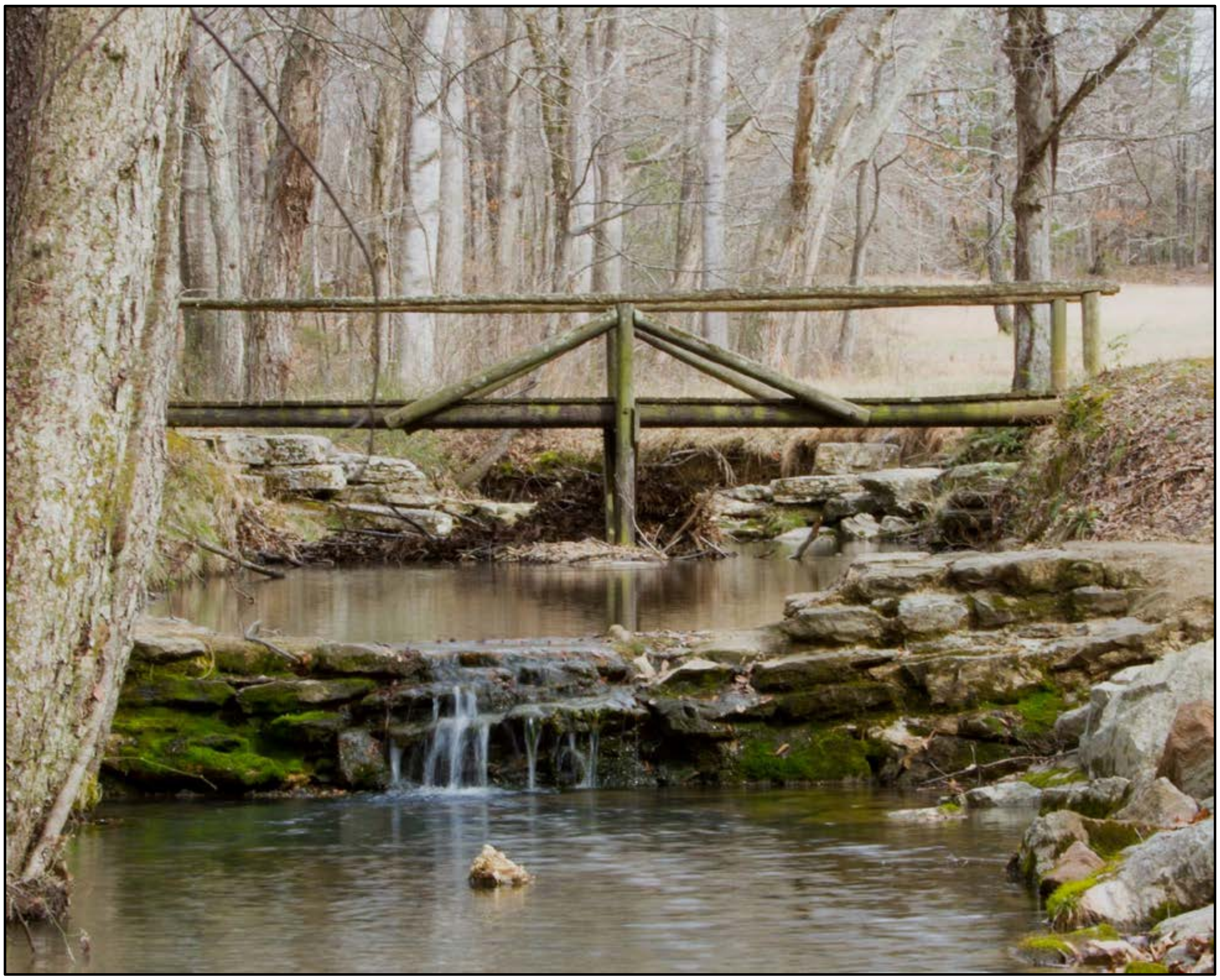
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Shiloh National Military Park

Natural Resource Condition Assessment

Natural Resource Report NPS/SHIL/NRR—2017/1387



ON THE COVER
Bridge over the Shiloh Branch in SHIL. Photo courtesy of Robert Bird.

Shiloh National Military Park

Natural Resource Condition Assessment

Natural Resource Report NPS/SHIL/NRR—2017/1387

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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Contents

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Figures

Page

Figures (continued)

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Photos

Appendices

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Shiloh National Military Park (SHIL) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at SHIL. The final project framework contains 11 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by SHIL resource managers, NPS Cumberland Piedmont Network staff, or outside experts.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for 3 of the 11 components (27%) due to these data gaps.

For featured components with available data and fewer information gaps, assigned conditions varied. Six of the components were considered to be in good condition (hardwood forest community, wetland and riparian communities, birds, herpetofauna, water quality, adjacent land cover and use); however, the wetland and riparian communities, birds, and adjacent land cover and use condition scores were at the edge of the good condition range (0.33) and any small decline in the communities could shift them into the moderate concern range. There were no components determined to be of moderate concern, but there were two components (air quality, dark night skies) that fell within the significant concern threshold. Confidence in current condition assessments varied, as instances where condition was assessed using professional judgement and anecdotal information were typically indicated with a low confidence border on the condition graphic (e.g., birds, herpetofauna; Table 48).

Several park-wide threats and stressors influence the condition of priority resources in SHIL. Those of primary concern include non-native species (both plant and animal), climate change, air and water pollution, and human manipulation of the landscape. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem, as well as its cultural landscape.

Acknowledgments

We acknowledge Shiloh National Military Park staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, Stacy Allen and Marcus Johnson. Cumberland Piedmont Inventory and Monitoring Network staff, including Teresa Leibfreid, Bill Moore, Steven Thomas, Johnathan Jernigan, and Joe Meiman, offered logistical insight and critical review of interim documents. Dale McPherson, Southeast Region NRCA and RSS Coordinator, and Jeff Albright, National Natural Resource Condition Assessment Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

ABC – Accipiter Biological Consultants

ALR – Anthropogenic Light Ratio

ANC – Acid Neutralizing Capacity

AQI – Air Quality Index

ARD – Air Resources Division

BA – Basal Area

BBS – Breeding Bird Survey

BPP – North American Bird Phenology Program

CAA – Clean Air Act

CBC – Christmas Bird Count

CCD – Charge-Coupled Device

CFU – Colony Forming Units

CUPN – Cumberland Piedmont Network

DBH – Diameter-at-Breast-Height

DDT – Dichlorodiphenyltrichloroethane

DO – Dissolved Oxygen

DOT – State Department of Transportation

EPA – U.S. Environmental Protection Agency

GAP – Gap Analysis Program

GIS – Geographic Information System

HGM – Hydrogeomorphic

HS – State Historical Society

I&M – Inventory and Monitoring

IBI – Index of Biotic Integrity

Acronyms and Abbreviations (continued)

IMPROVE – Interagency Monitoring of Protected Visual Environments Program

ITIS – Integrated Taxonomic Information System

IUCN – International Union for Conservation of Nature

LDDB – Lower Dill Branch

MACA – Mammoth Cave National Park

MDN – Mercury Deposition Network

MRLC – Multi-Resolution Land Characteristics Consortium

NAAQS – National Ambient Air Quality Standards

NADP – National Atmospheric Deposition Program

NADP-NTN – National Atmospheric Deposition Program–National Trends Network

NHP – State Natural Heritage Program

NIDIS – National Integrated Drought Information System

NLCD – National Landcover Dataset

NOAA – National Oceanic and Atmospheric Administration

NRCS – Natural Resource Conservation Service

NSNSD – Natural Sounds and Night Sky Division

NVC – National Vegetation Classification

NWI – National Wetlands Inventory

OMB – Office of Management and Budget

PAD-US – Protected Areas Database of the United States

PDSI – Palmer Drought Severity Index

PM – Particulate Matter

POMS – Portable Ozone Monitoring Station

POP – Persistent Organic Pollutants

Acronyms and Abbreviations (continued)

ppb – Parts per Billion

ppm-hrs – Parts per Million-Hours

SERGoM – Spatially Explicit Regional Growth Model

SHIL – Shiloh National Military Park

SOP – Standard Operating Procedure

SpC – Specific Conductance

SQM – Sky Quality Meter

TDEC – Tennessee Department of Environment and Conservation

TMDL – Total Maximum Daily Load

TN-EPPC – Tennessee Exotic Pest Plant Council

TVA – Tennessee Valley Authority

TWRA – Tennessee Wildlife Resources Agency

USACE – U.S. Army Corps of Engineers

USCB – United States Census Bureau

USFS – U.S. Forest Service

USFWS – U.S. Fish and Wildlife Service

USGS – United States Geological Survey

VOCs – Volatile Organic Compounds

WNS – White Nose Syndrome

ZLM – Zenith Limiting Magnitude

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 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*

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 Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- Follow national NRCA guidelines and standards for study design and reporting products.

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

[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-up 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.

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 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 decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-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 confidence for indicator-level condition findings*

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 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.

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)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[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.

[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

Often referred to as one of the most secluded and well-preserved battlefields in the United States, the Shiloh National Military Park (SHIL) was established on 27 December 1894, by President Grover Cleveland (NPS 2015). Its purpose is to:

> *Protect, interpret, and make accessible the sites, and associated historic and natural resources, related to the 1862 Battle of Shiloh, Tennessee (known also as the Battle of Pittsburg Landing); along with associated events and historic sites in and around Corinth, Mississippi, as they relate to the Civil War – the reason it occurred, particularly the impact the conflict and these specific battles had on the people and the land* (NPS 2009, p.19).

On 22 September 2000, President William J. Clinton approved S. 1117, which established and added the Corinth Battlefield Unit of SHIL (NPS 2003, p. 1):

> *The purpose of the unit, as outlined in Public Law 106-271, was to facilitate the protection and interpretation of resources associated with the Siege and Battle of Corinth and other Civil War actions in the area in and around the city of Corinth.*

Adding the Corinth Battlefield Unit increased the park's authorized size to over 2,833 ha (7,000 ac). The Corinth Unit does not share a boundary with the Shiloh Battlefield Unit; it can be found 37 km (23 mi) southwest of Pittsburg Landing, comprised of areas in and around Corinth, Mississippi (NPS 2015).

2.1.2. Geographic Setting

The enabling legislation of the park designated 2,428 ha (6,000 ac) of protected land. With the addition of the Corinth Battlefield Unit in 2000, the park grew to over 2,833 ha (7,000 ac) (Figure 1). As of 2015, 1,659 ha (4,100 ac) of the park were federally owned. The park continues to attempt to acquire more of the private land within the authorized park boundary. Since 1990, the NPS has acquired 142 ha (350 ac), and efforts continue with the Civil War Preservation Trust to obtain more than 405 ha (1,000 ac) of the remaining private land within the park's authorized boundary (NPS 2015). The continuing addition of lands within and around SHIL results in frequently changing "official" boundaries. The spatial boundary file used in the figures of this assessment is currently out of date, as additional acquisitions have been made to the park. While the updated boundary is not currently available, mentions in the text have been provided so that the reader is aware of potential discrepancies with the displayed boundary and the actual official boundary.

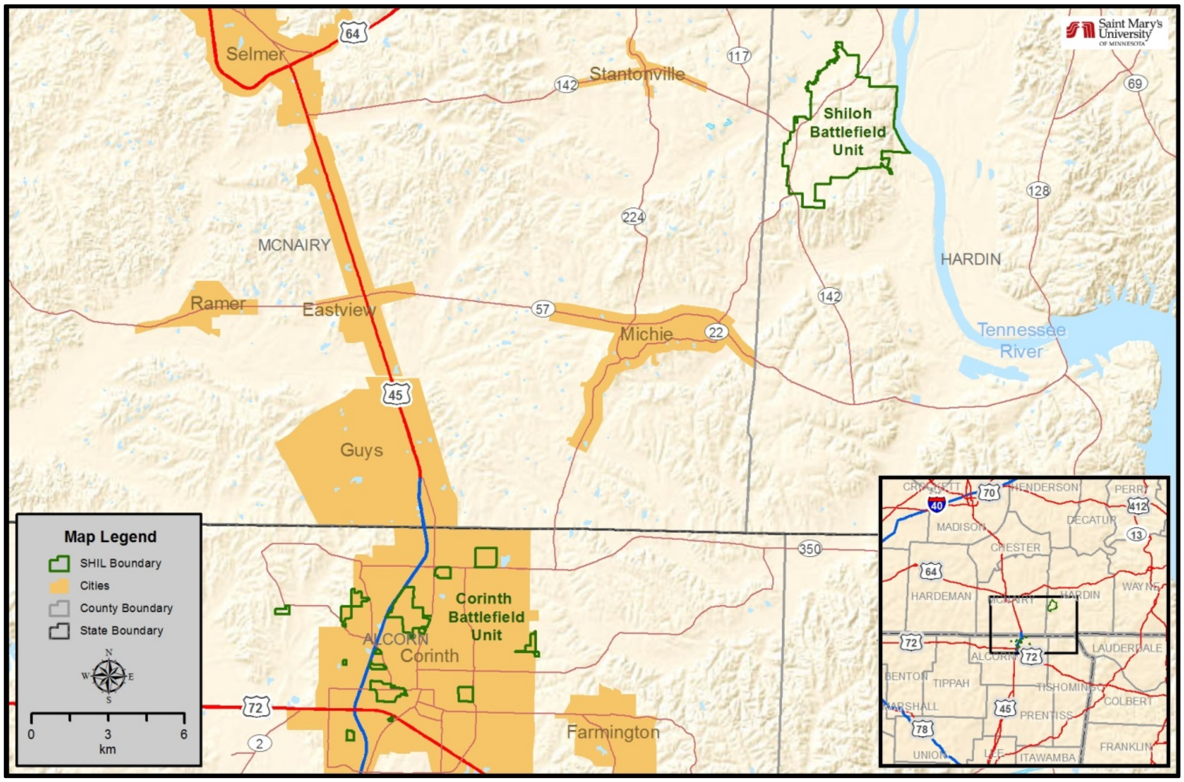

Figure 1. The geographic setting of both the Shiloh Battlefield Unit and the Corinth Battlefield Unit of SHIL.

SHIL falls within Hardin County, Tennessee, which had a population of 26,025 as of 2010 (USCB 2015b). It lies on the western bank of the Tennessee River, near the unincorporated community of Shiloh, Tennessee and is mainly surrounded by private development. The Corinth Unit of SHIL is comprised of areas in and around Corinth, Mississippi (NPS 2015), which had a population of 14,573 as of 2010 (USCB 2015a).

Mean annual temperature in the SHIL area is 15.9°C (60.7°F). The annual mean high temperature is 22.6°C (72.6°F), with an average of 57.2 days above 32.2°C (90°F) (Table 1). The average low temperature is 9.3°C (48.7°F), with freezing temperatures (0°C or 32°F or below) occurring an average 73.8 days per year (NCDC 2015b). Mean annual temperature in the area near the Corinth Unit is 15.3°C (59.6°F) (Table 2). The annual mean high temperature is 21.8°C (71.3°F), with an average of 50 days above 32.2°C (90°F). The average low temperature is 8.8°C (47.9°F), with freezing temperatures (0°C or 32°F or below) occurring an average 76.5 days per year (NCDC 2015a). Mean annual precipitation in the SHIL area is 147.7 cm (58.16 in) with July and August being peak seasons (NCDC 2015b). Mean annual precipitation near the Corinth Unit is similar to the SHIL area at 144 cm (56.69 in) (NCDC 2015a).

Table 1. 30-year climate normal (1981-2010) for the Savannah 6 SW, TN weather station near SHIL (NCDC 2015b).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	10.1	12.8	18.2	23.1	27	31.1	32.8	32.9	29.4	23.9	17.8	11.4	22.6
Min	-2.2	-0.6	3.9	8.9	14.1	18.4	20.6	19.9	15.6	9.1	4.2	-0.4	9.3
Average Precipitation (cm)													
Total	11.3	12.4	12.6	13.2	17	11.2	13	8.6	10.8	10	13.2	14.5	147.7

Table 2. 30-year climate normals (1981-2010) for the Corinth 7 SW, MS weather station near the Corinth Unit (NCDC 2015a).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	9.3	12.1	17.3	22.4	26.6	30.5	32.4	32.3	28.8	23.0	16.7	10.7	21.8
Min	-1.9	-0.1	3.7	8.0	13.6	17.9	20.1	19.3	14.9	8.2	3.1	-0.5	8.8
Average Precipitation (cm)													
Total	11.9	11.9	12.1	12.5	15.1	11.1	11.8	8.3	10.7	10.3	13.3	15.1	144.0

2.1.3. Visitation Statistics

From 2004 to 2014, SHIL had an average of 520,614 visitors per year (NPS 2014). There are more than 800 monuments and markers, 4,000 headstones, and 227 cannons throughout SHIL (Figure 2). Both units of the park have films, self-guided or audio tours, living history events, and museums/interpretive centers. For those interested in natural resources, SHIL has restored 243 ha (600 ac) of land to the native forest conditions and about 81 ha (200 ac) of virgin bottomland oak/hickory forest can be found in the park's Owl Creek watershed (NPS 2015).

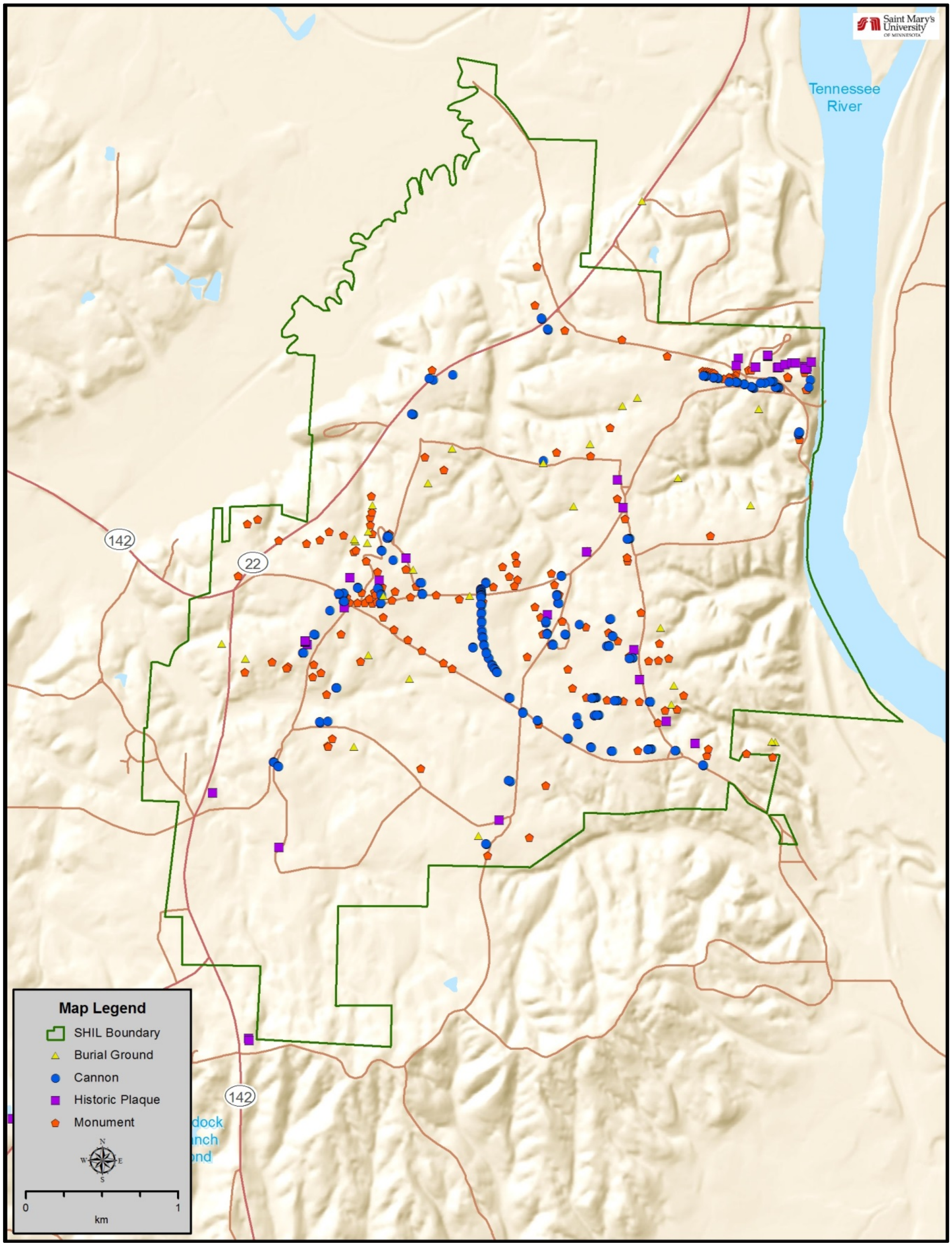

Figure 2. Significant cultural features of SHIL including burial grounds, cannon placements, historic plaques, and monuments.

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

The Shiloh Battlefield Unit lies within the Tennessee Western Valley (Beech River) Watershed, which is the upstream portion of the Tennessee Western Valley. The watershed's boundaries are within both Tennessee and Kentucky. The entire watershed drains 5,431 km^2 (2,097 mi^2), and of that 5,286 km^2 (2,041 mi^2) lies within the state of Tennessee. There are 23 dams located within the watershed (Tennessee Department of Environment & Conservation 2005). The Corinth Battlefield Unit lies within the Upper Hatchie River Watershed of the Mississippi River Basin. This watershed falls in both Tennessee and Mississippi, with a drainage area of approximately 72,439 ha (179,000 ac) (Figure 3) (Mississippi Department of Environmental Quality 2002).

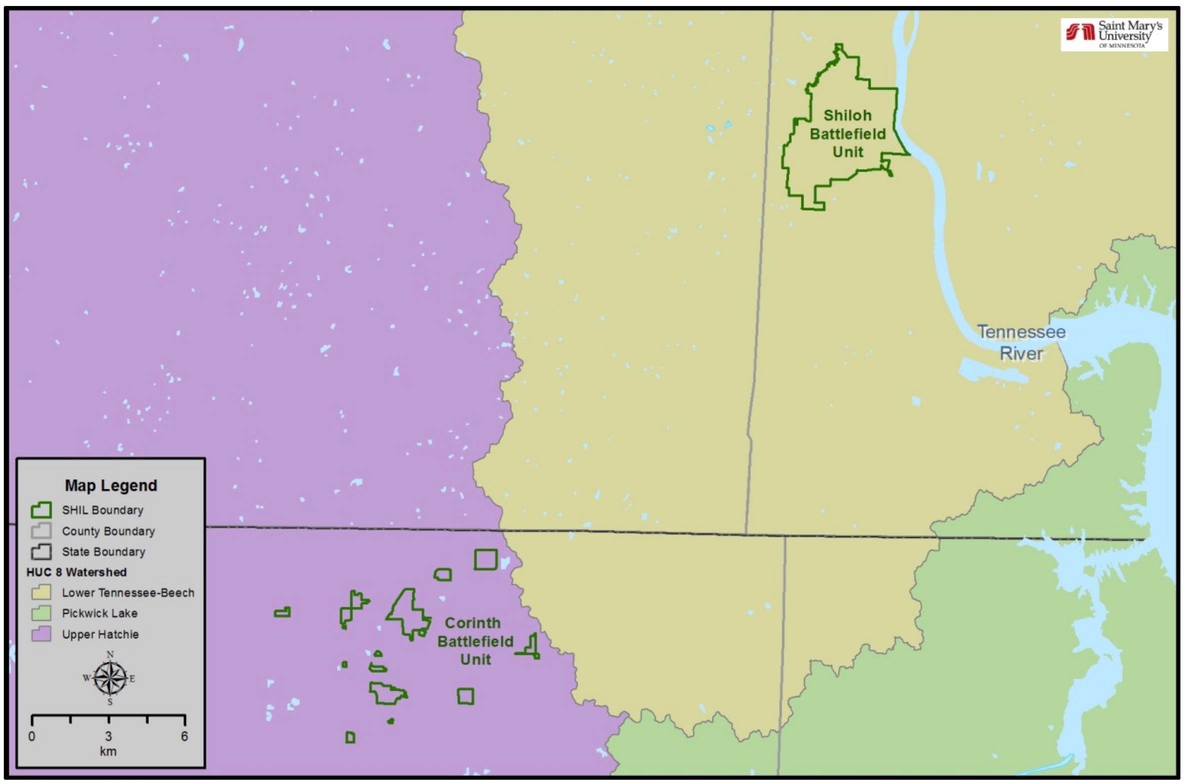

Figure 3. SHIL major HUC 8 watersheds (EPA 2011).

Both the Shiloh Battlefield and the Corinth Battlefield Unit can be found in the U.S. Environmental Protection Agency's (EPA) Southeastern Plains Level III Ecoregion (EPA 2003). This region is an interior coastal plain that stretches from Maryland to Mississippi and Louisiana. It has a mild, mid-latitude, humid subtropical climate which means hot, humid summers and mild winters. The perennial streams and rivers have a moderate to dense network, and there are few lakes and reservoirs (Griffith et al. 2011). According to the EPA (2013, p.13), the Southeastern Plains:

> *[H]ave a mosaic of cropland, pasture, woodland, and forest. Natural vegetation was predominantly longleaf pine, with smaller areas of oak-hickory-pine and Southern mixed forest. The Cretaceous or Tertiary-age sands, silts, and clays of the region contrast*

geologically with the older metamorphic and igneous rocks of the Piedmont (45), and with the Paleozoic limestone, chert, and shale found in the Interior Plateau[.]

In terms of the EPA's Level IV Ecoregions, SHIL contains the Blackland Prairie and the Northern Hill Gulf Coastal Plain (Figure 4).

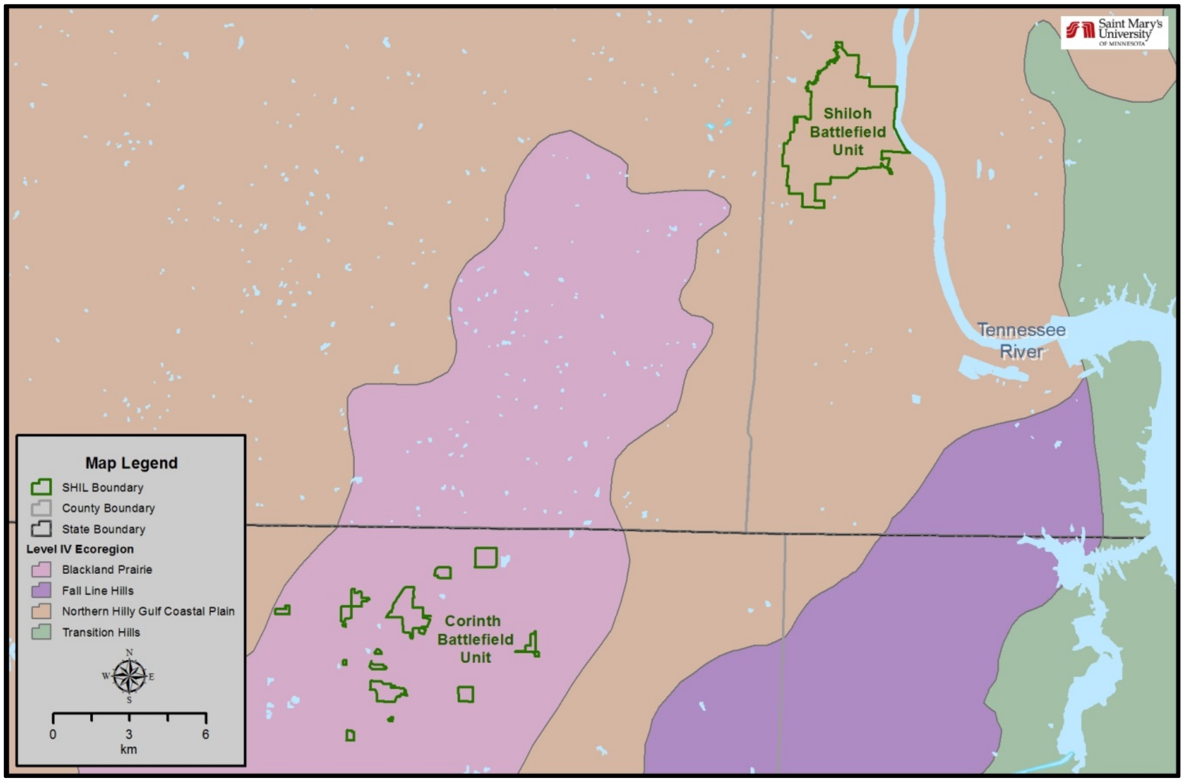

Figure 4. Level IV Ecoregions for SHIL (EPA 2011).

2.2.2. Resource Descriptions

Biological Resources

Even though SHIL is known for its cultural resources, it also contains mixed hardwood forests (Photo 1) and historic agricultural fields. According to the National Park Service Certified Species List, 1,064 vascular plant species have been identified within SHIL (NPS 2016). The park's upland areas are dominated by species such as white oak (*Quercus alba*), shagbark hickory (*Carya ovata*), eastern red cedar (*Juniperus virginiana*), shortleaf pine (*Pinus echinata*) and black walnut (*Juglans nigra*). Within the park's ravines common tree species include sweetgum (*Liquidambar styraciflua*), American sycamore (*Platanus occidentalis*), tulip poplar (*Liriodendron tulipifera*), and American basswood (*Tilia americana* var. *heterophylla*). In the park's bottomlands, cherrybark oak (*Quercus pagoda*), sweetgum, and river birch (*Betula nigra*) are dominant.

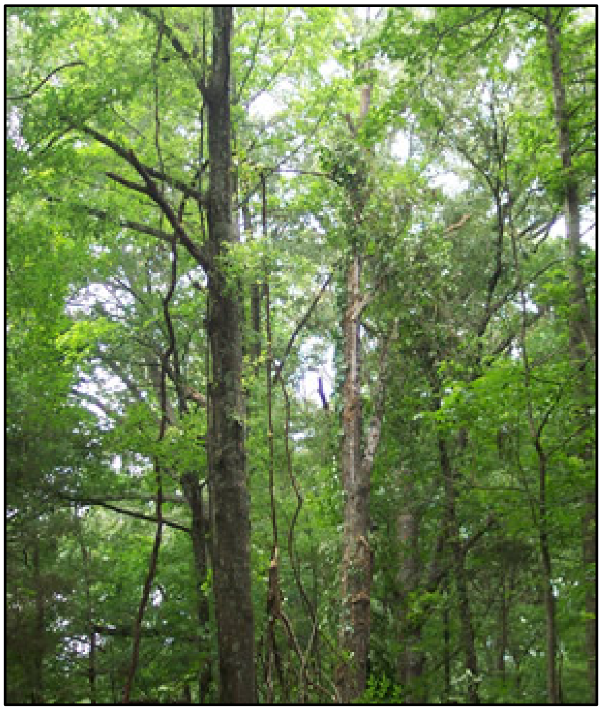

Photo 1. Hardwood forests are prevalent throughout SHIL (NPS).

Some fields are mowed and maintained by park staff to preserve the landscape as it appeared at the time of the 1862 battle. Other areas in SHIL have been planted with non-native tall fescue (*Schedonorus phoenix*) or fescue species (*Festuca* spp.) and Bermudagrass (*Cynodon dactylon*), while other areas have native species like broomsedge (*Andropogon virginicus*) (NPS 2015).

There are 59 mammal species found in SHIL (NPS 2016), with populations of beaver (*Castor canadensis*) and river otter (*Lontra canadensis*) recently increasing along riparian areas of the park. The most abundant mammal found in the park is the white-tailed deer (*Odocoileus virginianus*). SHIL provides suitable habitat for multiple species of bats including the gray bat (*Myotis grisescens*), as the Owl Creek wetlands and Bloody Pond provide bats with proper foraging areas within the park (NPS 2015).

Over 225 species of birds have been confirmed in SHIL (NPS 2016). Common breeding birds in the park include the prothonotary warbler (*Protonotaria citrea*) and yellow-breasted chat (*Icteria virens*). While there are numerous bird species in the park, there is some concern that the park's mowing of fields may be causing the diversity of land bird species to decline (Stedman and Stedman 2006). Raptor species are also common in SHIL, and can be observed foraging in both the forests and the agricultural fields. The bald eagle (*Haliaeetus leucocephalus*) utilizes both the riparian habitat along the Tennessee River and the agricultural fields within SHIL and has been found breeding on park land. The nest in the park is easily observed by park visitors, and the first successful nesting attempt was recorded in early 2008 (NPS 2015) (Photo 2).

Photo 2. A bald eagle perched on a tree within SHIL (©KENNETH WALKER).

Currently there are 26 amphibian species that are either confirmed as present or probably present, and 28 reptile species within the park (NPS 2016). While there are no species listed as endangered or threatened within the park boundaries, herpetofauna continue to be species of particular concern across much of the planet (Accipiter Biological Consultants 2006).

Approximately 51 species of fish have been documented in the SHIL area (NPS 2016). An inventory of the fish within SHIL was completed in 1998, which noted that there was a great deal of diversity of fish species within the streams originating within SHIL (Higgins 1998). Common and abundant fish species in the park's streams included the creek chub (*Semotilus atromaculatus*), southern redbelly dace (*Chrosomus erythrogaster*), and the striped shiner (*Luxilus chrysocephalus*) (Higgins 1998). The Tennessee River also supports a diverse population of fish, with game fish such as largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and sauger (*Sander canadensis*) occasionally observed in the SHIL reach of the river (Higgins 1998).

2.2.3. Resource Issues Overview

<u>Urban Development and Land Use</u>
Some of the land within the SHIL boundary is not owned by the park, such as the public right of way for Tennessee State Highway 22 and the private land owned by the Shiloh United Methodist Church.

In 2002, there were approximately 846 privately owned ha (2,090 ac) within the park including farmland, estates, communities, and public roads (NPS 2002). The park does not have secured gates after visitation hours, which allows people to enter the battlefield without park staff on hand. It is this land use and development that contributes to increased road traffic, auto accidents, wildlife-vehicle collisions, opportunistic wildlife poaching from park roads, vandalism, theft, overnight parking, noise, and pollution (NPS 2015).

<u>Ground Maintenance and Non-Native Species</u>

The park staff and farmers in the park boundary mow fields and perform lawn maintenance to maintain the landscape as it appeared at the time of the 1862 battle. These practices, such as mowing grass short with no buffer zone around wetlands and forested areas, affect bird, reptile, and amphibian habitats. Also, of the 88 non-native plant species found in the park, 16% are designated as posing a serious threat to the native and ecological communities because of their ability to outcompete and replace native species (NPS 2015). In 2006, plants such as wisteria (*Wisteria frutescens*), Chinese privet (*Ligustrum sinense*), mimosa (*Albizia julibrissin*), crepe myrtle (*Hagerstroemia indica*), and Japanese honeysuckle (*Lonicera japonica*) were identified as invasive. Invasive faunal species such as nine-banded armadillos (*Dasypus novemcinstus*), feral dogs (*Canis familaris*), and stinging fire ants (*Solenopsis wagneri*) are also a concern (NPS 2015).

<u>Air and Water Quality</u>

A pulp and paper mill is located near Counce, Tennessee, which is about 19 km (12 mi) south of SHIL. The emissions from the plant are considered low, but odor from the mill is still experienced in the park. Also, agricultural operations, motor vehicles, commercial shipping, and recreational boating contribute to the air pollution in the park (NPS 2015). A study was completed in four parks within the CUPN that looked at the foliar injury caused by ozone pollution. Foliar injury was confirmed in two plant species at SHIL (Jernigan et al. 2010). In 2013, water quality in the park was considered good except for low levels of dissolved oxygen (NPS 2013).

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In the 1980 draft of the SHIL general management plan and development concept plan, it states that,

> *The park offers visitors a visually pleasing setting with well-maintained forests and fields. The environmental features at Shiloh afford an opportunity to present to our increasingly urban population the important role natural features play in influencing the turn of historical events that occur in an area. A potential exists to better acquaint visitors with the natural world around them and how that world affects their lives (NPS 1980, p.4).*

Priorities were put in place to help with guiding the park's decision making in the proper direction (Figure 5) (NPS 1980, p.4).

OBJECTIVES

FIRST PRIORITY	Protection and Preservation of the physical resources through continued sounds management.	KEEP IT
SECOND PRIORITY	Expanded utilization of all park resources including historical, archaeological, and environmental. DEVELOPMENT PRIORITIES 1. Battle Story 2. Indian Mound Story 3. Environmental Story	USE IT
THIRD PRIORITY	Maximize the visitor experience through attention to the details in everyday decisions.	ENJOY IT

Figure 5. The three priority levels used to provide direction for decision making within SHIL (NPS 1980).

2.3.2. Status of Supporting Science

The CUPN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2005, the CUPN completed and released a Vital Signs Monitoring Plan (Leibfreid et al. 2005); Table 3 shows the CUPN Vital Signs selected for monitoring in SHIL.

Table 3. CUPN Vital Signs selected for monitoring in SHIL (Leibfreid et al. 2005).

Category	CUPN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]	No Monitoring Planned
Air and Climate	Ozone and Ozone Impact	X	-	-	-
Air and Climate	Visibility and Particulates	-	-	-	X
Air and Climate	Atmospheric Deposition	-	-	-	X
Air and Climate	Air Contaminants	-	-	-	X
Air and Climate	Weather	-	X	-	-
Geology and Soils	Stream/River Morphology	-	-	-	X
Geology and Soils	Cave Air Quality	-	-	-	X
Geology and Soils	Soil Chemistry and Structure	-	-	-	X
Geology and Soils	Soil Invertebrates and Associated Predators	-	-	-	X

a. Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

b. Category 2 represents Vital Signs that are monitored by SHIL, another NPS program, or by another federal or state agency using other funding.

c. Category 3 represents high-priority Vital Signs for which monitoring will likely be done in the future.

Table 3 (continued). CUPN Vital Signs selected for monitoring in SHIL (Leibfreid et al. 2005).

Category	CUPN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]	No Monitoring Planned
Water	Water Quality and Quantity	X	-	-	-
Water	Benthic Macro-invertebrates	-	-	-	X
Water	Microbes	-	-	-	X
Biological Integrity	Invasive Plants "early detection"	X	-	-	-
Biological Integrity	Forest Pests	X	-	-	-
Biological Integrity	Amphibians	-	-	-	X
Biological Integrity	Birds	-	-	X	-
Biological Integrity	Cave Aquatic Fauna	-	-	-	X
Biological Integrity	Cave Beetles	-	-	-	X
Biological Integrity	Cave Crickets	-	-	-	X
Biological Integrity	Cave Entrance Invertebrate Community	-	-	-	X
Biological Integrity	Guano-dependent Invertebrate Communities	-	-	-	X
Biological Integrity	Vegetation Communities	X	-	-	-
Biological Integrity	Mussel Diversity	-	-	-	X
Biological Integrity	Fish Diversity	-	-	X	-
Biological Integrity	Cave Bats	-	-	-	X
Biological Integrity	Deer	-	-	X	-
Biological Integrity	Allegheny Woodrats	-	-	-	X
Biological Integrity	Plant Species of Concern	-	-	-	X
Human Use	Poached Plants	-	-	-	X
Landscapes (Ecosystem Patterns and Processes)	Adjacent Land Use	X	-	-	-

a. Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

b. Category 2 represents Vital Signs that are monitored by SHIL, another NPS program, or by another federal or state agency using other funding.

c. Category 3 represents high-priority Vital Signs for which monitoring will likely be done in the future.

Table 3 (continued). CUPN Vital Signs selected for monitoring in SHIL (Leibfreid et al. 2005).

Category	CUPN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]	No Monitoring Planned
Landscapes (Ecosystem Patterns and Processes)	Fire	-	X	-	-
Landscapes (Ecosystem Patterns and Processes)	Guano Deposition in Caves	-	-	-	X

a. Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

b. Category 2 represents Vital Signs that are monitored by SHIL, another NPS program, or by another federal or state agency using other funding.

c. Category 3 represents high-priority Vital Signs for which monitoring will likely be done in the future.

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Chapter 3. Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the SHIL resource management team, CUPN Inventory and Monitoring Program staff, and Southeast Regional Office staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1. Preliminary Scoping

A preliminary scoping meeting was held from 12-13 March 2015. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the SHIL NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to SHIL managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by SHIL resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid SHIL resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding
- resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: SHIL resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.
- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify “management critical” data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.
- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Utilize “gray literature” and reports from third party research to the extent practicable.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a “framework” is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

“Components” in this process are defined as natural resources (e.g., birds, plant communities), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more “measures” that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain “stressors,” which are also considered during assessment. A “stressor” is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the SHIL NRCA scoping process, key resource components were identified by NPS staff and are represented as “components” in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to SHIL in some way, or are of greatest concern or highest management priority in SHIL. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A “reference condition” is a benchmark to which current values of a given component’s measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Many of the key resources for SHIL were adapted from the CUPN Vital Signs monitoring plan (Leibfreid et al. 2005). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in May 2015 following acceptance from NPS resource staff. It contains a total of 11 components (Figure 6) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

SHIL NRCA Draft Framework
Natural Resource Condition Assessment

	Component	Measures (Significance Level)	Stessors	Reference Condition
Biotic Composition				
Ecological Communities				
	Hardwood Forest Community	Species richness, species diversity, forest succession [defined as percent canopy cover by species & percent area by tree size], coarse woody debris cover	Deer browsing, forest pests, exotic sepcies, extreme weather events (ice/wind storms), climate change, air quality, prescribed burns, arson	Jones (1981)
	Wetland and Riparian Communities	Number and area of wetlands, number of vernal pools, vegetation species diversity, water quality, herpetofauna species richness	Climate change, drought, exotic species, adjacent land uses, atmospheric deposition, visitor use,	Roberts and Morgan (2008), Smart et al. (2010)
Mammals				
	Mammals	Species composition and diversity, bat species richness, white tail deer density, native rodent abundance	Drought, climate change, deforestation of surrounding area, feral dogs and cats (potential for feral hog), hunting pressure on surrounding properties, poaching (primarily deer), visitor use, grounds management (mowing/clearing)	Kennedy 1984, WTD 20-30 per sq mile
Birds				
	Birds	Passerine species richness, raptor species richness, species diversity, turkey density	Cultural use and management practices, pesticide/herbicide application, feral cats, land cover change, brood parasitism, climate change	Stedman & Stedman (2006)
Fish				
	Native Fish	Species composition (richness), species diversity, habitat/stream integrity, water quality	Grass carp, upstream agricultural practices, drought, pesticide use, alterations in watershed affecting water chemistry, atmospheric deposition, habitat alterations (beaver dams) in watershed	Higgins (1998)
Herpetofauna				
	Herpetofauna	Species composition (richness), species diversity, species abundance, species distribution	Climate change, potential loss of aquatic habitat, drought, park management practices (mowing), natural predation, feral hogs, Rana virus	Pritts (1999)

Figure 6. Shiloh National Military Park Natural Resource Condition Assessment framework.

SHIL NRCA Draft Framework
Natural Resource Condition Assessment

	Component	Measures (Significance Level)	Stessors	Reference Condition
Environmental Quality				
	Water Quality	Water temperature, pH, dissolved oxygen, specific conductance, acid neutralizing capacity, *E. coli*	Upstream agricultural practices, climate change, upstream human use (trash), atmospheric depostion, grounds maintenance	State standards except for ANC & specific conductance.
	Air Quality	Ozone, sulfur wet deposition, mercury deposition, deposition of nitrogen, visibility, particulate matter	Agricultural practices, industrial practices, vehicle emissions, air pollution from nearby major metropolitan areas	State and National Standards; NPS ARD benchmarks
	Dark Night Skies	NPS Night Sky Team Suite of Metrics	Urban light sources, lighting around VC and other park buildings, vehicle lights, haze (fire/smoke),	Absence of anthropogenic light
	Adjacent Land Cover and Use	Change in external land cover/land use (habitat types; scale outside park = viewshed/watershed level), total population (scale = census blocks at county level), population density (census blocks at county level), housing development (census blocks at county level), land ownership	Lack of zoning, (many of the threats are represented as measures, and the component is a threat/stressor in and of itself)	Time of park establishment (1894)
	Soundscape	Sound pressure levels, frequency, duration of sounds	Chainsaws and grounds maintenance noise, vehicles (transportation noises), visitor use/picnic area, battle interpretive noise (cannon/musket fire), urban noise sources in Corinth	Loudness: 55 dBA (level of speech interference for interpretive programs (EPA 1974)

Figure 6 (continued). Shiloh National Military Park Natural Resource Condition Assessment framework

3.2.2. General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time SHIL staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were also provided by NPS staff. Additional data and literature were acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from SHIL and the CUPN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 4. This categorization allows measures that are more important for determining condition of a component (higher Significance Level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 4. Scale for a measure's Significance Level in determining a component's overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 5). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 5. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

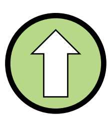
$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.0). Figure 7 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles that a resource is in good condition. White circles are used to represent situations in which SMUMN GSS analysts, park staff, and network staff felt there were currently insufficient data to make a statement about the condition of a component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a "snapshot-in-time" of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A horizontal arrow indicates an unchanging condition or trend, and an arrow pointing down indicates deterioration in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. In general, trends area assigned to components only when time series data, or data from recent times (<5 years), are available. More confident trend designations typically occur when trend data are available within the last 5 years that extend 5-10 years. In situations where the trend of the component's condition is currently unknown, no arrow is given.

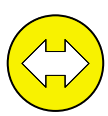
Condition Status		**Trend in Condition**		**Confidence in Assessment**	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Figure 7. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

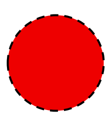
<u>Example indicator symbols and how they should be interpreted for tables in NRCA reports:</u>



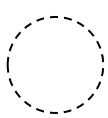
Resource is in good condition; its condition is improving; high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.



Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and SHIL and CUPN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data are or literature is limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by CUPN resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and outside resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend

This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component are presented and interpreted in this section.

Threats and Stressor Factors

This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps

This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that component's "Literature Cited" section.

3.3. Literature Cited

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. http://glei.nrri.umn.edu/default/glossary.htm (accessed 31 January 2013).

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The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Stoddard. J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Chapter 4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 11 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Figure 6):

4.1 Hardwood Forest Community

4.2 Wetland and Riparian Communities

4.3 Mammals

4.4 Birds

4.5 Native Fish

4.6 Herpetofauna

4.7 Water Quality

4.8 Air Quality

4.9 Dark Night Skies

4.10 Adjacent Land Cover and Use

4.11 Soundscape

4.1. Hardwood Forest Community

4.1.1. Description

While SHIL is primarily known for its historic and cultural significance, the park also supports significant natural resources, particularly its hardwood forests (Nordman 2004). Over two-thirds of SHIL consists of mixed hardwood forest, which can be divided into three broad categories: upland oak-hickory woodlands, mesic hardwood slope and ravine forests, and bottomland forests (Jones 1983, Mangi Environmental Group 2004). The importance of SHIL's forests has become more significant over time, as surrounding lands have been altered by pulpwood logging, farming, and other developments (Jones and White 1981). The hardwood slope forests are especially rare in the region around the park (Jones 1983). In the southeast, forests provide valuable wildlife habitat, protect soil and water resources, provide recreational opportunities, and also store carbon that could otherwise contribute to climate change (Moore 2013, NPS 2015).

SHIL lies in a physiographic transition area between the western Highland Rim and the Coastal Plain, meaning its forests contain a mixture of typically eastern and southern plant species (Jones and White 1981). For example, the composition of the mesic ravine forests is more similar to Appalachian vegetation communities, while the oak-hickory woodlands more closely resemble southern and western upland forests (Jones 1983). The park's mesic slope and ravine forests are dominated by American beech (*Fagus grandifolia*), white oak, sweetgum, and tulip poplar, many of which reach large sizes (>100 cm diameter [39.4 in]) (Jones and White 1981, Nordman 2004). The herbaceous understory is rich and includes several species of ferns and orchids (Jones and White 1981). The upland forests are dominated by oaks (white, southern red [*Quercus falcata*], northern red [*Q. rubra*], post [*Q. stellata*], black [*Q. velutina*]) and a mix of other hardwoods such as hickories (mockernut [*Carya tomentosa*], pignut [*C. glabra*]), black gum (*Nyssa sylvatica*), sweetgum, and black cherry (*Prunus serotina*) (Jones and White 1981). Some conifers also occur in these stands, such as shortleaf pine and eastern red cedar. The understory of these stands is typically shrubby, with flowering dogwood (*Cornus florida*), mountain azalea (*Rhododendron canescens*), and deerberry (*Vaccinium stamineum*) (Jones and White 1981). The bottomland forests of SHIL, although consisting primarily of hardwoods, will be discussed in Chapter 4.2 of this NRCA, as they occur primarily along rivers and in floodplains in SHIL.

Vegetation classification and mapping efforts at SHIL identified 10 unique hardwood forest community types (excluding bottomland/riparian forests) occurring within park boundaries (Nordman 2004). These types (or "associations") and the prominent tree species in SHIL stands are presented in Table 6. Together, these 10 community types cover approximately 975 ha (2,409 ac, 40% of the park), as shown in Figure 8 (Jordan and Madden 2010).

Table 6. Hardwood forest vegetation associations documented within SHIL (excluding bottomland/riparian forests) and the most prominent tree species in each (Nordman 2004). Classifications are based on National Vegetation Classification (NVC) standards.

Association	Prominent Tree Species
Southern Mesic Beech - Tuliptree Slopes	American beech, tulip poplar, white ash (*Fraxinus americana*)
Central Interior Beech – White Oak Forest	white oak, mockernut and pignut hickory, sand hickory (*Carya pallida*), shagbark hickory, southern red oak, post oak
Interior Mid- to Late- Successional Sweetgum – Oak Forest	sweetgum, red maple (*Acer rubrum*), mockernut and pignut hickory, white and southern red oak, black cherry, black gum
Interior Mid- to Late- Successional Tuliptree – Hardwood Upland Forest (Acid Type)	tulip poplar (successional stage to oak-hickory forests)
White Oak – Red Oak Dry- Mesic Acid Forest	white and northern red oak, pignut hickory, tulip poplar, black gum
Southern Red Oak – White Oak – Mixed Oak Forest	white and southern red oak, post oak, winged elm (*Ulmus alata*), mockernut hickory
Dry Acid Eastern Coastal Plain Oak- Hickory Forest	southern red and post oak, mockernut hickory, sweetgum,
Southern Red Oak Flatwoods Forest	southern red oak
Upper East Gulf Coastal Plain Chinquapin Oak – Mixed Oak – Hickory Forest	Chinquapin oak (*Quercus muehlenbergii*), white and black oak, white ash, black walnut, hickories
Central Interior Upland Cherrybark Oak Forest	cherrybark oak, black oak

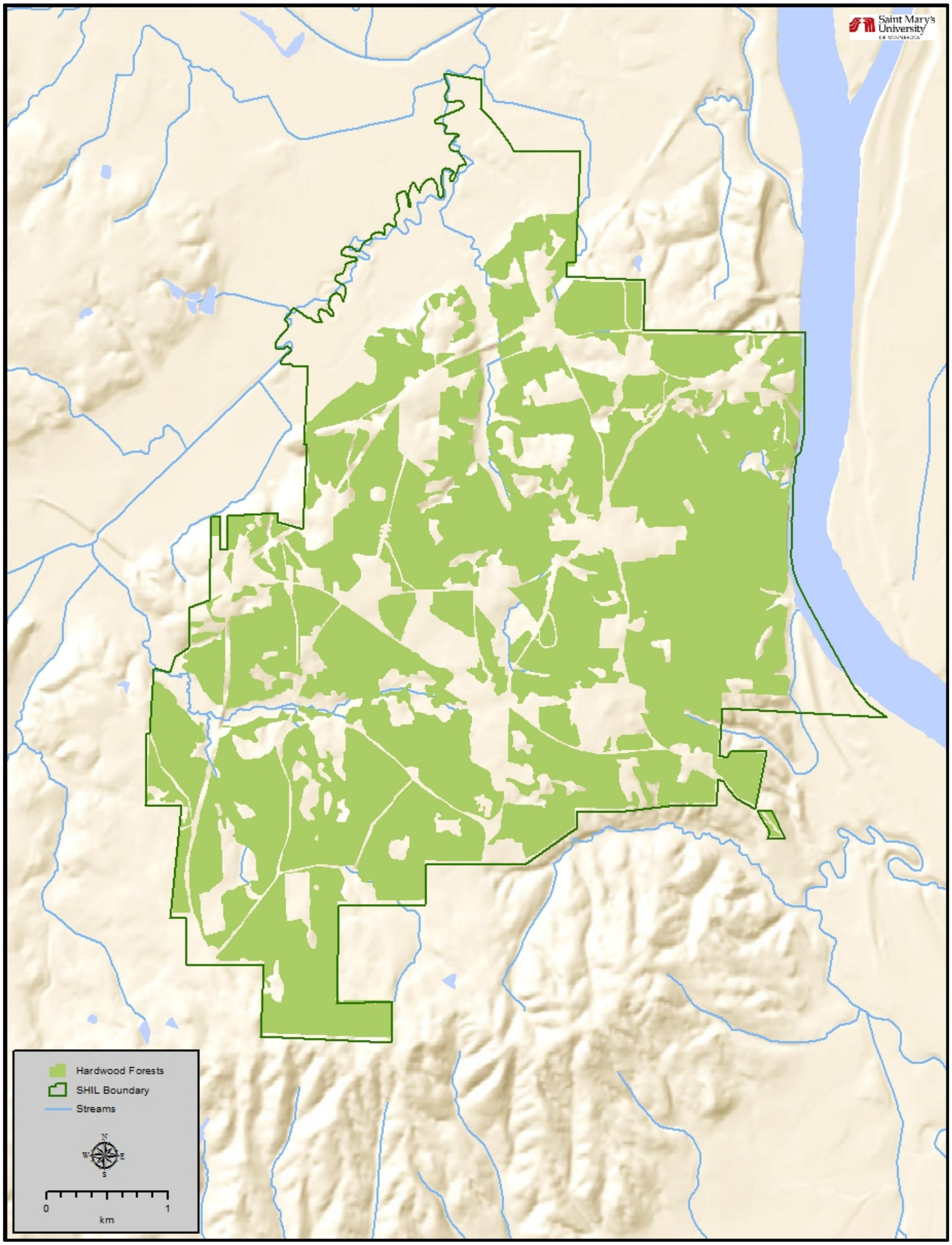

Figure 8. The extent of non-bottomland/riparian hardwood forests within SHIL, as mapped by Jordan and Madden (2010). Note that SHIL has recently acquired additional acreage that is not represented on this map, as an updated boundary file is not yet available.

4.1.2. Measures

- Species richness
- Species diversity
- Forest succession (percent basal area by tree size)
- Coarse woody debris cover

4.1.3. Reference Conditions/Values

The ideal reference condition for this component would be the appearance and condition of hardwood forests at the time of the battle. However, little scientific information regarding the forests is available from this time. The earliest botanical inventory of the park (Jones and White 1981) may provide some insight for the species richness measure, but due to methodological differences, this survey is not directly comparable to more recent vegetation sampling data/information for SHIL (Bill Moore, CUPN Ecologist/Data Manager, written communication, 6 July 2016). The information presented in this NRCA with regard to species richness, as well as other measures, may be used as a baseline in future assessments of SHIL's hardwood forests.

The CUPN vegetation monitoring protocol (White et al. 2011) has suggested a rating system for assessing one component of forest succession: stand structural class. For oak-hickory dominated forests, at least 25% late-successional stands indicate good condition (White et al. 2011). This will be used as a reference condition for the forest succession measure at this time, given the available data and project scope.

4.1.4. Data and Methods

Jones and White (1981) conducted a thorough floristic inventory of SHIL, covering the entire park during field visits between April 1980 and April 1981. Specific study goals included establishing a park species checklist and herbarium, assessing the presence of rare and endangered plants, and completing an inventory of exotic species (Jones and White 1981). Prior to this inventory, field investigations of vegetation in this region of Tennessee were lacking. Jones and White (1981) documented a total of 655 vascular plant species from 112 different families. The annotated species list identified the habitat type(s) where each plant species was found.

Butler and White (1981) published the results of exotic woody species surveys conducted at SHIL in August 1980. All roads and trails within the park were surveyed; off-trail study of several large Japanese honeysuckle populations also occurred (Figure 9) (Butler and White 1981). Parameters recorded at each sample site included area of exotic cover, density, stem counts (for trees), total forest canopy cover, successional stage, and exotic species impact (scale of 0-5). Cultivated areas within the park and isolated plants at old home sites were not included in sampling (Butler and White 1981).

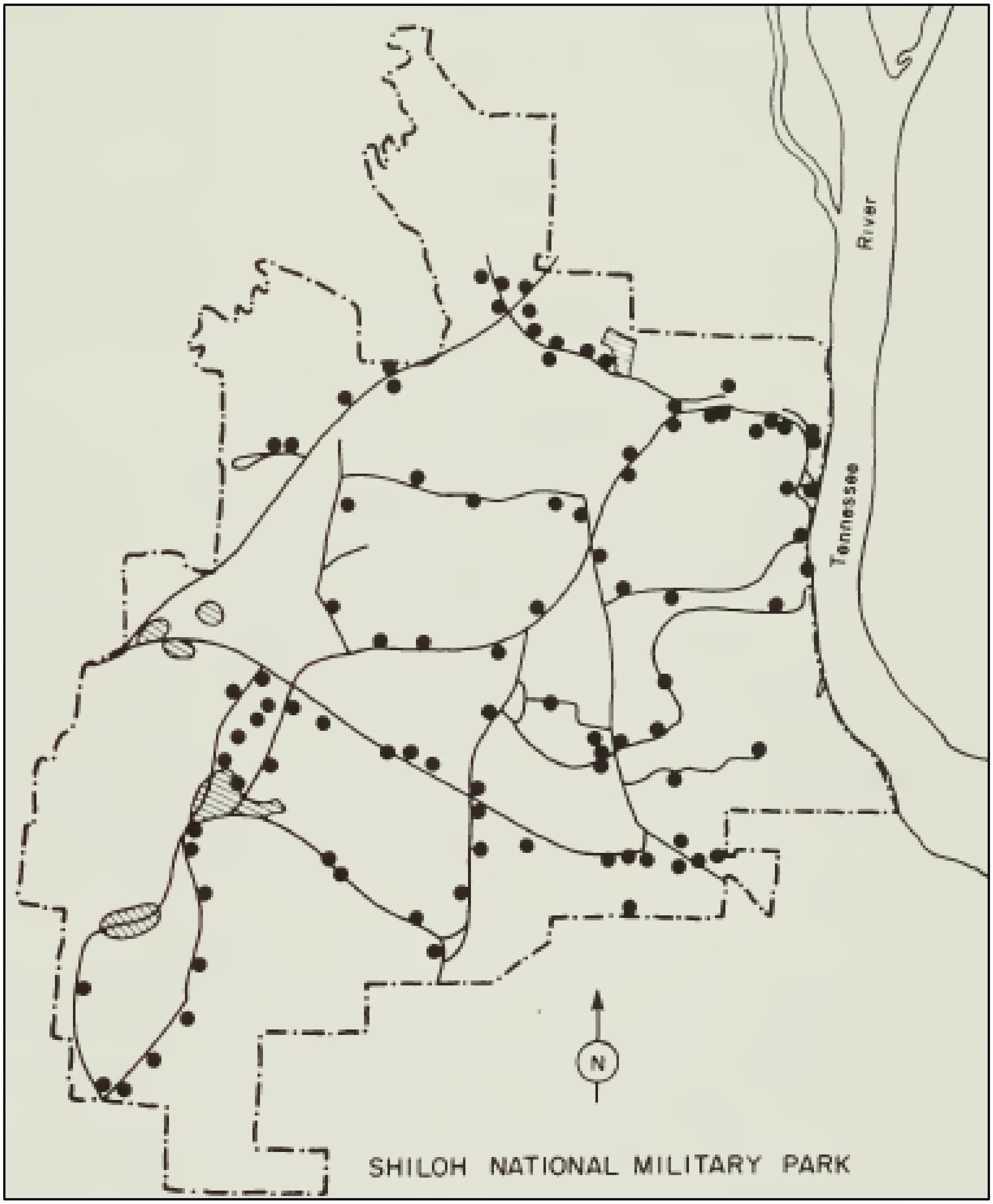

Figure 9. Exotic plant survey routes (solid lines), sampling sites (black circles), and large Japanese honeysuckle patches (cross-hatched areas) within SHIL (reproduced from Butler and White 1981).

In August 2002, NatureServe initiated a vascular plant inventory and vegetation classification project at SHIL (Nordman 2004). Ecologists sampled a total of 23 one-ha (2.5-ac) circular plots within the park. Thirteen of these plots fell within non-bottomland hardwood forest communities. At each plot, environmental characteristics were recorded and every vascular plant species present was recorded

(Nordman 2004). Each species was also assigned a cover value by strata (e.g., canopy, understory) and overall. This information was then used to classify plots into National Vegetation Classification (NVC) plant associations. Species data by sampling plot are available in NatureServe (2004).

The CUPN recently established a forest vegetation monitoring program to detect meaningful changes in species composition and vegetation structure within each park, and to determine whether any changes are related to trends in key stressors (Moore 2013). Survey and data analysis protocols are outlined in White et al. (2011). Twenty-four monitoring plots have been established at SHIL, each consisting of a 20 x 20 m square (66 x 66 ft) with several nested sampling frames ranging from 1 m^2 (10.8 ft^2) to 100 m^2 (1,076 ft^2) (Moore 2013). Twenty-two of these plots are within non-bottomland hardwood forest communities. Plots are scheduled to be surveyed every five years. Data collected includes species presence, frequency, and cover by strata (tree, sapling, seedling, and herb layers), canopy cover, tree growth and health, coarse woody debris, and evidence of forest pests (Moore 2013).

4.1.5. Current Condition and Trend

<u>Plant Species Richness</u>

Determining the total species richness (woody and herbaceous) of SHIL's hardwood forests is challenging, as not all floristic surveys have used similar habitat/vegetation classifications. Jones and White (1981) listed the general habitat type(s) where each plant species was found. While "hardwood forest" was not one of the specific habitat types listed, habitats such as mesic woods, mesic slopes, upland woods, oak-pine woods, open woods, dry woods, and wooded slopes were given and will be considered hardwood forest for the purpose of this assessment. Species listed by Jones and White (1981) as occurring on woodland borders/edges were also included. Jones and White (1981) documented a total of 329 plant species in habitats that were considered "hardwood forest" (Appendix A). The vast majority of these species (93.6%) were native species (Jones and White 1981).

Within the 10 associations identified as hardwood forest (non-bottomland) by Nordman (2004) (see Table 14 in Chapter 4.2.1), 348 plant species were identified, 92.5% of which were native (Appendix A). Many of the species documented by Nordman (2004) that had not been previously documented in hardwood forests by Jones and White (1981) had been documented in other park habitats (e.g., old fields, roadsides, swamps) (Appendix A).

Through 2013, the CUPN forest vegetation monitoring program had documented 206 plant species in hardwood forest monitoring plots, 96.1% of which were native (CUPN 2015) (Appendix A). While this total was lower than previous surveys (Jones and White 1981, Nordman 2004), it is worth noting that 33 of the species documented in prior surveys that were *not* observed by CUPN (2015a) were non-native (and therefore undesirable) species. It should also be noted that these surveys covered different-sized areas and therefore the total numbers of plant species documented are not directly comparable. Jones and White (1981) intensively surveyed the entire park, Nordman (2004) sampled plots totaling 13 ha (32 ac), and the 24 CUPN monitoring plots covered just under one ha (2.5 ac) (Moore 2013).

Between all three surveys, a total of 496 plant species have been documented in SHIL's hardwood forests, representing approximately 46% of the park's total plant richness (Jones and White 1981, Nordman 2004, CUPN 2015). This includes 41 non-native species, accounting for 8% of the total plant species (Appendix A).

Plant Species Diversity

Species diversity typically incorporates both species richness (number of species) and some measure of species evenness (i.e., are all species equally abundant or are a few species more abundant than all others). For the purposes of this assessment, species diversity was assessed more simply by exploring only the number of species per hardwood forest plot across the park (alternative recommended by Rickie White, NatureServe Ecologist, email communication, 21 January 2016). Given that forest sampling plots are distributed across different hardwood community types, some variation in diversity is to be expected due to environmental variation (e.g., soil type, disturbance regime, water availability). For example, forests with acidic soils often show lower levels of plant diversity than forests with neutral or basic soils (White, written communication, 6 July 2016).

Across NatureServe's (2004) 13 hardwood forest plots at SHIL, the number of plant species per one-hectare plot ranged widely from 18 to 123 (Table 7) (NatureServe 2004). These results suggests that, while overall species richness is high in SHIL's hardwood forests, the richness is not evenly distributed between forest community types and stands. The number of non-native species per plot ranged from zero to 16; all plots except one had six or fewer non-native species (NatureServe 2004). Generally, few non-natives occurred in plots with low total species richness. The most diverse plot (SHIL.20) was classified as an Upper East Gulf Coastal Plain Chinquapin Oak-Mixed Oak -Hickory Forest, while the least diverse plot (SHIL.23) was classified as a Southern Red Oak-Mixed Oak/Deerberry Forest (NatureServe 2004).

Table 7. Number of plant species and number of non-native plant species per one-hectare SHIL hardwood forest plot, as documented by NatureServe (2004).

Plot	Number of Species	Number of Non-Natives	Plot	Number of Species	Number of Non-Natives
SHIL.3	111	16	SHIL.17	59	0
SHIL.4	70	2	SHIL.18	90	3
SHIL.6	108	0	SHIL.20	123	6
SHIL.11	82	3	SHIL.21	69	5
SHIL.12	41	0	SHIL.22	77	2
SHIL.13	82	3	SHIL.23	18	0
SHIL.14	111	0	-	-	-

The number of plant species in the CUPN's 22 forest vegetation monitoring plots ranged from 29 to 74 (Table 8) (CUPN 2015). As is typical in forested communities, much of the difference in diversity was determined by the herbaceous layer vegetation, as species richness in the tree/sapling/seedling layers only varied from 10 to 21 species (Table 8). The number of non-native species per plot ranged from zero to four, meaning the vast majority of diversity was from native species (CUPN 2015). With the exception of two plots where Chinese privet was present in the seedling/sapling layer, all non-native species were found only in the herbaceous layer. While there was less overall variation in species richness among CUPN plots than between NatureServe (2004) plots, it still suggests that species diversity was not evenly distributed between forest community types and stands. The most diverse plot (Plot 023) was classified as a mix of White Oak-Red Oak Dry-Mesic Acid Forest and a White Oak-Hickory Forest while the least diverse plots (Plots 010 and 011) were in Southern Red Oak-White Oak-Mixed Oak Forest and Dry Acid Eastern Coastal Plain Oak- Hickory Forest (CUPN 2015).

Table 8. Number of plant species documented per 400 m^2 CUPN monitoring plot, in the tree/sapling/seedling layer and overall (CUPN 2015).

Plot Number	Tree/Sapling/ Seedling layer	Total Species	Number Non-Natives	Plot Number	Tree/Sapling/ Seedling layer	Total Species	Number Non-Natives
003	15	42	0	020	16	46	2
004	17	44	1	023	18	74	3
006	10	58	1	024	11	66	3
008	11	34	0	026	11	35	0
010	11	29	0	028	14	59	3
011	11	29	2	029	20	70	0
012	17	54	2	031	12	41	1
013	12	37	0	032	17	36	0
014	21	62	4	035	15	45	0
015	13	52	2	036	16	56	1
016	11	38	0	037	13	50	3

Forest Succession

One aspect of forest successional status is stand structural stage, which is assessed using tree size and canopy position measurements (White et al. 2011). Structural stage can serve as an indicator of altered disturbance regimes (e.g., fires, wind storms) and of habitat availability for species that prefer particular successional stages (White et al. 2011). The CUPN has adopted a method for calculating stand structural class by plot for their forest vegetation monitoring program from Lorimer and White (2003). The first step is to calculate basal area (BA) for each live tree in the dominant, sub-dominant, and intermediate tree crown classes. Each tree is then assigned to a stage class based on diameter-at-breast-height (dbh): pole (10-25.9 cm), mature (26-45.9) and large (≥ 46 cm) (White et al. 2011). The

BA of trees within each class is added and then divided by the total BA of all three classes to find the percent of BA in each of the three classes. Based on these percentages, forest stands are assigned to one of three classes as described in Table 9. The CUPN uses a guideline that, for oak-hickory dominated forests, at least 25% late-successional stands indicates good condition while less than 25% late-successional stands indicates a cause for caution (White et al. 2011).

Table 9. Successional stage classes and criteria utilized by the CUPN forest vegetation monitoring program (White et al. 2011).

Stage	Criteria
Pole	≥67% BA in pole plus mature sizes, with more BA in pole than mature size
Mature	≥67% BA in pole plus mature sizes, with more BA in mature than pole size OR ≥67% BA in mature plus large sizes, with more BA in mature than large size
Late-successional	≥67% BA in mature plus large sizes, with more BA in large than mature size

According to CUPN data from 2011-2013, all of the vegetation monitoring plots in SHIL's hardwood forests fall in the mature or late-successional stage class (CUPN 2015). Thirteen of 22 plots (59%) were in the mature stage and nine (41%) fell in the late-successional class (Table 10). The percentage of plots/stands in the late-successional class meets the guideline suggested by the CUPN for good condition (White et al. 2011).

Table 10. Stand structural class percentages and stage for CUPN forest vegetation monitoring plots in SHIL's hardwood forests (CUPN 2015).

Plot Number	% Pole size	% Mature size	% Large size	Stage
003	22	48	30	Mature
004	33	67	0	Mature
006	0	20	80	Late-Successional
008	24	36	40	Late-Successional
010	4	36	60	Late-Successional
011	3	9	88	Late-Successional
012	24	76	0	Mature
013	3	48	49	Late-Successional
014	10	68	22	Mature
015	28	38	34	Mature
016	36	64	0	Mature
020	27	49	24	Mature

Table 10 (continued). Stand structural class percentages and stage for CUPN forest vegetation monitoring plots in SHIL's hardwood forests (CUPN 2015).

