected by Johnston (2007). Parkway areas outside the reporting areas for this study have been clipped out.

Table 29. Fish assemblage condition for the Town (HUC 8 03160102) fish reporting area was poor. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Town	Red circle (Poor)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Tibbee

The Tibbee fish reporting area lies south of the Town reporting area and within the Tombigbee River Drainage (Figure 38). Eight samples were collected in this reporting area. Mean sample catchment area was 44.0 km^2. Mean sample species richness was 7.5, mean number of intolerant species was 0.4, and mean percentage of tolerant species was 45.4. The condition of the Tibbee fish reporting area was ranked as poor (Table 30, Figure 38). The data quality was ranked as fair (Table 30). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 30. Fish assemblage condition for the Tibbee (HUC 8 03160104) fish reporting area was poor. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Tibbee	(red circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Upper Pearl

The Upper Pearl fish reporting area lies south of the Tibbee reporting area, east of the Upper Big Black reporting area, and within the Pearl River drainage (Figure 38). Five samples were collected in this reporting area. Mean sample catchment area was 19.1 km^2. Mean sample species richness was 6.8, mean number of intolerant species was 0.8, and mean percentage of tolerant species was 13.0. The condition of the Upper Pearl fish reporting area was ranked as fair (Table 31, Figure 38). The data quality was ranked as fair (Table 31). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 31. Fish assemblage condition for the Upper Pearl (HUC 8 03180001) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Upper Pearl		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Middle Pearl-Strong

The Middle Pearl-Strong fish reporting area lies south of the Upper Pearl reporting area, east of the Lower Big Black Reporting area, and within the Pearl River drainage (Figure 38). Two samples were collected in this reporting area. Mean sample catchment area was 20.8 km^2. Mean sample species richness was 8.0, mean number of intolerant species was 1.0, and mean percentage of tolerant species was 25.5. The condition of the Middle Pearl fish reporting area was ranked as fair (Table 32, Figure 38). The data quality was ranked as marginal (Table 32). The data were collected within the park but only two samples were collected within the reporting area. Therefore, the data did not receive a spatial coverage check. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 32. Fish assemblage condition for the Middle Pearl-Strong (HUC 8 03180002) fish reporting area was fair. Data quality for fish condition assemblage was marginal. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Middle Pearl-Strong		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage		Coverage	
		3 of 6: Marginal					

Upper Big Black

The Upper Big Black fish reporting area lies south of the Tibbee reporting area, west of the Upper Pearl reporting area, and within the Lower Mississippi River drainage (Figure 39). Four samples were collected in this reporting area. Mean sample catchment area was 62.5 km^2. Mean sample species richness was 4.3, mean number of intolerant species was 0.8, and mean percentage of tolerant species was 30.0. The condition of the Upper Big Black fish reporting area was ranked as fair (Table 33, Figure 39). The data quality was ranked as fair (Table 33). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 33. Fish assemblage condition for the Upper Big Black (HUC 8 08060201) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Upper Big Black	(yellow circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Lower Big Black

The Lower Big Black fish reporting area lies south of the Upper Big Black, west of the Middle Pearl-Strong reporting area, and within the Lower Mississippi River drainage (Figure 39). Five samples were collected in this reporting area. Mean sample catchment area was 72.1 km^2. Mean sample species richness was 10.2, mean number of intolerant species was 0.6, and mean percentage of tolerant species was 33.4. The condition of the Lower Big Black fish reporting area was ranked as fair (Table 34, Figure 39). The data quality was ranked as fair (Table 34). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but

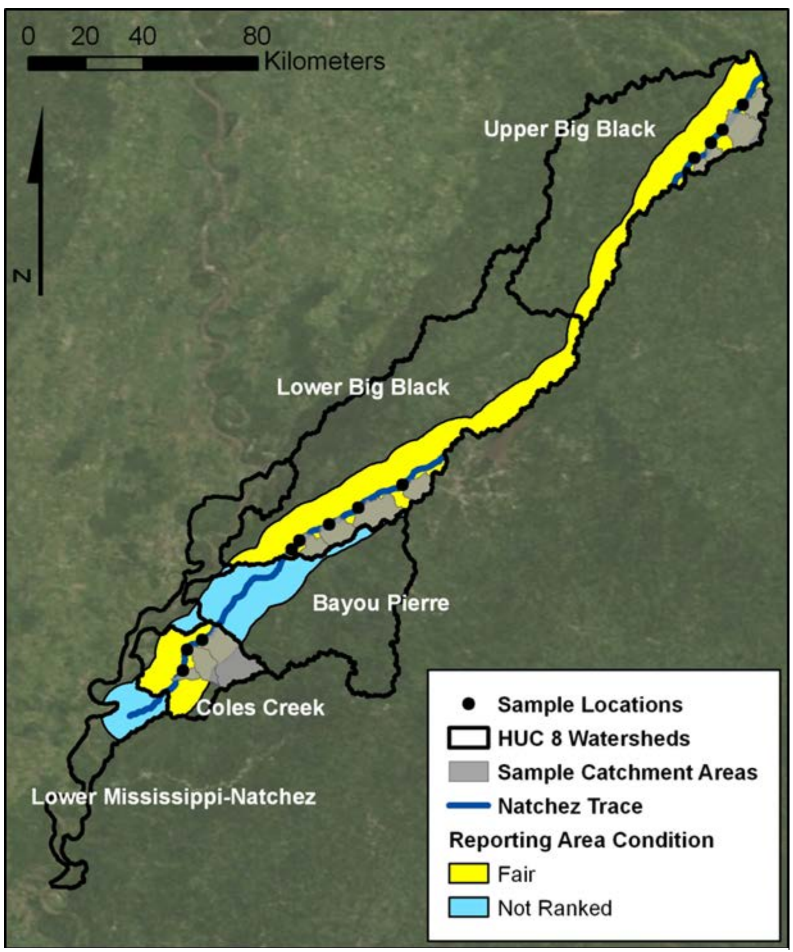

Figure 39. Biotic integrity condition ranks of fish reporting areas, and sample catchment areas of the southern portion of NATR. Based on samples collected by Johnston (2007).

did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 34. Fish assemblage condition for the Lower Big Black (HUC 8 08060202) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Lower Big Black		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

Coles Creek

The Coles Creek fish reporting area lies south of the Bayou Pierre HUC 8 watershed and within the Lower Mississippi River drainage (Figure 39). Three samples were collected in this reporting area. Mean sample catchment area was 118.8 km^2. Mean sample species richness was 7.0, mean number of intolerant species was 1.3, and mean percentage of tolerant species was 42.0. The condition of the Coles Creek fish reporting area was ranked as fair (Table 35, Figure 39). The data quality was ranked as fair (Table 35). The data were collected within the park and adequately covered the fish habitat of the area. Data were sufficiently recent but were collected only during summer. Therefore, the data did not receive a temporal coverage check. The data were of a type useful for assessing condition, but did not represent repeated sampling from the same sites. Therefore, the data did not receive a check for thematic sufficiency.

Table 35. Fish assemblage condition for the Coles Creek (HUC 8 08060204) fish reporting area was fair. Data quality for fish condition assemblage was fair. No trend was assigned to fish assemblage quality condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Fish Assemblages: Coles Creek		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency		Coverage	✓	Coverage	
		4 of 6: Fair					

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4.7 Bird Assemblages

4.7.1 Relevance and Context

Birds specialize in a variety of habitats and are relatively easy to monitor, making them valuable indicators of terrestrial ecosystem quality and function (Maurer 1993). Key species of eastern U.S. obligate forest birds have shown a steady decline in abundance for over 40 years, causing concern for managers (USGS 2009). The Natchez Trace Parkway has a large geographic extent, traversing ecologically distinct regions. The narrow corridor of park land, and the presence of the motor road, may preclude some species of interior forest specialists from some areas of park habitat. Nevertheless, NATR is a long transect of relatively protected land that can provide habitat for many species of concern. Furthermore, bird monitoring on the park can provide valuable insight on the status of birds in the region.

4.7.2 Resource Knowledge

General Background

A general understanding of breeding season bird richness and relative abundance in the NATR region was derived from the North American Breeding Bird Survey (BBS). The BBS program, coordinated by the U.S. Geological Survey, uses standardized point counts to annually collect data on breeding birds along established driving routes (Sauer et al. 2011). Although there are biases associated with a survey conducted entirely along roadways, the standardized methods, long-term nature, and continental scope of the BBS make this data a valuable tool for understanding breeding bird distribution and trends at large spatial scales. Furthermore, because NATR is characterized by a motor roadway, BBS data are uniquely useful for providing a picture of expected breeding birds in the park. BBS routes for the 20-year period 1992 – 2011 for which the entire length was located within a 40 km park buffer were selected (Figure 40). This dataset contained 131 species. The Northern Cardinal (*Cardinalis cardinalis*) was the most relatively abundant species in the dataset, and the 10 most abundant species included nine native birds and the introduced European Starling (*Sturnus vulgaris*) (Table 36).

A basic understanding of common winter bird species in NATR region was derived from Christmas Bird Count (CBC) data. The CBC is coordinated by the Audubon Society and conducted each winter (Audubon 2013). Birds are recorded in December and January within established 24-km diameter circles. Because the ability of volunteers varies, and the amount and type of effort is not standardized, CBC data are best suited to provide a general idea of winter bird diversity. From a dataset provided by NPS, we selected data collected from locations near NATR from the 20-year period 1989/90 – 2008/09 (Figure 40). We excluded birds not identified to species, and species reported in low numbers (fewer than five individuals) that were reported outside their normal range and not expected to normally occur in the NATR region. This dataset contained 176 species. The Red-winged Blackbird (*Agelaius phoeniceus*) was the most relatively abundant species in the dataset, and the 10 most abundant birds included eight native species, the European Starling, and the range expanding Brown-headed Cowbird (*Molothrus ater)* (Table 36).

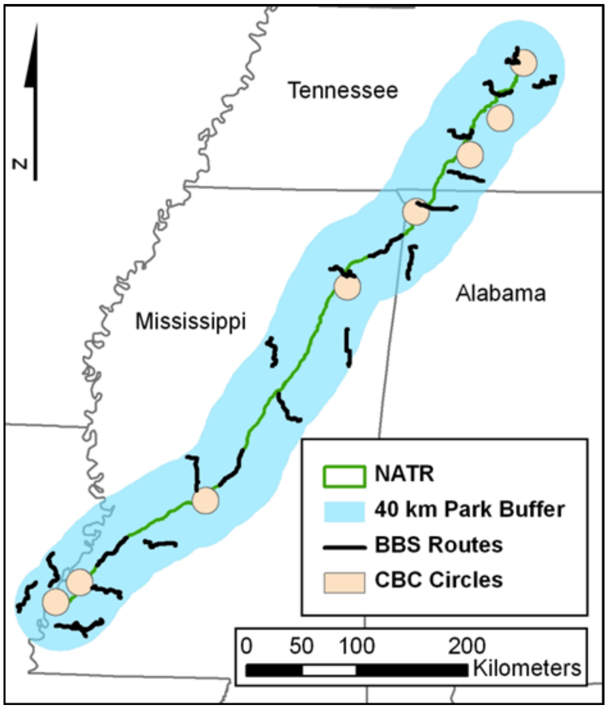

Figure 40. Location of Breeding Bird Survey (BBS) routes and Christmas Bird Count (CBC) circles near the Natchez Trace Parkway.

Table 36. Ten most relatively abundant bird species in a 20-year dataset of BBS routes within 40 km of NATR, in a 20-year dataset of CBC circles located near NATR, and in a dataset collected during 1999 – 2000 within NATR.

Scientific Name	Common Name
10 Most Common: BBS 1992-2011	
Cardinalis cardinalis	Northern Cardinal
Corvus brachyrhynchos	American Crow
Passerina cyanea	Indigo Bunting
Zenaida macroura	Mourning Dove
Agelaius phoeniceus	Red-winged Blackbird
Mimus polyglottos	Northern Mockingbird
Sturnus vulgaris	European Starling
Thryothorus ludovicianus	Carolina Wren
Icteria virens	Yellow-breasted Chat
Baeolophus bicolor	Tufted Titmouse
10 Most Common: CBC 1989/90 - 2008/09	
Agelaius phoeniceus	Red-winged Blackbird
Sturnus vulgaris	European Starling
Quiscalus quiscula	Common Grackle
Turdus migratorius	American Robin
Fulica americana	American Coot
Phalacrocorax auritus	Double-crested Cormorant
Corvus brachyrhynchos	American Crow
Zonotrichia albicollis	White-throated Sparrow
Molothrus ater	Brown-headed Cowbird
Cardinalis cardinalis	Northern Cardinal
10 Most Common: NATR Bird Inventory 1999 - 2000	
Baeolophus bicolor	Tufted Titmouse
Corvus brachyrhynchos	American Crow
Cyanocitta cristata	Blue Jay
Melanerpes carolinus	Red-bellied Woodpecker
Cardinalis cardinalis	Northern Cardinal
Passerina cyanea	Indigo Bunting
Petrochelidon pyrrhonota	Cliff Swallow
Poecile carolinensis	Carolina Chickadee
Hirundo rustica	Barn Swallow
Turdus migratorius	American Robin

Park Birds

Accipiter Biological Consultants conducted a comprehensive park-specific bird inventory of NATR (Accipiter 2001). Birds were sampled within park boundaries from 1999 – 2000 using breeding bird survey roadside point counts, general habitat-stratified point counts, and raptor road counts (Accipiter 2001). These combined methods resulted in 134 species reported from within park boundaries. The most relatively abundant species was the Tufted Titmouse (*Baeolophus bicolor*), and the 10 most relatively abundant birds were all native species (Table 36).

A number of birds of conservation concern were reported from the NATR bird inventory (Accipiter 2001). No federal threatened or endangered species were reported, although three whooping cranes (endangered) from an experimental flock were at NATR for several weeks. They were thought to have been part of a flock that uses nearby Wheeler National Wildlife Refuge (L. McInnis, personal communication). Four state protected species were observed (Table 37). A number of species of conservation concern, as indicated by a Partners in Flight (PIF) score-based ranking system, were also reported (Table 37). PIF is a partnership of federal, state, academic, and non-governmental organizations that assigns threat scores based on regional and continental-scale population factors (Panjabi et al. 2012). We used regional scores to create conservation ranks for species where "0" indicated exotic species and "4" indicated species of high conservation concern that are declining or face threats to persistence (Nuttle et al. 2003). All of the concern species in Table 37, except the American White Pelican (*Pelecanus erythrorhynchos*) and the American Kestrel (*Falco sparverius*), were reported from NATR during the breeding season. However, the Bewick's Wrens (*Thryomanes bewickii*), reported from several locations in May 1999, are not expected to breed there, and these individuals may have been the result of a late migration (Accipiter 2001). The reported concern species had a range of habitat associations, including forest, grassland, early successional, scrub, and edge habitats.

Table 37. Bird species of conservation concern reported from a 1999 – 2000 bird inventory (Accipiter 2001) at Natchez Trace Parkway.

Scientific Name	Common Name	Status	PIF4
Accipiter cooperii	Cooper's Hawk	SP(AL)	
Aimophila aestivalis	Bachman's Sparrow	E(TN)	X
Ammodramus savannarum	Grasshopper Sparrow		X
Dendroica cerulea	Cerulean Warbler		X
Falco sparverius	American Kestrel		X
Hylocichla mustelina	Wood Thrush		X
Lanius ludovicianus	Loggerhead Shrike		X
Limnothlypis swainsonii	Swainson's Warbler		X
Oporornis formosus	Kentucky Warbler		X
Passerina ciris	Painted Bunting		X
Pelecanus erythrorhynchos	American White Pelican	SP(AL)	
Seiurus motacilla	Louisiana Waterthrush		X
Sitta pusilla	Brown-headed Nuthatch		X
Thryomanes bewickii	Bewick's Wren	E(MS,TN), SP(AL)	X
Vermivora pinus	Blue-winged Warbler		X

Six exotic or range-expanding species of birds were reported from the NATR bird inventory (Accipiter 2001) (Table 38). The House Finch (*Carpodacus mexicanus*), Brown-headed Cowbird, and House Wren (*Troglodytes aedon*) are species native to North America that have expanded from their historic ranges into the NATR region. The other three birds are exotic European species. Of these six, only the Brown-headed Cowbird was widely occurring and relatively abundant in the NATR bird survey. All six species are typically associated with human-altered landscapes.

Table 38. Species of introduced or range-expanding birds reported from Natchez Trace Parkway during a 1999 – 2000 bird inventory.

Scientific Name	Common Name
Carpodacus mexicanus	House Finch
Columba livia	Rock Pigeon
Molothrus ater	Brown-headed Cowbird
Passer domesticus	House Sparrow
Sturnus vulgaris	European Starling
Troglodytes aedon	House Wren

4.7.3 Threats and Stressors

North American birds face a number of general threats including land conversion, development, exotic plant and animal species, nest parasitism, forest pests, and agricultural and land management practices (Robinson et al. 1995, Schmidt and Whelan 1999, USGS 2009). Because of the park's narrow shape and large geographic extent, it can be expected that many of these affect NATR birds to some degree, although this is conjecture. A potential stressor relevant to NATR is the impact of the motor roadway itself. Paved roads can cause direct mortality, limit movement, and pose indirect threats related to artificial noise and light (Kociolek et al. 2011). The road corridor results in fragmentation of the landscape and fragmentation may limit the abundance or success of some interior forest specialists in the park. Habitat fragmentation decreases the amount of some habitats and provides greater access of Brown-headed Cowbirds to nests of native breeding species. Cowbirds are relatively common throughout the park and are known to negatively impact nest success of native species in fragmented habitats (Robinson et al. 1995). Fragmentation can also lead to increased predation pressure by corvids on other birds, however whether this is an issue in NATR is not known. In fragmented areas, even apparently diverse assemblages containing native species of concern could be population sinks at the meta-population level (Robinson et al. 1995). Human-altered habitats are preferred by the widespread European Starling, which competes for nest cavities with significant negative effects on native species (Cabe 1993). However, Starlings were relatively uncommon in the NATR bird inventory (Accipiter 2001). The proximity of the Parkway to some residential areas suggests that feral or free-ranging domestic animals, namely cats (*Felis catus*) and dogs (*Canis familiaris*), can access park lands. Free-ranging cat predation may negatively impact breeding bird population (Lepcyzk et al. 2003). The Park also contains a number of non-native plant species. Some species of non-native vegetation may contribute to lower nest success for some native species that choose them as nest sites (Schmidt and Whelan 1999).

4.7.4 Reporting Areas

For assessment purposes, we divided NATR into two reporting areas: North and South (Figure 41). The North Reporting Area included Park lands from mile marker 325 north to the northern terminus of the Parkway, and was approximately 195 km long. The South Reporting Area included Park lands from mile marker 325 south to the southern terminus of the parkway, and was approximately 523 km long. These reporting areas were chosen because they corresponded with ecological and bird management boundaries. The North Reporting Area approximately corresponded with the EPA Interior Plateau Level III Ecoregion (EPA 2012) (Figure 41), and with the USDA Continental Eastern Broadleaf Forest Ecosystem Province (Bailey 1995). It was primarily located within PIF Physiographic Area 14: Interior Low Plateaus (Ford et al. 2000). The NATR bird inventory used 12 physiographic regions to describe the Park; the bird North

Reporting Area consisted of West Tennessee Plain region and the Nashville Basin region (Accipiter 2001).

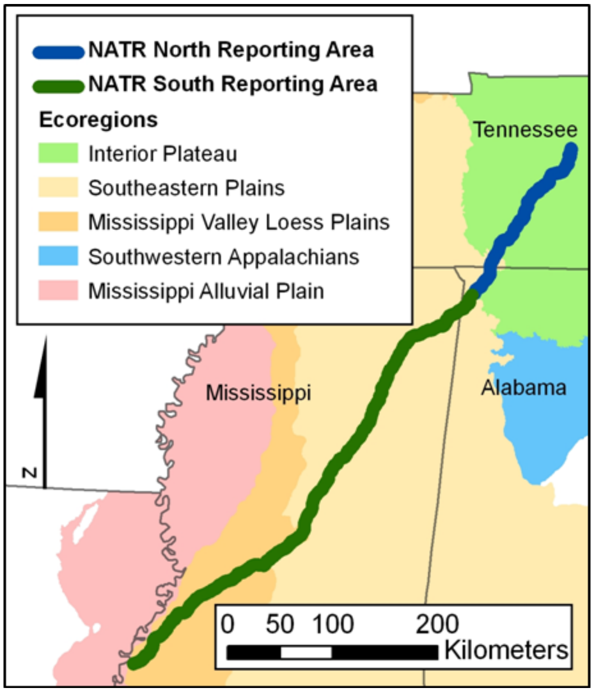

Figure 41. Natchez Trace Bird Reporting Areas and surrounding EPA Level III Ecoregions.

The South Reporting Area approximately corresponded with the EPA Southeastern Plains and Mississippi Valley Loess Plains Level III Ecoregions (EPA 2012) (Figure 41), and with the USDA Southeastern Mixed Forest Ecosystem Province (Bailey 1995). It was primarily located within PIF Physiographic Area 4: East Gulf Coastal Plain (PIF 2001). The bird South Reporting Area contained 10 physiographic regions as reported by Accipiter (2001), and these were, from north to south: Tennessee Valley, Fall Line Hills, Pontotoc Hills, Black Prairie, Flatwoods, North Central Mississippi Hills, Jackson Prairie, Long Leaf Pine Hills, Loess Hills, and Mississippi Alluvial Plain.

4.7.5 Data

To assess NATR bird condition we used data from the Park bird inventory conducted by Accipiter (2001), USGS BBS data, and CBC data. The NATR-specific bird inventory data was taken from the text and tables of the Accipiter (2001) report and included relative abundance, by species, reported by three methods, at several geographic scales, and by habitat type.

The USGS BBS data included results of completed BBS surveys for routes located entirely within a 40-km park buffer. From these routes, we used results from the period 1992 – 2012 for routes with at least five years of data during that time. Three routes, all located in the South Reporting Area, were located entirely within NATR boundaries. The USGS BBS dataset included 196,392 individuals, of 131 species, from 21 BBS routes. We used several subsets of this dataset in our assessment.

The CBC dataset included results of completed surveys for circles located near the Parkway. Data were provided by the GULN network, but are also available for download online. From these counts, we used results from the winter of 1989-90 to the winter of 2008-09, for circles with data collected during this time. We removed from this dataset all individuals not identified to species, species that we believed were extremely rare migrants, and a few species we suspected were the result of misidentification. Rare migrants removed included species occurring at less than five individuals for the 20-year period for which all known breeding and wintering distributions are located far from NATR boundaries. Most of these were obligate coastal wintering species that breed in polar or boreal regions. We acknowledge that these species can occur in NATR, but excluded them because our goal was to provide an estimate of the species that are reasonably expected to use NATR habitat and thus be of concern to managers. CBC data are collected by individuals of widely varying abilities, and collection effort and methods are not standardized. For this reason, and for the other caveats mentioned, we used the CBC data to provide context to NATR-area bird assemblages, but not for assessment purposes. This dataset included 3,234,754 individuals of 176 species, from eight CBC circles.

4.7.6 Methods

We made several comparisons of expected species richness to observed species richness. The expected species lists were taken from the 20-year BBS and CBC datasets described above. We created expected species lists, by reporting area, for all species reported by the combined BBS and CBC datasets, for all concern species reported by both datasets, for all BBS species, and for all BBS concern species. We compared these lists of species actually reported by the NATR bird inventory (Accipiter 2001), and calculated the percentage of expected species observed for each category. The expected lists were compiled from substantially greater effort over a wider geographic area, relative to the observed lists. Expected species lists were intended to be an estimate of maximum potential richness for the area, and not an expectation of the richness observed from any single study.

Because three USGS BBS routes are located within park boundaries in the South Reporting Area, comparisons between park and non-park samples were possible for this reporting area. The NATR routes were sampled starting in 2007. Therefore, we created a comparison dataset containing these routes and eight other routes located near the Parkway in the South Reporting Area (Figure 42). For all routes we included only data from 2007 – 2011 and routes that had at least three years of data during that time period. This dataset included data from 11 routes (including the NATR routes), and was termed the comparison dataset.