Plot Number	% Pole size	% Mature size	% Large size	Stage
023	3	28	69	Late-Successional
024	11	68	21	Mature
026	4	80	16	Mature
028	9	49	42	Mature
029	9	34	57	Late-Successional
031	11	12	77	Late-Successional
032	20	7	73	Late-Successional
035	19	47	34	Mature
036	45	55	0	Mature
037	8	72	20	Mature

Coarse Woody Debris Cover

Coarse woody debris consists of downed trees and large branches on the forest floor, which tend to accumulate in older forests that are not logged (White et al. 2011). This debris provides habitat for fungi, non-vascular plants, and a variety of animals, particularly arthropods, herptiles, and small mammals (Petranka et al. 1994, White et al. 2011). Therefore, coarse woody debris cover can serve as an indicator of habitat availability and ecological health or integrity (White et al. 2011). The CUPN uses Huber's formula (see Appendix C of White et al. 2011) to estimate coarse woody debris volume (m^3/ha) from line transect intersect data. Two 40-m (131-ft) transects are run through each plot, and the diameter of each piece of woody debris that intersects the transects is recorded (White et al. 2011). A value for each transect is created using Huber's formula, and these values are then averaged to find the mean coarse woody debris volume for each plot. Values are often slope-corrected for percent-slope of the transect. Slope values were not available for SHIL transects, so coarse woody debris volumes presented in this NRCA have *not* been slope-corrected. However, it is unlikely that slope corrections would make an appreciable difference in the results for SHIL (Moore, written communication, 6 July 2016).

Coarse woody debris data are available for 19 of the 22 monitoring plots in SHIL's hardwood forests. In the remaining three plots, no coarse woody debris intersected the established transects (Moore, email communication, 29 January 2016). In plots where woody debris was documented, volumes ranged from 0.12 m^3/ha to 3.16 m^3/ha (1.7-45.2 ft^3/ac) with an overall average of 0.96 m^3/ha (13.7 ft^3/ac) (CUPN 2015). Of the 44 total transects surveyed (two per plot), twelve did not intersect with any woody debris (Table 11).

Table 11. Coarse woody debris volume (m^3/ha) by plot (CUPN 2015). N/A = no debris intersected transect.

Plot Number	Transect X	Transect Y	Mean
003	1.36	1.08	1.22
004	0.74	0.74	0.74
006	0.74	1.17	0.96
008	N/A	0.77	0.39
010	1.17	1.36	1.26
011	1.76	0.83	1.30
012	1.26	N/A	0.63
013	0	1.76	0.88
014	1.14	1.63	1.39
015	0.8	0.93	0.86
016*	-	-	0.12
020	0.62	0.52	0.57
023	N/A	N/A	N/A
024	N/A	0.28	0.14
026	N/A	N/A	N/A
028	1.45	0.31	0.88
029	0	1.45	0.72
031	0.49	0.25	0.37
032	1.11	5.21	3.16
035	1.20	1.08	1.14
036	0.83	0.89	0.86
037	N/A	N/A	N/A

* One entry was recorded for Plot 016 but the transect on which it occurred was not identified.

Threats and Stressor Factors

Threats to SHIL's hardwood forests include deer browsing, forest pests (e.g., insects and diseases), exotic species, climate change and extreme weather events, air pollution, and fires outside the natural disturbance regime. White-tailed deer are known to be abundant within SHIL (Kennedy and Jennings 2007). Based on qualitative assessments of the level of deer browsing observed on monitoring plots, this activity appears to be impacting forest vegetation in some areas (Moore 2013). For example, deer browsing may be contributing to poor tree regeneration, particularly among oaks (Moore 2013). Deer have become abundant throughout the eastern United States due to clearing of forest lands for agricultural and timber harvest, which creates increased forage availability for white-tailed deer (Horsley et al. 2003, Cote et al. 2004). Higher deer densities can contribute to reduced plant diversity, altered species composition (by favoring species not palatable to deer), and reduced plant height in hardwood forests (Horsley et al. 2003, Cote et al. 2004). In addition, overbrowsing can alter nutrient cycling and impact habitat for other wildlife species, including birds, insects, and other mammals (Cote et al. 2004).

Non-native invasive plants are among the greatest threats to forests worldwide, including at SHIL. The roads, trails, and waterways that crisscross SHIL, as well as nearby developments, serve as potential vectors for the spread of invasive plants and pests (Mack 2003, Keefer et al. 2014). To date, a total of 41 non-native plant species have been confirmed in SHIL's hardwood forests (Appendix A). Twenty-eight of these are considered invasive by the Tennessee Exotic Pest Plant Council (TN-EPPC), and 10 species are considered a severe threat to native communities (Table 12) (Nordman 2004, TN-EPPC 2009). These aggressive species are able to invade and persist in native communities in the absence of disturbance, competing with native plants (Jones and White 1981, Nordman 2004). One of the species of greatest concern, Japanese honeysuckle, has been present in large patches at SHIL since at least 1980 (Butler and White 1981, Jones and White 1981).

Table 12. Non-native invasive plant species confirmed in SHIL's hardwood forests and considered a "severe threat" in Tennessee (TN-EPPC 2009).

Scientific Name	Common Name	Growth Form
Albizia julibrissin	silktree, mimosa	tree
Dioscorea oppositifolia	Chinese yam	vine
Kummerowia stipulacea	Korean clover	forb
Lespedeza cuneata	Chinese lespedeza	forb
Ligustrum sinense	Chinese privet	shrub
Lonicera japonica	Japanese honeysuckle	vine
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	grass
Paulownia tomentosa	Princess tree	tree
Rosa multiflora	multiflora rose	shrub
Sorghum halepense	Johnson grass	grass

Butler and White (1981) found that non-native woody plant infestations were most frequent in abandoned old fields which were being invaded by young trees. During the 1980 sampling, 99 individual woody non-native infestations were identified throughout the park, ranging from 1 m^2 to 4,970 m^2 (10.8 ft^2 to 53,497 ft^2) in size (Butler and White 1981). Japanese honeysuckle was found at 83% of these locations and covered a total of 49,395 m^2 (12.2 ac). In recent surveys by the CUPN, Japanese honeysuckle remained the most prevalent invasive species, detected in half of sampling plots (eight of 16) during 2011-2012 (Moore 2013). Chinese privet was second-most prevalent, found at six of 16 plots. An average of 1.4 non-native plant species were detected per 400 m^2 (4,305 ft^2) plot, although no non-native species were found in six of the 16 plots (Moore 2013). This suggests that although non-native species are widespread and potentially impacting native vegetation in SHIL's forests, their prevalence is relatively low, particularly compared to other CUPN parks (Moore 2013).

Native and exotic insect, fungal, and bacterial pests pose serious threats to forests across the southeastern U.S., including the hardwood communities at SHIL (Leibfreid et al. 2005). These pests are capable of altering plant community structure and composition, as well as reducing overall species diversity (Keefer et al. 2014). Potential insect threats to SHIL's hardwood forests include Asian long-horned beetle (*Anoplophora glabripennis*), gypsy moth (*Lymantria dispar*), and emerald ash borer (*Agrilus planipennis*, Photo 3) (Keefer 2012, Keefer et al. 2014). To date, none of these species have been found in the park (NPS 2015, Marcus Johnson, SHIL Natural Resource Management Specialist, written communication, 14 July 2016). Emerald ash borer infests and kills only ash tree species (*Fraxinus* spp.) and was detected in eastern Tennessee from 2010-2013 (CERIS 2016). Gypsy moth infestation does not cause direct mortality but increases a tree's vulnerability to other stressors (e.g., disease, other pests) (Keefer 2012). Oaks are the primary host for this moth, but it will also feed on maple, beech, cherry, and other hardwoods (Keefer 2012). Gypsy moths were detected in central Tennessee in 2015 (CERIS 2016). The Asian long-horned beetle has not been detected in any southeastern state in recent years (CERIS 2016), but "it has the potential to cause more destruction than Dutch elm disease, chestnut blight and the gypsy moth combined" (Keefer 2012, p. 8). This beetle targets hardwood species including maple, poplar, elm, ash, and hackberry (Keefer 2012).

Photo 3. Emerald ash borers (NPS/J. S. KEEFER).

The atmospheric pollutant ozone can cause foliar injury to sensitive plants at high levels (>80 parts per billion [ppb]) (Kohut 2007). Several ozone-sensitive plant species occur in SHIL's hardwood forests, including eastern redbud (*Cercis canadensis*), white ash, sweetgum, tulip poplar, black cherry, and Virginia creeper (*Parthenocissus quinquefolia*, Photo 4) (Kohut 2007). During 2009 sampling in and around SHIL, foliar injury from ozone was confirmed on several blackberry (*Rubus* sp.) and sweetgum plants at three park locations (Faulkner Property, Russian Tenant Field, and Spain Field) (Jernigan et al. 2010). However, the observed damage was considered limited and moderate (Jernigan et al. 2010).

Photo 4. Virginia creeper as it climbs a hardwood tree in SHIL (NPS).

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the CUPN (Davey et al. 2007). Climate also affects the spread of invasive plant species and atmospheric pollutant levels, which also threaten SHIL's hardwood forests (Davey et al. 2007). The region around SHIL occasionally experiences tornadoes or other storms with high winds and ice that could damage park forests (Jones and White 1981). As a result of global climate change, temperatures are projected to increase across the southeast over the next century (Carter et al. 2014). Warming temperatures will likely allow invasive plants and forest pests to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014). In an effort to estimate the magnitude of potential change that forests on eastern national park lands may experience, Fisichelli et al. (2014) assessed the percentage of tree species expected to show large decreases or large increases in habitat suitability under climate change scenarios. Across 121 national park properties in the eastern U.S., estimated potential forest change ranged from 22-77%. The estimate forest change for SHIL (i.e., percent of tree species expected to experience large increases or decreases in habitat suitability) was 54% (Fisichelli et al. 2014). Habitat suitability projections for several of SHIL's key hardwood species are shown in Table 13.

Table 13. Potential change in habitat suitability by 2100 for select SHIL hardwood species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, and the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from NPS (2015), based on assessments by Fisichelli et al. (2014).

Scientific Name	Common Name	Least Change Scenario	Major Change Scenario
Acer rubrum	red maple	small decrease	no change
Carya glabra	pignut hickory	large decrease	small decrease
Liquidambar styraciflua	sweetgum	no change	no change
Liriodendron tulipifera	yellow-poplar	large decrease	small decrease
Nyssa sylvatica	blackgum	small increase	small increase
Quercus alba	white oak	small decrease	small decrease
Quercus falcata	southern red oak	no change	no change
Quercus stellata	post oak	large increase	large increase
Ulmus alata	winged elm	no change	small increase

Data Needs/Gaps

At least some data are available for all of the measures selected for the hardwood forest component. Comparing the available data from SHIL forests to regional datasets or reference stands of similar communities may provide further insight into the condition of the park's forests. A more detailed study of forest succession could explore tree regeneration, particularly among oaks and hickories. Poor regeneration has been noted throughout eastern forests and may be associated with dense canopy shading, fire suppression, and deer browsing (Moore 2013). Initial CUPN monitoring data suggests that oak-hickory regeneration at SHIL may be better than at other network parks, but further study is needed to better understand tree regeneration and its implication for forest successional dynamics in the park (Moore 2013).

Monitoring of the park's white-tail deer population could be helpful in understanding the impacts of deer browsing on SHIL's hardwood forests (Kennedy and Jennings 2007). Continued monitoring within the park for forest pests, exotic plants, and foliar ozone damage will be critical in detecting any changes in these threats to forest communities.

Overall Condition

Plant Species Richness

The project team assigned this measure a *Significance Level* of 3. Nearly 500 plant species have been documented in SHIL's hardwood forest communities, 8% of which are non-natives (Appendix A). The most recent CUPN monitoring efforts (CUPN 2015) have identified fewer species than previous studies (Jones and White 1981, Nordman 2004), but this is likely due to the smaller area sampled. When plant species lists from early studies (Jones and White 1981) are compared to recent monitoring (CUPN 2015), the species composition seems fairly similar (Appendix A). As a result, species richness is currently of low concern (*Condition Level* = 1).

Plant Species Diversity

The species diversity measure was also assigned a *Significance Level* of 3. As mentioned previously, species diversity incorporates both species richness and some measure of species evenness. While plant species richness is relatively high in SHIL's hardwood forests, comparisons between study plots (NatureServe 2004, CUPN 2015) show that this richness is not evenly distributed between forest types and stands within the park. However, some variation is to be expected between communities due to environmental variation (e.g., soil type, disturbance regime, water availability). Based on the available data, there is no evidence of cause for concern regarding this measure, but additional data and analysis would be needed to fully assess this measure. Therefore, a *Condition Level* is not assigned at this time.

Forest Succession

This measure was assigned a *Significance Level* of 3. One method used by the CUPN to assess forest succession is by stand structural stage. According to vegetation data collected by the CUPN, 59% of SHIL's hardwood forest monitoring plots are in the mature stage class and 41% are in the late-successional stage class (CUPN 2015). None of the plots sampled are in the younger, pole stage class. These percentages fall within the "good condition" guideline suggested by the CUPN of at least 25% forests in the late-successional stage. As a result, this measure is currently of no concern (*Condition Level* = 0).

Coarse Woody Debris Cover

The project team assigned a *Significance Level* of 2 for this measure. Coarse woody debris volumes in CUPN monitoring plots at SHIL ranged from 0.12 m^3/ha to 3.16 m^3/ha. Twelve of the 44 transects surveyed (27%) – including both transects in three separate plots – did not intersect with any woody debris. This lack of debris may suggest that some SHIL forests are relatively young (White et al. 2011) and could be a cause for concern in terms of wildlife habitat availability. Coarse woody debris is therefore assigned a *Condition Level* of 2, indicating moderate concern.

Weighted Condition Score

The *Weighted Condition Score* for hardwood forests at SHIL is 0.29, which is in good condition. A trend could not be assigned, as comparable data are limited for several of the selected measures. As a result of this limited data, a medium confidence border has also been applied.

Hardwood Forest Community			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.29**
Species Richness	3	1	
Species Diversity	3	N/A	
Forest Succession	3	0	
Coarse Woody Debris Cover	2	2	

4.1.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Rickie White, NatureServe Ecologist
- Marcus Johnson, SHIL Natural Resource Management Specialist

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4.2. Wetland and Riparian Communities

4.2.1. Description

Wetlands are defined by the U.S. Army Corps of Engineers (USACE) as “areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (USACE 1987, p. 9). The term “riparian” applies to any community that occurs along a river or other waterway. Wetlands provide critical ecosystem functions, including surface water storage, groundwater recharge, nutrient cycling, and sediment trapping (Roberts and Morgan 2008). Wetlands and riparian areas also provide valuable habitat for a variety of plants and wildlife, contributing greatly to overall biodiversity (Brooks and Hayashi 2002, Roberts and Morgan 2008). However, approximately 53% of the original wetlands in the lower United States have been lost since European settlement, primarily due to human activities (Dahl 1990). Losses have continued in many parts of the country, with some of the greatest losses during the 1990s occurring in freshwater forested wetlands (Dahl 2000).

The majority of wetlands and riparian areas within SHIL are forested, with only small areas of herbaceous wetlands (Roberts and Morgan 2008). These forested wetlands occur in bottomlands or floodplains along the Tennessee River, Owl Creek, and other drainages in the park (Photo 5) (Jones and White 1981). Common tree species include sweetgum, red maple, green ash (*Fraxinus pennsylvanica*), willow oak (*Quercus phellos*), and cherrybark oak (Jones and White 1981, Roberts and Morgan 2008).

Photo 5. A forested wetland in SHIL (NPS /ROBERTS & MORGAN 2008).

Smaller wetlands are also interspersed within the uplands, where depressions catch and hold rainwater temporarily. These pond communities support emergent vegetation including sedges (*Carex* spp.) and spikerushes (*Eleocharis* spp.) (Jones and White 1981). Several springs occur in the park (e.g., Shiloh and Rhea Springs along Peabody Road) and can support small wetland communities (Jones and White 1981). At SHIL, these wetland and riparian communities provide important habitat for amphibians (e.g., frogs and salamanders), aquatic insects, and birds (National Park Service (NPS) 2015). The 13 distinct wetland/riparian vegetation community types that have been identified within SHIL (Nordman 2004) are listed in Table 14. Together, these 13 vegetation communities cover 169.4 ha (418.5 ac) or approximately 7% of the park (Figure 10) (Jordan and Madden 2010).

Table 14. Wetland and riparian vegetation communities (associations) and the most prominent plant species in each (Nordman 2004). Community/association names are from the NVC.

Association	Prominent Plant Species
Forested	
Successional Sweetgum Floodplain Forest (disturbed sites)	sweetgum, tulip poplar, red maple, willow oak
Sweetgum Cherrybark Oak Floodplain Forest	sweetgum, cherrybark oak, shagbark hickory
Southern Green Ash - Elm - Sugarberry Forest	American elm (*Ulmus americana*), sugarberry (*Celtis laevigata*), silver maple (*Acer saccharinum*), green ash
Gulf Coastal Plain Sycamore – Sweetgum Floodplain Forest	sweetgum, American sycamore, green ash, sugarberry
Water Tupelo Swamp Forest	water tupelo (*Nyssa aquatica*), black willow (*Salix nigra*)
Boxelder Floodplain Forest	boxelder (*Acer negundo*), red maple, white ash, sweetgum
River Birch Levee Forest	river birch, tulip poplar, sycamore
East Gulf Coastal Plain Beech Floodplain Forest	hickories, American beech, blackgum
Sycamore – Silver Maple Calcareous Floodplain Forest	green ash, boxelder, sycamore, silver maple
Bald-cypress Swamp*	bald cypress (*Taxodium distichum*)
Interior Forested Acid Seep	blackgum, sweetgum, tulip poplar, cherrybark oak
Shrubland/Herbaceous	
Southern Buttonbush Pond	buttonbush (*Cephalanthus occidentalis*), greater marsh St. John's wort (*Triadenum walteri*), black willow, trumpet creeper (*Campsis radicans*)
Smartweed – Cutgrass Beaver Pond	smartweeds (*Polygonum* spp.), cutgrass (*Leersia* spp.), beggarticks (*Bidens* spp.), lizard's tail (*Saururus cernuus*)

* This community was not confirmed during SHIL field sampling but may be present in riparian areas along Owl Creek or the Tennessee River (Jones and White 1981).

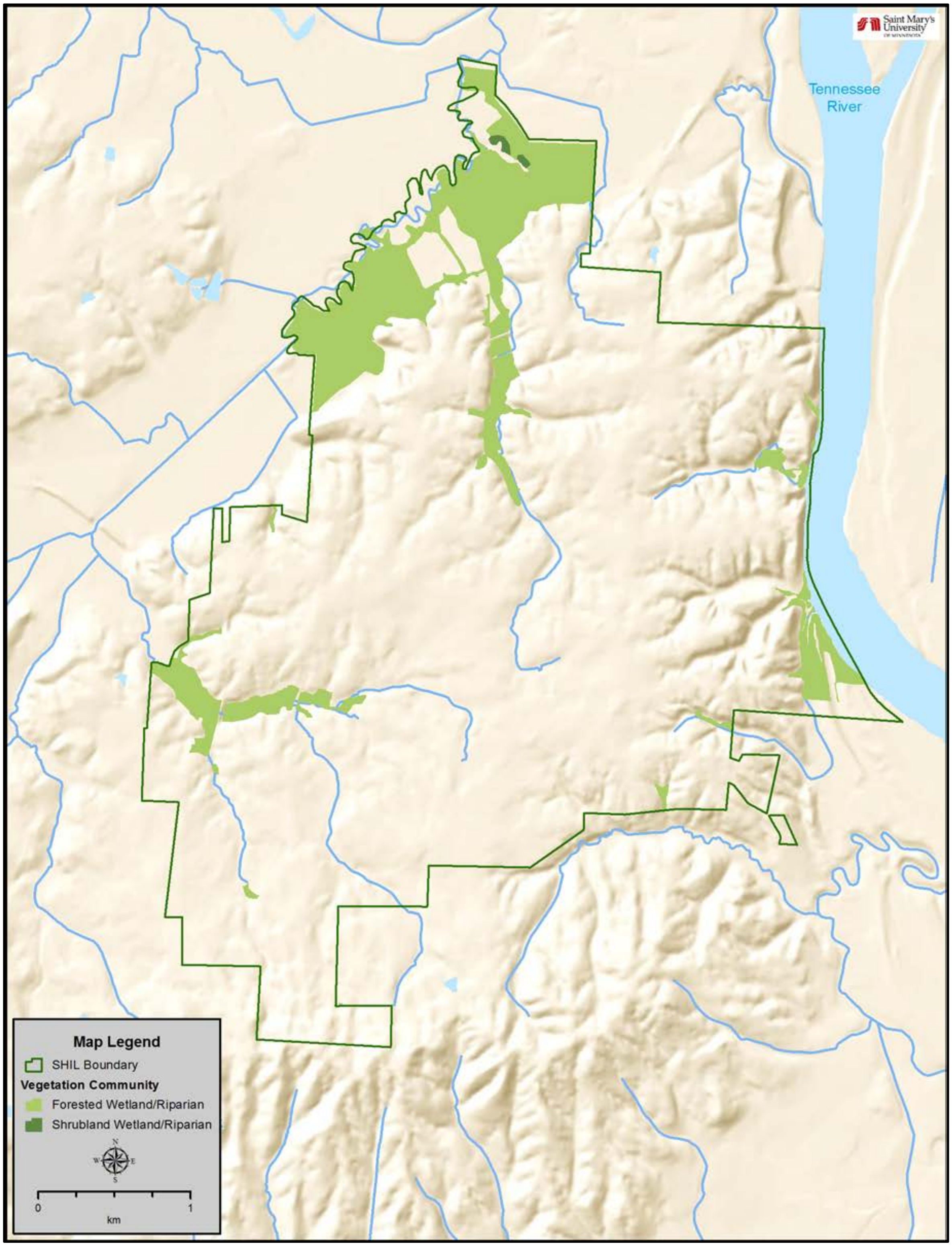

Figure 10. Location of wetland/riparian vegetation communities within SHIL, as mapped by Jordan and Madden (2010). Note that the minimum mapping unit for the project was 0.5 ha (1.2 ac); wetland communities below this size would not have been captured by the mapping effort. Also note that SHIL has recently acquired additional acreage that is not represented on this map, as an updated boundary file is not yet available.

One wetland complex at SHIL of particular importance is the Owl Creek bottomland forest along the park's northwestern boundary (Photo 6) (Jones and White 1981). Historically, forests looked like these covered large areas of western Tennessee, but most have been cleared for agriculture (Roberts and Morgan 2008). The Owl Creek bottomland is now the largest wetland complex within all the CUPN parks (NPS 2015). Some mature stands occur in this area, with trees exceeding 100 cm (39.4 in) in diameter (Jones and White 1981). Another wetland of interest is Bloody Pond, the only pond within the park's uplands that holds water year-round (Jones and White 1981).

Photo 6. Bottomland forests in the Owl Creek complex (NPS/ ROBERTS and MORGAN 2008).

4.2.2 Measures

- Number and area of wetlands
- Number of vernal pools
- Vegetation species diversity
- Water quality
- Herpetofauna species richness

4.2.3 Reference Conditions/Values

As with hardwood forests, the ideal reference condition for this component would be the appearance and condition of hardwood forests at the time of the battle. Unfortunately, little scientific information is available from this historic time period. The reference condition for number and area of wetlands will be based on the Roberts and Morgan (2008) wetland inventory of the park. A reference condition could not be defined for number of vernal pools due to limited information. The earliest botanical survey of the park (Jones and White 1981) will provide some insight towards a reference condition for plant species richness/diversity. Reference conditions for water quality and herpetofauna species richness will be discussed in Chapters 4.6 and 4.7 of this NRCA, respectively.

4.2.4. Data and Methods

Many of the data sources for this component were also utilized previously in Chapter 4.1.1 (hardwood forests). As described in that chapter, Jones and White (1981) conducted a thorough floristic inventory of SHIL, covering the entire park during field visits between April 1980 and April 1981. The annotated species list in this work identified the habitat type(s) where each plant species was found (Jones and White 1981). Additional sources utilized for this component and previously described include the NatureServe inventory and classification project (Nordman 2004) and the CUPN forest vegetation monitoring program (Moore 2013, CUPN 2015). Descriptions of these sources can be found in Chapter 4.1.4. Only five of the plots sampled by NatureServe (Nordman 2004) and two plots established by the CUPN fall within wetland/riparian communities.

Roberts and Morgan (2008) conducted a baseline wetlands inventory at SHIL in 2005. This comprehensive study searched transects throughout the park on foot to identify and delineate wetlands. Wetland identification procedures followed the USACE Wetland Delineation Manual (USACE 1987). Data collected for each wetland identified included location, estimated size, soils, hydrology, wetland type (Cowardin and hydrogeomorphic [HGM] classifications), and dominant plant species (Roberts and Morgan 2008). Any observations regarding evidence of alteration/degradation and the presence of invasive plant species were also noted. These data and observations were then used to assess the functions and values of the wetlands (Roberts and Morgan 2008).

Data and methods for herpetofaunal species and water quality information are discussed in detail in Chapters 4.6 and 4.7, respectively.

4.2.5. Current Condition and Trend

<u>Number and Area of Wetlands</u>

Prior to the 2005 comprehensive wetland inventory, Roberts and Morgan (2008) conducted a preliminary investigation of National Wetlands Inventory (NWI) data for SHIL. According to the NWI database, only 10-15 wetlands occurred within park boundaries (Roberts and Morgan 2008). However, NWI methodology is known to have several limitations that can result in under-counting of wetlands. For example, the NWI utilizes remotely-sensed aerial imagery to identify wetlands. As a result, it is more accurate in open landscapes (Roberts and Morgan 2008) and can have difficulties identifying forested wetlands, such as those common in SHIL. Also, wetlands smaller than 0.4 ha (1 ac) are commonly missed due to the scale of the imagery used (Roberts and Morgan 2008).

Roberts and Morgan (2008) identified a total of 81 wetlands in or near SHIL, totaling 152.4 ha (376.6 ac) (Figure 11). Seventy-four of these wetlands were within SHIL boundaries at that time, for a total of 152.3 ha (376.3 ac); given recent boundary expansions, it is likely that more (perhaps all) of the 81 total wetlands are now within park boundaries (Johnson, written communication, 17 March 2016).

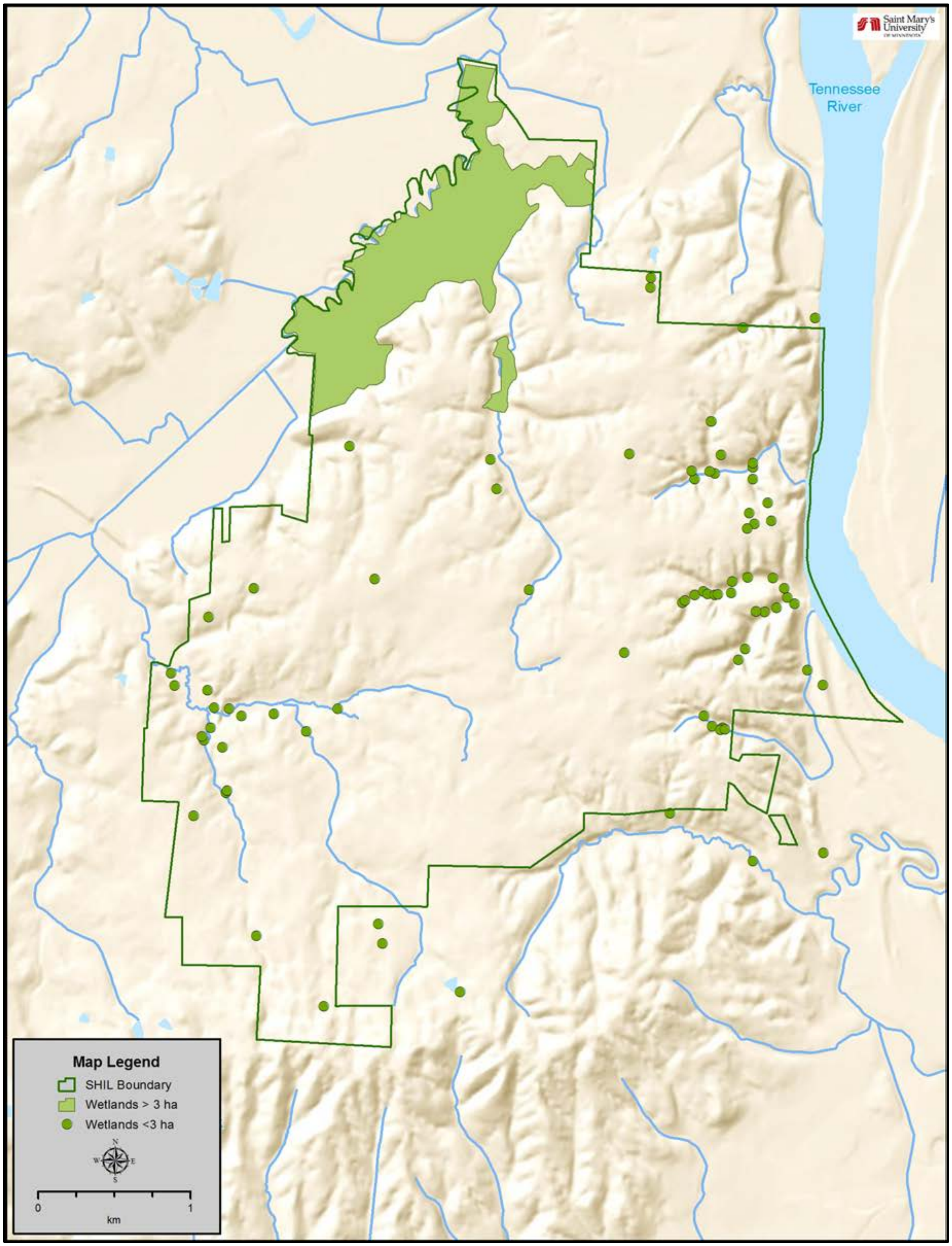

Figure 11. The locations of wetlands within or near SHIL, as identified by Roberts and Morgan (2008). Note that SHIL has recently acquired additional acreage that is not represented on this map and some (perhaps all) sites that appear to be outside the park may now be within its boundaries.

The Owl Creek wetland complex comprised approximately 127.5 ha (315 ac) of this total area (Roberts and Morgan 2008). Average wetland size at SHIL with the Owl Creek complex included was 1.9 ha (4.6 ac); excluding Owl Creek, wetlands averaged 0.3 ha (0.8 ac) in size (Roberts and Morgan 2008). According to Cowardin classifications, 66 of the wetlands within SHIL boundaries were forested and dominated by deciduous tree species (Table 15). The majority of these wetlands (46 of 66) are considered seasonally flooded, meaning "surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years. When surface water is absent, the water table is often near the land surface" (Cowardin et al. 1979, p. 24).

Table 15. Wetland area in hectares (acres) within SHIL boundaries by Cowardin class (Roberts and Morgan 2008). In the codes, P = palustrine (non-tidal, non-riverine), FO = forested, EM = emergent vegetation (non-woody), A = temporarily flooded, C = seasonally flooded, E = seasonally flooded/saturated, F = semipermanently flooded.

Coded Area	Number	Area Hectares (Acres)
PFO1A	16	13.8 (34.2)
PFO1C	46	134.1 (331.4)
PFO1E	4	0.2 (0.6)
Forested total	**66**	**148.1 (366.2)**
PEM1A	2	0.08 (0.2)
PEM1C	3	1.0 (2.6)
PEM1E	2	0.8 (2.1)
PSS1F	1	2.1 (5.2)
Total wetlands	**74**	**152.3 (376.3)**

According to HGM classifications, the majority of SHIL's wetlands (54 of 74) fell in the slope class (Table 16) (Roberts and Morgan 2008). However, the majority of wetland *area* fell within the riverine class, due to the large size of the Owl Creek wetland complex. These classifications can be helpful in evaluating wetland functions. For example, depressional wetlands are likely to provide surface water storage while slope wetlands are not (Roberts and Morgan 2008).

Table 16. Wetland area in hectares (acres) at SHIL by HGM class (Roberts and Morgan 2008).

Class	Number	Area Hectares (Acres)
Depression	15	1.4 (3.4)
Slope	54	21.0 (52.0)
Flat	2	0.05 (0.1)
Riverine	3	129.8 (320.7)

Number of Vernal Pools

Vernal pools are isolated ephemeral wetlands commonly found in eastern U.S. forests (Brooks and Hayashi 2002, Zedler 2003). These pools provide important habitat for amphibians and aquatic invertebrates, and are considered obligatory breeding habitat for many *Ambystoma* salamanders (Kenney and Burne 2000), some of which are found at SHIL. Since vernal pools are ephemeral (i.e., do not hold water year-round), they often contain fewer predators (e.g., fish) than other wetlands (Zedler 2003). These pools typically occur in depressions with no permanent inflow or outflow to other water bodies. As a result, water levels are controlled by precipitation, evaporation, and groundwater exchange (Brooks and Hayashi 2002, Zedler 2003).

In terms of wetland classification systems (Cowardin and HGM), there is no clear correlation between certain classes and vernal pools. While vernal pools are commonly found in the depression class of the HGM system, some may occur in the slope and riverine classes (Ken Morgan, Tennessee Technological University research specialist, phone communication, 3 February 2016). Within the Cowardin classification system, vernal pools typically have a temporarily flooded (A) or saturated (B) water regime, but could also have a seasonally flooded (C) regime (Morgan, phone communication, 3 February 2016). Therefore, it is not possible to identify the number of vernal pools at SHIL from these classifications alone. As part of their wetland inventory, Roberts and Morgan (2008) evaluated the functional values of all the wetlands identified at SHIL. One of the functions assessed was research/scientific value, and Roberts and Morgan (2008) identified many wetlands that had value for herpetological research. This determination may serve as the best “starting point” for identifying vernal pools at SHIL (Morgan, phone communication, 3 February 2016).

Roberts and Morgan (2008) identified 49 wetlands in SHIL as having herpetological research value. However, five of these wetlands had E (seasonally flooded/saturated) or F (semipermanently flooded) water regimes according to the Cowardin classification, suggesting they were wet for a longer period of time than a vernal pool would be. Of the 44 remaining wetlands, seven were in the “depression” HGM class, adding further evidence that they could support vernal pools. Of the wetlands with herpetological value but in other HGM classes (slope or riverine), two were large enough (>0.5 ha [1.3 ac]) that they could perhaps support multiple vernal pools.

In summary, the exact number of vernal pools in SHIL cannot be determined from the data available. There are seven wetlands identified by Roberts and Morgan (2008) that are in the “depression” HGM class and have herpetological research value. It is highly likely that these wetlands support vernal pools; therefore, the *minimum* estimate of vernal pools for SHIL is seven. If all the wetlands identified as having herpetological value and an appropriate water regime (A or C) do indeed support vernal pools, then SHIL contains at least 44 vernal pools. Given that two of these wetlands (including the vast Owl Creek complex) are large enough to potentially support multiple vernal pools, the number could be even higher. Considering the ephemeral nature of these pools, it is also possible that vernal pools could have been missed during the Roberts and Morgan (2008) inventory. A detailed on-the-ground survey focusing specifically on vernal pools would be necessary to more accurately count the number of vernal pools at SHIL.

Vegetation Species Diversity

As mentioned in Chapter 4.1.5, species diversity typically incorporates both species richness and some measure of species evenness. For the purposes of this assessment, the evenness component will be more simply assessed by exploring the number of species per wetland/riparian forest plot across the park.

Similar to the hardwood forests component, determining the total plant species richness of SHIL's wetland and riparian communities is challenging, as not all floristic surveys have used similar habitat/vegetation classifications. Of the general habitat types identified by Jones and White (1981) during an intensive park-wide survey, categories considered wetland or riparian for this assessment are swamps, bottoms, stream/river banks, upland pools, floodplains, and "moist places." A total of 218 plant species were listed as occurring in these types of habitats within SHIL, only nine of which were non-native (Appendix B) (Jones and White 1981).

A total of 206 plant species were identified in the five NatureServe (2004) plots that fell within wetland/riparian communities, 11 of which were non-native species. Roberts and Morgan (2008) identified 105 plant species during the wetland inventory, including eight non-native species. However, some taxa were only identified to the genus level (e.g., *Aster* sp., *Eleocharis* sp.), and it may be possible that multiple species within these genera were present. Several of the non-native species documented by Roberts and Morgan (2008) had not previously been documented in the park's wetland or riparian areas (e.g., barnyard grass [*Echinochloa crus-galli*], tall fescue [*Schedonorus arundinaceus*]).

The CUPN monitoring documented 91 plant species in wetland/riparian communities, three of which were non-native (CUPN 2015). However, it is important to keep in mind that only two CUPN plots totaling 800 m^2 (less than 0.1 ha or 0.2 ac) fall within wetland riparian communities, while previous surveys covered much larger areas (the entire park by Jones and White [1981] and 5 ha by NatureServe [2004]). Altogether, vegetation inventories and surveys at SHIL have identified a total of 388 plant species in wetland and riparian vegetation communities, representing approximately 36% of the park's total plant richness. Twenty-six of these (7%) are non-native (Appendix B).

In terms of evenness, the number of plant species per one-hectare plot during the NatureServe (2004) inventory ranged from 42 to 95 (Table 17). This suggests that the relatively high species richness in SHIL's wetland/riparian communities is not evenly distributed between community types and stands. However, there is less variation between NatureServe (2004) wetland/riparian plots than between hardwood forest plots (see Chapter 4.1.5). The number of non-native species per plot ranged from zero to seven, indicating that most of the plant diversity is from native species. The most diverse plot was classified as an Interior Red Maple-Blackgum Forested Acidic Seep while the least diverse was a Southern Green Ash-Elm-Sugarberry Forest (NatureServe 2004).

Table 17. Number of plant species per one-hectare plot in SHIL wetland/riparian communities, as documented by NatureServe (2004).

Plot	Number Of Species	Number Non-Natives
SHIL.2	95	7
SHIL.7	69	3
SHIL.15	42	0
SHIL.16	65	1
SHIL.19	75	2

Evenness is difficult to assess using CUPN (2015) data, as only two monitoring plots (400 m^2 each) fall within wetland/riparian communities. These two plots had 42 and 70 plant species with zero and three non-native species, respectively (Table 18). As with SHIL's hardwood forests, much of the diversity was found in the herbaceous layer. Non-native species were found only in the herbaceous layer, and were not in the seedling/sapling or tree layers. The more diverse plot was classified as a Successional Sweetgum Floodplain Forest while the less diverse plot was, again, a Southern Green Ash-Elm-Sugarberry Forest (CUPN 2015).

Table 18. Number of plant species documented per 400 m^2 CUPN monitoring plot, in the tree/sapling/seedling layer and overall (CUPN 2015).

Plot Number	Tree/Sapling/ Seedling layer	Total Species	Non-Natives
002	10	70	3
033	7	42	0

Water Quality

Water quality has the potential to influence the plant species that are able to survive in wetland and riparian areas. Degraded water quality could also negatively impact the wildlife that rely on wetland habitats, particularly sensitive amphibian and invertebrate species (USGS 2015). SHIL's water quality will be discussed in depth in Chapter 4.7 of this report; this measure will be assessed based on the information presented there.

Herpetofauna Species Richness

Many herpetofaunal species rely on wetlands as habitat, particularly for breeding (Brooks and Hayashi 2002, Roberts and Morgan 2008). All amphibians require water at some stage to complete their life cycles. During a 2004-2005 inventory, Accipiter Biological Consultants (2006) documented 23 amphibian and 20 reptile species in the park using various survey methods. Four salamander, four frog and toad, three snake, and one turtle species were found only in aquatic habitats (e.g., ponds, streams, springs, or bogs) (Accipiter Biological Consultants 2006). Herpetofaunal species will be discussed in further detail in Chapter 4.6 of this NRCA.

Threats and Stressor Factors

Threats to SHIL's wetland and riparian communities include non-native invasive species, climate change, drought, adjacent land uses, atmospheric deposition of pollutants, and visitor use. Possible negative impacts from visitors include trampling of vegetation (Pescott and Stewart 2014) and increased risk of invasive species introduction and spread (Westbrooks 1998). Non-native invasive plants are among the greatest threats to natural ecosystems around the world and at SHIL (NPS 2015). Roberts and Morgan (2008) documented non-native species in 64 of the 81 wetlands surveyed. A total of 26 non-native plant species have been confirmed in SHIL's wetland and riparian communities to date (Appendix B). Fourteen of these are considered invasive by TN-EPPC, and six species are considered a severe threat to native communities (Table 19) (TN-EPPC 2009). Four of the six "severe threat" species were observed in park wetlands by Roberts and Morgan (2008). These aggressive species are able to invade and persist in native communities in the absence of disturbance, competing with native plants (Jones and White 1981, Nordman 2004). Japanese stiltgrass (*Microstegium vimineum*) was by far the most common non-native, found at 56 (69%) of the 81 wetlands identified by Roberts and Morgan (2008). Japanese honeysuckle was the second most common non-native but was documented at only four wetlands (Roberts and Morgan 2008). Japanese stiltgrass was also found in four of the five NatureServe (2004) plots while Japanese honeysuckle was found in two of the five plots. According to Nordman (2004), Japanese stiltgrass was the most dominant herbaceous plant in the park's River Birch Levee Forest.

Table 19. Non-native invasive plant species confirmed in SHIL's wetland/riparian communities and considered a "severe threat" in Tennessee (TN-EPCC 2009).

Scientific Name	Common Name	Growth form
Dioscorea oppositifolia	Chinese yam	vine
Hypericum perforatum	common St. John's wort	shrub
Lespedeza cuneata	Chinese lespedeza	forb
Ligustrum sinense	Chinese privet	shrub
Lonicera japonica	Japanese honeysuckle	vine
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	grass

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the CUPN (Davey et al. 2007). Climate also affects the spread of invasive plant species and atmospheric pollutant levels, which also threaten SHIL's wetland and riparian communities (Davey et al. 2007). As a result of global climate change, temperatures are projected to increase across the southeast over the next century (Carter et al. 2014). Warming temperatures will likely allow invasive plants to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). Warmer temperatures will also likely accelerate the loss of water to the atmosphere through evapotranspiration, which could cause a general drying among wetland ecosystems (Brooks 2009). Since the hydrology of ephemeral wetlands such as vernal pools is strongly influenced by weather events and climate, they are particularly sensitive to climate change (Brooks 2009). With warming temperatures, it is likely that vernal pools will dry up faster, potentially reducing their value as wildlife habitat. In addition to temperature changes, climate change is projected to cause precipitation events to become less frequent but more intense, with longer dry periods between rain events (Bates et al. 2008, Brooks 2009). Such a change would also affect water levels and retention times in vernal pools and other small wetlands. For further discussion of climate change's potential impacts on trees, which would affect forested wetlands, see Chapter 4.1.5 (threats and stressors).

Wetland and riparian communities could be vulnerable to acidification or nutrient enrichment from the atmospheric deposition of pollutants. This atmospheric deposition can alter plant, algae, and animal communities at various scales in both terrestrial and aquatic ecosystems (Sullivan et al. 2011a, b). Wetlands are thought to be among the ecosystems most sensitive to nutrient enrichment from atmospheric deposition (Sullivan et al. 2011b). The causes and impacts of atmospheric deposition are further discussed in Chapters 4.7 and 4.8 (water and air quality).

Data Needs/Gaps

Historic data regarding the number and area of wetlands at SHIL are unavailable, making it impossible to identify any changes in wetlands over time. Revisiting wetlands identified by Roberts and Morgan (2008) in several years would allow for comparisons that could help identify any trends in wetland conditions at SHIL. Given the importance of hydroperiod (i.e., the duration and frequency of inundation) in the composition and productivity of wetlands, monitoring of hydroperiods could provide useful information regarding wetland condition, function, and the impacts of climate change (Brooks 2004, White et al. 2011).

Small wetlands, including vernal pools, have generally received little research attention (Brooks and Hayashi 2002, Roberts and Morgan 2008). At SHIL, the value of wetland patches within the uplands as water sources for wildlife, particularly during extended dry periods, could be investigated (Roberts and Morgan 2008). On-the-ground inventories specifically for vernal pools along with a study of their hydrologic regimes and use by herpetofauna would help park managers better understand this unique resource.

Overall Condition

Number and Area of Wetlands

The project team assigned this measure a *Significance Level* of 3. Roberts and Morgan (2008) documented a total of 74 wetlands within SHIL boundaries, totaling 152.3 ha (376.3 ac). With the exception of the Owl Creek complex, these wetlands are generally small (>0.5 ha). It should be noted that recent park boundary expansions have added more wetland acreage to the park (e.g., Lick Creek bottomlands) that has not yet been mapped and measured (Johnson, written communication, 18 March 2016). While wetland loss has been an issue throughout the U.S., both historically and currently, SHIL's wetlands are generally protected from the common causes of wetland loss (e.g., development, agriculture) and there is no indication that this is an immediate cause for concern at the park. Therefore, the number and area of wetlands measure is assigned a *Condition Level* of 1 for low concern.

Number of Vernal Pools

This measure was also assigned a *Significance Level* of 3. It is not possible to precisely identify the number of vernal pools within SHIL based on the available data. The small size and ephemeral nature of these pools make them difficult to identify and count. Based on wetland classifications and functional value assessments from Roberts and Morgan (2008), there are at least seven wetlands that are highly likely to support vernal pools. An additional 37 wetlands are likely to support vernal pools, and two of these are large enough that they could contain multiple vernal pools. However, these numbers are largely based on speculation and a detailed on-the-ground survey would be necessary to accurately count the number of vernal pools at SHIL. As a result, a *Condition Level* has not been assigned for this measure at this time.

Vegetation Species Diversity

The project team assigned the species diversity measure a *Significance Level* of 3. Altogether, vegetation inventories and surveys at SHIL have identified a total of 388 plant species in wetland and riparian vegetation communities (Jones and White 1981, NatureServe 2004, Roberts and Morgan 2008, CUPN 2015). Only 26 of these species (7%) are non-native. This species richness is not evenly distributed between SHIL's wetland/riparian community types and stands, as the number of plant species per plot in the NatureServe (2004) inventory ranged from 42 to 96. However, some variation is to be expected between communities and plots due to environmental variation (e.g., soil type, disturbance regime, water availability). Therefore, this measure is assigned a *Condition Level* of 1, indicating low concern.

Water Quality

A *Significance Level* of 3 was assigned to the water quality measure. As will be discussed in Chapter 4.7, SHIL's water quality is generally considered very good (Meiman 2007, 2013). The pH and acid neutralizing capacity are low in many of the park's water bodies, but these are considered natural conditions and are not indicative of degradation or pollution. Water quality is currently of low concern at SHIL (*Condition Level* = 1).

Herpetofauna Species Richness

This measure was also assigned a *Significance Level* of 3. SHIL's wetlands provide valuable habitat for herpetofauna. Vernal pools are particularly critical as amphibian breeding habitat (Kenney and Burne 2000). Based on the assessment in Chapter 4.6 of this NRCA, the herpetofauna measure is assigned a *Condition Level* of 1.

Weighted Condition Score

The *Weighted Condition Score* for SHIL's wetland and riparian communities is 0.33, which is at the top of the good condition range. Any small decline in one or more of the measures could push this resource into the moderate concern range. Due to the limited time frame of data available for several measures, particularly number and area of wetlands, a trend could not be identified for this component.

Wetland and Riparian Communities			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Number and Area of Wetlands	3	1	
Number of Vernal Pools	3	N/A	
Vegetation Species Diversity	3	1	
Water Quality	3	1	
Herpetofauna Species Richness	3	1	

4.2.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Ken Morgan, Tennessee Technological University Research Specialist
- Rickie White, NatureServe Ecologist
- Marcus Johnson, SHIL Natural Resource Management Specialist

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4.3. Mammals

4.3.1. Description

Despite anthropogenic disturbances inside the park, SHIL provides fairly intact and mature habitats for many mammal populations (Kennedy and Jennings 2007). This is likely attributed to the early establishment of the park (1894) and of the ongoing preservation and management efforts (NPS 2015). Due to this level of ecological preservation, SHIL represents an important area for understanding mammalian populations and biodiversity; the park can provide insight into the overall mammal biodiversity for the greater SHIL region (Photo 7) (Kennedy and Jennings 2007).

Photo 7. The raccoon (*Procyon lotor*) is considered to be native to SHIL and is abundant throughout the park (NPS 2016b) (NPS).

Land outside of the park has been strongly impacted by agricultural practices, clear-cutting, erosion, and other human activity such as urban development (Kennedy and Jennings 2007). These land use changes can have negative effects on mammalian habitat quality, which in turn can negatively influence mammalian species inside the park (Kennedy 2002). According to the International Union for Conservation of Nature (IUCN), certain species can be more susceptible to land use changes caused by humans (e.g., residential and commercial development, agriculture, transportation). Some of these are found inside SHIL, including the river otter, the long-tailed weasel (*Mustela frenata*), the white-tailed deer, and the eastern small-footed bat (*Myotis leibii*) (IUCN 2015).

4.3.2. Measures

- Species composition
- Bat species richness
- White-tailed deer density
- Native rodent abundance

4.3.3. Reference Conditions/Values

The reference condition for the mammal component was defined by Kennedy (1984). Kennedy (1984) conducted a mammal inventory in SHIL between 1983 and 1984. When a species was collected, sighted, or a sign was found (e.g., tracks, scat), Kennedy (1984) verified that particular species for his inventory, resulting in 35 total mammal species (Appendix C).

4.3.4. Data and Methods

NPS (2016b) represents the NPS Certified Mammal Species List for SHIL and contains a list of all mammal species in the park. Occurrence in the park is classified as present, probably present, or unconfirmed.

Kennedy (1984) conducted a small mammal research project in SHIL between 1983 and 1984. A list of 55 mammal species (41 terrestrial mammals and 14 bats) was compiled based off previous mammalian literature pertaining to the park. When a species was collected, sighted, or sign was found, (Kennedy 1984) would verify it on a list (Appendix C). Kennedy (1984) also noted mammal species that were on the endangered species list.

Kennedy and Jennings (2007) conducted an updated mammal inventory for SHIL in 2005 and 2006. For this inventory, 21 randomly selected 1-ha (2.47-ac) plots were established throughout the park (Figure 12). Fifty Sherman live traps were placed throughout these plots for a total of 3,850 trap nights (one trap night = one trap set for one night) during 2005 and 2006 (Kennedy and Jennings 2007). Empty pitfall traps were installed in the randomly selected plots for a total of 2,100 pitfall-trap nights (one pitfall trap night = one pitfall trap set for one night) during October and November 2005 (Kennedy and Jennings 2007). Along with traps, 21 scent-stations were placed – one at each plot – in areas likely to represent a travel corridor for mammals. Each station consisted of a cotton ball soaked in bobcat (*Lynx rufus*) urine and was in operation for one night (Kennedy and Jennings 2007). Nine bait stations were also utilized at selected locations: three on ground level and six at an arboreal level. Bait included shelled corn and canned cat food for the ground level stations and mixed-bird feed for the arboreal stations. Infrared-triggered cameras were also set up at these stations. The bait and camera stations were utilized year-round and checked bi-weekly (Kennedy and Jennings 2007). In addition to traps, scent stations, and bait stations, opportunistic sightings of mammals and tracks/sign were also recorded during the study (Kennedy and Jennings 2007).

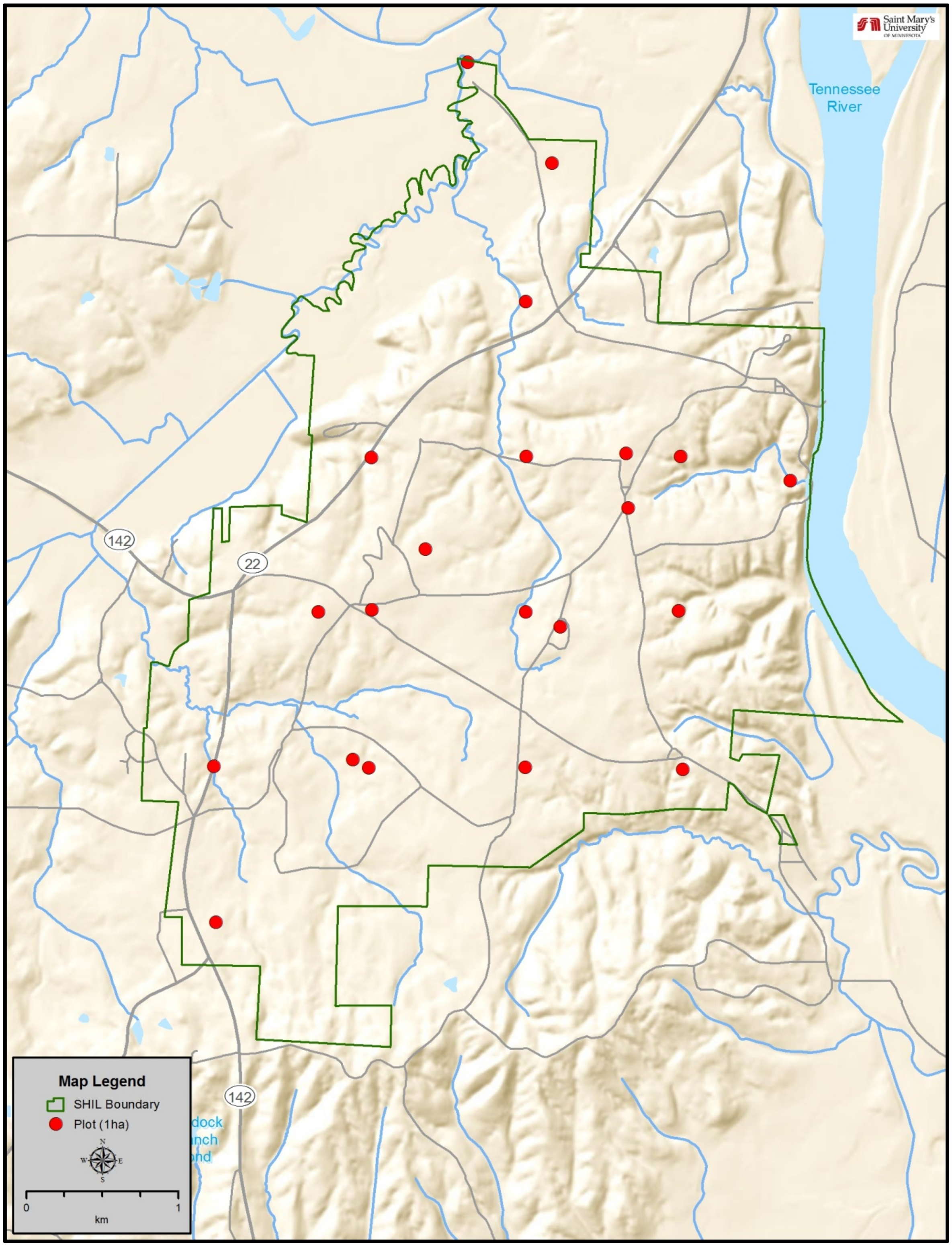

Figure 12. Locations of the 21 one-ha (2.47-ac) plots established for the Kennedy and Jennings (2007) study.

In 2002, a survey of bats inside SHIL was completed by Kennedy (2002). Bats were captured during a 6-month period (May – October) in 2001, which amounted to 567 net nights (one net night = one net set for one night) (Kennedy 2002) during 66 nights of netting. Fourteen survey locations were selected throughout the park, including both wet and dry sites; wet sites were areas over streams, sloughs, or ponds, and dry sites were areas near forest trails or secondary roads. Bats were captured using 2.6 x 6.0 m (8.5 x 19.7 ft) and 2.6 x 9.0 m (8.5 x 29.5 ft) mist nets (Kennedy 2002).

4.3.5. Current Condition and Trend

Species Composition

The species composition measure can be described as the total number of mammalian species observed in a given study per year and is analogous to a species richness measure. Since bat species richness is reported as a separate metric in this component, all estimates of species richness reported in this measure exclude bats.

The NPS Certified Mammals Species List (2016b) for SHIL identifies 43 terrestrial species as either being present, probably present, or unconfirmed inside the park. When excluding 11 species that have not been confirmed in the park, the total number of terrestrial mammal species at SHIL drops to 32 (Appendix D). This list, however, does not allow for a specific analysis of species composition over time, as no data are collected yearly, and the list only documents the presence (or historic presence) of identified species.

Kennedy (1984) verified 25 of the 41 terrestrial mammal species inside SHIL that had already been identified in previous literature (Appendix D). Of the mammals indicated in previous literature to occur in the park, 16 were not collected, sighted, or identified by sign during the time of his study.

Kennedy and Jennings (2007) identified a total of 42 terrestrial mammal species with a high probability of occurrence inside SHIL, of which they documented 29 species (Appendix D). Many species appeared to be abundant throughout the park, including the Virginia opossum (*Didelphis virginiana*), the gray fox (*Urocyon cinereoargenteus*), and the striped skunk (*Mephitis mephitis*) (Kennedy and Jennings 2007). During this study, no endangered or threatened species were documented. However, the following species identified by Kennedy and Jennings (2007) in SHIL are on Tennessee’s wildlife in need of management list: the southeastern shrew (*Sorex longirostris*), the southern bog lemming (*Synaptomys cooperi*), and the meadow jumping mouse (*Zapus hudsonius*) (TWRC 2000).

Bat Species Richness

As noted in Kennedy (1984), 10 of the 14 bats species documented in previous literature were collected, sighted, or verified by sign (Table 20). This included the gray bat, which is on the endangered species list.

Table 20. Bat species verified through the Kennedy (1984) study, documented in the Kennedy (2002) study, and listed as present or probably present in SHIL – according to the NPS Certified Mammals Species List (NPS 2016b). (For the Kennedy [1984] study, species documented from previous literature but not verified in the study are noted below).

Scientific Name	Common Name	Kennedy (1984)	Kennedy (2002)	NPSpecies
Corynorhinus rafinesquii[a]	Rafinesque's big-eared bat	-	-	X
Eptesicus fuscus	big brown bat	Not Verified	-	X
Lasionycteris noctivagans	silver-haired bat	X	X	X
Lasiurus borealis	eastern red bat	X	X	X
Lasiurus cinereus	hoary bat	X	-	X
Lasiurus seminolus	Seminole bat	X	-	X
Myotis austroriparius	southeastern bat	X	X	X
Myotis grisescens	gray bat	X	X	X
Myotis leibii	eastern small-footed bat	X[b]	-	X
Myotis lucifugus	little brown bat	X	X	X
Myotis septentrionalis	northern long-eared bat	-	-	X
Myotis sodalis	Indiana bat	-	-	X
Nycticeius humeralis	evening bat	X	X	X
Perimyotis subflavus[c]	tri-colored bat	X[d]	X[d]	X

a. Historic scientific name was *Plecotus rafinesquii.*

b. At the time of the Kennedy (1984) study, the eastern small-footed bat was commonly known as the Keen's bat. Keen's bat is now used for *Myotis keenii*.

c. Historic scientific name was *Pipistrellus subflavus.*

d. At the time of both Kennedy studies (1984, 2002), the tri-colored bat was referred to as the eastern pipistrelle.

According to Kennedy (2002), western Tennessee is a region of the U.S. that is lacking in bat studies. Population studies concerning distribution, status, and ecology must be completed in order to fully understand the conservation management needs of the species (Kennedy 2002). Due to the park's location in the Tennessee River Valley and the unique older age classes of forests, SHIL provides highly suitable habitat for a number of bats (Kennedy 2002). A total of seven species (121 bats total) were captured during the Kennedy (2002) study, including one endangered species (gray bat) and one rare species (southeastern bat [*Myotis austroriparius*]) (Table 20).

<u>White-tailed Deer Density</u>

Monitoring white-tailed deer populations is important because an over-abundance of the species in an area can have negative impacts on forestry, agriculture, and transportation, in addition to contributing to the transmission of animal and human diseases (Photo 8) (Côté et al. 2004, Kennedy and Jennings

2007). According to research conducted through the U.S. Forest Service (USFS), depending on the ecosystem and landscape, plant communities can survive and thrive when white-tailed deer densities are around 15-20 per square mile (Nisley 2012). Lower densities of white-tailed deer (approximately 10 per square mile) can actually cause certain plant communities to become overabundant due to a lack of foraging pressure (Nisley 2012).

Photo 8. White-tailed deer are abundant throughout SHIL. Monitoring and managing white-tailed deer populations are important for overall ecosystem health (Kennedy and Jennings 2007) (NPS).

During their study, Kennedy and Jennings (2007) noticed the white-tailed deer to be fairly abundant throughout the park. SHIL park management has articulated that white-tailed deer densities of 20-30 deer per square mile are considered appropriate for the SHIL area (Stacy Allen, SHIL Chief Park Ranger, personal communication, 11 March 2015). At the time of this writing, there is no information available on monitoring or completed surveys studying the density of white-tailed deer inside SHIL. Park and network staffs have referenced observable browse lines in the park, which is indicative of a denser population, but a quantifiable estimate of density is not available at this time.

Native Rodent Abundance

Both native and non-native rodent species are found inside SHIL boundaries. The NPS Certified Mammals Species List (2016b) identifies 21 rodent species (native and non-native) that may be found in SHIL, although only 12 species are considered to be present or probably present. Eleven of these are native. Seven of the 11 are considered common or abundant. Table 21 lists the rodent species found in SHIL, along with their occurrence, nativeness, and abundance as determined by the NPS (2016b).

Table 21. Rodents listed in the NPS Certified Mammals Species List for SHIL, along with each species' occurrence, nativeness, and abundance (NPS 2016b).

Scientific Name	Common Names	Occurrence	Nativeness	Abundance
Castor canadensis	American beaver	Present	Native	Common
Glaucomys volans	southern flying squirrel	Unconfirmed	Native	N/A
Marmota monax	woodchuck	Present	Native	Common
Microtus ochrogaster	prairie vole	Unconfirmed	Native	N/A
Microtus pinetorum	woodland vole	Present	Native	Common
Mus musculus	house mouse	Probably present	Non-native	N/A
Neotoma floridana	eastern woodrat	Unconfirmed	Native	N/A
Ochrotomys nuttalli	golden mouse	Present	Native	Uncommon
Ondatra zibethicus	muskrat	Present	Native	Uncommon
Oryzomys palustris	marsh rice rat	Present	Native	Uncommon
Peromyscus gossypinus	cotton mouse	Present	Native	Common
Peromyscus leucopus	white-footed mouse	Present	Native	Common
Peromyscus maniculatus	deer mouse	Unconfirmed	Native	N/A
Rattus norvegicus	Norway rat	Unconfirmed	Non-native	N/A
Rattus rattus	black rat	Unconfirmed	Non-native	N/A
Reithrodontomys humulis	eastern harvest mouse	Probably present	Native	N/A
Sciurus carolinensis	eastern gray squirrel	Present	Native	Abundant
Sciurus niger	eastern fox squirrel	Unconfirmed	Native	N/A
Sigmodon hispidus	hispid cotton rat	Present	Native	Common
Synaptomys cooperi	southern bog lemming	Unconfirmed	Native	N/A
Zapus hudsonius	meadow jumping mouse	Unconfirmed	Native	N/A

During the Kennedy (1984) study, the white-footed mouse (*Peromyscus leucopus*) and the woodland vole (*Microtus pinetorum*), both native to SHIL, were the most abundant small mammals. Kennedy and Jennings (2007) reported that, the white-footed mouse (Photo 9) and the eastern gray squirrel (*Sciurus carolinensis*), also native to SHIL, were abundant throughout the park. Despite both studies claiming abundance of the aforementioned species, there was no quantitative data available to support these conclusions.

Photo 9. The white-footed mouse (*Peromyscus leucopus*) was considered abundant throughout the park by both Kennedy (1984) and Kennedy and Jennings (2007) (NPS).

Threats and Stressor Factors

SHIL staff have identified the following threats and stressors to mammal populations inside the park: deforestation of and hunting in surrounding areas, poaching, grounds management and maintenance, visitor use, feral animals (dogs, cats [*Felis catus*], hogs [*Sus scrofa*]), drought, and climate change.

Many mammal species depend on a rich and diverse forested ecosystem similar to what is present in SHIL (e.g., high quality forest cover) (Kennedy and Jennings 2007). Forest communities were selected as one of the highest priority Vital Signs across the CUPN due to forests being a dominant feature in the many park landscapes (Leibfreid et al. 2005, Moore 2013). Over two-thirds of the park consists of mixed hardwood forests: upland oak-hickory woodlands, mesic hardwood slope and ravine forests, and bottomland forests (Jones 1983). The importance of SHIL's forests has become more significant over time, as surrounding lands have been altered by pulpwood logging, farming, and other developments (Jones and White 1981). Loss of habitat has a negative effect on biodiversity and can result in changes to ecological functions and ecosystem services (Fahrig 2003), ultimately affecting mammal species through altered migration patterns and introduction of invasive species (Emmott and Murdock 2008). The Tennessee Wildlife Resources Agency (TWRA) suggests that the biggest factor contributing to forests containing little diversity or understory, poor regeneration, and limited wildlife is the lack of understanding in proper forest management practices (TWRA 2011).

The TWRA provides rules and regulations for hunting throughout the entire state of Tennessee. Even though hunting is not allowed inside the park (Kennedy and Jennings 2007) it is legal on lands surrounding the park (TWRA 2015). The TWRA provides regulations on small and large game mammal hunting; small mammals include the American beaver (Photo 10), bobcat, eastern gray squirrel, and river otter (TWRA 2016b), while large mammals include the white-tailed deer and the black bear (TWRA 2016a).

Photo 10. The American beaver (*Castor canadensis*), native and considered a common species in SHIL, is hunted throughout the entire State of Tennessee (NPS).

Game mammal populations naturally fluctuate over time, but the TWRA, with public input and assistance, has been monitoring species such as the white-tailed deer to make sure population levels stay at a healthy level (TWRA 2015). According to state wildlife laws, permission from private landowners is required to hunt on private property (TWRA 2015). Despite heavy regulation and clear guidelines, illegal poaching of species (i.e., deer and box turtles [*Terrapene* spp.]) still occurs in Tennessee (Tennessee State Wildlife Action Plan Team 2015). At this time, there is no mention of poaching of mammals occurring around SHIL.

Both park staff and farmers mow fields and perform lawn maintenance (chemical treatments) in and around the park. Practices such as these can degrade mammal habitats, disrupt the natural food chain, and introduce non-native and/or invasive species (Kennedy and Jennings 2007, NPS 2015). Kennedy and Jennings (2007) suggest that implementing mowing rotations, reducing chemical treatments, and controlling litter from visitors could all help increase mammal biodiversity and promote healthy habitats.

On average, the park receives about 400,000 visitors per year (NPS 2016a). According to Haas and Wakefield (1998), 72% of visitors say one of the reasons they enjoy visiting national parks is to experience the sounds of nature. However, human-caused sounds (i.e. talking and traffic use) have been causing disruption in these natural environments, which in turn, affect mammal species through increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers from young (Anderssen et al. 1993). With public roads running through park boundaries, Kennedy and Jennings (2007) suggest monitoring vehicle traffic and reducing flow in sensitive areas of the park.

During Kennedy (1984), it was noted that feral cats were not found inside the park, but feral dogs were abundant. Both species were discovered during the Kennedy and Jennings (2007) study and are listed on the NPS Certified Mammals Species List as common (NPS 2016b). Feral hogs are found throughout Tennessee (TWRA 2016) and have been known to disrupt native communities through rooting for food and natural predation (Tennessee State Wildlife Action Plan Team 2015), but at this time, they have not been documented inside SHIL. Kennedy and Jennings (2007) suggest that monitoring and management of feral dog and cat populations needs to occur because these species are more prone to spread diseases that could affect native wildlife (Kennedy 1984). Also, feral dogs have been known to harass both deer and raccoon (*Proctor lotor*) species, along with scaring away visitors in the park (Kennedy 1984). Feral cats have also been known to reduce mammal populations and even contribute to wildlife extinctions (Loss et al. 2013).

Tennessee's abundance of wildlife and natural resources are at risk from climate change. Slight changes in temperature or precipitation levels could disrupt the state's forest and aquatic ecosystems (Wathen et al. 2015). Throughout the CUPN, distinct seasonal variations in precipitation levels are evident (Davey et al. 2007). In the western portion of the network, where SHIL is located, winter and early spring tends to be the wettest time of the year and fall is the driest (Davey et al. 2007). Any changes to precipitation patterns, along with climate change effects such as warming temperatures, have the potential to affect mammal populations inside SHIL (Wathen et al. 2015).

Data Needs/Gaps

Updated mammal inventory or monitoring could be performed inside the park due to the most recent inventory occurring almost ten years ago (Kennedy and Jennings 2007). In addition, the park bat inventory is over ten years old, and with white-nose syndrome (WNS) having been detected inside Hardin County in 2011-12 (USFWS 2016), up-to-date data could benefit both park staff and regional bat populations. Despite the TWRA monitoring white-tailed deer populations for hunting purposes (TWRA 2015), there are no data available on white-tailed deer density within SHIL or across the entire state. With fluctuations in white-tailed deer populations causing a potential concern for hunters and general ecosystem health, monitoring deer density (or deer damage to vegetation) could inform park staff about important issues. Also, even though most of the rodents found in SHIL are native, there is little park-specific quantitative data available about the abundance of these rodent species.

Overall Condition

Species Composition

The project team assigned a *Significance Level* of 3 for species composition. Despite minor differences in research methodology and overall project scope, since the time of the Kennedy (1984) study, eight terrestrial mammal species have been newly documented by Kennedy and Jennings (2007). During both studies, no terrestrial mammal species were documented that were on the endangered species list (Kennedy 1984, Kennedy and Jennings 2007); however, the southeastern shrew, the southern bog lemming, and the meadow jumping mouse are all on Tennessee's wildlife in need of management list (TWRC 2000). Due to the aforementioned factors, the *Condition Level* assigned to this measure is 1, or of low concern.

Bat Species Richness

The project team also assigned a *Significance Level* of 3 for bat species composition. SHIL is located in an environment that has the potential to provide valuable habitat for bat populations (Kennedy 2002). Again, despite minor differences in research methodology and overall project scope, from the Kennedy (1984) to the Kennedy (2002) study, bat species richness had actually declined (from 10 bats verified to seven verified), but according to the NPS Certified Mammals Species List (2016b), 14 bat species are present or probably present inside the park. Of the bats documented inside the park, the gray bat is on the endangered species list (Kennedy 2002), the northern long-eared bat is considered a threatened species (USFWS 2015), while both the southeastern bat (Kennedy 2002) and the Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) (NPS 2016b) are considered a rare species (Kennedy 2002, NPS 2016b). The Rafinesque's big-eared bat is also on the Tennessee Wildlife in Need of Management list (TWRC 2000). Due to bat species richness staying fairly stable, or even decreasing, this measure is currently of moderate concern (*Condition Level* = 2).

White-tailed Deer Density

This measure was assigned a *Significance Level* of 2. The abundance and density of white-tailed deer populations can have a large influence on the surrounding plant communities, wildlife populations, and overall ecosystem (Côté et al. 2004, Kennedy and Jennings 2007). Kennedy and Jennings (2007) emphasize the importance of monitoring white-tailed deer populations for conservation of park biodiversity. The TWRA (2015) actually does some monitoring throughout Tennessee, but density is not included in this monitoring. SHIL park management has articulated that white-tailed deer densities of 20-30 deer per square mile is considered appropriate for the SHIL area (Allen, personal communication, 11 March 2015), but according to research conducted through the USFS, plant communities can survive and thrive when white-tailed deer densities are around 15-20 per square mile. At the time of this writing, there are no white-tailed deer density data available for SHIL, thus a *Condition Level* cannot be assigned.

Native Rodent Abundance

A *Significance Level* of 3 was assigned for native rodent abundance. According to Kennedy (1984) and Kennedy and Jennings (2007) the white-footed mouse, the woodland vole, and the eastern gray squirrel (respectively) are considered abundant in the park. In terms of nativity, the majority (86%) of the rodents found in the park were native (only one was non-native and considered probably present) (NPS 2016b). Despite the high number of native rodent species, due to a lack of quantitative data on rodent abundance at SHIL, a *Condition Level* cannot be assigned at this time.

Weighted Condition Score

A *Weighted Condition* Score of 0.50 was assigned for this component. Due to SHIL sitting in an ecologically diverse and rich area of Tennessee, it provides suitable habitat for many mammal populations (Kennedy and Jennings 2007). Monitoring of these mammal species inside SHIL could potentially reflect the mammal biodiversity for the wider region (Kennedy and Jennings 2007). Even though the mammal surveys used in this analysis provided sufficient species richness data, they are both almost or over ten years old (Kennedy 2002, Kennedy and Jennings 2007). Due to these factors, along with a lack of quantitative data regarding white-tailed deer density and native rodent abundance, a *Condition Level* cannot be assigned at this time.

Mammals			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Species composition	3	1	
Bat species richness	3	2	
White-tailed deer density	2	N/A	
Native rodent abundance	3	N/A	

4.3.6. Sources of Expertise

- Steven Thomas, CUPN Monitoring Program Leader
- Marcus Johnson, SHIL Natural Resource Management Specialist

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4.4. Birds

4.4.1. Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Despite being recognized more for the historic nature of the park, SHIL is home to several unique habitat types. The hardwood forest community of the park supports many forest-dependent species, the Owl Creek wetlands in the northwest portion of the park support many riparian species, and the grasslands of the park, while mowed regularly, support some lower numbers of grassland-dependent bird species. Recently established beaver pond habitat in the park's southeast corner provides habitat for several wetland and wading species such as the American bittern (*Botaurus lentiginosus*) (Photo 11) and the least bittern (*Ixobrychus exilis*). Some cavity nesting bird species also utilize the cannon tubes scattered across the park as nesting habitat (Photo 12).

Photo 11. An American bittern (*Botaurus lentiginosus*) wading through a wetland area (NPS).

Photo 12. An eastern bluebird (*Sialia sialis*) nest inside one of the many cannon tubes scattered across SHIL (NPS).

SHIL has confirmed the presence of 186 bird species within the park (Appendix E), and another 39 species are identified as unconfirmed, but likely occurred historically within the general area of the park (NPS 2016). While still unconfirmed in the park, priority species such as the Bachman's sparrow (*Peucaea aestivalis*) and Bewick's wren (*Thryomanes bewickii*) (both state-listed as endangered species), may be present in the park at various stages of the year. The Bewick's wren has been observed in the park in the past decade, but its official status remains unconfirmed on NPS (2016).

4.4.2. Measures

- Passerine species richness
- Raptor species richness
- Species diversity
- Turkey density

4.4.3. Reference Conditions/Values

The reference condition for the birds component in SHIL will be the Stedman and Stedman (2006) avian inventory of the park. This study represents the most recent inventory that has occurred in the park. While no new data are available to compare to Stedman and Stedman (2006) for this assessment, that inventory will serve as a valuable baseline for future comparisons or condition assessments.

4.4.4. Data and Methods

Research regarding the avian communities in SHIL has been extremely limited, and Stedman and Stedman (2006) represent the only avian-specific inventory effort to occur within the park. This inventory took place from 2004-2005, and utilized five different survey methodologies in an effort to identify as many bird species as possible within the park. The most regimented survey methodology utilized during Stedman and Stedman (2006) was the point count technique. Fifteen point counts were established in the park and were surveyed twice a year in late May. Observers stood at the point for 10 minutes and identified all birds heard and seen within a 100 m (328 ft) diameter area; flyover species were also included in observation records. Observers recorded the species observed, the distance interval of each observation (<25 m [82 ft], 50-100 m [164-328 ft], and >100 m [328 ft]), and the temporal interval that the bird(s) were observed (0-3 min, 3-5 min, 5-10 min).

The second survey methodology used by Stedman and Stedman (2006) was a migration walk. Observers took three or four walks in both the spring and fall seasons of 2004 and 2005. These walks lasted between 1 and 2 hours and generally went for 1.5 km (1 mi). The purpose of the migration walk was to traverse habitats that may be suitable for migrant bird species; all species seen or heard during these walks were recorded.

Stedman and Stedman (2006) also conducted raptor-specific surveys in SHIL. These surveys generally lasted 2-4 hours, and were completed during the late mornings in the fall and early winter. Raptor surveys were conducted via an automobile, and followed a consistent route along all of the roads of the Shiloh Battlefield Unit (about 15 km [9.3 mi]). All raptor species (and shrike species) that were seen or heard were documented by observers.

The fourth survey type utilized by Stedman and Stedman (2006) was a nighttime survey. These surveys were mostly informal, and were useful in identifying owl and nightjar species. Tape-recorded owl calls were used in an attempt to elicit a response from owls at each site. All species that were heard or seen were recorded.

The final survey type used by Stedman and Stedman (2006) was a general inventory of the park. This inventory involved relatively informal visits to habitat sites in the park that were suspected to support bird species. These searches also documented all suspected breeding species, and documented species that were confirmed as breeding, probable as breeding, or possible as breeding. Additional searches focused on the Tennessee River area at dawn and dusk, while hawk-specific watches occurred from the bluff near Dill Branch. All of the species that were seen or heard during these searches were recorded.

An annual Christmas Bird Count (CBC) is centered just outside of SHIL boundaries and has been completed almost every year since 1966. The Savannah CBC is part of the International CBC, which started in 1900 and is coordinated by the Audubon Society. Data from the Savannah CBC are available for 34 years: 1965-73 and 1987-2014. Multiple volunteers surveyed a 24-km (15-mi) diameter area on one day, typically between 14 December and 5 January, by foot, boat, and car. The center point of the 24-km (15 mi) diameter was 35.163222ºN, -88.166627ºW (Figure 13). Unlike surveys that occur during the breeding season (such as the North American Breeding Bird Survey [BBS]), the CBC surveys overwintering and resident birds that are not territorial and singing. The total number of species and individuals were recorded each year; data from the Savannah CBC have been modified for this assessment to only include passerine species, raptor species, or wild turkeys in accordance with the measures identified above.

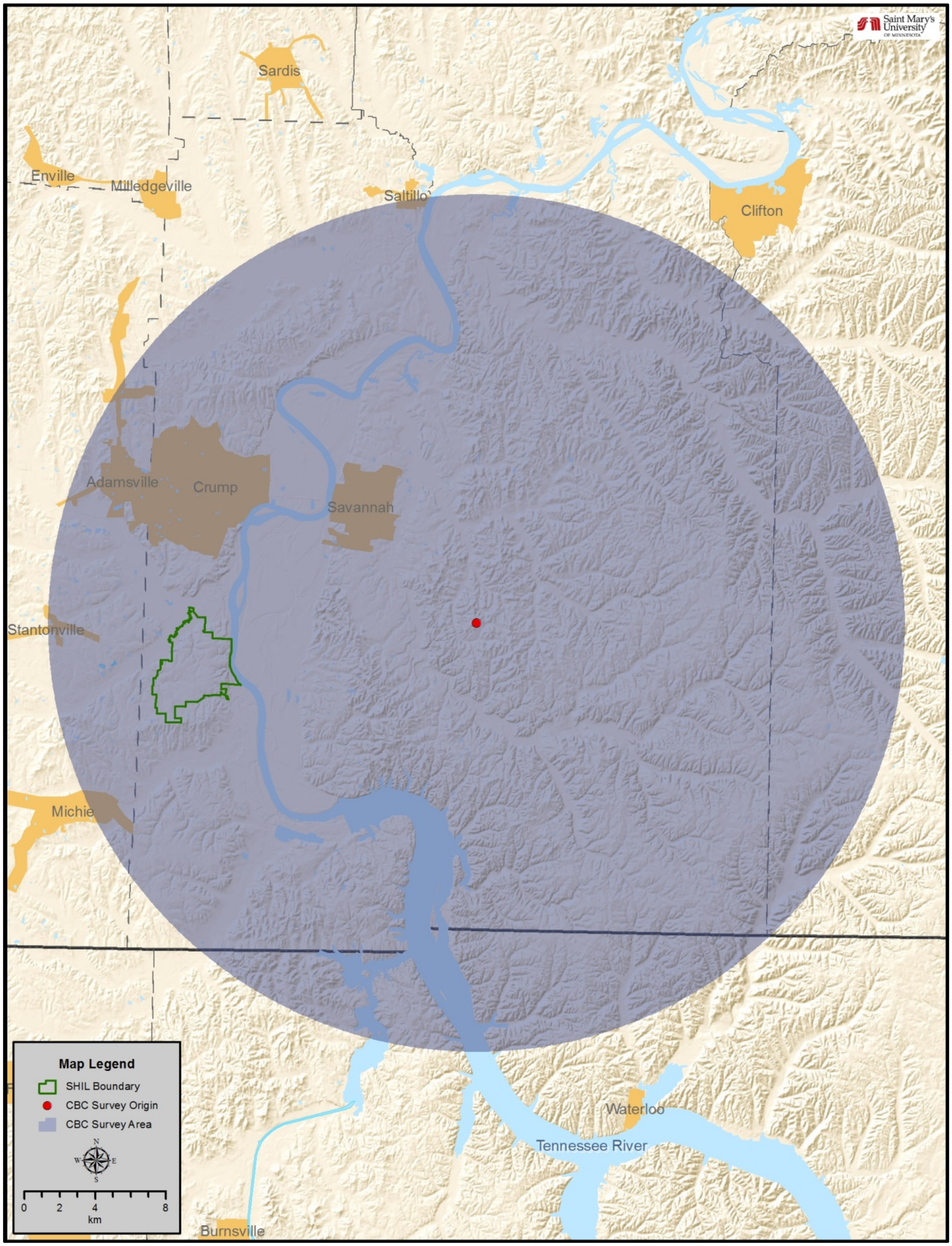

Figure 13. The Savannah Christmas Bird Count study area. The diameter of the count circle is 24 km (15 mi).

There were also some sporadic bird surveys conducted in SHIL between 1933 and 1974, as 57 field trips to SHIL were organized by the Memphis Chapter of the Tennessee Ornithological Society. Trips primarily took place following the major roads along the self-guided auto tour of the park and occurred most often during April, May, and June, although surveys were completed in every month of the year except for January. While these surveys pre-date Stedman and Stedman (2006) by many years, the data are not completely documented and incomplete hardcopy field sheets exist for these survey efforts, so the exact methodology and survey routes are unknown. The species that were observed during these efforts are presented in Appendix E and are referenced below when appropriate.

4.4.5. Current Condition and Trend

Passerine Species Richness

Passerines are birds that belong to the order Passeriformes, commonly referred to as "perching birds." The species richness measure can indicate overall habitat suitability for passerines, and is vital to understanding the effects of changing landscapes on native biodiversity. However, there may be undetected changes in the species richness of native species compared to non-native species, or in Neotropical migrant species compared to resident species. Such changes would not be apparent in the tables and figures presented in this document.

NPS Certified Species List (NPS 2016)

The NPS Certified Bird Species List contains 225 species, 133 (59%) of which are passerine species (Appendix E). When excluding species that have not been confirmed in the park, the total number of species in SHIL drops to 186 species, 112 (60%) of which are passerines. This list, however, does not allow for a specific analysis of annual species richness, as no data are collected yearly, and the list only documents the presence (or historic presence) of the identified species. The NPS Certified Bird Species List was largely assembled based on the work of Stedman and Stedman (2006), as there was no SHIL checklist for bird species prior to Stedman and Stedman (2006). The list was last certified by the NPS in 2007 and has not been reviewed since that time (Moore, written communication, 2 June 2016). A detailed discussion of Stedman and Stedman (2006) is provided below.

Stedman and Stedman (2006)

During 2004 and 2005 surveys and inventories in SHIL, Stedman and Stedman (2006) identified 203 species, of which 186 were confirmed as present (the remaining 17 species were identified as probably present based on historic regional records). Of these 186 confirmed species, 112 species (60%) were identified as passerines (Appendix E). Stedman and Stedman's (2006) 2004 and 2005 point count surveys yielded 48 unique passerine species in SHIL, with results being nearly identical in both years. 2004 counts identified 43 passerine species, while 2005 counts identified 42 passerine species (Appendix F). The species richness results of the other various survey techniques were not reported in Stedman and Stedman (2006).

In addition to documenting all species that were observed during their inventory and survey efforts, Stedman and Stedman (2006) also documented possible, probable, and confirmed breeding species in the park. Thirty-five species were documented as breeding within SHIL, with an additional 20 species identified as probably breeding in the park. Only three species were documented as having possible breeding sites within SHIL.

The order Passeriformes makes up more than half of all living species of birds (Ericson et al. 2002), so it is not surprising to find that the majority of the bird species observed by Stedman and Stedman (2006) belonging to this order. Continued monitoring is needed to identify any trends in species richness of passerines in order to more accurately understand the current condition of this measure.

Savannah Christmas Bird Count (1966-2015)

The Savannah CBC survey area encompasses SHIL (Figure 13). Counts such as the CBC (or other index counts, e.g., breeding bird surveys) are neither censuses nor density estimates (Link and Sauer 1998). Possible biases of count locations and the number of observers limit the overall usefulness of index count data, and it is often not advisable to estimate overall population sizes from these data alone (Link and Sauer 1998); these biases may influence how many individuals are observed in a given year, and may potentially explain the annual variation observed in species each year. Results of the Savannah CBC should be interpreted with a degree of caution.

During the 34 years of CBC efforts for the entire Savannah count circle, 74 passerine species have been observed. The highest number of passerine species observed in a given year was 57 (1994; 12 observers), while the lowest number of species observed was 35 (1965, 1967-68; eight, three, and four observers, respectively) (Figure 14). The average number of passerine species observed during the Savannah CBC was 47.5, and the average number of observers per year was 9.5.

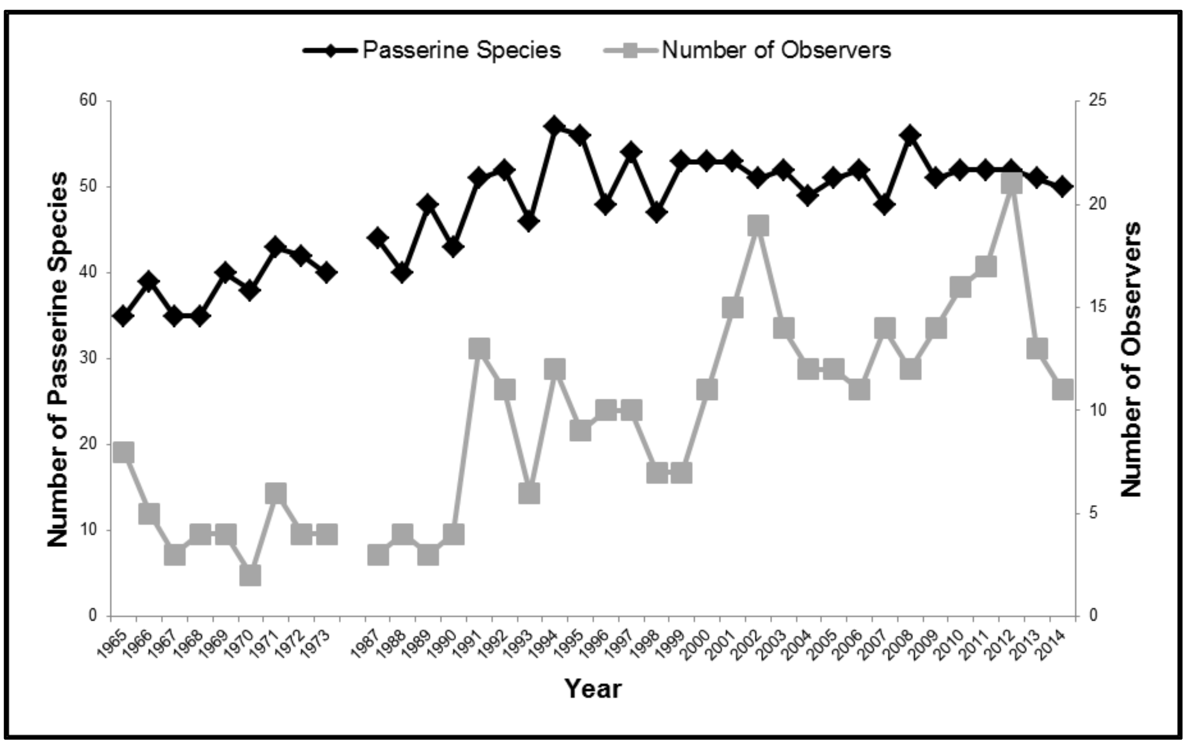

Figure 14. Number of passerine species and observers during the Savannah CBC from 1965-2014. Note that data include all count circle results and are not specific to SHIL.

Memphis Chapter of the Tennessee Ornithological Society Visits (1933-1998)

Members of the Tennessee Ornithological Society visited SHIL on occasion throughout all seasons from 1933-1999. In total, 203 different species were suspected to occur in the park based on observations from the surrounding areas, and 162 species were confirmed in the park. Of the 162 confirmed species, 111 were passerine species (69%; Appendix E).

Raptor Species Richness

Raptors are top-level predators and are excellent bioindicators of the health of their associated ecosystems (Morrison 1986, Hutto 1998). In the 1940s, raptor populations across North America experienced a population decline due to the use of organophosphates (e.g., dichlorodiphenyltrichloroethane – DDT) as insecticides. Bioaccumulation of these chemicals (particularly DDE, a persistent metabolite of DDT) inhibited calcium metabolism in many raptor species (Fischer 2000). As a result, affected birds laid eggs that were too thin for successful incubation; eggs that did not break during incubation often contained dead embryos, and mortality rates for hatchlings were high (Fischer 2000).

DDT was banned in the United States in December 1972 and reproductive success rates subsequently increased following this ban (Fischer 2000). Species especially affected by the use of organochlorines, such as the peregrine falcon (*Falco peregrinus*), experienced a dramatic population recovery following the ban. Some affected raptor species recovered to population levels that allowed for their removal from the Endangered Species List (the peregrine falcon was delisted in 1999) (USFWS 2003).

The many diverse habitats of SHIL (e.g., grasslands, hardwood forests, wetlands and riparian areas) can support a variety of different raptor species. Observed raptor species in SHIL include the red-tailed hawk (*Buteo jamaicensis*), broad-winged hawk (*Buteo platypterus*), and the great horned owl (*Bubo virginianus*) (NPS 2016). The NPS Certified Bird Species List for SHIL identifies 19 raptor species in the park, with four of those species representing historical occurrences that have not been confirmed (Table 22, NPS 2016).

Table 22. Raptor species identified on the NPS Certified Bird Species List (NPS 2016). Species listed in bold were identified during field research conducted by Stedman and Stedman (2006).

Raptor Species	
Cooper's hawk	**osprey**
sharp-shinned hawk	merlin *
red-tailed hawk	peregrine falcon *
rough-legged hawk *	**American kestrel**
red-shouldered hawk	short-eared owl *
broad-winged hawk	**great horned owl**

*Species that is unconfirmed in the park, but is included due to historic or regional observations (Stedman and Stedman 2006)

Table 22 (continued). Raptor species identified on the NPS Certified Bird Species List (NPS 2016). Species listed in bold were identified during field research conducted by Stedman and Stedman (2006).

Raptor Species	
northern harrier	**eastern screech-owl**
bald eagle	**barred owl**
turkey vulture	**barn owl**
black vulture	-

*Species that is unconfirmed in the park, but is included due to historic or regional observations (Stedman and Stedman 2006)

One of the more charismatic raptor species that can be easily observed in SHIL is the bald eagle (*Haliaeetus leucocephalus*, Photo 13). The bald eagle had not been recorded as a nesting species in SHIL prior to 2007, although the species had nested downriver of the park for many years. However, in 2007 a pair of bald eagles constructed a nest in a high traffic area of the park and has occupied the territory each year since 2007; an alternate nest was constructed and used in 2013, but the pair returned to the original nest for the 2014 breeding season.

Stedman and Stedman (2006) identified 15 raptor species during 2004 and 2005 searches of SHIL (identified in bold in Table 22). According to Stedman and Stedman (2006), the number of raptor species was low in all seasons. This trend was especially evident in the grassland habitat, as species of raptors that depend on grasslands for food and habitat were either observed in low numbers or not at all. Stedman and Stedman (2006) mentioned several potential reasons for low grassland species richness values in the park, and many of these included specific park management policies on the grassland habitats. Examples of these policies included:

- Mowing often and very close to the ground;
- Using commercial lawn-type grasses rather than native species;
- Mowing in wetland areas whenever they are dry enough to be mowed;
- Mowing right up to the forest edge without leaving a buffer zone of tall grass and shrubs to provide food and cover (Stedman and Stedman 2006).

Partially in response to the suggestions of Stedman and Stedman (2006), SHIL maintenance altered the mowing regime in the park in 2013. Park maintenance cuts a 6 m (20 ft) buffer around the perimeter of the fields near the park roads; this change benefits several wildlife species by creating a buffer zone along the forest edge and also benefits the park by saving money on fuel costs (Johnson, written communication 13 June 2016).

Additional surveys of the park, preferably raptor-specific, are needed in order to establish a more accurate current condition of raptor species richness in SHIL. Traditionally, bird surveys are conducted during the breeding season, and one of the biases of breeding bird surveys is that species that are calling or vocalizing are more likely to be detected. Species that are less vocal and more reclusive or difficult to see (e.g., raptors) may not be adequately observed or represented in the data of these surveys. Until more recent and specific raptor species richness data exists for SHIL, it will not be possible to determine an accurate current condition for this measure.

Photo 13. An adult bald eagle leaving the nest in SHIL. Eagles have used this nest almost every year since 2007 (© FAYE ARMOUR).

Savannah Christmas Bird Count (1965-2014)

From 1965-2014, 21 raptor species have been observed during the Savannah CBC. The number of raptor species observed on the CBC is higher than the total number of raptor species that have been confirmed in SHIL, this may be due to the larger survey area of the CBC and potentially due to the longer period of survey data. The highest number of raptor species observed in a given year was 16 (1991, 2000, 2011), while the lowest number of species observed was three (1968) (Figure 15). The average number of raptor species observed during the Savannah CBC was 11.7.

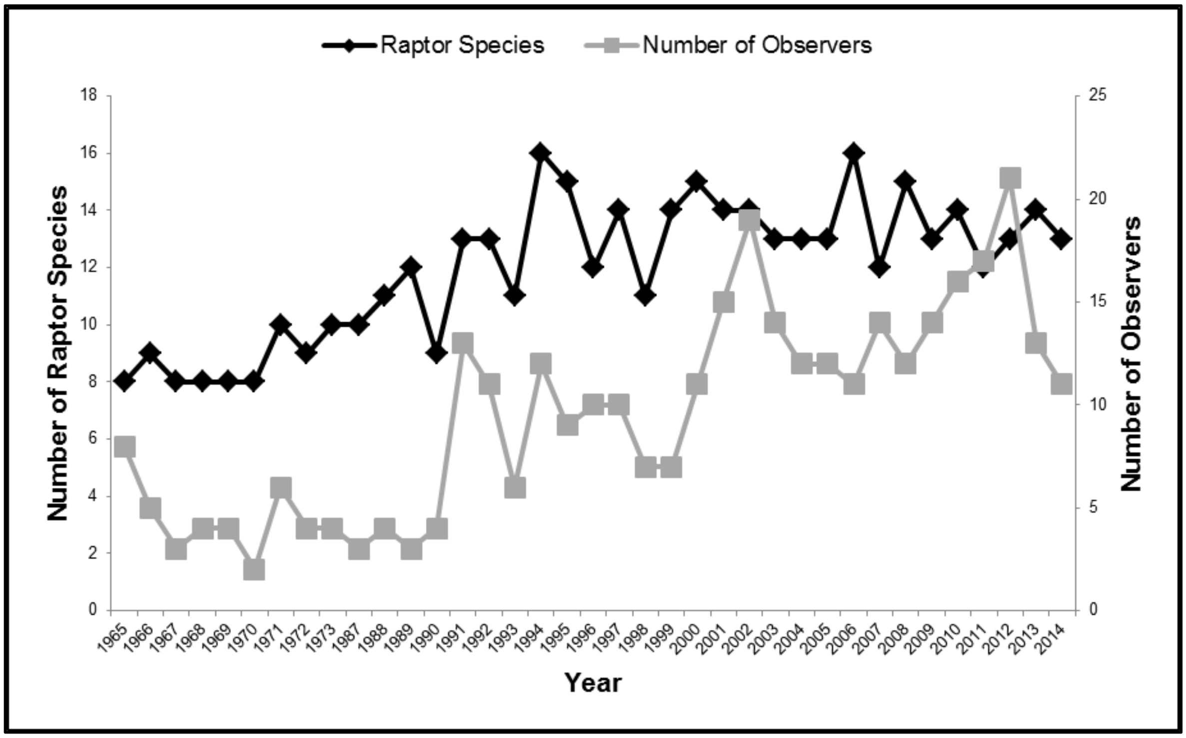

Figure 15. Number of raptor species and the number of observers during the Savannah CBC from 1965-2014. Note that data include all count circle results and are not specific to SHIL.

Memphis Chapter of the Tennessee Ornithological Society Visits (1933-1998)

The Tennessee Ornithological Society documented 18 raptor species that may occur in the SHIL area, and confirmed the presence of 14 species within the park during site visits from 1933-1998 (Appendix E).

Turkey Density

The wild turkey (*Meleagris gallopavo*) exists in a wide variety of habitats across its native range (historically in 39 states in the Unites States), and the bird was almost driven to extinction shortly after North America was colonized by Europeans (Dickson 1992). By 1920, wild turkey populations had been extirpated in 18 of the 39 states within the species' native range (Dickson 1992). Wild turkeys were historically present in the SHIL area. In an effort to re-establish the SHIL population, the NPS, in cooperation with the Tennessee Wildlife Resources Association (TWRA), had reintroduced between 75 and 100 turkeys to the park (Watson 2005). Population numbers nationwide have returned to high levels, and hunting seasons exist for the species in nearly every state where it is found.

Currently, no monitoring of wild turkey density exists in SHIL. Stedman and Stedman (2006) confirmed breeding evidence of the species in the park, and hens and their poults are commonly observed in the park (Photo 14). Stedman and Stedman (2006) identified only two individuals on point counts in 2004, and six individuals in 2005. However, it should be noted that these point counts were conducted in May/June, which is well after turkey breeding activity which normally occurs in the spring, and thus the species would be much less vocal and detectable by auditory surveys. Until a more in-depth and species-specific survey occurs in the park, the current condition of turkey density in the park cannot be determined.

Photo 14. A hen and four poults observed in SHIL (NPS).

Wild turkeys were among the 74 species reported during the Savannah CBC between 1965 and 2014. While density estimates were not reported during this effort, abundance estimates were calculated. Peak wild turkey abundance during the CBC efforts was observed in 2012, and 128 wild turkeys were identified. The average wild turkey abundance for the duration of the CBC was two turkeys per year. Wild turkeys were only observed during 3 years before 1999 (1989, 1994, 1997), but the species was more frequently observed in higher numbers starting in 1999 (Figure 16). Average turkey abundance from 1999-2014 was seven turkeys per year.

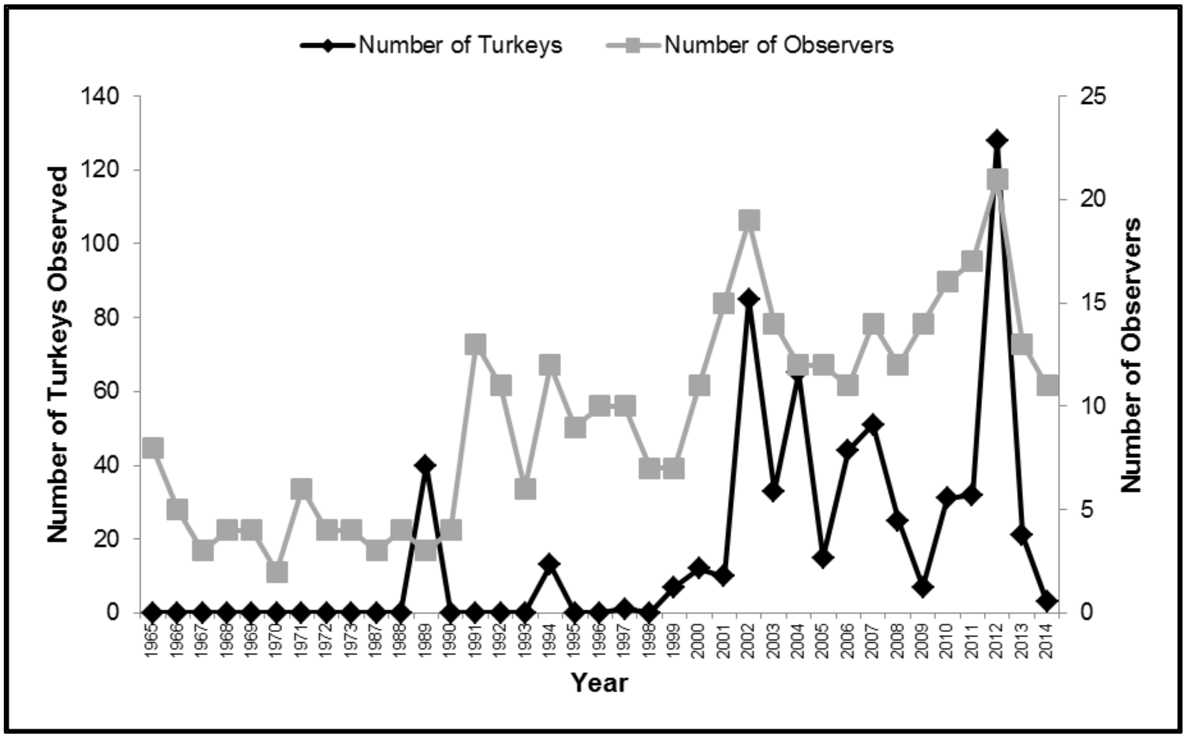

Figure 16. Wild turkey abundance and the number of observers during the Savannah CBC from 1965-2014. Note that data include all count circle results and are not specific to SHIL.

Threats and Stressor Factors

Stedman and Stedman (2006) identified several threats to the avian community in SHIL that were tied closely to management activities of the park. SHIL staff has the difficult task of balancing the preservation of the historical and cultural artifacts of the battlefield with creating and maintaining the natural habitat of the native faunal species in the park. Grassland and shrub-scrub dependent species were observed in low numbers during Stedman and Stedman (2006), and one hypothesis for this trend was that the intense mowing and application of pesticides in grassland areas created a lack of habitat for these species. The historic timing and location of mowing and pesticide application likely prevented many grassland species from breeding in the park; however, recent changes to the mowing regime will hopefully provide more buffer habitat for breeding bird species in the park. A more extensive investigation into this avian community and how it is affected by park maintenance activities is needed.

While the threat of predation is a natural occurrence for avian species, there are several instances of predation from non-native predators that represent a more substantial threat. Domestic and feral cats (*Felis catus*) are one of the largest causes of bird mortality in the United States. According to Loss et al. (2012), annual bird mortality caused by outdoor cats is estimated to be between 1.4 and 3.7 billion individuals. The median number of birds killed by cats was estimated at 2.4 billion individuals, and almost 69% of bird mortality due to cat predation was caused by un-owned cats (i.e., strays, barn cats, and completely feral cats) (Loss et al. 2012).

One of the major threats facing land bird populations across all habitat types is land cover change (Morrison 1986). Land cover change is not restricted to the breeding habitat; many species depend on specific migratory and wintering habitat types that are also changing. The encroachment of non-native plant species may be a contributor to land cover change in all habitats. Altered habitats can compromise the reproductive success or wintering survival rates of species adapted to that habitat. They can also allow generalist, non-native species, such as the European starling (*Sturnus vulgaris*) or house sparrow (*Passer domesticus*), to move in and outcompete native bird species. Grassland and shrub-scrub dependent species in SHIL, such as the eastern meadowlark (*Sturnella magna*) and field sparrow (*Spizella pusilla*), require specific vegetative communities for successful nesting to occur. A loss or alteration of these vegetative structures, or competition for resources from non-native species could compromise the nesting success of these native species in SHIL.

As urban areas continue to develop and grow, modern alterations to the landscape often foster competition between native and non-native bird species. Human-made structures may fragment and reduce the continuity of a landscape, and often as these changes occur, non-native bird species are able to inhabit the areas. Marzluff (2001, pp. 26-28) states that, "The most consistent effects of increasing settlement were increases in non-native species of birds, increases in birds that use buildings as nest sites (e.g., swallows and swifts), increases in nest predators and nest parasites (brown-headed cowbirds [*Molothrus ater*]), and decreases in interior- and ground-nesting species." Non-native bird species can often be observed at SHIL, and include species such as rock dove (*Columba livia*), Eurasian collared-dove (*Streptopelia decaocto*), European starling, and house sparrow.

Migratory bird species also face deteriorating habitat conditions along their migratory routes and wintering grounds. Most of the birds that breed in the United States winter in the Neotropics (MacArthur 1959); deforestation rates in these wintering grounds have occurred at an annual rate up to 3.5% (Lanly 1982). While forest and habitat degradation does occur in the United States, it does not approach the level of degradation seen in the tropics (WRI 1989). Furthermore, Robbins et al. (1989) supported the suggestion that deforestation in the tropics has a more direct impact on Neotropical migrant populations than deforestation and habitat loss in the U.S.

Avian brood parasite species (e.g., brown-headed cowbird) represent a threat to several avian species in SHIL. Brood parasites are species that lay their eggs in the nests of other breeding species, which then in turn incubate and care for the young (Photo 15, Payne 1977). Brood parasitism generally reduces the reproductive success of the host species, as host species typically fledge fewer young compared to non-parasitized parents of the same species (Payne 1977).

Photo 15. Brown-headed cowbird egg (mottled color), that has been laid in a chipping sparrow (*Spizella passerina*) nest (NPS).

Brown-headed cowbirds are a native species in SHIL, but human development and forest fragmentation across their range has likely contributed to an increase in abundance and elevated the levels of brood parasitism on some species (Smith et al. 2000). Cowbirds can directly contribute to the reduced nesting success of host species, as they will often puncture or remove host species eggs (Freidmann 1963). Brown-headed cowbirds often hatch earlier than host species eggs, and grow larger and faster than the host species, which often results in the death of the host chicks due to starvation, neglect, overcrowding, or direct mortality by trampling or removal from the nest (Freidmann 1963, Payne 1977). Many breeding species are targeted by brood parasites, although warblers, blackbirds, and vireos are among the most commonly parasitized species. While a natural phenomenon, brood parasitism can be actively managed against; instances of cowbird egg removal from host nests has resulted in increases in reproductive success in various parts of the species' home range (Mayfield 1960, Walkinshaw 1972, Payne 1977).

Climate change is one of the major forces affecting bird communities across the globe; this threat is becoming better understood as research and data continue to become available. Changes in the temperature and precipitation norms in the park could have both direct and indirect effects on the breeding bird community of SHIL. An example of a direct impact to the bird community in the park includes potential shifts in the timing of spring plant phenology, while indirect impacts resulting from shifts in temperature and precipitation could include effects on the frequency, extent, and severity of insect outbreaks. These insect outbreaks often have lasting effects on communities, as tree mortality can influence the overall habitat structure and species composition of areas for many years.

Another climate-related threat facing breeding landbird populations is the shifting of species' reproductive phenology. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins (*Turdus migratorius*) in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success and population declines (Jones and Cresswell 2010).

The North American Bird Phenology Program (BPP) is currently analyzing the migration patterns and distribution of migratory bird species across North America (USGS 2008). Information from this analysis will provide new insights into how bird distribution, migration timing, and migratory flyways have changed since the later part of the 19th century. This information may also be applied to estimate changes in breeding initiation periods in specific habitats.

Data Needs/Gaps

The establishment of an annual bird monitoring program in SHIL is needed in order to accurately assess the current condition of this community in the park. Utilization of point counts during the breeding or migratory seasons would help give managers a better understanding of the overall avian community and could potentially help to expand the park's species list. Other survey methodologies, such as winter surveys, raptor road surveys, or general inventories, would also be beneficial. Specific research regarding what potential detrimental effects mowing or pesticides have on grassland species would also be of value. Monitoring of the turkey population in SHIL would also better inform the turkey density measure.

Watson (2005) identified several data gaps that were present for SHIL's bird community. These data gaps included:

- The need for abundance and distribution data in order to fully understand the current status of birds in the park. This would also allow for conservation actions to be implemented for priority bird species;
- Efforts to identify appropriate monitoring programs for high priority bird species and habitats are needed;
- The establishment of a monitoring program, based on Stedman and Stedman (2006)'s final inventory, in order to measure abundance and population trends for high priority species across a variety of habitats;
- Standardization of monitoring methodology is needed to conform to NPS and or U.S. Fish and Wildlife Service (USFWS) recommended standards (Fancy and Sauer 2000, Hunter 2000).

Overall Condition

Passerine Species Richness

The project team assigned the passerine species richness measure a *Significance Level* of 3 during project scoping. Species richness values as detected by Stedman and Stedman (2006) were about what was expected by the authors prior to the inventory; although not as many grassland passerine species were observed as was expected. High species richness values were observed in the park's Owl Creek Bottomlands and beaver ponds. Uncommon species, such as the LeConte's sparrow (*Ammodramus leconteii*), Connecticut warbler (*Oporornis agilis*), Bell's vireo (*Vireo bellii*), and Swainson's warbler (*Limnothlypis swainsonii*) were also observed in the park during the Stedman and Stedman (2006) inventory. Results from the nearby Savannah CBC have been stable in the past six years, although trends and estimates of passerine richness are difficult to obtain from CBC due to variability in sampling intensity, the ability of the volunteers, and timing (migratory species likely not sampled). While existing data appear to indicate low concern for the passerine species richness measure, an inventory or survey has not been completed in the park in the last 10 years. A *Condition Level* of 0, indicating no concern, was assigned to this measure.

Raptor Species Richness

The raptor species richness measure was assigned a *Significance Leve*l of 2 during project scoping. Stedman and Stedman (2006) noted low overall raptor species richness levels in the park during monitoring from 2004-2005, and raptors depending on grassland habitats were either not observed, or were observed in lower than expected numbers. A *Condition Level* of 1, indicating low concern, was assigned to this measure. However, additional data are needed to more accurately assess the current condition of raptor species richness in the park.

Turkey Density

The turkey density measure was assigned a *Significance Level* of 3 during project scoping. Despite reintroduction efforts in the park and surrounding areas during the twentieth century, no formal monitoring or surveys of wild turkeys have taken place in SHIL. The species is observed during CBC efforts in the area, and visitors also frequently encounter the species as they travel through the many park roads and loops. Until additional data become available, a *Condition Level* cannot be assigned to this measure.

Weighted Condition Score

A *Weighted Condition Score* of 0.13 was assigned to the bird component, which indicates that the resource is currently in good condition. This condition designation is assigned with low confidence, primarily due to the fact that the main data source used in this component are now over 10 years. Due to the lack of recent data, a trend was not assigned to this component.

Birds			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.13**
Passerine Species Richness	3	0	
Raptor Species Richness	2	1	
Turkey Density	3	N/A	

4.4.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager

- Marcus Johnson, SHIL Natural Resource Management Specialist

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4.5. Native Fish

4.5.1. Description

SHIL contains multiple streams and a few small ponds that support aquatic ecosystems. Water resources within the park include the isolated Bloody Pond and the Tilghman and Shiloh Branches, two major streams that lead into Owl Creek along the northwestern edge of SHIL (Photo 16). Smaller streams connect with these branches, and together they host diverse communities of native fish species (Higgins 1998). Fifty-one total fish species were inventoried in the park, with 49 of those being native to SHIL (Higgins 1998, NPS 2016). The two non-native species discovered were the yellow perch (*Perca flavescens*) and the grass carp (*Ctenopharyngodon idella*). Some fish species were more prevalent than others, including the creek chub, western mosquitofish (*Gambusia affinis*), southern redbelly dace, striped shiner, spotfin shiner (*Cyprinella spiloptera*), ribbon shiner (*Lythrurus fumeus*), and the threadfin shad (*Dorosoma petenense*) (Higgins 1998).

Photo 16. Tilghman Branch starts in SHIL and flows northward into Owl Creek (NPS).

4.5.2. Measures

- Species composition
- Species diversity
- Habitat/stream integrity
- Water quality

4.5.3. Reference Conditions/Values

Higgins' (1998) fish baseline inventory was selected by SHIL staff as the reference condition for all five measures since it is currently the only available source of native fish information for the park. Since this study represents the only fish data source for this assessment, it could be used as a baseline for future inventories or surveys of the park's native fish community.

4.5.4. Data and Methods

Higgins (1998) represents the first, and only, native fish inventory that has taken place within SHIL's boundaries. Sampling occurred from 1995 to 1997 in the small spring-fed streams that originate within SHIL's boundaries. The sampled streams, which together comprised 13.7 km (8.5 mi), included: Owl Creek Drainage (Tilghman Branch, Mulberry Spring Branch, Shiloh Branch, Picnic Branch, and Owl Creek Beaver Ponds [three ponds counted as one]); Tennessee River Drainage (Dill Branch, Mounds Branch, Riverbottoms Branch, Hagy Branch, Rogers Branch, Johnson Branch, Quarry Branch, and Owl Creek) (Higgins 1998).

The timing of Higgins (1998) sampling efforts was coordinated to ensure all collections and observations occurred during low water levels because of the accessibility of the fish and to sample in "natural state" conditions. When the Tennessee River floods, it brings more fish than normal into the SHIL streams found, and it was important to sample when the water level was in a more realistic state (Higgins 1998). Observations occurred during the day due to the presence and activity of venomous cottonmouths (*Agkistrodon piscivorus*) at sampling locations at night. Because of this timing, nocturnal fish species such as pirate perch (*Aphredoderus sayanus*), brown madtom (*Noturus phaeus*), black bullhead (*Ameiurus melas*), and yellow bullhead (*Ameiurus natalis*) may have been underrepresented in the data.

Higgins (1998) first attempted to inventory the park's fish population using visual observation and recognition. However, it was later determined that in order to ensure proper identification, a specimen had to be collected. Three major methods were used for specimen collection: dip net, minnow seines, and gravel scuff trapping. The dip net method was generally found to be unsuccessful unless an individual fish could be found in a location such as an isolated pothole. Minnow seines were used most often and provided the most success. Four different sizes were utilized and would gather different fish sizes (Higgins 1998, p. 9):

1. 1.5 x 1.2 m (5 x 4 ft) seine with a mesh size of 5 mm (0.2 in) was used by one person for smaller or slender species
2. 4.6 x 1.2 m (15 x 4 ft) seine also with a mesh size of 5 mm (0.2 in) was used by two people for smaller or slender species
3. 3 x 1.2 m (10 x 4 ft) seine with a mesh size of 4 mm (0.16 in)
4. 6 x 1.2 m (20 x 4 ft) seine with a mesh size of 3 mm (0.12 in)

The 3 mm (0.12 in) mesh size provided the most success and was recommended for use in future samplings (Higgins 1998). Gravel scuff trapping is a method used to gather species that tend to hide under gravel. This method sets up a net at the tail end of riffles and the sampler scuffs the gravel with hands or feet. After the fish species were collected, they were identified to species using one of four methods: out of water/held in hand, in a jar full of clear water, in an aquarium for an extended period of time or preserved and under a 10x or 20x dissecting microscope. This process also helped determine the abundance level for species within SHIL.

NPS (2016) represents the NPS Certified Fish Species List for SHIL and contains a list of all fish species in SHIL. Occurrence in the park is identified as either being present, probably present, or unconfirmed. Other categories identified in this list include nativeness and relative abundance. Higgins (1998) is the sole source of information contained within the NPSpecies list (2016).

4.5.5. Current Condition and Trend

<u>Species Composition</u>

Higgins (1998) identified 49 native, and one non-native, fish species in SHIL during 1995 and 1996 inventories of the park (Appendix G). These 50 species represented 10 orders, 14 families, and 35 genera. There were no fish species considered to be endemic, rare, or endangered. Fish were considered to be quite small in size, ranging between 35 mm (1.4 in) and 90 mm (3.5 in), because of the small size of streams they inhabited. The largest fish discovered was a gizzard shad (*Dorosoma cepedianum*) at 295 mm (11.6 in) found behind a beaver dam in Riverbottoms branch (Higgins 1998). Any "sport" fish in SHIL would be small as well. The largest species found, in terms of gamefish, was a sauger at 270 mm (10.6 in). Additionally, Higgins (1998) identified four conditions that contributed to the unusually high fish species richness in SHIL, despite the small geographical size of the park (Higgins 1998, p. 20):

1. **Variable habitat**. Springs and spring branches flowing to clear gravel streams and on to bottomland floodplain streams with sand substrates, or beaver ponds with silt, mud, and/or clay substrate with aquatic vegetation provide variable habitat.
2. **Physiographic location**. The park is situated near the intersection of two major physiographic provinces (divisions based on prevailing geology) in Tennessee. They are the Coastal Plain (Mississippi Embayment) which is dominated by Cretaceous to Quaternary geological formations consisting of mainly sands, hard clays, and silt, and the Highland Rim which is composed primarily of limestones and chert, and some shales (Etnier and Starnes 1993). Shiloh adjoins the west bank of the Tennessee River which more or less divides the two provinces.
3. **High ground**. Most of the park is located on the highest ground in the vicinity, well above the Tennessee River flood plain. The small, clear spring fed streams originate from within and flow out of the park, so except for the bottomlands along the park boundary, contamination from outside sources does not happen.
4. **Federal protection**. The streams have been protected within a National Park for over 100 years.

Higgins (1998) mentioned that an additional 32 fish species "theoretically could be considered at least part-time residents of the park" (Higgins 1998, p. 29) (Table 23) because of the SHIL boundary extending to the middle of Owl Creek and to the lowest stream level of the Tennessee River. Presently, the SHIL boundary extends to the bank of Owl Creek and because Kentucky Lake impounds water past SHIL due to the damming of the Tennessee River at the confluence of the Ohio River in Kentucky, a portion of the eastern boundary of SHIL is underwater (Joe Meiman, NPS Hydrologist, written communication, 9 February 2016). The SHIL park staff does not manage these waters, thus these additional 32 species were not included in the inventory.

Table 23. Fish species listed by Higgins (1998) as being possibly present in SHIL waters at some point in the year. The NPS Certified Fish Species List for SHIL identifies 51 fish species in the park. The additional species discovered was the non-native grass carp (NPS 2016).

Scientific Name	Common Name	Scientific Name	Common Name
Ichthyomyzon castaneus	chestnut lamprey	*Ictalurus furcatus*	blue catfish
Polyodon spathula	paddlefish	*Ictalurus punctatus*	channel catfish
Alosa chrysochloris	skipjack herring	*Noturus miurus*	brindled madtom
Cyprinella whipplei	steelcolor shiner	*Noturus nocturnus*	freckled madtom
Cyprinus carpio	common carp	*Pylodictis olivaris*	flathead catfish
Macrhybopsis storeriana	silver chub	*Esox niger*	chain pickerel
Carpiodes carpio	river carpsucker	*Cottus carolinae*	banded sculpin
Carpiodes cyprinus	quillback	*Morone chrysops*	white bass
Ictiobus bubalus	smallmouth buffalo	*Morone mississippiensis*	yellow bass
Ictiobus cyprinellus	bigmouth buffalo	*Morone saxatilis*	striped bass
Ictiobus niger	black buffalo	*Micropterus dolomieu*	smallmouth bass
Moxostoma anisurum	silver redhorse	*Micropterus punctulatus*	spotted bass
Moxostoma carinatum	river redhorse	*Etheostoma nigripinne*	blackfin darter
Moxostoma duquesnii	black redhorse	*Percina caprodes*	logperch
Moxostoma macrolepidotum	shorthead redhorse	*Percina shumardi*	river darter
Ameiurus catus	white catfish	*Percina vigil*	saddleback darter

<u>Species Diversity</u>

There are no specific data related to species diversity within SHIL at this time, although Higgins (1998) included rough approximations of species abundance; species abundance is a component of the overall species diversity measure. The brief discussion that follows is meant to provide some context in regards to the number of species and number of individuals observed during the study, but will not accurately reflect the overall species diversity of the park.

The majority of fish identified in Higgins (1998) were found in Tilgham Branch (25 species), Shiloh Branch (21 species), and Owl Creek (18 species) (Higgins, 1998). Some common species that inhabited four or more streams included: blackspotted topminnow (*Fundulus olivaceus*), bluegill, longear sunfish (*Lepomis megalotis*), bluntnose minnow (*Pimephales notalus*), emerald shiner (*Notropis atherinoides*), and brook silverside (*Labidesthes sicculus*). The pugnose minnow (*Opsopoeodus emiliae*) was only found in one stream but is considered a common species. For a detailed list of where species were found, how many were collected, and their level of abundance, see Appendix H.

Higgins (1998) concluded that the many small streams in SHIL remained ecologically intact and supported a tremendous diversity in regards to the native fish community. SHIL was noted as having some of the last intact small stream ecosystems in west Tennessee, and likely had comparable diversity estimates with larger protected sites, such as Great Smoky Mountains National Park in eastern Tennessee (Higgins 1998).

<u>Habitat/Stream Integrity</u>

An Izaak Walton League of America "Save Our Streams" stream quality survey was completed on three streams in the SHIL area: Dill Branch, Tilghman Branch, and Shiloh Branch. This study analyzes the quality and quantity of macroinvertebrate populations which can articulate the health of a stream (Higgins 1998). According to the survey results, the three streams had excellent biological diversity for the macroinvertebrate indicator species. Even though the park has had a significant amount of human activity on the grounds, the stream ecosystems have been kept relatively intact (Higgins 1998).

In smaller streams and areas of SHIL such as the Owl Creek Beaver Ponds, a native beaver population is found. Through beaver stick and mud dams (Photo 17), minor aquatic communities, like native fish, are being supported in larger numbers than average; 36% of the total fish species discovered by Higgins (1998) were found near beaver dams (Higgins 1998). Some fish species that have been found in abundance near these beaver dams include: longnose gar (*Lepisosteus osseus*), white crappie (*Pomoxis annularis*), flier (*Centrarchus macropterus*), and the golden shiner (*Notemigonus crysoleucas*).

Photo 17. Beaver dam found in tributary of Owl Creek (NPS).

Water Quality

Fish need habitat with clean water free of excess sediments and pollutants, tolerable oxygen levels, and a specific water temperature for optimal health (Thompson and Larsen 2004). For more specific information on SHIL's water quality, please refer to Chapter 4.7 of this document.

Threats and Stressor Factors

SHIL staff identified the following threats and stressors to the park's native fish: grass carp, upstream agriculture practices, pesticide use, atmospheric deposition, drought, watershed alterations affecting water chemistry, and habitat alterations (beaver dams).

In 1989, Bloody Pond was pumped dry for maintenance and it was later refilled with water and certain fish species to help control undesirable insects, pond debris, and aquatic vegetation. Grass carp, a non-native species for SHIL, was one of those fish species added to prevent vegetation overgrowth (NPS 2015). This fish is known to dramatically reduce aquatic vegetation, which in turn can increase phosphorus levels (MnDNR 2016). Increased phosphorous levels lead to an overgrowth in algae which can create an unpleasant odor and appearance. Oxygen is consumed as algae dies and decomposes, causing fish and other organisms to suffer from the lack of oxygen (MPCA 2008).

Even though this grass carp species was introduced in the isolated Bloody Pond, there is some potential that the species could affect the native fish population through eliminating food sources, shelter and spawning substrates (USGS 2016). This could occur through intentional introduction from humans, or biotic mechanisms such as translocation from birds or other mammals into other streams.

Runoff from the surrounding landscape can deliver excessive nutrients (phosphorus and nitrogen) from agricultural fertilizers as well as persistent organic pollutants (POPs) from pesticides and other farm chemicals (Gallaher et al. 2005). At the time of the Higgins (1998) study, Owl Creek was the only stream to have significantly lower water quality because of agricultural and rural residential drainage. According to an EPA Waterbody Quality Assessment Report (EPA 2012b), the overall status of the creek is impaired and a total maximum daily load (TMDL) analysis should be performed on the creek. A TMDL calculates the maximum amount of a pollutant that is acceptable in a waterbody and allocates the necessary reductions to proper sources (EPA 2016).

Nitrogen and sulfur oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012a). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia). Wet atmospheric deposition, also known as acid rain, is a result from these air pollutants and can be a potential threat for native fish species through increased pH levels (pH <7 is acidic, 7 is neutral, and >7 is basic). Some potential threats to fish species from wet atmospheric deposition include reduced growth rate, skeletal deformities, failed reproduction, and increased mortality rates. Every lake is different depending on where it is, what the underlying geology is comprised of, and what the surrounding environment looks like (e.g., soil types can influence healthy water pH levels) (NADP 2014). Generally speaking, a healthy lake has a pH of 6.5 or greater and a lake is considered “dead” at a pH of 4 (NADP 2014). According to Higgins (1998), small springs in SHIL had a pH of 4.6 to 4.8, Owl Creek ranged from 6.3 to 8.4, Bloody Pond ranged from 6.3 to 7.5, the Tennessee River ranged from 7.2 to 8.1 and the local rainfall ranged from 5.9 to 7.8 (Higgins 1998). A more detailed discussion regarding water quality and contaminants can be found in Chapter 4.7 of this document.

Throughout the CUPN, distinct seasonal variations in precipitation are evident. In the western portion of the network where SHIL is located, winter and early spring tend to be the wettest times of the year and fall is the driest (Davey et al. 2007). Drought can affect fish populations at all stages of life through reducing migration to spawning grounds and holding areas, drying up spawning and feeding grounds, creating unbalanced water temperatures through pooling, and increasing fish injury and vulnerability to disease and predation (WDFW 2016).

Data Needs/Gaps

The data that are available are outdated, as Higgins (1998) is almost 20 years old. With the park boundary having expanded approximately 25% since the Higgins (1998) inventory (Marcus Johnson, Natural Resource Management Specialist, email communication, 31 March, 2016), an update of the fish inventory is needed to more accurately determine the current condition of the measures used in this assessment. Using modern technologies, like electrofishing techniques, could help improve accuracy and cover more area in collecting fish species. Also, determining an Index of Biotic Integrity (IBI) for SHIL will help determine the effect of human disturbances on streams and watersheds (NRCS nd). The implementation of an IBI would reflect:

- Fish species richness and composition;
- Number and abundance of species;

- Trophic organization and function;
- Reproductive behavior;
- Fish abundance;
- Condition of individual fish (NRCS nd, p. 2).

<u>Overall Condition</u>

Species Composition

The project team assigned the *Significance Level* of species composition as 3. Higgins (1998) documented 50 species in the park, with an additional 32 species suspected to be present in the general area. According to Higgins (1998), this species richness estimate puts SHIL's native fish population at, or even above, much larger protected areas with the same or similar ecoregions, relatively speaking. However, the data collected by Higgins (1998) are now out of date and are in need of an update in order to assess the current condition of the species composition measure with any certainty. As a result, a *Condition Level* cannot be assigned at this time.

Species Diversity

The project team assigned a *Significance Level* of 3 for species diversity. No study has specifically documented native fish species diversity in the park. While Higgins (1998) noted that the park had tremendous diversity when compared to other west Tennessee habitats, assessment is now almost 20 years old. Additional research is needed to determine the current diversity of the park's fish community, and until such a study takes place, a *Condition Level* cannot be assigned.

Habitat/Stream Integrity

The project team assigned this measure a *Significance Level* of 3. Due to the lack of current data, a *Condition Level* cannot be assigned at this time.

Water Quality

The project team assigned the *Significance Level* of water quality as 3. The park's water quality is discussed in detail in Chapter 4.7 of this NRCA. Water quality in SHIL is currently considered to be of low concern, and was assigned a *Condition Level* of 1.

Weighted Condition Score (WCS)

A WCS was not calculated at this time due to data gaps for three of the four measures. The current condition and any trends for native fish at SHIL are unknown.

Native Fish			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Species Composition	3	N/A	
Species Diversity	3	N/A	
Habitat/Stream Integrity	3	N/A	
Water Quality	3	1	

4.5.6. Sources of Expertise

- Marcus Johnson, Natural Resource Management Specialist
- Joe Meiman, NPS Hydrologist

4.5.7. Literature Cited

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4.6. Herpetofauna

4.6.1. Description

Herpetofauna species are considered important components of terrestrial and aquatic ecosystems, and are often used as indicator species in assessments of environmental health (ABC 2006). Reptile and amphibian taxa are often understudied in protected areas, and have become a focal topic as the shift to protecting biodiversity has become a critical goal in NPS units (Scott and Seigel 1992). In the last 10 years there have been inventory and monitoring efforts targeted at the herpetofauna in the park; these monitoring efforts have largely been instigated by the CUPN. SHIL has been an actively managed and protected ecosystem since 1894, and has large expanses of mixed forests (10 unique hardwood forest types exist in the park) interspersed with open grassy areas and river bluffs and ravines (Nordman 2004). The park boundary is flanked on the east by the Tennessee River and on the northwest by Owl Creek. Streams, springs, and ponds are sporadically located throughout the park's interior, and these aquatic habitats support numerous amphibian species that rely on fishless and unpolluted water to carry out their life cycles.

Photo 18. A five lined skink (*Eumeces fasciatus*) resting on top of a maple leaf (NPS).

4.6.2 Measures

- Species composition
- Species abundance
- Species distribution

4.6.3. Reference Conditions/Values

The 1997 and 1998 herpetofaunal surveys conducted by Pritts (1999) serve as the reference condition for this component. Thirty-one species of herpetofauna were observed during the surveys: seven frogs and toads, 10 salamanders and newts, eight snakes, three lizards and skinks, and three turtles were observed (Table 24) (Pritts 1999). Pritts (1999) did not include any reference data on abundance or distribution of individuals collected. Reference conditions for those measures are considered a data gap, and current condition will be based on best professional judgment of park staff.

Table 24. Reference condition list of species present from Pritts (1999).

Category	Scientific Name	Common Name
Frogs and toads	*Anaxyrus fowleri*	Fowler's toad
	Anaxyrus americanus americanus	American toad
	Hyla chrysoscelis	Cope's gray treefrog
	Lithobates catesbeianus	bullfrog
	Lithobates clamitans	green frog
	Lithobates sphenocephalus	southern leopard frog
	Pseudacris crucifer	spring peeper
Salamanders and newts	*Ambystoma maculatum*	spotted salamander
	Ambystoma opacum	marbled salamander
	Ambystoma talpoideum	mole salamander
	Desmognathus conanti	spotted dusky salamander
	Eurycea guttolineata	three-lined salamander
	Eurycea bislineata	two lined salamander
	Notophthalmus viridescens louisianensis	central newt
	Notophthalmus viridescens viridescens	red spotted newt
	Plethodon mississippi	(Mississippi) slimy salamander
	Pseudotriton ruber ruber	red salamander
Snakes	*Agkistrodon contortrix*	copperhead
	Agkistrodon piscivorus	cottonmouth
	Coluber constrictor priapus	black racer
	Diadophis punctatus	ringneck snake
	Heterodon platirhinos	eastern hognose snake
	Nerodia sipedon pleuralis	midland water snake

Table 24 (continued). Reference condition list of species present from Pritts (1999).

Category	Scientific Name	Common Name
Snakes (cont'd)	*Storeria dekayi*	brown snake
	Storeria occipitomaculata	redbelly snake
Lizards and skinks	*Eumeces fasciatus*	five-lined skink
	Sceloporus undulatus	eastern fence lizard
	Scincella lateralis	ground skink
Turtles	*Apalone spinifera*	spiny softshell turtle
	Terrapene carolina	eastern box turtle
	Trachemys scripta elegans	red-eared slider

4.6.4. Data and Methods

Pritts (1999) conducted herpetofaunal surveys in SHIL on nine separate trips between 17 September 1997 and 24 August 1998. Surveys were conducted by identifying all species observed by lifting logs, debris, and rocks within terrestrial habitats and also along the edges of aquatic habitats (Pritts 1999). Aquatic habitats were surveyed using seine nets, dip nets, minnow traps, and baited hoop traps (Pritts 1999). Additionally, nighttime road cruises were conducted along several of the park roads, and identification of chorusing frogs was conducted on rainy evenings and nights.

Accipiter Biological Consultants (ABC) completed a park-wide inventory of herpetofauna in order to gather baseline information on the distribution, presence, and abundance of species present in the park (ABC 2006). Stated goals and objectives of that effort were to:

1. Determine species presence information, both habitat specific and across landscapes and to document at least 90% of the species thought to occupy the park lands.
2. Document relative frequencies of occurrence by habitat type within the park.
3. Describe the distribution and relative abundance of species of special concern within the park.
4. Collect voucher specimens or photographs of species occurring in the park which are not already documented. Emphasis is put on photographic vouchers in this park (ABC 2006, p. 2).

Accipiter Biological Consultants targeted nine major habitats in SHIL (Figure 17), and the inventory was conducted from 2003 to 2005 (ABC 2006). Sampled habitats included terrestrial forests and open fields, and aquatic habitats consisting of streams, springs, bogs, and ponds (ABC 2006). Sampling for terrestrial species was conducted using cover boards in areas within floodplains or open environments and area-constrained searches within 8 m^2 (86.1 ft^2) plots were used in upland forest and woodland areas (ABC 2006).

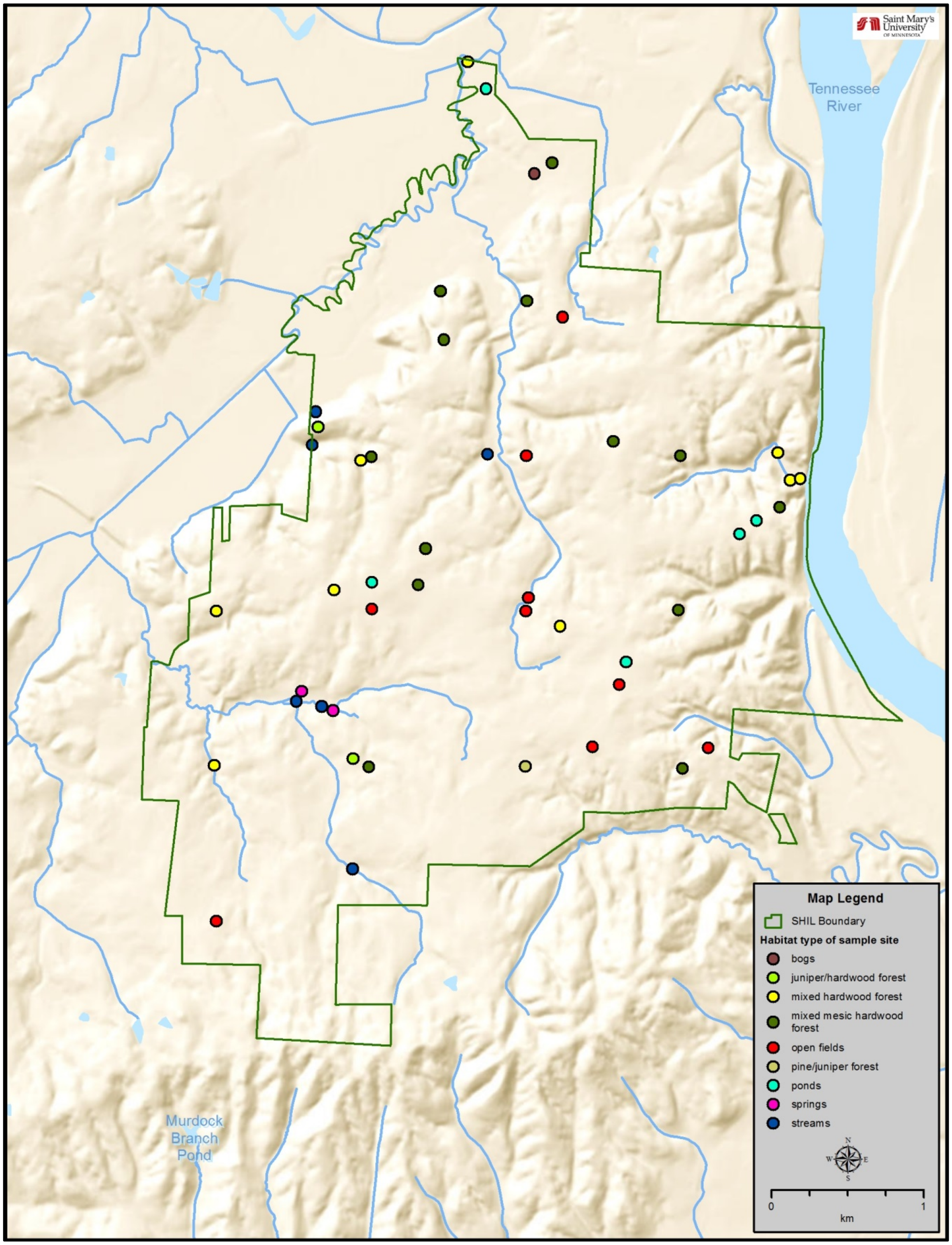

Figure 17. Locations of herpetofauna sampling in the park conducted by ABC (2006).

A total of six field methods were utilized in park, including general collecting, minnow traps, random plots (i.e., cover boards and area constrained searches), frog breeding surveys, road surveys, and drift fences (ABC 2006). Individuals captured through sampling were identified to species, sexed (if possible), measured in length (mm), weighed (g), and checked for reproductive condition.

The NPS Certified Amphibian and Reptile Species List (NPS 2016) documents the occurrence of all herpetofaunal species in NPS units. This list is available online via the NPS' Integrated Resource Management Application (IRMA) web portal at https://irma.nps.gov/NPSpecies/. All species on this list are identified as present, probably present, unconfirmed, or not in the park. These designations are determined largely by a species being documented by on-the-ground researchers/NPS staff during an inventory or survey. SHIL's Certified Species List was compiled largely using the results of Pritts (1999) and ABC (2006), and it has not been re-certified since approximately 2007 (Moore, written communication, 14 April 2016).

4.6.5. Current Condition and Trend

Species Composition

NPS Certified Species List

The NPS Certified Species List identifies 62 herpetofauna species in SHIL as present, probably present, or unconfirmed. When excluding the unconfirmed species from the total, the number of herpetofauna species in SHIL drops to 54 (Appendix I). Twenty-six species of amphibians are listed by NPS (2016) as either present or probably present in SHIL, and four species are identified as unconfirmed (Appendix I). Among amphibian species included for SHIL are 13 frog and toad species listed as present, two probably present, and two unconfirmed; eight species of salamanders and newts are listed as present, three probably present, and two unconfirmed (NPS 2016).

There are 28 reptile species documented in SHIL that are either present or probably present, and four species that are identified as unconfirmed (Appendix I). There are 10 species of snakes listed as present, six probably present, and three unconfirmed; six species of lizards and skinks are listed as present and one probably present, and four species of turtles listed as present and one probably present. The list provided by NPS (2016) was populated largely using the results of Pritts (1999) and ABC (2006) and does not provide any sort of annual species richness estimate. It represents an approximation of what herpetofaunal species one could expect to find in SHIL at any given time.

Pritts (1999)

Pritts (1999) represents the earliest herpetofauna monitoring effort in SHIL. Pritts (1999) identified 31 herpetofauna species during surveys in the park from 1997-1998, with 14 of the species being reptiles (eight snakes, three lizards, three turtles) and 17 species being amphibians (seven frogs and toads, 10 salamanders and newts) (Table 24).

ABC (2006)

ABC (2006) documented 43 herpetofauna species during inventory efforts from 2003-2005. Twenty species of reptiles (four turtles, 10 snakes, and six lizards/skinks) were identified in SHIL. The total number of herpetofauna species observed in ABC (2006) was greater than what was reported in Pritts

(1999) (43 species compared to 31 species). Variation in species composition observed between the two studies could be attributed to a variety of factors, such as weather, timing, and methodology.