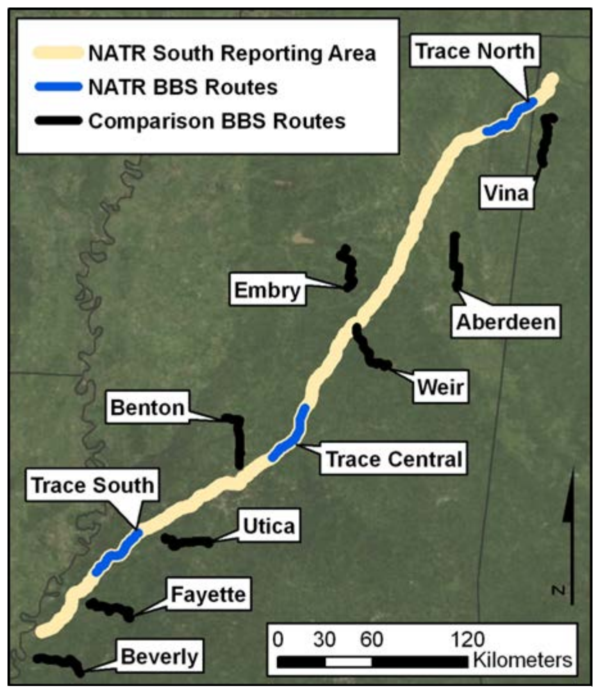

Figure 42. USGS BBS routes located within NATR boundaries and comparison routes located within 40 km of park boundaries for the South Reporting Area.

<u>Trait Data</u>

We used species trait designations to compare the NATR BBS routes to the regional comparison routes in the South Reporting Area. O'Connell et al. (1998, 2003) used life history traits of bird species to assess the biotic integrity of bird habitat in the mid-Atlantic highlands (O'Connell et al. 1998) and the mid-Atlantic piedmont and coastal plain (O'Connell et al. 2003). This Bird Community Index was developed to assess the level of anthropogenic disturbance using bird point count data. Although the regions of suggested applicability for the indices included most of NATR, no points were collected in the Gulf coastal plain during the development of the indices (O'Connell et al. 1998, 2003). Therefore, we did not use the indices in our assessment. However, we used a selection of trait designations from these publications to explore differences between NATR and non-NATR BBS data. We selected traits from three categories: primary habitat association, nesting location, and foraging methods (Table 39). O'Connell et al. (1998, 2003) classed all traits as "generalist" or "specialist" where generalist traits were those found in species that are successful across a variety of human-altered habitats, and specialist traits were those found in species requiring less altered habitat.

Table 39. Selected generalist and specialist life history traits in three categories used to compare between NATR and non-NATR BBS data. Traits were taken from O'Connel et al. (1998, 2003).

Trait	Type
Primary Habitat Association	
Forest Generalist	Generalist
Forest Edge	Generalist
Agriculture and Urban Land	Generalist
Interior Forest Obligate	Specialist
Pine	Specialist
Grassland and Savannah	Specialist
Nesting Location	
Shrub	Generalist
Forest Ground	Specialist
Open Ground	Specialist
Tree Canopy	Specialist
Cavity	Specialist
Foraging Method	
Omnivore	Generalist
Bark Probing Insectivore	Specialist
Ground Gleaning Insectivore	Specialist
Upper Canopy Insectivore	Specialist
Lower Canopy Insectivore	Specialist

We used the numbers and proportions of species and individuals to compare between NATR and non-NATR BBS route data. Because some species did not have trait data, we used only the assemblage of birds with traits available when determining these values. Traits were not mutually exclusive within or among categories and all birds were not assigned traits in all categories. Therefore, the sum of all proportions in any assemblage did not have to have a value of one, even within a given category. We created a ratio of specialist to generalist traits for each route by dividing the sum of the proportion of individuals showing specialist responses by the sum of the proportion of individuals showing generalist responses. In theory, the higher this value, the more "specialized" the observed assemblage in terms of requiring habitat with less anthropogenic disturbance. We graphically represented the proportion of individuals, the proportion of species, and the actual number of individuals with selected specialist and generalist traits for the combined data from each route to determine if the NATR routes tended to have greater numbers or proportions of specialists.

Conservation Ranks

We used the comparison dataset described above to calculate and compare conservation rank indices for USGS BBS routes. Partners in Flight prepares conservation values in several categories that are designed to reflect the level of threats to persistence experienced by bird species (Panjabi et al. 2012). Scores are prepared at global and regional scales (Panjabi et al. 2012). Nuttle et al. (2003) used these scores to develop ranks for individual species ranging from 0 – 4 (Table 40). We used PIF global and regional scores to calculate conservation ranks for species sampled in USGS BBS routes within NATR and within a 40-km buffer of bark boundaries.

Table 40. Rank, level of concern, and rank description for a conservation ranking method developed by Nuttle et al. (2003), and used to compare USGS BBS data for NATR and non-NATR routes 2007 – 2011.

Rank	Concern	Description
4	High Concern	Population is rapidly declining, has small range, or has high threats
3	Moderate Concern	Declining with moderate threats, or trend unknown with high threats
2	Low Concern	Species is common
1	No Risk	All other native species
0	Non-native	Exotic or range expanding species

Trend
For the South Reporting Area we examined potential trends in NATR bird assemblages using USGS BBS data collected within the park. For each of the three park routes we calculated several indices for each year of available data and used linear regression to test for a significantly non-negative slope. As responses we analyzed log-transformed abundance (number of individuals), log-transformed species richness, specialist-to-generalist trait ratio, and a relative abundance-weighted PIF rank index.

4.7.7 Condition and Trend

North Reporting Area
The NATR bird inventory reported 109 species from the North Reporting Area, including 11 species of concern. This represented 57% of the 192 species on the area expected list (Table 41). The BBS expected list for the region included 117 species and 89 (76%) of these were reported by BBS methods during the NATR bird inventory (Table 41).

Table 41. Comparison of expected species richness, compiled from 20-year BBS and CBC regional datasets, and actual observed species richness from a 1999 – 2000 bird inventory conducted in NATR (Accipiter 2001).

Comparison	Expected	Observed	% Observed
North Reporting Area			
Total	192	109	57
Concern Spp.	19	11	58
BBS	117	89	76
BBS Concern Spp.	15	10	67
South Reporting Area			
Total	211	126	60
Concern Spp.	22	13	59
BBS	132	108	82
BBS Concern Spp.	19	12	63

The overall percentage of expected species was low. However, this list was compiled from 20-year BBS and CBC datasets from the region, and does not represent a realistic expectation for the richness observed during a single study within the park. The BBS expected data were collected by standardized methods by experienced observers, and probably offer a better comparison for NATR data collected with similar methods.

We did not rank the condition of the North Reporting Area bird assemblages (Table 42). This area of NATR is shown to contain a relatively rich bird assemblage, similar in terms of species richness to the South Reporting Area, despite the fact that the North Reporting Area is substantially smaller and therefore received less sampling effort during the park bird inventory. The region was considered a separate reporting area because it is geologically and ecologically different from the portions of the park located to the south. The lack of a condition assignment resulted primarily because of a lack of reference data with which to compare the park data. The quality of the data used in this assessment was fair. Data were collected with appropriate methods in all park habitats and across all seasons. Because the data were more than 10 year old, the currency category did not receive a check. We also did not assign a check to thematic sufficiency because of the lack of sufficient comparison data. No trend was assigned to the North Reporting Area bird condition. A single inventory is insufficient to examine trend.

Table 42. No condition was assigned to bird assemblages in the NATR North Reporting Area. Quality of the data was fair. No trend was assigned to bird condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Bird Assemblages: North Reporting Area		Relevancy	✓	Proximity	✓	Currency	
		Sufficiency		Coverage	✓	Coverage	✓
		4 of 6: Fair					

South Reporting Area

The NATR bird inventory reported 126 species from the South Reporting Area, including 13 species of concern. This represented 60% of the 211 species on the area expected list (Table 41). The BBS expected list for the region included 132 species and 108 (82%) of these were reported by BBS methods during the NATR bird inventory (Table 41).

Among the BBS routes in the comparison dataset, NATR samples resulted in fewer individuals and lower richness than the mean for these values across all samples in most categories (Table 43). The mean number of concern species per year for the Trace Central route was higher than the mean of all samples, and the number non-native species for all NATR routes was lower than the mean (Table 43). The mean number of non-native individuals per year was markedly lower for NATR routes relative to all other routes (Table 43).

Table 43. Summary of comparison data for USGS BBS routes sampled within NATR and in the surrounding region. All routes were sampled from 2007 – 2011. Shown are the number of years sampled during this period, the average number of individuals per year, the overall species richness, the species richness of birds with available trait data and PIF rank data, the number of concern species reported during the period, the average number of concern individuals per year, the number of non-native species reported during the period, and the average number of non-native individuals per year. Bold type indicates routes conducted inside the park. Concern species are those listed in Table 37. From top to bottom, routes are in order of occurrence when traveling from southwest to northeast along the Parkway.

Route Name	Route ID	Years Sampled	Birds/ Year	All Spp. Rich	Trait Spp. Rich.	PIF Spp. Rich.	Conc. Spp.	# Conc. /Year	Non-nat. Spp.	# Non-nat./Year
Beverly	51002	5	644	85	60	66	5	15	2	11
Fayette	51010	5	482	85	59	67	4	10	4	30
Trace South	**51035**	**5**	**528**	**68**	**54**	**63**	**4**	**7**	**2**	**6**
Utica	51008	5	525	81	61	70	7	13	4	18
Benton	51006	4	970	88	61	71	6	10	4	29
Trace Central	**51032**	**5**	**527**	**71**	**59**	**65**	**4**	**21**	**2**	**6**
Weir	51038	5	650	83	67	76	5	27	6	38
Embry	51113	5	558	87	59	68	3	23	3	19
Aberdeen	51025	5	425	76	54	64	9	5	5	24
Trace North	**51042**	**4**	**453**	**70**	**60**	**66**	**4**	**16**	**3**	**5**
Vina	02201	3	876	93	69	77	5	35	4	23
		Mean	**603.5**	**80.6**	**60.3**	**68.5**	**5.1**	**16.5**	**3.5**	**19.0**

The ratio of relative-abundance weighted specialist to generalist species was greater for NATR BBS routes than for nearby BBS routes for nearly all pairwise comparisons (Figure 43). This ratio does not have units and is designed only for comparison among the data collected at different BBS route locations. Higher values imply that a site has a greater proportion of individuals with specialist responses.

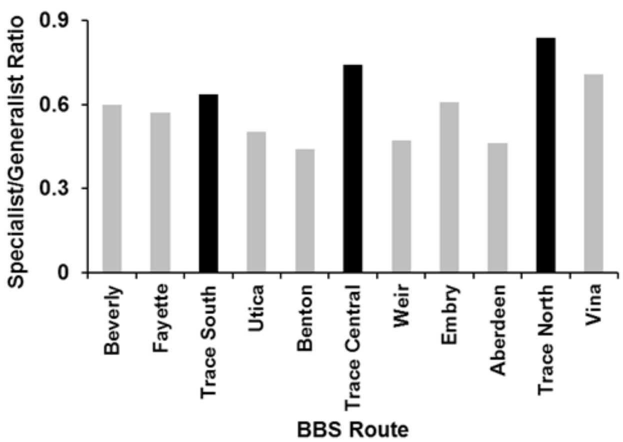

Figure 43. Ratio of specialist to generalist assemblage proportions for USGS BBS routes collected within NATR and in the nearby region, 2007 – 2011. Black bars are routes collected inside NATR.

Examination of individual traits supported the hypothesis that NATR BBS samples had more specialists and fewer generalists than non-NATR samples. We graphically represented pairs of mutually exclusive traits in each trait category (primary habitat association, nest location, and foraging habits). Although there was variability in the observed relationships, the NATR samples tended to have lower proportions of individuals and species, and fewer individuals with generalist traits (Figure 44). Conversely, for specialist traits, NATR routes tended to have greater proportions and more individuals (Figure 44). Cavity nesting species were an exception, and NATR routes tended to have a lower proportion and fewer individuals of these species (Figure 44). Generally, these data suggest that the habitat present in the park supports.

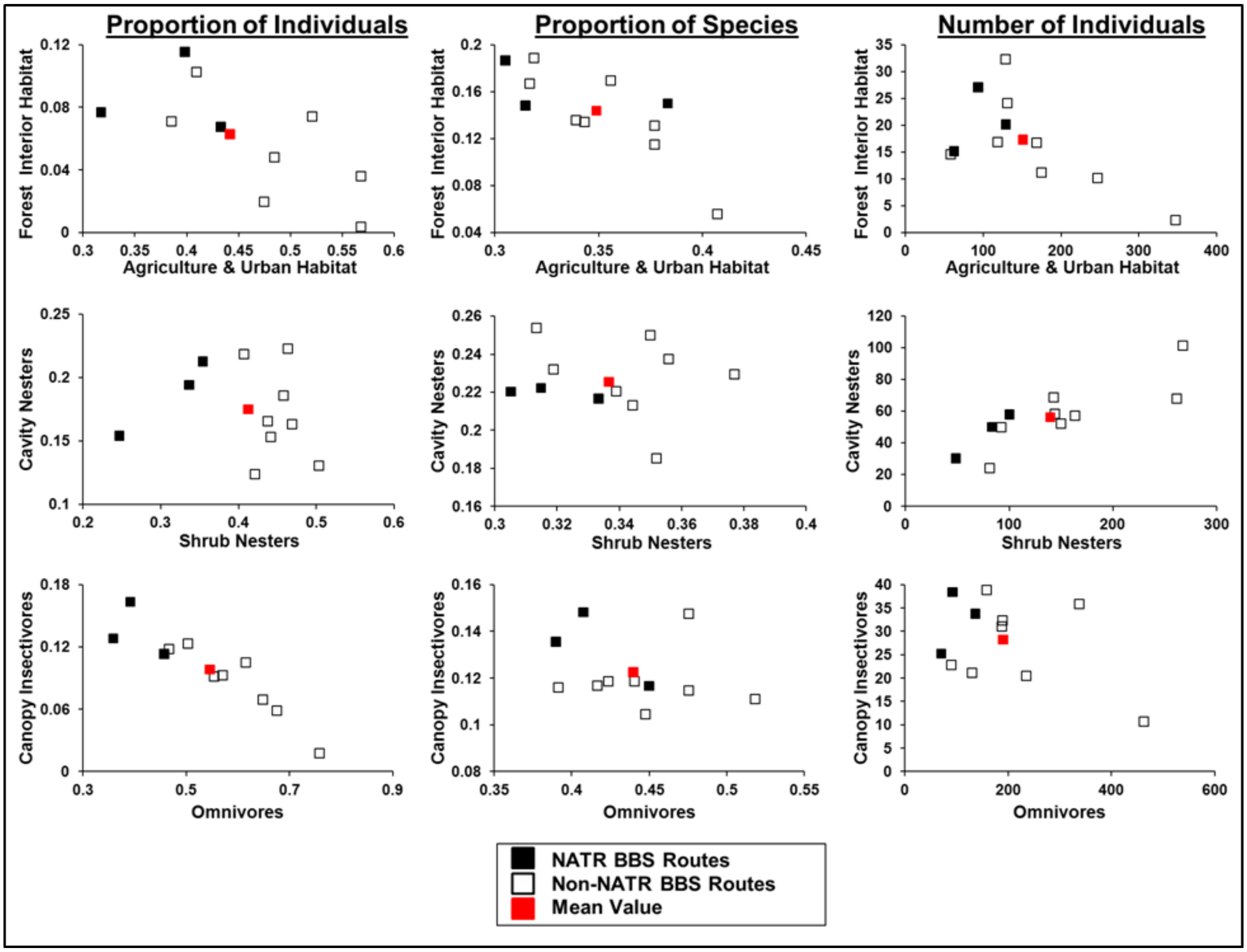

Figure 44. The proportion of individuals, proportion of species, and number of individuals (per year) with selected specialist and generalist life history traits from 2007 – 2011 USGS BBS data for routes sampled inside NATR boundaries and for routes outside NATR within 40 km of park boundaries.

Comparisons of BBS data using Partners in Flight-based ranks showed that “conservation value” indices varied among the park routes but that NATR routes tended to differ from non-park samples consistently for some indices (Figure 45). Mean species PIF rank was relatively high for two of three park samples and mean individual PIF rank was relatively high for one NATR sample (Figure 45). On average, non-native individuals made up a smaller proportion of the observed assemblage of NATR routes relative to non-NATR routes. Park samples universally had higher proportions of rank one and two individuals, but were not obviously different in the proportion of rank three and four individuals (Figure 45).

We ranked the condition of NATR South Reporting Area bird assemblages as good (Table 44). The most recent bird inventory demonstrated a rich assemblage of native birds. Comparisons of expected to observed richness for samples collected with BBS methods found 82% of the expected birds. Comparisons among USGS BBS data collected from park and non-park areas showed that NATR samples contained fewer non-native species and non-native individuals. Trait data suggested that NATR samples generally were characterized by a high proportion of birds requiring specialized habitat relative to proportions in non-park samples. From a conservation value perspective, NATR samples were not dissimilar to comparison samples in terms of overall mean conservation rank and in terms of proportions of the most at-risk species. However, proportions of common non-risk native species were relatively high and proportions of non-native (no conservation value) species were relatively low. This is consistent with a hypothesis that park habitat generally has a lower level of anthropogenic disturbance than habitat elsewhere in the region. The quality of the data used for the assessment was good (Table 44). Because the data from the NATR bird survey were greater than 10 years old, it did not receive a temporal currency check. However, the BBS data upon which much of the assessment was based were current.

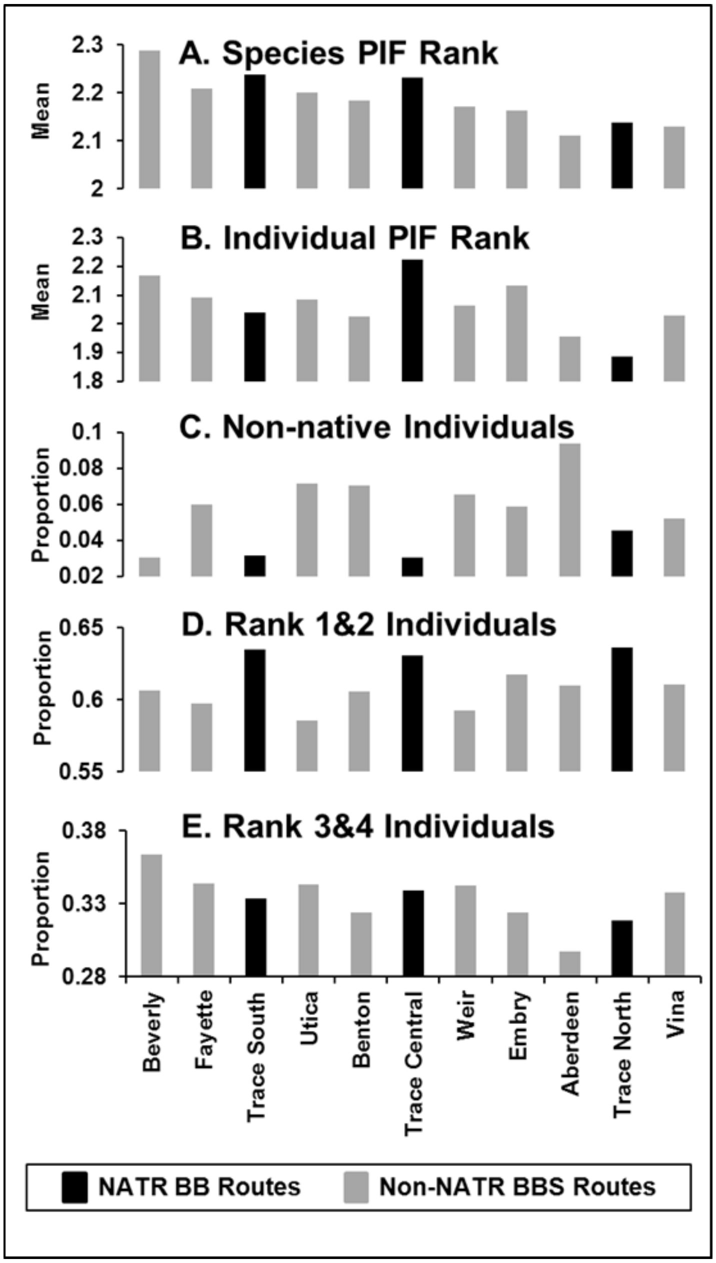

Figure 45. Mean species (A) and individual (B) PIF scores, and proportion of non-native individuals (C), rank 1 and 2 individuals (D), and rank 3 and 4 individuals (E) for USGS BBS routes sampled within NATR and in the surrounding region.

We did not assign a trend to South Reporting Area bird assemblage condition (Table 44). Regressions of abundance, richness, specialist-to-generalist ratio, and conservation value index for NATR BBS routes over the period of available data showed that slopes were not significantly different from zero ($\alpha = 0.05$) for any route. This is consistent with a stable trend in bird condition over this time period. However, because of the variation observed and because of the short (five year) time period available, we chose not to assign a trend.

Our assessment of NATR South Reporting Area birds was based largely upon comparisons of standardized BBS point count samples collected in the park to similar samples collected in the surrounding area. There are several caveats and assumptions that must be considered with this approach. BBS point count data are collected along roadsides and are therefore likely biased towards having more birds that are associated with habitat found along roadsides. However, because the BBS data used for comparison were collected with identical methods, this bias is consistent in park and non-park data. Furthermore, because NATR is characterized by a motor roadway, BBS data are likely to be more representative of park birds than could be expected in other situations. The assessment of “good” can essentially be interpreted as “evidence of lower anthropogenic disturbance to bird habitat than found in similar habitat in the surrounding region.” This assumes that greater anthropogenic disturbance, as evidenced by greater proportions of non-native species and generalists, is a signifier of poorer-quality habitat. This concept is widely accepted as evidenced by its application in a variety of indices of biotic integrity. Finally, “better than the surrounding habitat” may not have the same meaning as “good” by an alternative definition. We acknowledge the relative nature of the assessment but believe the assessment is valid when these caveats are understood. The native bird richness, number of species of concern, and percent of expected species evidenced in the NATR bird inventory support this assessment.

Table 44. The condition of bird assemblages in the NATR South Reporting Area was ranked as good. The quality of the data was good. No trend was assigned to bird condition.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Bird Assemblages: South Reporting Area		Relevancy	✓	Proximity	✓	Currency	
		Sufficiency	✓	Coverage	✓	Coverage	✓
		5 of 6: Good					

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4.8 Herpetofauna Assemblages

4.8.1 Context and Relevance

The southeastern U.S. contains the highest diversity of herpetofauna in North America, and amphibians and reptiles are important components of southeastern U.S. ecosystems (Gibbons and Buhlmann 2001). Global declines in amphibians (Stuart et al. 2004) and reptiles (Gibbons et al. 2000) have been noted for decades, and herpetofauna have become the focus of increasing management concern and effort.

4.8.2 Resource Knowledge

Accipiter Biological Consultants conducted a park-wide inventory of NATR reptiles and amphibians from 1999 – 2000 (Accipiter 2001). This effort used active searching at 300 plots, turtle trapping at 12 sites, frog call surveys at 30 sites, 66 minnow trap arrays, 65 coverboard arrays, 35 drift fence arrays with pitfalls and funnel traps, and driving road surveys for the entire length of the Parkway (Accipiter 2001). All individual species records were reported by parkway mile-marker location.

This inventory reported over 1,100 individuals of 67 species, including 25 snakes, 14 turtles, six lizards, one crocodilian, 15 anurans, and six salamanders (Accipiter 2001). Excluding frog auditory survey data, the most frequently reported species, by total number reported, was the red-eared slider (Chrysemys scripta elegans) (Table 45). Four of the five most abundant species reported by the survey were frogs; lizards and snakes were also included in the most abundantly sampled herpetofauna (Table 45). At the relatively coarse spatial scale of 71.8-km parkway sections, the most broadly distributed species was the five-lined skink (Eumeces fasciatus), which occurred in all sections (Table 46).

Table 45. The most numerically abundant herpetofaunal species reported by a 1999 – 2000 NATR inventory (Accipiter 2001). Results exclude frog call audio data.

Common Name	Scientific Name	N
Red-Eared Slider	*Chrysemys scripta elegans*	109
Southern Leopard Frog	*Rana utricularia*	103
Bronze Frog	*Rana c. clamitans*	66
Southern Cricket Frog	*Acris gryllus*	60
Green Frog	*Rana clamitans melanota*	58
Three-Toed Box Turtle	*Terrapene carolina triunguis*	51
Ground Skink	*Scincella lateralis*	44
Red-Spotted Newt	*Notophthalmus v. viridescens*	34
Southern Black Racer	*Coluber constrictor priapus*	34
Eastern Box Turtle	*Terrapene c. carolina*	28
Five-Lined Skink	*Eumeces fasciatus*	28

Table 46. Most widely distributed herpetofaunal species reported by a 1999 – 2000 NATR inventory (Accipiter 2001). Spatial distribution was estimated by determining the presence of the species among 10 equal-length (71.8 km) Parkway sections.