In regards to reptiles, ABC (2006) documented 20 species, while Pritts (1999) documented 14. The reptile species composition varied between the two studies. ABC (2006) observed two of the three turtle species detected by Pritts (1999), but failed to detect a spiny softshell turtle (*Apalone spinifera*) (Table 25). However, ABC (2006) identified both an eastern mud turtle (*Kinosternon subrubrum*) and a common snapping turtle (*Chelydra serpentia*); neither of these species was detected in the park previously (Table 25). While neither Pritts (1999) nor ABC (2006) identified an alligator snapping turtle (*Macrochelys temminckii*), a species which is an "in need of management species" in Tennessee, the species may occur in the park in the Tennessee River.

Table 25. Turtle species in SHIL with observation records from herpetofaunal studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Apalone spinifera	spiny softshell turtle	X	-
Chelydra serpentina	common snapping turtle	-	X
Kinosternon subrubrum	eastern mud turtle	-	X
Macrochelys temminckii	alligator snapping turtle	-	-
Terrapene carolina	eastern box turtle	X	X
Trachemys scripta elegans	red-eared slider	X	X

ABC (2006) documented 11 species of snakes, including five of the eight snake species that were previously observed by Pritts (1999) (Table 26). ABC (2006) did not identify any individuals of eastern hognose snake (*Heterodon platirhinos*), brown snake (*Storeria dekayi*), or redbelly snake (*Storeria occipitomaculata*), which were previously observed by Pritts (1999) (Table 26). However, ABC (2006) did detect the worm snake (*Carphophis amoenus*), corn snake (*Elaphe guttata*), gray rat snake (*E. spiloides*), rat snake (*E. obsoleta*), yellowbelly water snake (*Nerodia erythrogaster flavigaster*), and the eastern garter snake (*Thamnophis sirtalis*), which were not observed by Pritts (1999) (Table 26). One species, the gray rat snake (which is included in the NPS Certified Species list for the park as synonymous with the rat snake) is listed as a separate species since ABC (2006) identified both snakes in the park and listed them as two distinct species (Table 26). However, it should be noted there is some disagreement amongst herpetologists regarding the taxonomy of North American rat snakes (i.e., How many unique species exist? What are the range and contact zones between taxa? etc.).

Table 26. Snake species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Agkistrodon contortrix	copperhead	X	X
Agkistrodon piscivorus	cottonmouth	X	X
Carphophis amoenus	worm snake	-	X
Cemophora coccinea	scarlet snake	-	-
Coluber constrictor priapus	black racer	X	X
Diadophis punctatus	ringneck snake	X	X
Elaphe guttata	corn snake	-	X
Elaphe spiloides	gray rat snake	-	X
Elaphe obsoleta	rat snake	-	X
Heterodon platirhinos	eastern hognose snake	X	-
Lampropeltis getula	kingsnake	-	-
Lampropeltis triangulum	milk snake	-	-
Nerodia rhombifer	diamondback water snake	-	-
Nerodia erythrogaster flavigaster	yellowbelly water snake	-	X
Nerodia sipedon pleuralis	midland water snake	X	X
Opheodrys aestivus	rough green snake	-	-
Storeria dekayi	brown snake	X	-
Storeria occipitomaculata	redbelly snake	X	-
Tantilla coronata	southeastern crowned snake	-	-
Thamnophis sirtalis	eastern garter snake	-	X

ABC (2006) observed all three lizard and skink species detected by Pritts (1999), but failed to identify the broadhead skink (*Eumeces laticeps*) (Table 27). In addition to the previously observed species, ABC (2006) identified the coal skink (*E. anthracinus*), southeastern five-lined skink (*E. inexpectatus*), and the six-lined racerunner (*Cnemidophorus sexlineatus*); neither of these species were detected in the park previously (Table 27). While neither Pritts (1999) nor ABC (2006) identified a broadhead skink, the species likely occurs in the park, as SHIL staff have photographic evidence of this species and the rough green snake (*Opheodrys aestivus*) from when they were encountered during non-herpetological monitoring activities (Johnson, written communication, 2 May 2016).

Table 27. Lizard and skink species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Sceloporus undulatus	eastern fence lizard	X	X
Eumeces anthracinus	coal skink	-	X
Eumeces fasciatus	five-lined skink	X	X
Eumeces inexpectatus	southeastern five-lined skink	-	X
Eumeces laticeps	broadhead skink	-	-
Scincella lateralis	ground skink	X	X
Cnemidophorus sexlineatus	six-lined racerunner	-	X

In regards to amphibians, ABC (2006) documented 23 species, while Pritts (1999) documented 17. The amphibian species composition varied between the two studies. ABC (2006) observed all seven frog and toad species detected by Pritts (1999), and observed eight species in addition to those observed previously (Table 28). Included in those additional eight species observed by ABC (2006) was the barking treefrog (*Hyla gratiosa*) which is a State of Tennessee species of special concern (Table 28). While neither Pritts (1999) nor ABC (2006) identified the gopher frog (*Lithobates capito*), mountain chorus frog (*Pseudacris brachyphona*), or upland chorus frog (*P. feriarum*), these species may occur in the park (Table 28). One species, the bronze frog (*Lithobates clamitans clamitans*) (which is included in the NPS Certified Species list for the park as synonymous with the green frog (*L. clamitans*) is listed as a separate species since ABC (2006) identified both frogs in the park and listed them as two distinct species (Table 28).

Table 28. Frog and toad species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Acris crepitans	northern cricket frog	-	X
Acris gryllus	southern cricket frog	-	X
Anaxyrus fowleri	Fowler's toad	X	X
Anaxyrus americanus americanus	American toad	X	X
Gastrophryne carolinensis	eastern narrowmouth toad	-	X
Hyla avivoca	bird-voiced treefrog	-	X
Hyla chrysoscelis	Cope's gray treefrog	X	X
Hyla cinerea	green treefrog	-	X
Hyla gratiosa	barking treefrog	-	X

Table 28 (continued). Frog and toad species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Hyla versicolor	gray treefrog	-	X
Lithobates clamitans	green frog	X	X
Lithobates capito	gopher frog	-	-
Lithobates catesbeianus	bullfrog	X	X
Lithobates clamitans clamitans	bronze frog	-	X
Lithobates sphenocephalus	southern leopard frog	X	X
Pseudacris brachyphona	mountain chorus frog	-	-
Pseudacris crucifer	spring peeper	X	X
Pseudacris feriarum	upland chorus frog	-	-

ABC (2006) observed five of the ten salamander and newt species detected by Pritts (1999), but failed to detect five other species that were previously detected by Pritts (1999) (Table 29). However, ABC (2006) identified the southern two-lined salamander (*Eurycea cirrigera*), northern zigzag salamander (*Plethodon dorsalis*), and southern red salamander (*Pseudotriton ruber vioscai*); neither of these species were detected in the park previously (Table 29). There were four additional species identified by NPS (2016) that were not detected by Pritts (1999) or ABC (2006): smallmouth salamander (*Ambystoma texanum*), eastern tiger salamander (*A. tigrinum*), spring salamander (*Gyrinophilus porphyriticus*), and eastern newt (*Notophthalmus viridescens*). It is possible that these species may be present but have yet to be identified during a survey (Table 29). The NPS Certified Species List includes 13 species of salamanders and newts. However, between ABC (2006) and Pritts (1999), there are an additional four species that were detected; these include the two lined salamander (*Eurycea bislineata)*, central newt (*N. v. louisianensis*), red spotted newt (*N.v. viridescens*), and the southern red salamander (Table 29).

Table 29. Salamander and newt species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Ambystoma maculatum	spotted salamander	X	X
Ambystoma opacum	marbled salamander	X	-
Ambystoma talpoideum	mole salamander	X	-
Ambystoma texanum	smallmouth salamander	-	-
Ambystoma tigrinum	eastern tiger salamander	-	-

Table 29 (continued). Salamander and newt species in SHIL with observation records from herpetofauna studies conducted in the park (Pritts 1999, ABC 2006).

Scientific Name	Common Name	Pritts (1999)	ABC (2006)
Desmognathus conanti	spotted dusky salamander	X	X
Eurycea cirrigera	southern two-lined salamander	-	X
Eurycea guttolineata	three-lined salamander	X	X
Eurycea bislineata	two lined salamander	X	-
Gyrinophilus porphyriticus	spring salamander	-	-
Notophthalmus viridescens	eastern newt	-	-
Notophthalmus viridescens louisianensis	central newt	X	-
Notophthalmus viridescens viridescens	red spotted newt	X	X
Plethodon dorsalis	northern zigzag salamander	-	X
Plethodon mississippi	(Mississippi) slimy salamander	X	X
Pseudotriton ruber vioscai	southern red salamander	-	X
Pseudotriton ruber ruber	red salamander	X	-

Species Abundance

ABC (2006)

ABC (2006) reported species abundance by determining the relative abundance factor for each amphibian and reptile species that was observed in SHIL. Relative abundance factors provide an estimate of how abundant species are compared to other species within an assemblage (ABC 2006), and were determined using the methodology of Jones (1988). Put simply, the relative abundance of a species was estimated by dividing the number of individuals observed by the number of sampling points in a certain area/habitat (ABC 2006). For this measure, only the park-wide relative abundance estimates were reported. Habitat specific relative abundance estimates are reported in the species distribution measure.

According to the data collected by ABC (2006) the four most abundant (greatest to least abundance) reptiles in the park were the eastern fence lizard (*Sceloporus undulatus*), eastern box turtle (*Terrapene carolina*), ground skink (*Scincella lateralis*), and midland water snake (*Nerodia sipedon pleuralis*) (Table 30). The eastern fence lizard is considered abundant, while the latter three are common species in the park.

Table 30. Relative abundances of reptiles observed in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Sceloporus undulatus	eastern fence lizard	2.167
Terrapene carolina	eastern box turtle	0.150
Scincella lateralis	ground skink	0.117
Nerodia sipedon pleuralis	midland water snake	0.117
Cnemidophorus sexlineatus	six-lined racerunner	0.083
Eumeces inexpectatus	southeastern five-lined skink	0.083
Nerodia erythrogaster flavigaster	yellowbelly water snake	0.083
Coluber constrictor priapus	black racer	0.067
Agkistrodon piscivorus	cottonmouth	0.050
Carphophis amoenus	worm snake	0.050
Eumeces anthracinus	coal skink	0.033
Eumeces fasciatus	five-lined skink	0.033
Chelydra serpentina	common snapping turtle	0.017
Agkistrodon contortrix	copperhead	0.017
Elaphe guttata	corn snake	0.017
Thamnophis sirtalis	eastern garter snake	0.017
Kinosternon subrubrum	eastern mud turtle	0.017
Elaphe obsoleta	rat snake	0.017
Trachemys scripta elegans	red-eared slider	0.017
Diadophis punctatus	ringneck snake	0.017

Among turtle taxa, the eastern box turtle was found in the highest abundance, followed by the common snapping turtle, eastern mud turtle, and the red-eared slider (*Trachenys scripta elegans*) (Table 31) (ABC 2006).

Table 31. Relative abundance of turtles in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Terrapene carolina	eastern box turtle	0.150
Chelydra serpentina	common snapping turtle	0.017
Kinosternon subrubrum	eastern mud turtle	0.017
Trachemys scripta elegans	red-eared slider	0.017

Among the lizard and skinks observed in the park, the most abundant were the eastern fence lizard and ground skink (Table 32) (ABC 2006). The six-lined racerunner and southeastern five-lined skink (*Eumeces anthracinus*) were next highest and in equal relative abundance to each other (Table 32). The coal skink and five-lined skink were found in low numbers (ABC 2006).

Table 32. Relative abundances of lizards and skinks in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Sceloporus undulatus	eastern fence lizard	2.167
Scincella lateralis	ground skink	0.117
Cnemidophorus sexlineatus	six-lined racerunner	0.083
Eumeces inexpectatus	southeastern five-lined skink	0.083
Eumeces anthracinus	coal skink	0.033
Eumeces fasciatus	five-lined skink	0.033

The three most abundant snake species observed in the park were the midland water snake, yellowbelly water snake, and black racer (*Coluber constrictor priapus*) (Table 33) (ABC 2006). The midland water snake was among the four reptiles found in highest overall reptile abundances in the park (ABC 2006).

Table 33. Relative abundance of the snake species in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Nerodia sipedon pleuralis	midland water snake	0.117
Nerodia erythrogaster flavigaster	yellowbelly water snake	0.083
Coluber constrictor priapus	black racer	0.067
Agkistrodon piscivorus	cottonmouth	0.050
Carphophis amoenus	worm snake	0.050
Agkistrodon contortrix	copperhead	0.017

Table 33 (continued). Relative abundance of the snake species in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Elaphe guttata	corn snake	0.017
Thamnophis sirtalis	eastern garter snake	0.017
Elaphe obsoleta	rat snake	0.017
Diadophis punctatus	ringneck snake	0.017

According to the data collected by ABC (2006) the most abundant amphibians in the park were the green frog and the southern leopard frog (*Lithobates sphenocephalus*), both of which had relative abundances more than double the next closest amphibian (Table 34). The seven most abundant species of amphibians consisted of frogs and toads (ABC 2006).

Table 34. Relative abundance of amphibians in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Lithobates clamitans	green frog	9.017
Lithobates sphenocephalus	southern leopard frog	7.700
Acris gryllus	southern cricket frog	2.833
Lithobates catesbeianus	bullfrog	2.767
Anaxyrus fowleri	Fowler’s toad	2.050
Acris crepitans	northern cricket frog	1.250
Gastrophryne carolinensis	eastern narrowmouth toad	1.000
Ambystoma maculatum	spotted salamander	0.683
Anaxyrus americanus americanus	American toad	0.500
Pseudacris crucifer	spring peeper	0.333
Hyla chrysoscelis	Cope’s gray treefrog	0.250
Desmognathus conanti	spotted dusky salamander	0.233
Hyla avivoca	bird-voiced treefrog	0.217
Plethodon mississippi	(Mississippi) slimy salamander	0.200
Notophthalmus viridescens viridescens	red spotted newt	0.133
Eurycea guttolineata	three-lined salamander	0.083
Hyla gratiosa	barking treefrog	0.033
Lithobates clamitans clamitans	bronze frog	0.017

Table 34 (continued). Relative abundance of amphibians in the park as reported in ABC (2006).

Scientific Name	Common Name	Relative Abundance
Hyla versicolor	gray treefrog	0.017
Hyla cinerea	green treefrog	0.017
Plethodon dorsalis	northern zigzag salamander	0.017
Pseudotriton ruber vioscai	southern red salamander	0.017
Eurycea cirrigera	southern two-lined salamander	0.017

Among the salamander and newt species, there were eight species observed during the inventory, and the most abundant species was the spotted salamander (*Ambystoma maculatum*) (Table 34) (ABC 2006). The next most abundant species included the spotted dusky salamander (*Desmognathus conanti*), slimy salamander (*Plethodon mississippi*), red spotted newt, and the three-lined salamander (*Eurycea guttolineata*), respectively (ABC 2006).

Species Distribution

ABC (2006)

Distributions of species within the park were categorized by park habitats. Nine habitats were identified and sampled during 2003-2005 surveys (ABC 2006). Forests are the dominant habitat type in SHIL, and four forest types were defined in the survey area descriptions: mixed hardwood forests, mixed mesic hardwoods, juniper/hardwood forests, and pine/juniper forests (ABC 2006). Mixed hardwood forests were dominated by American beech and maple (*Acer* spp.) trees with some oak (*Quercus* spp.) trees in the mesic areas (ABC 2006). Mixed mesic hardwood forests were found in lower areas than the mixed hardwood forest and often near streams or springs (ABC 2006). This forest type also had American beech with red and white oaks, basswood, and buckeye trees (ABC 2006). Juniper/hardwood forests contained a variety of hardwood species mixed with junipers and shrub and forb understory (ABC 2006). This type of forest was typically found in patches throughout the park. Pine/juniper forest was, as the name suggests, a mixture of juniper and pine and was typically drier than the other habitats and was sparse in the park (ABC 2006).

The five other habitat types sampled by ABC (2006) included: open fields, ponds, springs, streams, and bogs. Open field habitats included both natural (open grassy areas) and converted areas (mowed areas and agricultural fields in the park) (ABC 2006). Ponds consisted of bodies of water surrounded by hydric vegetation, occasionally emergent vegetation, and included manmade lakes along with natural beaver ponds (ABC 2006). Springs were places in the park with groundwater discharge at the surface, which occasionally resulted in the formation of a small stream. Streams included any channel of flowing water whether it be ephemeral, intermittent, or perennial with a range of substrate types (bedrock, cobble, sand, and mud). Bog habitats were uncommon and were found in the low areas, characterized by seasonally flowing and standing water with hydric vegetation (ABC 2006).

In general, reptile species were more commonly detected in open fields and forests. Conversely, there were two habitat types in ABC (2006) where no reptile species were observed (springs and pine-juniper forests) (Table 35). The eastern box turtle was most abundant in bog habitats (Table 35). This species was observed in three other habitat types: mixed hardwood forest, mixed mesic hardwood forest, and open field habitat, ordered from greatest to least abundance (Table 35) (ABC 2006). This was the most widely distributed turtle species observed in the park. Other turtle species were each only observed in a single habitat type (ABC 2006). The common snapping turtle was observed in open field habitat, eastern mud turtle was observed only in juniper-hardwood forest habitat, and the red-eared slider in pond habitat (Table 35) (ABC 2006).

Table 35. Relative abundance of turtle species by habitat types as reported in ABC (2006); PO = pond, BO = bog, MF = mixed hardwood forest, MH = mixed mesic hardwood forest, JH = juniper/hardwood forest, and OF = open field.

Scientific Name	Common Name	PO	BO	MF	MH	JH	OF
Terrapene carolina	eastern box turtle	-	0.500	0.300	0.267	-	0.111
Chelydra serpentina	common snapping turtle	-	-	-	-	-	0.111
Kinosternon subrubrum	eastern mud turtle	-	-	-	-	0.333	-
Trachemys scripta elegans	red-eared slider	0.111	-	-	-	-	-

Lizards and skinks were only found in forested (three types) and open field habitats. All six species observed during the inventory were observed in the open field habitat (Table 36) (ABC 2006). The most abundant species in the open fields was the eastern fence lizard, which was also the most abundant species of reptile in the park (Table 36) (ABC 2006). Eastern fence lizards were observed, from highest to lowest abundance, in juniper/hardwood forest and mixed mesic hardwood forests (ABC 2006). The other lizard and skink species observed in open field habitats were of varied abundances (Table 36) (ABC 2006). The ground skink was the most widely distributed species, observed in all four habitats where lizards and skinks were observed (Table 36) (ABC 2006). Ground skinks were most abundant in juniper/hardwood forest, followed by mixed hardwood forest, mixed mesic hardwood forest, and open field habitats (ABC 2006). The coal skink was found in juniper/hardwood forest and open field habitats, while the last three species were only found in open field habitat (Table 36) (ABC 2006).

Table 36. Relative abundance of lizard and skink species by habitat types as reported in ABC (2006); MF = mixed hardwood forest, MH = mixed mesic hardwood forest, JH = juniper/hardwood forest, and OF = open field.

Scientific Name	Common Name	MF	MH	JH	OF
Sceloporus undulatus	eastern fence lizard	-	0.600	2.333	12.67
Scincella lateralis	ground skink	0.200	0.130	0.667	0.111
Cnemidophorus sexlineatus	six-lined racerunner	-	-	-	0.556
Eumeces inexpectatus	southeastern five-lined skink	-	-	-	0.556
Eumeces anthracinus	coal skink	-		0.333	0.111
Eumeces fasciatus	five-lined skink	-	-	-	0.222

Snake species were distributed across six habitat types in the park including both aquatic and terrestrial, with the most species (5) observed in mixed mesic hardwood forests (Table 37) (ABC 2006). The snake species found in mixed mesic hardwood forest were observed in equal abundances and were not observed in other habitats (Table 37) (ABC 2006). The black racer was the most widely distributed snake species and was found in juniper/hardwood forest, mixed hardwood forest, and open field habitats (Table 37) (ABC 2006). The midland water snake, yellowbelly water snake, and cottonmouth (*Agkistrodon piscivorus*) were found exclusively within pond and stream habitats, with the highest abundances of each species observed within pond habitat (Table 37) (ABC 2006). The rat snake was only observed in mixed hardwood forest habitat (Table 37). There were no snake species observed within spring or bog habitats in the park (ABC 2006).

Table 37. Relative abundance of snake species by habitat types as reported in ABC (2006); PO = pond, ST = stream MF = mixed hardwood forest, MH = mixed mesic hardwood forest, JH = juniper/hardwood forest, and OF = open field.

Scientific Name	Common Name	PO	ST	MF	MH	JH	OF
Nerodia sipedon pleuralis	midland water snake	0.667	0.110	-	-	-	-
Nerodia erythrogaste flavigaster	yellowbelly water snake	0.444	0.110	-	-	-	-
Coluber constrictor priapus	black racer	-	-	0.100	-	0.333	0.222
Agkistrodon piscivorus	cottonmouth	0.222	0.110	-	-	-	-
Carphophis amoenus	worm snake	-	-	-	0.067	-	-
Agkistrodon contortrix	copperhead	-	-	-	0.067	-	-
Elaphe guttata	corn snake	-	-	-	0.067	-	-
Thamnophis sirtalis	eastern garter snake	-	-	-	0.067	-	-
Elaphe obsoleta	rat snake	-	-	0.100	-	-	-
Diadophis punctatus	ringneck snake	-	-	-	0.067	-	-

Amphibian species were observed in all habitat types inventoried in the park, although no individual species was documented within all nine habitat types (ABC 2006). Despite the fact that the gray treefrog (*Hyla versicolor*) breeds in pond habitats it was not observed in that habitat type in SHIL; all other amphibian species were observed in this habitat type (Table 38) (ABC 2006). Many species were in their highest abundances in the pond habitat as well. Bullfrogs (*L. catesbeianus*), Fowler's toads (*Anaxyrus fowleri*), and American toads (*A. americanus americanus*) were the most widely distributed in the park, documented in five different habitats (Table 38) (ABC 2006). Green frogs were most abundant in the pond habitat, but were also found within the stream and the mixed mesic hardwood forest habitats (Table 38) (ABC 2006). Southern leopard frogs were also most abundant in pond habitat, but were also found in the mixed hardwood forest habitat. Southern cricket frogs (*Acris gryllus*) were most abundant in the pond habitat and were observed in the stream, mixed hardwood forest, and juniper/hardwood forest habitats as well (Table 38) (ABC 2006). Bullfrogs were most abundant in the pond habitat, but were widely distributed among other park habitats, including spring, bog, mixed hardwood forest, and stream habitats (in order of greatest to least abundance in each) (Table 38) (ABC 2006).

Table 38. Relative abundance of frog and toad species by habitat types as reported in ABC (2006); PO = pond, ST = stream, BO = bog, MF = mixed hardwood forest, MH = mixed mesic hardwood forest, JH = juniper/hardwood forest, and OF = open field.

Scientific Name	Common Name	PO	ST	SP	BO	MF	MH	JH	PJ	OP
Lithobates clamitans	green frog	59.333	0.556	-	-	-	0.133	-	-	-
Lithobates sphenocephalus	southern leopard frog	51.111	-	-	-	0.200	-	-	-	-
Acris gryllus	southern cricket frog	16.556	1.444	-	-	0.400	-	1.333	-	-
Lithobates catesbeianus	bullfrog	16.778	0.333	2.000	1.500	0.500	-	-	-	-
Anaxyrus fowleri	Fowler's toad	4.667	-	-	-	0.800	1.733	-	17.500	1.333
Acris crepitans	northern cricket frog	4.667	0.222	8.000	-	-	1.000	-	-	-
Anaxyrus americanus americanus	American toad	1.444	-	-	-	0.200	0.200	-	4.500	0.333
Pseudacris crucifer	spring peeper	1.111	0.222	-	-	-	0.533	-	-	-
Hyla chrysoscelis	Cope's gray treefrog	1.556	-	-	-	-	0.067	-	-	-
Hyla avivoca	bird-voiced treefrog	1.333	-	-	-	-	-	-	-	0.111
Gastrophryne carolinensis	eastern narrowmouth toad	0.667	-	-	-	-	-	-	-	-
Hyla gratiosa	barking treefrog	0.222	-	-	-	-	0.533	-	-	-
Lithobates clamitans clamitans	bronze frog	0.111	-	-	-	-	-	-	-	-
Hyla versicolor	gray treefrog	-	-	-	-	-	0.067	-	-	-
Hyla cinerea	green treefrog	0.111	-	-	-	-	-	-	-	-

Fowler's toads were most abundant in pine/juniper forest habitats as well as pond, mixed mesic hardwood forest, open field, and mixed hardwood forest habitats, respectively (Table 38) (ABC 2006). The American toad had a similar distribution to the Fowler's toad, with highest abundance in pine/juniper forest habitat, followed by pond, open field, and equal abundance between mixed mesic hardwood and mixed hardwood forest habitats (Table 38) (ABC 2006). The northern cricket frog (*Acris crepitans*) was most abundant in the spring habitat, but was also observed in highest abundances within the pond habitat as well as mixed mesic hardwood forest and stream habitats (Table 38) (ABC 2006). Spring peepers (*Pseudacris crucifer*) were most abundant in the pond habitat and observed in the mixed mesic hardwood forest and the stream habitat as well (Table 38) (ABC 2006).

The eastern narrowmouth toad (*Gastrophryne carolinensis*), bronze frog, and green treefrog (*Hyla cinerea*) were observed within the pond habitat exclusively (ABC 2006). Gray treefrogs were only observed in the mixed mesic hardwood forest habitat (Table 38) (ABC 2006). The remaining three species were arboreal (treefrogs) and were each observed within the pond habitat along with one other habitat (ABC 2006). Those treefrog species were the Cope's gray treefrog (*H. chrysoscelis*) and barking treefrog, which were observed in the mixed mesic forest habitat in addition to the pond habitat, and the bird-voiced treefrog (*H. avivoca*) which was observed in the open field habitat in addition to the pond habitat (Table 38) (ABC 2006).

Salamanders and newts were found in seven park habitats, excluding pine/juniper forest and open field habitats (Table 39) (ABC 2006). Spotted salamanders were the most abundant salamander species and were detected exclusively within pond habitat (Table 39) (ABC 2006). The red-spotted newt and three-lined salamanders were also found only in the pond habitat (ABC 2006). Southern two-lined salamander observations were confined to the stream habitat, while northern zigzag salamanders and southern red salamanders were found only in the mixed mesic hardwood forest habitat (Table 39) (ABC 2006). Two species were more widely distributed: the slimy salamander and the three-lined salamander, which were both observed in four different habitats (Table 39) (ABC 2006). Slimy salamanders were observed within juniper/hardwood forest, mixed hardwood forest, bog, and mixed mesic hardwood forest habitats, in order of greatest to least abundance per habitat, respectively (Table 39) (ABC 2006). The three-lined salamander was observed in juniper/hardwood forest, mixed mesic hardwood forest, pond, and mixed hardwood forest habitats, also in order of greatest to least abundance per habitat, respectively (Table 39) (ABC 2006). The spotted dusky salamander was observed in two habitats; it was most abundant in spring habitat and also observed in stream habitat (Table 39) (ABC 2006).

Table 39. Relative abundance of salamander and newt species by habitat types as reported in ABC (2006); PO = pond, ST = stream, BO = bog, MF = mixed hardwood forest, MH = mixed mesic hardwood forest, and JH = juniper/hardwood forest.

Scientific Name	Common Name	PO	ST	SP	BO	MF	MH	JH
Ambystoma maculatum	spotted salamander	4.556	-	-	-	-	-	-
Desmognathus conanti	spotted dusky salamander	-	1.000	2.500	-	-	-	-
Plethodon mississippi	(Mississippi) slimy salamander	-	-	-	0.500	0.600	0.133	1.000
Notophthalmus viridescens viridescens	red spotted newt	0.889	-	-	-	-	-	-
Eurycea guttolineata	three-lined salamander	0.111	-	-	-	0.100	0.133	0.333
Plethodon dorsalis	northern zigzag salamander	-	-	-	-	-	0.067	-
Pseudotriton ruber vioscai	southern red salamander	-	-	-	-	-	0.067	-
Eurycea cirrigera	southern two-lined salamander	-	0.111	-	-	-	-	-

Threats and Stressor Factors

Climate change has enormous threat potential for herpetofauna as it stands to alter and impact the hydrology and local weather patterns in the SHIL region. Climate change has been implicated in widespread drought events which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and flooding that have damaged riparian areas and other important habitats and degradation to water quality (Bates et al. 2008). This has caused losses in biodiversity in response to disrupted ecosystems that rely on the timing of seasonal events for reproduction and food sources (Bates et al. 2008, Carter et al. 2014). This is particularly true for amphibians since their survival is so closely tied to water. Increasing temperature averages result in heat waves which are associated with spikes in unhealthy ozone levels. Elevated ozone levels are a known problem in the park and can cause foliar damage which may result in riparian vegetation damage. Riparian vegetation serves as habitat structure and regulates water temperatures by shading the water surfaces; any loss in riparian vegetation may reduce critical herpetofauna habitats in the park (Sung 2000).

Extended periods of drought are sometimes the result of an overall increase in global temperatures which has a combined effect on biota by causing both temperature and water stress (Bates et al. 2008). Under stress, organisms tend to be more susceptible to diseases, such as ranaviruses, which have caused massive die-offs in over 25 states, although more research is required to determine what increases susceptibility to these viruses (USGS 2016). Ranavirus is a genus in the family Iridoviridae which can infect multiple species of amphibians and some reptiles (USGS 2016). Ranavirus is a DNA-based strain of virus which has not been extensively isolated into single, named strains (USGS 2016). Observed outbreaks have often been within wetland environments and cause mass die-off of frogs and salamanders, with highest mortality rates occurring in juveniles (USGS 2016).

Chytrid fungus, specifically *Batrachochytrium dendrobatidis*, is a chytrid pathogen of amphibians that could potentially affect amphibian populations in SHIL. The pathogen has been identified as the cause of severe population declines on several continents, including North America (Piotrowski et al. 2004). Amphibians infected by *B. dendrobatidis* develop chytridiomycosis, an infectious non-hyphal zooporic fungus that causes roughening and reddening of the skin, convulsions, ulcers and hemorrhages, and sporadic death. Not all amphibians infected with *B. dendrobatidis* develop chytridiomycosis or die; environmental factors, such as pH or the environment, drought, and temperature at time of infection, may affect mortality rates. Some research indicates that the fungus growth is inhibited by high temperatures (28°C or 82°F) and exposure of infected individual to high temperatures may kill the fungus (Woodhams et al. 2003). Monitoring of the presence of diseases in the amphibians of SHIL would be helpful for early identification of potential outbreaks, and could help managers better prepare/combat any such outbreak.

Feral cats are an invasive species found throughout the United States and are considered common inside the park (Kennedy and Jennings 2007). Cats are considered a threat to the herpetofauna community at the park since they are indiscriminate predators of any small animal such as lizards, frogs, and toads. Loss et al. (2013) estimated that between 95 and 299 million amphibians may be killed by feral cats in the United States each year. Management action has, at times, been exercised in the park to reduce the feral cat population to an acceptable level (Kennedy and Jennings 2007).

The feral hog (*Sus scrofa*) is most well-known for its destructive rooting behavior and rampant reproductive capabilities. This species of invasive mammal has become established in Tennessee, and initially spread in the state after hogs escaped from farms in a hunting reserve in the 1920s, resulting in two isolated feral populations which then spread rapidly (TWRA 2016). In 1999, Tennessee opened up a statewide hog hunting season, which apparently encouraged stocking of feral hogs in unoccupied areas for hunting purposes (TWRA 2016). In Hardin County, where the park is situated, there lacks information on whether there is presence of feral hogs. Threats to herpetofauna from the presence of feral hogs include direct predation, destruction of critical habitat, introduction of disease, and competition for resources.

Potential loss of aquatic habitat is a serious concern for the park's herpetofauna, particularly in regard to the many amphibian species that rely on aquatic habitat to carry out their life cycle. In general, losses in area of freshwater wetlands (mostly from land development), an important aquatic habitat, have been substantial in North America (Dahl 2000). Loss of wetland habitat and landscape fragmentation has been implicated in declining trends in aquatic biodiversity, particularly aquatic reptile and amphibian taxa (Bates et al. 2008). Aquatic habitat is essential to herpetofauna in the park and monitoring and inventory programs will help managers track trends in species that are sensitive to losses of aquatic habitat.

Park management of mowed grassy areas poses a potential threat to herpetofauna. Mowing can directly and indirectly impact herpetofauna by direct mortality and elimination of buffered areas around their preferred habitats (i.e., forests, meadows, and aquatic areas). Natural predation among herpetofauna species is known to occur at all life stages (egg, larvae, juvenile, and adult) and many species of wildlife are known to prey on herpetofauna. Aquatic predators of amphibians include dragonfly naiads (order Odonata), which prey on amphibian larvae (Eck et al. 2014), native fish, and wading birds such as herons and egrets. Many terrestrial wildlife species also include herpetofauna in their diet; raptor species prey on amphibian and reptile species, and mammals such as raccoons (*Procyon lotor*), coyotes (*Canis latrans*), and skunks also prey on herpetofauna species. Levels of natural predation on herpetofauna in the park are understudied, so impacts on distribution, richness, and abundance from other organisms are unknown.

<u>Data Needs/Gaps</u>

There is a large period of time (~100 years) without any herpetofauna data collected in the park since establishment in 1894 leaving the historic conditions of the herpetofauna community a data gap. Since the park has been protected from development for this long, it may be that herpetofauna are largely as they were historically. The methodologies developed for the inventory conducted by ABC (2006) were designed and intended for use in the long term herpetofauna monitoring and inventory efforts in the park and expansion/continuation of these efforts are needed to more accurately assess the current condition of the park's herpetofauna.

Overall Condition

Species Composition

The species composition measure was assigned a *Significance Level* of 3 by the project team. The most recent data related to this measure are over 10 years old. However, when compared to the Pritts (1999) inventory, the inventory conducted by ABC (2006) detected an additional 12 species in SHIL. It is possible that future surveys may also detect new species in the area or confirm species that NPS (2016) identifies as probably present. Due to the fact that the past inventories have provided a relatively clear picture of which species occur in the park, and because these species are about what should be expected in the habitats and location of SHIL, this measure was assigned a Condition Level of 0, indicating no concern.

Species Abundance

The species abundance measure was assigned a *Significance Level* of 3. Similar to the species composition measure, the species abundance measure is only informed by data that are over 10 years old. However, abundance values observed during those efforts, especially when compared to the reference condition, did not indicate any substantial cause for concern. Due in large part to those data, and also due to the fact that SHIL has remained a protected landscape and continues to expand in size due to land acquisitions, the Condition Level for this measure was assigned as a 1, indicating low concern.

Species Distribution

Distribution was assigned a *Significance Level* of 2. The only distribution data available is the ABC (2006) inventory; without a reference condition or another similar assessment, it not possible to identify any trends in species distribution at this time. Indications from NPS managers indicate overall low concern regarding species distribution in the park, although the lack of gray treefrogs in the pond habitats (as observed previously by ABC 2006) is puzzling. A *Condition Level* of 1, indicating low concern, was assigned to this measure.

Weighted Condition Score

The herpetofauna at the park are likely preserved close to the historic condition considering the length of time this area has been preserved and undeveloped. There is now baseline inventory on the community for future comparison in order to monitor the health of herpetofauna. There are not enough data available to identify any trends in species composition, species abundance, and species distribution; the most recent inventory that addresses those measures is also now outdated (>10 years). The lack of herpetofauna-related data for SHIL in the last 10 years in SHIL lowers the overall confidence in the condition assessment, which estimated a *Weighted Condition Score* as 0.21, indicating a good condition for the park.

Herpetofauna			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.21**
Species Composition	3	0	
Species Abundance	3	1	
Species Distribution	2	1	

4.6.6 Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Marcus Johnson, SHIL Natural Resource Management Specialist
- Timothy Pinion, NPS Southeast Region Wildlife Biologist

4.6.7 Literature Cited

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4.7. Water Quality

4.7.1. Description

Water quality and quantity has been identified as a high-priority Vital Sign for all parks in the CUPN, including SHIL (Leibfreid et al. 2005). Recognizing long-term trends in water quality is critical to the conservation of aquatic ecosystems (Leibfreid et al. 2005). The CUPN categorized its parks with regards to water resource significance based on site visits and discussions with park management. SHIL was selected as a "Category One" park (Meiman 2005). This category includes parks 1) where water resources are central to park establishment or mission, 2) that support endangered, threatened, or rare aquatic or dependent species, or 3) have a high probability of water resource damage with little information on fundamental elements of hydrogeology or water quality (Meiman 2005).

The watersheds of SHIL's surface waters are primarily contained within park boundaries, with the exception of Owl Creek and the Tennessee River (Meiman 2005). As a result, SHIL's streams are the most undisturbed within the lower Tennessee River watershed and can serve as a regional benchmark of pristine condition (NPS 2015). The surface water features of the park include three perennial streams (Dill Branch, Shiloh Creek, and Tilghman Branch), two springs (Shiloh and Rea Springs), and the two larger streams that form the northwestern and eastern park boundaries (Owl Creek and the Tennessee River, respectively) (Figure 18) (Meiman 2005).

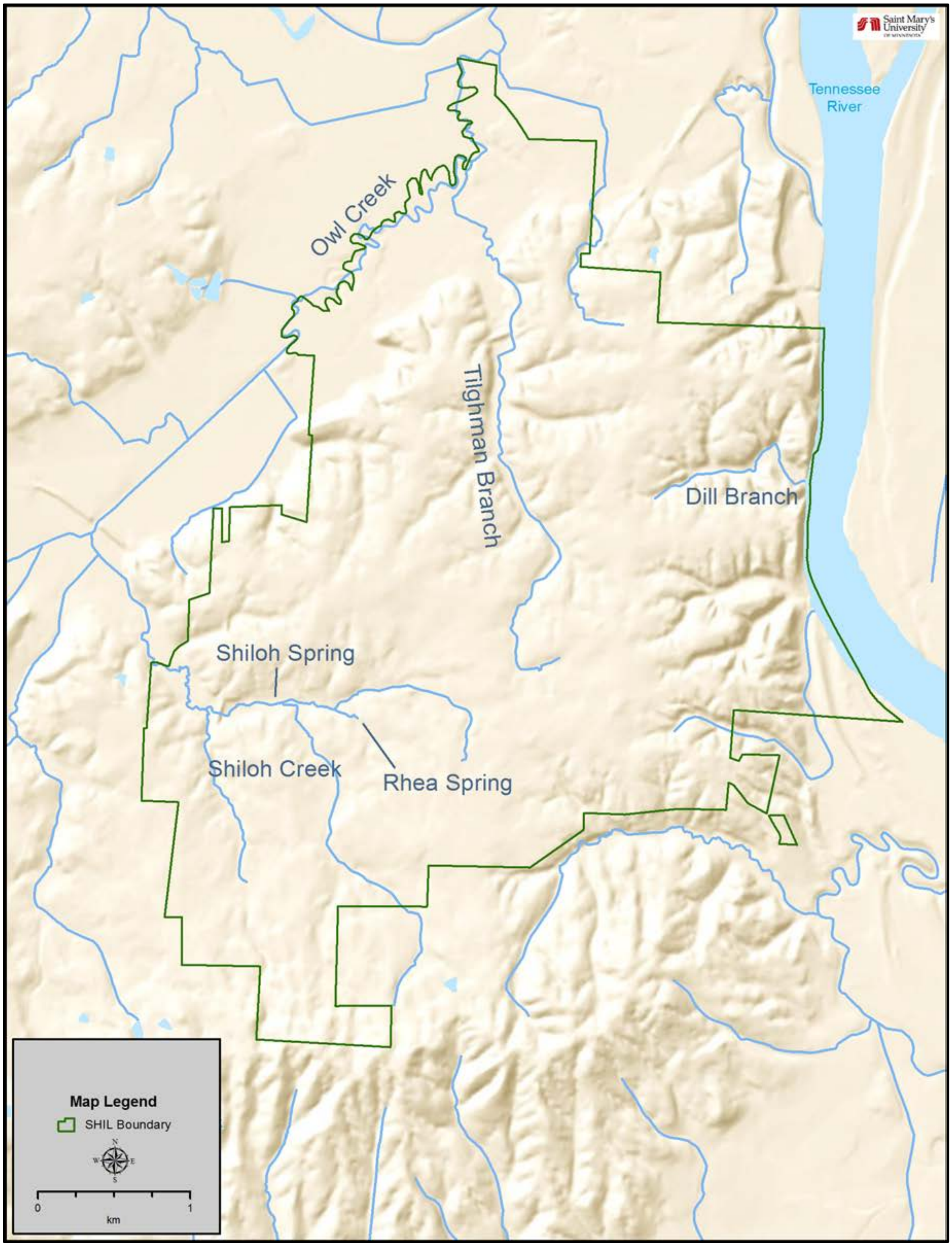

Figure 18. Surface water features of SHIL. Note that SHIL has recently acquired additional acreage that is not represented on this map, as an updated boundary file is not yet available.

4.7.2. Measures

- Water temperature
- pH
- Dissolved oxygen
- Specific conductance
- Acid neutralizing capacity
- *E. coli* bacteria

Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, but it also affects biological activity and growth within water systems (USGS 2015). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2015). As temperature increases or decreases too far past this range, the number of species and individuals able to survive eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water, making them more toxic to aquatic life (USGS 2015).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7.0 being neutral (USGS 2015). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2015). Chemicals can change the pH of water and harm animals and plants living there; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2015).

Photo 19. Water quality sampling along the Shiloh Branch in SHIL (NPS/JOE MEIMAN).

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. In order to survive, fish and zooplankton filter out or "breathe" dissolved oxygen from the water (USGS 2015). Oxygen enters water from the air when it mixes with water at turbulent, shallow riffles in a waterway, or when released by algae and other plants as a byproduct of photosynthesis. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2015). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than warm water (USGS 2015). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2015).

Specific Conductance

Specific conductance (SpC) is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved ions in the water (Allan and Castillo 2007). Water with low amounts of dissolved ions (such as purified or distilled water) will have a low SpC, while water with high amounts of dissolved solids (such as salty sea water) will have a higher SpC (Allan and Castillo 2007). SpC is an important water quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2015). SpC can also quickly and reliably estimate dissolved solids in water (Meiman 2007).

Acid Neutralizing Capacity

Acid neutralizing capacity (ANC), measured in mg/l as $CaCO_3$, is the ability of solutes and particulates in an unfiltered water sample to buffer acids (Meiman 2007). Waters with low ANC are more at risk of reductions in pH due to acid deposition, such as from acid rain (Meiman 2007).

E.coli

Bacteria are a common natural component of surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals, can cause illness in humans (USGS 2011). Fecal coliform bacteria are a subgroup of coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. *Escherichia coli* (*E. coli*) is a specific species of bacteria that belongs to the larger group of coliform bacteria and is characterized by its ability to break down urease (an enzyme that breaks down urea into carbon dioxide and ammonia) (USGS 2011). *E. coli* is a preferred indicator for determining if potential pathogens are present in freshwater resources. It is tested by counting colonies that grow on micron filters placed in an incubator for 22-24 hours. High concentrations of *E. coli* can cause serious illness in humans (USGS 2011).

4.7.3. Reference Conditions/Values

The reference conditions for water quality will be the Tennessee state standards for water bodies with a "fish and aquatic life" designated use (Table 40). The Tennessee River also has a "recreation" designated use; water quality standards for this use are the same as for the fish and aquatic life designated use, with the exception of a stricter *E. coli* bacteria standard. These standards are outlined by the Tennessee Department of Environment and Conservation (TDEC) (TDEC 2013). However, there is an additional qualification stating that

Where naturally formed conditions (e.g., geologic formations) or background water quality conditions are substantial impediments to attainment of the water quality standards, these natural or background conditions shall be taken into consideration in establishing any effluent limitations or restrictions on discharges to such waters. For purposes of water quality assessment, exceedances of water quality standards caused by natural conditions will not be considered the condition of pollution (TDEC 2013, p. 20).

Table 40. Tennessee state water quality standards for the fish and aquatic life designated use (unless otherwise noted) (TDEC 2013).

Parameter	State standard
Water temperature	not to exceed 30.5°C (86.9°F)
pH	6.0 – 9.0 in wadeable streams and 6.5 – 9.0 in larger rivers, lakes, reservoirs, and wetlands
Dissolved oxygen	not less than 5.0 mg/l
E. coli bacteria	**Aquatic life:** not to exceed 630 colony forming units (cfu) per 100 ml as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours AND not to exceed 2,880 cfu per 100 ml in any single sample. **Recreation:** not to exceed 126 cfu per 100 ml, as a geometric mean AND not to exceed 487 cfu per 100 ml in any single sample.

State standards are not available for two of the measures selected for this assessment: SpC and ANC. It is difficult to determine reference conditions for these parameters at SHIL because they vary greatly with the size and source of the water body (Meiman, email communication, 8 February 2016). Based on available data from SHIL, the natural ranges for water bodies originating within SHIL (e.g., Dill Branch, Shiloh Branch, and both springs) appear to be 0-50 µS/cm for SpC and 0-15 mg/l as $CaCO_3$ for ANC (Meiman, email communication, 8 February 2016). These ranges will be used as informal reference conditions for this NRCA, as values outside these ranges could indicate a need for further investigation and/or cause for concern.

4.7.4. Data and Methods

Historic (pre-1990) water quality data are nearly nonexistent for SHIL. One historic pH reading was found for Shiloh Spring from 1963 (Criner 1963). During 1994-1995, the NPS conducted 13 monthly sampling visits to six sites within SHIL (Meiman 2005). Parameters measured included pH, water temperature, DO, and SpC. From 2000-2002, the NPS contracted with the University of Memphis to conduct water quality monitoring and aquatic community sampling at the park (Meiman 2005). Field measurements during this sampling also included pH, water temperature, DO, and SpC. Data from these monitoring efforts can be obtained through the EPA's STORET database (http://www3.epa.gov/storet/dbtop.html).

In 2004, the CUPN initiated a water quality monitoring program at SHIL. Based on the lack of previous data and information, the first round of data collection can essentially be considered a baseline inventory (Meiman 2007). Monthly sampling was conducted from October 2004 through September 2006 at eight sites across the park (Figure 20), for a total of 24 sampling events per site (Meiman 2007). These 2 years of monthly sampling are then followed by 5 years of no sampling, before the 2-year sampling process is repeated (Meiman 2013). The results of the initial sampling effort, since they establish a baseline range for the selected sampling sites, are presented as "box-plots." A guide to interpreting box-plot results is shown in Figure 19. It should be noted that results for ANC and *E. coli* from this survey are based on one year of sampling only, as results from the first year (2004-2005) were deemed inadequate and sampling methodology was changed (Meiman 2007).

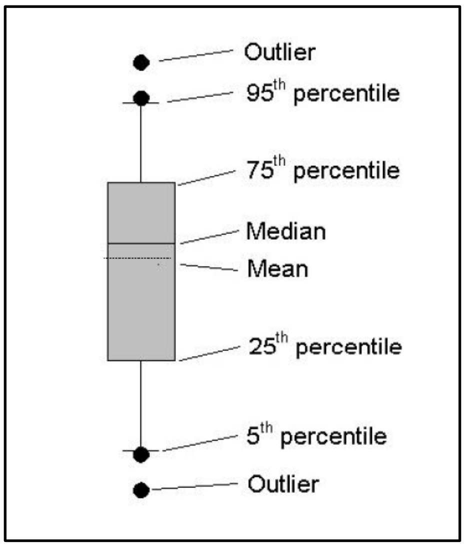

Figure 19. A guide for interpreting box-plot results (reproduced from Meiman 2007).

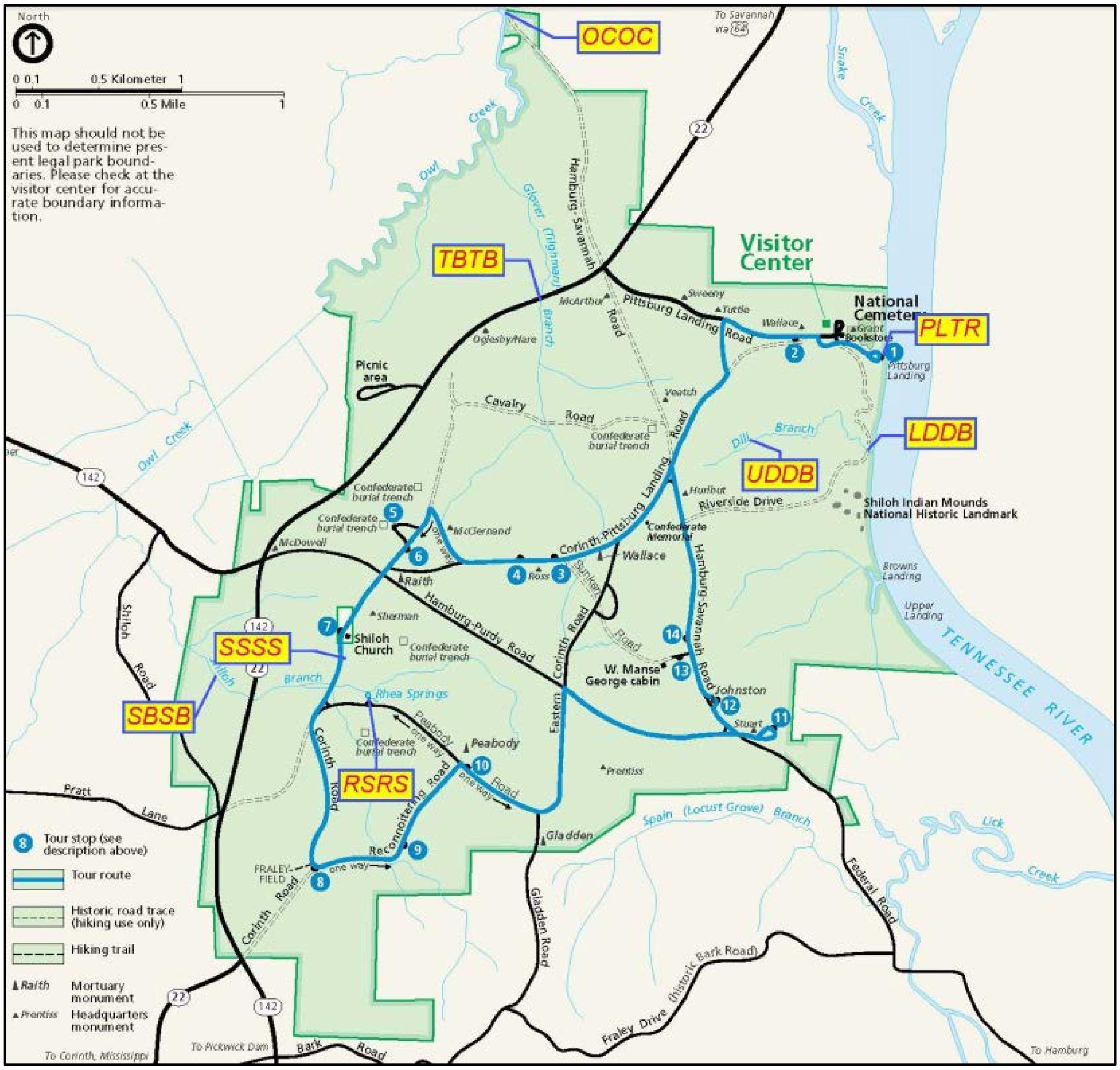

Figure 20. CUPN water quality monitoring sites within SHIL (reproduced from Meiman 2012). OCOC = Owl Creek, TBTB = Tilghman Branch, PLTR = Pittsburg Landing, Tennessee River, LDDB = Lower Dill Branch (Photo 20), UDDB = Upper Dill Branch, SSSS = Shiloh Spring, SBSB = Shiloh Branch/Creek, RSRS = Rhea Spring.

Photo 20. The Lower Dill Branch at the CUPN monitoring site in SHIL (NPS/JOE MEIMAN).

The CUPN conducted water quality sampling at SHIL again during 2011-2013 (Meiman 2012, 2013). The same eight sampling sites were revisited and are scheduled to be sampled again in 2019 (Meiman 2013).

4.7.5. Current Condition and Trend

<u>Water Temperature</u>

Based on the available data, water temperatures within SHIL are largely within the range supportive of aquatic life. During 2004-2006 sampling, only one measurement from Pittsburg Landing (Tennessee River) exceeded the state standard of 30.5°C (86.9°F) (Meiman 2007). The range of water temperatures at Rhea and Shiloh Springs is notably narrow, due to the groundwater-fed nature of the springs (Figure 21) (Meiman 2007).

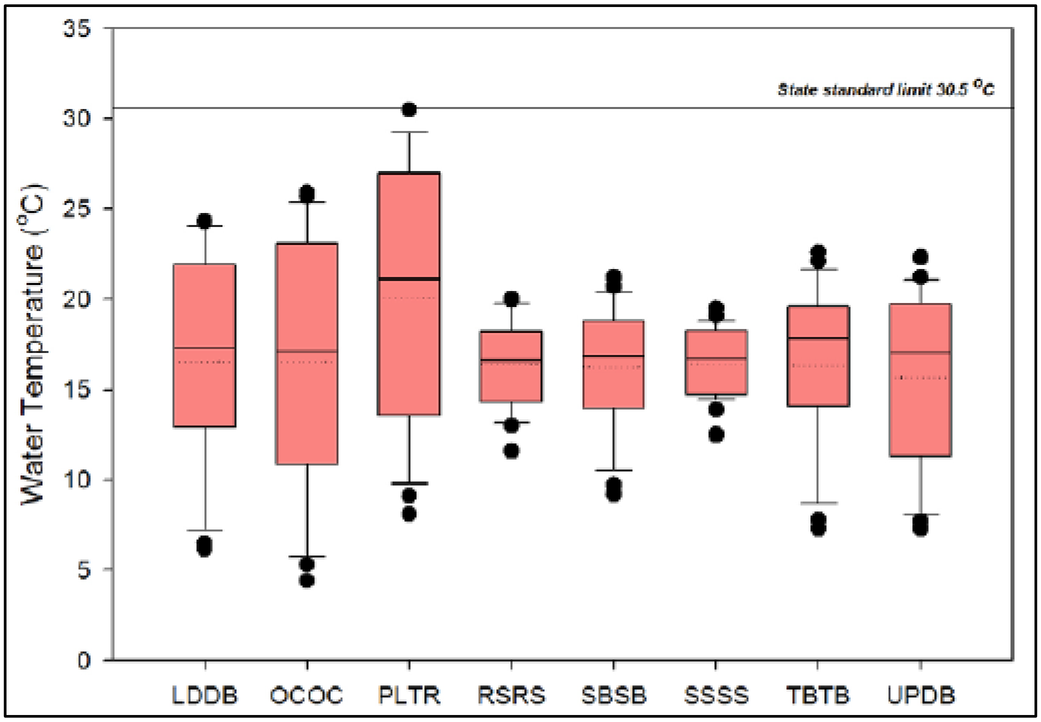

Figure 21. Water temperature sampling results for SHIL monitoring locations, based on monthly sampling from October 2004-September 2006 (reproduced from Meiman 2007). Refer back to Figure 19 for guidance in interpreting a box-plot.

No temperature exceedances occurred at SHIL monitoring sites during 2011-2013 sampling (Meiman 2012, 2013). A graphical representation of all water temperature sampling results available for SHIL is shown in Figure 22.

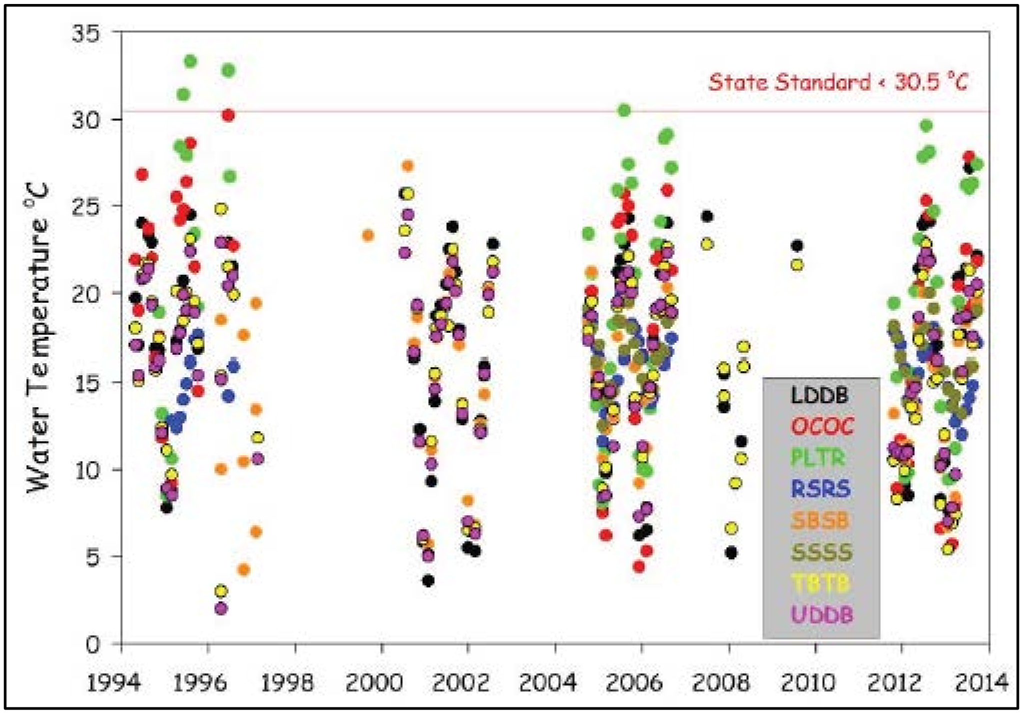

Figure 22. All water temperature sampling results for SHIL locations, 1994-2013 (graph provided by Joe Meiman, March 2015).

pH

The pH of most of SHIL's waters is naturally acidic (Meiman 2007). With the exception of the Tennessee River and Owl Creek, samples from CUPN monitoring locations were nearly all below the state standard of 6.0-9.0 (Figure 23) (Meiman 2007). The slightly less acidic pH readings from the Lower Dill Branch (LDDB) may be due to back flooding from the Tennessee River. The one historic measurement from Shiloh Spring, taken in 1963, yielded a pH value of 5.5 (Criner 1963), supporting the conclusion that pH is naturally low and not a recent development. While these low readings would normally indicate the water bodies are in non-attainment of water quality standards, the state exception for "natural conditions" outside the established standard apply here (see section 4.7.3 above) (Meiman 2007, 2012, 2013). Therefore, low pH readings from the majority of SHIL monitoring locations are not considered indicators of degraded water quality.

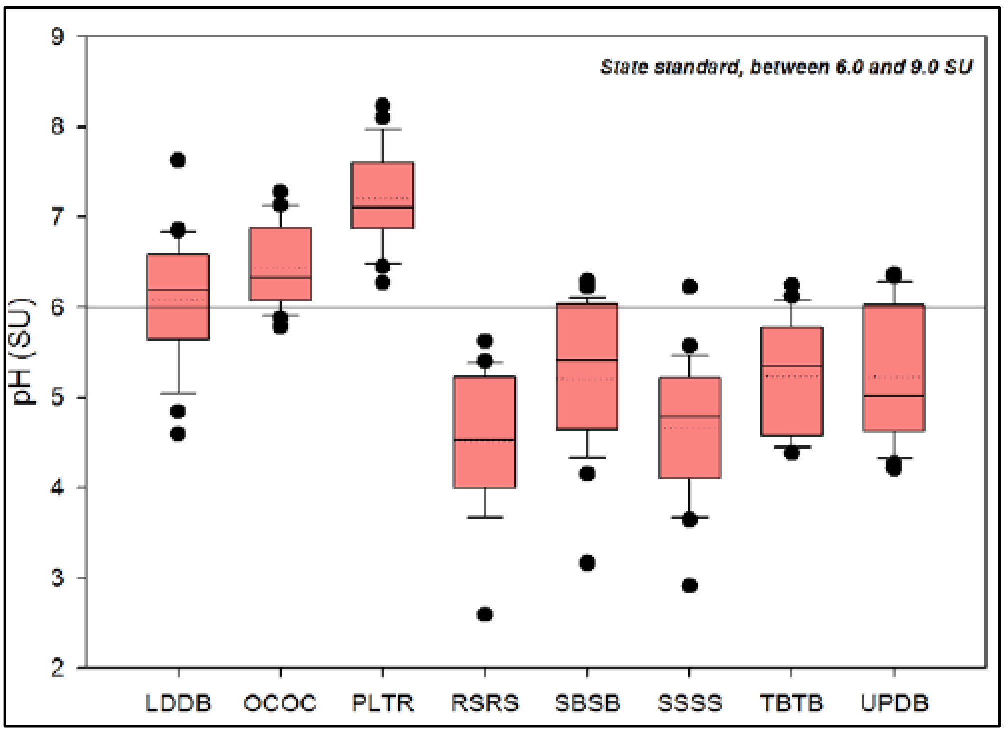

Figure 23. pH sampling results for SHIL monitoring locations, based on monthly sampling from October 2004-September 2006 (reproduced from Meiman 2007).

During 2012-2014 CUPN sampling, there were also numerous measurements below the minimum state standard of 6.0, including all samples from Shiloh and Rhea Springs (Meiman 2012, 2013). Again, due to natural conditions, these are not considered violations of the state standard (Meiman 2012, 2013). All pH measurements available for SHIL monitoring locations are shown in Figure 24.

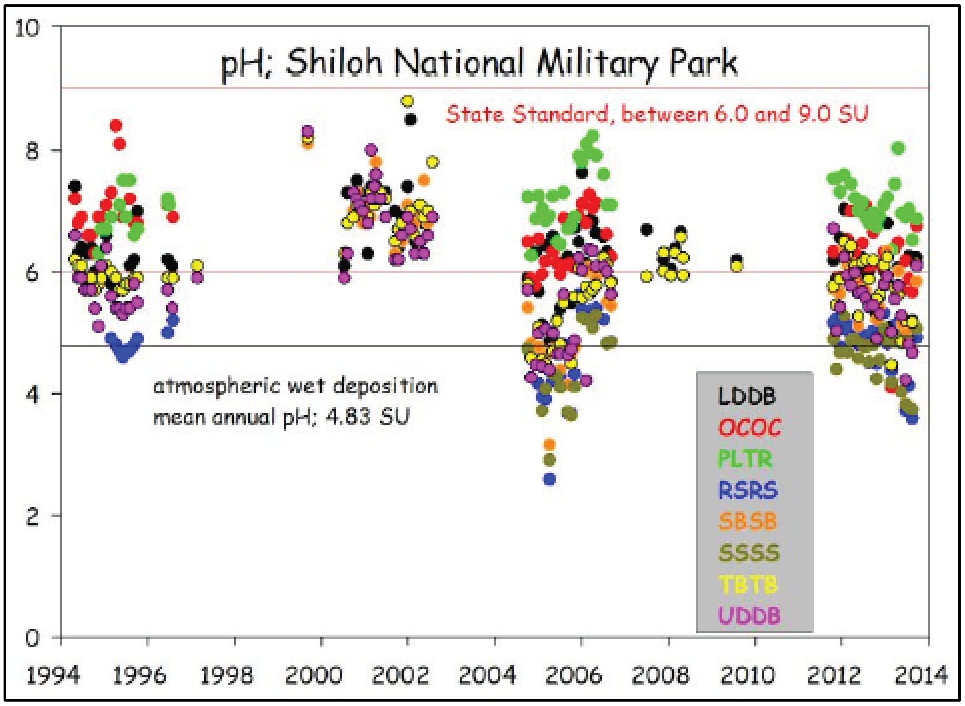

Figure 24. All pH sampling results for SHIL locations, 1994-2013 (graph provided by Joe Meiman, March 2015).

Dissolved Oxygen

Dissolved oxygen levels at SHIL's monitoring locations typically meet the state standard of >5 mg/l (Meiman 2007). DO levels are often lowest at the two spring sites, which are supplied by groundwater that does not have much opportunity for aeration (Figure 25) (Meiman 2007). During 2004-2006 sampling, several DO measurements from Tilghman Branch (TBTB) fell below the state standard, but it was later realized that this was due to a sampling error (Meiman, email communication, 5 February 2016).

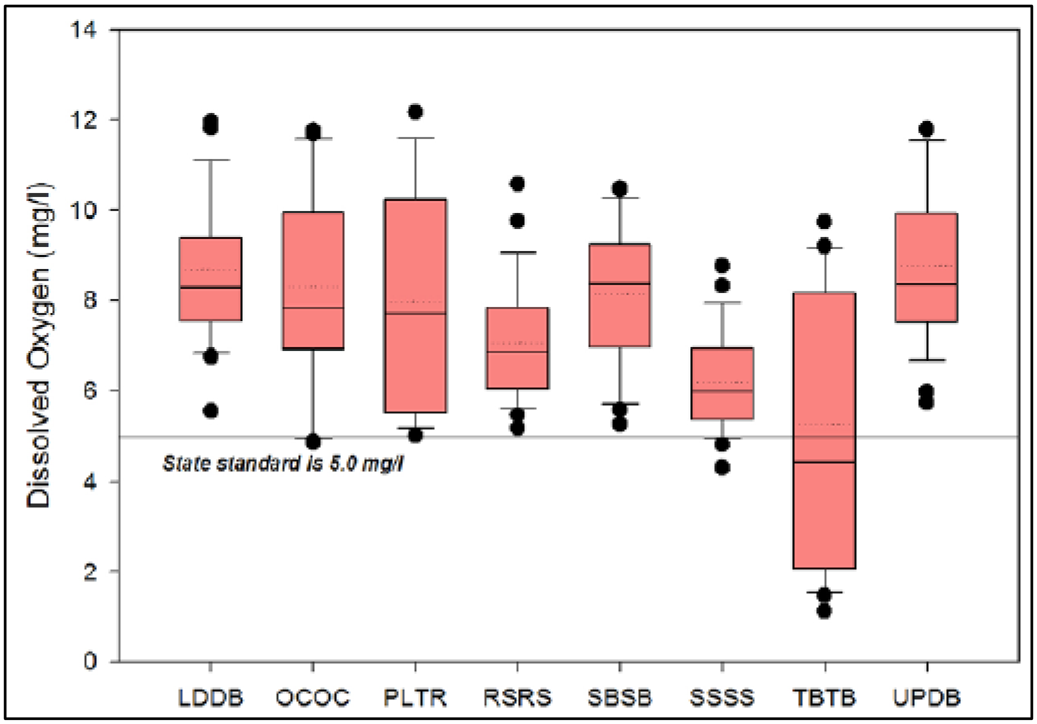

Figure 25. Dissolved oxygen sampling results for SHIL monitoring locations, based on monthly sampling from October 2004-September 2006 (reproduced from Meiman 2007).

During 2011-2013 sampling, DO levels were below the state standard of 5 mg/l three times at Shiloh Spring, once at Rhea Spring, and twice at Owl Creek during very low flow conditions in the summer of 2013 (Figure 26) (Meiman 2012, 2013). The low values at the two springs are considered natural due to the low aeration of groundwater (Meiman 2012). All available DO measurements for SHIL monitoring locations are shown in Figure 26. Several low measurements were recorded in the Shiloh Branch (SBSB) during 2000-2001. Although the exact cause of these low levels is not known, they are likely due to beaver impoundments along the stream, which can create temporary stagnant conditions (Jack Grubaugh, UT-Martin Professor, email communication, 9 February 2016).

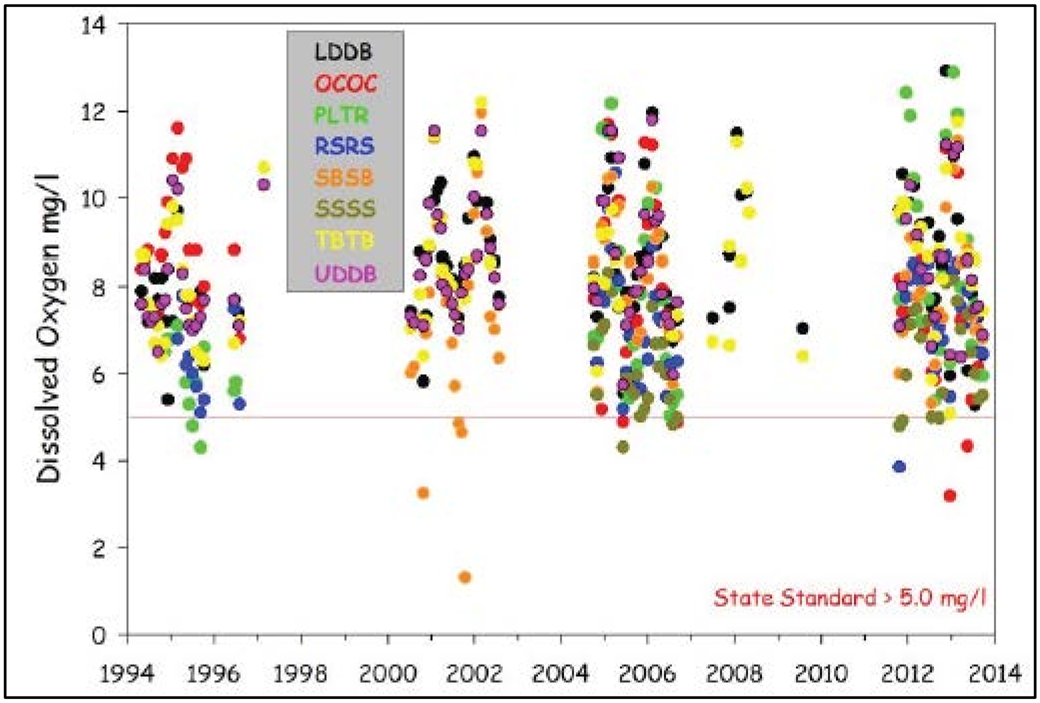

Figure 26. All dissolved oxygen sampling results for SHIL locations, 1994-2013 (graph provided by Joe Meiman, March 2015).