Common Name	Scientific Name	# Sections Reported
Five-Lined Skink	*Eumeces fasciatus*	10
Corn Snake	*Pantherophis guttatus*	9
Southern Leopard Frog	*Rana utricularia*	9
Ground Skink	*Scincella lateralis*	9
Red-Eared Slider	*Chrysemys scripta elegans*	8
Broad-Headed Skink	*Eumeces laticeps*	8
Rough Green Snake	*Opheodrys aestivus*	8

No federal threatened or endangered species were reported from the 1999-2000 NATR inventory (Accipiter 2001). A single state-listed species, the rainbow snake (*Farancia erytrogramma*), was reported from the state in which it was listed. An individual rainbow snake, listed as endangered in Mississippi, was reported from road-driving surveys in the Mississippi portion of the park.

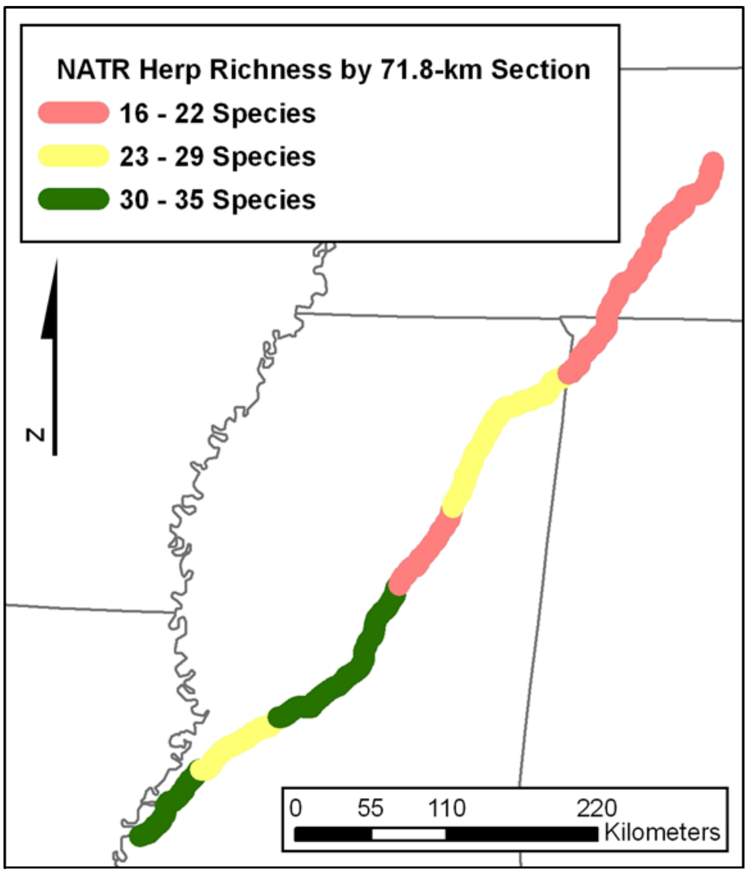

Figure 46. Herpetofaunal species richness, by 71.8-km section, reported during a 1999-2000 NATR inventory (Accipiter 2001).

Reptile and amphibian species richness varied along the length of the Parkway. When herpetofaunal species sampled by the Accipiter (2001) inventory were apportioned among 10 equal-length (71.8 km) parkway sections, species richness was generally greater in the southern sections of the park (Figure 46).

Starting in 2011, GULN began monitoring the herpetofauna in GUIS under the aegis of the GULN I&M Network using terrestrial cover-board (CB) and arboreal PVC-pipe (PVC) sampling methods coupled with environmental conditional monitoring (Woodman 2013). Two sites were selected for monitoring – Rocky Springs (RS) and Jeff Busby (JB) – based on logistical concerns for data collection and inclusion of a habitat gradient. These sites are sampled monthly for each year. However, data from the monitoring locations do not provide a complete inventory of the entire available herpetofaunal community at NATR. The park cuts through four ecosystem provinces and many species are historically reported only from specific locations and in specific habitats. For example, aquatic habitats, and therefore the species associated with these habitat types, are not sampled and underrepresented by this study.

The amphibian and reptile monitoring protocol reported 22 species (Woodman 2013). No new species were detected that had not been previously reported from NATR. At the time of this report, the GULN I&M herpetofauna narrative report included data from October 2011 – September 2012. For reptiles, these data showed the lowest abundance during winter and early spring for both sites. Amphibian abundance varied seasonally between the two sites. Amphibian richness was fairly stable at RS, and increasing in spring and summer at JB. Reptile richness showed similar trends at the two sites, peaking in the month of June. No federal or state listed threatened or endangered herpetofauna species have been reported from the park in this monitoring report. However, NATR is particularly focused on the abundance and distribution of the Webster's salamander (*Plethodon websteri*) in the park. The Webster's salamander is imperiled in MS and ongoing GULN monitoring has detected this species at the RS site (Woodman 2013).

Other efforts have sampled NATR reptiles and amphibians. Herpetology classes from Southeastern Louisiana University conducted field trips to NATR from 1988-1996, and reported 53 species (Seigel 1997). Excepting for salamanders, the observed species lists for taxonomic groups were very similar to the species list observed by Accipiter (2001). The Seigel (1997) list included 12 species not reported by the Accipiter (2001) inventory, and seven of these species were salamanders. Because the reliability of the Seigel (1997) list was unknown, because some data were collected outside the park, and because the type, amount, timing, and location of samples were unknown, we did not use these data for analysis and present them for context only.

4.8.3 Threats and Stressors

General threats to herpetofauna include habitat loss and fragmentation, habitat degradation, pollution, disease, climate change, direct consumptive use, invasive species, and road mortality (Gibbons et al. 2000, Semlitsch 2000, Steen and Gibbs 2004). Specific threats to NATR herpetofauna are not very well-understood, but work is ongoing. Ranaviruses and the chytrid fungus *Batrochochytrium dendrobatidis* have emerged in the last two decades as important diseases of amphibians, potentially causing severe population-level declines (Daszak et al. 1999, Briggs et al. 2005). However, these diseases have not been reported from NATR, and major amphibian disease events have not been reported in the park. Feral hogs are known to occur in the park, and may pose threats to herpetofauna, particularly amphibians. Hogs root destructively in moist habitats, causing changes in soil properties, vegetation, and leaf litter, with potential negative impacts to amphibians that prefer these habitats (Seward et al. 2004). They may also prey directly upon herpetofauna (Seward et al. 2004).

Road mortality is considered and important threat by park staff (L. McInnis, personal communication), and evidence is growing in support of this concern. Volunteer research zoologist Tom Mann (Mississippi Museum of Natural Science) is counting mortalities along a 2-mile stretch of the Parkway south of Interstate 20 (milepost 87) in association with researchers from Milsaps and Mississippi College. Also, a report by Dr. Hardin Waddell of USGS in this same area looking at mortality is forthcoming. Both of these datasets should be available within the next year.

4.8.4 Reporting Areas

For the purposes of reported herpetofauna assemblage condition, we divided the park into two reporting areas: North and South (Figure 47). The South Reporting Area included all park land starting from the southern terminus of the Parkway and extending northward through mile 293. The North Reporting Area included all park land from the beginning of mile 294 northward. These reporting areas were chosen based on breaks observed in the species assemblages between the two areas, and on the differences between ecotypes. The southern end of the North Reporting Area corresponds roughly with the beginning of the Tennessee Valley ecoregion when moving northward on the Parkway.

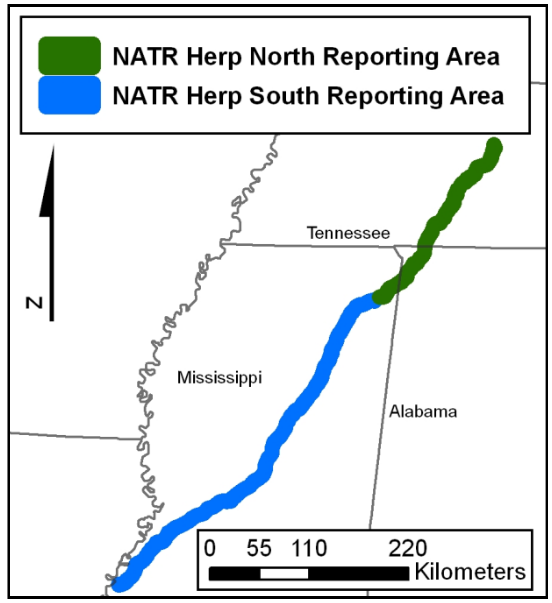

Figure 47. Reporting areas for herpetofaunal assemblage condition.

4.8.5 Data

For the assessment of NATR herpetofaunal assemblages, we used the data collected during the 1999-2000 inventory conducted by Accipiter (2001) and the 2012 GULN monitoring year (Woodman 2013). These data included a narrative report and electronic records of each individual sampled by all methods. The inventory dataset included records of over 1,100 individuals of 67 species, as well as records of frog call auditory surveys in which specific numbers of individuals were not counted (Accipiter 2001). The monitoring dataset included records of 171 individuals of 22 species (Woodman 2013). These two datasets combined were termed the analysis dataset. For comparative purposes, we also used the species lists compiled by nine other inventory-style herpetofauna sampling efforts that occurred within the NATR region in Mississippi and Tennessee. These data were termed the comparison dataset.

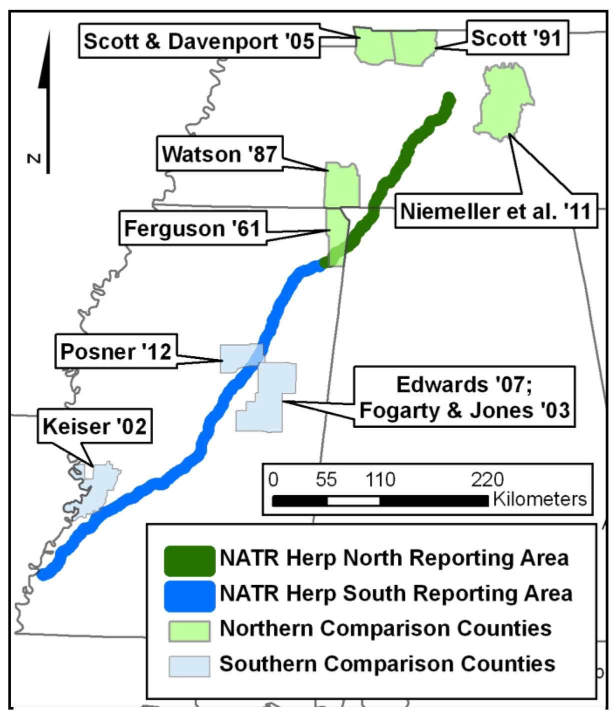

Figure 48. Counties where comparison herpetofauna inventories were conducted.

4.8.6 Methods

The assessment of NATR herpetofauna assemblage condition relied primarily upon comparisons between data from the NATR inventory and GULN monitoring to data from other studies in region. We used nine studies conducted relatively near the park as comparison studies. All comparison studies were inventory-style efforts, in that they aimed to sample as many taxa as possible, and generally employed a variety of methods. We divided the comparison studies into northern and southern groups for comparison with the

North and South NATR Herpetofauna Reporting Areas (Figure 48). For each of the reporting areas, we created an expected list that included all the species reported in the area by the Accipiter (2001) inventory, as well as all species reported by the comparison studies for the area. For the NATR North Reporting Area, we also included data from recent monitoring by Woodman (2013) in the reported list, since this monitoring only occurred within the northern section of the parkway. Where appropriate, we calculated the percentage of expected species that were actually observed during the 1999-2000 inventory and 2011-2012 monitoring by taxonomic group.

Because observed species richness is expected to vary with area sampled, we also examined the relationship of species richness to area sampled for the Accipiter (2001) inventory, GULN monitoring (Woodman 2013), and a subset of the comparison studies. The various curves that describe or predict the relationship of species richness to sample area have been a topic of discussion and debate in the ecological community for over 100 years (Connor and McCoy 1979, Tjorve 2003). Several mathematical relationships between diversity and area have been observed or proposed, and several mechanisms have been proposed to explain why these relationships are common in biological assemblages (Connor and McCoy 1979, Tjorve 2003). Connor and McCoy (1979) suggested that one of the most useful applications of species area curves was to compare diversity among a range of sample sizes, and that species area relationships could be useful in "factoring out" the effect of area on diversity. We chose four of the nine studies in our comparison dataset for use with this approach. We chose these studies because they used a variety of methods similar to those used by the Accipiter (2001) study and Woodman (2013), and because they occurred in circumscribed areas and had the goal of sampling the maximum possible richness from these areas. We used a simple exponential model, relating the number of herpetofaunal species to the natural log of the sampled area. The primary goal of this approach was to place the results of the NATR inventory in context with similar regional studies while controlling for differences in area among the samples. Adjusted R^2 values were reported to show the amount of variation explained by fitted relationships. P-values were reported to show the estimated confidence that the slope of the fitted lines were different from zero ($\alpha = 0.05$).

The taxonomic classification of herpetofauna species and subspecies is constantly changing, and studies vary in the level to which organisms are identified. Subspecies are sometimes designated based primarily upon where they are sampled. Because of the park's large geographical extent, the potential for more than one subspecies to occur within the park is relatively high. For the purposes of this report we roughly standardized nomenclature to the NATR inventory report. For example, the NATR inventory identified the northern black racer (*Coluber constrictor constrictor*) and the southern black racer (*Coluber constrictor priapus*), while other studies identified the species simply as black racer or eastern racer (*Coluber constrictor*). In these and similar cases, the comparison study species was considered as either the northern or southern subspecies, based on the location of the study. In cases where comparison studies identified an organism to finer scale than did the NATR inventory, the subspecies was considered as the species to which it corresponded in the NATR data.

Several caveats apply to our approach of assessing NATR herpetofaunal assemblage condition. Implicit in the approach is the basic assumption that assemblages in better condition will have higher species richness, other factors being equal. This common assumption is generally well-supported by observations that net losses in the number of herpetofauna species occur in areas that undergo habitat loss and fragmentation (Gibbons et al. 2000, Semlitsch 2000). We acknowledge that richness is a simple metric; more in-depth studies of reproductive success, individual condition, or other parameters might be of relatively greater use in determining assemblage condition. Another caveat concerns the value of expected species lists. Given the inevitable variation in effort, researcher experience, environmental conditions, and many other factors, it is impossible to reliably standardize the list of species expected to occur in any relatively large, circumscribed area. We made efforts to include the most appropriate studies for comparison with the NATR inventory and GULN monitoring. While acknowledging the imperfections of the approach, we believe it provides good context for park managers and a useful discussion of herpetofaunal condition.

4.8.7 Condition and Trend

Park-wide Summary

For the entire park, 69 (64%) of the 107 expected herpetofaunal species were reported by the Accipiter (2001) inventory and GULN monitoring (Table 47). As a group, reptiles were better-represented than amphibians, although frogs and toads were the best-represented group (other than crocodilians) with 79% of expected species reported. The least well-represented group was salamanders, with only 29% of expected species reported. The dearth of salamanders in the Accipiter (2001) inventory is notable, and may have resulted from a drought that occurred during the sampling period of the study. Other data suggest that at least 12 species of salamander not found by Accipiter (2001) have been found in the park during past efforts (Table 48). However, the marbled salamander (*Ambystoma opacum*) was found in more recent GULN monitoring (Woodman 2013).

Table 47. Comparisons (by taxonomic group) of expected herpetofaunal species richness to the observed richness reported by a 1999-2000 NATR inventory (Accipiter 2001) and GULN monitoring efforts (Woodman 2013).

Comparison	Expected	Observed	% Observed
	Park-wide		
All	107	69	64
Reptiles	61	46	75
Crocodilian	1	1	100
Lizards	9	6	67
Snakes	33	25	76
Turtles	18	14	78
Amphibians	46	21	46
Anurans	19	15	79
Salamanders	27	8	29
	North Reporting Area		
All	69	38	55
Reptiles	38	24	63
Crocodilian	0	0	N/A
Lizards	7	5	71
Snakes	24	16	67
Turtles	7	3	43
Amphibians	31	12	39
Anurans	14	9	64
Salamanders	17	5	30
	South Reporting Area		
All	96	58	60
Reptiles	56	39	70
Crocodilian	1	1	100
Lizards	8	6	75
Snakes	31	18	58
Turtles	16	14	88
Amphibians	40	19	48
Anurans	18	14	78
Salamanders	22	5	23

Table 48. Species of salamander anectodally reported to occur within NATR boundaries, but not found during a 1999 – 2000 herpetofaunal inventory (Accipiter 2001). The '*' indicates that these records could include records of the three-lined salamander (*Eurycea guttolineata*), as this species is known to hybridize with and look similar to *E. longicauda longicauda.*

Common Name	Scientific Name
Cave Salamander	*Eurycea lucifuga*
Dusky Salamander	*Desmognathus fuscus*
Green Salamander	*Aneides aeneus*
Long-tailed Salamander*	*Eurycea l. longicauda*
Marbled Salamander	*Ambystoma opacum*
Northern Zigzag Salamander	*Plethodon dorsalis*
Southern Two-lined Salamander	*Eurycea cirrigera*
Spotted Salamander	*Ambystoma maculatum*
Spring Salamander	*Gyrinophilus porphyriticus*

North Reporting Area

In the NATR North Herpetofauna Reporting Area, 38 (55%) of 69 expected species were reported by the NATR inventory and GULN monitoring (Table 47). The best-represented groups were lizards and snakes, and the least well-represented group was salamanders. The notable lack of salamanders throughout the park has been discussed above, and was probably due, in part, to a drought that occurred during the sampling period. When sampled area was accounted for by regressing species richness against the log-transformed area, the “expected” species area relationship was not significantly supported (Figure 49A). This was evidenced by the facts that the observed richness was below the fitted line describing the expected species-area relationship, the R^2 values were generally low, and the estimated confidence in the slope of the fitted line was generally low (Figure 49). Fitting the relationship to comparison sites alone resulted in greater R^2 values and lower p-values for most taxonomic groups (Figure 49B).

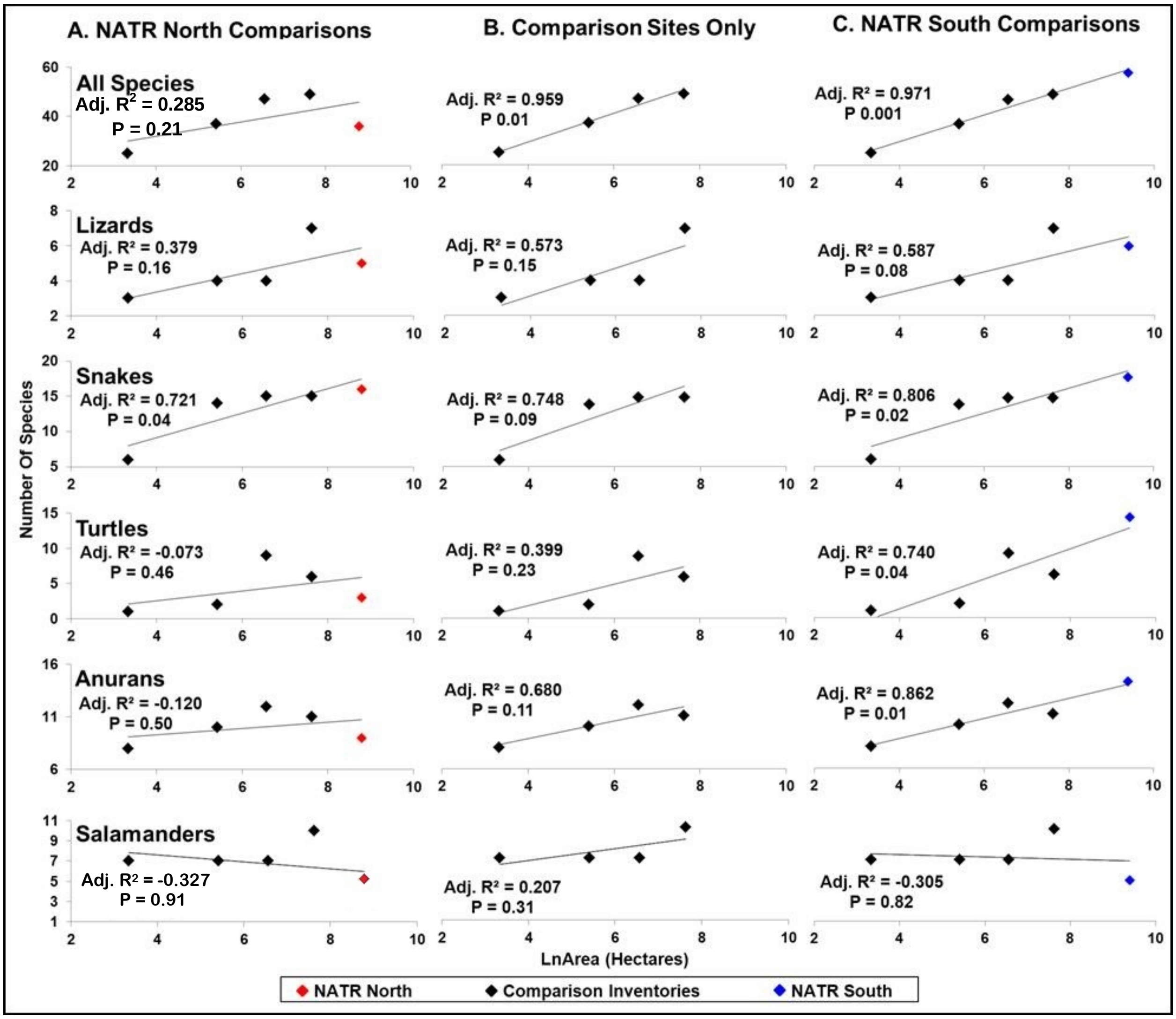

Figure 49. Taxonomic groups of herpetofauna reported from the north and south sections of NATR during a 1999-2000 inventory (Accipiter 2001) and GULN monitoring (Woodman 2013), and from four comparison inventories conducted in the region, related to sampled area. Taxonomic groups are arranged in rows of figures, and comparison types are arranged in columns.

We ranked the condition of NATR North Reporting Area herpetofauna assemblages as fair (Table 49). Comparisons of expected versus observed species richness revealed that the percentage of observed species was relatively low, ranging from 30% to 71% among taxonomic groupings (Table 47). When an attempt was made to account for area sampled, NATR North Reporting Area assemblages were less rich than expected, given the size of the area (Figure 49). The observed salamander richness was low, but this is likely attributable to local environmental conditions at the time of the inventory and only one year of monitoring data from the GULN. No trend was assigned to herpetofauna assemblage condition for the NATR North Reporting Area (Table 49). The baseline inventory and only one year of monitoring upon which the assessment was based was not suitable for assessing trend. The data used to make the assessment were very good (Table 49). The inventory collected relevant data, using a variety of appropriate methods, across the entire park area, during all seasons. Although the monitoring was more limited in scope, it also covered a variety of methods and habitats (Woodman 2013) and the data were collected in 2011-2012, thus the currency category of temporal data quality also received a check.

Table 49. The condition of herpetofauna assemblages for the NATR North Reporting Area was fair. No trend was assigned to herpetofauna assemblage condition. The quality of the data used to make the assessment was very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Herpetofauna Assemblages: North Reporting Area	Fair (yellow circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

The assessment was made based on observed species richness compared to "expected" richness values. The methods used to establish the expected richness are subject to several caveats discussed above. The results of the assessment depend largely upon the results of the comparison studies used. To our knowledge, there are no published, empirically-tested references for expected herpetofauna richness in this region. Therefore, this assessment is somewhat qualitative and subjective. It bears noting, however, that when standardized to 71.8-km sections, the northern sections of the Parkway exhibited lower herpetofauna richness than did the southern sections. Focused GULN monitoring efforts in the North Reporting Area will hopefully help to better sample the available herpetofauna and understand this relationship. The assessment is provided for discussion purposes, and to place the NATR North Reporting Area within a regional context that will be useful to managers as they continue to study park herpetofauna.

<u>South Reporting Area</u>

In the NATR South Herpetofauna Reporting Area, 58 (60%) of expected species were reported by the NATR inventory (Table 47). Several groups were relatively well-represented with over 70% of expected species reported. These included crocodilians (only one expected species), turtles, anurans, and lizards. Salamander richness was lower than in the North Reporting Area, with five (23%) of expected species reported. The lack of salamanders throughout the park has been discussed above, and was probably due, in part, to a drought that occurred during the sampling period. When sampled area was accounted for by regressing species richness against the log-transformed area, the "expected" species area relationship was generally well-supported, with fitted relationships for combined species, snakes, turtles, and anurans all having relatively high R^2 values and slopes significantly different from zero (Figure 49C). Fitting the relationship to comparison sites alone resulted in lower R^2 values and lower p-values for all groups except salamanders, suggesting that adding NATR South Reporting Area to the analyses improved the confidence in the "expected" species-area relationship (Figure 49B).