Specific Conductance

Specific conductance (SpC) is primarily influenced by the amount of dissolved solids in water, which depend on the lithology (i.e., rock/sediment composition) encountered by the water and its residence time (i.e., how long is water exposed to various lithologies) (Meiman 2007). The results of CUPN water quality monitoring at SHIL are reflective of these influences. SpC values are low at the two springs and smaller creek sites completely within the park, where contact with carbonate strata that would contribute dissolved solids is limited (Figure 27) (Meiman 2007). Owl Creek and the Tennessee River, on the other hand, are fed by larger watersheds with more opportunity to collect dissolved solids, and therefore show higher SpC readings (Meiman 2007). The high outlying SpC values for Lower Dill Branch (LDDB) are due to back-flooding of the stream by waters from the Tennessee River (Meiman 2007).

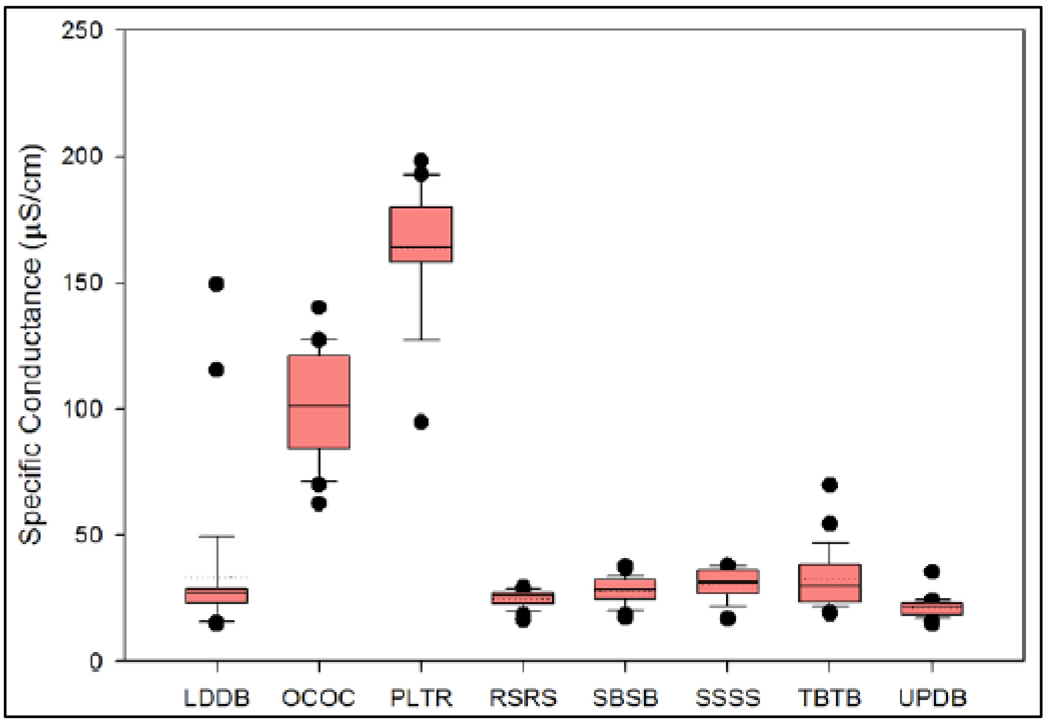

Figure 27. Specific conductance sampling results for SHIL monitoring locations, based on monthly sampling from October 2004-September 2006 (reproduced from Meiman 2007).

During the most recent round of CUPN water quality sampling (2011-2013), SpC measurements for each site were very similar to previous results, as shown in Figure 28. Nearly all samples from waters originating in the park fell within the informal reference condition range of 0-50 µS/cm. Values from LDDB outside this range were again due to back-flooding by waters from the Tennessee River.

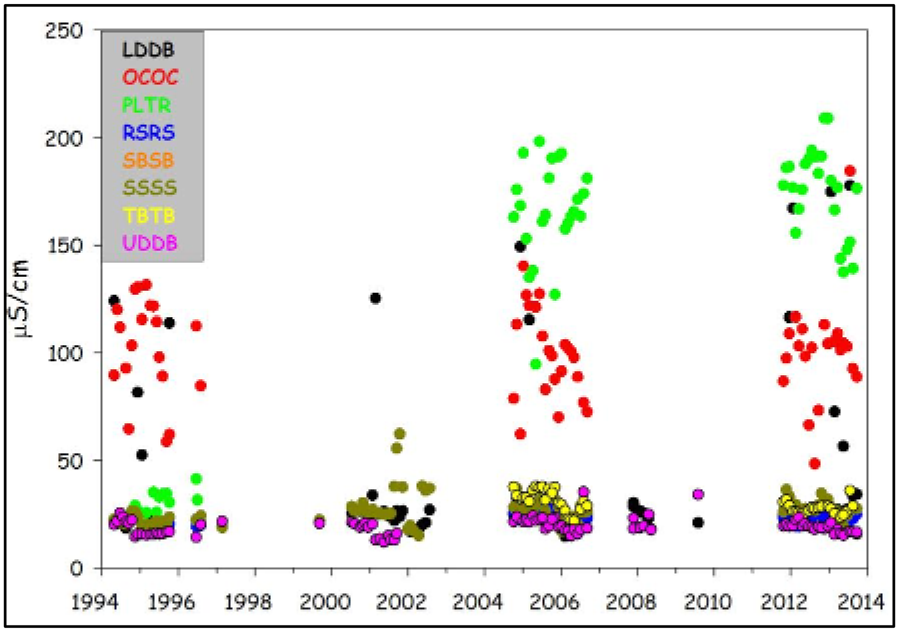

Figure 28. All specific conductance sampling results for SHIL locations, 1994-2013 (graph provided by Joe Meiman, February 2016).

Acid Neutralizing Capacity

The spring and small stream monitoring locations at SHIL yielded the lowest ANC values among all the CUPN park monitoring sites (Meiman 2007). As with SpC, these low values reflect the lithology of the basin, as water sources completely within park boundaries have little contact with carbonate strata (Meiman 2007). Owl Creek and the Tennessee River waters have more exposure to carbonate strata and, therefore, higher ANC values (Figure 29). As with SpC, several high outlying ANC values are seen for LDDB, due to back-flooding by the Tennessee River (Meiman 2007). Lower ANC levels increase a water body's vulnerability to the negative effects of acid precipitation/deposition, as there are limited bicarbonates available to counter additional acid inputs (Meiman 2007).

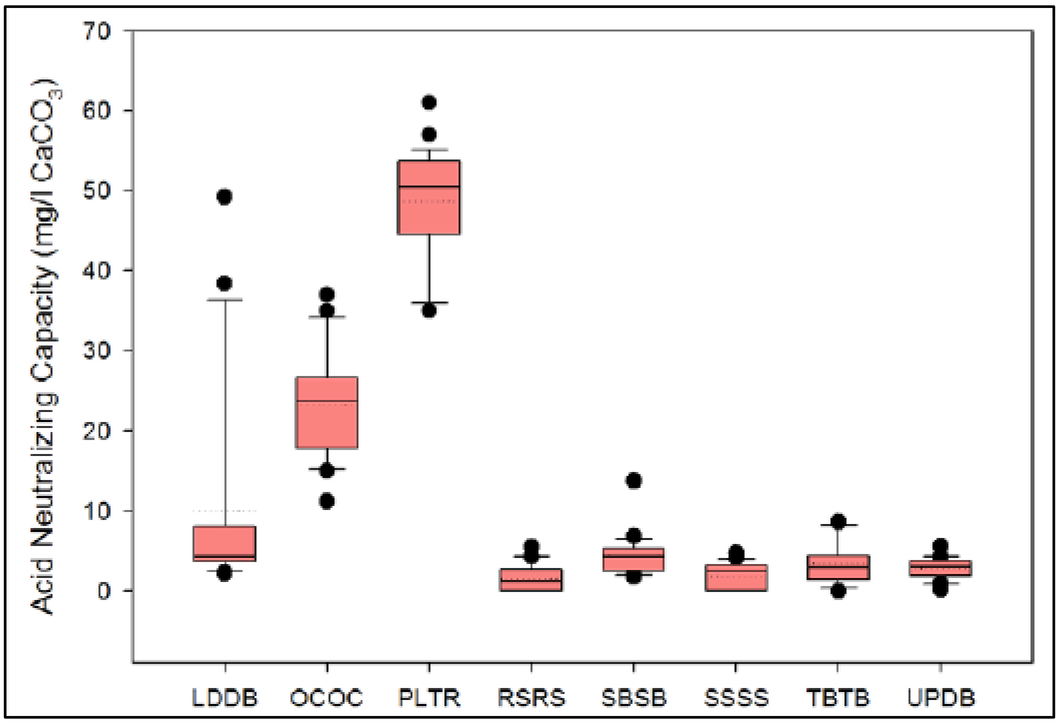

Figure 29. Acid neutralizing capacity results for SHIL monitoring locations, based on monthly sampling in 2005-2006 (reproduced from Meiman 2007).

Acid neutralizing capacity measurements during the most recent round of water quality sampling (2011-2013) were similar to previous results, with the exception of additional higher readings at LDDB (Figure 30). These were again due to back-flooding from the Tennessee River.

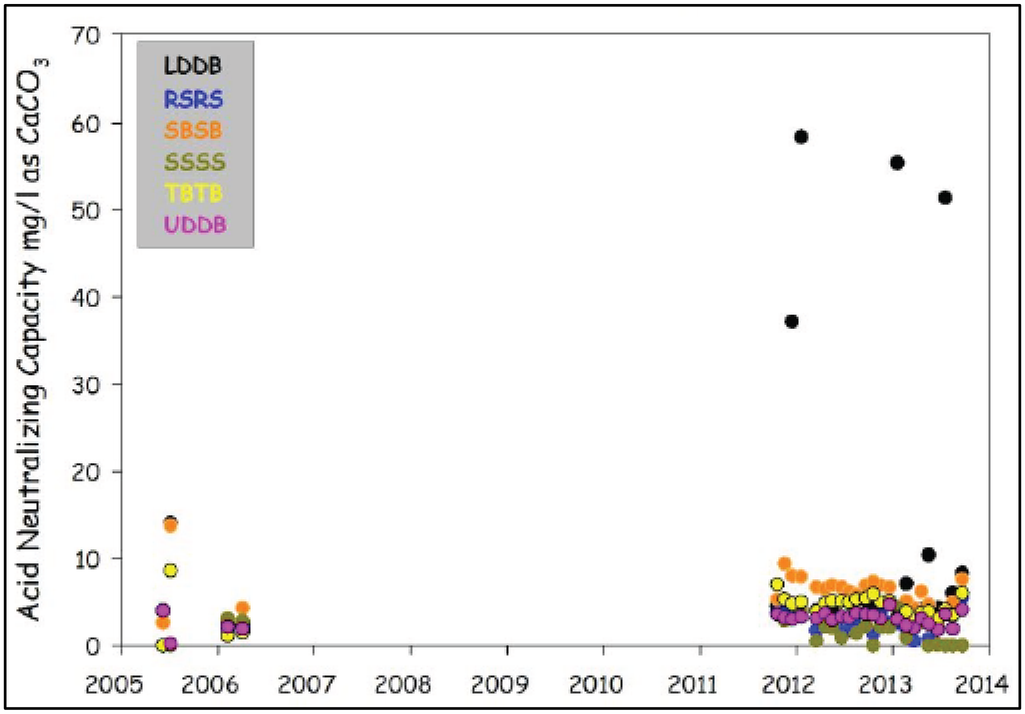

Figure 30. Acid neutralizing capacity sampling results for SHIL locations, 2005-2013 (graph provided by Joe Meiman, March 2015). Owl Creek and Tennessee River results are not shown, as this measure is not of concern at those locations due to high carbonate loads (Meiman, email communication, 8 February 2016).

<u>*E. coli* Bacteria</u>

E. coli levels in SHIL waters are generally low, but with occasional spikes, such as on the Shiloh and Tilghman Branches during 2005-2006 sampling (Figure 31) (Meiman 2007). Even these high measurements are still below the single-sample state standard of 2,880 cfu/100 ml. Since there is no agriculture and little to no development upstream of these sampling sites, the elevated levels are not caused by these common sources of coliform bacteria (Meiman 2007). They are likely due to wildlife activity just upstream of sampling locations and should be considered within the range of natural, background conditions (Meiman 2007, 2013).

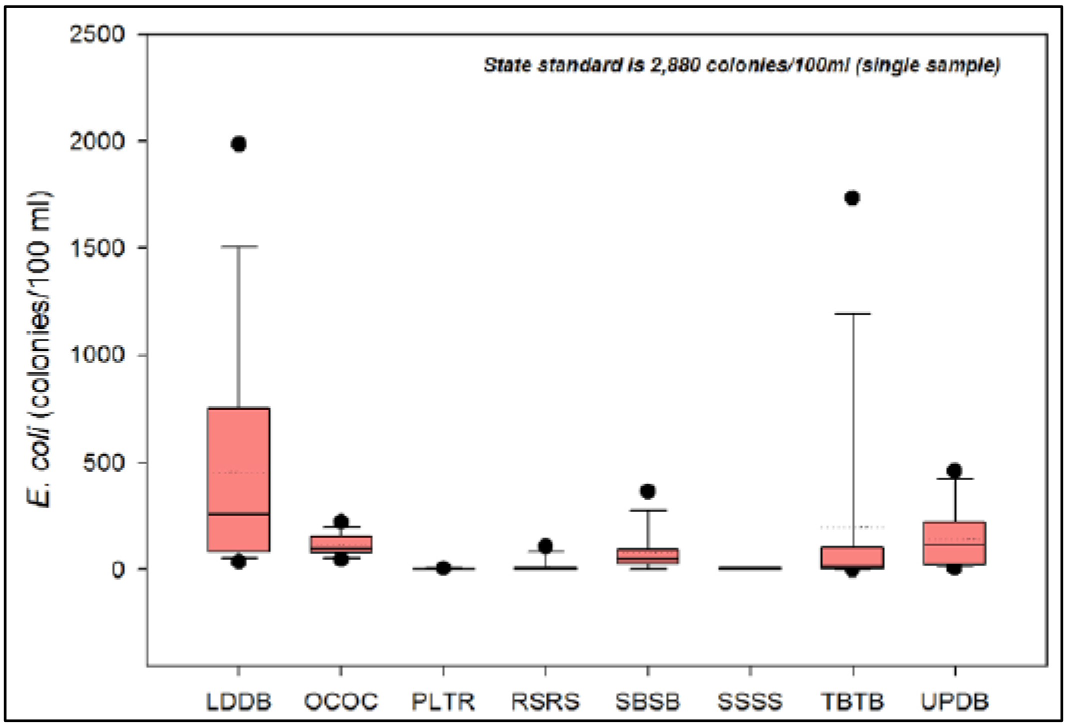

Figure 31. *E. coli* sampling results for SHIL monitoring locations, based on monthly sampling from October 2004-September 2006 (reproduced from Meiman 2007).

During 2012-2014 sampling at SHIL, there were no exceedances of the single-sample state standard for aquatic life use (2,880 cfu/100 ml) (Meiman 2012, 2013). However, fourteen samples were considered elevated (>487 cfu/100 ml, the state standard for recreational waters): five from Lower Dill Branch, two from Owl Creek, three from Shiloh Branch, three from Tilghman Branch, and one from Upper Dill Branch (Figure 32) (NPS 2012, 2013). In each instance, elevated levels were associated with wildlife activity or runoff following thunderstorms (Meiman 2012, 2013).

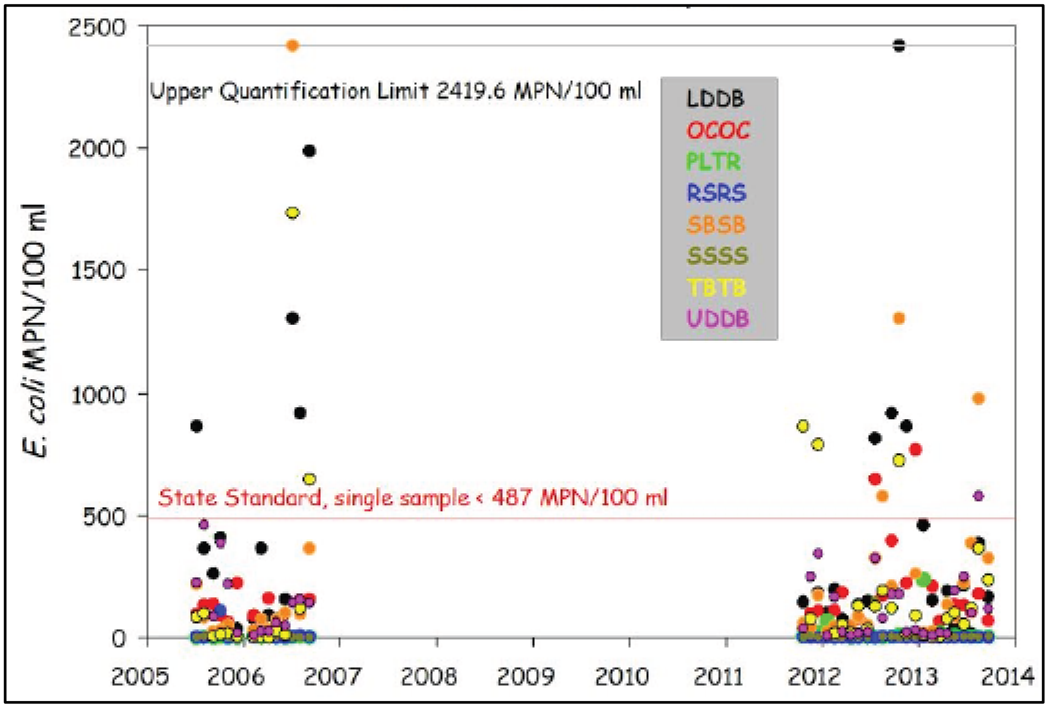

Figure 32. All *E. coli* sampling results for SHIL locations, 2005-2013 (graph provided by Joe Meiman, March 2015).

<u>Threats and Stressor Factors</u>

Threats to SHIL's water quality include upstream agricultural practices and human use, atmospheric deposition, climate change, and grounds maintenance at the park. Much of the land across Owl Creek and further upstream is agricultural and has been intensively row-cropped (Meiman 2005). Much of this agricultural land has been altered through tiling, draining, and channelization. These changes, along with other alterations to the hydrology and riparian areas of Owl Creek, have increased the flow of sediment into the stream, some of which is deposited in the park (Meiman 2005). Fertilizers and other chemicals may also run off into Owl Creek from agricultural lands. Additional human development upstream of the park could contribute trash and/or pollutants to Owl Creek and the Tennessee River. For example, there is a pulp mill on the Tennessee River just upstream of the park, near Pickwick Dam (Meiman, email communication, 11 February 2016). Grounds maintenance within the park itself has the potential to influence water quality (e.g., fertilizers, pesticides), although this is not presently a concern (Meiman, email communication, 11 February 2016).

During their most recent round of sampling at SHIL, the CUPN noted that atmospheric wet deposition (e.g., rain, snow, fog) in the region had a mean annual pH that was acidic and below the Tennessee state standard, at 4.8 (measured at Hatchie National Wildlife Refuge, 80 km [50 mi] northwest of SHIL) (Meiman 2013). The low pH of precipitation/deposition is often retained in the park's surface waters because of the low acid neutralizing capacity of many of SHIL's waters (Meiman 2013). While the pH of regional wet deposition has increased in recent years, it is still more acidic than natural precipitation and below the Tennessee state standard for surface water pH of 6.0-9.0 (Figure 33) (NADP 2016). It is unclear if the acidic nature of this deposition is due to natural or anthropogenic causes. Human-related contributors to acidic deposition include motor vehicles, electric power generation (e.g., coal-burning facilities), and industrial/chemical plants (NADP 2014).

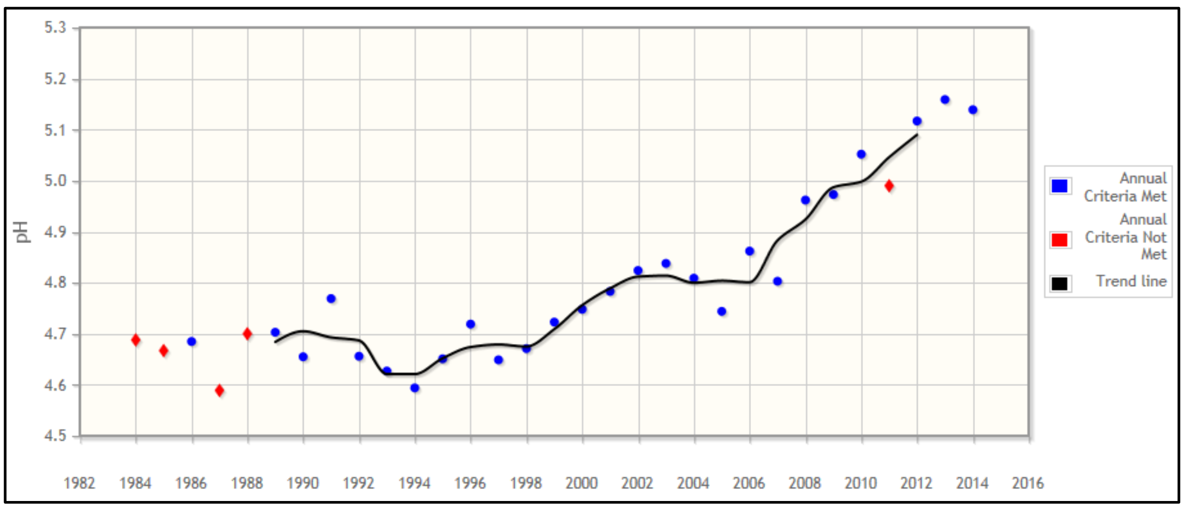

Figure 33. Annual mean pH of wet atmospheric deposition at NTN Site TN14, Hatchie National Wildlife Refuge (80 km [50 mi] northwest of SHIL) (NADP 2016). Red diamonds represent years when NADP's data completeness criteria (valid samples and precipitation amounts for 75% of time period) were not met.

Global climate change is projected to increase temperatures across the southeast over the next century (Carter et al. 2014). Increasing air temperatures contribute to increased water temperatures, which influence a wide variety of water chemistry parameters, particularly DO (Delpla et al. 2009). Warmer temperatures will also likely accelerate the loss of surface water to the atmosphere through evapotranspiration (Bates et al. 2008), which could influence the concentrations of solutes (e.g., minerals, nutrients, pollutants) in the remaining water (Delpla et al. 2009). In addition to temperature changes, climate change is projected to cause precipitation events to become less frequent but more intense, with longer dry periods between rain events (Bates et al. 2008). This could contribute to low flow conditions in streams and rivers, particularly during summer, which are often linked to decreased DO levels and increased solute concentrations (Bates et al. 2008, Delpla et al. 2009).

Data Needs/Gaps

Sufficient data are available to assess the condition of the parameters/measures selected for this component. The continuation of the CUPN monitoring program will allow managers to detect any changes or trends in water quality over time. Additional research into the impacts of various water quality threats (e.g., atmospheric deposition, upstream development, climate change) may help in the management of this vital resource. Additional water quality threats such as mercury and contaminants of emerging concern (e.g., endocrine disruptors, other pharmaceuticals) have not been monitored at SHIL (Jeff Duncan, NPS Southeast Region Water Quality Specialist, written communication, 14 March 2016).

Overall Condition

Water Temperature

The project team assigned the temperature measure a *Significance Level* of 3. With the exception of one sample from the Tennessee River at Pittsburg Landing during 2004-2006, water temperature measurements during CUPN sampling have all met the state standard of <30.5°C (86.9°F) (Meiman 2007, 2012, 2013). As a result, this measure is currently of no concern (*Condition Level* = 0).

pH

This measure was also assigned a *Significance Level* of 3. The majority of SHIL's waters, particularly those completely within park boundaries, have a naturally low pH (Meiman 2007). With the exception of Owl Creek and the Tennessee River, most pH measurements from the park were below the state standard of 6.0 (Meiman 2007, 2012, 2013). However, since this is due to natural conditions, these low values are not considered indicative of degraded water quality. Therefore, pH is currently of low concern at SHIL (*Condition Level* = 1).

Dissolved Oxygen

The dissolved oxygen measure was assigned a *Significance Level* of 3. DO level in SHIL waters generally meet the state standard of >5 mg/l. The park's springs typically have lower DO levels, as they are primarily fed by groundwater which has limited opportunity for aeration (Meiman 2007, 2012). Occasional low DO levels at other SHIL monitoring locations are typically associated with low or altered flow conditions. This measure was assigned a *Condition Level* of 1, indicating low concern.

Specific Conductance

The project team also assigned this measure *Significance Level* of 3. The SpC of SHIL waters is naturally low, with the exception of Owl Creek and the Tennessee River, due to the lithology encountered by the waters (Meiman 2007). Nearly all samples from waters originating within the park fell within the informal reference condition range of 0-50 µS/cm. Samples from the Lower Dill Branch outside this range are due to back flooding of Tennessee River waters, which are naturally higher in SpC (Meiman 2007). Currently, there is no cause for concern regarding this measure within SHIL (*Condition Level* = 0).

Acid Neutralizing Capacity

This measure was assigned a *Significance Level* of 3. Like SpC, the majority of SHIL waters have a naturally low ANC (Meiman 2007). With the exception of the Lower Dill Branch, all CUPN samples from waters originating within the park fell within the informal reference condition range of 0-15 mg/l as $CaCO_3$, which appears to be a natural range for these waters. Measurements outside this range from the Lower Dill Branch are a result of back flooding from the Tennessee River (Meiman 2007). ANC is generally not a concern in Owl Creek and the Tennessee River due to their high carbonate loads (Meiman, email communication, 8 February 2016). While the low ANC values at SHIL are natural, they are somewhat concerning, as these water bodies are more vulnerable to the negative effects of acid precipitation/deposition (Meiman 2007). As a result, this measure is assigned a *Condition Level* of 1.

E. coli Bacteria

The *E. coli* bacteria measure received a *Significance Level* of 3. Occasional spikes in *E. coli* bacteria levels have been documented in some SHIL waters, but no measurements have exceeded the single-sample state standard for the protection of aquatic life (Meiman 2007, 2012, 2013). High measurements were generally associated with wildlife activity or stormwater runoff and are considered within the range of natural, background conditions (Meiman 2007, 2013). Therefore, this measure is assigned a *Condition Level* of 0, indicating no current concern.

Weighted Condition Score

The *Weighted Condition Score* for SHIL's water quality is 0.17, indicating good condition. This is reflective of the relatively pristine nature of many of the park's water resources. Given that sampling results for the selected measures have been fairly consistent over the period of record, the trend for water quality is considered unchanging or stable.

Water Quality			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.17**
Water Temperature	3	0	
pH	3	1	
Dissolved Oxygen	3	1	
Specific Conductance	3	0	
Acid Neutralizing Capacity	3	1	
E. coli Bacteria	3	0	

4.7.6. Sources of Expertise

- Joe Meiman, National Park Service Hydrologist
- Jack Grubaugh, Professor, University of Tennessee-Martin
- Jeff Duncan, NPS Southeast Region Water Quality Specialist

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4.8. Air Quality

4.8.1. Description

Air pollution can significantly affect natural resources, their associated ecological processes, and the health of park visitors. In the Clean Air Act (CAA), Congress set a national goal "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic or historic value" (42 U.S.C. §7470(2)). This goal applies to all units of the National Park System. The act includes special provisions for 48 park units, called "Class I" areas under the CAA; all other NPS areas are designated as Class II, including SHIL. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas which can allow for more development (NPS 2004). Additional authority to consider and protect air quality in Class II parks is provided by Title 54 (54 USC 100101(a) et seq.), commonly known as the NPS Organic Act.

Parks designated as Class I and II airsheds typically use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA standards are designed to protect human health and the health of natural resources (EPA 2016c). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008). In addition, the CUPN has identified ozone and ozone impacts as a Vital Sign for all network parks, including SHIL (Leibfreid et al. 2005).

Photo 21. A portable ozone monitoring station (POMS) deployed by the CUPN in SHIL's Russian Tenant Field in 2009 (NPS/ J. JERNIGAN).

4.8.2 Measures

- Ozone
- Sulfur wet deposition

- Nitrogen deposition
- Mercury deposition
- Particulate matter (PM)
- Visibility

Ozone

Ozone occurs naturally in the earth's upper atmosphere where it protects the earth's surface against ultraviolet radiation (EPA 2012). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone precursors are emitted from both anthropogenic and natural source types, including power plants, industry, motor vehicles, oil and gas development, forest fires, and other sources (Beitler 2006, EPA 2008).

Ozone is one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth defects for sensitive plants in natural ecosystems. Specific defects include reduced photosynthesis, premature leaf loss, and reduced biomass; prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). Plant species occurring in SHIL that are known to be sensitive to ozone include green and white ash, tulip poplar, and Virginia creeper (Kohut 2007).

At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans through reduced lung function, increased acute respiratory problems, and elevated susceptibility to respiratory infections (EPA 2016b). Visitors and staff engaging in aerobic activities in the park (e.g., hiking), as well as children, the elderly, and people with heart and lung diseases are especially sensitive to elevated ozone levels.

Atmospheric Deposition of Sulfur and Nitrogen

Sulfur and nitrogen are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012). While in the atmosphere, these emissions form compounds that may be transported long distances, eventually settling out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (NPS 2008, EPA 2012). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b). The acidic nature of nitrogen and sulfur deposition can also contribute to the deterioration of stone in monuments and historic structures (Charola 1998).

Atmospheric Deposition of Mercury

Sources of atmospheric mercury (Hg) include anthropogenic sources such as fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, along with natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008). Atmospheric deposition of Hg from coal-burning power plants has been identified as a major source of Hg to remote ecosystems (Landers et al. 2008). Hg is a potential problem for ecosystems in regions with heavy current or historic coal use.

Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species, resulting in exposure to wildlife and humans that consume them (EPA 2008). Hg exposure can cause liver, kidney, and brain (neurological and developmental) damage (EPA 2008). High Hg concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success (Mast et al. 2010, Eagles-Smith et al. 2014).

Particulate Matter and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2016d). There are two particle size classes of concern: $PM_{2.5}$ – fine particles found in smoke and haze, which are 2.5 micrometers in diameter or less; and PM_{10} – coarse particles found in wind-blown dust, which have diameters between 2.5 and 10 micrometers (EPA 2012). Fine particles are a major cause of reduced visibility (haze) in many national parks and wilderness areas (EPA 2012). $PM_{2.5}$ can either be directly emitted from sources (e.g., forest fires) or they can form when gas emissions from power plants, industry, and/or vehicles react in the air (EPA 2016d). Particulate matter can either absorb or scatter light, causing the clarity, color, and distance seen by humans to decrease, especially during humid conditions when additional moisture is present in the air. $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2016d). Exposure to these particles can cause airway irritation, coughing, and difficulty breathing (EPA 2016d).

4.8.3. Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (NPS 2015c). This approach is discussed by indicator in the following paragraphs and the ratings are summarized in Table 41 and Table 42.

Table 41. National Park Service Air Resources Division air quality index values for wet deposition of nitrogen or sulfur, ozone, particulate matter, and visibility (NPS 2015c).

Condition Level	Human Health Risk from O_3 (ppb)	Vegetation Health Risk from O_3 (ppm-hrs)	Wet Deposition of N or S (kg/ha-yr)	Human Health Risk from $PM_{2.5}$ (ppb)	Visibility (dv*)
Significant Concern	≥71	>13	>3	≥35.5	>8
Moderate Concern	55–70	7-13	1–3	12.1–35.4	2–8
Good Condition	≤55	<7	<1	≤12	<2

*A unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview (dv) represents the minimal perceptible change in visibility to the human eye.

Table 42. National Park Service Air Resources Division air quality assessment matrix for mercury status (NPS 2015c). Green = Good Condition, yellow = Moderate Concern, and red = Significant Concern.

Predicted Methylmercury Concentration Rating	Mercury Wet Deposition Rating				
	Very Low (<3 µg/m2/yr)	Low (≥3–<6 µg/m2/yr)	Moderate (≥6–<9 µg/m2/yr)	High (≥9–<12 µg/m2/yr)	Very High (≥ 12 µg/m2/yr)
Very Low (< 0.038 ng/L)	-	-	-	-	-
Low (≥0.038–< 0.053 ng/L)	-	-	-	-	-
Moderate (≥0.053–<0.075 ng/L)	-	-	-	-	-
High (≥0.075–<0.12 ng/L)	-	-	-	-	-
Very High (≥0.12 ng/L)	-	-	-	-	-

Ozone

The primary NAAQS for ground-level ozone is set by the EPA, and is based on human health effects. The 2008 NAAQS for ozone was a 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb) (NPS 2015c). On 1 October 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb (EPA 2015). The NPS ARD recommends a benchmark for *Good Condition* ozone status in line with the updated Air Quality Index (AQI) breakpoints (NPS 2015c).

Current condition for human health risk from ozone is based on the estimated 5-year 4th-highest daily maximum 8-hour ozone average concentration in ppb (NPS 2015c). Ozone concentrations ≥71 ppb are assigned a *Significant Concern*, from 55–70 ppb are assigned *Moderate Concern*, and <55ppb are assigned a Good Condition (NPS 2015c).

In addition to being a concern to human health, long-term exposures to ozone can cause injury to ozone-sensitive plants (EPA 2014). The W126 metric relates plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the primary (human-health based) standard (EPA 2014). The W126 metric measures cumulative ozone exposure over the growing season in "parts per million-hours" (ppm-hrs) and is used for assessing the vegetation health risk from ozone levels (EPA 2014).

The W126 condition thresholds are based on information in the EPA's Policy Assessment for the Review of the Ozone NAAQS (EPA 2014). Research has found that for a W126 value of:

- ≤7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10% per year in sensitive species.

The NPS ARD recommends a W126 of <7 ppm-hrs to protect most sensitive trees and vegetation. Levels below this guideline are considered *Good Condition*, 7-13 ppm-hrs is *Moderate Condition*, and >13 ppm-hrs is considered to be of *Significant Concern* (NPS 2015c).

Atmospheric Deposition of Sulfur and Nitrogen

Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Wet deposition is used as a surrogate for total deposition (wet plus dry), because wet deposition is the only nationally available monitored source of nitrogen and sulfur deposition data (NPS 2015c). Values for nitrogen (from ammonium and nitrate) and sulfur (from sulfate) wet deposition are expressed as amount of nitrogen or sulfur in kilograms deposited over a 1 ha (2.5 ac) area in 1 year (kg/ha/yr). The NPS ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This is based on studies linking early stages of aquatic health decline correlated with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Sheibley et al. 2014). Parks with ≤1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned *Good Condition*, those with 1-3 kg/ha/yr are assigned *Moderate Concern*, and parks with depositions ≥3 kg/ha/yr are assigned *Significant Concern* (NPS 2015c).

Mercury Deposition

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (micrograms per m^2 per year [$\mu g/m^2/yr$]) and the predicted surface water methylmercury concentrations (nanograms per liter [ng/L]) at NPS I&M parks (NPS 2015c). It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition because atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and able to accumulate in food webs (NPS 2015c). Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors, like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH), must also be considered (NPS 2015c). Mercury wet deposition and predicted methylmercury concentration are considered concurrently in the mercury status assessment matrix displayed previously (Table 42) to determine park-specific mercury/toxics status (NPS 2015c).

Particulate Matter

The particulate matter condition is based on the NAAQS for $PM_{2.5}$ and PM_{10}, which are established by the EPA to protect human health (NPS 2015c). NPS units that are in EPA-designated nonattainment areas for particulate matter are assigned *Significant Concern* condition for particulate matter (NPS 2015c). The NAAQS primary standard for $PM_{2.5}$ is an annual 98th-percentile mean of 35 μg/m^3 for a 24-hour period over a 3-year average or a weighted annual mean of 15.0 μg/m^3 in a 24-hour period over a 3-year average (EPA 2016c).

For NPS units that are outside particulate matter nonattainment areas, EPA AQI breakpoints for 24-hour average (μg/m^3) are used to assign a particulate matter condition (NPS 2015c). $PM_{2.5}$ concentrations ≥35.5 ppb are assigned a *Significant Concern* (NPS 2015c). $PM_{2.5}$ concentrations from 12.1-35.4 ppb are assigned *Moderate Concern*. *Good Condition* is when $PM_{2.5}$ concentrations are ≤12 ppb (NPS 2015c).

Visibility

Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews [dv]) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2013). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier (NPS 2013). The NPS ARD assesses visibility condition status based on the deviation of the estimated current visibility on mid-range days from estimated natural visibility on mid-range days (i.e., those estimated for a given area in the absence of human- caused visibility impairment, EPA-454/B003-005) (NPS 2015c). The NPS ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network. Visibility on mid-range days is defined as the mean of the visibility observations falling within the 40th and 60th percentiles (NPS 2015c). A visibility condition estimate of <2 dv above estimated natural conditions indicates a *Good Condition*, estimates ranging from 2-8 dv above natural conditions indicate *Moderate Concern*, and estimates >8 dv above natural conditions indicate *Significant Concern* (NPS 2015c).

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days (NPS 2015c). Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend (NPS 2015c).

4.8.4. Data and Methods

<u>Monitoring in the Park</u>

Air quality monitoring in the park has been limited. Ozone was monitored by the CUPN from 16 July to 2 November 2009 and 24 April to 31 October 2015 using a portable ozone monitoring station (POMS) at Russian Tenant Field (Jernigan et al. 2010). The CUPN monitors ozone at two network parks each year, resulting in a 6-year sampling rotation for each park (Jernigan et al. 2012). Atmospheric deposition, $PM_{2.5}$, and visibility have never been measured within SHIL.

<u>NPS Data Resources</u>

Although data on most air quality parameters are not actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in SHIL. NPS ARD provides estimates of ozone, wet deposition (nitrogen, sulfur, and mercury), and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2009–2013). Estimates and conditions data for SHIL were obtained from the NPS Air Quality by park data products page (http://www.nature.nps.gov/air/data/products/parks/index.cfm).

On-site or nearby data are needed for a statistically valid trends analysis. There are no on-site or nearby representative monitors to assess ozone, $PM_{2.5}$, and nitrogen, sulfur and mercury deposition trends at this time. For visibility trend analysis, monitoring data from an Interagency Monitoring of Protected Visual Environments Program (IMPROVE) station is required (NPS 2015c). An IMPROVE monitoring site considered representative of a Class II park has to be between within +/- 30.48 m (100 ft) or 10% of maximum and minimum elevation of the park and at a distance of no more than 150 km (93 mi) (NPS 2015c). No currently operational IMPROVE monitoring locations meet these criteria for SHIL.

Other Air Quality Data Resources

The EPA Air Trends Database provides annual average summary data for ozone and $PM_{2.5}$ concentrations near SHIL (EPA 2016a). The nearest $PM_{2.5}$ monitor is located in Jackson, TN (Site ID: 47-113-0006) and is operated by the Tennessee Division of Air Pollution Control (Figure 34). This station, which has collected data from 2005–2007 and 2013-2015, is located approximately 68 km (42 mi) northwest of the SHIL boundary. The station is located in a more urban setting than SHIL (Johnathan Jernigan, CUPN Physical Scientist, email communication, 21 March 2016) and $PM_{2.5}$ measurements are likely to be slightly higher than in the more rural setting of the park. The nearest active ozone monitor is in Muscle Shoals, AL (Site ID 01-033-1002), just over 70 km (43 mi) southeast of SHIL, and has been active since 2003.

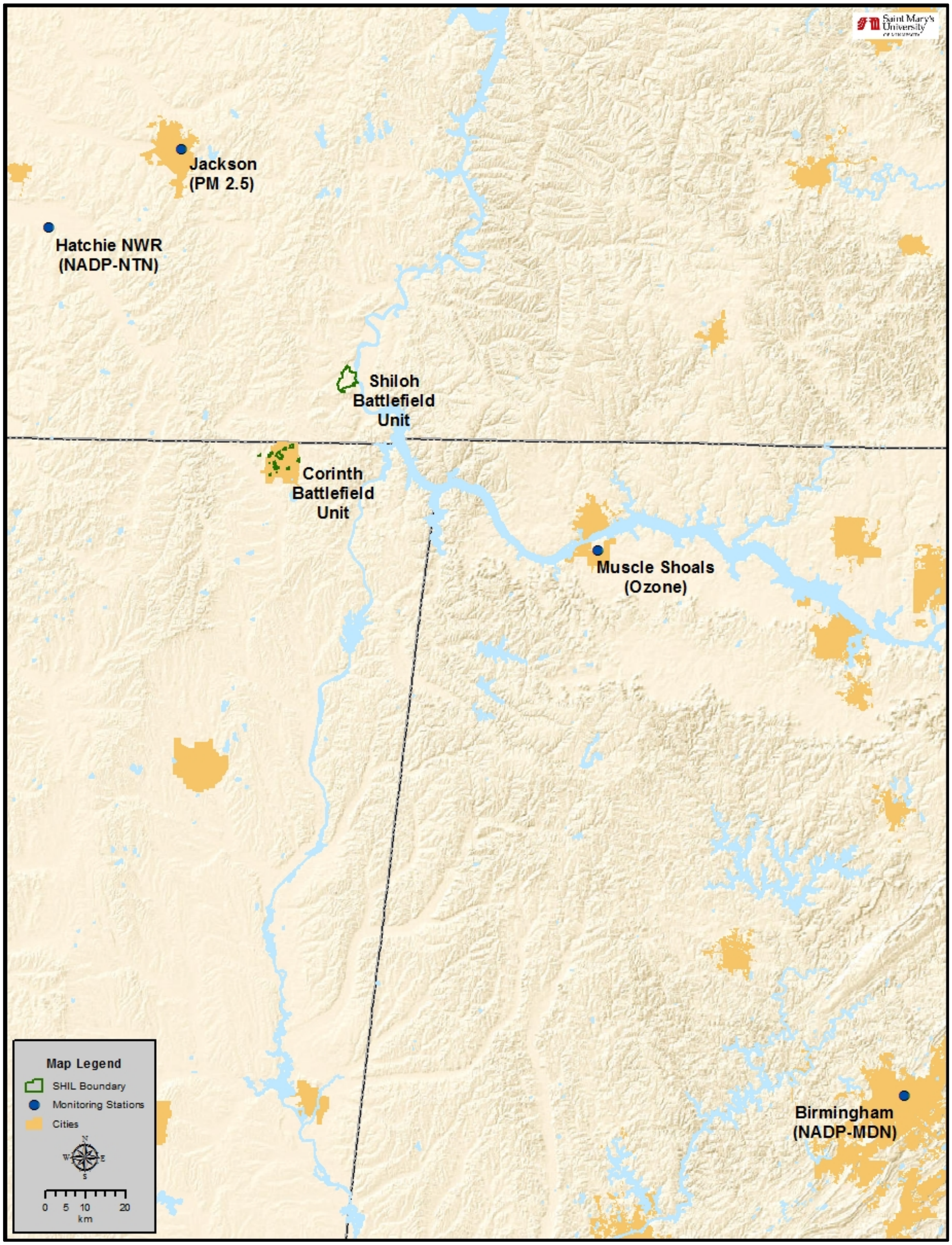

Figure 34. Air quality monitoring locations in relation to SHIL.

The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database provides annual average summary data for nitrogen and sulfur concentration and deposition across the U.S. (NADP 2016b). The NADP-NTN monitoring site closest to SHIL is located at Hatchie National Wildlife Refuge, in western Tennessee (site ID: TN14), approximately 80 km (50 mi) northwest of SHIL (Figure 34). This site has collected deposition data for the region since 1984 and is currently active in monitoring (NADP 2016b). Data summaries for this monitor are available on the NADP-NTN website (NADP 2016b).

The NADP Mercury Deposition Network (MDN) provides weekly summary data for mercury deposition and concentration (NADP 2016a). Wet mercury deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses. Trends are computed for parks with a representative NADP-MDN wet deposition monitor that is within 16 km (10 mi) of park boundaries (NPS 2015c). The monitor closest to SHIL is in Birmingham, AL, nearly 225 km (140 mi) southeast of SHIL (NADP 2016a) (Figure 34). Predicted methylmercury concentrations in surface water were obtained from a model that predicts surface water methylmercury concentrations for hydrologic units throughout the U.S. based on relevant water quality characteristics (pH, sulfate, and total organic carbon) and wetland abundance (USGS 2015).

<u>Special Air Quality Studies</u>

Sullivan et al. (2011a, 2011c) identified ecosystems and resources at risk to acidification and excess nitrogen enrichment in national parks. These reports provided a relative risk assessment of acidification and nutrient enrichment impacts from atmospheric nitrogen and sulfur deposition for parks in 32 I&M networks. Ecosystem sensitivity ratings to acidification from atmospheric deposition were based on percent sensitive vegetation types, number of high-elevation lakes, length of low-order streams, length of high-elevation streams, average slope, and acid-sensitive areas within the park (Sullivan et al. 2011a). Ecosystem sensitivity ratings to nutrient enrichment effects were based on percent sensitive vegetation types and number of high-elevation lakes within the park (Sullivan et al. 2011c).

Kohut (2007) employed a biologically-based method to evaluate the risk of foliar injury from ozone at parks within the 32 Vital Signs Networks, the Appalachian National Scenic Trail, and the Natchez Trace National Scenic Trail. The assessment allowed resource managers at each park to better understand the risk of ozone injury to vegetation within their park and permits them to make a better informed decision regarding the need to monitor the impacts of ozone on plants.

Pardo et al. (2011) synthesized current research relating atmospheric nitrogen deposition to effects on terrestrial and aquatic ecosystems in the U.S. and identified empirical critical loads for atmospheric nitrogen deposition.

4.8.5. Current Condition and Trend

<u>Ozone</u>

Historically, ozone has been a concern in the SHIL region. Kohut (2007) determined that the risk of ozone exposure at the park was high, with concentrations estimated (through kriging) to exceed 100 ppb multiple times annually from 1995-1999. During these same years, the estimated W126 value remained above 30 ppm-hrs, peaking at 62 ppm-hrs in 1999 (Kohut 2007).

The condition of human risk from ozone in NPS units is determined by calculating the 5-year average of the 4th-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2011). The most recent 5-year (2009–2013) estimated average for 4th-highest 8-hour ozone concentration at SHIL is 69.0 ppb (NPS 2015b), which is at the top of the *Moderate Concern* range. A comparison of this estimate to previous estimates suggests that ozone conditions are improving at SHIL; 5-year average estimates have declined annually from a high of 74 ppb for 2005-2009 (Figure 35).

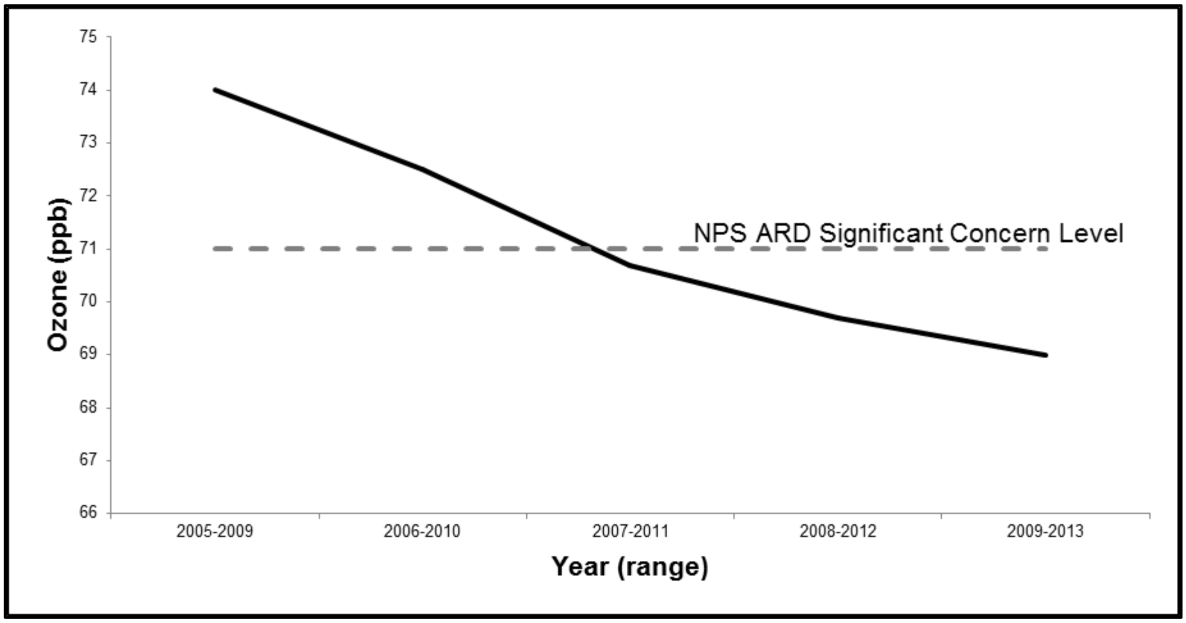

Figure 35. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for SHIL (NPS 2015b).

This suggested improvement is supported by data from the nearest year-round ozone monitor (Muscle Shoals, AL), which show ozone levels fluctuating over time but with an overall decreasing trend (Figure 36) (EPA 2016a, b, c).

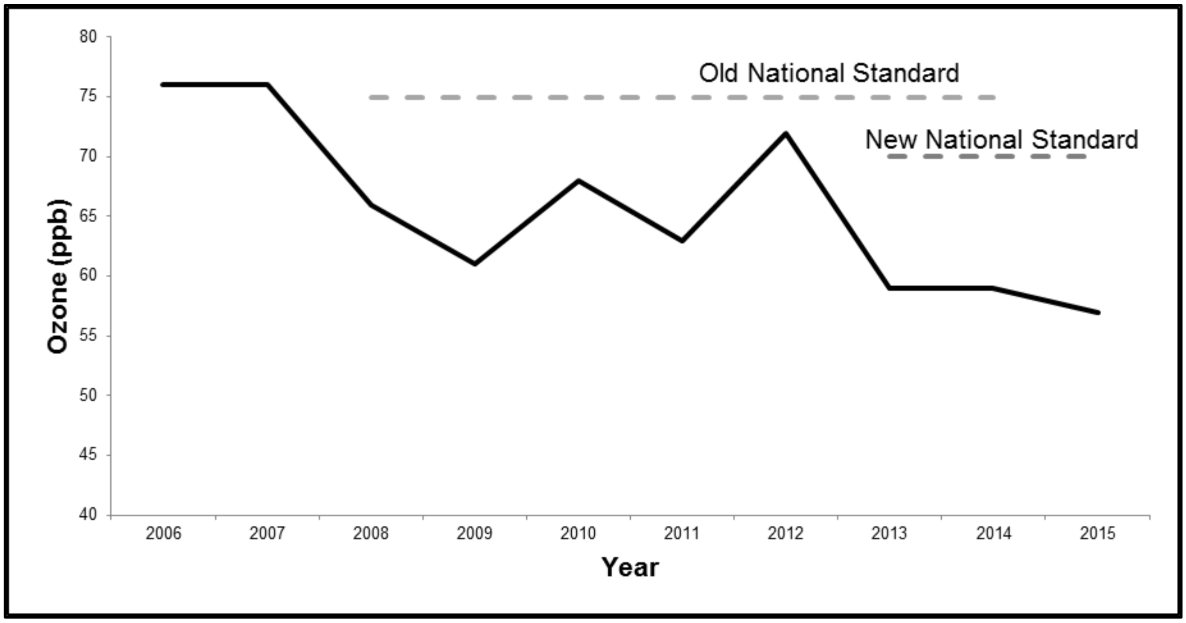

Figure 36. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Muscle Shoals monitoring station (Site ID 01-033-1002), 2006-2015 (EPA 2016a, c). Note: this site is located just over 70 km (43 mi) southeast of SHIL.

Vegetation health risk from ground-level ozone condition is determined by estimating a 5-year average of annual maximum 3-month, 12-hour W126 values. The 2009–2013 estimated W126 metric of 8.7 ppm-hrs falls in the *Moderate Concern* category (NPS 2015b).

Ozone was monitored during the growing season at SHIL from 16 July to 2 November 2009 and 24 April to 31 October 2015 (Jernigan et al. 2010, NPS ARD 2016b). During 2009 monitoring, ozone levels were well below the national standard and never exceeded 60 ppb (Figure 37). The W126 metric yielded a value of 0.74 ppm-hrs for the nearly 4-month monitoring period (Jernigan et al. 2010), which is well within the range considered *Good Condition* by the NPS ARD (< 7 ppm-hrs). However, ozone foliar injury was detected on multiple plants at three park locations (see Chapter 4.1.5).

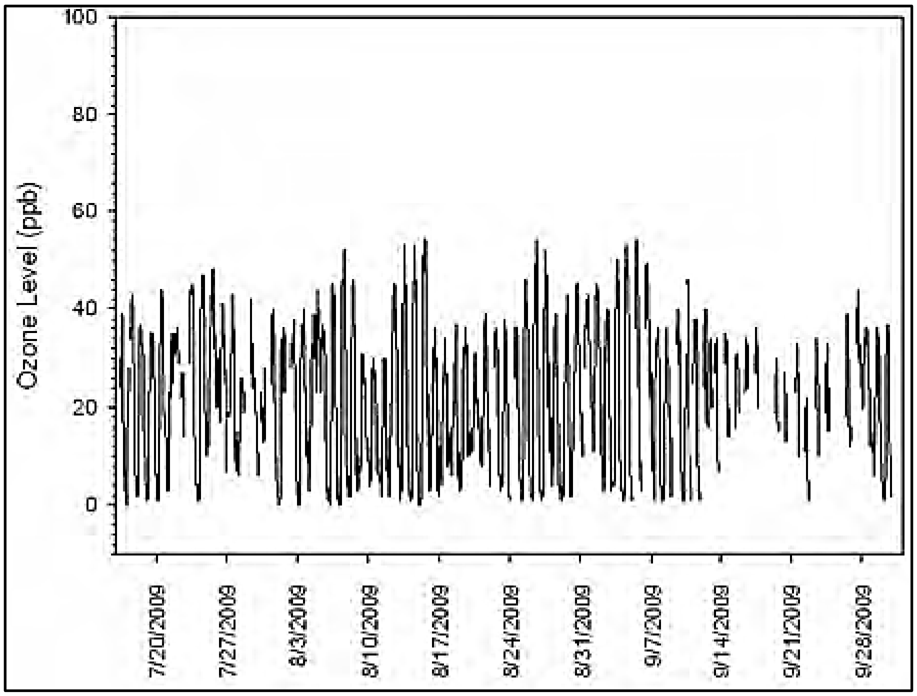

Figure 37. Ozone levels at SHIL, July to November 2009 (reproduced from Jernigan et al. 2010).

During 2015 sampling, hourly readings of ozone levels at SHIL ranged from 0-64 ppb (NPS ARD 2016b). Eight-hour ozone concentrations were reported from late April through May and ranged from 4-59 ppb (NPS ARD 2016b). The W126 metric was calculated with May-July data and yielded a value of 1.4 ppm-hrs (NPS ARD 2016b). While this is higher than the 2009 measurement, it is still well within the NPS ARD's *Good Condition* range. No foliar injury was detected on plants at the three sampling locations in 2015 (Jernigan, written communication, June 2016).

Sulfur Wet Deposition

Five-year interpolated averages of sulfur (from sulfate) wet deposition are used to estimate condition for deposition. The most recent 5-year (2009–2013) estimate for sulfur wet deposition at SHIL is 3.4 kg/ha/yr (NPS 2015b). Based on the NPS ratings for air quality conditions (see Table 41), this is of *Significant Concern*. A comparison to previous estimates suggests that sulfur deposition may be slowly decreasing at SHIL (Figure 38).

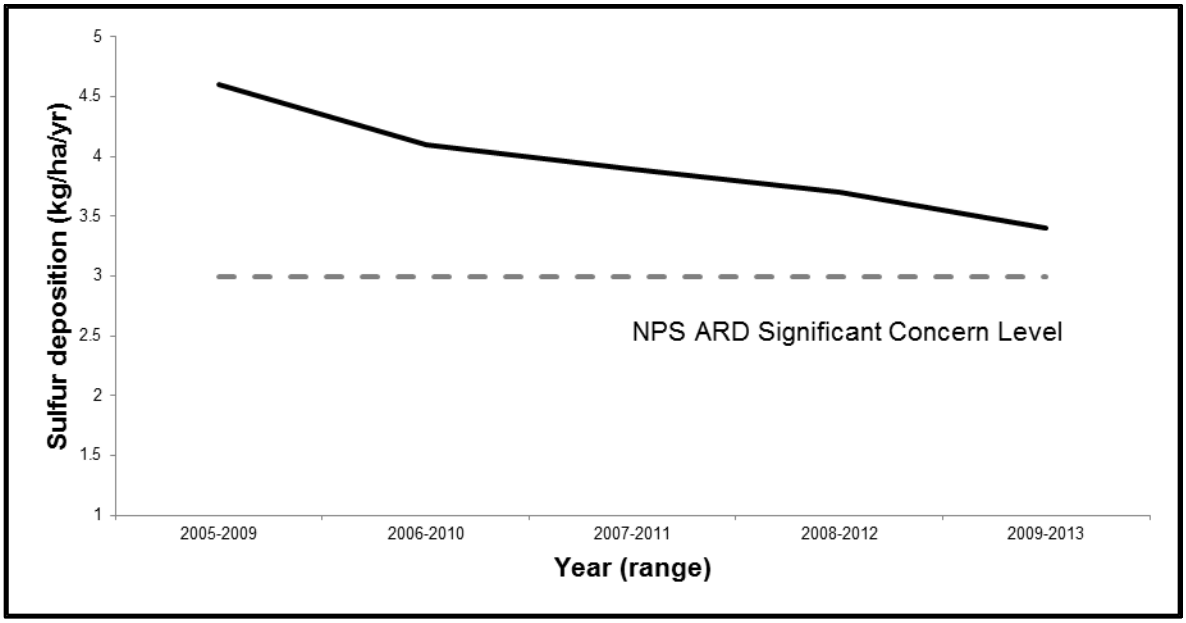

Figure 38. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at SHIL (NPS 2015b).

Concentrations (mg/L) of sulfur compounds in wet deposition can be used to evaluate overall trends in deposition. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Figure 39 shows that the sulfate concentration in the SHIL region has declined over time, recently dropping below 0.8 mg/L (NADP 2016b).

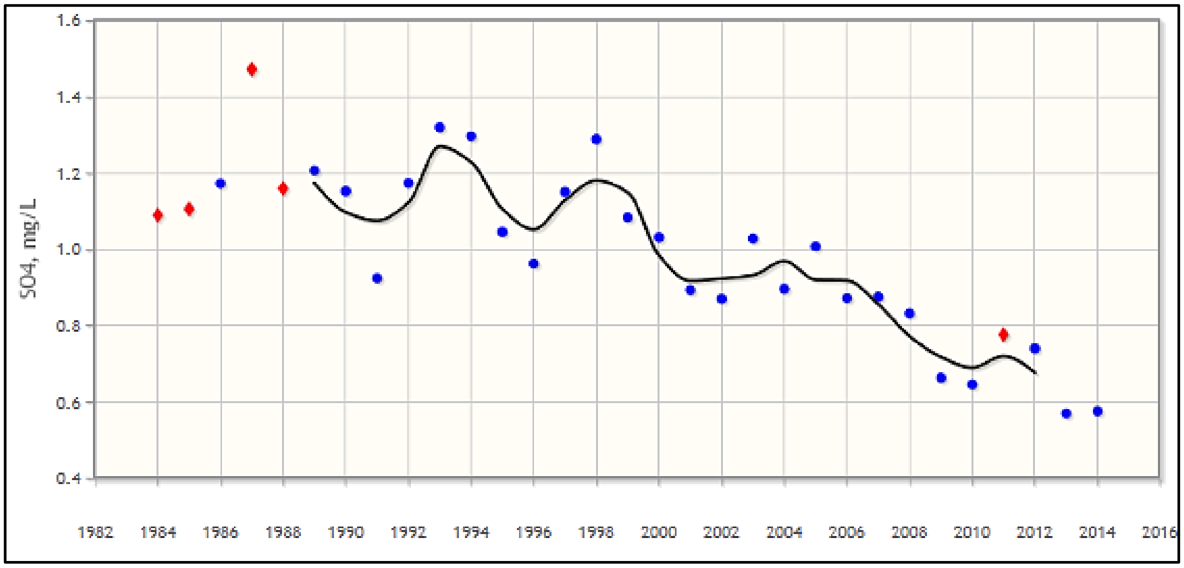

Figure 39. Annual weighted mean concentration of sulfate in wet deposition from Hatchie NWR (NTN Site TN 14) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

Sullivan et al. (2011a) ranked SHIL as having relatively high risk of pollutant exposure, but park ecosystems generally have low sensitivity to acidifying pollution. As a result, the overall relative risk of acidification from sulfur and nitrogen deposition at SHIL was ranked as moderate (Sullivan et al. 2011b).

Nitrogen Deposition

Five-year interpolated averages of nitrogen (from nitrate and ammonium) wet deposition are used to estimate condition for deposition. The most recent 5-year (2009–2013) estimate for nitrogen deposition at SHIL is 4.3 kg/ha/yr (NPS 2015b). This falls in the *Significant Concern* range. A comparison to previous 5-year estimates shows that nitrogen deposition appears relatively stable over recent time (Figure 40).

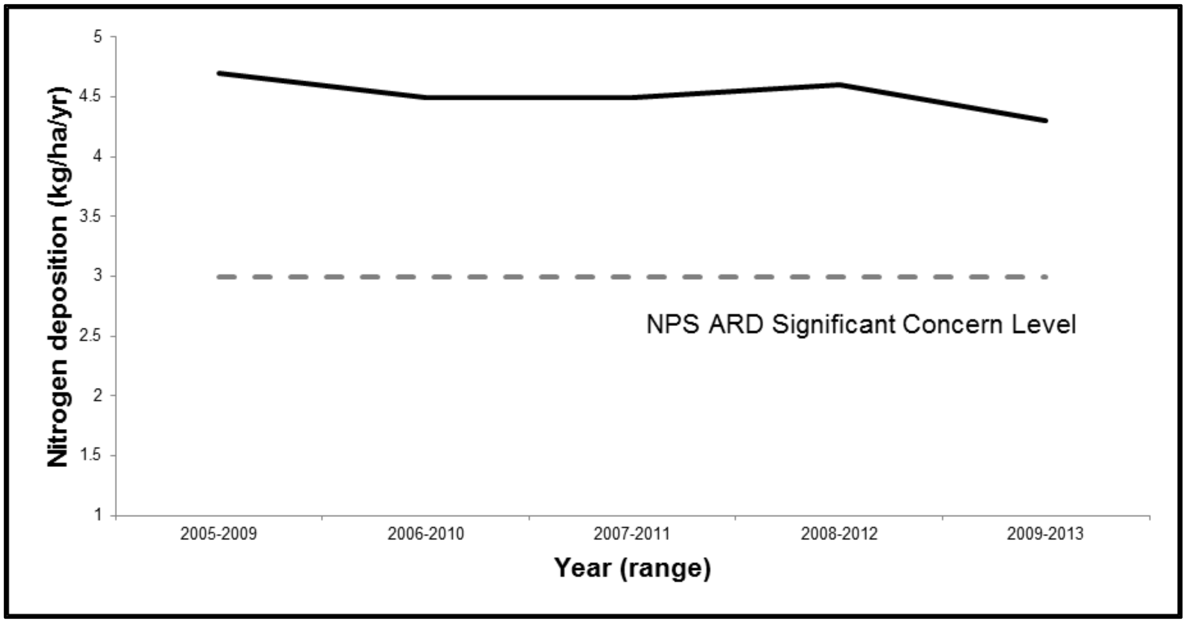

Figure 40. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at SHIL (NPS 2015b).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to park resources (Pardo et al. 2011). A critical load is defined as the level of deposition below which harmful effects to the ecosystem are not expected (Pardo et al. 2011). For the Eastern Temperate Forest, the ecoregion where SHIL is located, Pardo et al. (2011) suggested critical load ranges for total nitrogen deposition (wet plus dry) of 4-8 kg/ha/yr to protect lichen, 8 kg/ha/yr to protect hardwood forests, and <17.5 kg/ha/yr to protect herbaceous species. The lowest critical load level (4.0 kg/ha/yr) is identified as an appropriate management goal because it will protect the full range of vegetation in the park (Pardo et al. 2011). The 2009-2013 estimated deposition at SHIL of 4.3 kg/ha/yr was just above the minimum ecosystem critical load for the ecoregion, suggesting that sensitive vegetation elements may be at risk for harmful effects. Similarly, Sullivan et al. (2011c) ranked SHIL as at moderate risk of nutrient enrichment from nitrogen deposition, due to high pollutant exposure but generally low levels of ecosystem sensitivity.

As with sulfur, concentrations (mg/L) of nitrogen compounds in wet deposition can also be used to evaluate overall trends in deposition. Figure 41 shows that nitrate concentrations increased during the 1990s but then decreased, recently dropping to the lowest levels recorded at the monitoring station. In contrast, ammonium concentrations have slowly increased over the period of record (Figure 42) (NADP 2016b).

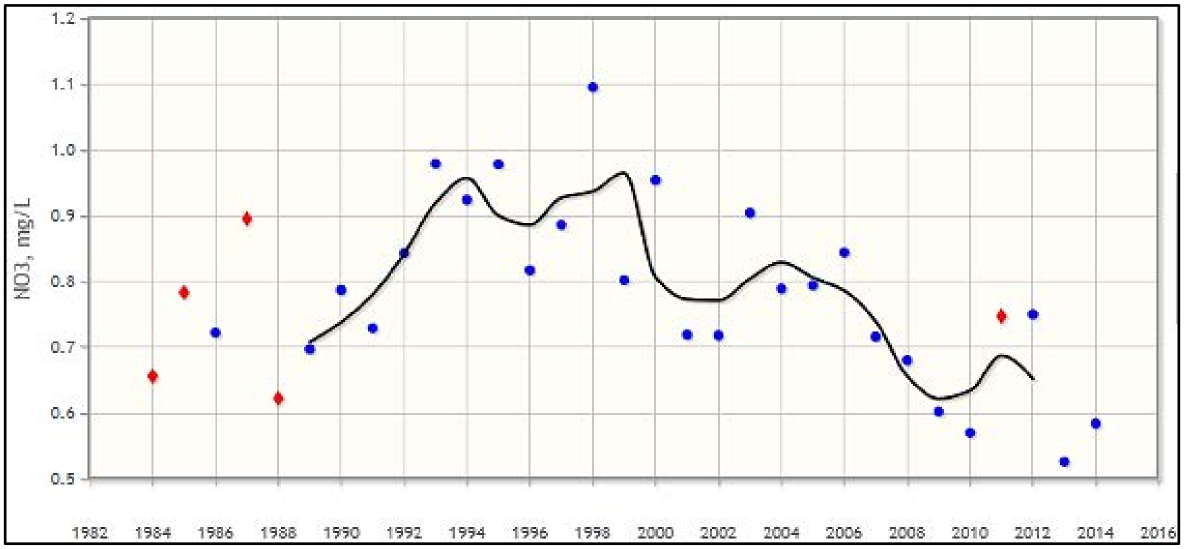

Figure 41. Annual weighted mean concentration of nitrate in wet deposition from Hatchie NWR (NTN Site TN 14) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

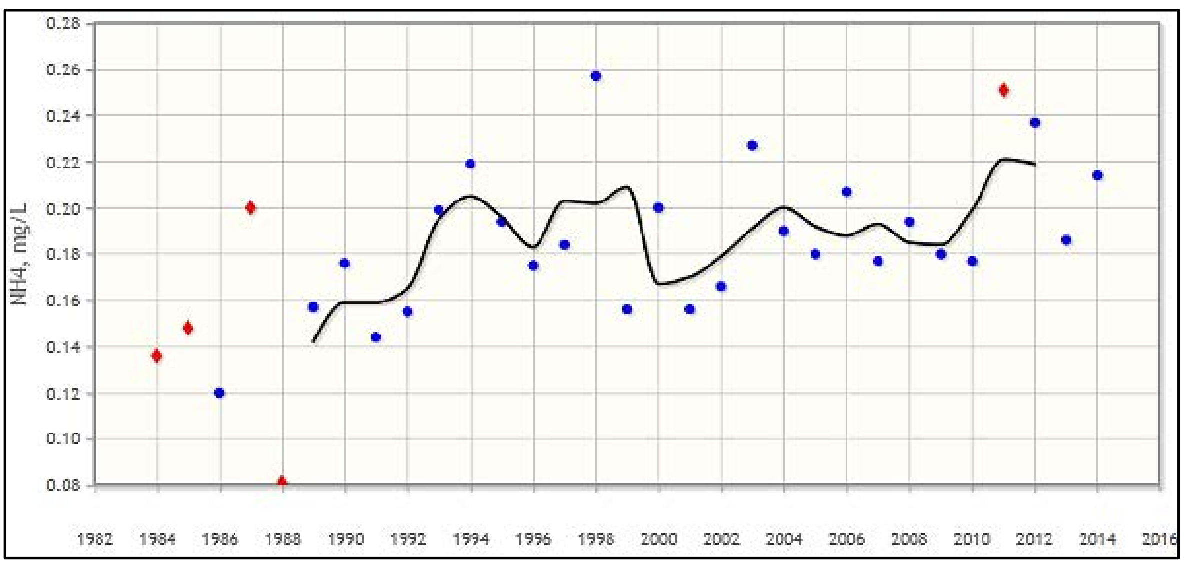

Figure 42. Annual weighted mean concentration of ammonium in wet deposition from Hatchie NWR (NTN Site TN 14) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

Similar to the nutrient enrichment assessment discussed previously, Sullivan et al. (2011b) ranked SHIL as at moderate risk of acidification from nitrogen deposition, due to high pollutant exposure but generally low levels of ecosystem sensitivity.