We ranked the condition of NATR South Reporting Area herpetofauna assemblages as good (Table 50). Comparisons of expected versus observed species richness revealed that the percentage of observed was 70% or greater for several taxonomic groupings (Table 47). When an attempt was made to account for area sampled, NATR South assemblages were about as rich as expected, compared to other protected areas in the region (Figure 49). The observed salamander richness was very low, but this is likely significantly attributable to local environmental conditions at the time of the inventory. No trend was assigned to herpetofauna assemblage condition for the NATR South Reporting Area (Table 50). The baseline inventory and recent monitoring efforts upon which the assessment was based was not suitable for assessing trend. The data used the make the assessment were good (Table 50). The inventory collected relevant data, using a variety of appropriate methods, across the entire park area, during all seasons. Because the data were collected in 1999-2000, the currency category of temporal data quality did not receive a check.

Table 50. The condition of herpetofauna assemblages for the NATR South Reporting Area was good. No trend was assigned to herpetofauna assemblage condition. The quality of the data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Herpetofauna Assemblages: South Reporting Area	Good (green circle, no trend)	Relevancy	✓	Proximity	✓	Currency	
		Sufficiency	✓	Coverage	✓	Coverage	✓
		5 of 6: Good					

The assessment was made based on observed species richness compared to "expected" richness values. The methods used to establish the expected richness are subject to several caveats discussed above. The results of the assessment depend largely upon the results of the comparison studies used. To our knowledge, there are no published, empirically-tested references for expected herpetofauna richness in this region. Therefore, this assessment is somewhat qualitative and subjective. The assessment is provided for discussion purposes, and to place the NATR South Reporting Area within a regional context that will be useful to managers as they continue to study park herpetofauna.

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4.9 Wildlife Damage

4.9.1 Context and Relevance

In an environment occupied and altered by humans, the presence and activity of wildlife can cause impacts that are perceived as negative for a variety of reasons. The results of these impacts include damage to the natural environment and damage to human health, property, agriculture, or quality of experience. Both native and non-native species can be responsible. Non-native wildlife includes exotic introduced species, free-ranging or feral domestic animals, and species that have expanded outside their historical ranges. Non-native animals may compete with or prey upon native species, damage habitats upon which native species depend, and damage native vegetation communities (Warner 1985, Gompper 2002, Seward et al. 2004, Baker et al. 2005, Kilgo et al. 2010). Native species may cause similar impacts when anthropogenic ecosystem alteration has allowed them to exceed environmentally healthy densities (Rooney and Waller 2003), or when they impact critically endangered native species (Remley 2005, Stephens 2007). Damage to human health, property, and enterprise occurs when wildlife, through disease transmission, vehicle impact, or predation, directly impacts the health of humans or agricultural animals (Romin and Bissonette 1996, Seward et al. 2004). Wildlife can also damage human infrastructure or detract from recreational experience (NPS 2012, NPS undated).

The Parkway supports, or likely supports, several species of wildlife that can potentially cause the negative impacts listed above. Feral hogs, beaver (*Castor canadensis*), and white-tailed deer (*Odocoileus virginianus*) occur in the park, and can cause negative impacts to native assemblages and habitat, human health and safety, and park infrastructure. Non-native species with potential negative impacts that probably occur in the park include coyotes (*Canis latrans*), domestic dogs (*Canis familiaris*), domestic cats (*Felis catus*), and nine-banded armadillos (*Dasypus novemcinctus*). Of the species listed above, feral hogs and beaver were the species for which significant data existed, and were therefore, the species addressed in this report.

4.9.2 Attribute Knowledge

Feral Hogs

Feral hogs have been present in the park since its inception, and have been documented to cause damage to native wildlife habitat, agricultural settings, and developed interpretive areas (NPS

2012). Hog rooting activities result in disturbance of scenic areas and disrupt mowed surfaces in a manner that can result in damage to mowing equipment (NPS 2012). Hog foraging and rooting causes disruption of native small mammal, fish, and herpetofauna habitat; and hogs directly compete with native species for hard mast and other resources (NPS 2012). Hogs vector a number of bacteria and parasites that make them a concern for human and livestock health (NPS 2012). Damage occurs throughout the park, but is most common south of MP 320 (NPS 2012). The park identifies three areas of particular concern for hog impacts: 1) damage to rare species critical habitat, including lands in the Bear Creek and Buffalo River drainages that support endangered fish and mussels, 2) damage to rare plant assemblages in the Blackbelt Prairie region of Mississippi, and 3) damage to habitat of the rare plant Eggert's sunflower (*Helianthus eggertii*) in Alabama and Tennessee (NPS 2012).

Beavers

Beavers are a native rodent and are relatively common throughout the NATR region. As such, they are recognized as important and primarily beneficial members of the NATR ecological community (NPS undated). Beaver data collection has been sporadic in the park, but apparent increases in beaver density and adjacent development have led to increased conflicts with adjacent landowners and increased incidences of damage to park drainage structures (NPS undated). The motor roadway crosses many rivers, streams, and wetlands. Therefore, many bridges, culverts, and other drainage structures are required to maintain natural flows and adequate drainage. Blockage and damage to these structures, resulting in threats to the integrity or accessibility of the motor roadway, are among the most important negative beaver impacts in NATR (NPS undated). Other potential impacts from beaver dam flooding include damage to agricultural lands or sensitive cultural resources (NPS undated). Beaver activities can significantly change tree stand density and composition, and these impacts can be viewed as aesthetically unpleasing to some park visitors. Beavers may create risks to human health and safety by creating less safe landscapes, by creating mosquito habitat, or by vectoring *Giardia lamblia*, an organism that causes diarrhea when ingested by humans (NPS 2012). In addition, beaver can create standing water conducive to the establishment of nonnative fish species, in addition to impacting connectivity in a way that appears to affect freshwater mussel habitat, growth and survival (Hoch 2012). However, beaver activity can also have positive effects. For example, the endangered Satyr butterfly is known to establish subpopulations in areas of abandoned beaver ponds (Kuefler et al. 2008).

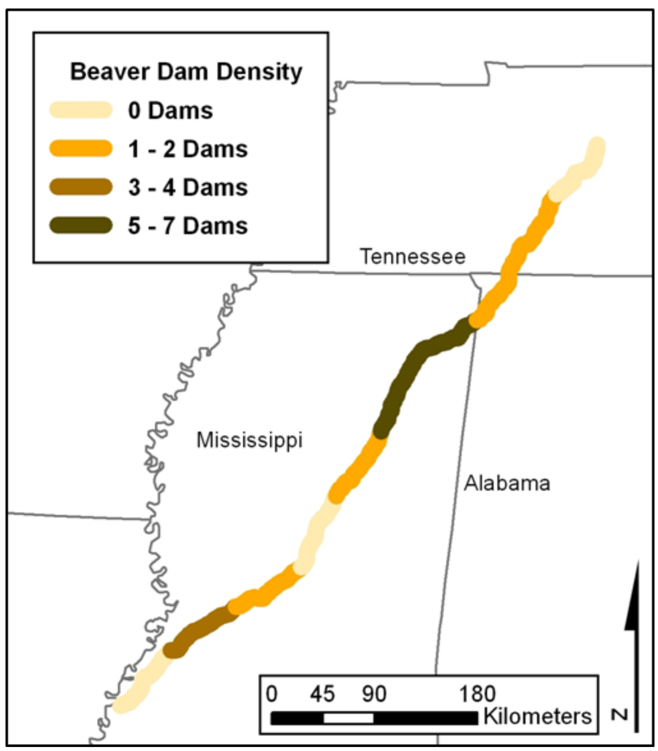

Figure 50. Density of known beaver dams, by 71.8-km section, from an NATR inventory updated September 2012 (unpublished park data).

Beavers are found throughout the park. A

1979 data collection effort reported 18 active colonies in the approximate southern half of the Parkway (NPS undated). Since 2002, beaver monitoring has been more standardized, with park staff driving the roadway during winter and recording the location of active colonies (NPS undated). Recent efforts have reported 22 dams (NPS unpublished data). The distribution of these dams suggests their impacts are likely greatest in the northern Mississippi portion of NATR (Figure 50).

4.9.3 Management Activities

Feral Hogs

Feral hogs are managed in NATR, and a draft hog management plan outlines the approaches used (NPS 2012). The plan acknowledges the inevitability of hog presence in the park, and directs control activities at removing specific animals that are causing significant resource damage (NPS 2012). Hog sightings and hog damage will be documented, and damage will be classified based on the size of the disturbed area. Targeted hog removal will consist of a combination of trapping then shooting and free range shooting. Specific training and application of safety precautions will be used. Animals will be disposed of in a manner that avoids negative impacts to visitor safety and experience (NPS 2012).

Beaver

As an important native species, beavers enjoy a relatively high level of protection under park management paradigms. Under the park's beaver management plan, beaver control activities are triggered only when potential damage to sensitive resources are recognized. Resource damage is defined as: "beaver activity that poses a threat to visitor safety, adversely impacts sensitive park resources, jeopardizes compliance with Federal and/or state law, compromises the integrity of the parkway motor road foundation, or causes unacceptable economic loss to the parks adjacent landowners" (NPS undated). Potential for these kinds of damage is noted during the annual winter survey, and threats are categorized into high, moderate, and low categories (NPS undated). Each threat level triggers monitoring or mitigation actions by park staff. Monitoring with no other action is the preferred alternative, and is used as much as possible for low and moderate threats (NPS undated). For cases where control action is required, the management plans outlines a number of potential strategies for removing dams and for controlling the water level behind beaver dams. Trapping with relocation or lethal removal is reserved as an effort to be used only when other actions have been unsuccessful (NPS undated). Unpublished park records indicate that at least four of the 22 dams reported in the 2012 inventory had recently required some mitigation action or were in imminent need of mitigation.

4.9.4 Data

For this report we considered data from three sources: a draft feral hog management plan, an undated beaver management plan, and an electronic record of results of a December 2012 beaver dam inventory.

4.9.5 Condition and Trend

Several native and non-native wildlife species have the potential to damage NATR resources. Of these, feral hogs and beaver are of primary importance to park managers. Hogs are non-native species and their actions are considered almost entirely detrimental to park resources and interests. The eradication of hogs is impossible, and park management focuses on identifying and lethally removing individuals in the most threatening cases. Beaver are a native species, and their actions are recognized as largely beneficial to park resources and interests. Park management focuses on accurate monitoring of beaver colonies coupled with non-lethal methods of dam removal or mitigation as appropriate. Relocation and lethal removal are considered last resort measures for beaver management.

However, both the beaver management plan and the feral hog management plan are still in draft form, as environmental compliance to address potential impacts of management on park resources has not been fully evaluated (L. McInnis, personal communication). As a result, park staff do not currently feel that damage issues (particularly for beavers) are being adequately addressed.

The condition of the wildlife damage attribute was not ranked (Table 51). Park management appears to adequately address damage issues by feral hogs and beavers. Therefore, in one sense, the condition of wildlife damage could be considered good in the park. However, detailed data were unavailable on the density of problem wildlife, and on the level of activity needed to control wildlife damage. Furthermore, no reliable reference standard for the condition of wildlife damage was available. The quality of data used in the assessment was marginal (Table 51). Park management plans were available for hogs and beaver, and beaver dam inventory results were available. Management plans supply data relevant to the assessment of wildlife damage, and indicate that monitoring occurs regularly throughout the year within the entire park. Therefore, the thematic relevancy, spatial proximity, and temporal coverage categories received checks. However, data on the number, timing, and location of hog control actions were not available, nor were reports on the success of control measures, however as of 2012, hog collection reports are actively recorded (L. McInnis, personal communication). For this reason, checks were not given to the thematic sufficiency, spatial coverage, and temporal currency categories. No trend was assigned to wildlife damage condition.

Table 51. The condition of the wildlife damage attribute was not ranked. No trend was assigned to wildlife damage condition. The quality of the available data was marginal.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Wildlife Damage		Relevancy	✓	Proximity	✓	Currency	
		Sufficiency		Coverage		Coverage	✓
		3 of 6: Marginal					

4.9.6 Literature Cited

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4.10 Adjacent Land Use

4.10.1 Landcover

<u>Relevance and Context</u>
Adjacent land use is considered a high-priority vital sign in the GULN, as it affects many processes inside the park. Changes outside the park can influence spread of non-native species, impact air and water quality, inhibit viewsheds and soundscapes, and generally increase visitor impact (GULN 2009). These effects may act differently depending on the temporal spatial scale of consideration (Kotliar and Wiens, 1990). One of the most relevant considerations associated with landscape dynamics at NATR is habitat loss and fragmentation, which, though independent

of each other, often happen in association. Complete loss of habitat through anthropogenic conversion is one of the greatest threats to biodiversity (Bender et al. 1998, Turner et al. 2001, Fahrig 2003,). Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself. This is particularly relevant at NATR because of its linear orientation that facilitates maximum edge effect on the park area as well as compounding the effect of the latitudinal gradient. The range of a particular species, for example, may be larger than the protected area of a park unit, in which case the periphery area can play a large role in determining species composition within the park. In addition, changes in the landscape can alter communities over vastly different temporal scales such that effects of a disturbance may not be apparent for many years (Kuussaari et al. 2009). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of both natural and cultural resources in the park (Monahan et al. 2012).

Data and Methods

In order to document land use change and provide landscape-scale information, this section uses the suite of data sources and products created by NPScape, which is an ongoing land use monitoring project designed by NPS to help interpret the role of the overall landscape on natural resources in individual park units (NPScape; NPS 2012). NPScape allows users to manipulate data and products in such a way to meet their own needs (Gross et al. 2012). Landscapes are analyzed and defined using various areas of analyses, the main of which are two pre-set park buffer widths of 3 km and 30 km. Other areas of analysis may be substituted where appropriate. NPScape analyses focus on six main landscape measures: landcover, housing, roads, population, pattern, and conservation status. As of this writing, the NPScape project recently released its second product development phase for NPS units, which includes updated data sources and areas of analysis from the original release.

NLCD

Several sources of landcover information are available to analyze anthropogenic land use alteration. The National Landcover Dataset (NLCD) produced by the Multi-Resolution Land Characteristics Consortium (MRLC) generated a retrofit change product that allows analysis of landcover change between the period of its two datasets based on imagery in 2001 and 2006. Although classifications schemes were not identical for the two periods, the change product reconciles the different classes to common landcover names. As part of the NPScape product, the NLCD change product is also reclassified into two main categories of natural and converted (Table 52). The ratio of these categories (converted area/natural area) is referred to as the U-index (O'Neill et al. 1988), and is intended as a direct representation of landscape anthropogenic disturbance.

Table 53 depicts landcover proportions for 2006 for level-1 and level-2 Anderson classifications, which refer to the level of detail in landcover categories (Monahan et al. 2012) (Table 52), in addition to the change product between the 2001 and 2006 time periods. For the 2006 NLCD classification (Figure 51), the proportion of forested land increases slightly beyond the park boundary (49.4%) to the successive 3 km (51.8%) buffer before decreasing at the 30 km (46.8%) buffer width. Agricultural land is the second most predominant class at each of the buffer widths, though within the park boundary it is developed land, due to the presence of the Parkway itself. This result is in contrast to the 2.6% developed land classified by Rangoonwala et al. (2011) as identified in section 4.4.2. The discrepancy is likely due to the definition of developed for the NLCD classification scheme. The majority of the developed land as classified by the NLCD is in the sub-category "developed-open space," which is described in the NLCD product legend as "areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes." (http://www.mrlc.gov/nlcd06_leg.php). These areas were most likely classified by Rangoonwala et al. as "grassland."

The change product shows that only around 1% of the park area underwent change between 2001 and 2006. Much of this change occurred in the portion of the Parkway adjacent to Jackson, and included transitions from forested and pastureland to developed areas. Other sections around the southern portion of the Parkway indicate changes that might be due to succession. However, these small changes could also result from classification error in one or both of the 2001 and 2006 NLCD products, because classification error, depending on class, can be 15-20%. The other buffer widths show greater rates of conversion, most notably in the "natural to natural" category, which may reflect classification errors, natural succession, or possibly conversion of areas considered "natural" in the database that are in fact managed lands. The U-index calculated for the park boundary was moderately high (0.64), likely reflecting historically converted land that may be associated with the road. U-indices for the 3 km and 30 km buffers were 0.35 and 0.43, respectively.

Table 52. Aggregation of NLCD landcover classes into Anderson level I and II classifications and change product converted and natural categories. [Source: Monahan et al. 2012]

Anderson Level I	Anderson Level II	Natural/Converted
Open Water	Open Water Perennial Ice/Snow	Natural
Developed	Developed Open Space Developed Low Intensity Developed Medium Intensity Developed High Intensity	Converted
Barren/Quarries/Transitional	Barren Land Unconsolidated Shore	Natural
Forest	Deciduous Forest Evergreen Forest Mixed Forest	Natural
Shrub/Scrub	Dwarf Scrub Shrub/Scrub	Natural
Grassland/Herbaceous	Grassland/Herbaceous Sedge/Herbaceous Lichens Moss	Natural
Agriculture	Pasture/Hay Cultivated Agriculture	Converted
Wetlands	Woody Wetlands Emergent Herbaceous Wetlands	Natural

Table 53. Landcover area and proportions of NATR for each buffer class based on NLCD Anderson level 1 and 2 classifications and the change product, as aggregated by Monahan et al. (2012). The three highest proportions are highlighted for each buffer width and dataset.

	-30 km buffer-		-3 km buffer-		-no buffer-	
NLCD 2006 Anderson Level-1	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	933.5	2.12	102.7	2.3	0.7	0.4
Developed	3262.6	7.4	392.9	8.6	60.5	32.6
Barren/Quarries/Transitional	49.7	0.1	2.4	5.2	<0.1	<0.1
Forest	20618.1	46.8	2361.7	51.8	91.6	49.4
Scrub/Shrub	3993.4	9.1	429.5	9.4	6.3	3.4
Grassland/Herbaceous	1014.1	2.3	93.5	2.1	1.7	0.9
Agriculture	10000.4	22.7	798.8	17.5	11.8	6.4
Wetlands	4222.1	9.6	375.5	8.2	12.7	6.8
NLCD 2006 Anderson Level-2						
Open Water	933.5	2.1	102.7	2.3	0.7	0.4
Developed, Open Space	2197.5	5.0	281.8	6.2	56.4	30.4
Developed, Low Intensity	733.2	1.7	77.5	1.7	3.7	2.0
Developed, Medium Intensity	243.0	0.6	26.8	0.6	0.3	0.2
Developed, High Intensity	88.9	0.2	6.8	0.1	<0.1	<0.1
Barren Land	49.7	0.1	2.4	0.1	<0.1	<0.1
Deciduous Forest	13171.9	29.9	1602.4	35.2	56.8	30.6
Evergreen Forest	4531.1	10.3	447.3	9.8	18.5	10.0
Mixed Forest	2915.2	6.6	312.0	6.8	16.3	8.8
Shrub/Scrub	3993.4	9.1	429.5	9.4	6.3	3.4
Herbaceous	1014.1	2.3	93.5	2.1	1.7	0.9
Hay/Pasture	6231.3	14.1	554.7	12.2	9.1	4.9
Cultivated Crops	3769.1	8.5	244.1	5.4	2.7	1.5
Woody Wetlands	3944.1	8.9	352.4	7.7	12.3	6.6
Emergent Herbaceous Wetlands	278.0	0.6	23.1	0.5	0.3	0.2
NLCD Change (2001-2006)						
--Overall--						
Converted	13262.9	30.1	1191.7	26.2	72.3	39.0
Natural	30831.0	69.9	3365.3	73.8	113.0	61.0
--Changed--						
Natural to Agriculture	63.8	0.1	5.3	0.1	0.1	<0.1
Natural to Urban	66.3	0.2	7.7	0.2	0.4	0.2
Agriculture to Urban	78.1	0.2	7.9	0.2	0.3	<0.1
Converted to Natural	603.3	1.4	64.7	1.4	1.5	0.8
Natural to Natural	1767.1	4.0	190.7	4.2	3.1	1.7
U-Index	**0.43**		**0.35**		**0.64**	

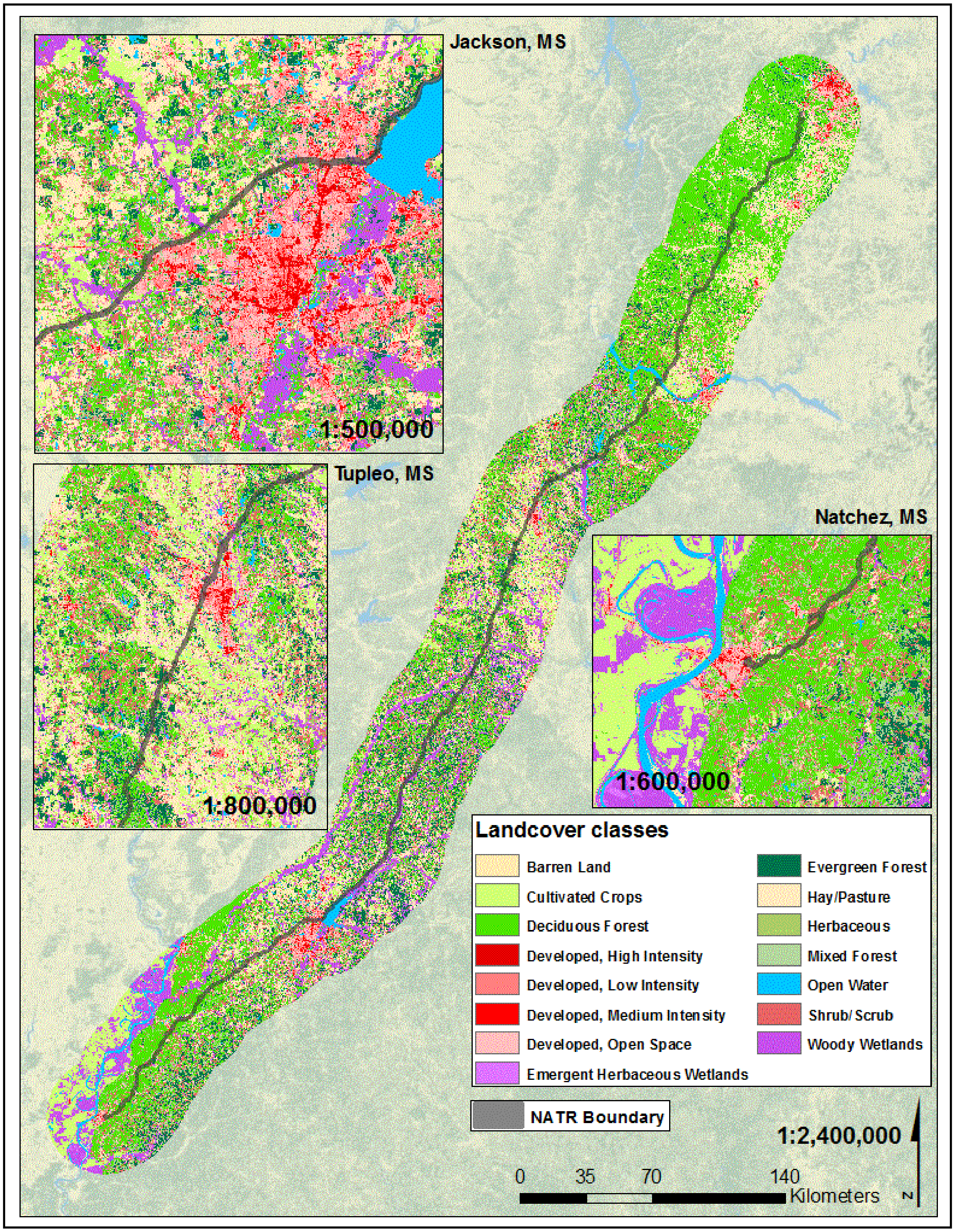


Figure 51. NPScape landcover product showing 2006 NLCD level-2 Anderson classification for NATR. High variability in the level of forest intactness and amount of urban area surrounding NATR Parkway is apparent.

4.10.2 Impervious Surface

Relevance and Context

One of the most direct influences of anthropogenic conversion on natural areas comes from the amount of impervious surface within a watershed. Highly urbanized areas with large amounts of impervious surface can disrupt hydrologic regimes in several ways, such as increased amounts of flow and decreased infiltration rates. This, in turn, can result in lower water tables, stream flashiness, and intermittent flow (Harbor 1994, Arnold and Gibbons 1996). Decreased water tables in areas with high areas of impervious surface can negatively affect wetland areas maintained by ground water flow. In smaller catchments, storm events can also greatly increase peak flow over a short period of time.

Many studies have outlined threshold levels of impervious surface at different scales for biotic integrity, and like the thresholds of connectivity for essential habitat, these values vary widely. A study in Maryland by Klein (1979) reported a threshold of 12 - 15% imperviousness before encountering a drop in stream quality, while severe inhibition was generally associated with levels of imperviousness of 30% and above. Lussier et al. (2008) suggest 8 – 10% as the range of imperviousness, typical of suburban areas, wherein macroinvertebrates are affected. In several Wisconsin watersheds, Wang et al. (2001) measured the effects of urbanization on fish habitat using several biotic and abiotic factors and found 8% imperviousness as a threshold for negative effects. In a review of the effects of impervious cover and urbanization, Paul and Meyer (2001) outlined an even lower threshold for change in geomorphological characteristics, starting at proportions of 2 - 6%. Other studies have shown even lower thresholds, including impaired stream biota at levels as low as 0.5 - 2% (King et al. 2011).

Data and Methods

The 2006 NLCD version of impervious surface includes difference levels of development intensity in addition to developed open space. Figure 52 shows weighted impervious area of the 16 adjacent cataloging units within the 30 km buffer. The Middle Pearl-Strong cataloging unit shows the greatest average imperviousness, due mostly to the presence of Jackson, MS so close to the park. Most cataloging units average imperviousness rates less than 2%, with exceptions being Harpeth (which contains Tupelo, MS) and Town (outskirts of Nashville, TN). Using this classification, the proportion impervious area with each successive buffer class is 1.4% within the park boundary, 8.0% at the 3 km buffer, and 0.6% at the 30 km buffer width. Despite the predominance of roads and urban areas at points along the Parkway, 8.0% imperviousness for the 3 km buffer is still a relatively low value. At the larger 30 km extent, imperviousness is extremely low, reflecting a landscape of primarily forest and agriculture (Table 53).

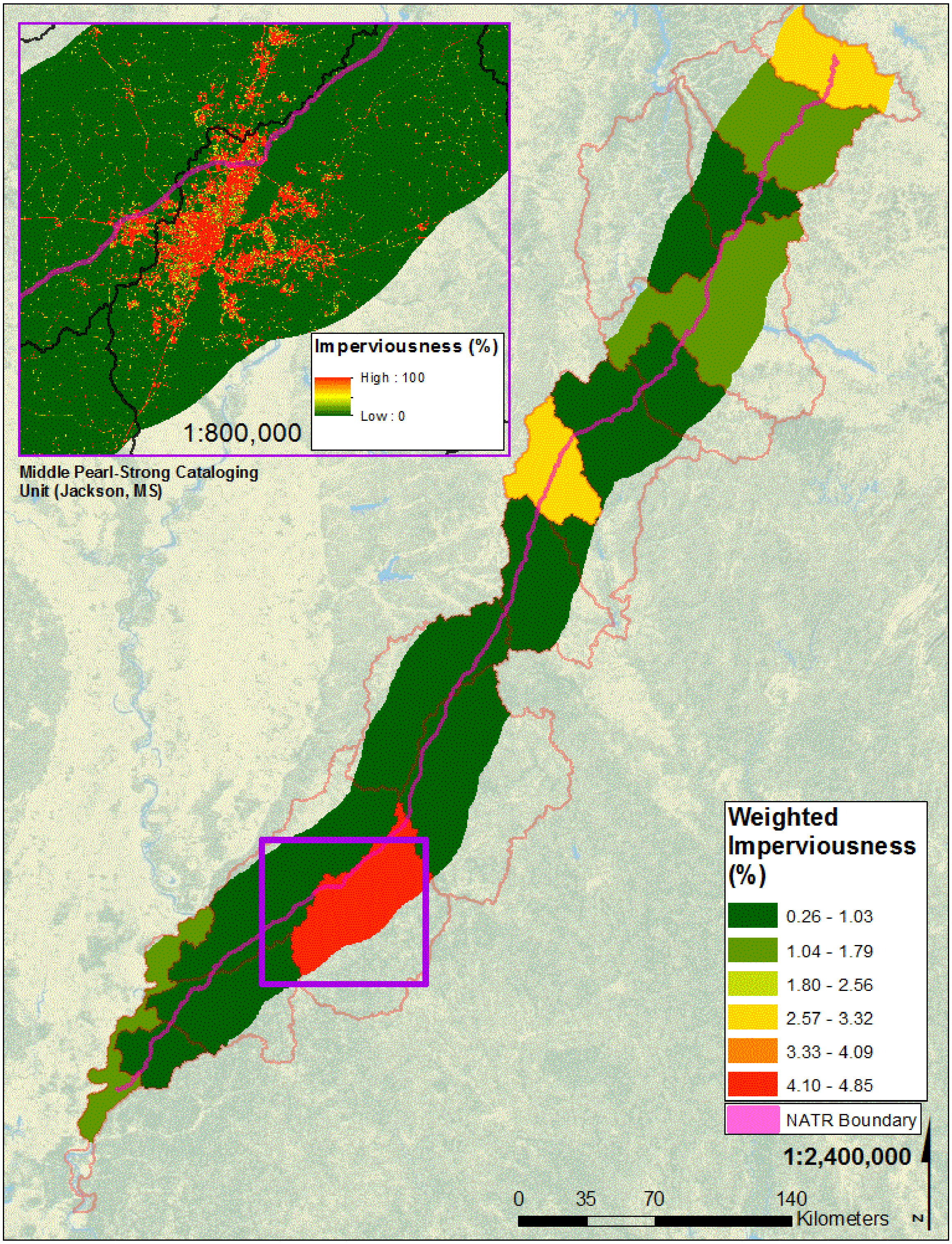


Figure 52. Weighted imperviousness by cataloging unit. Relative levels of imperviousness were low, ranging from 0 to 5% overall.

4.10.3 Roads

Relevance and Context

Roads are one of the main drivers of landscape fragmentation (Monahan et al. 2012), and can also disrupt hydrological processes (Jones et al. 1999). Trombulak and Frissell (1999) outline the seven main effects of roads on biotic integrity as follows: (1) construction-related mortality, (2) vehicle mortality, (3) animal behavior modification, (4) alteration of the physical environment, (5) alteration of the chemical environment, (6) spread of exotics, and (7) increased use by humans. Even in relatively undeveloped areas, effects are pervasive and can impact areas several hundred meters beyond the roadside (Forman 2000, Forman et al. 2002). Monahan et al. (2012) outlines several sources of information documenting the effects of roads on natural resources and terrestrial biodiversity. The NPScape analysis of roads selected three main metrics to describe their effects: road density, distance to road, and effective mesh size.

Road density, or total road length (km) per area (km^2), can directly affect wildlife populations (Figure 53). Steen and Gibbs (2004) reported altered sex ratios and populations of painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) in high road density sites (>1.5 km km^{-2}) in central New York. Gibbs and Shriver (2002) found that areas with >1 km km^{-2} and >100 vehicles $lane^{-1}$ day^{-1} were likely to contribute to the mortality of land turtles, especially in the eastern U.S. where road densities are higher.

Figure 53. Spotted salamander (*Ambystoma maculatum*) crossing road in NATR.

The distance to nearest road metric can help determine how much roads can influence certain ecological factors. Roads, for example, are a main contributor to human-caused vertebrate mortality in addition to altered population densities around zones of road avoidance (Parris and Schneider 2009). Exotic plant species can also be introduced and spread via road corridors up to 1 km from the roadside. Traffic exhaust can influence roadside vegetation up to 200 m away (Forman and Alexander 1998).

Effective mesh size refers to road-created contiguous patches greater than 500 m from a road, or the area enclosed by the road network. Girvetz et al. (2007) define this metric as "the average size of the area that an animal placed randomly in the landscape would be able to access without crossing barriers."

Data and Methods

Each of the three road metrics were calculated for both buffer widths and are shown in Table 54. Metrics consistently show a slightly greater presence of roads at the 3 km buffer. Figure 54 shows road density in the surrounding landscape, showing the concentration of roads around Jackson, MS and other cities. Figure 55 shows the average roadless patch areas, organized into size classes. Larger roadless patches were found in the southern portion of the Parkway overall, and largest patches were associated with undeveloped areas surrounding the Mississippi River, Yazoo River, and Pickwick Lake. However, some of the larger patches are very narrow strips, and some appear agricultural, which may have implications for the true value to wildlife.

Table 54. Mean landscape road metrics for NATR at each buffer width.

Buffer Width	Road Density	Distance to Road	Roadless Patches
	-km per km^2-	-m-	-km^2-
3 km	1.90	312.87	1.75
30 km	1.80	353.70	1.63

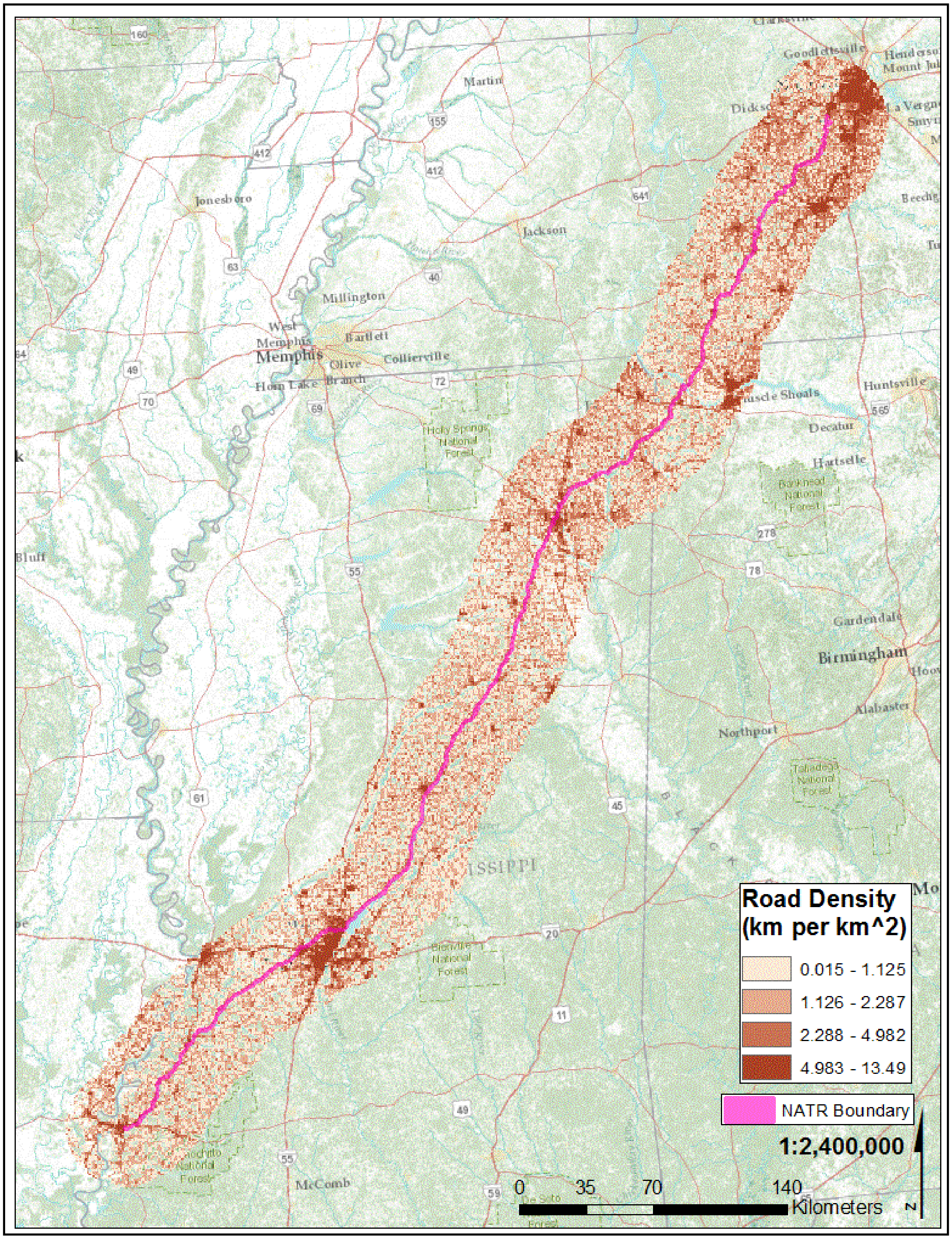


Figure 54. Road density surrounding NATR within a 30 km buffer width.

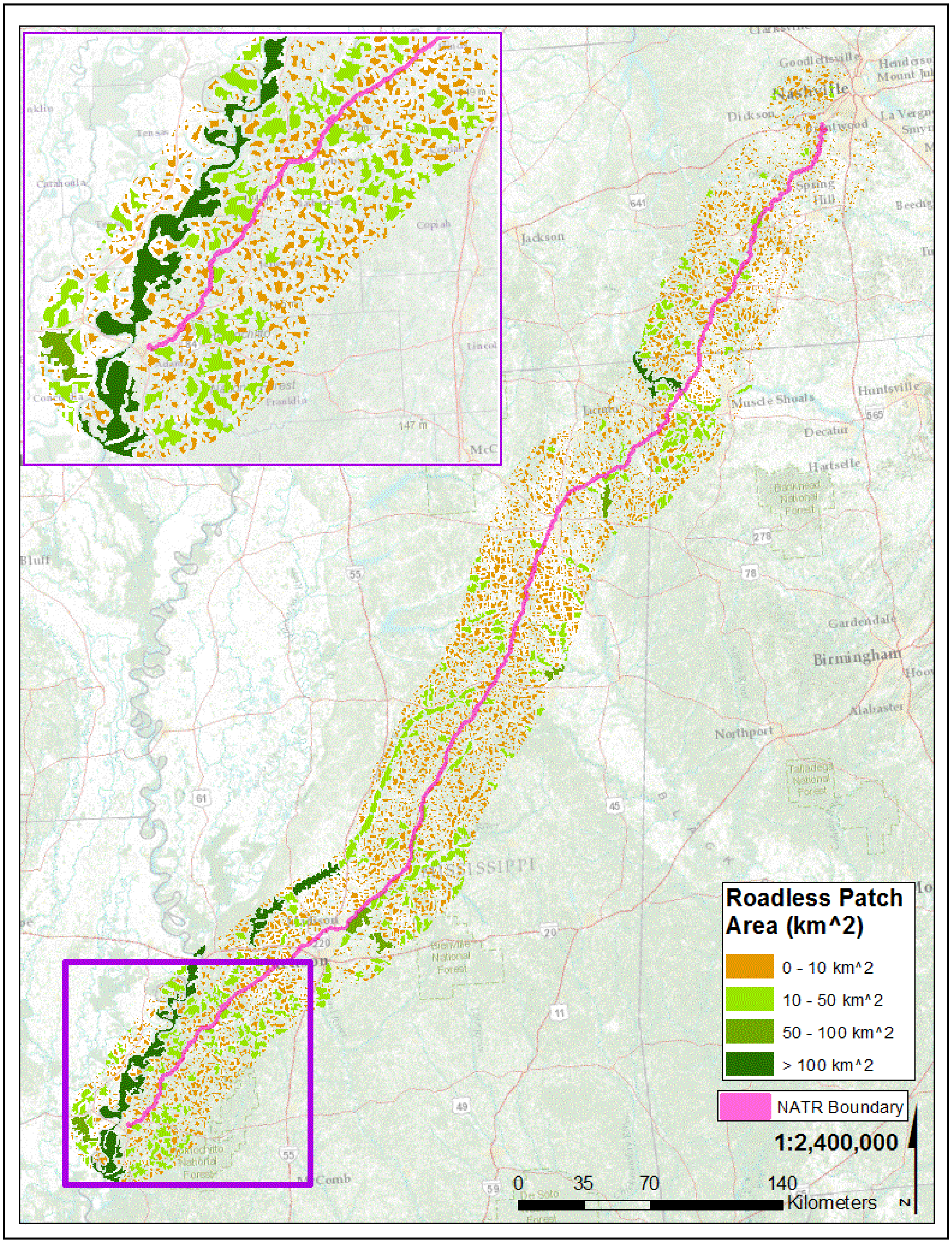


Figure 55. Roadless patch area surrounding NATR within a 30 km buffer width.

4.10.4 Population and Housing

Relevance and Context

Population pressure can provide an approximation of how much impact humans have on the landscape in a given area. Areas of high population have been shown to contribute to the decline of terrestrial biodiversity (Kerr and Curie 1995), which is usually the result of habitat loss stemming from land use conversion (Wilcove 1998). Monahan et al. (2012) provide a comprehensive reference list for the effects of population pressure on different taxa, and outline the following six main effects resulting from human settlements: (1) loss of habitat to structures and non-habitat cover types, (2) habitat fragmentation, (3) resource consumption, (4) disturbance by people and their animals (pets, livestock, etc.), (5) vegetation modification, and (6) light and noise pollution. In general, they offer that the impact of human settlements is far-reaching, and certain species are more sensitive to humans and their effects than others.

Data and Methods

NPScape products developed to analyze trends include population and housing density maps created at the county level from U.S. Census Bureau data. Monahan et al. (2012) report that housing density is closely correlated with population density, but as Liu et al. (2003) point out, housing density also accounts for changing household demographics, such as average household size and per capita consumption.

Figure 56 shows population density by census block group. For the most part, the surrounding landscape along the Parkway falls within the lowest density class, with the exception of three main urban areas surrounding Jackson, Tupelo, and Nashville. The corridor east of the Parkway from Florence, AL to Nashville also falls within mid-density classification. Population data for counties within the 30 km buffer show mostly steady increases during the period 1790 to 1990 (Figure 57), with especially rapid increases in population in Hinds and Davidson Counties, which correspond respectively to the state capitals Jackson and Nashville. Of the 25 counties through which NATR passes, ten show significant population increases over the period 1950 to 1990, indicated in Figure 56.

The NPScape product for housing density divides areas into 13 development classes, plotted for six decades from 1950 and 2000. Figure 58 depicts the change in proportion represented by each housing density class within the 30 km buffer for NATR. There is a visible decrease in proportions of least density housing classes over this time period, though linear regression shows no significance. Regression does show significant increases for all except the three lowest density and the commercial/industrial classes. This is consistent with the findings of Hansen et al. (2005), who noted that beginning in 1950, exurban development (6-25 units km^{-2}) became the fastest-growing form of land use in the US.

Monahan et al. (2012) acknowledge that housing density might be most useful when used as a constituent of other, more complex and ecologically-relevant landscape metrics. Although population and housing also correlate highly with other more ecologically-relevant factors like impervious surface and road density, their ease of use makes them valid for comparisons across scales and regions. To that end, NPScape also produced a plot of population densities for all areas of NPScape analyses in 2000 (Figure 59), which shows that NATR falls among the lowest of overall population density classes (39.4 individuals km^{-2}) relative to other NPS units.

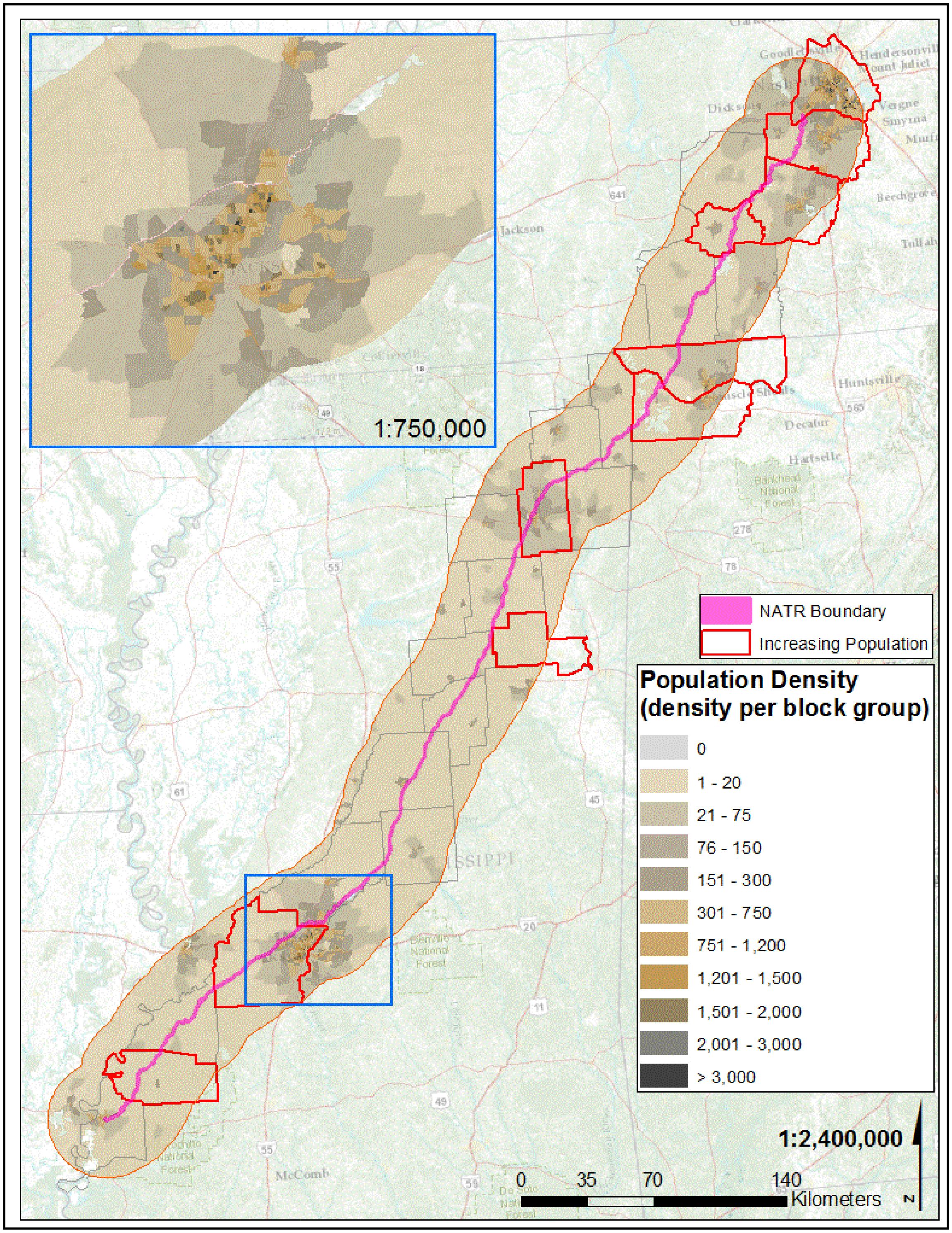


Figure 56. Population density surrounding NATR in 2010. Counties with significant population increase over the period 1950 to 1990 are highlighted in red.

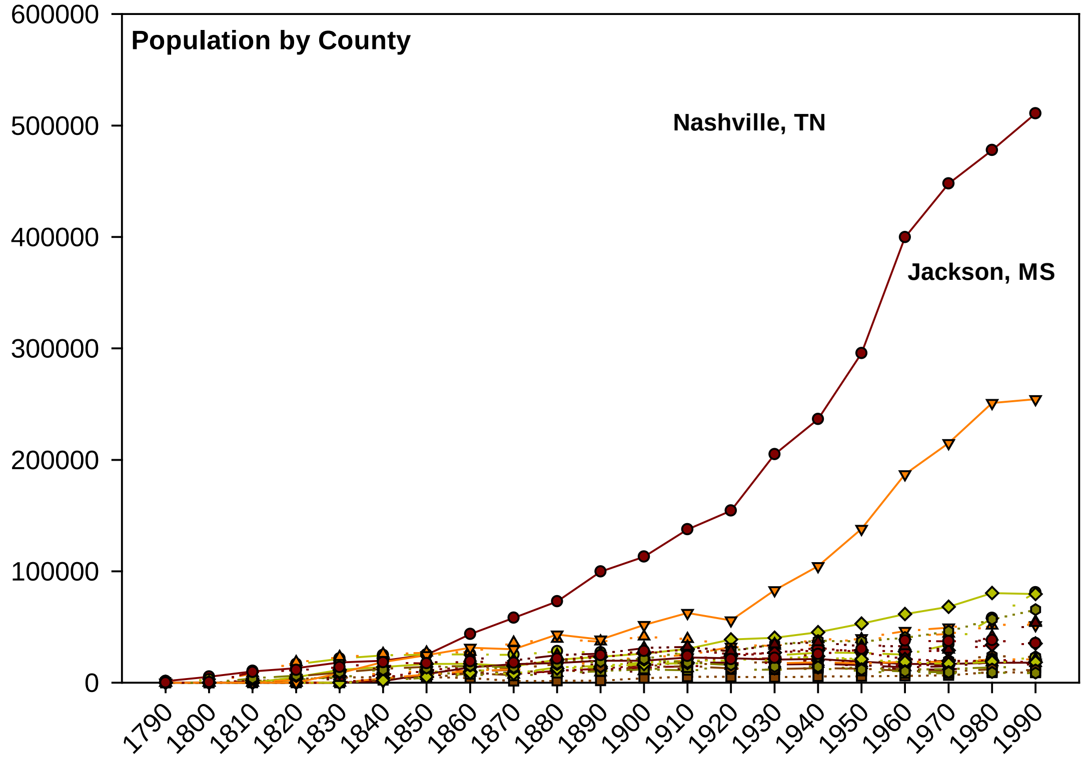


Figure 57. Population for counties within the NATR landscape for the period 1790 to 1990.