<u>Mercury Deposition</u>

The 2011-2013 wet mercury deposition estimates are very high for SHIL, at 14.4 µg/m2/yr, but predicted methylmercury concentrations in surface waters are very low, estimated at 0.035 ng/l (NPS ARD 2016a). When compared to the NPS ARD mercury status assessment matrix (Table 42), these estimates result in a condition of *Moderate Concern*.

Total mercury deposition at the monitor nearest to SHIL (Birmingham, AL) is rather high, measuring 17.3 $\mu g/m^2$ in 2014 (Figure 43) (NADP 2014). Based on interpolations by the MDN, deposition levels in the SHIL area in 2014 were likely in the 12-16 $\mu g/m^2$ range (Figure 43).

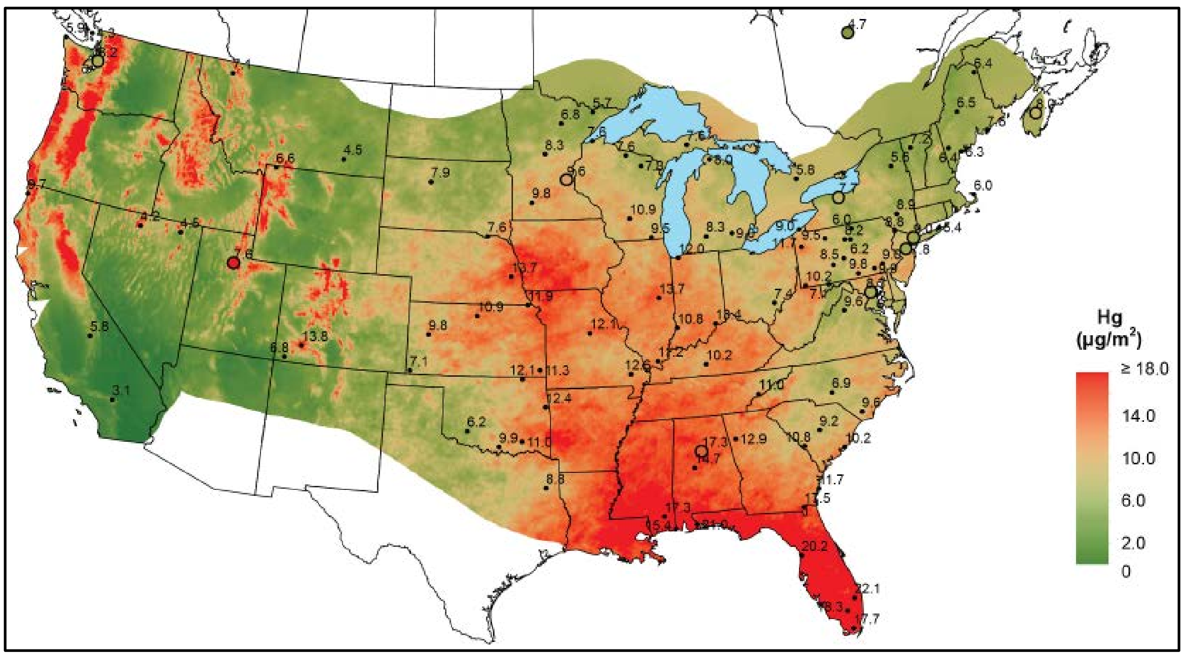

Figure 43. Total annual mercury wet deposition in 2014 (NADP 2014).

Mercury concentrations are also relatively high at the Birmingham, AL monitoring station, with a value of 13.3 ng/L in 2014 (Figure 44) (NADP 2014). Based on interpolations displayed in Figure 44, total mercury concentrations in the SHIL area were likely 9-12 ng/L (NADP 2014).

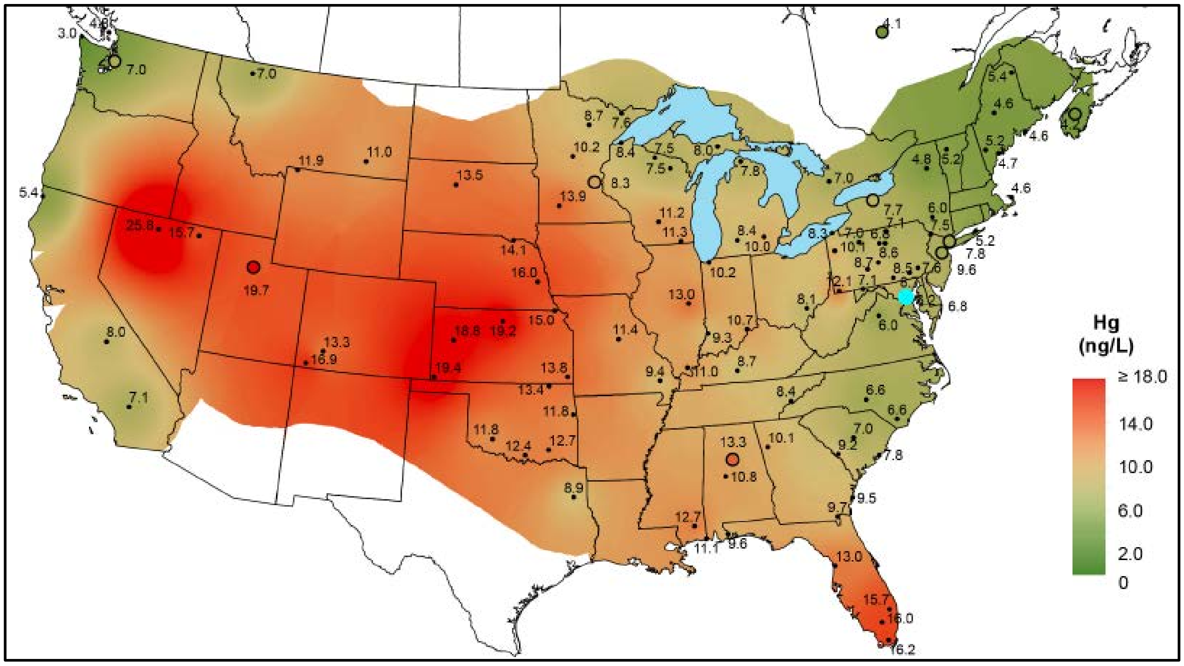

Figure 44. Total mercury concentrations in 2014 (NADP 2014).

The NPS ARD has measured mercury wet deposition at 16 parks across the U.S (NPS 2013). The location closest to SHIL where monitoring has occurred is Mammoth Cave National Park (MACA), approximately 300 km (186 mi) northeast of SHIL. According to an analysis of mercury concentrations in precipitation, concentrations at MACA have been relatively stable, decreasing by just 0.08 ng/L/yr from 2000-2009 (NPS 2013).

Particulate Matter

Annual average 24-hour $PM_{2.5}$ concentrations are available from a station in Jackson, TN, for 2005-2007 and 2013-2015. This station is in a more urban setting than SHIL and $PM_{2.5}$ measurements are likely to be slightly higher than conditions at the more rural park, but these are the best available data. These observations suggest that $PM_{2.5}$ concentrations have recently decreased in the region and are currently within the EPA standards for levels that are protective of human health (35 µg/m^3) (Figure 45) (EPA 2016d). However, the most recent 3-year average 98th percentile 24-hour $PM_{2.5}$ concentration of 17.2 µg/m^3 falls in the NPS ARD's *Moderate Concern* range.

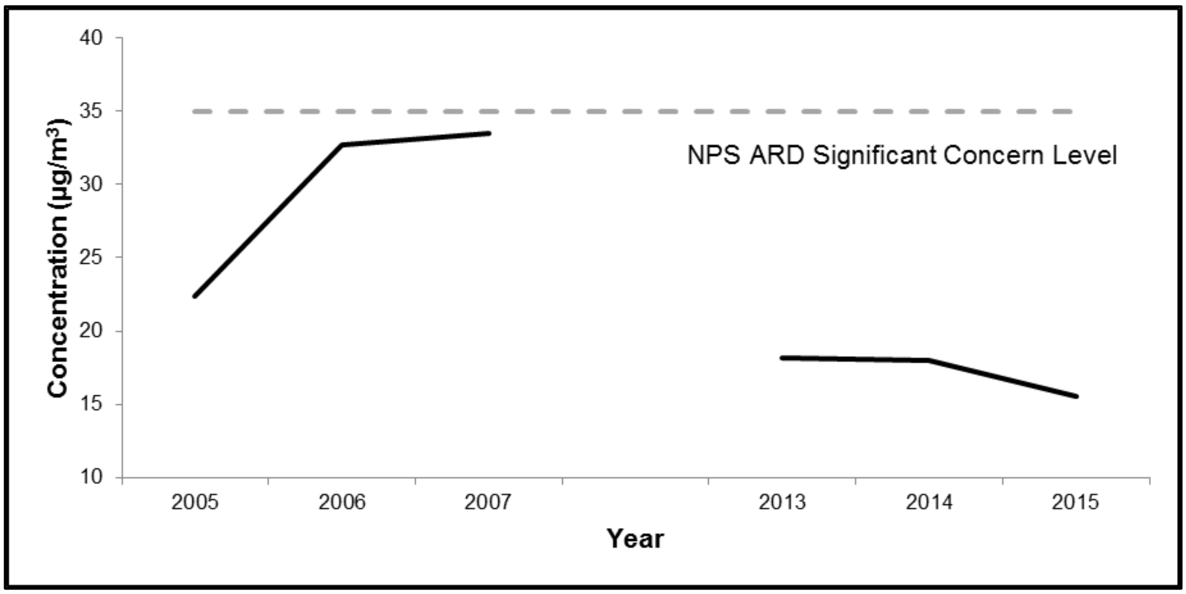

Figure 45. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) for the SHIL region, 2005-2007 and 2013-2015 (EPA 2016a). The monitoring station is located in Jackson, TN (Site ID: 47-113-0006).

Visibility

Five-year estimated averages of visibility on mid-range days minus natural condition visibility on mid-range days are used to estimate condition for visibility. The 2009–2013 estimated visibility on mid-range days for SHIL was 10.6 dv above estimated natural conditions (NPS 2015b). This estimate falls into the *Significant Concern* category based on NPS criteria for air quality assessment. Estimates are also generated for the 20% clearest and 20% haziest days. For 2009-2013, visibility was 5.0 dv above natural conditions on the 20% clearest days and 16.2 dv above natural conditions on the 20% haziest days (NPS 2015a).

Comparing the most recent mid-range estimate to previous NPS ARD estimates of visibility suggests that conditions may be improving at SHIL. The 2005-2009 estimated visibility was 13.4 dv above estimated natural conditions, but the 5-year average has declined every year since, although it is still well above the significant concern threshold (>8 dv) (Figure 46).

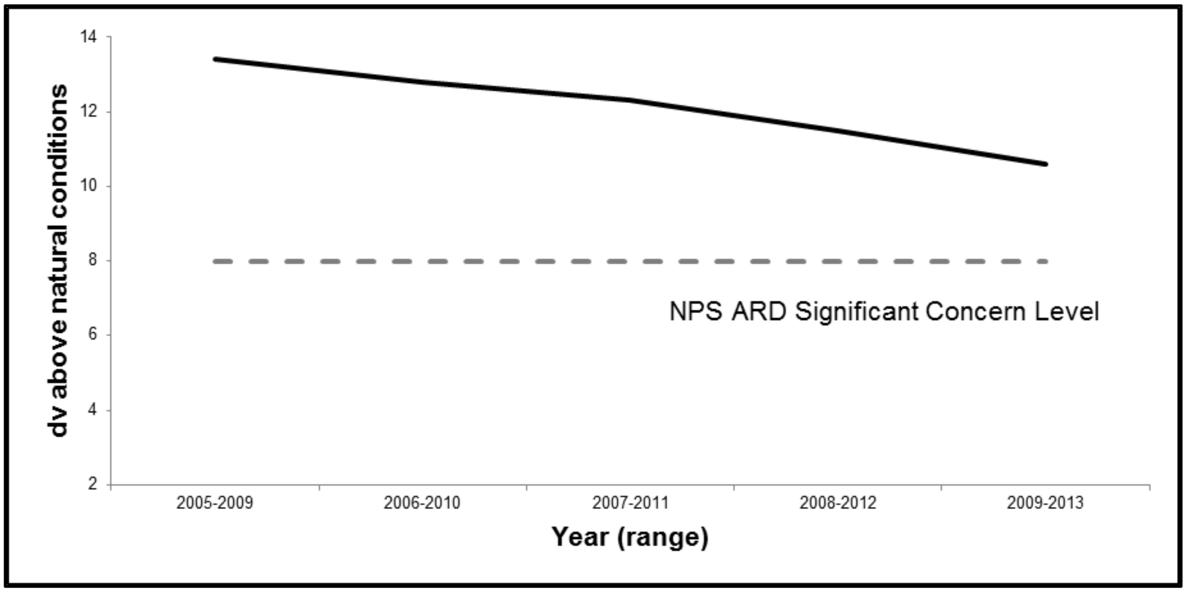

Figure 46. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at SHIL (NPS 2015b).

<u>Threats and Stressor Factors</u>

Threats to SHIL's air quality include vehicle emissions, industrial and agricultural practices, and pollution from regional metropolitan areas. Transportation sources account for a significant portion of nitrogen oxide and VOC emissions in the U.S. and also produce some particulate pollution and sulfur dioxides (Small and Kazimi 1995). These emissions can contribute to ozone formation and impact visibility. State Highway 22 passes through the west side of SHIL, allowing for a relatively high level of traffic through the park. Also, the NPS has created a self-guided auto tour route through the park with 20 stops at various historically significant locations (NPS 2016). This route and the associated stops may encourage additional vehicle travel (and idling at stops) in the park.

Regional industrial sources also contribute pollution to the region. For example, the Tennessee Valley Authority (TVA) has operated a coal-burning power plant in Colbert County, AL, on Pickwick Landing Lake since the 1950s. Due to environmental concerns, this plant is scheduled to be retired in 2016 (TVA 2016). There is also a pulp mill on the Tennessee River just upstream of the park (Meiman, email communication, 11 February 2016) which likely produces hazardous air pollutants.

The conversion of natural areas to agriculture and development can reduce the ecosystem's ability to regulate climate and air quality (Foley et al. 2005). Trees and other natural vegetation can remove pollutants such as sulfur dioxides, nitrogen dioxides, and ozone from the atmosphere by absorbing them along with CO_2 (McPherson et al. 1994). When forests are cleared for agriculture or development, this benefit is lost along with them. Agricultural practices can also contribute air pollutants from dust, biomass burning, and motorized equipment emissions (Foley et al. 2005).

SHIL may be impacted by air pollution from major metropolitan areas in the region, including Memphis (155 km [96 mi] west) and Nashville (180 km [112 mi] northeast). The degree and timing of these impacts depends on prevailing wind directions, which can vary with season. For Memphis air pollution to reach SHIL, winds would have to be from the west. Based on wind speed and direction data for Memphis (from the 1961-1990 climate normal period), winds in the area are rarely from the west (<6% frequency) (NRCS 2010). Similarly, for Nashville air pollution to reach SHIL, winds would have to be from the northeast. Nashville wind data for the same period show that northeast winds are rare (<6% frequency) but would be most likely to occur in August and September (NRCS 2010).

Air pollutants such as ozone and particulates are strongly influenced by weather shifts (e.g., heat waves, droughts) (EPA 2012). According to the EPA and IPCC, warmer temperatures associated with global climate change are expected to negatively affect air quality (EPA 2012). For example, the EPA (2012) projects that climate change could increase summertime average ground-level ozone concentrations in many areas by 2-8 ppb.

<u>Data Needs/Gaps</u>

If budget and personnel limitations allow, on-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury), particulate matter, and visibility will help managers better understand air quality conditions in the park. Studies of mercury concentrations in park wildlife (e.g., fish, birds) may also provide insight into the impact this contaminant is having on the park.

<u>Overall Condition</u>

Ozone

The project team assigned this measure a *Significance Level* of 3. In recent decades, ozone levels have been a serious issue at SHIL. As recently as 2010, the 5-year estimated average for 4th-highest 8-hour ozone concentration fell within the NPS ARD's *Significant Concern* range (NPS 2015b). In the past few years, ozone estimates for SHIL have decreased and now fall in the *Moderate Concern* range. Evidence of ozone foliar injury was detected on multiple plants at three park locations in 2009 but no injury was detected in 2015 (Jernigan et al. 2010, CUPN 2015). Ozone is currently of moderate concern at SHIL (*Condition Level* = 2) with an improving trend.

Sulfur Wet Deposition

This measure was also assigned a *Significance Level* of 3. The most recent 5-year (2009-2013) estimate for sulfur wet deposition at SHIL falls in the *Significant Concern* range, as defined by the NPS ARD (NPS 2015b). However, the current 5-year estimate of 3.4 kg/ha/yr is lower than previous estimates (NPS 2015b), suggesting that conditions may be improving. Data from the nearest NADP monitor show that the concentration of sulfate in wet deposition has also been decreasing (NADP 2016b). Despite potential improvements, this measure is still of significant concern (*Condition Level* = 3).

Nitrogen Deposition

A *Significance Level* of 3 was assigned to this measure. The most recent 5-year estimate for nitrogen deposition at SHIL also falls in the *Significant Concern* range; 5-year estimates have remained relatively stable in recent years (NPS 2015b). Data from the nearest NADP monitor show that nitrate concentrations in wet deposition have decreased over time but ammonium concentrations have increased (NADP 2016b). Nitrogen deposition is currently of significant concern (*Condition Level* = 3) at SHIL.

Mercury Deposition

The project team assigned mercury deposition a *Significance Level* of 3. While the 2011–2013 estimated wet mercury deposition was very high for SHIL (14.4 µg/m2/yr), the predicted methylmercury concentrations in surface waters were very low (0.035 ng/l) (NPS ARD 2016a). These values result in a moderate concern (*Condition Level* = 2) for mercury deposition at the park.

Particulate Matter

Particulate matter was also assigned a *Significance Level* of 3. The $PM_{2.5}$ monitor closest to SHIL is in the urban setting of Jackson, TN, where particulate levels are likely higher than at the more rural park. $PM_{2.5}$ readings from this monitor have decreased in the past decade and are within the EPA standards considered protective of human health (EPA 2016b). However, the most recent 3-year average 98th percentile 24-hour $PM_{2.5}$ concentration falls in the NPS ARD's *Moderate Concern* range. Therefore, this measure is assigned a *Condition Level* of 2.

Visibility

This measure was assigned a *Significance Level* of 3. According to NPS ARD estimates, visibility conditions at SHIL on mid-range days were 10.6 dv above estimated natural conditions, which falls in the *Significant Concern* range (NPS 2015b). Comparisons to previous estimates suggest that visibility conditions may slowly be improving in the region. However, this measure currently remains a significant concern (*Condition Level* = 3).

Weighted Condition Score

The *Weighted Condition Score* for SHIL's air quality is 0.83, which indicates significant concern. Data suggest that several measures (e.g., ozone, sulfur deposition, visibility) are slowly improving, so an improving trend has been assigned for the component as a whole. Since much of the air quality information for SHIL is based on interpolations from monitors some distance away rather than on-site measurements, a medium confidence border is used.

Air Quality			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.83**
Ozone	3	2	
Sulfur Wet Deposition	3	3	
Nitrogen Deposition	3	3	
Mercury Deposition	3	2	
Particulate Matter	3	2	
Visibility	3	3	

4.8.6. Sources of Expertise

- Johnathan Jernigan, CUPN Physical Scientist

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4.9. Dark Night Skies

4.9.1. Description

A lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2015). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, 2015). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2015). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

SHIL sits on the western bank of the Tennessee River, near the unincorporated community of Shiloh, Tennessee. The park falls in Hardin County which had a population of 26,025 as of 2010 (USCB 2015b). Many small communities are within close proximity (no more than 32 km [20 mi] in straight-line distances) to the park. These include (2010 population): Savannah (6,928), Olivet (1,350), Crump (1,428), Adamsville (2,207), Stantonville (238), Bethel Springs (718), Selmer (4,396), Eastview (705), Guys (466), Michie (591), and Corinth, Mississippi (14,573) (USCB 2016) (Figure 47).

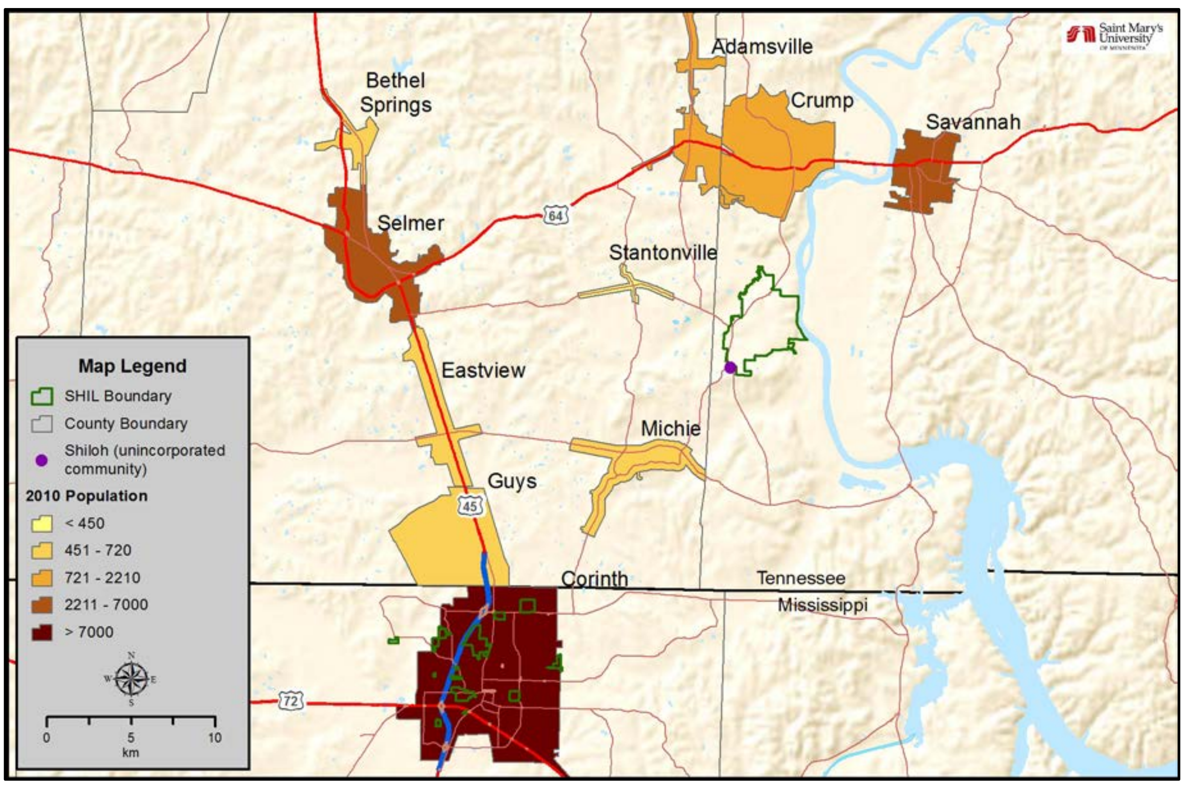

Figure 47. Surrounding communities and traffic cause potential sources of anthropogenic light pollution for SHIL.

The resource of a dark night sky is important to the NPS for a variety of reasons. First, the preservation of natural lightscapes (the intensity and distribution of light on the landscape at night) will keep the nocturnal photic environment within the range of natural variability. Excursions outside this natural range may result in a modification to natural ecosystem function, especially to systems involving the behavior and survival of nocturnal animals (NPS 2015). The natural night sky is therefore one of the physical resources under which natural ecosystems have evolved. Second, the "scenery" of national park areas does not just include the daytime hours (NPS 2015). Third, the history and culture of many civilizations are steeped in interpretations of night sky observations, whether for scientific, religious, or time-keeping purposes (NPS 2015). As such, the natural night sky may be a very important cultural resource, especially in areas where evidence of aboriginal cultures is present. Fourth, the recreational value of dark night skies is important to campers and backpackers, allowing the experience of having a campfire or "sleeping under the stars" (NPS 2015). And lastly, night sky quality is an important wilderness value, contributing to the ability to experience a feeling of solitude in a landscape free from signs of human occupation and technology (NPS 2015).

4.9.2. Measures

The dark night sky at SHIL was assessed using the suite of measures that the NPS Natural Sounds and Night Sky Division (NSNSD) uses to define the dark night conditions in a park unit. The measures are as follows:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second [mag/arcsec^2] or milli-candela per square meter [mcd/m^2]) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude (mags) is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a "Johnson-Cousins V" filter. It is similar to the "CIE photopic" broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);
- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;
- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;
- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;
- Visual observations by a human observer, such as Bortle Class and Zenith limiting magnitude (ZLM);
- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter (SQM), in mag/arcsec^2.

In the absence of this data, the NPS NSNSD recommends the use of the anthropogenic light ratio (ALR) as a measure of the quality of the photic environment and lightscape within a park (Moore et al. 2013). The ALR measures the average anthropogenic sky luminance as a ratio of natural conditions (Moore et al. 2013). This measure is easily modeled and provides a robust and descriptive metric (Moore et al. 2013).

4.9.3. Reference Conditions/Values

Park staff identified the absence of anthropogenic light as the preferred reference condition. This condition can be defined as the absence of artificial light in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> *No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated a naturally dark zone* (Dan Duriscoe, NPS NSNSD, pers. comm., 2011).

The agency directive for preserving natural night skies is well summarized in the NPS Management Policies (NPS 2006, p. 7) in section 4.10 as follows:

> *The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.*

Implementing this directive in SHIL requires that facilities within the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;
- be of an intensity that meets the minimum requirement for the task, but does not excessively exceed that requirement;
- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;
- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

4.9.4. Data and Methods

The NPS NSNSD has developed a geographic information system (GIS) model derived from data from the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001), which depicts zenith sky brightness (the brightness of the sky directly above the observer) (Moore et al. 2013). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the entire sky. Anthropogenic light up to 200 km (124 mi) from parks can have an impact on a park's night sky quality. Finally, the modeled anthropogenic light over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Duriscoe, in preparation).

4.9.5. Current Condition and Trend

Background for NPS Night Sky Division's Suite of Measures

Anthropogenic light in the night environment can be very significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a "detector" or a measuring device, or entering the observer's pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English), and is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen/m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified (Ryer 1997).

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as "sky glow." This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional. When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a “full cutoff” design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 48 and Figure 49, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NSNSD.

Figure 48. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Dan Duriscoe, NPS NSNSD).

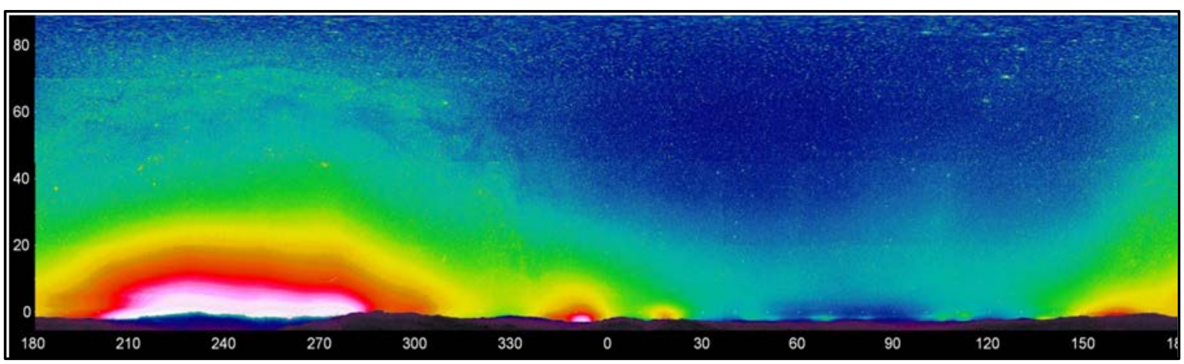

Figure 49. False color representation of Figure 48 after a logarithmic stretch of pixel values (Dan Duriscoe, NPS NSNSD).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NSNSD utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 48 and Figure 49 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called “permanent aurora” which varies in intensity over time) (Roach and Gordon 1973). The NSNSD has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 50). Figure 49 represents “total sky brightness” while Figure 50 displays “anthropogenic sky glow” or “net light pollution.” This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

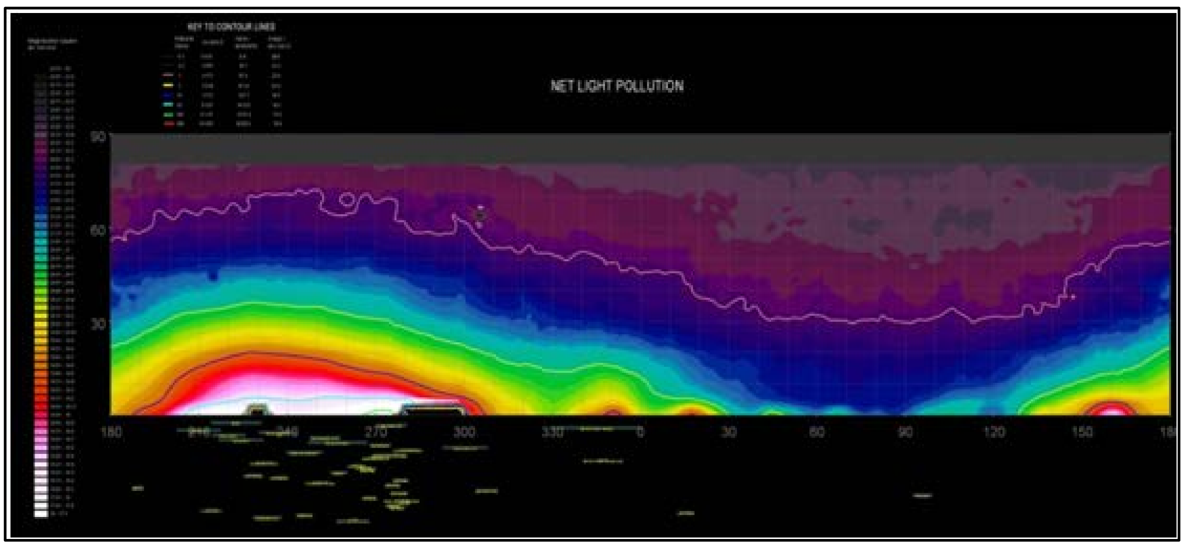

Figure 50. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 49 with natural sources of light subtracted (Dan Duriscoe, NPS Night Sky Division).

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric of the resource condition - a ratio of anthropogenic to natural light, the ALR identified previously (Moore et al. 2013). Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2010). This so-called “light pollution ratio” is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NSNSD data, the atmospheric conditions determined from each individual data set. The ALR is derived from ground–based measurements when available, or from a GIS model (calibrated to ground-based measurements in the park) when field based data or measures are not available (Moore et al. 2013).

A quick and moderately accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron SQM. The Unihedron SQM is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Since the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NSNSD produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron SQM. The performance of the SQM has been tested and reviewed by Cinzano et al. (2001). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered “pristine,” providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken (Moore et al. 2013).

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a “pristine sky” filled with easily observable features and class 9 represents an “inner city sky” where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

Another visual method for assessing sky quality is the ZLM, which is the apparent brightness or magnitude of the faintest star observable to the unaided human eye, which usually occurs near the Zenith. This method involves many factors, the most important of which is variability from observer to observer. A ZLM of 7.0-7.2 is usually considered “pristine” or representing what should be observed under natural conditions; observation of ZLM is one of the factors included in the Bortle Dark Sky Scale. The ZLM is often referenced in literature on the quality of the night sky, and is the basis for the international “Globe at Night” citizen-scientist program (see http://www.globeatnight.org/index.html). The NSNSD has experimented with the use of this observation in predicting sky quality, and has found that it is a much coarser measure and prone to much greater error than accurate photometric measures over the entire sky. For these reasons, it is not included in the reference conditions section.

NPS Night Sky Division Suite of Measures

The NSNSD has not made a field visit to SHIL; however, data is available for the GIS-modeled ALR. The results of the ALR model for the area surrounding SHIL are shown in Figure 51. A condition level can be assigned to the modeled ALR data, based on a threshold applied spatially to the park (Moore et al. 2013). This threshold is dependent on whether the park is considered to be urban or non-urban (Moore et al. 2013). The distinction between urban (Level II) and non-urban (Level I) parks is based on the relative proximity of the park (and its borders) to urban areas as defined by the 2010 U.S. Census (Moore et al. 2013). For parks managed as wilderness, the designated condition is based on the ALR level that exists in more than 90% of the wilderness area (Moore et al. 2013). Due to its “non-urban” designation, SHIL falls into the Level I category.

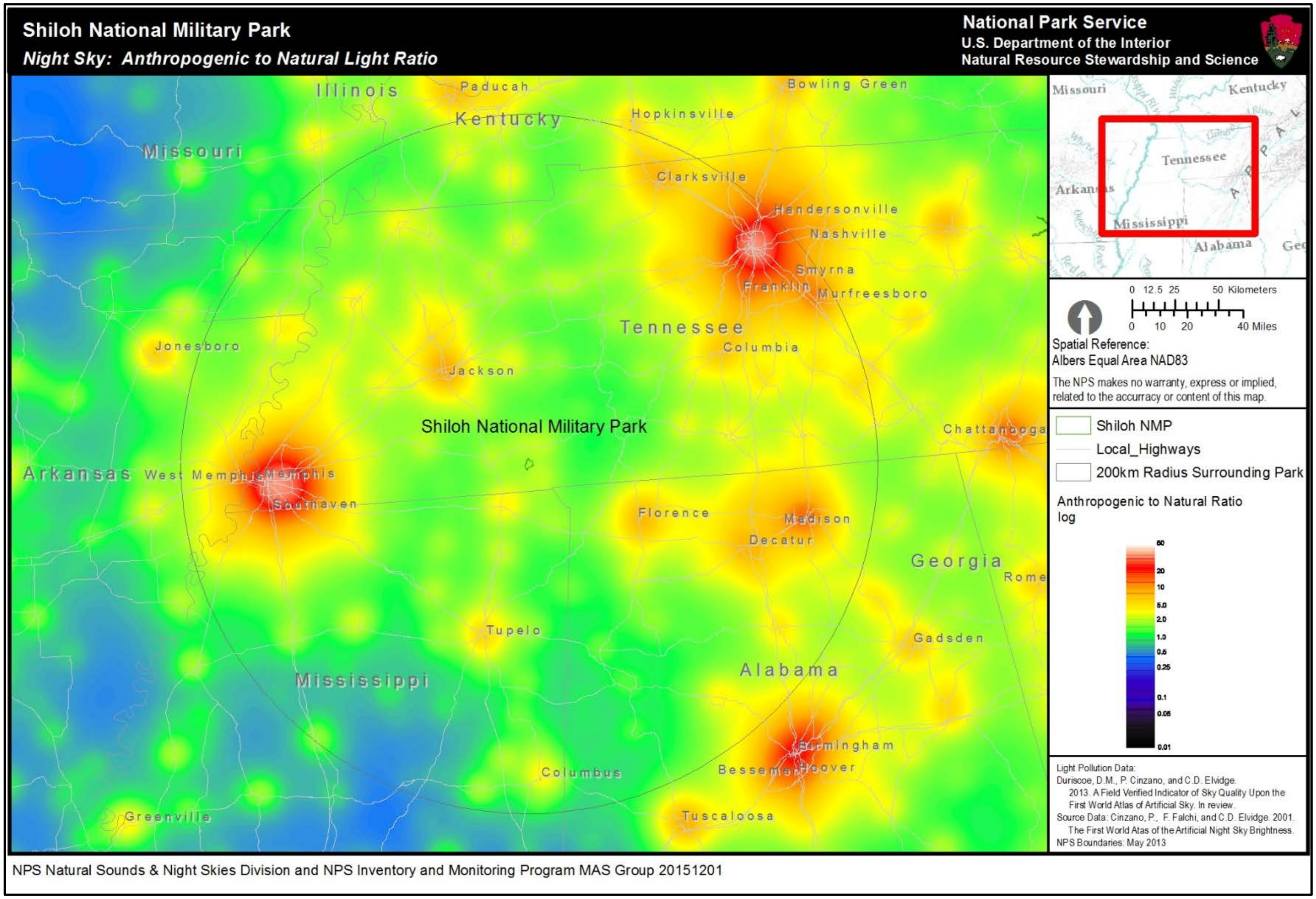

Figure 51. Output of the NPS NSNSD GIS model for the anthropogenic to natural light ratio (ALR) for SHIL. Graphic of the model output was provided by the NPS NSNSD.

In interpreting the results of the model, for both urban and non-urban parks, the condition (green, amber, red) corresponds to the ALR level that represents the median condition (in at least half the park's area) for the park's landscape (Moore et al. 2013). This median condition reflects the probable night sky quality that park visitors will experience at any location within the park (Moore et al. 2013). It is also probable that the majority of wildlife and habitats within the park exist under this quality of night sky (Moore et al. 2013). The NPS NSNSD recommendations for ALR condition are given in Table 43. The median ALR value for SHIL is 2.08, which puts the park at the lower limit of the poor condition category for non-urban parks (Moore et al. 2013).

Table 43. NPS NSNSD recommendations for condition levels for modeled ALR values (Moore et al. 2013).

Park Locale	Good Condition (Green)	Moderate Condition (Amber)	Poor Condition (Red)
Non-urban (Level 1) parks	< 0.33	0.33–2.00	> 2.00
Urban (Level 2) parks	< 2.00	2.00–18.00	> 18.00
Areas Managed as Wilderness	< 0.33	0.33–2.00	> 2.00

Threats and Stressor Factors

Park staff identified the following threats and stressors for this component: urban light sources, lighting around the visitor center and other park buildings, vehicle lights, and haze.

There are no major urban centers in close proximity to SHIL; in fact, as stated in SHIL's land protection plan (2006), "the 2000 census was the first to record the population of Hardin County as greater than the total killed, wounded, and missing at the Battle of Shiloh" (NPS 2006, p. 13). Despite that, SHIL is subjected to some sources of light pollution. These sources could potentially come from surrounding private development, traffic on the main roads that go through the park, and the building infrastructure. Lorenz and Danko (2006, 2014) created a light pollution map that displays levels of light pollution occurring in and around the park (Figure 52). SHIL is located in one level of light pollution; it falls in category 4 on the Bortle Scale, which means the dark night sky is under rural/suburban transition.

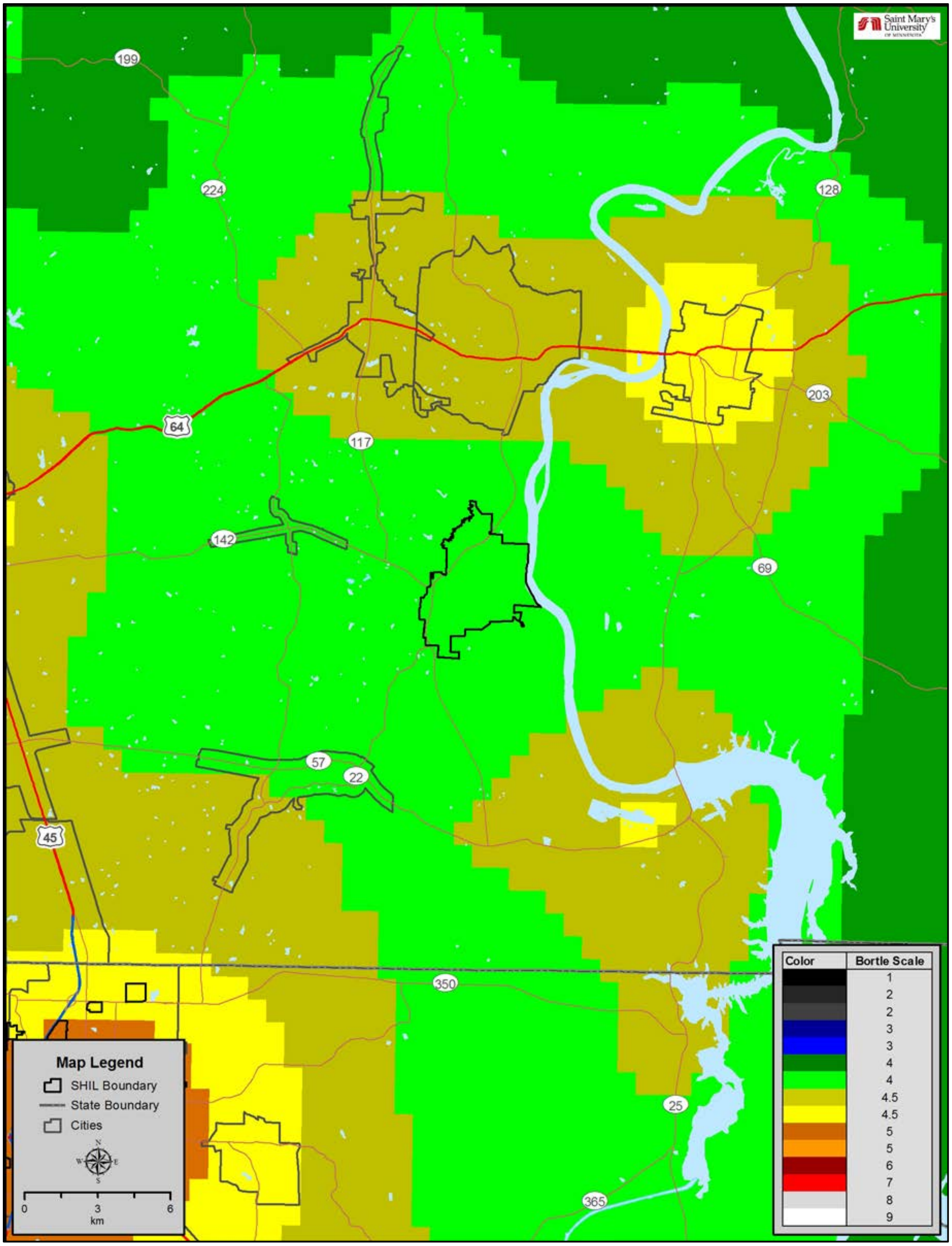

Figure 52. The levels of light pollution in and around SHIL, according to the Bortle Scale; SHIL falls into category 4, meaning the dark night sky is under rural/urban transition (Lorenz 2006, Danko 2014).

Air pollution and light pollution can have an indirect relationship with each other. PM, or haze, can both absorb and scatter light depending on where the observation point is located (EPA 2012, 2016) (Figure 53). When there are higher concentrations of PM suspended in the air, light scatters off those particles, thus causing brighter light pollution closer to the light source. At a distance from that same location, less light pollution is observed due to light absorption by PM. When there are lower concentrations of PM suspended in the air and fewer particles are available for absorbing light, light pollution can travel farther distances (EPA 2012, 2016).

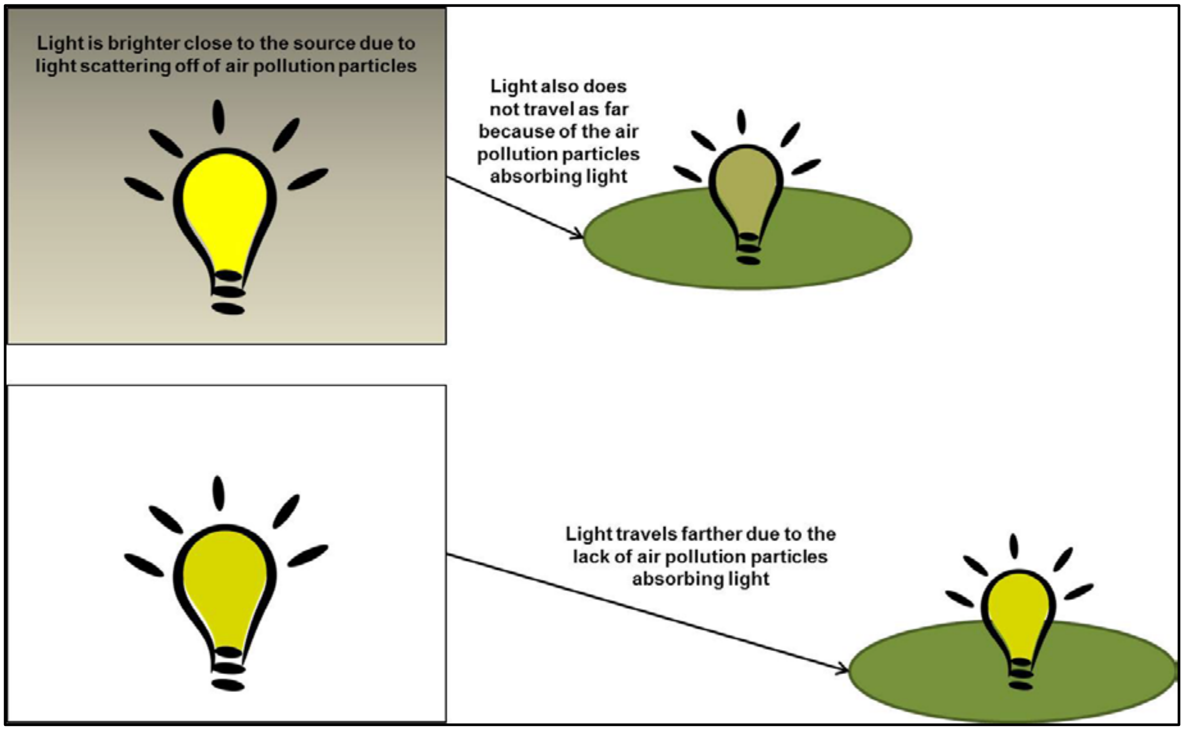

Figure 53. Air pollution and light pollution can have an indirect relationship. PM, or haze, can both absorb and scatter light, depending on where the observation point is located (EPA 2012, 2016).

With public roads going through the park, the immediate glare coming from headlights can provide something called disability glare, which is the loss of visibility from stray light being scattered within the eye (NLPIP 2007).

<u>Data Needs/Gaps</u>

The NPS NSNSD has never visited SHIL to collect data. The night sky condition data collected by the NPS NSNSD would provide a more comprehensive suite of measures that are more conducive to developing desired conditions or making management decisions than the modeled data currently available for SHIL. Along with periodic park monitoring visits, the NPS NSNSD could assess and track external light source impacts within SHIL.

Overall Condition

NPS NSNSD's Suite of Measures

During scoping meetings, the SHIL NRCA team assigned the NPS NSNSD suite of measures a *Significance Level* of 3. While NPS NSNSD has not conducted a field visit to SHIL, ALR data modeled by the NPS NSNSD can be used as a surrogate for the Average Natural Sky Luminance data collected during their field visits (Moore et al. 2013). The modeled ALR data for SHIL was 2.08, which places it at the lower end of the NPS NSNSD poor condition. This measure was assigned a *Condition Level* of 2, or moderate concern for the NRCA.

Weighted Condition Score

A *Weighted Condition Score* of 0.67 was calculated for the dark night sky component, indicating significant concern. Normally when more than half of the measures are not assigned a *Condition Level*, the overall scoring is not calculated. Since the ALR is recommended by the NPS NSNSD for use when the more comprehensive suite of data is not available, the overall score was calculated. A stable trend was assigned due to a number of factors. Even though the small communities surrounding the park have had slow to moderate population growth (Corinth, Mississippi [3.2%] and Savannah, Tennessee [3.2%]) over the period 1 April 2010 to 1 July 2014 (USCB 2015a), potential expansion inside the park could lead to increased light pollution. According to SHIL's Long-Range Interpretive Plan (NPS 2009), an expanded visitor center, more paved roads, and increased visitor access to certain areas of the park could all require more lighting, thus increasing the overall light pollution. This may change with the addition of future night sky assessments of SHIL or if external light sources increase with additional urban sprawl and other human development in the area.

Dark Night Skies			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.67**
Average Natural Sky Luminance	3	2	
Average Anthropogenic Light Dome	3	N/A	
Horizontal Illuminance	3	N/A	
Maximum Vertical Illuminance	3	N/A	

4.9.6. Sources of Expertise

- National Park Service Night Sky Division members Dan Duriscoe and Jeremy White.

4.9.7. Literature Cited

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4.10. Adjacent Land Cover and Use

4.10.1. Description

SHIL is surrounded by fairly different land cover and land uses, which threaten many different natural resources including the park's soundscape, quality of dark night skies, and the overall continuity of the landscape (Figure 54). The land adjacent to the Shiloh Battlefield Unit is largely rural but some agricultural, road infrastructure, and residential developments have occurred (NPS 2002, 2015b). The Corinth Battlefield Unit sits in the middle of an urbanized area, with the city of Corinth having a population of 14,573 as of 2010 (USCB 2016). Since park establishment, land ownership in and around the park has changed between public (federal, state, and local) and private ownership (NPS 2002). Due to the amount of non-federally owned land in and around SHIL, historic and cultural features of the park (specifically in the Shiloh Battlefield Unit) are susceptible to unregulated development that could have a negative impact on the park's landscape and viewscape (NPS 2002).

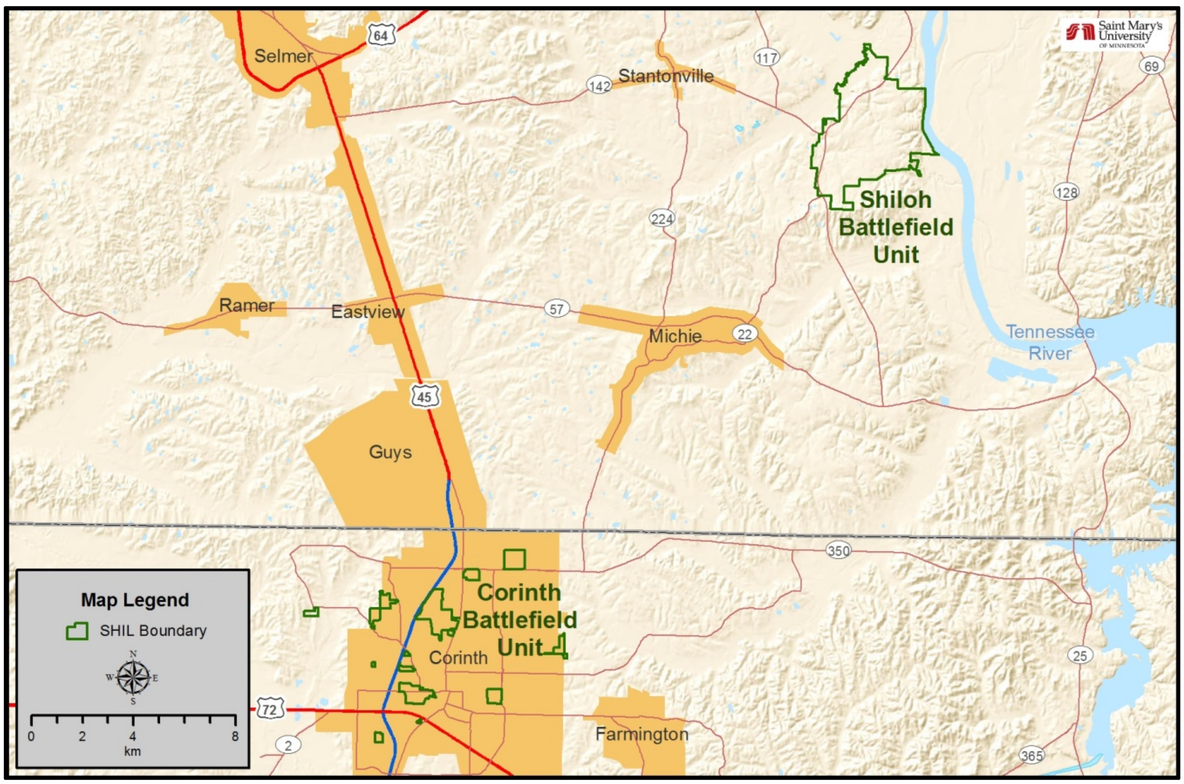

Figure 54. SHIL is currently comprised of two separate units: the Shiloh Battlefield Unit and the Corinth Battlefield Unit. Each unit is surrounded by different land cover and land uses.

4.10.2. Measures

- Change in external land cover/land use
- Total population
- Population density

- Housing development
- Land ownership

4.10.3. Reference Conditions/Values

Due to the slow growth and development of the land surrounding the Shiloh Battlefield Unit, the area's natural and cultural landscape of forests and open clearings, which characterized the area in 1862, has been well preserved (NPS 2002). The reference condition for this component was defined as in 1894, which refers to the condition at the time of park establishment.

4.10.4. Data and Methods

The NPS has created a set of metrics, standard operating procedures (SOPs), and pre-processed datasets in order to provide NPS units with information on landscape-scale land cover and land use changes occurring throughout North America (lower 48, Alaska, Pacific Islands, Caribbean, Mexico, and Canada) (Monahan et al. 2012, NPS 2014b). These landscape metrics are collectively called NPScape and include the following datasets: population, housing, roads, land cover, landscape patterns, climate, and conservation status (NPS 2014b). These NPScape data were analyzed at either the census block group level or the 10-digit watershed level for the following three watersheds in the SHIL vicinity: Snake Creek, Chambers Creek-Tennessee River, and Bridge Creek-Tuscumbia River Canal (Figure 55).

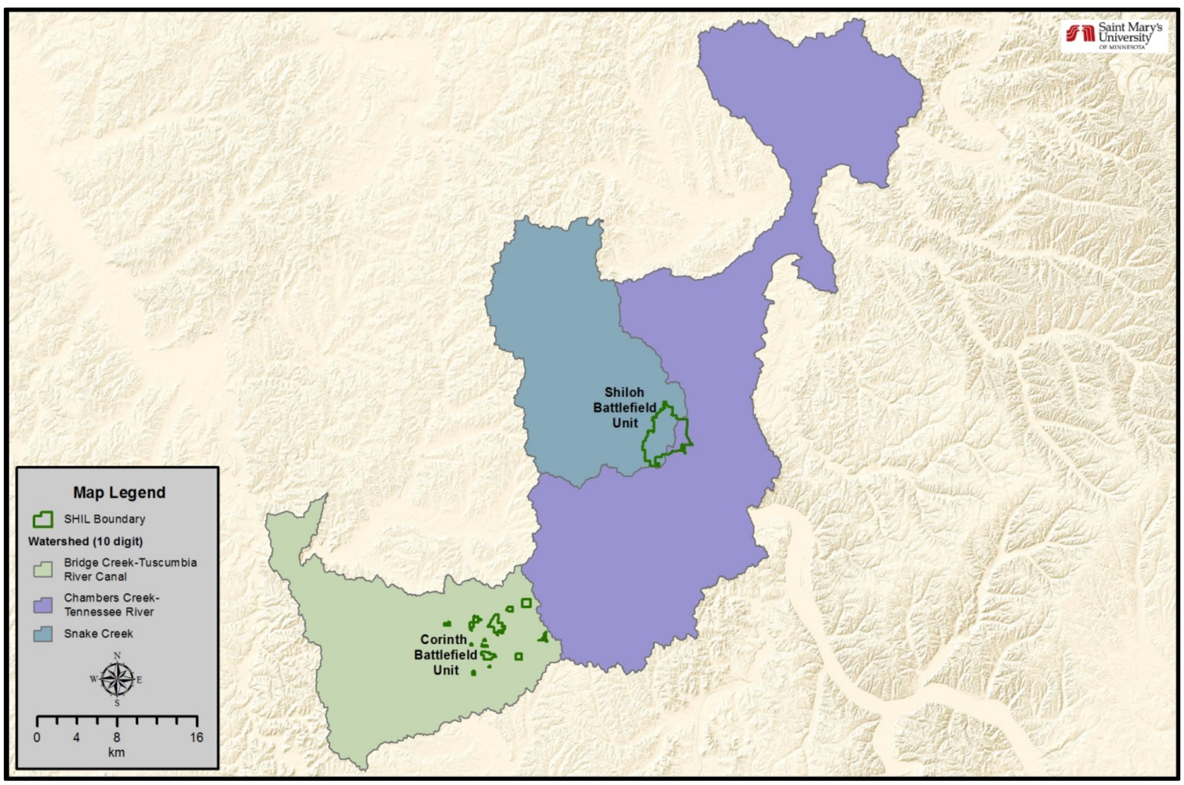

Figure 55. The three 10-digit watersheds in the SHIL area: Bridge Creek-Tennessee River Canal, Chambers Creek-Tennessee River, and Snake Creek.

National Landcover Dataset

The National Landcover Dataset (NLCD) is created by the USGS in cooperation with the Multi-Resolution Land Characteristics (MRLC) Consortium. This raster dataset is considered to be the most up-to-date land cover product for the U.S., with updates created every 5 years (USGS 2011). This dataset contains a variety of attribute information including: 2001-2011 land cover change, 2006-2011 land cover change, 2006-2011 percent developed impervious surface change, 2011 land cover data, 2011 percent developed impervious surface, and 2011 tree canopy cover (USGS 2011). The landcover is classified as: unclassified, open water, developed-open space, developed-low intensity, developed-medium intensity, developed-high intensity, barren land, deciduous forest, evergreen forest, mixed forest, shrub/scrub, grassland/herbaceous, pasture/hay, cultivated crops, woody wetlands, or herbaceous wetlands (USGS 2011).

The 2001-2011 land cover change NLCD dataset was used to determine the change in external land cover/land use measure in this NRCA. Within this dataset, a plethora of attribute information is provided, including 2001 and 2011 individual land cover, along with 2001 to 2011 landcover change. The 2001 to 2011 landcover change attribute information was used to calculate total changed area and percent change of land cover within the designated watershed extent.

U.S. Census Bureau

The U.S. Census Bureau (USCB) provides population data which comes preprocessed by NPScape (NPS 2014a); data can be obtained for 1990, 2000, 2010, historic (1790-1990), and projected (2000-c.2050) census years (NPS 2014b). The study area for the total population and population density measures were created by selecting all census blocks that intersected with Hardin and Alcorn county boundaries (Figure 56).

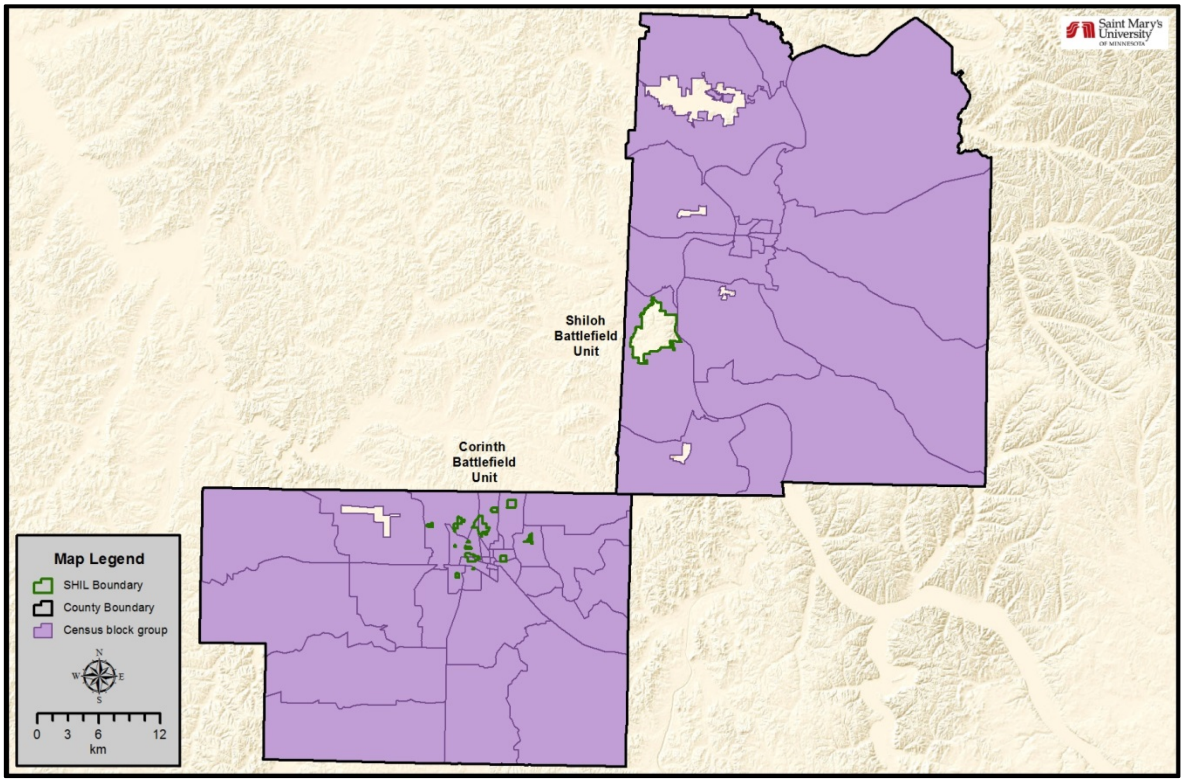

Figure 56. An example of the census block group level used for the analysis extent of some measures in this component.

Protected Areas Database

The Protected Areas Database of the United States (PAD-US) provides information on publically-owned land, along with voluntarily provided protected areas (e.g., Nature Conservancy Preserves), that focus on conservation management (USGS 2012). This database is mainly comprised of:

- Geographic boundaries of public land ownership and voluntarily provided private conservation lands;
- Description of land owner, manager, and management decision or type;
- USGS Gap Analysis Program (GAP) status code;
- Protection levels categories which provide a measurement of management intent for long-term biodiversity conversation;
- IUCN category for protected areas (USGS 2012).

SHIL Park Atlas

The park atlas for SHIL contains basic park information in a spatial data format. It provides information on the park's cultural and natural resources, appropriate base maps, and feature boundaries (NPS 2015a).

Spatially Explicit Regional Growth Model

Spatially Explicit Regional Growth Model (SERGoM) data provides housing density information from 1970 to 2100 based on ten-year increments (1970, 1980, 1990, etc.) (NPS 2013). Due to the ever-changing socioeconomic and development patterns within a given geography, it is noted that the forecasting used in this data model are predictions and the outcomes can likely change (NPS 2013).

4.10.5. Current Condition and Trend

Change in External Land Cover/Land Use

Due to the variant topography and predominant forested landscape surrounding the Shiloh Battlefield Unit, distant development of landmarks can be difficult to see from inside the park (NPS 2002). The area around the Tennessee River does allow for a visitor to see farther distances due to its lower and flatter elevation (NPS 2002). According to the NPS Land Protection Plan (2002 p. 12),

> *From the bluffs overlooking the river at the National Cemetery, the Indian Mounds, and the "Union Left" overlook position, the high ground marking the eastern geological extent of the three-mile wide Tennessee River floodplains is visible to the east. Development on this distant high ground would have only minor impact on the visitor experience. However, recreational development along the eastern riverbank itself would have a dramatic impact on what today is a view with few intrusions on the historic scene.*

Based on the watershed (10-digit) scale used for this measure, approximately 7% (11,070 ha [27,354 ac]) of the external land cover has changed from 2001 to 2011 (Figure 57); the total area analyzed at this scale was 15,819 ha (390,901 ac). Due to the large study area, the legend provided for Figure 57 below only articulates the colors associated with what the landcover changed to by 2011. Please see Appendix J for a full detailed list of the 2001 to 2011 land cover change for the entire analyzed area.

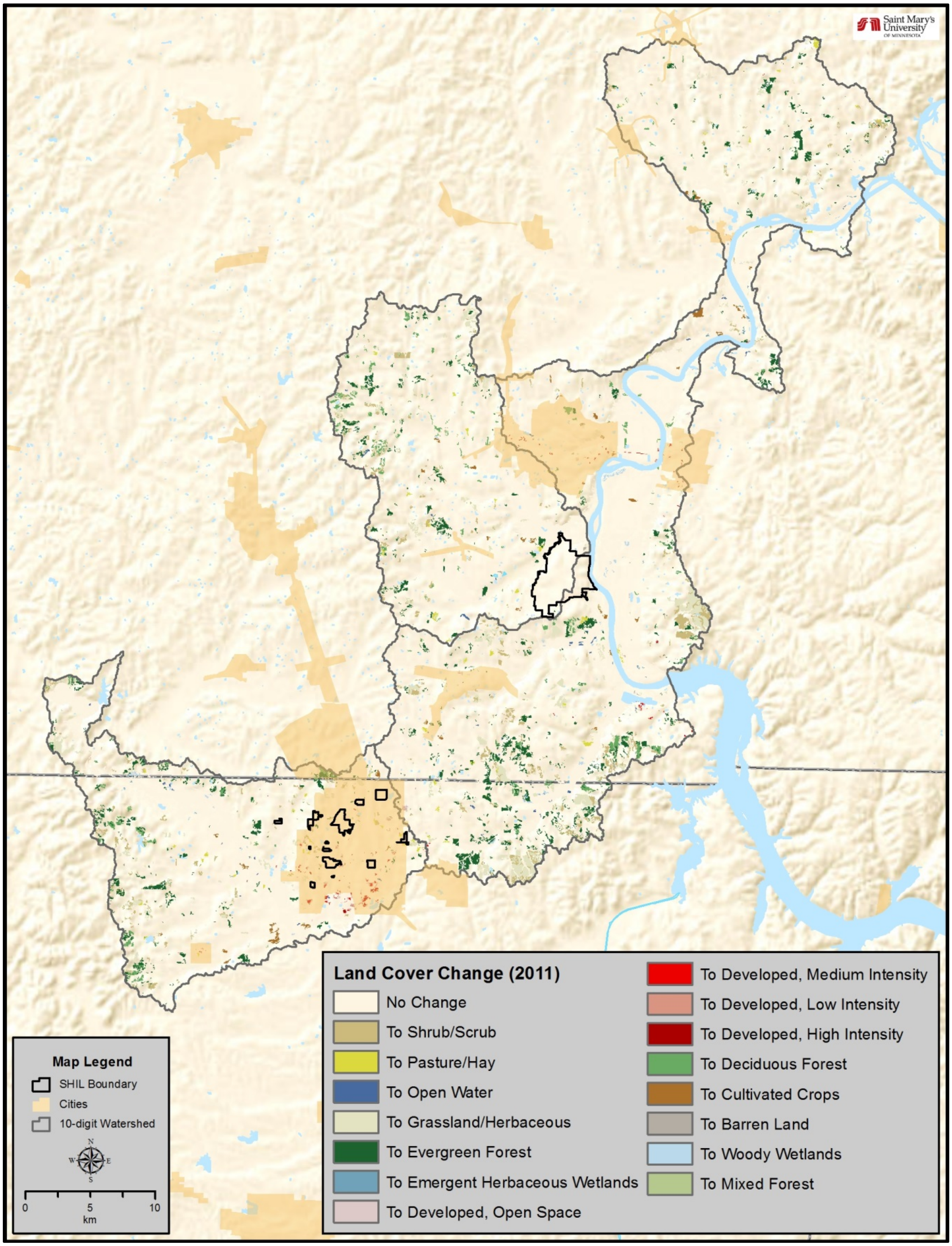

Figure 57. The external land cover change from 2001-2011 within the 10-digit watershed extent displays minimal landcover change (7%) over the past ten years. Due to the large study area, the legend provided in the figure only articulates what the land cover changed to by 2011. See Appendix J for more detail on what the original landcover type was.

Of the 7% changed land cover, only 3% was converted to some sort of development (open space, low intensity, medium intensity, high intensity). The development landcover classes are defined as follows (USGS 2011):

- Developed, Open Space = 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.
- Developed, Low Intensity = Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity = Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- Developed, High-Intensity = Highly-developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

Total Population

As stated in SHIL's Land Protection Plan (2002), "...the 2000 census was the first to record the population of Hardin County as greater than the total of killed, wounded, and missing at the 'Battle of Shiloh'" (NPS 2002 p. 13). Total population has been variable through the years for each county associated with SHIL (Figure 58). In Hardin County, Tennessee (where the Shiloh Battlefield Unit is located) population levels have ranged from 14,793 (1880) to 26,026 (2010), with an average annual growth rate of 0.6% from 1880-2010. In Alcorn County, Mississippi (where the Corinth Battlefield Unit is located), population levels have ranged from 13,115 (1890) to 37,057 (2010), with an average annual growth rate of 1.2% from 1880-2010.

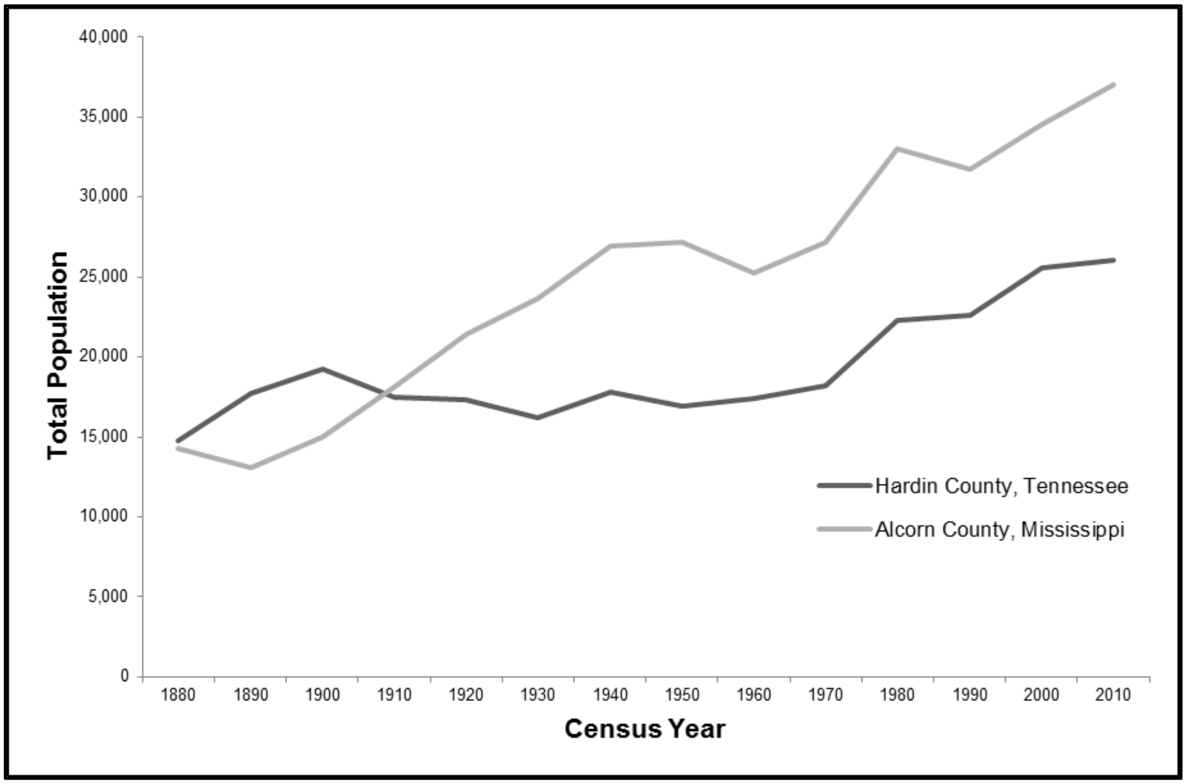

Figure 58. The graph articulates total population for both Hardin County, Tennessee and Alcorn County, Mississippi. The Shiloh Battlefield Unit falls in Hardin County and the Corinth Battlefield Unit falls in Alcorn County (USCB 1996).