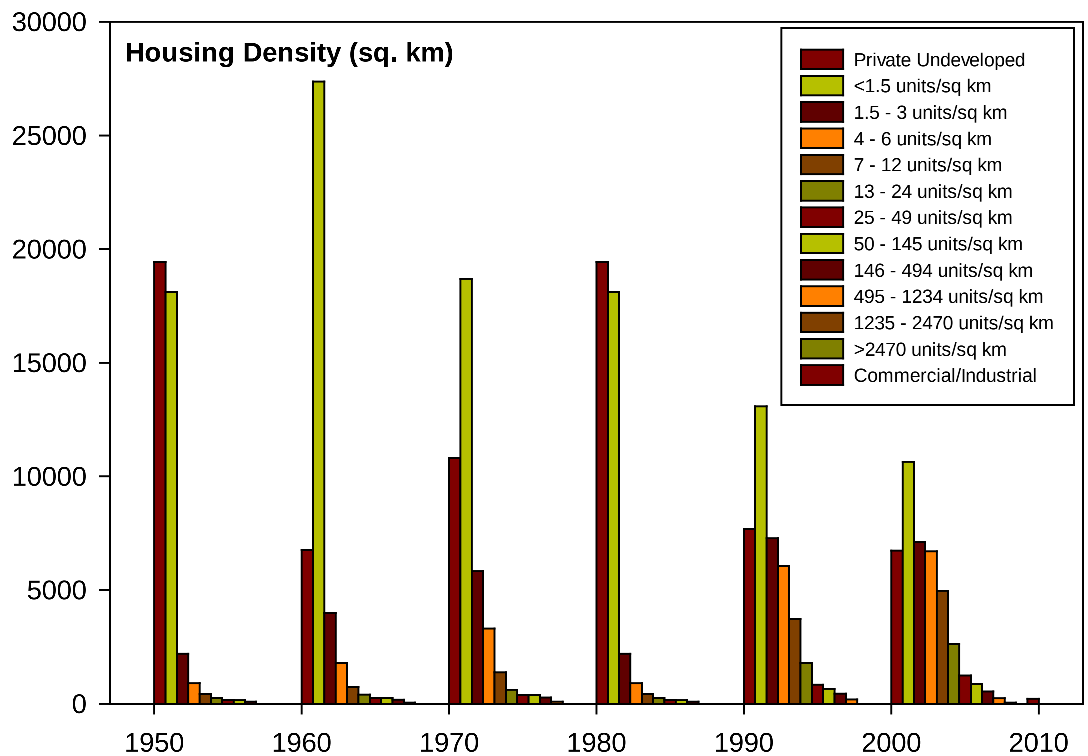


Figure 58. Housing density classes by decade for the NATR landscape.

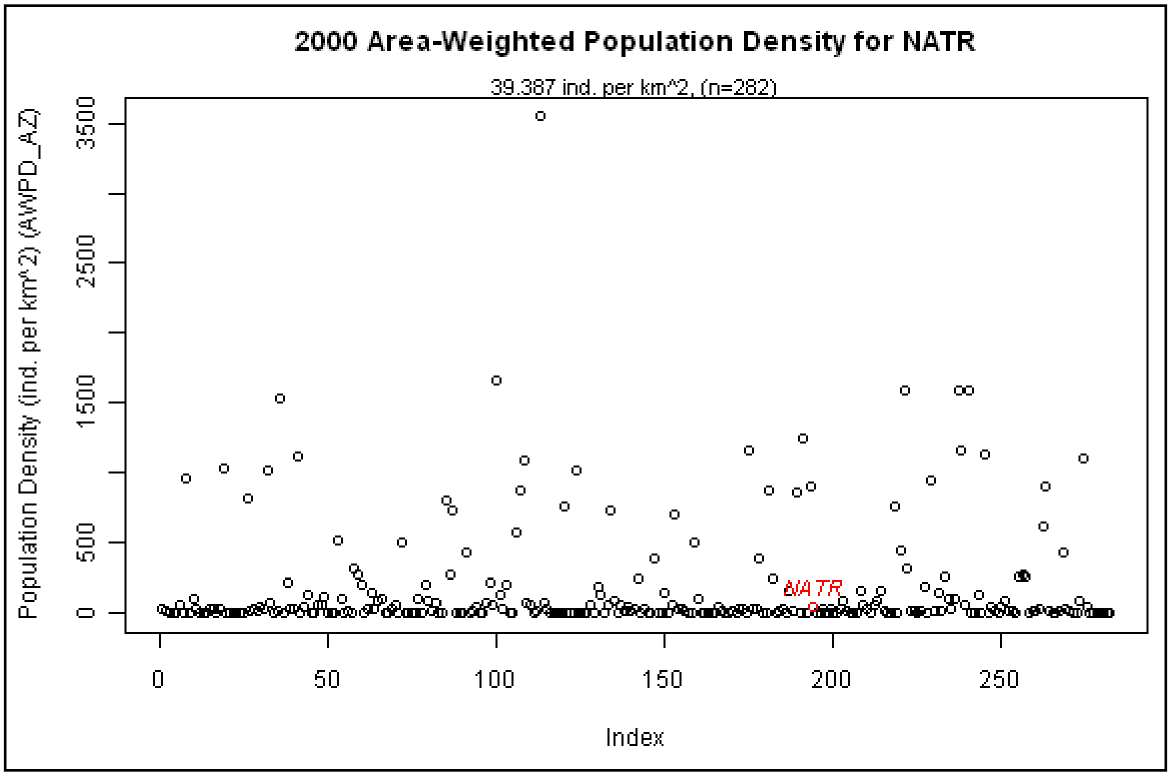


Figure 59. NPScape (Phase 1) product showing population density of NATR in 2000 relative to landscapes of other NPS units.

4.10.5 Pattern

<u>Relevance and Context</u>
The configuration and composition of landcover types and specific landscape features play a large role in the dynamics of ecological processes, and more specifically can play a role in determining the species assemblages found in a certain area (Turner 1989). Natural landcover and the amount of suitable habitat it provides is one component of species composition, though it is also affected by the arrangement of that habitat. These two components of landcover are often confounded, and thus individual effects are difficult to identify (Trzcinski et al. 1999). However, landscape metrics intended to describe general patterns of landcover can be helpful in determining which features strongly influence patterns of species distribution. Monahan et al. (2012) point out that some of the most commonly used landscape metrics include patch size and shape, connectivity, core habitat, and edge habitat.

Edge
Edges are the boundary between two different patch types, and as certain landcover types are divided and become more patchy, edge density increases, which can affect numerous ecological processes. Conditions at patch edges may be intermediate of those at adjacent patches, such that a forested edge next to an open patch may be hotter, drier, windier, and lighter than interior forest conditions, which may in turn also result in different species composition (Ries et al. 2004). Edges may also alter species composition by facilitating the transport of pollen or other organisms into interior habitat area. Species interactions may also

be affected by the presence of edges. Numerous studies report that birds undergo increased rates of parasitism and predation within edge habitats and demonstrate greater rates of nest success in larger patches (Andrén and Angelstem 1988, Paton 1994, Donovan et al. 1997).

Patch Size

The patch size of individual landcover types is closely related to the effects of edges on organism interactions and resource movement. A larger patch will usually contain more core habitat than a smaller patch size, meaning that the habitat is not subject to the higher predation rates and other outcomes associated with edge effects. The amount of edge, however, can increase or decrease depending on the shape of the patch, which lends usefulness to the perimeter (edge) to area ratio—another commonly used landscape metric. However, as Andrén (1994) notes, patch size is also confounded by fragmentation, and thus each of these three metrics (patch size, edge, and fragmentation) must be considered in tandem.

Data and Methods

In an assessment of microclimate variation along forest edges, Matlack (1993) found that edge effects for several factors were detectable at sites of eastern deciduous forest up to 50 m from the edge. Another estimate by Ranney (1977) suggested that edge habitats extend from 5 m up to 20 m and may affect a variety of factors including tree species composition, primary productivity, structure and development, animal activity, and propagule dispersal.

The NPScape project constructed maps of core habitat using edge widths of 30 m and 150 m. Both of the above estimates most closely match the 30 m edge width used in the NPScape product describing forest habitat types shown in Figure 60. In this product, landscape elements are classified according to morphological spatial pattern analysis (MSPA) types, which include core, islet, perforation, edge, bridge, branch, loop and background. Table 55 shows definitions for these features and their respective contribution for each of the classes using a 30 m edge definition.

Core forest area is slightly higher in the surrounding 3 km buffer (44.2%) compared to the overall 30 km landscape (39.6%) along the Parkway. Edge proportion is also slightly higher within the 3 km buffer (9.3%) than the 30 km landscape (8.4%). This is likely reflects the greater amount of non-forested land at the broader landscape scale. Figure 60 depicts the results of MSPA throughout the NATR landscape.

NPScape also developed a forest density product based on moving window analysis, shown in Figure 61. While similar to the MSPA, it describes broader-scale forest patterns using seven density classes: intact, interior, dominant, transitional, patchy, and rare (Riitters et al. 2012). Figure 62 depicts proportion of forest coverage for different classes, ranging from 0% to 100% at each buffer width. Not unexpectedly, more area falls within the lower class proportions for the 30 km buffer, while the higher density classes starting roughly around 25% coverage represent a higher proportion of the 3 km buffer.

Table 55. Morphological spatial pattern analysis (MSPA) class types used by NPScape for NATR forest patches at 30 km, 3 km, and no buffer widths. Edge width was defined as 30 m.

Pattern type	Definition	-30 km buffer- Area (km^2)	% Area	-3 km buffer- Area (km^2)	% Area
Core	Interior forest area not influenced by edge	17,455.7	39.6	2,015.3	44.2
Islet	Patch too small to contain core area	346.5	0.8	36.4	0.8
Perforated	Edge (linear) internal to core forest type (30 km)	1,614.2	3.7	168.8	3.7
Edge	Perimeter (linear) of forest patch (30 km)	3,701.2	8.4	425.9	9.3
Bridge	Non-core (linear) forest connecting disjunct core patches	562.0	1.3	75.0	1.6
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	1,208.0	2.7	150.9	3.3
Background	Non-forested enclosure	1,349.3	3.1	153.0	3.4
Loop	Non-core (linear) forest connected to same forest patch at both ends	445.4	1.0	55.2	1.2

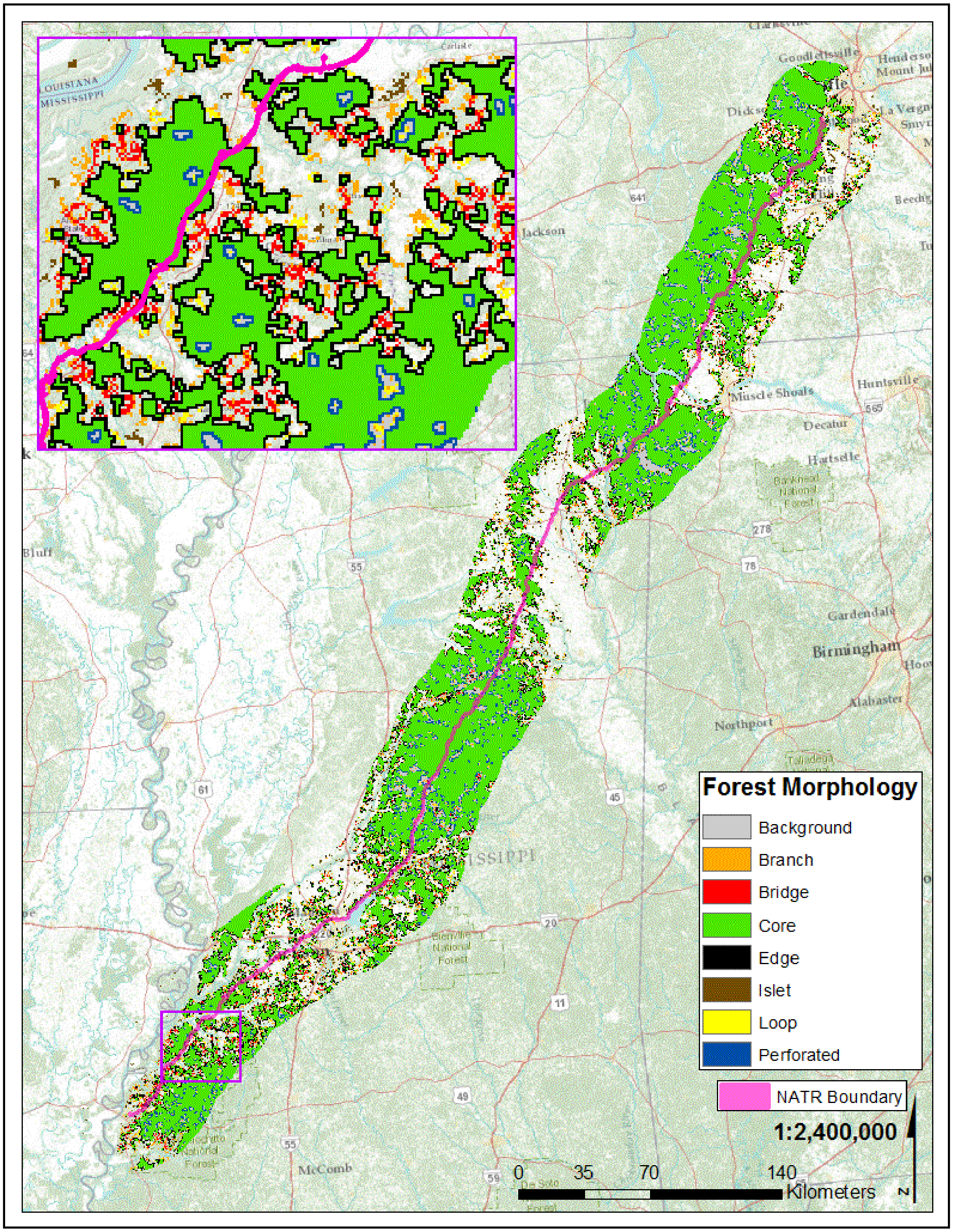


Figure 60. Forest morphology resulting from morphological spatial pattern analysis (MSPA).

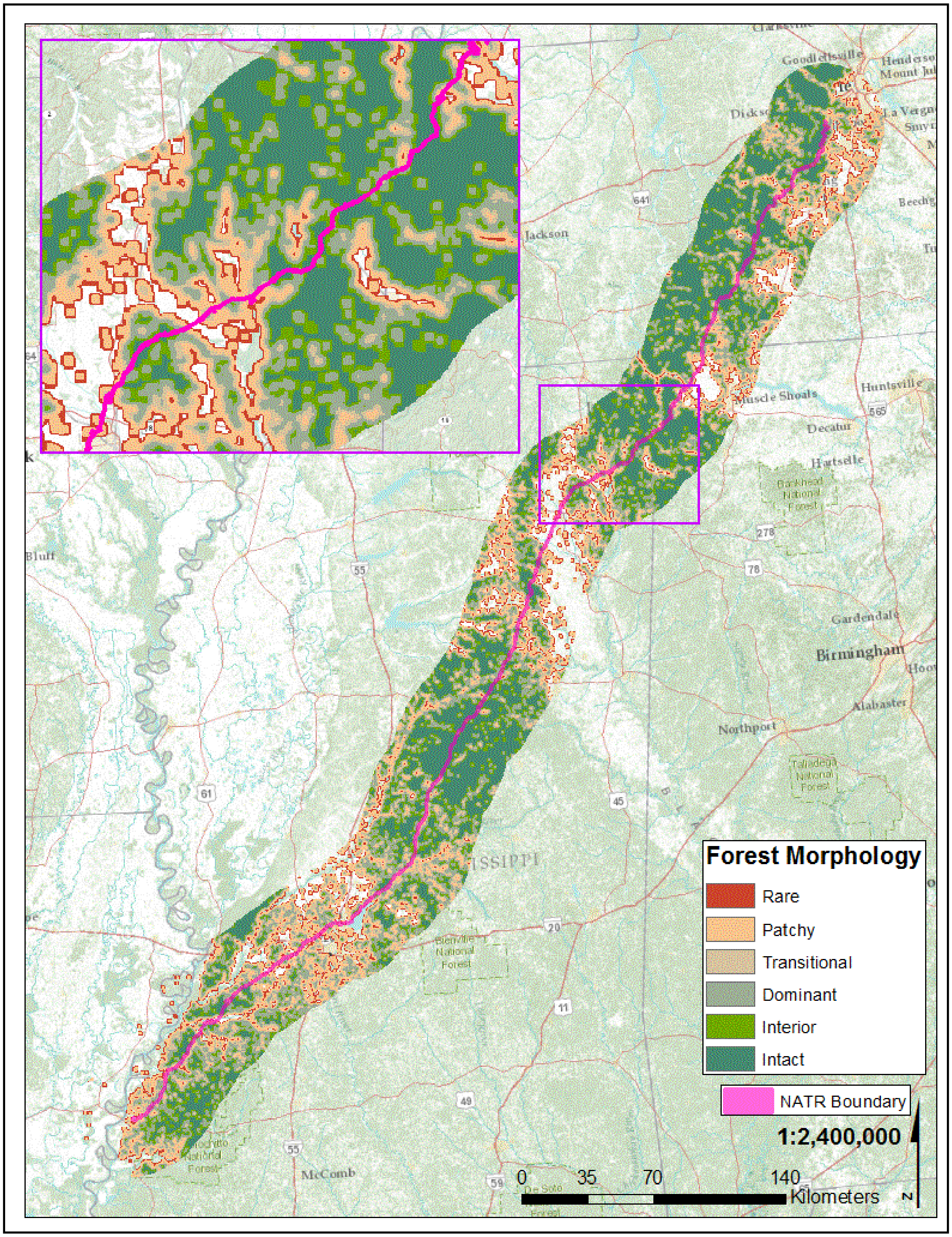


Figure 61. NPScape product showing forest density for NATR with a 30 km buffer.

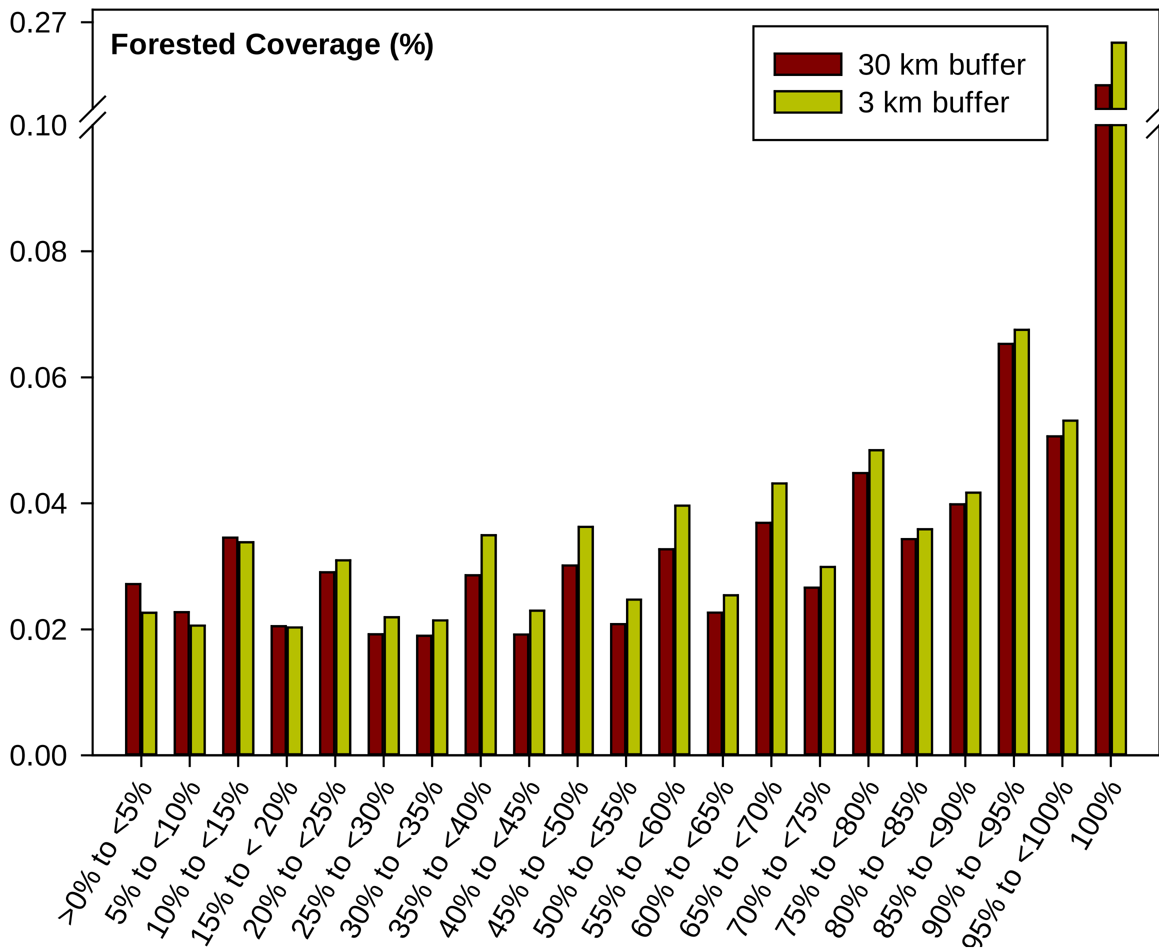


Figure 62. Forest density product after Riitters (2012) showing proportion of forest coverage for each buffer size.

4.10.6 Conservation Status

Relevance and Context

The creation of protected areas is generally considered a safeguard against habitat loss and degradation. These protected areas, in combination with other landscape factors posing a risk to natural resources, can help prioritize areas for further conservation at fairly large scales.

Similar to the variety of thresholds discussed for critical habitat, impervious surface, and road density, Monahan et al. (2012) point out that conservation goals describing ideal amounts of protected area also vary widely. As Soulé and Sanjayan (1998) note, preservation goals such as 10 to 12% protected area are posed frequently for their political appeal (Rodrigues and Gaston 2001, Svancara et al. 2005), but such low proportions, when considered in the context of species-area relationships, are grossly inadequate and could translate into a loss of up to 50% of species richness. A review of evidence-based studies outlining conservation targets by Svancara et al. (2005) yielded an average threshold of 41.6% ± 7.7 % (*n* = 33), wherein the studies considered were ones whose "research results…identified thresholds at which habitat fragmentation or loss has deleterious effects on the feature of interest." This threshold was much higher than the average threshold value of 13.3% ± 2.7% for policy-based targets that were based in little or no scientific grounding. Although it is difficult to identify a one-size-fits-all threshold, evidence-based examples express the need for much higher thresholds of protected area, as well as ones that are individually targeted toward the biological needs of communities, species, and ecosystems of the area in question (Svancara et al. 2005).

Conservation Risk Index

Besides thresholds of protection, Monahan et al. (2012) outline out a metric described by Hoekstra et al. (2005) called the Conservation Risk Index (CRI). Similar to the U-Index calculated as the ratio of natural to converted land, the CRI is calculated as the ratio of converted area to protected area. Hoekstra et al. (2005) outlines thresholds for the index based on the IUCN Red List species, such that areas where habitat conversion is > 20% and CRI > 2 is classified as vulnerable; those with conversion > 40% and CRI > 10 as endangered; and those with conversion > 50% and CRI > 25 as critically endangered. Although originally created as a means to gauge human alteration threats to regional biomes, the CRI is still a useful reference for the NATR landscape, despite its much finer park-level scale of analysis.