More information specific to population levels near the park are provided at a census block level (Figure 59). The general trend is that population is growing around the park and urban centers are expanding. On average, population around SHIL has been growing as follows (numbers are based on averages between census block groups for both counties combined): 1,072 in 1990, 1,313 in 2000, and 1,334 in 2010 (USCB 1990-2010). Between 1990 and 2000, both counties saw, on average, a 20% population growth followed by only a 1.5% population growth between 2000 and 2010.

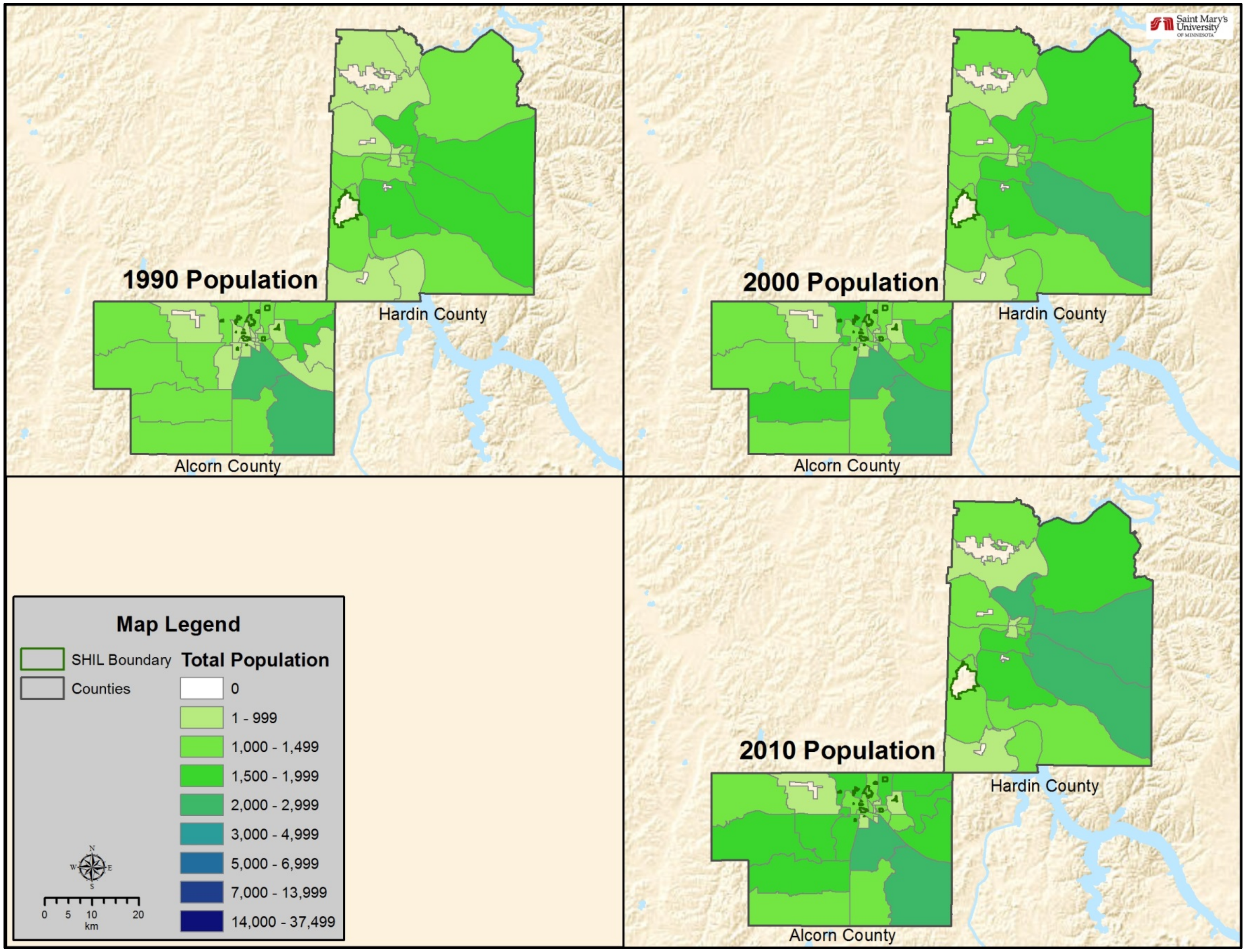

Figure 59. Total population per census block group (1990, 2000, 2010) for both Alcorn and Hardin Counties.

Population Density

Population density can provide insight into patterns of population concentration, or how closely people are grouped together within an area (Wilson et al. 2012). As shown in Figure 60, populations are concentrated around more urbanized areas; in Hardin County populations are centered around Savannah, Tennessee, while in Alcorn County, populations are concentrated around Corinth, Mississippi. The U.S. Office of Management and Budget (OMB) define and delineate metropolitan and micropolitan statistical areas, also known as metro areas and micro areas (Wilson et al. 2012). These metro and micro areas are based on one or more whole counties that contain a core urban area. They can also include adjacent counties with high degrees of social and economic integration (Wilson et al. 2012). Metro areas contain at least one urban area with a population of 50,000 or more, and a micro area will contain at least one urban cluster (and one or more principle cities) of at least 10,000 (but no more than 50,000) people. Alcorn County, Mississippi is considered a micro area (Wilson et al. 2012) and Corinth, Mississippi is the principle city.

From 2000 to 2010, approximately 6% of the nation's population growth occurred in micro areas (Wilson et al. 2012). Of that 6%, micro areas with fewer than 50,000 people (e.g., Alcorn County, Mississippi) grew at a slow rate of only 5% within that 10-year period (Wilson et al. 2012). According to Wilson et al. (2012), micro areas with populations less than 50,000 are decreasing in density; Alcorn County, Mississippi fits into this category. On the other hand, Hardin County's population density has increased slightly but is still well below Alcorn's (Table 44).

Table 44. Average population densities (people/km^2) for both counties surrounding SHIL units.

City, State	1999 average density	2000 average density	2010 average density
Alcorn County, MS	230.46	166.18	169.62
Hardin County, TN	81.84	88.96	88.37

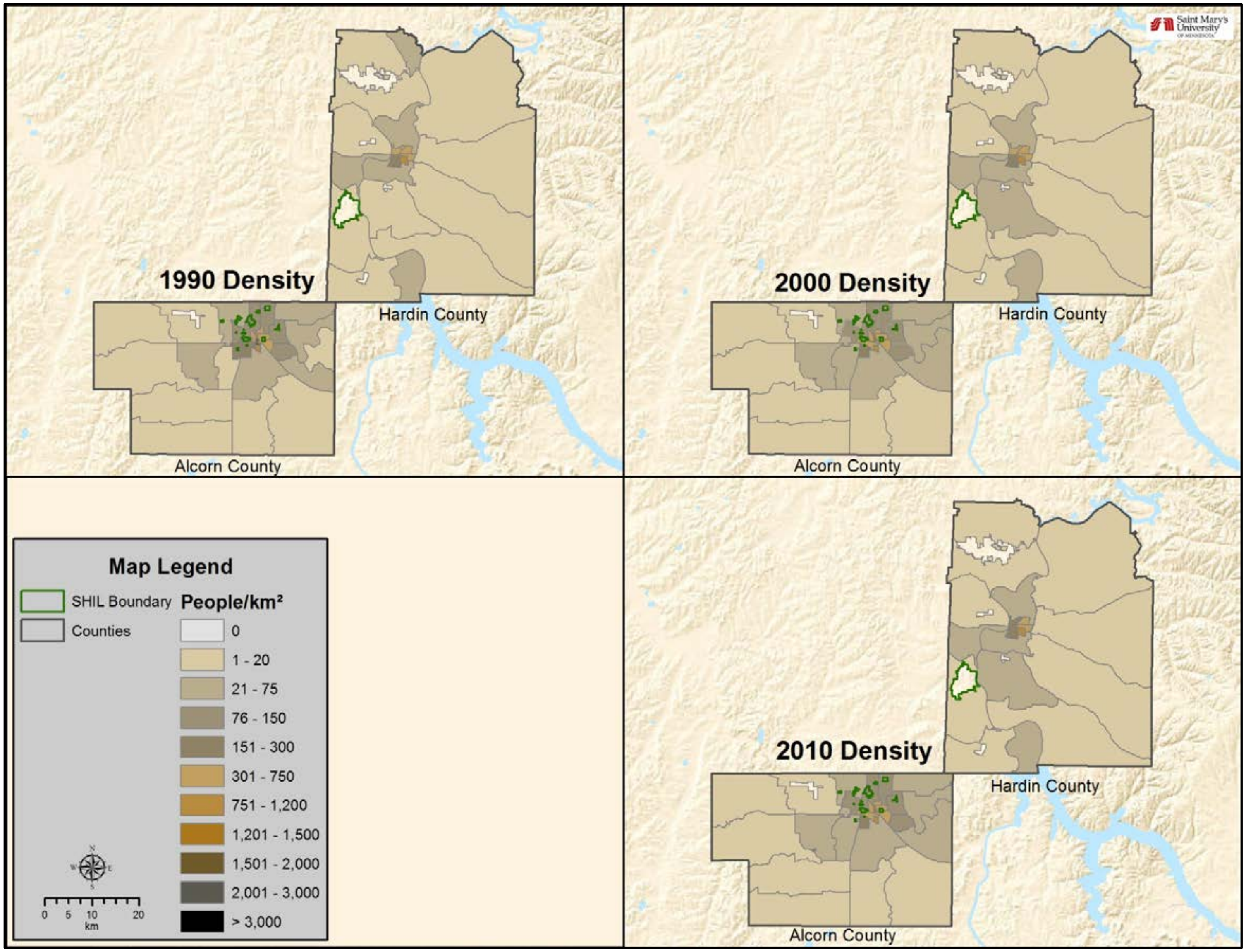

Figure 60. Displayed is total population density in people per square kilometers for census block groups in both Hardin and Alcorn counties.

Housing Development

As populations are increasing in the region around SHIL, more homes are being developed to support that population growth. Housing development comes in many classifications, ranging in density of housing from less than 1.5 units per km² to greater than 2,470 units per km². According to SERGoM data, in 1970 housing density of less than 1.5 units per km² comprised the largest area at 99,834 ha (246,695 ac). In 1990, that same housing density decreased to 48,616 ha (120,133 ac) and 1.5 to 3 units per km² were the largest at 49,502 ha (122,322 ac). Higher density housing developments continued to increase into 2010, with 4 to 6 units per km² covering the largest area at 50,216 ha (124,086 ac). Overall, the housing density in both Hardin and Alcorn Counties has slightly increased over time (Table 45, Figure 61).

Table 45. Displayed are the total areas of varying housing densities in hectares (acres) from 1970, 1990, and 2010 for a combined area of both Hardin and Alcorn County.

Housing Density in units/km²	1970 area	1990 area	2010 area
< 1.5	99,834 (246,695)	48,616 (120,133)	35,930 (88,785)
1.5-3	40,977 (101,256)	49,502 (122,322)	40,841 (100,994)
4-6	29,417 (72,691)	42,820 (105,810)	50,216 (124,086)
7-12	14,980 (37,016)	32,590 (80,532)	37,547 (92,781)
13-24	7,641 (18,881)	18,512 (45,747)	24,519 (60,588)
25-49	3,020 (7,463)	9,689 (23,942)	13,327 (32,932)
50-145	1,829 (4,520)	4,956 (12,247)	7,256 (17,930)
146-494	749 (1,851)	1,609 (3,976)	2,162 (5,342)
495-1234	225 (556)	418 (1,033)	542 (1,339)
1235-2470	59 (146)	108 (267)	139 (343)
>2470	14 (35)	27 (67)	31 (77)
Total	**198,745 (491,109)**	**208,848 (516,074)**	**212,540 (525,197)**

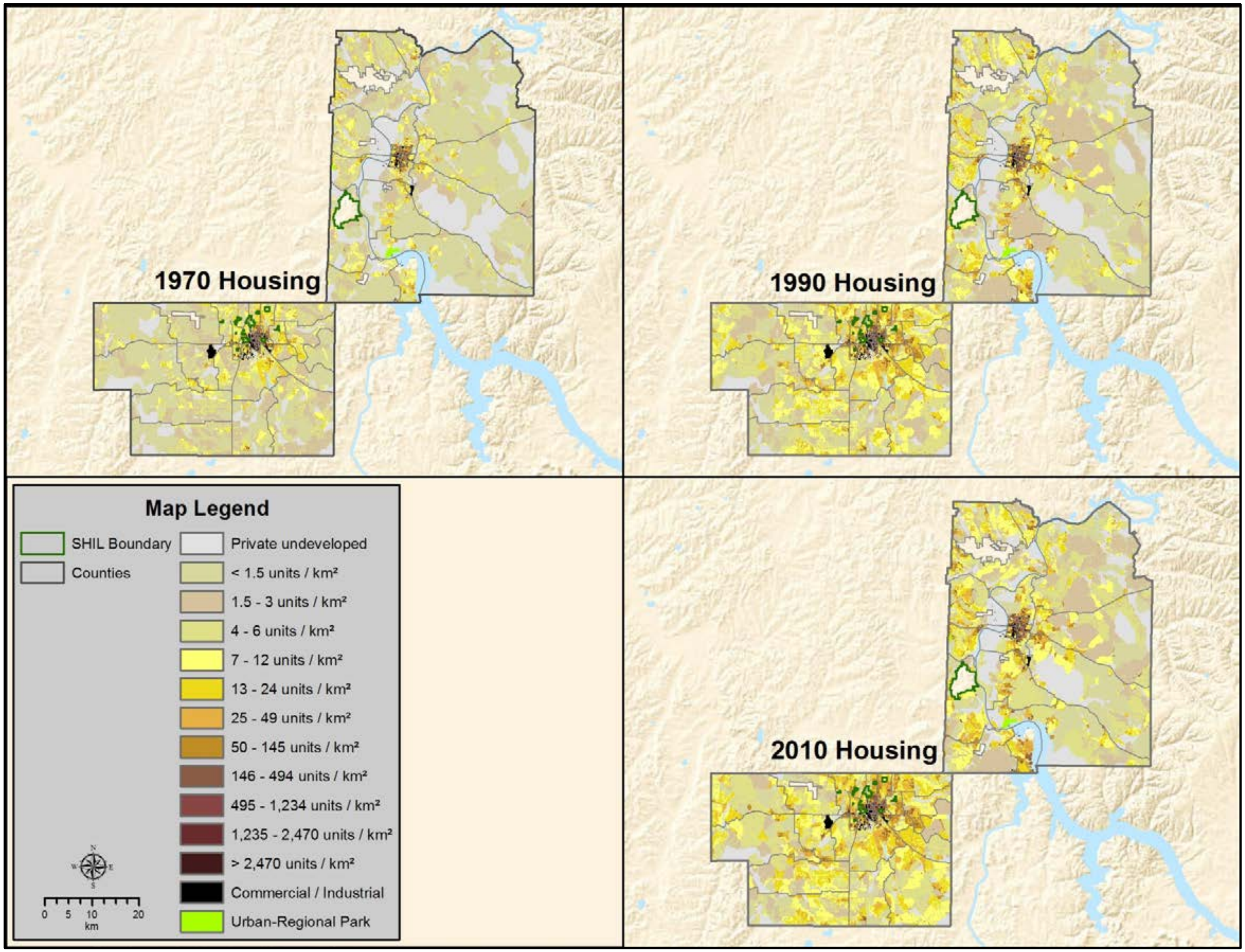

Figure 61. Housing densities (units/km²) in 1970, 1990, and 2010 for both Hardin and Alcorn Counties.

Land Ownership

When looking at land ownership outside SHIL boundaries at a county-level scale and according to the PAD-US data, 7,308 ha (18,059 ac) of protected land are found surrounding the park (Figure 62). Of that protected land 12,763 ha (31,539 ac) are owned by federal entities such as the TVA, NRCS, and the National Oceanic and Atmospheric Administration (NOAA); 4,908 ha (12,129 ac) are owned by state parks and recreation; 3,772 ha (9,320 ac) by state fish and wildlife; 2,541 ha (6.279 ac) by private conservation organizations and/or private corporations; and 113.7 ha (281 ac) are owned and managed by either other state entities such as the State Natural Heritage Program (NHP), State Department of Transportation (DOT), the State Historical Society (HS), and/or state universities.

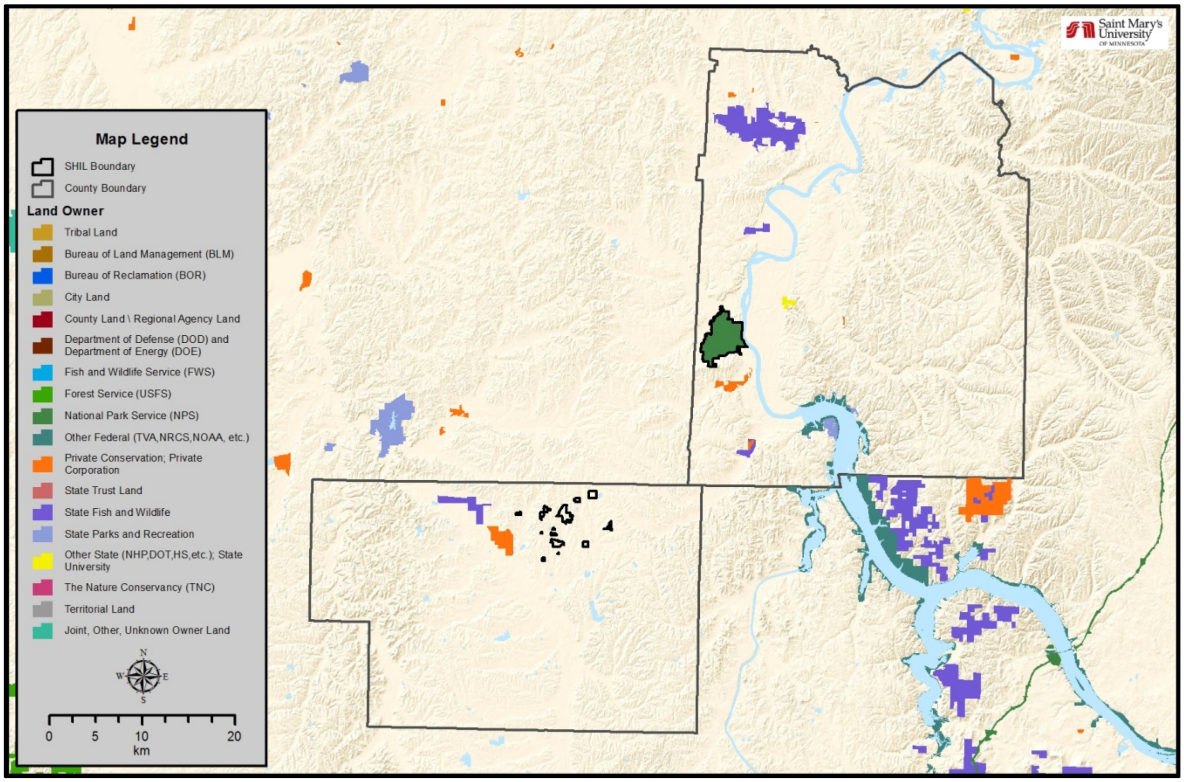

Figure 62. Land ownership of protected lands outside of SHIL's boundaries.

Also according to PAD-US data, the primary land management designation for the Shiloh Battlefield Unit is considered a historic and cultural area managed by the NPS. It has restricted public access, meaning access is granted through either a permit or allowed at variable times (USGS 2012). In terms of GAP status, the Shiloh Battlefield Unit is considered to have a Status 2 management measure. This is defined as:

> *[P]ermanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance (USGS 2012).*

The IUCN management category assigned for the Shiloh Battlefield Unit is category III. This is defined as:

> *Natural monument or feature protected areas are set aside to protect a specific natural monument, which can be a land form, sea mount, submarine caverns, geological feature such as caves or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value (USGS 2012).*

The scale of the PAD-US data provides a broader, more generalized overview of land ownership designations. The SHIL Park Atlas data provides a more in-depth look into the Shiloh Battlefield Unit's land ownership boundaries. According to the SHIL Park Atlas, private land is found inside and surrounding the Shiloh Battlefield Unit (Figure 63).

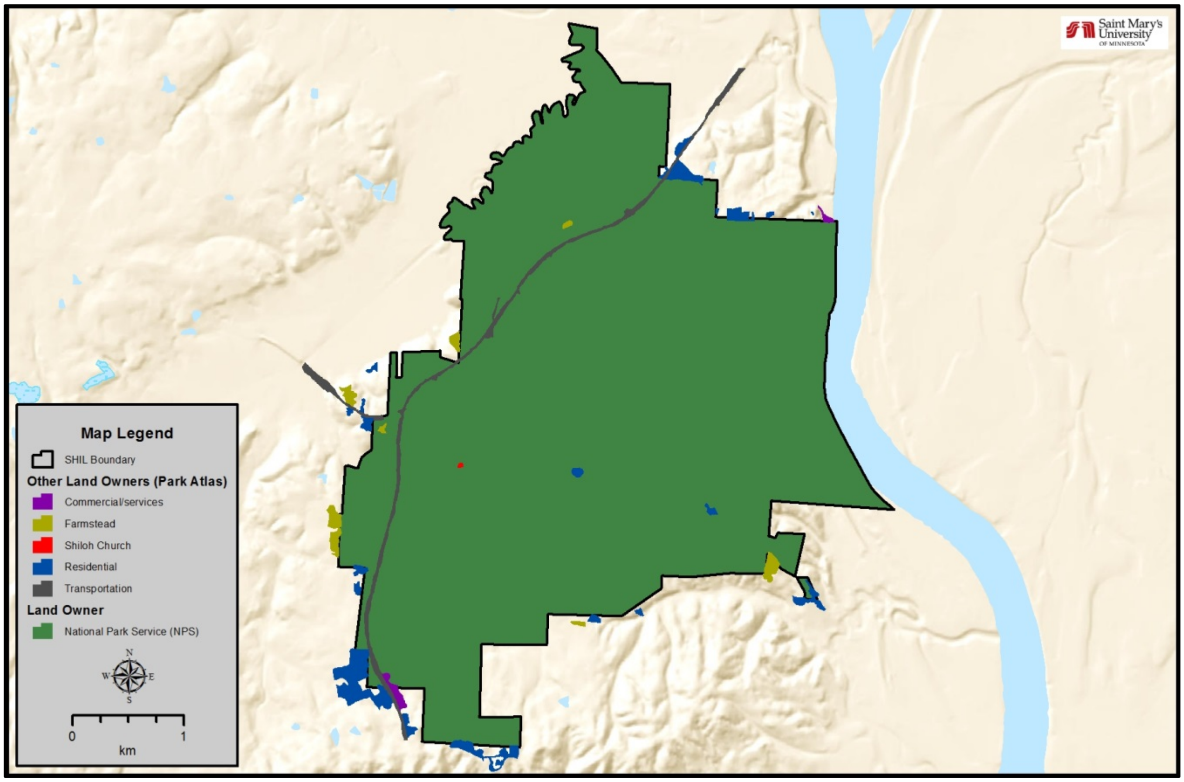

Figure 63. Even though the majority of land inside the Shiloh Battlefield Unit is owned by NPS, approximately 48.4 ha (119.6 ac) of land in and around the park is privately owned.

According to the Park Atlas data (NPS 2015a), 48.4 ha (119.6 ac) of land in and around the park are considered privately owned. Of this, residential use covers 25.9 ha (64.04 ac), farmsteads cover 11.46 ha (28.31 ac), roads within park boundaries cover 9.76 ha (19.68 ac), commercial/services cover 2.86 ha (7.06 ac), and the Shiloh Church occupies 0.19 ha (0.48 ac) of land.

<u>Threats and Stressor Factors</u>

The park staff identified a lack of zoning as a potential threat and stressor to the park, as this allows adjacent land uses that are not compatible with NPS management objectives.

Both Hardin County, Tennessee and Alcorn County, Mississippi do not have zoning laws in place at this time. Zoning laws can provide guidelines and restrictions on the basic type and intensity of land use for a particular area of land (Los Angeles County Department of Regional Planning 2009). Because Hardin County does not have any zoning laws in place, any non-federally-owned land near the Shiloh Battlefield Unit is susceptible to unregulated development (NPS 2002). According to the park's Land Protection Plan (2002), the only way for SHIL to control development within and surrounding its boundaries is to acquire an interest in the land. Even though Alcorn County, Mississippi does not have any zoning laws in place, the City of Corinth, Mississippi does (City of Corinth 2015); the Corinth Battlefield Unit falls inside the city boundaries. When looking at the City of Corinth zoning map, the park areas are zoned under the "Special Use (S-U)" zone.

<u>Data Needs/Gaps</u>

Extensive data are available for this component through NPScape. However, additional information regarding specific land use immediately adjacent to park boundaries (e.g., types of agriculture or other development) may help managers better assess the threats posed by such uses.

<u>Overall Condition</u>

Change in External Land Cover/Land Use

The *Significance Level* for this measure was assigned a 3. From 2001 to 2011, only 7% of the external land cover has changed surrounding SHIL, and of that 7%, the majority stayed in a natural land cover class. Due to this slow rate of landcover change over a 10-year period, a *Condition Level* of 0, meaning no concern, was assigned for this measure.

Total Population

A *Significance Level* of 2 was assigned for total population. Population around the Shiloh Battlefield Unit is minimal as it is a largely rural environment. The Corinth Battlefield Unit is different since it sits in a more urbanized area. Population seems to be growing in and around Corinth, Mississippi and not as much around the Shiloh Battlefield Unit. Since the Corinth Battlefield Unit is already in an urbanized area with land use zoning in place to help protect park boundaries (City of Corinth 2015) and because the population is experiencing slow growth around the Shiloh Battlefield Unit, a *Condition Level* of 1, or low concern, was assigned for this measure.

Population Density

Population density was also assigned a *Significance Level* of 2. Again, since the Shiloh Battlefield Unit is situated in a more rural environment, population densities are lower and less likely to influence that particular unit of SHIL. The Corinth Battlefield Unit is fairly different due to it being set in a more urbanized area. Alcorn County is considered a micro area, and Wilson et al. (2012) articulates that micro areas with populations less than 50,000 are decreasing in population density. Due to evidence pointing to overall population density decreasing or remaining relatively stable around the park, the *Condition Level* for this measure was assigned a 1, or of low concern.

Housing Development

The *Significance Level* for this measure was assigned a 3. Housing density throughout the years has been increasing in both counties, as more housing units are being built per square kilometer. With a lack of county-based zoning laws in place to manage residential development (NPS 2002), people could potentially build homes close to the park. This measure was assigned a *Condition Level* of 2, or of moderate concern due to some housing development affecting both the Shiloh and Corinth Battlefield Units.

Land Ownership

A *Significance Level* of 3 was also assigned for this measure. Due to a lack of county-based zoning laws for both Hardin and Alcorn County, the potential for development is a risk in areas near the park (NPS 2002). When looking at both PAD-US data and the park atlas, not all land around the park is owned by entities that would necessarily support park management goals. At this time, the *Condition Level* for land ownership was assigned a 1, or of low concern, although continued monitoring of land ownership trends is needed.

Weighted Condition Score (WCS)

The *WCS* for this component was assigned a 0.33, implying that adjacent land cover and land use is of moderate concern. With total populations increasing, more homes being developed per square kilometer, and population density decreasing, this could potentially indicate that people are spreading out and building more homes. This population sprawl could have a negative effect on the park, interfering with visitor's viewscape and soundscape. Due to a lack of county-based zoning for both Hardin and Alcorn County, the potential for excess and unwanted development is a risk for the park (NPS 2002). Overall, the majority of the measures are relatively stable, thus a trend was applied with medium confidence in the overall assessment.

Adjacent Land Cover and Use			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Change in External Land Cover/Land Use	3	0	
Total Population	2	1	
Population Density	2	1	
Housing Development	3	2	
Land Ownership	3	1	

4.10.6. Sources of Expertise

- Marcus Johnson, SHIL Natural Resource Management Specialist
- Teresa Leibfreid, CUPN I&M Program Manager

4.10.7. Literature Cited

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4.11. Soundscape and Acoustic Environment

4.11.1. Description

Acoustic resources are physical sound sources, including both natural sounds (wind, water, wildlife, vegetation) and cultural and historic sounds (battle reenactments, tribal ceremonies, quiet reverence) (NPS 2014b). The acoustic environment is the combination of all the acoustic resources within a given area, natural sounds and human-caused sounds (NPS 2014b). The acoustic environment includes sound vibrations made by geological processes, biological activity, and even sounds that are inaudible to most humans, such as bat echolocation calls (NPS 2014b). Soundscape is the component of the acoustic environment that can be perceived by humans (NPS 2014b). The character and quality of the soundscape influence human perceptions of an area, providing a sense of place that differentiates from other places (NPS 2014b). Noise refers to sound which is unwanted either because of its effects on humans and wildlife, or its interference with the perception or detection of other sounds (NPS 2014b). The natural soundscape is an inherent component of the scenery, the natural and historic objects, and the wildlife protected by the Organic Act of 1916 (NPS 2014b). NPS Management Policies (§4.9) require the NPS to preserve the park’s natural soundscape, to restore the degraded natural conditions wherever possible, and to prevent or minimize noise (NPS 2014b).

Photo 22. A cannon is fired during a reenactment in SHIL. Interpretive programs like this one are considered part of SHIL’s cultural soundscape. These sounds are important for educating the public on the park's history and protecting the park’s resources (Gramann 2000) (NPS).

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (Ackerman 2012). Despite this desire for quiet environments, anthropogenic noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

Noise not only affects visitor experience, but it can also alter the behavior of wildlife. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (Anderssen et al. 1993, NPS 1994, NPS 2016). Repeated noise can cause chronic stress to animals, possibly affecting their energy use, reproductive success, and long-term survival (Radle 2007). Even low levels of noise can interfere with ecological processes in surprising and complex ways (Shannon et al. 2015).

4.11.2. Measures

Sound measures may be classified in terms of amplitude, frequency, or duration, as described below. Additional details are provided in Chapter 4.11.4.

- Sound pressure levels (in decibels [dB], a logarithmic unit) are the most common measure of sound amplitude, and especially A-weighted sound levels (in A-weighted decibels [dBA]);
- Frequency is a measure of the repetition rate of a sound wave component (in hertz [Hz] or less commonly, cycles per second [cps]); it may be perceived as pitch by an auditory system;
- Duration of sounds; examples include Time Above Ambient (TAA), Time Above 35 dBA (or other level), Noise Free Interval (NFI), Time Audible (TAud), in hours, minutes, or seconds, and Percent Time Audible (%TAud), in percent.

4.11.3. Reference Conditions/Values

Reference conditions should address the effects of noise on human health and physiology, the effects of noise on wildlife, the effects of noise on the quality of the visitor experience, and finally, how noise impacts the acoustic environment itself. NPS policy states that the natural ambient sound level is the baseline (reference condition) and standard against which current conditions in a soundscape are to be measured and evaluated (NPS 2006). The NPS defines natural ambient sound level as the environment of sound that would exist in the absence of human-caused noise (NPS 2006). Also, according to an EPA (1974) document that examines the levels of environmental noise necessary to protect public health and welfare, to maintain the integrity of interpretive programs at the park, outdoor background ambient levels should not exceed 55 dB.

4.11.4. Data and Methods

<u>Sound Science</u>

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and volume (amplitude), or sound level. Noise, essentially the negative evaluation of sound, is defined as extraneous or undesired sound (NPS 2014b).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave (NPS 2014b). Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz (NPS 2014b). High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

In addition to the pitch of a sound, we also perceive the amplitude (or level) of a sound (NPS 2014b). This metric is described in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy (NPS 2014b). This also means that small variations in sound pressure level can have significant effects on the acoustic environment (NPS 2014b). Sound pressure level is commonly summarized in terms of dBA (A-weighted decibels) (NPS 2014b). Table 46 provides examples of A-weighted sound levels measured in national parks.

Table 46. Examples of sound levels measured in national parks (NPS 2014b) and comparable sound levels in common developed settings.

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (Haleakala National Park)	Human breathing at 3m	10
Leaves rustling (Canyonlands NP)	Whispering	20
Crickets at 5m (Zion NP)	Residential area at night	40
Conversation at 5m (Whitman Mission National Historic Site)	Busy restaurant	60
Snowcoach at 30m (Yellowstone National Park)	Curbside of busy street	80
Thunder (Arches National Park)	Jackhammer at 2m	100
Military jet at 100m AGL (Yukon-Charley Rivers National Preserve)	Train horn at 1m	120

The natural acoustic environment is vital to the function and character of a national park. Natural sounds include those sounds upon which ecological processes and interactions depend. Examples of natural sounds in parks include (NPS 2014b):

- Sounds produced by birds, frogs or insects to define territories or attract mates
- Sounds produced by bats to navigate or locate prey
- Sounds produced by physical processes such as wind in trees, flowing water, or thunder

Although natural sounds often dominate the acoustic environment of a park, human-caused noise has the potential to mask these sounds. Noise impacts the acoustic environment much like smog impacts the visual environment; obscuring the listening horizon for both wildlife and visitors.

4.11.5. Current Condition and Trend

Unlike other components within this NRCA, the specified measures for this component are discussed in conjunction with each other below. The use of measure-specific subheadings was not used in this assessment.

Because it is difficult to collect acoustic data across all landscapes, the NPS developed a novel geospatial sound model that predicts natural and existing sound levels within 270 m (886 ft) resolution (Figure 64). The model is based on acoustic data collected at 244 sites and 109 spatial explanatory layers (such as location, landcover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports) (Mennitt et al. 2013).

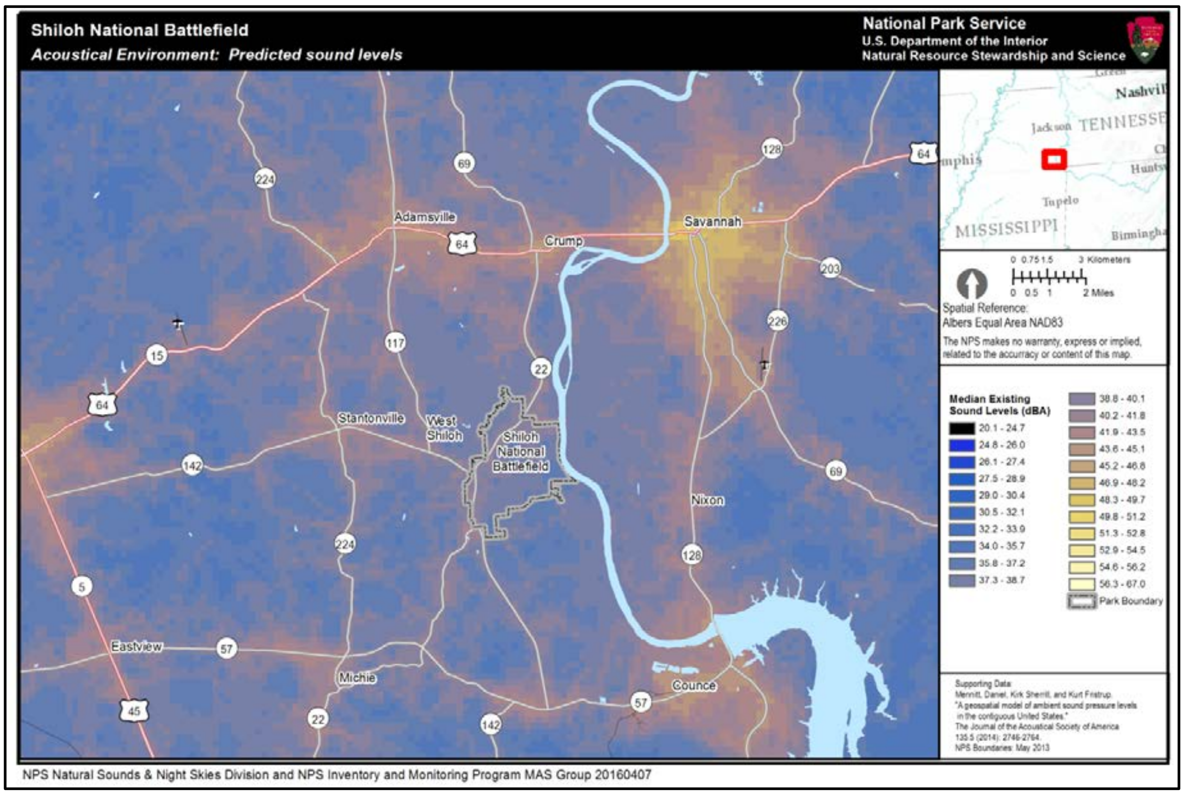

Figure 64. Map displaying predicted median existing sound levels (L_{50}) in dBA (Emma Brown, NPS Natural Sounds and Night Skies Division).

The model shows that predicted median existing daytime sound levels within SHIL are moderate, ranging from 36 to 40.5 dBA. No on the ground data have been collected in SHIL, and the modeled sound levels are currently the only source of acoustic data that exist for the park.

Threats and Stressor Factors

Multiple factors can go into increasing anthropogenic sound inside a park (NPS 2016). This can be anything from park maintenance equipment to noisy visitors. In a sound study completed in Muir Woods National Monument, it was discovered that it was noisy visitors, loud talking, and other related sounds that created the most distraction and disruption in a quality visitor experience (NPS 2016).

Specific threats to the SHIL's soundscape include grounds maintenance practices like mowing lawns. This is done to help maintain the landscape as it appeared at the time of the 1862 battle. In addition to the biological effects a lawn mower can have on an ecosystem, a power lawn mower can produce a noise level ranging from 80 to 95 dBA (EPA 1974). This is above the level known to disrupt interpretive programs (EPA 1974). Vehicle noise is also a concern especially with public roads going through the park (Figure 65). Barber et al. (2009) stated that park transportation corridors have sound levels more than four orders of magnitude higher than natural conditions. This type of noise from transportation networks are increasing at a faster rate than population size (Barber et al. 2009). According to the U.S. Federal Highway Administration (2008), "between 1970 and 2007, the U.S. population increased by approximately one-third (USCB 2007), but traffic on U.S. roads nearly tripled, to almost 5 trillion vehicle kilometers (3 trillion miles) per year."

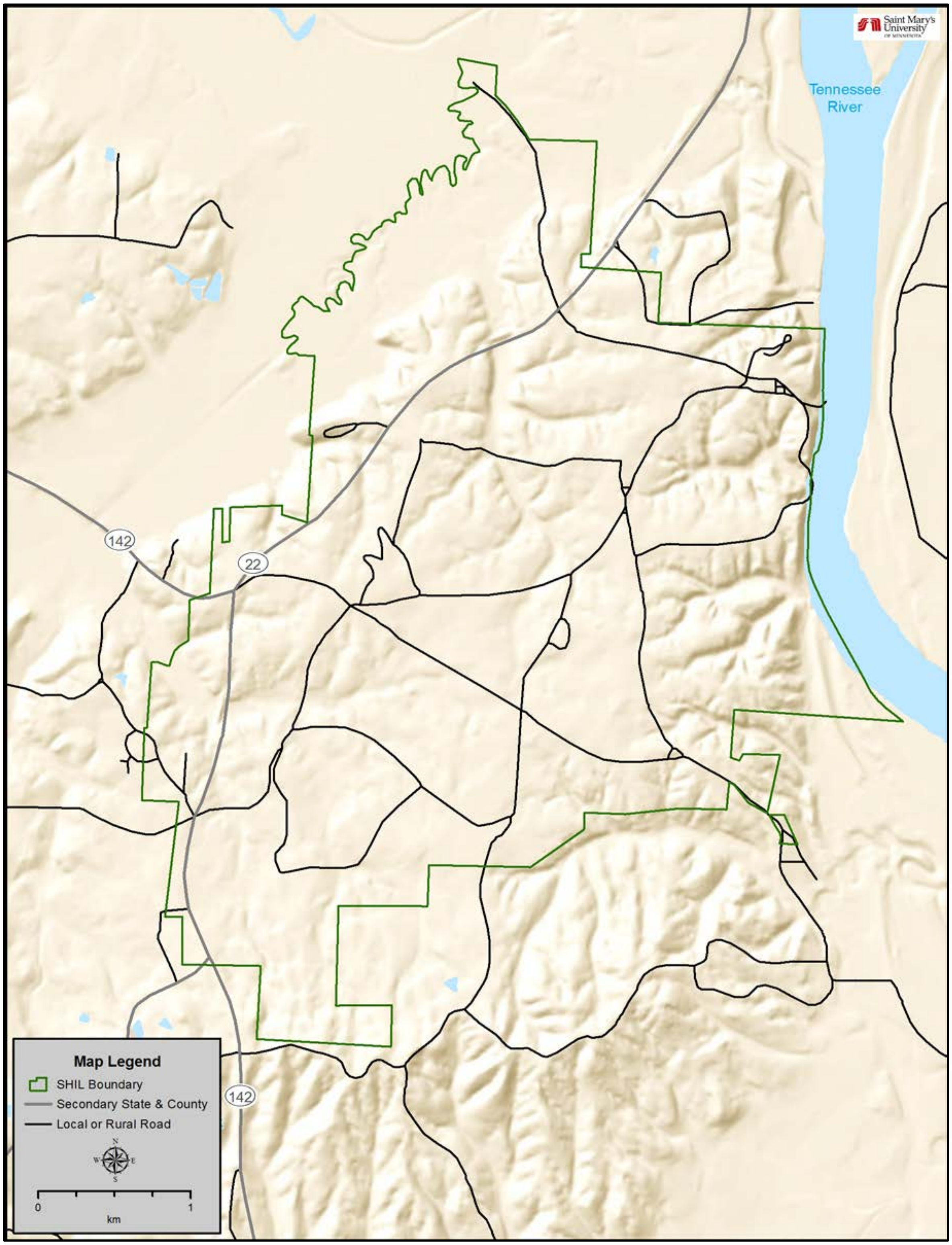

Figure 65. State Highway 22 and many local roads travel through the park boundaries. This increases the potential to disrupt the park's soundscape.

The park receives approximately 400,000 visitors a year (NPS 2014a) and in 2015, around 2,500 people utilized the picnic areas in the park (NPS 2014a). Most visitors to SHIL expect to hear certain sounds associated with the overall park experience; these can be anything from cultural sounds (such as cannons firing) to natural sounds (birds chirping or wind rustling leaves) (NPS 2006). Battle interpretations are an essential part of the SHIL experience for visitors. As such, sounds coming from these events represent the park's relevance and significance (NPS 2012). Besides cultural and natural sounds inside the park, the Corinth Unit (found approximately 40km [25mi] southwest of SHIL) is located in an urban setting, which is another potential threat to the park's soundscape. The city of Corinth, Mississippi had a population of 14,573, according to the 2010 U.S. Census (USCB 2016), and increased to 14,865 in 2014 (USCB 2015).

<u>Data Needs/Gaps</u>

There are no soundscape data for SHIL. Implementing a monitoring program of sound levels and sound recordings is essential for the management of the park's soundscape.

<u>Overall Condition</u>

Sound Pressure Levels

The *Significance Level* for this measure was assigned a 3. A quiet and serene soundscape is important to park visitors. Studies have shown that people specifically visit parks to get away from everyday noise (NPS 2016). Loud and unexpected bursts of sound can cause disruption inside parks (NPS 2016). While modeling appears to indicate moderate noise impacts within the park, a lack of on the ground data makes it difficult to accurately understand current condition. SHIL is unique in that anthropogenic noise was present during the time of battle, and reenactments and interpretive programs often recreate some of the sounds associated with the battle. These sounds and actions are allowed within the park's enabling legislation, and are not considered significant detractions from the managed condition of the park. Due to the lack of soundscape monitoring inside SHIL, and a current understanding of actual sound impacts from cannon fire and other war-related noises, a *Condition Level* cannot be assigned.

Frequency

The *Significance Level* for this measure was also assigned a 3. High pitched sounds can cause disruption to wildlife and distract park visitors (NPS 2016). Implementing soundscape monitoring inside SHIL can provide information as to where in particular high frequency sounds are disrupting resources in the park. With no monitoring in place, a *Condition Level* cannot be assigned at this time.

Duration of Sounds

A *Significance Level* of 3 was assigned for this measure. Sound durations can be used to calculate the percent of time human-caused sound is audible and noise-free intervals. Wildlife has had to adapt and/or incur costs due to the increased occurrence of anthropogenic-sourced sounds (i.e., shorter noise-free intervals) (NPS 2016). Measurements of sound duration can provide managers with insight into the stress levels human sounds may be causing park wildlife and visitors. Due to the lack of data, a *Condition Level* cannot be assigned at this time.

Weighted Condition Score

The soundscape and acoustic environment was not assigned a *Weighted Condition Score* at this time. To fully understand if the outdoor background noise inside the park is affecting the overall park integrity, soundscape monitoring needs to occur.

Soundscape			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Sound Pressure Levels	3	N/A	
Frequency	3	N/A	
Duration of Sound	3	N/A	

4.11.6. Sources of Expertise

- Randy Stanley, Natural Sounds and Night Skies Coordinator, Natural Resources Division
- Emma Brown, Acoustical Resource Specialist, NPS Natural Sounds and Night Skies Division

4.11.7. Literature Cited

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Chapter 5. Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1. Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 47 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 47. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Hardwood Forest Community	➢ Comparing the available data from SHIL forests to regional datasets or reference stands of similar communities may provide further insight into the condition of the park's forests. ➢ A more detailed study of forest succession could explore tree regeneration, particularly among oaks and hickories. Poor regeneration has been noted throughout eastern forests and may be associated with dense canopy shading, fire suppression, and deer browsing. ➢ Further study is needed to better understand tree regeneration and its implication for forest successional dynamics in the park. ➢ Monitoring of the park's white-tailed deer population could be helpful in understanding the impacts of deer browsing on SHIL's hardwood forests, and continued monitoring within the park for forest pests, exotic plants, and foliar ozone damage will be critical in detecting any changes in these threats to forest communities.
Wetland and Riparian Communities	➢ Historic data regarding the number and area of wetlands at SHIL are unavailable, making it impossible to identify any changes in wetlands over time. ➢ Revisiting wetlands identified by Roberts and Morgan (2008) in several years would allow for comparisons that could help identify any trends in wetland conditions at SHIL. ➢ Monitoring of hydroperiods could provide useful information regarding wetland condition, function, and the impacts of climate change. ➢ An on-the-ground inventory specifically focused on vernal pools, along with a study of their hydrologic regimes and use by herpetofauna, would help park managers better understand this unique resource.

Table 47 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Mammals	➢ An updated mammal inventory is needed to accurately assess the current condition of this resource. The most recent inventory in the park is over 10 years old, and no monitoring of annual trends in abundance or richness has occurred. Similarly, the park is in need of an updated bat inventory/monitoring project, especially with the presence of WNS in the general area. ➢ There are no data available regarding white-tailed deer density in the park; monitoring deer density could inform park staff and regional hunters/conservationists about the overall health of the region's deer population. ➢ Native rodent monitoring is needed in the park in order to assess that resource's current condition.
Birds	➢ The establishment of an annual bird monitoring program in SHIL is needed to accurately assess the current condition of the bird community of the park. ➢ Research into the effects of mowing regimes and pesticides on the grassland bird community is needed. ➢ No information exists regarding the turkey community of the park.
Native Fish	➢ An updated fish inventory/survey is needed, as the most recent fish-related data for the park are over 20 years old. ➢ An IBI would be beneficial for SHIL managers as it may help determine the effects of human disturbances on regional streams and watersheds.
Herpetofauna	➢ Expansion and continuation of the efforts and study design of ABC (2006) is needed to expand the park's understanding of the herpetofauna community of SHIL.
Water Quality	➢ Additional research into the impacts of various water quality threats (e.g., atmospheric deposition, upstream development, climate change) may help in the management of this vital resource. ➢ Additional water quality threats such as mercury, endocrine disruptors, and other pharmaceuticals have not been monitored at SHIL.
Air Quality	➢ On-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury), particulate matter, and visibility would help managers better understand air quality conditions in the park. ➢ Studies of mercury concentrations in park wildlife (e.g., fish, birds) would provide insight into the impact this contaminant is having on the park.
Dark Night Skies	➢ Dark night skies monitoring in SHIL is needed in order to assess the component's current condition.
Adjacent Land Cover and Use	➢ Additional information regarding specific land use immediately adjacent to park boundaries (e.g., types of agriculture or other development) would help managers better assess the threats posed by such uses.
Soundscape and Acoustic Environment	➢ There are no soundscape data for SHIL. Implementing a monitoring program of sound levels and sound recordings is essential for the management of the park's soundscape.

Several of the park's data needs involve the continuation or expansion of existing monitoring programs to accumulate enough data for identification of trends over time (e.g., hardwood forest community, water quality). However, many of the identified data gaps for SHIL center around the need for the establishment of an annual (or at least standardized) monitoring or inventory effort (e.g., birds, mammals, native fish, herpetofauna). Many of the existing data sets for these resources are outdated, some by as much as 20 years (e.g., native fish). Other components, such as dark night skies, air quality, and soundscape, do not have data specific to SHIL, and the data used in those assessments relied on either regional projections and trends or the best professional judgement of experts. Many components in the park are in need of expanded data sets in order to have an accurate assessment of current condition that is based more on data and less on professional judgement.

5.2. Component Condition Designations

Table 48 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 66 following Table 48). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Since the assigned condition of a component (as represented by the symbols in Table 48) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural) for some measures, or even current information. Condition could not be determined for four of the 24 selected components: sea ducks, breeding landbirds, mid-trophic level marine forage community, and air quality.

For featured components with available data and fewer information gaps, assigned conditions varied. Six of the components are considered to be in good condition (Table 48); however, the wetland and riparian communities, birds, and adjacent land cover and use condition scores were at the edge of the good condition range (0.33) and any small decline in the communities could shift them into the moderate concern range. There were no components determined to be of moderate concern, but there were two components (air quality, dark night skies) that fell within the significant concern threshold. Only three of the 11 selected components did not have enough available data to assess current condition: mammals, native fish, and soundscape (Table 48). Confidence in current condition assessments varied, as instances where condition was assessed using professional judgement and anecdotal information were typically indicated with a low confidence border on the condition graphic (e.g., birds, herpetofauna; Table 48).

Table 48. Summary of current condition and condition trend for featured NRCA components.

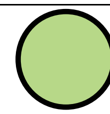
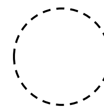
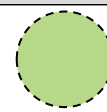
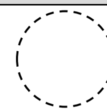
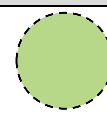
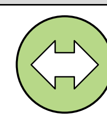
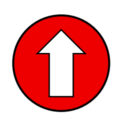
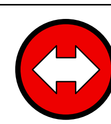
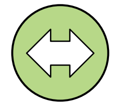
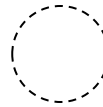
Component	WCS	Condition
Biotic Composition		
Ecological Communities		
Hardwood Forest Community	0.29	
Wetland and Riparian Communities	0.33	
Mammals		
Mammals	N/A	
Birds		
Birds	0.33	
Fish		
Native Fish	N/A	
Herpetofauna		
Herpetofauna	0.21	
Environmental Quality		
Water Quality	0.17	
Air Quality	0.83	
Dark Night Skies	0.67	

Table 48 (continued). Summary of current condition and condition trend for featured NRCA components.

Component	WCS	Condition
Environmental Quality		
Adjacent Land Cover and Use	0.33	
Soundscape	N/A	

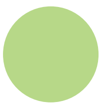
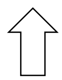
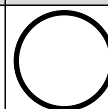
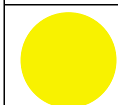
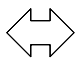
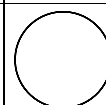
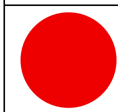
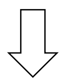
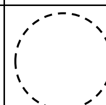
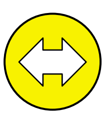
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

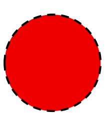
Figure 66. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

<u>Example indicator symbols and how they should be interpreted for tables in NRCA reports:</u>

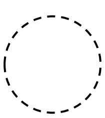
Resource is in good condition; its condition is improving; high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.



Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

5.3. Park-wide Condition Observations

Despite the wide variety of habitats many of SHIL's resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park, critical communities). The park represents a long-protected area in the American Southeast, and the threats/stressors, data needs, and priority habitats of SHIL are critical to park managers in order to fully understand this ecosystem.

5.3.1. Vegetation Communities

SHIL is regarded for its military significance during the Civil War; however, the park possesses tremendous ecological value as well. SHIL is heavily vegetated, with over two-thirds of the park consisting of mixed hardwood forests. These forests are often further divided into broader categories consisting of upland oak-hickory woodlands, mesic hardwood slope and ravine forests, and bottomland forests (Jones 1983, Mangi Environmental Group 2004). Additionally, the majority of wetlands and riparian areas within SHIL are forested, with only small areas of herbaceous wetlands (Roberts and Morgan 2008). The fact that SHIL has been protected since 1894 is especially important, as it has allowed the forests to be protected from the pulpwood logging and clear-cutting for farming or other developments that has occurred on the lands surrounding the park. The Owl Creek bottomland forests and wetlands are representative of what much of western Tennessee looked like historically, and is the largest wetland complex within all of CUPN parks.

The hardwood forest community of SHIL is host to a tremendous diversity of plant species, with over 500 species of plants documented to date. A relatively small percentage of the identified species are comprised of exotic species (8% in the most recent estimate). With the exception of the Owl Creek wetlands, the wetlands in SHIL are small but have been generally protected from the common causes of wetlands loss (i.e., development and agriculture). Over 350 plant species have been identified in SHIL's wetlands, and much like the forest community a small percentage of the identified species are exotic (7% at last estimate).

The current condition of the park's vegetation communties was determined to be good, as both the hardwood forest community component and the wetland and riparian communities component had weighted condition scores that fell below 0.33. Overall observations were that these communities had high estimates of species richness and composition, and that the prevalance of non-native species was relatively low when compared to other CUPN parks (Moore 2013). Japanese honeysuckle was the most prevalent invasive species, and was detected in half of the 16 forest sampling plots in 2011-2012 (Moore 2013). The acreage of the park has changed in the last few years, and additional areas of protected forests and wetlands have been added. With the addition of these areas, and the continued acquisition of additional lands surrounding the park, the vegetation communities will continue to expand. Continued research in both of these communities is needed in order to allow for a long term trend analysis and to observe any patterns in non-native species expansion. Close monitoring of these communities is needed as they provide valuable habitat for not just plant species, but also several species of wildlife such as amphibians, birds, and mammals.

5.3.2. Wildlife Components

Animals featured as NRCA components included birds, amphibians and reptiles (under the herpetofauna component), mammals, and native fish. The data that were available for these resources were generally outdated, with limited inventory or survey updates occurring in the past decade. The native fish and mammal components in this NRCA were not assigned a current condition due in large part to the fact that the only data sources that existed were outdated. Both the birds and herpetofauna components were determined to be in good current condition. However, the available data for these components were also sparse, and these assessments relied heavily upon the best professional judgement of managers. The limited data for these two components results in a low overall confidence in condition assessment, as indicated in Table 48.

As was discussed previously, SHIL represents an isolated area of preserved natural habitats in a setting that has otherwise been heavily influenced by agriculture, clear-cutting, erosion, and other human influences. While anthropogenic disturbances are still present in SHIL, the park provides a fairly intact and mature habitat for many wildlife populations. Many of the selected measures for the wildlife-related components represented data gaps, but the species richness and species composition measures all appeared to display that the species documented in SHIL are about what should be expected to occur in the region. In addition to the expected species in the park, SHIL is home to several species of conservation concern. Examples of species of concern in the park include the northern-long-eared bat, the gray bat, the southeastern shrew, and the Bewick’s wren.

While there appears to be little concern regarding the species richness of the wildlife communities in SHIL, additional research is needed for the other selected metrics for each of these components. Further study into distribution, abundance, diversity, and certain focal species (e.g., white-tailed deer and wild turkeys) will allow for a more accurate assessment of the overall health of each community. The establishment and continuation of monitoring efforts will allow for long-term monitoring of these components, and will also allow for the identification of trends and how certain threats or natural stressors may be affecting each focal community.

5.3.3. Environmental Quality

Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms can be substantially affected by the condition of air and water quality. Air quality was one of two components in this NRCA determined to be of significant concern in SHIL, and was assigned this condition largely due to high levels of nitrogen and sulfur deposition. The most recent 5-year (2009-2013) estimate for sulfur wet deposition and nitrogen deposition at SHIL fell in the *Significant Concern* range, as defined by the NPS ARD (NPS 2015). Ozone conditions in the park were also of concern, as evidence of ozone foliar injury was detected on multiple plants in three park locations in 2009; however, 2015 visits failed to detect any instance of ozone foliar injury. This air quality parameter may be improving in the area, as the past few years have shown decreasing ozone estimates and now fall within the *moderate concern* range of the NPS ARD monitoring. In fact, in recent years an improving trend has been observed in several of the air quality parameters in the park (e.g., sulfur wet deposition, $PM_{2.5}$, and visibility), which may suggest improving air quality conditions in the park. Regardless, air quality continues to be degraded in the SHIL area, and warrants additional monitoring efforts.

Water quality was considered to be in good current condition in CHCH. This condition is reflective of the relatively pristine nature of many of the park's water resources and confidence in this assessment is high given that sampling results and records have been fairly consistent over a long period. Several metrics of water quality have been consistently documented as being in excellent health, and only one instance of water temperature that exceeded the state standard of <30.5°C (86.9°F) has been recorded. Occasional spikes in *E. coli* bacteria levels have been documented in some SHIL waters, but no measurements have exceeded the single-sample state standard for the protection of aquatic life (Meiman 2007, 2012, 2013). Further, high *E. coli* measurements were generally associated with wildlife activity or stormwater runoff and were considered within the range of natural, background conditions.

The current condition of the park's dark night skies was determined to be of significant concern in this assessment. There has been no site visit to SHIL from the NPS NSNSD, but the median ALR value for SHIL (as interpreted from a regional model) was 2.08, which put the park at the lower limit of the poor condition category for non-urban parks (Moore et al. 2013). The small communities surrounding the park have had slow to moderate population growth, and potential expansion inside the park could lead to increased light pollution. According to SHIL's Long-Range Interpretive Plan (NPS 2009), an expanded visitor center, more paved roads, and increased visitor access to certain areas of the park could all require more lighting, thus increasing the overall light pollution. Additional monitoring or the quality of the dark night skies in SHIL is needed to more accurately determine the current condition of this resource and how it may affect visitor experience and the native wildlife that rely on high-quality night skies.

5.3.4. Park-wide Threats and Stressors

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the CUPN (Davey et al. 2007). Climate also affects the spread of invasive plant species and atmospheric pollutant levels, which also threaten SHIL's priority resources (Davey et al. 2007). As a result of global climate change, temperatures are projected to increase across the southeast over the next century (Carter et al. 2014). Warming temperatures will likely allow invasive plants to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). Riparian vegetation serves as habitat structure and regulates water temperatures by shading the water surfaces; any loss in riparian vegetation may reduce critical herpetofauna habitats in the park (Sung 2000).

The loss of water to the atmosphere through evapotranspiration is projected to be accelerated by warming temperatures; this could cause a general drying among wetland ecosystems (Brooks 2009). The threat of future heat waves and extended periods of above average temperatures is cause for concern as these periods are associated with spikes in unhealthy ozone levels; elevated ozone levels are a known problem in the park and can cause foliar damage.

Throughout the CUPN, distinct seasonal variations in precipitation levels are evident (Davey et al. 2007). In the western portion of the network, where SHIL is located, winter and early spring tend to be the wettest times of the year and fall is the driest (Davey et al. 2007). Precipitation events are projected to become less frequent but more intense, with longer dry periods between rain events (Bates et al. 2008, Brooks 2009). Deluge events following periods of drought results in huge amounts of runoff, erosion, and flooding that have damaged riparian areas and other important habitats and degradation to water quality (Bates et al. 2008). This has caused losses in biodiversity in response to disrupted ecosystems that rely on the timing of seasonal events for reproduction and food sources (Bates et al. 2008, Carter et al. 2014). This is particularly true for amphibians since their survival is so closely tied to water. Precipitation changes would also affect water levels and retention times in vernal pools and other small wetlands. These patterns, along with warming temperatures, have the potential to affect nearly every plant and animal population inside SHIL (Wathen et al. 2015).

Non-native invasive plants are among the greatest threats to forests worldwide, including at SHIL. The roads, trails, and waterways that crisscross SHIL, as well as nearby developments, serve as potential vectors for the spread of invasive plants and pests (Mack 2003, Keefer et al. 2014). To date, a total of 41 non-native plant species have been confirmed in SHIL's hardwood forests, with 28 of those species considered invasive by the TN-EPPC and 10 species considered a severe threat to native communities. In the park's wetlands, 26 non-native species have been observed, with 14 of those species considered invasive and six considered severe threats to native species (TN-EPPC 2009). Roberts and Morgan (2008) documented non-native plant species in 79% of all wetlands and riparian areas that were sampled.

Non-native species in SHIL are not confined only to plant species, however, as several mammals, fish, and avian non-native species are present in the park. Feral cats represent one of the largest causes of bird and herpetofaunal mortality in the U.S. The median number of birds killed in the U.S. by cats is 2.4 billion individuals/year, while the number of amphibians killed each year is between 95 and 299 million individuals (Loss et al. 2012). Feral hogs also represent a threat to SHIL's priority communities, although their presence in the area remains unconfirmed. These non-native mammals have destructive rooting behavior and are efficient reproducers; they have the ability to completely change the dynamic of the ecosystem they inhabit and can outcompete and prey upon natives in the area. Non-native grass carp were introduced into Bloody Pond in order to reduce vegetation growth. This species remains present in the pond, and is known throughout its native range to dramatically reduce aquatic vegetation, thus increasing phosphorus levels. An increase in phosphorus in the pond could create an overgrowth in algae; as algae dies and decomposes, oxygen in the water is consumed and can cause oxygen depletion for other fish and aquatic organisms (MPCA 2008).

Modern alterations to the landscape often foster competition between native and non-native bird species. Human-made structures may fragment and reduce the continuity of a landscape, and often as these changes occur, non-native bird species (such as rock doves, Eurasian collared-doves, European starlings, and house sparrows) are able to inhabit the areas. Marzluff (2001, pp. 26-28) states that,

> *The most consistent effects of increasing settlement were increases in non-native species of birds, increases in birds that use buildings as nest sites (e.g., swallows and swifts), increases*

in nest predators and nest parasites (brown-headed cowbirds), and decreases in interior- and ground-nesting species.

Pollution in the SHIL region, including both air and water pollutants, was identified as a threat and stressor in nearly half of all components discussed in this report. The major air pollution-related threats came from ozone and nitrogen and sulfur deposition, although atmospheric haze is also a concern as well. Ozone can cause foliar injury to sensitive plants when present at high levels (>80 ppb), and several ozone-sensitive plant species occur in SHIL's hardwood forests (Kohut 2007). As has been mentioned, low to moderate levels of ozone-related foliar injury were documented in SHIL in 2009, and while ozone appears to have marginally improved in the area in the last decade, it is a threat that continues to warrant monitoring.

Atmospheric wet deposition (e.g., rain, snow, fog) in the SHIL region was found to have a mean annual pH that is acidic and below the Tennessee state standard, at 4.8 (measured at Hatchie National Wildlife Refuge, 80 km [50 mi] northwest of SHIL) (Meiman 2013). The low acid neutralizing capacity of many of SHIL's waters means that low pH of precipitation/deposition is often retained in the park's surface waters (Meiman 2013). The native fish of SHIL may be impacted by atmospheric deposition, and effects on this community could include reduced growth rates, skeletal deformities, reproductive failure, and an increase in mortality rates. Additionally, the wetlands and riparian areas of the park are likely to see additional impacts, as these communities are among the most vulnerable to acidification and nutrient enrichment that result from atmospheric deposition. Water pollution in the park is not tied exclusively to atmospheric pollutants and deposition, as agricultural practices also contribute to water contamination in the SHIL region. Much of the agricultural practices upstream have altered the land and hydrology of the area, and have resulted in an increased flow of sediment into several streams in the area (most notably Owl Creek). In addition, fertilizers, other chemicals, and trash may also run off of agricultural lands and into Owl Creek.

5.3.5. Overall Conclusions

SHIL is unique in that it possesses incredible cultural, historic, and ecological importance. While renowned primarily for its preservation of Civil War battlefields, this federal protection has allowed many of the ecosystems in the park to remain true to what should be expected in this region. The lands surrounding SHIL have largely been developed, converted to agriculture, or heavily deforested, yet SHIL remains an island of protected forests, wetlands, and Civil War monuments. While several park-wide threats and stressors are certainly present, and the continued threat of climate change looms, many of SHIL's priority resources remain in good or stable condition. Continued monitoring of these priority resources, combined with management efforts directed at minimizing disturbance potential, will aide many of these communities and maintain their presence within the park. SHIL possesses tremendous opportunity for scientific study, and continuing advancements in the scientific understanding of SHIL's resources will not only benefit the park, but other locales in the southeast with shared resources.

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Appendices

Appendix A. Plant species documented in hardwood forests at SHIL.

In the second column, a “/” indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Acalypha gracilens	-	X	-
Acalypha rhomboidea	X	X	X
Acalypha virginica	/	X	-
Acer negundo	X	X	X
Acer rubrum var. *rubrum*	X	X	X
Acer saccharum (*A. barbatum*)	X	-	X
Achillea millefolium	X	X	-
Adiantum pedatum	X	X	-
Aesculus pavia	X	-	-
Agalinis fasciculate [a]	X	-	-
Agalinis purpurea	X	-	-
Agalinis tenuifolia [a]	X	-	-
Ageratina altissima	-	X	X
Agrimonia sp.	-	-	X
Agrimonia gryposepala	X	X	-
Agrimonia microcarpa	-	X	-
Agrimonia parviflora	-	X	-
Agrimonia rostellata	-	X	-
Agrostis hyemalis	-	X	-
Albizia julibrissin [c]	X	X	X
Allium canadense	X	X	-
Ambrosia artemisiifolia	/	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).

b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.

c. Non-native species.