Data and Methods

To this end, the Gap Analysis Program (GAP) has developed the Protected Areas Database (PAD) of the U.S., based primarily on the prescribed management of individual land units rather than ownership (USGS GAP 2012). This database ranks protected areas on a scale of 1 (highest protection) to 4 (lowest protection) depending on the relative degree of biodiversity protection offered by each unit (Monahan et al. 2012). GAP status levels 1 and 2 are commonly used to define protected areas, treating them separately from the 3 and 4 statuses that are typically reserved for "multiple-use" areas, such as those managed by the Bureau of Land Management (BLM) or the USFS. Most NPS units are classified at level 1 or 2, though some of the cultural parks are level 3, including NATR (Monahan et al. 2012). Gross et al. (2009) point out that a 5% threshold for intensive human use is used when assigning protection levels, which may also explain the level 3 classification of NATR.

Throughout the 30 km landscape, the largest area of protected land is the Tombigbee National Forest, comprising two main areas totaling 201.9 km^2 and portions of which are classified as level 1 protection. Other large protected areas also include the Homochitto and Bienville National Forests, comprising 170.0 km^2 and 107.3 km^2, respectively. Overall, 1,472 km^2, or roughly 3% of the landscape, are classified as level 1, 2, or 3 by the GAP PAD within the 30 km landscape, not including portions of contiguous areas that fall outside the buffer (Figure 63).

According to Monahan et al. (2012), the CRI is typically applied using GAP level-1 and 2 protected areas. Using these criteria, the ratio of converted land (from NLCD) to protected land is 21.9, which alone would place it in the endangered category, though the proportion of converted land, 30.0%, would place it in the vulnerable class. Because of the disparity in class assignment due to differences in the CRI ratio and converted area proportions, a reasonable compromise would be to adopt the intermediate "endangered" classification. Including level-3 areas in the definition of protected lands would add considerable area to this definition, and the resulting CRI would be 9.0, which taken alone would place the index in the vulnerable category. Including level 1 and 2 areas in addition to NATR results in an index of 16.8, which may be more realistic due to the level of natural resource protection which the park affords.

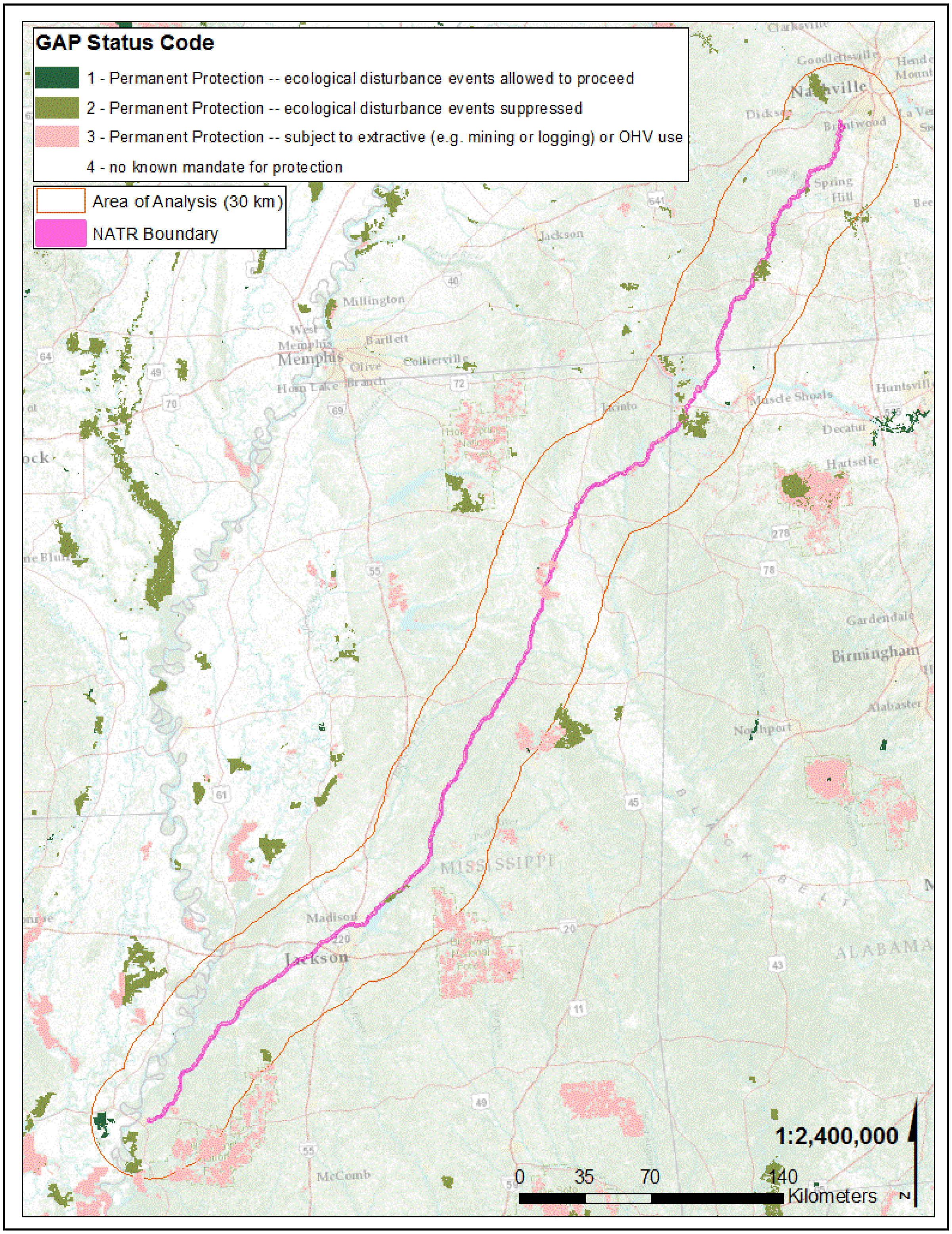


Figure 63. The GAP Protected Areas Database assigns land areas with classifications on a scale of 1 to 4 to describe level of conservation.

4.10.7 Landscape Synthesis and Considerations

The NPScape effort that directs much of the landscape dynamics section was designed to outline specific measureable features that would reflect resource conditions within individual park units. Because most of the park units lie within larger ecosystems and interact with resources far beyond their own boundaries, multiple spatial scales were considered for analysis. In an effort to strike a balance between reproducibility among park units and relevancy across scales and regions, analysis was divided among six main landscape aspects: landcover, impervious surface, roads, population and housing, pattern, and conservation status. Below, each of these six sections is summarized, and key findings for NATR are presented and discussed.

<u>Landcover</u>

Analyses of landcover was based mainly on data from the NLCD, which includes several datasets based on 2006 imagery, including Anderson level-1 and level-2 landcover classifications, imperviousness, and natural vs. converted area, in addition to a change product highlighting different classifications between 2001 and 2006.

- Forested area is similar across buffer widths and is the most dominant landcover class at each scale, though highest at the 3 km buffer width. The second most common class within just the park boundary is developed open space, or road, reflecting the presence of the Parkway itself. At each buffer width, the second most common class is pasture land.

- A U-index representing the ratio of converted to natural area was calculated, resulting in indices of 0.64, 0.35, and 0.43 respectively for the park boundary, 3 km buffer, and 30 km buffer, respectively.

<u>Impervious Surface</u>

Amount of impervious surface area is another metric used often in landcover analyses. Perhaps more than several other aspects of landscape change and analysis, the effects of imperviousness has a large literature base attempting to relate specific thresholds to changes in water and habitat quality. Some of the lowest thresholds are those potentially resulting in geomorphological changes—mainly stream channel enlargement and destabilization—at levels of 2 to 6% imperviousness (Paul and Meyer 2001). Klein (1979) suggests that thresholds such as 12 - 15% imperviousness are where stream water quality begins to degrade, while Lussier et al. (2008) suggests that at 8% imperviousness stream biota are affected in suburban watersheds. King et al. (2011) offer the lowest threshold, suggesting that some biota are affected at levels of 0.5 – 2.0% imperviousness.

At NATR, weighted imperviousness was determined for each cataloging unit within the 30 km buffer. Most calculated imperviousness rates were below one percent, including six cataloging units with imperviousness levels below 0.5%. The Middle Pearl –Strong cataloging unit averaged the highest imperviousness due to urban influence of Jackson, MS. The Harpeth and Town cataloging units were also slightly elevated due to the influence of Nashville, TN and Tupelo, MS urban areas, respectively.

Roads

NPScape used three main metrics to describe the effects of roads in the landscape: road density, distance to road, and effective mesh size. Mean rates of traffic were not used in the NPScape assessment but were used to estimate land turtle mortality by Gibbs and Shriver (2002), who suggested a road density threshold at 1.0 km km^{-2}. Steen and Gibbs (2004) offered another threshold of 1.5 km km^{-2} for a central NY study involving aquatic turtles. Lin (2006) offers that the average road density throughout the U.S. is 0.67 km km^{-2}.

- Metrics indicate a consistently strong influence of road presence closer to the park within the 3 km buffer, though the difference with the 30 km scale is minimal.

Road density at the broader landscape scale is 1.8 km km^{-2}, which based on literature estimates may be sufficient to result in effects on wildlife.

Population and Housing

These two measures are highly related and correlate well with other landscape metrics like impervious surface and road density. It is particularly difficult to identify thresholds of housing or population densities that affect specific changes in the landscape. However, Monahan et al. (2012) point out several studies that make general observations regarding influences of human settlements on plants and vertebrates. In a study involving exurban areas in Colorado, for example, Maestas et al. (2002) found (1) increased richness and cover of non-native plant species, (2) increased densities of human-commensal bird species such as Blue Jays (*Cyanocitta cristata*) and Black-billed Magpies (*Pica hudsonia*), and (3) high densities of domestic dogs and cats. In a study in California, Merenlender et al. (2009) found lower proportions of temperate migrant bird species in exurban and suburban areas, and in dense housing areas found higher relative abundances of urban adapter species like American Crow (*Corvus brachyrhynchos*) and Turkey Vulture (*Cathartes aura*).

- For the most part, NATR falls within a sparsely populated landscape, with the exception of the three major urban areas of Jackson, Tupelo, and Nashville.

Since 1950, the lowest density housing class (<1.5 units km^{-2}) appears to decrease within the 30 km buffer, although the trend is not significant. Regression does show significant increases in higher density classes, which is consistent with a nationwide trend of exurban growth.

Pattern

Landscape pattern can affect availability of resources to different species assemblages and as a result may dictate their abundance. Much of the natural landscape within the NATR vicinity is forested, with exceptions such as the Blackbelt Prairie region. Fragmentation of natural landcover introduces an edge effect on the remaining habitat, which influences ecological processes. Besides edge effect, the remaining patch size is a fundamental landscape metric that addresses habitat availability. Although the effect of patch size is dependent on scale, both spatially and temporally, small patches often offer insufficient levels of habitat to maintain high levels of biodiversity.

- The NATR landscape contains large areas of core forest habitat in central MS and in portions of AL and TN. Overall, core forest area (>30 m from edge) comprises 39.6% of the landscape.

Forest cover per unit area at the 3km buffer scale is higher than the 30 km buffer, reflecting less dissection of the landscape immediately adjacent to the park.

Conservation Status

The NPScape assessment used the Protected Areas Database (PAD) created by the Gap Analysis Program (GAP) to analyze the amounted of protected area within the vicinity of NATR. Protected areas are assigned a rating of 1 to 4 corresponding to a descending scale of the amount of biodiversity protection offered by each land unit. As a guideline, 10% to 12% protected area is often posed as a minimum objective (Rodrigues and Gaston 2001), though a review of evidence-based studies by Svancara et al. (2005) yielded a considerably higher suggested minimum threshold of 41.6% ± 7.7 %.

An additional guideline for amount protected area outlined by Monahan et al. (2012) is the Conservation Risk Index (CRI), which is the ratio of converted to protected area. Hoekstra et al. (2005) describes thresholds based on the amount of habitat conversion and the CRI, beginning with minimal threat when habitat conversion reaches 20% and CRI > 2.

- Notably, the PAD has assigned a rating of level-3 protection to NATR, which connotes a lower level of resource protection. This likely stems from the main purpose of the park as a historical and cultural memorial, as well as the high proportion of converted area due to the road.

There are almost 1,500 km^2 of level 1, 2, or 3 protected area within the landscape, or roughly 3% of the landscape.

The CRI risk rating is defined by a combination of 1) converted land within a landscape and 2) the ratio of converted to protected area. At the NATR landscape, this ratio results in a CRI risk rating of endangered, while the proportion of converted land alone would result in a vulnerable designation. Only level 1 and 2 protected areas are used in this definition, which may result in a conservative assessment of the level of resource protection.

4.10.8 Landscape Conclusions

Each of the five components assessed by NPScape presents a slightly different outlook on the state of adjacent land use within the vicinity of NATR. Considered individually, there are several aspects of the analysis that are encouraging, such as:

1. Proportions of impervious landcover are very low for most cataloging units, though the influence of urban areas is apparent in three of the units.

2. Population density is relatively low in the overall surrounding landscape (39.4 per km^2 in 2000).

3. Pattern metrics reveal large areas of core forest throughout the NATR landscape, and especially closer to the park (3 km buffer).

Other aspects of the analysis are less encouraging, especially when viewed across all buffer classes:

1. The overall landscape is highly dissected by roads, including the area immediately surrounding the park.

2. Although regional population density is low, most of the higher density housing classes show a steady and significant increase since 1950, which can indicate increasing pressure on landscape resources.

3. Calculation of the CRI leads to a mixed rating between vulnerable and endangered designations, reflecting a moderate threat of human alteration to the region.

The complexity of the adjacent land use vital sign makes it difficult to summarize into a single condition status ranking. By combining NPScape aspects into key points as above, it becomes easier to pick out the most significant landscape qualities. As a result, adjacent land use is assigned an overall ranking of "fair" (Table 56).

Based on the NLCD change layer, some change occurred throughout the landscape between 2001 and 2006 time periods, totaling about 6% of the landscape. Four percent of this change, however, was a transition between natural landcover types, likely due to succession. Just over 1% was due to conversion from converted area returning to natural, while the small remaining proportion represented a transition from natural to converted. Perhaps a more meaningful representation of changes in the landscape comes from the population and housing data, the latter of which shows a steady increase in exurban and denser housing classes since the 1950's. Of the 25 counties through which NATR passes, ten show significant population increases during the period 1950 to 1990. Taken together, these trends show an increasing anthropogenic pressure on the landscape surrounding NATR, therefore a declining trend is assigned.

The data quality is very good (Table 56), fulfilling all six of the data quality checks. The NPScape data products provide a comprehensive analysis at a landscape scale using a variety of relevant metrics. Data used in this assessment represents the second phase of NPScape, which includes updates to data sources and processing methods since the original release (Table 57).

Table 56. The condition status for adjacent land use (measured landscape change surrounding the park) was fair, qualified with a declining trend. The data quality for this ranking was very good, with data meeting all six of the data quality criteria.

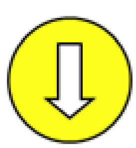
Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Adjacent Land Use		Relevancy ✓	Proximity ✓	Currency ✓
		Sufficiency ✓	Coverage ✓	Coverage ✓
		6 of 6: Very Good		

Table 57. List of NPScape metric categories and data source currency.

Category	Data Source	Year
Landcover	• National Landcover Dataset (NLCD)	• 2001 and 2006
Roads	• Tele Atlas streets Database	• 2005
Population and Housing	• US Census Bureau • Waisanen and Bliss • Theobald	• 2000 • 2002 • 2005
Pattern	• North American Landcover Dataset (NALC)	• 2005
Conservation Status	• Protected Areas Database (PAD) Version 1.2	• 2011

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Chapter 5 Conclusions

5.1 Summary

The Natchez Trace Parkway stretches across a long, linear expanse of the eastern Gulf Coast interior plain, and contains a vast array of natural resources. Natural resources for this report were chosen based on data availability, park-level importance, and vital sign status. The level of data completeness varied greatly among natural resource categories, though this aspect was considered independently when assigning condition rankings.

Based on a review of available ecological information for NATR, we addressed the current condition of 10 natural resource attributes in the park. Six of these were assessed at the park-wide scale. Four attributes—water quality, fish assemblages, bird assemblages, and herpetofauna assemblages—were divided into smaller reporting areas for assessment. To include these attributes in a park-wide summary, we used the proportions of individual reporting area condition ranks to create a mixed rank for the attributes. Overall, natural resource conditions in NATR were ranked 26% good, 45% fair, and 4% poor. The remaining 25% were not assigned a rank.

Summarized into broad categories, the percentages of condition rankings were:

Air and Climate (two attributes)—50% Fair, 50% Not ranked

Water (one attribute)—38.5% Good, 38.5% Fair, 23% Not ranked

Biological Integrity (six attributes)—37% Good, 35% Fair, 3% Poor, 25% Not ranked

Landscapes (one attribute)—100% Fair

We assigned trends to natural resource attribute conditions where appropriate. Because long-term data were not available in most cases, trends were only assigned to a few attributes. Attributes assessed for multiple reporting areas were summarized as described above. Overall, natural resource condition trends in NATR were 11% improving and 20% declining. The remaining 69% were not assigned a trend.

Summarized into broad categories, the condition trend assignments were:

Air and Climate (two attributes)—50% Improving, 50% Not ranked

Water (one attribute)—8% Improving, 92% Not ranked

Biological Integrity (six attributes)— 100% Not ranked

Landscapes (one attribute)—100% Declining

We also characterized the quality of data used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Attributes assessed for multiple reporting areas were summarized as described above. Data quality was assessed for all instances where data existed. Therefore, all attributes were assigned a data quality ranking, regardless of whether the attribute was assigned a condition rank. Overall, natural resource attribute data quality, for the existing data used in this report, was ranked 30% very good, 35% good, 13% fair, and 22% marginal.

Summarized into broad categories, the data quality rankings were:

Air and Climate (two attributes)—100% Very Good

Water (one attribute)—100% Good

Biological Integrity (six attributes)—42% Good, 21% Fair, 37% Marginal

Landscapes (one attribute)—100% Very Good

5.1.1 Attribute Assessment Summary

Ozone

Ozone data were available from several sources, including two portable ozone monitoring stations within the park, NPS Air Resources Division (ARD) interpolated park estimates, Mississippi Department of Environmental Quality (MDEQ) in regional cities, and NPS Gaseous Pollutant Monitoring Program (GPMP) summaries. EPA standards for the 4^{th} highest maximum 8-hour ozone concentration were used to assess ozone status. One of the park's two monitoring stations had values of moderate concern, and the other had values of low concern. NPS ARD values were just below the EPA standards for concern, and MDEQ values were in the moderate concern category. Ten-year periods assessed by NPS ARD and MDEQ data showed significantly declining ozone concentrations over the periods analyzed. The condition of ozone in NATR was ranked as fair. An improving trend was assigned to ozone condition. The quality of the data used to make this assessment was very good.

Weather and Climate

Long-term data were available from five National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Program (COOP) stations, and one U.S. Forest Service Remote Automated Weather Station (RAWS) located along the Natchez Trace Parkway. Precipitation, temperature, and wind speed and direction were summarized for this report. The sources listed above provide reliable temperature and precipitation histories for the region over approximately the last century. The RAWS station provided wind data from 1997-present. Four of five stations COOP stations showed increasing precipitation trends. Mean, minimum, and maximum annual temperature metrics had trends that varied among sites and among metrics. Of 15 possible trends (three metrics at five sites), eight had decreasing trends, two had increasing trends, and five had no discernible trend. Due to a lack of a good reference condition, no rank or trend were assigned to weather and climate condition. The condition of the available data was very good.

Water Quality

The Parkway traverses many watersheds and waterways, and aquatic resources are among the most important in the park. Water quality data were available starting in 2007 from a park-wide aquatic assessment of NATR streams, and from continuing GULN monitoring efforts. Several metrics were used to assess water quality including temperature, pH, dissolved oxygen, bacterial level, specific conductance, and the presence of 303(d) streams. Water quality was assessed by HUC 8 watershed boundary. Of the 16 HUC 8 watersheds traversed by NATR, 13 were assessed for water quality and three were not assessed due to lack of data. Therefore, 13 reporting areas were assigned conditions for this attribute. A park-wide condition also was assigned. Negative impacts on water quality resulted from high *E. coli* concentrations, high acidity, and low oxygen concentrations. The Upper Big Black, Lower Big Black, and Tibbee reporting areas had the most serious water quality problems. Of the 13 reporting areas assessed, five were ranked as good, five were ranked as fair, and three were ranked as poor. Overall, the park water quality condition was ranked as fair. Only one reporting area, Upper Pearl, was assigned a trend. The trend for this area was improving. Data quality was ranked as good for all assessments.

Terrestrial Vegetation

The Natchez Trace Parkway supports a great variety of floral species. In addition, several rare or sensitive species or communities occur in the park. Black Belt prairie complexes are found along the Parkway and are frequently managed with prescribed fire. The federally threatened Price's potato bean (*Apios priceana*) has been reported (but not confirmed), as well as over 60 species considered imperiled or critically imperiled at the state or province scale. Exotic plant species present a serious concern in the park and at least 215 species occur in NATR. Several invasive species are of particular concern to park managers. These include tree-of-heaven (*Ailanthus altissima*), mimosa (*Albizia julibrissin*), Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), Johnsongrass (*Sorghum halepense*) and kudzu (*Pueraria montana*). Active measures are taken by NATR staff and by the Gulf Coast Exotic Plant Management Team (EPMT) to reduce the cover and prevent the spread of these and other invasive plants. If a 1986 plant list is used as a baseline, it appears that the number of exotic plant species has increased in recent decades, however this could also be due to detecting more species in subsequent surveys. The condition of terrestrial vegetation in NATR was fair. The trend of vegetation condition was not assigned due to insufficient data to assess change in status. The data quality used to make this assessment was considered good.

Forest Pests and Disease

Several forest pests or diseases may affect trees along the Parkway. Dogwood anthracnose is an exotic fungus that has spread south and west since its introduction in the northeastern U.S. Southern pine beetle (*Dendroctonus frontalis*) is a native insect that attacks several pine species during periodic outbreaks. Fusiform rust is a native fungus that infects pines and can lead to mortality in significant infections. Data about the presence of these organisms in the park were available from several sources. A 1989 driving survey detected dogwood anthracnose infection of a single tree, and also found other dead trees that did not test positive for the pathogen. A U.S. Forest Service team prepared a risk map for southern pine beetle in the region. The map showed that infection risk was greatest along the central parkway between Jackson, Mississippi and the Alabama state line. Another Forest Service study sampled for fusiform rust in the region and sampled several trees in NATR. Infected Parkway trees were found, though mortality was not observed and growth of infected trees was not inhibited. The condition of forest pests and disease was ranked as good. No trend was assigned to this condition. The data quality was marginal, due to the age of the data and the lack of actual infection data for southern pine beetle.

Fish Assemblages

The park's many streams and waterways support a great variety of fish species. Data on expected fish species for the region were available from two studies that queried literature and academic databases to compile lists of all species reported from within 10 km of park boundaries in Tennessee and Mississippi. A peer-reviewed study reported on species reported from the Bear Creek drainage in Alabama. A comprehensive inventory was conducted on park fishes in 2005-2006. Most recently a master's thesis effort conducted fish sampling as part of a larger effort to assess land use effects on aquatic resources. Around 175 species have been reported from the immediate region from these efforts, and 92 species were reported from the comprehensive park inventory. The inventory data were primarily used to assess current park condition. The federally threatened slackwater darter (*Etheostoma boschungi*) was reported from the park inventory. Several state-listed species were also reported, but were not found in the states where they were listed. Non-native species were rare in the inventory samples. Fish assemblage condition was reported at the HUC 8 watershed scale. Of the 16 HUC 8 watershed traversed by NATR, data were available for 13. The remaining three were not ranked and were not discussed because current data were not available. Species richness, Simpson's Diversity Index, relative endemism, and percentages of tolerant and intolerant species were the metrics used to explore fish assemblage condition. Of the 13 assessed reporting areas, three were ranked as good, eight as fair, and two as poor. Data quality was fair for 10 of the reporting areas and marginal for three. No trend was assigned to any of these assessments.

Bird Assemblages

The Natchez Trace Parkway provides habitat for a variety of birds. Data from the immediate region were available from USGS Breeding Bird Survey (BBS) roadside surveys and from Audubon Society Christmas Bird Count (CBC) data. Three BBS routes were collected within park boundaries and provided recent data on park birds. A park-wide inventory provided data from a comprehensive effort to sample NATR birds. The NATR inventory reported 134 species within the park. No federally listed species were reported during the inventory and four species of state protected birds were reported. These were the Cooper's Hawk (*Accipiter cooperii*), Bachman's Sparrow (*Aimophila aestivalis*), American White Pelican (*Pelecanus erythrorhynchos*), and Bewick's Wren (*Thryomanes bewickii*). Additionally, a number of birds identified as conservation concern species by Partners-in-Flight were also reported in the inventory. Birds were assessed in two reporting areas: North and South. Comparisons of expected to observed species lists, trait based comparisons between NATR and regional samples, and PIF-based conservation rank comparisons between park and regional samples were used to explore and assess NATR bird communities. The North Reporting Area was not assessed, due to lack of recent BBS data for this region. The data quality was fair, and no trend was assigned. The South Reporting Area bird assemblage condition was good and the data quality was good. No trend was assigned to this condition.

Herpetofauna Assemblages

NATR supports a variety of species of reptiles and amphibians. Data on park herpetofauna were available from a 1999-2000 comprehensive park inventory and a 2011-2012 inventory in the northern section. These efforts reported 69 species, including 25 snakes, 14 turtles, six lizards, one crocodilian, 15 anurans, and eight salamanders. No federally listed species were reported, and one species, the rainbow snake (*Farancia erytrogramma*), was reported from Mississippi where it is endangered. Reptile and amphibian richness was generally greater in the southern sections of the park relative to northern sections. Salamander diversity from the inventory was low, and probably did not represent the actual richness found in NATR. Park herpetofauna condition was reported for two reporting areas: North and South. Assessments relied upon comparisons between the assemblages observed in the inventory to assemblages observed by other studies in Tennessee and Mississippi. The North Reporting Area was ranked as fair, and the South Reporting Area was ranked as good. No trend was assigned to herpetofauna assemblage condition. The data used to make the assessments was ranked as very good for the north reporting area and good for the south reporting area.

Wildlife Damage

Several species have potential to cause damage to the park's natural environments, native species assemblages, or infrastructure. These species may also pose risks to human health and safety or lower the quality of visitor experience. Of these potential animals, feral hogs (*Sus scrofa*) and beavers have been identified by park staff as populations in need of management. Data were available from a park beaver management plan, a draft feral hog management plan, and from electronic records of a beaver dam inventory. Generally, according to NATR staff, management of these two species does not appear terribly successful. The park is considering beaver relocation and an increase in feral hog trapping efforts. Because data was marginal, and we could not identify a reasonable method for ranking this attribute, it was not ranked.

Adjacent Land Use

The activities and changes on land adjacent to the park have great potential to impact park natural resources. Data for this extensive resource category were available primarily data sources and products created by NPScape, the NPS land use monitoring project. Data from the USGS GAP Protected Areas Database were also used. Adjacent land use was considered in six categories: vegetative landcover, impervious surface, road density, human population density, habitat pattern, and conservation status. The landscapes immediately surrounding the park were dominated by forest cover. The percent of impervious surface within the 30-km buffer was below 1% for most of the park's HUC 8 watershed units. Road density was relatively high around the park, within ranges thought to possibly impact wildlife. Human population density was relatively sparse around much of the park, with higher densities around Jackson and Tupelo, Mississippi, and Nashville, Tennessee. Higher density classes were significantly increasing in population over time. Core forest area (forest >30 m from edge) comprised about 40% of the NATR landscape. Roughly 3% of the immediately surrounding landscape had a relatively high protection status. In general, the low imperviousness, relatively low population density, and high percentage of core forest in the adjacent landscapes were viewed as positive for NATR natural resources. The high road density, increasing human density in high-density housing areas, and relatively low amount of surrounding protected land were viewed as negative for NATR natural resources. The complexity of the adjacent land use attribute makes it difficult to assess. However, based on the findings in six categories, the adjacent land use condition was ranked as fair. A declining trend was assigned to this condition. The quality of the available data was very good.

5.2 Discussion by Category

This project represents the first iteration in the development of a comprehensive natural resource monitoring program at NATR. Beyond this report, continued monitoring of resources and attention to data gaps, as well as the development of additional condition assessment protocols, will aid in the undertaking of future natural resource assessments.

5.2.1 Air and Climate

Air quality is an important issue in the NATR region, and appears to be currently improving. There was a fairly rich dataset on park ozone concentration, including data collected within the park, interpolated data for the park, and regional data collected at nearby cities. Values of the 4^{th} highest maximum 8-hour ozone concentration varied slightly among these sources, but were generally within the range of moderate concern. Evidence suggested that ozone concentration values are declining in the region of the park.

Weather trends showed generally increasing precipitation and decreasing temperatures, although temperature trends varied significantly among sites and among metrics. Winds were generally low and were most commonly out of the northwest and southeast.

5.2.2 Water Quality

Water quality is a primary resource issue for NATR. Water quality varies considerably among park streams and watersheds, and good, fair, and poor conditions were observed within the park. High bacterial levels, high acidity, and low oxygen concentrations were the major threats to water quality. The Red Hills Mine, located on the Upper Big Black River watershed appears to an important contributor to poor water quality in that drainage. Two other watershed reporting areas were in poor condition. There was an adequate amount of good-quality water monitoring data available, though collections started relatively recently. As monitoring continues, the ability to determine long-term trends will improve.

Because E. coli concentration standards vary by state and season, it would be preferable if NATR used the 487 colonies/100 ml standard (as with TN) throughout the year to avoid confusion. There is nothing to prevent a person from recreating in park waters prior to May or later than October (J. Meiman, personal observation); therefore, enforcing this standard could also improve safety.

5.2.3 Biological Integrity

The Parkway is demonstrated to contain a variety of significantly intact natural assemblages of flora and fauna. Many of the significant threats and stressors to native species and assemblages result from non-native species.

<u>Flora</u>

The Parkway supports a great variety of plant species. Primary landcover classes differed between the northern section of the park and the southern and central sections. The northern section contained more white oak cover and the southern/central portions contained more pine-cedar cover. At least one federally threatened and 65 state-listed plant species occur along the Parkway, many of them in rare native prairie complexes. The recent re-introduction of fire into some of these communities should improve the success of native species. Exotics were a major concern in NATR with over 200 exotic species known to occur in the park. Exotics appear to have increased in the park in the last two decades (although could be due to more surveys), and managing exotic plants is an important goal for park and network managers. A variety of sources provide useful information about NATR plants, and the status of the data was good, in general.

An exotic plant monitoring protocol would be useful for prioritizing and describing exotic control efforts.

Forest pests and diseases may cause a risk for several native tree species. The forest fungal pathogens dogwood anthracnose and fusiform rust have been found within NATR, though the data for these diseases were old, and neither disease was shown to cause a major issue at the time of sampling. A risk map for southern pine beetle infestations suggested that the central portion of the park was most at risk. Data on forest pests and diseases was relatively sparse and old. Updated surveys of the occurrence of dogwood anthracnose and fusiform rust might be useful to managers. A survey for southern pine beetle outbreaks would be a useful complement to the recent risk map for the area.

<u>Fauna</u>
A great variety of vertebrate species are found in NATR. At least 92 fish, 134 bird, and 69 herpetofauna species are documented to occur in the park. These numbers represent only the results of park-wide inventories and it is expected that significantly greater numbers of species actually are found in the park. Because of its large geographic scale, the Parkway includes many types of habitats and communities. Fish assemblages appeared to be in better condition in the northern park, whereas herpetofauna appeared to in better condition in the southern park regions. Several federal or state threatened or endangered species occur in NATR, and many others of conservation concern are present. Non-native species occur in the park, and may cause risk to native animal habitat and assemblages. The occurrence of native fishes was negligible in the park, and no known non-native herpetofauna occur. Several non-native bird species were reported, although the impacts of these species is not known. Feral hogs present a challenge to park management and measures to monitor and control individual problem animals are in place. Beaver activities sometimes compromise the integrity of the motor roadway and dams are inventoried and controlled regularly.

Updated NATR inventories would be useful, particularly for herpetofauna and bird assemblages. These inventories were over 10 years old and updates to these baseline reports would provide a better understanding of current condition and recent changes. USGS BBS data are collected annually within the park and help to provide a current understanding of breeding bird species. The park lacks a baseline mammal inventory, and could benefit from one if such were completed.

5.2.4 Adjacent Landscapes
The Natchez Trace Parkway is long and narrow with a large geographical extent. Therefore, the impacts of adjacent land use on park resources are particularly important. Several key metrics are good, from a natural resource perspective. Outside of urban areas, NATR has a low proportion of impervious surface. Population density is low in much of the surrounding landscape. Large areas of core forest occur in the surrounding landscape, particularly in areas immediately adjacent to the park. Conversely, several key metrics indicate potential negative impacts on park natural resources. The immediately surrounding landscape is highly dissected by roadways. Although regional human population density is relatively low, high-density housing classes have increased significantly and steadily since 1950. A conservation risk assessment based on the percentage of protected land indicates a status between vulnerable and endangered. Therefore, a variety of

impacts, both positive and negative, are expected in the park as a result of the land use in the adjacent region. Many of these impacts are essentially beyond the control of park management.

Appendix A.

List of Initial Scoping Meeting Attendees

Natchez Trace Parkway:

Lisa McInnis, Natural Resource Management Specialist
Cam Sholly, Superintendent

Gulf Coast Inventory and Monitoring Network:

Martha Segura, Network Coordinator
Joe Meiman, Hydrologist

University of Georgia:

Nate Nibbelink, Principal Investigator
Mike Mengak, Co-Principal Investigator
Gary Sundin, Research Professional
Luke Worsham, Research Professional

Southeast Regional Office:

Dale McPherson, Regional NRCA Program Coordinator

Appendix B.

Fish species reported from NATR and within 10 km of NATR borders reported by five researchers. Researchers conducting physical sampling included: Earleywine 2010 (Ew ’10), Johnston 2007 (Jo ’07), and Phillips and Johnston 2004 (Phil ’04). Researchers conducting database and literature searches included: Ross 2004 (Rs ’04), and Paxton et al. 2001 (Pxt ’01). HUC 8 watersheds listed are those sampled by Johnston (2007) and include: Harpeth (Hrp), Lower Duck (LDk), Buffalo (Buf), Pickwick Lake (PwL), Bear (Br), Upper Tombigbee (UT), Town (Twn), Tibbee (Tib), Upper Big Black (UB), Lower Big Black (LB), Upper Pearl (UP), Middle Pearl-Strong (MP), and Coles Creek (Col). An “*” indicates a species that was only reported in the watershed by Johnston (2007). An “^” indicates a species only reported by Earleywine (2010). Bold names indicate species only reported from HUC 8 watersheds not sampled by Johnston (2007).

		Researcher					HUC 8 Watershed												
Scientific Name	**Common Name**	**Ew '10**	**Jo '07**	**Phil '04**	**Pxt '01**	**Rs '94**	**Hrp**	**LDk**	**Buf**	**PwL**	**Br**	**UT**	**Twn**	**Tib**	**UB**	**LB**	**UP**	**MP**	**Col**
Alosa chrysochloris	skipjack herring				X			X											
Ambloplites ariommus	shadow bass					X						X					X		
Ambloplites rupestris	rock bass			X	X				X	X	X								
Ameiurus melas	black bullhead	X				X								X		X	X	X	
Ameiurus natalis	yellow bullhead	X	X		X	X		X	X	X	X	X	X*	X	X	X	X	X	X
Amia calva	bowfin					X					X	X				X			
Ammocrypta beanii	naked sand darter					X						X				X	X		
Ammocrypta vivax	scaly sand darter					X											X		
Aphredoderus sayanus	pirate perch	X	X			X					X	X			X	X	X		
Aplodinotus grunniens	freshwater drum					X					X								X
Campostoma anomalum	central stoneroller	X	X			X	X^		X^	X^						X			X
Campostoma oligolepis	largescale stoneroller	X	X	X	X	X	X	X	X	X	X	X	X						
Carpiodes carpio	river carpsucker					X													X
Carpiodes cyprinus	quillback		X																X*
Carpiodes velifer	highfin carpsucker		X			X						X	X						
Centrarchus macropterus	flier	X	X			X									X		X*		
Clinostomus funduloides	rosyside dace	X	X	X	X		X*	X	X	X	X								
Cottus carolinae	banded sculpin	X	X	X	X	X	X^	X	X	X*	X								
Crystallaria asprella	**crystal darter**					X													
Cyprinella camura	bluntface shiner	X	X			X									X	X		X*	X
Cyprinella galactura	whitetail shiner		X	X	X			X	X*	X	X								
Cyprinella lutrensis	red shiner		X			X										X			X
Cyprinella spiloptera	spotfin shiner		X	X	X	X		X	X		X								
Cyprinella venusta	blacktail shiner	X	X			X						X	X	X	X	X	X	X*	X

Appendix B. (continued)

Scientific Name	Common Name	Researcher Ew '10	Jo '07	Phil '04	Pxt '01	Rs '94	HUC 8 Watershed Hrp	LDk	Buf	PwL	Br	UT	Twn	Tib	UB	LB	UP	MP	Col
Cyprinella whipplei	steelcolor shiner			X		X					X								
Cyprinus carpio	common carp					X					X	X				X			X
Dorosoma cepedianum	gizzard shad		X			X					X	X	X	X	X	X			X
Dorosoma petenense	threadfin shad			X							X								
Elassoma zonatum	banded pygmy sunfish	X				X									X	X	X		
Erimonax monachus	spotfin chub				X				X										
Erimystax dissimilis	streamline chub				X				X										
Erimystax insignis	blotched chub				X			X	X										
Erimyzon oblongus	creek chubsucker	X	X	X	X	X	X^		X	X	X	X^	X	X	X	X	X	X*	X
Erimyzon sucetta	lake chubsucker					X						X				X	X		
Erimyzon tenuis	sharpfin chubsucker					X											X		
Esox americanus	redfin pickerel	X	X			X					X	X		X	X	X	X	X	
Esox niger	chain pickerel				X	X			X	X	X	X					X		
Etheostoma aquali	coppercheek darter				X				X										
Etheostoma asprigene	mud darter					X									X				
Etheostoma bison	buffalo darter				X				X										
Etheostoma blennioides	greenside darter		X	X	X	X	X*	X	X	X	X								
Etheostoma blennius	blenny darter		X		X			X	X	X									
Etheostoma boschungi	slackwater darter		X		X					X									
Etheostoma caeruleum	rainbow darter	X	X	X	X	X	X	X	X	X	X					X*			
Etheostoma camurum	bluebreast darter				X			X											
Etheostoma chlorosomum	bluntnose darter		X			X						X	X	X	X	X	X		
Etheostoma corona	crown darter		X		X					X									
Etheostoma crossopterum	fringed darter	X	X		X		X	X	X^		X*								
Etheostoma derivativum	stone darter		X				X*												
Etheostoma duryi	blackside darter		X	X	X					X	X								
Etheostoma flabellare	fantail darter	X	X		X		X*	X	X	X									
Etheostoma flavum	saffron darter	X	X		X			X	X	X^									
Etheostoma gracile	slough darter					X									X	X	X		
Etheostoma histrio	harlequin darter		X			X					X				X*		X		
Etheostoma jessiae	blueside darter			X							X								
Etheostoma kennicotti	stripetail darter				X				X										
Etheostoma lachneri	Tombigbee darter		X									X							

Appendix B. (continued)

Scientific Name	Common Name	Researcher: Ew '10	Jo '07	Phil '04	Pxt '01	Rs '94	HUC 8 Watershed: Hrp	LDk	Buf	PwL	Br	UT	Twn	Tib	UB	LB	UP	MP	Col
Etheostoma luteovinctum	redband darter				X			X											
Etheostoma lynceum	brighteye darter					X									X				
Etheostoma meridianum	southern sand darter					X						X	X						
Etheostoma neopterum	lollipop darter				X					X									
Etheostoma nigripinne	blackfin darter	X		X	X			X	X	X									
Etheostoma nigrum	johnny darter		X			X					X	X		X*	X				
Etheostoma parvipinne	goldstripe darter					X									X	X			X
Etheostoma proeliare	cypress darter	X	X			X						X*		X	X	X	X		X
Etheostoma rubrum	**bayou darter**					X													
Etheostoma rufilineatum	redline darter		X	X	X	X		X	X	X	X								
Etheostoma rupestre	rock darter					X						X							
Etheostoma simoterum	TN snubnose darter		X	X	X			X	X	X	X*								
Etheostoma stigmaeum	speckled darter	X		X	X	X		X	X	X		X	X		X		X		X
Etheostoma swaini	Gulf darter		X			X					X	X		X*		X*	X		
Etheostoma virgatum	striped darter	X			X		X												
Etheostoma whipplei	redfin darter	X	X			X						X	X	X		X			X
Etheostoma zonale	banded darter		X		X			X	X										
Etheostoma zonistium	bandfin darter	X		X							X			X^					
Fundulus catenatus	northern studfish	X	X	X	X	X	X	X	X	X	X								X
Fundulus notatus	blackstripe topminnow	X				X							X	X		X^	X		X
Fundulus nottii	bayou topminnow					X											X		
Fundulus olivaceus	blackspotted topminnow	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X
Gambusia affinis	mosquitofish	X	X	X	X	X		X	X	X*	X	X	X	X	X	X	X	X	X
Hemitremia flammea	flame chub	X	X		X					X									
Hybognathus hayi	cypress minnow					X						X					X		
Hybognathus nuchalis	MS silvery minnow	X	X			X						X	X		X	X	X		X
Hybopsis amblops	bigeye chub		X	X	X			X	X	X	X								
Hybopsis winchelli	clear chub		X			X						X					X		
Hypentelium etowanum	Alabama hog sucker					X						X							
Hypentelium nigricans	northern hog sucker	X	X	X	X	X		X	X	X	X	X							
Ichthyomyzon bdellium	Ohio lamprey				X				X										
Ichthyomyzon gagei	southern brook lamprey					X						X							
Ichthyomyzon greeleyi	mountain brook lamprey				X				X										

Appendix B. (continued)

Scientific Name	Common Name	Researcher					HUC 8 Watershed												
		Ew '10	Jo '07	Phil '04	Pxt '01	Rs '94	Hrp	LDk	Buf	PwL	Br	UT	Twn	Tib	UB	LB	UP	MP	Col
Ictalurus furcatus	blue catfish		X													X*			
Ictalurus punctatus	channel catfish		X			X					X	X	X	X		X	X		X
Ictiobus niger	black buffalo					X					X								
Labidesthes sicculus	brook silverside		X	X	X	X		X*	X		X	X*					X	X*	
Lampetra aepyptera	least brook lamprey			X	X	X			X	X	X	X							
Lepisosteus oculatus	spotted gar		X			X		X*			X								
Lepisosteus osseus	longnose gar		X			X					X							X*	
Lepomis cyanellus	green sunfish	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X
Lepomis gulosus	warmouth	X	X	X	X	X	X*	X	X		X	X		X	X	X	X	X	
Lepomis humilis	orangespotted sunfish					X							X	X		X			
Lepomis macrochirus	bluegill	X	X	X	X	X	X*	X	X	X	X	X	X	X	X	X	X	X	X
Lepomis marginatus	dollar sunfish			X		X					X				X		X		
Lepomis megalotis	longear sunfish	X	X	X	X	X		X	X	X*	X	X	X	X	X	X	X		X
Lepomis microlophus	redear sunfish		X		X	X	X*	X				X	X			X	X		
Lepomis miniatus	redspotted sunfish	X	X			X						X		X			X		
Luxilus chrysocephalus	striped shiner	X	X	X	X	X	X	X	X	X	X	X			X	X	X		X
Luxilus coccogenis	warpaint shiner		X		X					X									
Lythrurus ardens	rosefin shiner	X	X	X			X*			X*	X								
Lythrurus bellus	pretty shiner	X	X			X					X	X	X	X					
Lythrurus fasciolaris	scarlet shiner				X		X	X	X	X									
Lythrurus fumeus	ribbon shiner	X		X		X					X					X	X^		
Lythrurus lirus	mountain shiner				X			X	X	X									
Lythrurus roseipinnis	cherryfin shiner	X	X			X									X	X	X	X	X
Lythrurus umbratilis	redfin shiner	X	X			X					X	X		X^	X	X			X
Macrhybopsis aestivalis	speckled chub					X							X				X		
Micropterus dolomieu	smallmouth bass				X														
Micropterus punctulatus	spotted bass	X	X	X		X		X*			X	X	X*	X*	X	X	X		X
Micropterus salmoides	largemouth bass	X	X	X	X	X	X*	X	X	X*	X	X	X	X	X	X	X	X	X
Minytrema melanops	spotted sucker	X		X		X					X	X				X^			X
Morone chrysops	white bass					X													X
Moxostoma anisurum	silver redhorse				X				X										
Moxostoma carinatum	river redhorse					X					X								
Moxostoma duquesnei	black redhorse		X	X	X	X		X	X		X								

Appendix B. (continued)

		Researcher					HUC 8 Watershed												
Scientific Name	**Common Name**	**Ew '10**	**Jo '07**	**Phil '04**	**Pxt '01**	**Rs '94**	**Hrp**	**LDk**	**Buf**	**PwL**	**Br**	**UT**	**Twn**	**Tib**	**UB**	**LB**	**UP**	**MP**	**Col**
Moxostoma erythrurum	golden redhorse		X	X	X	X		X			X								
Moxostoma poecilurum	blacktail redhorse	X				X						X			X	X			X
Nocomis effusus	redtail chub				X		X	X											
Nocomis leptocephalus	bluehead chub		X			X					X	X			X	X	X*		X
Nocomis micropogon	river chub		X	X	X				X	X	X								
Notemigonus crysoleucas	golden shiner	X	X			X					X	X	X	X	X	X	X		
Notropis ammophilus	orangefin shiner	X	X			X						X	X	X					
Notropis ariommus	popeye shiner				X				X										
Notropis atherinoides	emerald shiner		X		X	X		X			X	X	X*	X	X	X	X	X	X
Notropis baileyi	rough shiner		X	X		X					X	X							
Notropis boops	bigeye shiner					X					X								
Notropis buccatus	**silverjaw minnow**					X													
Notropis leuciodus	Tennessee shiner		X		X			X	X	X									
Notropis longirostris	longnose shiner	X	X			X										X	X		X
Notropis photogenis	silver shiner				X				X										
Notropis rubellus	rosyface shiner				X	X			X		X								
Notropis stilbius	silverstripe shiner		X			X					X	X	X*						
Notropis telescopus	telescope shiner		X		X			X	X	X									
Notropis texanus	weed shiner	X	X			X					X	X			X	X	X		
Notropis volucellus	mimic shiner			X	X	X		X	X		X	X					X		X
Notropis wickliffi	channel shiner		X								X*								
Noturus elegans	elegant madtom				X			X	X										
Noturus eleutherus	mountain madtom				X			X											
Noturus exilis	slender madtom				X	X	X	X	X	X	X								
Noturus funebris	black madtom		X			X						X	X	X*					
Noturus gyrinus	tadpole madtom	X	X			X						X	X	X		X			
Noturus hildebrandi	**least madtom**					X													
Noturus leptacanthus	speckled madtom					X						X					X		
Noturus miurus	brindled madtom	X	X	X	X	X		X			X				X		X		X
Noturus nocturnus	freckled madtom	X				X					X						X^		
Noturus phaeus	brown madtom					X					X				X				X
Opsopoeodus emiliae	pugnose minnow		X			X					X	X			X	X	X		

Appendix B. (continued)

Scientific Name	Common Name	Researcher					HUC 8 Watershed												
		Ew '10	Jo '07	Phil '04	Pxt '01	Rs '94	Hrp	LDk	Buf	PwL	Br	UT	Twn	Tib	UB	LB	UP	MP	Col
Percina caprodes	logperch	X	X	X	X	X			X	X	X								
Percina evides	gilt darter				X	X		X			X								
Percina maculata	blackside darter		X			X						X		X	X			X*	
Percina nigrofasciata	blackbanded darter					X						X	X				X		
Percina phoxocephala	slenderhead darter				X	X		X			X								
Percina sciera	dusky darter	X	X	X	X	X			X		X	X		X	X		X	X*	X
Percina shumardi	river darter					X					X								
Percina vigil	saddleback darter	X	X			X						X					X		X
Phenacobius mirabilis	suckermouth minnow				X	X		X			X								
Phenacobius uranops	stargazing minnow				X				X										
Phoxinus erythrogaster	southern redbelly dace	X	X	X	X		X	X	X^	X	X								
Pimephales notatus	bluntnose minnow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X*	X
Pimephales vigilax	bullhead minnow	X	X	X		X	X^				X	X	X	X^	X	X	X		X
Pomoxis annularis	white crappie	X	X			X						X	X	X^	X	X	X		
Pomoxis nigromaculatus	black crappie					X					X	X	X			X	X		
Pylodictis olivaris	flathead catfish					X					X								
Rhinichthys atratulus	blacknose dace	X	X	X	X		X	X*	X^	X*	X								
Sander canadensis	sauger					X													X
Semotilus atromaculatus	creek chub	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
	TOTAL	**61**	**92**	**48**	**82**	**121**	**22**	**57**	**58**	**45**	**84**	**67**	**35**	**33**	**45**	**52**	**57**	**19**	**44**

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