Appendix A (continued). In the second column, a “/” indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a “-“

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Amelanchier arborea	X	X	X
Amphicarpaea bracteata	-	X	X
Amsonia tabernaemontana	X	-	-
Andropogon gyrans	-	X	-
Andropogon virginicus	-	X	X
Anemone virginiana [a]	X	-	-
Angelica venenosa	-	X	-
Antennaria plantaginifolia	/	-	X
Antennaria solitaria	/	X	-
Anthoxanthum odoratum[c]	X	-	-
Aralia spinosa	/	X	-
Arisaema dracontium	X	X	-
Arisaema triphyllum	X	X	-
Aristolochia serpentaria	X	X	X
Aronia arbutifolia	X	-	-
Aronia melanocarpa	X	-	-
Asarum canadense	X	X	-
Asclepias tuberosa[a]	X	-	-
Asclepias variegata	X	X	X
Asimina triloba	X	X	X
Asplenium platyneuron	X	X	X
Athyrium filix-femina	X	X	X
Aureolaria flava	X	X	-
Aureolaria pectinata	X	X	X
Bidens aristosa	/	X	-
Bidens bipinnata	X	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Bignonia capreolata	X	X	X
Blephilia ciliata	X	-	-
Boechera laevigata	X	-	-
Boehmeria cylindrica	X	X	X
Botrychium biternatum	-	X	X
Botrychium dissectum	X	-	X
Botrychium virginianum	X	X	X
Brachyelytrum erectum	X	X	-
Bromus commutatus[c]	/	X	-
Bromus pubescens	-	X	-
Broussonetia papyrifera[c]	X	-	-
Calystegia sepium[c]	-	X	-
Campanulastrum americana[b]	X	-	-
Campsis radicans	/	X	-
Cardamine diphylla	X	X	-
Cardamine concatenata	X	X	-
Carex albicans var. *albicans*	-	X	-
Carex albicans var. *australis*	X	X	-
Carex amphibola	X	X	X
Carex annectens	X	-	X
Carex blanda	X	X	X
Carex caroliniana	X	X	-
Carex cephalophora	X	X	-
Carex complanata	X	X	X
Carex digitalis	-	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Carex flaccosperma	-	-	X
Carex grayi	X	X	-
Carex hirsutella	-	X	X
Carex intumescens	X	X	-
Carex leavenworthii	-	X	-
Carex lupulina	X	-	-
Carex muehlenbergii	X	-	-
Carex oxylepis	X	X	-
Carex picta	X	X	X
Carex retroflexa	X	X	-
Carex rosea	/	X	X
Carex striatula	-	X	X
Carex swanii	-	X	X
Carex tribuloides	-	-	X
Carex willdenowii	-	X	X
Carpinus caroliniana	X	X	X
Carya cordiformis	X	X	X
Carya glabra	X	X	X
Carya ovalis	X	X	X
Carya ovata	X	X	X
Carya pallida	X	X	X
Carya tomentosa (*C. alba*)	X	X	X
Castanea dentata	X	-	-
Ceanothus americanus	X	-	X
Celastrus scandens [b]	X	-	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Celtis laevigata	/	X	-
Celtis occidentalis	-	X	X
Celtis tenuifolia	-	-	X
Cerastium nutans	/	X	-
Cercis canadensis	X	X	X
Chaenomeles speciosa[c]	X	-	-
Chaerophyllum tainturieri	X	X	-
Chamaecrista fasciculata	X	X	-
Chamaecrista nictitans[a]	X	-	-
Chasmanthium latifolium	/	X	X
Chasmanthium laxum	X	X	X
Chimaphila maculata	X	X	X
Chionanthus virginicus	X	X	-
Chrysopsis mariana	X	X	-
Cinna arundinacea	/	X	-
Circaea x *intermedia*	-	X	-
Circaea lutetiana	X	X	-
Cirsium horridulum	/	X	-
Claytonia virginica	X	X	-
Clitoria mariana[a]	X	-	-
Cocculus carolinus	X	X	X
Collinsonia canadensis	X	-	-
Comandra umbellata	X	-	-
Commelina virginica	/	X	-
Conoclinium coelestinum	-	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a “/” indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Conopholis americana	X	X	-
Conyza canadensis	/	X	-
Corallorhiza wisteriana	X	-	-
Coreopsis major	X	X	X
Coreopsis pubescens	X	-	-
Cornus amomum	X	-	-
Cornus drummondii	-	X	-
Cornus florida	X	X	X
Cornus racemosa	X	-	-
Corydalis flavula	X	X	-
Crataegus sp.	-	-	X
Crataegus crus-galli	X	-	-
Crataegus punctate [b]	X	-	-
Crotalaria sagittalis [a]	X	-	-
Croton glandulosus var. *septentrionalis*	-	X	-
Croton monanthogynus	/	-	X
Cruciata pedemontana[c]	-	X	-
Cryptotaenia canadensis	X	-	-
Cynodon dactylon[c]	/	X	-
Cynoglossum virginianum	X	X	-
Cyperus echinatus	-	X	-
Dactylis glomerata[c]	X	X	-
Danthonia spicata	X	X	X
Dasistoma macrophylla	X	-	-
Decumaria barbara	X	X	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).

b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.

c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Delphinium tricorne	X	X	-
Deparia acrostichoides	-	X	-
Desmodium glutinosum	X	X	-
Desmodium nudiflorum	X	X	X
Desmodium paniculatum	-	X	X
Desmodium pauciflorum	-	X	-
Desmodium procumbens	-	X	-
Desmodium rotundifolium	-	X	X
Desmodium viridiflorum	X	X	-
Dichanthelium acuminatum	-	X	X
Dichanthelium boscii	-	X	X
Dichanthelium commutatum	/	X	X
Dichanthelium depauperatum	-	X	X
Dichanthelium dichotomum	-	X	X
Dichanthelium laxiflorum	-	X	X
Dichanthelium linearifolium	X	-	X
Dichanthelium ravenelii	-	X	X
Dichanthelium sphaerocarpon var. *isophyllum*	-	X	-
Digitaria sanguinalis[c]	/	X	-
Diodia teres	/	X	X
Dioscorea oppositifolia[c] (*D. polystachya*)	X	-	X
Dioscorea villosa	X	X	X
Diospyros virginiana	X	X	X
Elephantopus tomentosus	X	X	X
Elymus virginicus	/	X	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
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c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Enemion biternatum	X	-	-
Epifagus virginiana	X	X	X
Erechtites hieraciifolius	/	X	X
Erigeron philadelphicus	X	-	-
Erigeron pulchellus	-	X	X
Erigeron strigosus	/	X	-
Euonymus americanus	X	X	X
Eupatorium capillifolium	-	X	-
Eupatorium hyssopifolium var. *hyssopifplium*	X	-	X
Eupatorium perfoliatum	X	-	-
Eupatorium rotundifolium	X	X	-
Eupatorium serotinum	X	-	-
Euphorbia corollata	X	X	X
Euphorbia pubentissima	-	X	-
Eurybia hemispherica	X	X	X
Fagus grandifolia	X	X	X
Festuca subverticillata	-	X	X
Frangula caroliniana (*Rhamnus caroliniana*)	X	-	X
Fraxinus americana	X	X	X
Fraxinus pennsylvanica	/	X	-
Galactia regularis	X	-	-
Galactia volubilis	-	X	X
Galium aparine	X	X	-
Galium circaezans	X	X	X
Galium obtusum	X	-	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Galium pilosum	-	X	-
Galium triflorum	-	X	X
Gentiana villosa	-	X	-
Geranium carolinianum	/	X	-
Geranium maculatum	X	-	-
Geum virginianum	X	X	X
Gillenia stipulata	X	X	-
Gleditsia triacanthos	X	X	-
Gratiola neglecta	-	-	X
Gymnadeniopsis clavellata	X	X	-
Halesia carolina	X	-	-
Halesia tetraptera	-	X	-
Hamamelis virginiana	X	X	-
Helianthus angustifolius	X	-	-
Helianthus divaricatus	-	X	-
Helianthus hirsutus	X	-	X
Helianthus silphioides [a]	X	-	-
Heuchera americana	X	-	-
Hibiscus syriacus[c]	X	-	-
Hieracium gronovii	X	X	X
Hordeum pusillum	X	X	-
Houstonia caerulea	X	X	-
Houstonia purpurea	X	X	X
Hybanthus concolor	X	-	-
Hydrangea arborescens	X	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Hydrangea quercifolia	X	-	-
Hymenocallis occidentalis	X	-	-
Hypericum hypericoides ssp. *hypericoides*	X	X	X
Hypericum punctatum	X	X	X
Hypochaeris radicata[c]	/	-	X
Hypoxis hirsuta	/	X	-
Ilex ambigua	-	X	-
Ilex decidua	X	X	X
Ilex verticillata	X	X	-
Ilex opaca	X	X	X
Iodanthus pinnatifidus	X	-	-
Ipomoea pandurata	X	X	-
Iris cristata	X	X	-
Isotria verticillata	-	-	X
Iva annua [a]	X	-	-
Juglans nigra	X	X	-
Juncus debilis	-	-	X
Juncus tenuis	X	X	X
Juniperus virginiana	X	X	X
Krigia virginica	-	X	-
Krigia dandelion	/	X	-
Kummerowia stipulacea[c] (*Lespedeza stipulacea*)	/	X	-
Kummerowia striata[c] (*Lespedeza striata*)	/	X	X
Lactuca sp.		-	X
Lactuca canadensis	/	X	-
Lactuca floridana	X	-	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Lactuca serriola[c]	-	X	-
Lagerstroemia indica[c]	X	-	-
Laportea canadensis	-	X	-
Lathyrus latifolius[a,c]	X	-	-
Lechea sp.	-	X	-
Lechea minor	/	-	X
Leersia virginica	/	X	X
Lespedeza cuneata[c]	/	X	-
Lespedeza procumbens	-	X	X
Lespedeza repens	/	X	X
Lespedeza violacea	-	X	-
Lespedeza virginica	/	X	-
Liatris aspera	-	X	-
Liatris squarrosa[a]	X	-	-
Liatris squarrulosa[a]	X	-	-
Ligustrum sinense[c]	X	X	X
Lindera benzoin	X	X	X
Linum medium	X	-	-
Liquidambar styraciflua	X	X	X
Liriodendron tulipifera	X	X	X
Lobelia inflata	X	-	-
Lobelia puberula	X	X	X
Lobelia siphilitica	X	-	-
Lobelia spicata	X	-	-
Lonicera japonica[c]	X	X	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a “/” indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Ludwigia alternifolia	/	X	-
Luzula echinata	-	X	X
Lycopodium digitatum	X	X	-
Lycopus virginicus	/	X	-
Lysimachia ciliata	/	-	X
Maclura pomifera	X	-	-
Maianthemum racemosum ssp. *racemosum*	X	X	X
Malaxis unifolia	-	-	X
Malus angustifolia	X	-	-
Manfreda virginica	X	X	X
Matelea sp.	-	-	X
Matelea carolinensis	-	X	-
Medeola virginiana	X	X	-
Melica mutica	X	X	-
Melilotus alba[c]	X	-	-
Microstegium vimineum[c]	X	X	X
Mimosa microphylla	X	X	X
Mimulus alatus	X	-	-
Mitchella repens	X	-	X
Molineriella laevis[c] (*Aira elegans*)	X	-	-
Mollugo verticillata	/	X	-
Monarda fistulosa [a]	X	-	-
Monotropa uniflora	-	-	X
Morus rubra	X	X	X
Myosotis macrosperma	X	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).

b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.

c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Narcissus pseudonarcissus[c]	-	X	-
Nemophila aphylla[a]	X	-	-
Nyssa sylvatica	X	X	X
Onoclea sensibilis	/	X	-
Ophioglossum vulgatum	-	-	X
Orbexilum pedunculatum var. *pedunculatum*	X	X	-
Osmorhiza longistylis	X	X	-
Osmunda cinnamomea	/	X	X
Osmunda regalis	/	-	X
Ostrya virginiana	X	X	X
Oxalis dillenii	-	X	-
Oxalis stricta	X	X	X
Oxalis violacea	X	X	-
Oxydendrum arboreum	X	X	X
Packera anonyma	X	X	-
Panicum anceps	/	X	-
Parthenocissus quinquefolia	X	X	X
Paspalum laeve	/	X	X
Passiflora lutea	X	X	X
Paulownia tomentosa[c]	X	-	-
Penstemon calycosus	X	X	-
Penstemon pallidus	X	-	-
Phegopteris hexagonoptera	X	X	-
Philadelphus sp.	-	X	-
Phlox sp.	-	-	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).

b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.

c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Phlox divaricata	X	-	-
Phlox pilosa	X	X	-
Phoradendron leucarpum	X	-	-
Phryma leptostachya	X	X	-
Physostegia virginiana	-	X	-
Phytolacca americana	/	X	X
Pilea pumila	X	X	-
Pinus echinata	X	X	X
Pinus taeda	X	X	X
Pinus virginiana	X	X	-
Plantago aristata	/	-	X
Plantago lanceolata[c]	/	X	-
Plantago rugelii	-	X	-
Plantago virginica	X	-	-
Pleopeltis polylepis	-	X	-
Pleopeltis polypodioides[b]	X	-	-
Pluchea camphorata	X	-	-
Poa pratensis[c]	X	-	-
Poa sylvestris	X	X	-
Podophyllum peltatum	X	X	X
Polemonium reptans	X	-	-
Polygala curtissii	-	-	X
Polygala mariana	-	X	-
Polygonatum biflorum	X	X	X
Polygonum caespitosum var. *longisetum*[c]	-	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Polygonum virginianum	X	X	X
Polystichum acrostichoides	X	X	X
Potentilla simplex	X	X	-
Prenanthes altissima	X	X	X
Prunus mexicana	-	-	X
Prunus serotina	X	X	X
Pteridium aquilinum	X	-	-
Pycnanthemum sp.	-	-	X
Pycnanthemum incanum	X	-	-
Pycnanthemum tenuifolium	X	-	-
Pycnanthemum torrei [a]	X	-	-
Pycnanthemum verticillatum var. *pilosum*	/	X	-
Pyrus communis[c]	X	-	-
Quercus alba	X	X	X
Quercus coccinea	X	X	X
Quercus falcata	X	X	X
Quercus marilandica	X	X	X
Quercus michauxii	X	X	-
Quercus muehlenbergii	X	X	-
Quercus nigra	X	X	X
Quercus pagoda	X	X	-
Quercus phellos	X	X	X
Quercus rubra	X	X	X
Quercus stellata	X	X	X
Quercus velutina	X	X	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Ranunculus abortivus [a]	X	-	-
Ranunculus micranthus[a]	X	-	-
Ranunculus recurvatus	X	X	-
Rhododendron canescens	X	X	X
Rhus aromatic [b]	X	-	-
Rhus copallinum	X	X	X
Rosa carolina	X	X	X
Rosa multiflora[c]	-	X	X
Rubus argutus	X	X	X
Rubus trivialis	X	X	-
Rudbeckia hirta [a]	X	-	-
Ruellia caroliniensis	X	X	X
Ruellia strepens	X	X	X
Rumex acetosella[c]	/	X	-
Saccharum sp.	-	X	X
Saccharum giganteum	-	-	X
Salvia lyrata	/	X	X
Sambucus nigra ssp. *canadensis*	X	-	X
Sanguinaria canadensis	X	X	X
Sanicula canadensis	X	X	X
Sanicula odorata	X	-	-
Sanicula smallii	X	X	X
Sassafras albidum	X	X	X
Saururus cernuus	/	X	-
Saxifraga virginiensis	X	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).

b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.

c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**CUPN (2015)**
Schedonorus pratensis	-	X	-
Schizachyrium scoparium	/	X	X
Scleria oligantha	-	X	X
Scrophularia marilandica	X	-	-
Scutellaria elliptica	X	X	X
Scutellaria integrifolia	/	X	-
Scutellaria ovata	-	X	-
Scutellaria parvula	/	X	-
Sedum ternatum	X	X	-
Sericocarpus linifolius	X	X	X
Setaria parviflora (*S. geniculata*)	/	X	-
Sherardia arvensis[c]	X	-	-
Sida spinosa	/	X	-
Sideroxylon lycioides	-	X	-
Silene stellata	X	X	X
Silene virginica	X	X	-
Silphium asteriscus var. *latifolium*[a]	X	-	-
Sisyrinchium angustifolium	X	-	-
Smilax bona-nox	X	X	X
Smilax glauca	X	X	X
Smilax herbacea	-	X	-
Smilax lasioneura	X	-	-
Smilax rotundifolia	X	X	X
Smilax tamnoides	-	X	-
Solanum carolinense	/	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Solidago hispida	X	-	-
Solidago odora	X	-	X
Solidago rugosa	X	X	-
Solidago ulmifolia	X	-	X
Sorghum halepense[c]	/	X	-
Sphenopholis nitida	X	X	-
Sphenopholis obtusata	-	X	-
Spigelia marilandica	X	X	-
Spiranthes cernua[a]	X	-	-
Spiranthes tuberosa[a]	X	-	-
Stachys sp.	-	X	-
Stachys tenuifolia	X	-	X
Staphylea trifolia	X	X	-
Stellaria media[c]	X	X	-
Stellaria pubera	X	X	-
Stylosanthes biflora	/	X	X
Styrax grandifolius	X	-	X
Symphoricarpos orbiculatus	X	X	X
Symphyotrichum drummondii[a]	X	-	-
Symphyotrichum cordifolium	X	-	-
Symphyotrichum dumosum	/	X	-
Symphyotrichum patens var. *patens*	X	X	-
Symphyotrichum shortii	X	-	-
Symphyotrichum undulates[a]	X	-	-
Taraxacum officinale[c]	/	X	-

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Tephrosia virginiana	X	X	X
Thalictrum thalictroides	X	X	X
Thaspium barbinode	X	-	-
Thaspium trifoliatum	X	X	-
Thelypteris noveboracensis	X	-	X
Thyrsanthella difformis	-	X	-
Tilia americana var. *heterophylla*	X	X	-
Tipularia discolor	X	X	-
Toxicodendron radicans	X	X	X
Tradescantia ohiensis	X	-	-
Trichostema dichotomum [a]	X	-	-
Tridens flavus	X	X	-
Trifolium pratense [c]	/	X	-
Trifolium repens [c]	/	X	-
Trillium recurvatum	X	X	-
Triodanis perfoliata	/	X	-
Ulmus alata	X	X	X
Ulmus americana	X	X	X
Ulmus rubra	X	-	X
Uvularia grandiflora	X	-	-
Uvularia sessilifolia	X	X	X
Vaccinium arboreum	X	X	X
Vaccinium corymbosum (*V. fuscatum*)	X	X	X
Vaccinium pallidum	-	-	X
Vaccinium stamineum	X	X	X

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix A (continued). In the second column, a "/" indicates a species that was present at SHIL but not in hardwood forest/woodland habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	CUPN (2015)
Valerianella radiata	/	X	-
Verbena simplex	X	-	-
Verbesina alternifolia	/	-	X
Vernonia gigantea	X	X	-
Vernonia missurica	/	X	-
Veronica arvensis[c]	/	X	-
Viburnum acerifolium	X	-	-
Viburnum dentatum	X	X	X
Viburnum nudum	X	-	-
Viburnum rufidulum	X	X	X
Vicia sativa ssp. *nigra*[c]	X	X	-
Vinca minor[c]	X	-	-
Viola affinis	X	-	-
Viola palmata	-	X	-
Viola pedata	X	X	-
Viola pubescens	-	X	X
Viola sororia	X	X	X
Vitis aestivalis	X	X	-
Vitis cinerea	X	X	X
Vitis riparia	-	X	-
Vitis rotundifolia	X	X	X
Vitis vulpina	-	-	X
Woodsia obtusa	/	X	-
Woodwardia areolata	/	X	X
Yucca filamentosa	X	-	-
Totals	**329 (401 total)**	**348**	**206**

a. Species listed as occurring on woodland borders/edges, according to Jones and White (1981).
b. Species listed as occurring on wooded slopes, blufftops, or upland thickets.
c. Non-native species.

Appendix B. Plant species documented in wetland and riparian areas at SHIL.

In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	**Jones and White (1981)**	**NatureServe (2004)**	**Roberts and Morgan (2008)**	**CUPN (2015)**
Acalypha rhomboidea	/	X	-	-
Acer negundo	X	X	X	X
Acer rubrum	-	X	X	-
Acer rubrum var. *drummondii*	X	-	-	-
Acer saccharinum	X	X	-	X
Acer saccharum	/	-	X	-
Acorus calamus	X	-	-	-
Actaea racemosa	X	-	-	-
Ageratina altissima	X	-	-	-
Ageratina aromatica	X	-	-	-
Agrostis sp.	-	-	X	-
Alisma subcordatum	-	X	-	-
Alnus serrulata	X	X	-	-
Ambrosia trifida	/	X	-	-
Amelanchier arborea	/	X	-	-
Ampelopsis arborea	X	-	-	X
Ampelopsis cordata	X	X	-	-
Andropogon virginicus	-	-	X	-
Apios americana	X	X	-	-
Arisaema dracontium	X	X	-	X
Arisaema triphyllum	X	X	X	X
Aristolochia serpentaria	X	X	-	X

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Aristolochia tomentosa	X	-	-	-
Arnoglossum atriplicifolium	X	-	-	-
Arthraxon hispidus[c]	-	X	-	-
Arundinaria gigantea	X	X	X	X
Asarum canadense	/	-	-	X
Asclepias perennis	X	-	-	-
Asclepias variegata	/	X	-	-
Asimina triloba	/	X	X	-
Asplenium platyneuron	/	X	-	-
Aster sp.	-	X	X	-
Athyrium filix-femina	X	X	X	-
Bartonia paniculata	-	X	-	-
Betula nigra	X	-	X	X
Bidens aristosa	X	X	-	-
Bidens bipinnata	X	-	-	X
Bidens frondosa	X	X	-	-
Bignonia capreolata	X	X	-	X
Boehmeria cylindrica	/	X	X	X
Boltonia diffusa	X	-	-	-
Botrychium biternatum	-	X	-	-
Botrychium dissectum	X	-	-	X
Botrychium virginianum	X	-	-	-
Brasenia schreberi	-	X	-	-
Brickellia eupatorioides var. *eupatorioides*	X	-	-	-
Bromus pubescens	X	-	-	-

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Brunnichia ovata	X	X	-	X
Calycanthus floridus	X	-	-	-
Campsis radicans	X	X	X	X
Cardamine bulbosa	X	-	-	-
Cardiospermum halicacabum[c]	X	-	-	-
Carex albolutescens	X	-	-	-
Carex amphibola	/	-	-	X
Carex atlantica ssp. *capillacea*	X	X	-	-
Carex blanda	X	-	-	-
Carex bromoides	X	-	-	-
Carex caroliniana	X	-	-	-
Carex crinita	X	X	X	-
Carex debilis	X	X	-	-
Carex festucacea	-	X	-	-
Carex flaccosperma	X	-	-	-
Carex frankii	X	-	-	-
Carex gigantea	-	-	X	-
Carex glaucodea	-	-	-	X
Carex grayi	/	X	-	X
Carex intumescens	/	X	X	-
Carex laevivaginata	X	-	-	-
Carex louisianica	X	X	-	X
Carex lupulina	/	X	-	-
Carex lurida	X	X	-	-
Carex picta	/	X	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Carex radiata	-	-	-	X
Carex retroflexa	X	-	-	-
Carex rosea	X	-	-	-
Carex seorsa	X	-	-	-
Carex tribuloides	-	X	X	-
Carex typhina	X	X	-	X
Carex venusta	X	-	-	-
Carex vulpinoidea	-	-	X	-
Carpinus caroliniana	/	X	X	X
Carya aquatica	X	-	-	-
Carya cordiformis	/	X	X	X
Carya glabra	/	X	-	-
Carya laciniosa	X	-	-	-
Carya ovalis	/	X	-	-
Carya ovata	/	X	X	-
Carya tomentosa (*C. alba*)	/	X	-	-
Catalpa speciosa	X	-	-	-
Celtis laevigata	X	X	X	X
Celtis occidentalis	-	X	-	X
Cephalanthus occidentalis	X	X	X	X
Ceratophyllum demersum	-	X	-	-
Cercis canadensis	/	X	X	-
Chamaecrista fasciculata	/	X	-	-
Chasmanthium latifolium	X	X	X	X
Chasmanthium laxum	/	X	X	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Chasmanthium laxum ssp. *sessiliflorum* (*C. sessiliflorum*)	/	X	X	-
Chelone glabra	X	-	-	-
Cicuta maculata	-	X	-	-
Cinna arundinacea	/	X	-	-
Clematis crispa	X	-	-	-
Cocculus carolinus	X	X	-	X
Coleataenia longifolia ssp. *elongata* (*Panicum stipitatum*)	X	-	-	-
Coleataenia longifolia ssp. *rigidula* (*Panicum rigidulum*)	X	-	X	-
Commelina erecta	X	-	-	-
Commelina virginica	X	X	X	X
Conoclinium coelestinum	-	-	X	-
Conyza canadensis	/	X	-	-
Corallorhiza wisteriana	X	-	-	-
Cornus sp.	-	-	X	-
Cornus florida	/	X	-	X
Cornus foemina	X	X	-	-
Corylus americana	X	-	-	-
Crataegus sp.	-	X	-	X
Crataegus viridis	X	-	-	-
Croton monanthogynus	X	-	-	-
Cryptotaenia canadensis	-	-	-	X
Cuscuta compacta	X	-	-	-
Cuscuta gronovii	X	X	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Cuscuta pentagona	X	-	-	-
Cynanchum laeve	X	-	-	X
Cynodon dactylon[c]	/	X	-	-
Cyperus esculentus	X	-	-	-
Cyperus strigosus	/	-	X	-
Cystopteris protrusa	X	-	-	-
Danthonia spicata	X	-	-	-
Decumaria barbara	/	X	-	-
Desmodium glutinosum	/	X	-	-
Desmodium nudiflorum	/	X	-	-
Desmodium viridiflorum	X	-	-	-
Dichanthelium boscii	/	X	-	-
Dichanthelium clandestinum	X	-	X	-
Dichanthelium commutatum	X	-	-	-
Dichanthelium dichotomum	-	X	-	-
Dichanthelium laxiflorum	-	X	-	-
Dichanthelium polyanthes	X	-	-	-
Dichanthelium scoparium	X	-	-	-
Dichanthelium sphaerocarpon var. *isophyllum*	-	X	-	-
Dicliptera brachiata	X	-	-	X
Digitaria ischaemum[c]	-	X	-	-
Dioclea multiflora	X	-	-	X
Diodella teres (*Diodia teres*)	/	-	X	-
Diodia virginiana	X	-	X	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Dioscorea oppositifolia[c] (*D. polystachya*)	/	-	-	X
Dioscorea villosa	/	X	-	-
Diospyros virginiana	/	X	X	X
Dysphania ambrosioides[c] (*Chenopodium ambrosioides*)	X	-	-	-
Echinochloa crus-galli[c]	-	-	X	-
Eclipta prostrata	X	X	-	-
Eleocharis sp.	-	-	X	-
Eleocharis obtusa	X	-	-	-
Eleocharis tenuis	X	-	-	-
Elephantopus carolinianus	/	X	-	X
Elephantopus tomentosus	/	X	-	-
Eleusine indica[c]	X	-	-	-
Elymus riparius	X	-	-	-
Elymus virginicus	X	-	-	-
Epifagus virginiana	/	X	-	-
Eragrostis hypnoides	X	-	-	-
Erechtites hieraciifolius	/	X	-	-
Eupatorium perfoliatum	/	-	X	-
Euphorbia corollata	/	X	-	-
Eutrochium fistulosum (*Eupatorium fistulosum*)	X	X	-	-
Fagus grandifolia	/	X	X	-
Fimbristylis autumnalis	X	-	-	-
Forestiera acuminata	X	-	-	-
Fraxinus americana	/	X	-	X

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Fraxinus pennsylvanica	X	X	X	X
Galium aparine	X	-	-	-
Galium tinctorium	-	X	-	X
Galium triflorum	-	-	-	X
Geum virginianum	/	-	-	X
Gleditsia triacanthos	/	X	-	X
Glyceria striata	X	-	-	-
Gonolobus suberosus var. *suberosus* (*Matelea gonocarpos*)	X	X	-	X
Gratiola virginiana	X	X	-	-
Gymnadeniopsis clavellata	X	X	-	X
Hedera helix[c]	X	-	-	-
Heliotropium indicum[c]	X	-	-	-
Heteranthera reniformis	-	X	-	-
Hibiscus moscheutos	-	-	X	-
Hydrangea arborescens	X	-	-	-
Hydrolea uniflora	X	-	-	-
Hymenocallis occidentalis (*H. caroliniana*)	/	X	-	X
Hypericum perforatum[c]	X	-	-	-
Ilex decidua	/	X	X	X
Ilex verticillata	X	X	-	-
Ilex opaca	X	X	X	-
Impatiens capensis	X	X	X	-
Ipomea sp.	-	X	X	-
Ipomea lacunosa	X	-	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Ipomoea pandurata	X	-	-	X
Itea virginica	X	X	-	-
Juncus acuminatus	X	-	-	-
Juncus brachycarpus	X	-	-	-
Juncus effusus	-	-	X	-
Juniperus virginiana	/	X	X	X
Justicia americana	-	-	X	-
Justicia ovata	X	-	-	-
Krigia dandelion	/	X	-	-
Kummerowia striata[c] (*Lespedeza striata*)	/	X	-	-
Lactuca serriola[c]	-	X	-	-
Laportea canadensis	X	X	-	X
Leersia oryzoides	X	X	X	-
Leersia virginica	X	X	-	X
Lemna sp.	-	-	X	-
Lespedeza cuneata[c]	/	-	X	-
Lespedeza procumbens	-	X	-	-
Ligustrum sinense[c]	/	X	X	X
Lindera benzoin	-	-	X	-
Lindernia dubia	X	-	-	-
Liquidambar styraciflua	X	X	X	X
Liriodendron tulipifera	/	X	X	-
Lobelia sp.	-	-	X	-
Lobelia cardinalis	X	X	-	-
Lobelia inflata	/	X	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Lobelia puberula	X	-	-	-
Lonicera japonica[c]	/	X	X	X
Ludwigia decurrens	X	X	-	-
Ludwigia glandulosa	X	-	-	-
Ludwigia peploides ssp. *glabrescens*	-	X	-	-
Luzula multiflora	-	X	-	-
Lycopus americanus [a]	X	-	X	-
Lycopus rubellus	-	X	-	X
Lycopus virginicus	X	X	-	-
Lysimachia ciliata	X	-	-	-
Magnolia grandiflora	X	-	-	-
Maianthemum racemosum ssp. *racemosum*	/	X	-	-
Medeola virginiana	X	-	-	-
Melanthera nivea	X	-	-	-
Melothria pendula	X	-	-	-
Menispermum canadense	X	-	-	-
Microstegium vimineum[c]	/	X	X	X
Mikania scandens	X	X	-	X
Mimulus alatus	/	-	X	-
Mitchella repens	X	X	-	-
Morus rubra	/	X	-	-
Myriophyllum aquaticum[c]	-	X	-	-
Nemophila aphylla	X	-	-	-
Nothoscordum bivalve	X	-	-	-

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Nyssa aquatica	X	X	-	X
Nyssa biflora	-	-	X	-
Nyssa sylvatica	X	X	X	-
Onoclea sensibilis	X	X	X	-
Ophioglossum vulgatum	-	-	-	X
Osmunda cinnamomea	X	X	X	-
Osmunda regalis	X	X	X	-
Oxydendrum arboreum	/	X	-	-
Packera glabella	X	-	-	-
Panicum anceps	/	X	-	-
Panicum dichotomiflorum	X	X	-	-
Panicum virgatum	-	-	X	-
Parthenocissus quinquefolia	/	X	-	X
Paspalum sp.	-	-	X	-
Paspalum laeve	/	X	-	-
Paspalum scrobiculatum (*P. boscianum*)	X	-	-	-
Passiflora lutea	/	X	-	-
Pedicularis canadensis	X	-	-	-
Peltandra virginica	X	X	-	-
Penthorum sedoides	X	X	-	-
Persicaria hydropiper (*Polygonum hydropiper*)[c]	-	-	X	-
Persicaria hydropiperoides	X	-	X	-
Persicaria punctate (*Polygonum punctatum*)	X	X	-	X

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Persicaria sagittata (*Polygonum sagittatum*)	X	X	-	-
Phegopteris hexagonoptera	X	-	-	-
Phlox paniculata	X	-	-	-
Phyllanthus caroliniensis	X	-	-	-
Physalis longifolia	X	X	-	-
Phytolacca americana	/	X	-	-
Pilea pumila	/	X	-	X
Pinus taeda	/	-	X	-
Planera aquatica	X	-	-	X
Plantago cordata	-	-	X	-
Platanus occidentalis	X	X	X	-
Pleopeltis polylepis	-	-	-	-
Pleopeltis polypodioides	-	X	-	-
Podophyllum peltatum	X	X	-	-
Polygonatum biflorum	/	X	-	-
Polygonum caespitosum var. *longisetum*[c]	-	X	-	-
Polygonum virginianum	/	X	X	X
Polystichum acrostichoides	/	X	X	X
Populus deltoides	X	-	-	-
Potamogeton diversifolius	X	-	-	-
Potentilla simplex	/	X	-	-
Prenanthes altissima	X	-	-	-
Proserpinaca sp.	-	-	X	-
Prunella vulgaris	X	-	-	-

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Prunus serotina	/	X	-	-
Pteridium aquilinum	/	X	-	-
Quercus alba	/	X	X	-
Quercus falcata	/	X	-	-
Quercus lyrata	X	-	X	X
Quercus michauxii	X	X	-	-
Quercus nigra	/	X	X	X
Quercus pagoda	X	X	-	-
Quercus palustris	X	-	-	-
Quercus phellos	X	X	X	X
Quercus rubra	/	X	-	-
Quercus shumardii	/	-	X	-
Quercus velutina	/	X	-	-
Ranunculus sp.	-	-	X	-
Ranunculus recurvatus	/	X	-	-
Rhexia mariana [a]	X	-	-	-
Rhexia virginica	X	-	-	-
Rhododendron sp.	-	-	X	-
Rhododendron canescens	/	X	-	-
Rhynchospora corniculata	X	-	-	-
Robinia pseudoacacia	X	-	-	-
Rorippa sessiliflora	X	-	-	-
Rotala ramosior	X	-	-	-
Rubus sp.	-	-	X	-
Rubus argutus	/	X	-	X

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Rubus trivialis	/	X	-	-
Ruellia caroliniensis	/	X	-	-
Ruellia strepens	X	X	-	X
Rumex altissimus	X	-	-	-
Rumex crispus[c]	/	-	X	-
Rumex obtusifolius[c]	X	-	-	-
Rumex verticillatus	X	-	-	-
Sagittaria sp.	-	-	X	-
Sagittaria latifolia	X	X	-	-
Salix nigra	X	X	X	-
Sambucus nigra ssp. *canadensis*	/	X	-	-
Sanicula sp.	-	-	-	X
Sanicula canadensis	/	X	-	-
Sassafras albidum	/	X	-	-
Saururus cernuus	X	X	X	X
Schedonorus arundinaceus[c] (*Lolium arundinaceum*)	-	-	X	-
Schoenoplectus tabernaemontani	-	-	X	-
Scirpus atrovirens	/	-	X	-
Scirpus cyperinus	X	X	X	-
Scirpus polyphyllus	X	-	-	-
Scutellaria elliptica	X	-	-	-
Scutellaria lateriflora	X	X	-	-
Senna hebecarpa	-	-	-	X
Senna marilandica	X	-	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a "/" indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a "-"

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Setaria viridis[c]	X	-	-	-
Sicyos angulatus	X	-	-	-
Sida spinosa	/	X	-	-
Sideroxylon lycioides	X	-	-	-
Silene virginica	/	X	-	-
Smilax bona-nox	X	X	X	X
Smilax glauca	X	X	-	X
Smilax pulverulenta	-	X	-	-
Smilax rotundifolia	X	X	X	X
Smilax tamnoides	X	X	-	X
Solanum carolinense	/	-	X	-
Solanum nigrum	X	-	-	-
Solanum ptychanthum	-	-	-	X
Solidago sp.	-	-	-	X
Solidago arguta	X	-	-	-
Solidago caesia	X	-	-	-
Solidago gigantea	X	-	-	-
Solidago patula	X	-	-	-
Solidago rugosa ssp. *aspera*	X	X	-	-
Solidago ulmifolia	/	X	-	-
Sphagnum sp.[b]	-	X	X	-
Spiranthes ovalis	-	X	-	-
Spirodela polyrrhiza	-	X	-	-
Stachys sp.	-	-	-	-

a. Occurs in ditches and "seepages."

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn't record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Stachys tenuifolia	X	-	-	X
Stylosanthes biflora	/	X	-	-
Symphoricarpos orbiculatus	X	-	-	-
Symphyotrichum lanceolatum var. *lanceolatum*	X	-	X	-
Symphyotrichum lateriflorum	X	-	-	X
Symphyotrichum ontarionis	-	X	-	-
Taxodium distichum	X	-	-	-
Thelypteris noveboracensis	X	X	X	-
Thyrsanthella difformis (*Trachelospermum difforme*)	X	X	-	-
Tipularia discolor	/	X	-	-
Toxicodendron radicans	/	X	X	X
Trepocarpus aethusae	X	-	-	-
Triadenum tubulosum	-	X	-	-
Triadenum walteri	X	X	-	X
Trifolium pratense[c]	/	X	-	-
Triosteum angustifolium	X	-	-	-
Typha latifolia	-	-	X	-
Ulmus alata	/	X	-	X
Ulmus americana	/	X	X	X
Ulmus rubra	/	-	X	X
Urtica dioica	-	-	X	-
Uvularia sessilifolia	/	X	-	-
Vaccinium sp.	-	-	X	-
Vaccinium arboreum	/	X	-	-

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix B (continued). In the second column, a “/” indicates a species that was present at SHIL but not in wetland/riparian habitats, and species not observed are indicated by a “-“

Species	Jones and White (1981)	NatureServe (2004)	Roberts and Morgan (2008)	CUPN (2015)
Vaccinium corymbosum (*V. fuscatum*)	-	X	-	-
Vaccinium stamineum	/	X	-	-
Valerianella locusta[a, c]	X	-	-	-
Verbena urticifolia	X	-	-	-
Verbesina alternifolia	X	-	-	-
Verbesina virginica	X	-	-	-
Vernonia gigantea	X	-	-	-
Vernonia missurica	X	-	-	-
Viola sp.	-	X	-	X
Viola affinis	X	-	-	-
Viola palmata	X	-	-	-
Viola sororia	/	-	-	X
Vitis sp.	-	-	X	-
Vitis aestivalis	/	X	-	-
Vitis palmata	X	-	-	-
Vitis rotundifolia	X	X	-	X
Vitis vulpina	-	-	-	X
Woodwardia areolata	X	X	-	-
Xanthium strumarium	/	X	-	-
	218 (326)	**206**	**105**	**91**

a. Occurs in ditches and “seepages.”

b. *Sphagnum* is a non-vascular plant and Jones and White (1981) focused specifically on vascular plants. So it may have been present but they didn’t record it.

c. Non-native species.

Appendix C. Mammal species indicated by the literature to occur and those verified on SHIL in the Kennedy (1984) study.

Scientific names are listed as identified during the time of the study.

Scientific Name	Common Name	Verified
Blarina carolinensis	southern short-tailed shrew	X
Canis latrans	coyote	X
Castor canadensis	American beaver	X
Cryptotis parva	least shrew	-
Dasypus novemcinctus	nine-banded armadillo	X
Didelphis virginiana	Virginia opossum	X
Eptesicus fuscus	big brown bat	-
Glaucomys volans	southern flying squirrel	-
Lasionycteris noctivagans	silver-haired bat	X
Lasiurus borealis	eastern red bat	X
Lasiurus cinercus	hoary bat	X
Lasiurus seminolus	Seminole bat	X
Lutra canadensis	river otter	-
Lynx rufus	bobcat	X
Marmota monax	woodchuck	X
Mephitis mephitis	striped skunk	X
Microtus ochrogaster	prairie vole	-
Microtus pinetorum	woodland vole	X
Mus musculus	house mouse	X
Mustela frenata	long-tailed weasel	-
Mustela vison	mink	X
Myotis austroriparus	southeastern bat	X
Myotis grisescens	gray bat	X
Myotis keenii	Keen's bat	X
Myotis leibii	eastern small-footed bat	-

* Now referred to as the tri-colored bat.

Appendix C (continued). Scientific names are listed as identified during the time of the study.

Scientific Name	Common Name	Verified
Myotis lucifugus	little brown bat	X
Myotis sodalis	Indiana bat	-
Neotoma floridana	eastern woodrat	-
Nycticeius humeralis	evening bat	X
Ochrotomys nuttalli	golden mouse	X
Odocoileus virginiana	white-tailed deer	X
Ondatra zibethicus	muskrat	-
Oryzomys palustris	marsh rice rat	X
Peromyscus gossypinus	cotton mouse	X
Peromyscus leucopus	white-footed mouse	X
Peromyscus maniculatus	deer mouse	-
Pipistrellus subflavus	eastern pipistrelle*	X
Plecotus rafinesquii	Rafinesque's big-eared bat	-
Procyon lotor	raccoon	X
Reithrodontomys humulis	eastern harvest mouse	X
Scalopus aquaticus	eastern mole	X
Sciurus carolinensis	eastern gray squirrel	X
Sciurus niger	eastern fox squirrel	X
Sigmodon hispidus	hispid cotton rat	-
Sorex longirostris	southeastern shrew	X
Spilogale putorius	eastern spotted skunk	-
Sylvilagus aquaticus	swamp rabbit	-
Sylvilagus floridanus	eastern cottontail	X
Synaptomys cooperi	southern bog lemming	-
Tamis striatus	eastern chipmunk	-
Urocyon cinereoargenteus	gray fox	X
Vulpes fulva	red fox	X
Zapus hudsonicus	meadow jumping mouse	-

* Now referred to as the tri-colored bat.

Appendix D. Terrestrial mammals in SHIL according to the NPS Certified Mammals Species List (2016b).

Species listed as unconfirmed are designated with a ‘U’; verified through the Kennedy (1984) study, and documented in the Kennedy and Jennings (2007) study. Some scientific names were updated to match those accepted by the Integrated Taxonomic Information System (ITIS).

Scientific name	Common name	Kennedy (1984)	Kennedy (2007)	NPSpecies
Blarina brevicauda	northern short-tailed shrew	-	-	U
Blarina carolinensis	southern short-tailed shrew	X	X	X
Canis lupus familiaris	domestic dog	-	X	X
Canis latrans	coyote	X	X	X
Castor canadensis	American beaver	X	X	X
Cryptotis parva	least shrew	-	X	X
Dasypus novemcinctus	nine-banded armadillo	X	X	X
Didelphis virginiana	Virginia opossum	X	X	X
Felis catus	domestic cat	-	X	X
Glaucomys volans	southern flying squirrel	-	-	U
Lontra canadensis[a]	river otter	-	X	X
Lynx rufus	bobcat	X	X	X
Marmota monax	woodchuck	X	X	X
Mephitis mephitis	striped skunk	X	X	X
Microtus ochrogaster	prairie vole	-	-	U
Microtus pinetorum	woodland vole	X	X	X
Mus musculus	house mouse	X	-	X
Mustela frenata	long-tailed weasel	-	-	U
Neotoma floridana	eastern woodrat	-	-	U
Neovison vison[b]	mink	X	X	X
Ochrotomys nuttalli	golden mouse	X	X	X
Odocoileus virginianus	white-tailed deer	X	X	X
Ondatra zibethicus	muskrat	-	X	X

a. Historic scientific name was *Lutra Canadensis.*

b. Historic scientific name was *Mustela vison.*

c. Historic scientific name was *Vulpes fulva.*

Appendix D (continued). Species listed as unconfirmed are designated with a ‘U’; verified through the Kennedy (1984) study, and documented in the Kennedy and Jennings (2007) study. Some scientific names were updated to match those accepted by the Integrated Taxonomic Information System (ITIS).

Scientific name	Common name	Kennedy (1984)	Kennedy (2007)	NPSpecies
Oryzomys palustris	marsh rice rat	X	X	X
Peromyscus gossypinus	cotton mouse	X	X	X
Peromyscus leucopus	white-footed mouse	X	X	X
Peromyscus maniculatus	deer mouse	-	-	U
Procyon lotor	raccoon	X	X	X
Rattus norvegicus	Norway rat	-	-	U
Rattus rattus	black rat	-	-	U
Reithrodontomys humulis	eastern harvest mouse	X	-	X
Scalopus aquaticus	eastern mole	X	X	X
Sciurus carolinensis	eastern gray squirrel	X	X	X
Sciurus niger	eastern fox squirrel	X	-	U
Sigmodon hispidus	hispid cotton rat	-	X	X
Sorex longirostris	southeastern shrew	X	-	X
Sylvilagus aquaticus	swamp rabbit	-	X	X
Sylvilagus floridanus	eastern cottontail	X	X	X
Synaptomys cooperi	southern bog lemming	-	-	U
Tamias striatus	eastern chipmunk	-	X	X
Urocyon cinereoargenteus	gray fox	X	X	X
Vulpes vulpes[c]	red fox	X	X	X
Zapus hudsonius	meadow jumping mouse	-	-	U

a. Historic scientific name was *Lutra Canadensis.*
b. Historic scientific name was *Mustela vison.*
c. Historic scientific name was *Vulpes fulva.*

Appendix E. Bird species present in SHIL based on the NPS (2016) list and Stedman and Stedman (2006).

Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Empidonax virescens	**Acadian flycatcher**	**X**	**X**	**X**
Empidonax alnorum	**alder flycatcher**	**U**	**U**	**-**
Botaurus lentiginosus	American bittern	X	U	X
Anas rubripes	American black duck	X	-	X
Fulica americana	American coot	X	-	X
Corvus brachyrhynchos	**American crow**	**X**	**X**	**X**
Pluvialis dominica	American golden-plover	X	U	X
Carduelis tristis	**American goldfinch**	**X**	**X**	**X**
Falco sparverius	*American kestrel*	*X*	*X*	*X*
Anthus rubescens	**American pipit**	**X**	**U**	**X**
Setophaga ruticilla	**American redstart**	**X**	**-**	**X**
Turdus migratorius	**American robin**	**X**	**X**	**X**
Spizella arborea	**American tree sparrow**	**U**	**X**	**U**
Anas americana	American wigeon	X	-	X
Scolopax minor	American woodcock	X	X	X
Aimophila aestivalis	**Bachman's sparrow**	**U**	**X**	**U**
Haliaeetus leucocephalus	*bald eagle*	*X*	*X*	*X*
Riparia riparia	**bank swallow**	**X**	**X**	**X**
Tyto alba	*barn owl*	*X*	-	*X*
Hirundo rustica	**barn swallow**	**X**	**X**	**X**
Strix varia	*barred owl*	*X*	*X*	*X*
Dendroica castanea	**bay-breasted warbler**	**X**	**X**	**X**
Vireo bellii	**Bell's vireo**	**X**	**-**	**X**
Ceryle alcyon	belted kingfisher	X	X	X
Thryomanes bewickii	**Bewick's wren**	**U**	**X**	**U**
Chlidonias niger	black tern	X	X	X
Coragyps atratus	*black vulture*	*X*	*X*	*X*

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Mniotilta varia	**black-and-white warbler**	**X**	**X**	**X**
Coccyzus erythropthalmus	black-billed cuckoo	X	U	X
Dendroica fusca	**blackburnian warbler**	**X**	**X**	**X**
Nycticorax nycticorax	black-crowned night-heron	X	-	X
Dendroica striata	**blackpoll warbler**	**X**	**X**	**X**
Dendroica virens	**black-throated green warbler**	**X**	**X**	**X**
Passerina caerulea	**blue grosbeak**	**X**	**X**	**X**
Cyanocitta cristata	**blue jay**	**X**	**X**	**X**
Polioptila caerulea	**blue-gray gnatcatcher**	**X**	**X**	**X**
Vireo solitarius	**blue-headed vireo**	**X**	**X**	**X**
Anas discors	blue-winged teal	X	U	X
Vermivora pinus	**blue-winged warbler**	**X**	**X**	**X**
Dolichonyx oryzivorus	**bobolink**	**X**	**U**	**X**
Larus philadelphia	Bonaparte's gull	X	X	X
Euphagus cyanocephalus	**Brewer's blackbird**	**U**	**U**	**-**
Buteo platypterus	*broad-winged hawk*	*X*	*X*	*X*
Certhia americana	**brown creeper**	**X**	**X**	**X**
Toxostoma rufum	**brown thrasher**	**X**	**X**	**X**
Molothrus ater	**brown-headed cowbird**	**X**	**X**	**X**
Sitta pusilla	**brown-headed nuthatch**	**U**	**U**	**-**
Bucephala albeola	bufflehead	U	U	-
Branta canadensis	Canada goose	X	X	X
Wilsonia canadensis	**Canada warbler**	**X**	**X**	**X**
Aythya valisineria	canvasback	U	X	U
Dendroica tigrina	**Cape May warbler**	**X**	**U**	**X**
Poecile carolinensis	**Carolina chickadee**	**X**	**X**	**X**
Thryothorus ludovicianus	**Carolina wren**	**X**	**X**	**X**
Sterna caspia	Caspian tern	X	X	X
Bombycilla cedrorum	**cedar waxwing**	**X**	**X**	**X**

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Dendroica cerulea	**cerulean warbler**	**X**	**X**	**X**
Dendroica pensylvanica	**chestnut-sided warbler**	**X**	**X**	**X**
Chaetura pelagica	chimney swift	X	X	X
Spizella passerina	**chipping sparrow**	**X**	**X**	**X**
Caprimulgus carolinensis	chuck-will's-widow	X	X	X
Petrochelidon pyrrhonota	**cilff swallow**	**X**	**X**	**X**
Spizella pallida	**clay-colored sparrow**	**U**	**U**	**-**
Bucephala clangula	common goldeneye	X	U	X
Quiscalus quiscula	**common grackle**	**X**	**X**	**X**
Columbina passerina	common ground-dove	U	U	-
Gavia immer	common loon	X	U	X
Chordeiles minor	common nighthawk	X	X	X
Sterna hirundo	common tern	U	X	U
Geothlypis trichas	**common yellowthroat**	**X**	**X**	**X**
Oporornis agilis	**connecticut warbler**	**X**	**U**	**X**
Accipiter cooperii	*Cooper's hawk*	*X*	*X*	*X*
Junco hyemalis	**dark-eyed junco**	**X**	**X**	**X**
Spiza americana	**dickcissel**	X	U	X
Phalacrocorax auritus	double-crested cormorant	X	X	X
Picoides pubescens	downy woodpecker	X	X	X
Calidris alpina	dunlin	U	U	-
Sialia sialis	**eastern bluebird**	**X**	**X**	**X**
Tyrannus tyrannus	**eastern kingbird**	**X**	**X**	**X**
Sturnella magna	**eastern meadowlark**	**X**	**X**	**X**
Sayornis phoebe	**eastern phoebe**	**X**	**X**	**X**
Megascops asio	*eastern screech-owl*	*X*	*X*	*X*
Pipilo erythrophthalmus	**eastern towhee**	**X**	**X**	**X**
Contopus virens	**eastern wood-pewee**	**X**	**X**	**X**
Streptopelia decaocto	Eurasian collared-dove	X	-	X

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	**Common Name**	**NPS (2016)**	**TOS 1998 Checklist**	**Stedman and Stedman (2006)**
Sturnus vulgaris	**European starling**	**X**	**X**	**X**
Coccothraustes vespertinus	**evening grosbeak**	**U**	**-**	**-**
Spizella pusilla	**field sparrow**	**X**	**X**	**X**
Sterna forsteri	Forster's tern	X	X	X
Passerella iliaca	**fox sparrow**	**X**	**X**	**X**
Anas strepera	gadwall	X	-	X
Regulus satrapa	**golden-crowned kinglet**	**X**	**X**	**X**
Vermivora chrysoptera	**golden-winged warbler**	**U**	**U**	**-**
Ammodramus savannarum	**grasshopper sparrow**	**X**	**U**	**X**
Dumetella carolinensis	**gray catbird**	**X**	**X**	**X**
Catharus minimus	**gray-cheeked thrush**	**X**	**X**	**X**
Ardea herodias	great blue heron	X	X	X
Myiarchus crinitus	**great crested flycatcher**	**X**	**X**	**X**
Ardea alba	**great egret**	**X**	**X**	**X**
Bubo virginianus	*great horned owl*	*X*	*X*	*X*
Butorides virescens	green heron	X	X	X
Anas crecca	green-winged teal	X	-	X
Picoides villosus	hairy woodpecker	X	X	X
Ammodramus henslowii	**Henslow's sparrow**	**U**	**X**	**-**
Catharus guttatus	**hermit thrush**	**X**	**X**	**X**
Larus argentatus	herring gull	X	X	X
Lophodytes cucullatus	hooded merganser	X	U	X
Wilsonia citrina	**hooded warbler**	**X**	**X**	**X**
Podiceps auritus	horned grebe	U	U	U
Eremophila alpestris	**horned lark**	**X**	**U**	**X**
Carpodacus mexicanus	**house finch**	**X**	**X**	**X**
Passer domesticus	**house sparrow**	**X**	**-**	**X**
Troglodytes aedon	**house wren**	**X**	**X**	**X**
Passerina cyanea	**indigo bunting**	**X**	**X**	**X**

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Oporornis formosus	**Kentucky warbler**	**X**	**X**	**X**
Charadrius vociferus	killdeer	X	X	X
Chondestes grammacus	**lark sparrow**	**U**	**X**	**U**
Ammodramus leconteii	**Le Conte's sparrow**	**X**	**-**	**X**
Ixobrychus exilis	least bittern	X	-	X
Empidonax minimus	**least flycatcher**	**X**	**U**	**X**
Tringa flavipes	lesser yellowlegs	X	-	X
Melospiza lincolnii	**lincoln's sparrow**	**X**	**X**	**X**
Egretta caerulea	little blue heron	X	X	X
Lanius ludovicianus	**loggerhead shrike**	**U**	**X**	**U**
Clangula hyemalis	long-tailed duck	U	U	-
Seiurus motacilla	**Louisiana waterthrush**	**X**	**X**	**X**
Dendroica magnolia	**magnolia warbler**	**X**	**X**	**X**
Anas platyrhynchos	mallard	X	X	X
Cistothorus palustris	**marsh wren**	**X**	**U**	**X**
Falco columbarius	*merlin*	*U*	*U*	-
Zenaida macroura	mourning dove	X	X	X
Oporornis philadelphia	**mourning warbler**	**U**	**X**	**X**
Vermivora ruficapilla	**Nashville warbler**	**X**	**U**	**X**
Colinus virginianus	northern bobwhite	X	X	X
Cardinalis cardinalis	**northern cardinal**	**X**	**X**	**X**
Colaptes auratus	northern flicker	X	X	X
Circus cyaneus	*northern harrier*	*X*	*X*	*X*
Mimus polyglottos	**northern mockingbird**	**X**	**X**	**X**
Icterus galbula	**northern oriole**	**X**	**X**	**X**
Parula americana	**northern parula**	**X**	**X**	**X**
Stelgidopteryx serripennis	**northern rough-winged swallow**	**X**	**X**	**X**
Anas clypeata	northern shoveler	X	-	X
Seiurus noveboracensis	**northern waterthrush**	**X**	**U**	**X**

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Contopus cooperi	**olive-sided flycatcher**	**U**	**X**	**X**
Vermivora celata	**orange-crowned warbler**	**X**	**X**	**X**
Icterus spurius	**orchard oriole**	**X**	**X**	**X**
Pandion haliaetus	*osprey*	*X*	*X*	*X*
Seiurus aurocapilla	**ovenbird**	**X**	**X**	**X**
Dendroica palmarum	**palm warbler**	**X**	**X**	**X**
Calidris melanotos	pectoral sandpiper	X	-	X
Falco peregrinus	*peregrine falcon*	*U*	*U*	-
Vireo philadelphicus	**Philadelphia vireo**	**X**	**X**	**X**
Podilymbus podiceps	pied-billed grebe	X	-	X
Dryocopus pileatus	pileated woodpecker	X	X	X
Carduelis pinus	**pine siskin**	**U**	**X**	**U**
Dendroica pinus	**pine warbler**	**X**	**X**	**X**
Dendroica discolor	**prairie warbler**	**X**	**X**	**X**
Protonotaria citrea	**prothonotary warbler**	**X**	**X**	**X**
Carpodacus purpureus	**purple finch**	**X**	**X**	**X**
Progne subis	**purple martin**	**X**	**X**	**X**
Melanerpes carolinus	red-bellied woodpecker	X	X	X
Mergus serrator	red-breasted merganser	U	U	-
Sitta canadensis	**red-breasted nuthatch**	**U**	**X**	**U**
Vireo olivaceus	**red-eyed vireo**	**X**	**X**	**X**
Aythya americana	redhead	X	U	X
Melanerpes erythrocephalus	red-headed woodpecker	X	X	X
Buteo lineatus	*red-shouldered hawk*	*X*	*X*	*X*
Buteo jamaicensis	*red-tailed hawk*	*X*	*X*	*X*
Agelaius phoeniceus	**red-winged blackbird**	**X**	**X**	**X**
Larus delawarensis	ring-billed gull	X	X	X
Aythya collaris	ring-necked duck	X	-	X
Columba livia	rock pigeon	X	X	X

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Pheucticus ludovicianus	**rose-breasted grosbeak**	**X**	**X**	**X**
Buteo lagopus	*rough-legged hawk*	*U*	*U*	-
Regulus calendula	**ruby-crowned kinglet**	**X**	**X**	**X**
Archilochus colubris	ruby-throated hummingbird	X	X	X
Oxyura jamaicensis	ruddy duck	U	U	-
Euphagus carolinus	**rusty blackbird**	**X**	**X**	**X**
Passerculus sandwichensis	**savannah sparrow**	**X**	**X**	**X**
Piranga olivacea	**scarlet tanager**	**X**	**X**	**X**
Tyrannus forficatus	**scissor-tailed flycatcher**	**U**	**X**	**U**
Cistothorus platensis	**sedge wren**	**U**	**U**	**-**
Charadrius semipalmatus	semipalmated plover	U	X	U
Calidris pusilla	semipalmated sandpiper	U	U	-
Accipiter striatus	*sharp-shinned hawk*	*X*	*X*	*X*
Asio flammeus	*short-eared owl*	*U*	*U*	-
Chen caerulescens	snow goose	X	-	X
Egretta thula	snowy egret	X	-	X
Tringa solitaria	solitary sandpiper	X	X	X
Melospiza melodia	**song sparrow**	**X**	**X**	**X**
Actitis macularius	spotted sandpiper	U	X	U
Piranga rubra	**summer tanager**	**X**	**X**	**X**
Catharus ustulatus	**Swainson's thrush**	**X**	**X**	**X**
Limnothlypis swainsonii	**Swainson's warbler**	**X**	**X**	**X**
Melospiza georgiana	**swamp sparrow**	**X**	**X**	**X**
Vermivora peregrina	**Tennessee warbler**	**X**	**X**	**X**
Tachycineta bicolor	**tree swallow**	**X**	**X**	**X**
Baeolophus bicolor	**tufted titmouse**	**X**	**X**	**X**
Cathartes aura	*turkey vulture*	*X*	*X*	*X*
Catharus fuscescens	**veery**	**X**	**X**	**X**
Pooecetes gramineus	**vesper sparrow**	**U**	**X**	**U**

Appendix E (continued). Species in bold indicate a passerine species, species with common names in italics indicate a raptor species. X = Confirmed, U = Unconfirmed, - = not observed.

Scientific Name	Common Name	NPS (2016)	TOS 1998 Checklist	Stedman and Stedman (2006)
Rallus limicola	Virginia rail	U	U	-
Vireo gilvus	**warbling vireo**	**X**	**X**	**X**
Caprimulgus vociferus	whip-poor-will	X	X	X
Sitta carolinensis	**white-breasted nuthatch**	**X**	**X**	**X**
Zonotrichia leucophrys	**white-crowned sparrow**	**X**	**X**	**X**
Vireo griseus	**white-eyed vireo**	**X**	**X**	**X**
Calidris fuscicollis	white-rumped sandpiper	U	U	-
Zonotrichia albicollis	**white-throated sparrow**	**X**	**X**	**X**
Meleagris gallopavo	wild turkey	X	X	X
Empidonax traillii	**willow flycatcher**	**X**	**U**	**X**
Gallinago delicata	Wilson's snipe	X	-	X
Wilsonia pusilla	**Wilson's warbler**	**U**	**X**	**U**
Troglodytes troglodytes	**winter wren**	**X**	**X**	**X**
Aix sponsa	wood duck	X	X	X
Hylocichla mustelina	**wood thrush**	**X**	**X**	**X**
Helmitheros vermivorum	**worm-eating warbler**	**X**	**X**	**X**
Dendroica petechia	**yellow warbler**	**X**	**X**	**X**
Empidonax flaviventris	**yellow-bellied flycatcher**	**U**	**U**	**-**
Sphyrapicus varius	yellow-bellied sapsucker	X	X	X
Coccyzus americanus	yellow-billed cuckoo	X	X	X
Icteria virens	**yellow-breasted chat**	**X**	**X**	**X**
Dendroica coronata	**yellow-rumped warbler**	**X**	**X**	**X**
Vireo flavifrons	**yellow-throated vireo**	**X**	**X**	**X**
Dendroica dominica	**yellow-throated warbler**	**X**	**X**	**X**
Total # of Species		**225**	**203**	**203**
Total # of Confirmed Species		**186**	**162**	**186**

Appendix F. Passerine species abundance estimates as determined by Stedman and Stedman (2006).

Common Name	2004	2005
Acadian flycatcher	22	14
American crow	25	17
American goldfinch	-	4
American robin	7	8
blue grosbeak	18	18
blue jay	28	26
blue-gray gnatcatcher	19	13
brown-headed cowbird	37	25
Carolina chickadee	23	15
Carolina wren	65	49
cedar waxwing	-	2
chipping sparrow	29	11
common grackle	4	2
common yellowthroat	1	5
eastern bluebird	21	9
eastern kingbird	-	5
eastern meadowlark	2	-
eastern phoebe	7	7
eastern towhee	11	15
eastern wood-pewee	18	20
field sparrow	2	-
great crested flycatcher	12	14
hooded warbler	3	3
indigo bunting	62	34
Kentucky warbler	7	6
Louisiana waterthrush	5	2
northern cardinal	80	55

Appendix F (continued). Passerine species abundance estimates as determined by Stedman and Stedman (2006).

Common Name	**2004**	**2005**
northern parula	1	3
northern rough-winged swallow	2	2
orchard oriole	-	2
ovenbird	4	-
pine warbler	4	5
prairie warbler	1	-
prothonotary warbler	14	10
purple martin	2	1
red-eyed vireo	40	35
red-winged blackbird	4	-
scarlet tanager	4	3
summer tanager	28	25
tufted titmouse	36	37
white-breasted nuthatch	18	19
white-eyed vireo	9	7
wood thrush	21	19
worm-eating warbler	1	-
yellow warbler	-	1
yellow-breasted chat	5	12
yellow-throated vireo	9	14
yellow-throated warbler	2	2
Total Passerine Abundance	713	576
Passerine Species Richness	**43**	**42**
Total Passerine Species Richness		**48**

Appendix G. List of fish species discovered in SHIL from the NPSpecies (2016) list, along with documentation in Higgins (1998).

Scientific Name	Common Name	Nativeness	Abundance	Higgins (1998)
Etheostoma zonistium	bandfin darter	Native	Common	X
Ameiurus melas	black bullhead	Native	Occasional	X
Rhinichthys atratulus	blacknose dace	Native	Uncommon	X
Fundulus olivaceus	blackspotted topminnow	Native	Common	X
Lepomis macrochirus	bluegill	Native	Common	X
Cyprinella camura	bluntface shiner	Native	Uncommon	X
Pimephales notatus	bluntnose minnow	Native	Common	X
Labidesthes sicculus	brook silverside	Native	Common	X
Noturus phaeus	brown madtom	Native	Common	X
Pimephales vigilax	bullhead minnow	Native	Occasional	X
Semotilus atromaculatus	creek chub	Native	Abundant	X
Erimyzon oblongus	creek chubsucker	Native	Common	X
Etheostoma proeliare	cypress darter	Native	Uncommon	X
Lepomis marginatus	dollar sunfish	Native	Common	X
Percina sciera	dusky darter	Native	Uncommon	X
Notropis atherinoides	emerald shiner	Native	Common	X
Centrarchus macropterus	flier	Native	Uncommon	X
Aplodinotus grunniens	freshwater drum	Native	Occasional	X
Dorosoma cepedianum	gizzard shad	Native	Uncommon	X
Moxostoma erythrurum	golden redhorse	Native	Uncommon	X
Notemigonus crysoleucas	golden shiner	Native	Common	X
Etheostoma parvipinne	goldstripe darter	Native	Common	X
Ctenopharyngodon idella	grass carp	Non-native	Unknown	X
Esox americanus	grass pickerel	Native	Uncommon	X
Lepomis cyanellus	green sunfish	Native	Uncommon	X

Appendix G (continued). List of fish species discovered in SHIL from the NPSpecies (2016) list, along with documentation in Higgins (1998).

Scientific Name	Common Name	Nativeness	Abundance	Higgins (1998)
Erimyzon sucetta	lake chubsucker	Native	Uncommon	X
Micropterus salmoides	largemouth bass	Native	Uncommon	X
Campostoma oligolepis	largescale stoneroller	Native	Uncommon	X
Lampetra aepyptera	least brook lamprey	Native	Common	X
Lepomis megalotis	longear sunfish	Native	Common	X
Lepisosteus osseus	longnose gar	Native	Occasional	X
Notropis volucellus	mimic shiner	Native	Occasional	X
Hypentelium nigricans	northern hog sucker	Native	Occasional	X
Aphredoderus sayanus	pirate perch	Native	Common	X
Opsopoeodus emiliae	pugnose minnow	Native	Common	X
Lepomis microlophus	redear sunfish	Native	Common	X
Lythrurus fumeus	ribbon shiner	Native	Abundant	X
Lythrurus ardens	rosefin shiner	Native	Uncommon	X
Clinostomus funduloides	rosyside dace	Native	Common	X
Sander canadensis	sauger	Native	Occasional	X
Phoxinus erythrogaster	southern redbelly dace	Native	Abundant	X
Cyprinella spiloptera	spotfin shiner	Native	Abundant	X
Minytrema melanops	spotted sucker	Native	Uncommon	X
Luxilus chrysocephalus	striped shiner	Native	Abundant	X
Etheostoma kennicotti	stripetail darter	Native	Uncommon	X
Dorosoma petenense	threadfin shad	Native	Abundant	X
Lepomis gulosus	warmouth	Native	Uncommon	X
Gambusia affinis	western mosquitofish	Native	Abundant	X
Pomoxis annularis	white crappie	Native	Uncommon	X
Ameiurus natalis	yellow bullhead	Native	Uncommon	X
Perca flavescens	yellow perch	Non-native	Occasional	X

Appendix H. Higgins' (1998) list of inventoried fish species, where they were documented, and their level of abundance in SHIL.

A = abundant, **C** = common, **U** = uncommon, **O** = occasional, **ip** = isolated populations, **- =** not observed. **1** = only one specimen collected, **2** = only two specimen collected, **3** = only three specimen collected

Scientific Name	Common Name	Owl Creek Drainage				Tennessee River Drainage							Owl Creek	Totals
		Tilghman Branch	Shiloh Branch	Picnic Branch	Owl Creek Beaver Ponds	Dill Branch	Mounds Branch	River-bottoms Branch	Hagy Branch	Rogers Branch	Johns-ton Branch	Quarry Branch		
Etheostoma zonistium	bandfin darter	C	C	-	U	U	-	-	-	-	-	-	U	5
Ameiurus melas	black bullhead	O^{2}	-	-	-	-	-	-	-	-	-	-	-	1
Rhinichthys atratulus	blacknose dace	-	-	-	-	-	-	-	-	-	-	U_{ip}	-	1
Fundulus olivaceus	blackspotted topminnow	C	C	-	C	C	C	C	-	C	-	-	C	8
Lepomis macrochirus	bluegill	C	U	-	A	U	C	C	-	C	-	-	C	8
Cyprinella camura	bluntface shiner	-	-	-	O^{2}	-	-	-	-	-	-	-	U	2
Pimephales notatus	bluntnose minnow	-	-	-	U	U	A	-	-	C	-	-	U	5
Labidesthes sicculus	brook silverside	-	-	-	U_{ip}	C	C	-	-	-	-	-	C	4
Noturus phaeus	brown madtom	U	C	-	-	U	O^{1}	-	-	-	-	-	-	4
Pimephales vigilax	bullhead minnow	-	-	-	-	-	O^{1}	-	-	-	-	-	-	1
Semotilus atromaculatus	creek chub	A	A	C	-	A	A	-	A	A	A	A	-	9

Appendix H (continued). **A** = abundant, **C** = common, **U** = uncommon, **O** = occasional, **ip** = isolated populations, **- =** not observed. **1** = only one specimen collected, **2** = only two specimen collected, **3** = only three specimen collected

Scientific Name	Common Name	Owl Creek Drainage				Tennessee River Drainage							Owl Creek	Totals
		Tilghman Branch	Shiloh Branch	Picnic Branch	Owl Creek Beaver Ponds	Dill Branch	Mounds Branch	River-bottoms Branch	Hagy Branch	Rogers Branch	Johns-ton Branch	Quarry Branch		
Erimyzon oblongus	creek chubsucker	U	C	-	-	C	-	-	-	-	-	-	-	3
Etheostoma proeliare	cypress darter	-	-	-	U_{ip}	-	-	-	-	-	-	-	-	1
Lepomis marginatus	dollar sunfish	-	-	-	C_{ip}	-	-	-	-	-	-	-	O^{2}	2
Percina sciera	dusky darter	O^{1}	O^{2}	-	-	-	O^{1}	-	-	-	-	-	-	3
Notropis atherinoides	emerald shiner	O^{2}	-	-	-	-	C	C	-	-	-	-	A	4
Centrarchus macropterus	flier	-	-	-	U_{ip}	-	-	-	-	-	-	-	-	1
Aplodinotus grunniens	freshwater drum	-	-	-	-	-	-	O^{2}	-	-	-	-	-	1
Dorosoma cepedianum	gizzard shad	-	-	-	-	-	-	U	-	-	-	-	-	1
Moxostoma erythrurum	golden redhorse	U	O^{1}	-	O^{1}	-	-	-	-	-	-	-	U	4
Notemigonus crysoleucas	golden shiner	-	-	-	C	U	U	C	-	-	-	-	-	4
Etheostoma parvipinne	goldstripe darter	C_{ip}	O^{1}	O^{1}	-	-	-	-	-	-	-	-	-	3
Esox americanus	grass pickerel	U_{ip}	-	-	U_{ip}	-	-	-	-	-	-	-	-	2

Appendix H (continued). A = abundant, **C** = common, **U** = uncommon, **O** = occasional, **ip** = isolated populations, **- =** not observed. **1** = only one specimen collected, **2** = only two specimen collected, **3** = only three specimen collected

		Owl Creek Drainage				Tennessee River Drainage								
Scientific Name	Common Name	Tilghman Branch	Shiloh Branch	Picnic Branch	Owl Creek Beaver Ponds	Dill Branch	Mounds Branch	River-bottoms Branch	Hagy Branch	Rogers Branch	Johns-ton Branch	Quarry Branch	Owl Creek	Totals
Lepomis cyanellus	green sunfish	U	U	-	-	-	-	-	-	-	-	-	O^1	3
Erimyzon sucetta	lake chubsucker	-	-	-	U_{ip}	-	-	-	-	-	-	-	-	1
Micropterus salmoides	largemouth bass	O^1	-	-	U	-	O^2	U	-	-	-	-	U	5
Campostoma oligolepis	largescale stoneroller	U	U	-	O^1	-	-	-	-	-	-	-	-	3
Lampetra aepyptera	least brook lamprey	-	C	-	-	C	-	-	-	-	-	-	-	2
Lepomis megalotis	longear sunfish	C	C	-	C	C	C	-	-	-	-	-	C	6
Lepisosteus osseus	longnose gar	-	-	-	O^2	-	-	-	-	-	-	-	U	2
Notropis volucellus	mimic shiner	-	-	-	-	-	O^3	-	-	-	-	-	-	1
Hypentelium nigricans	northern hog sucker	-	O^1	-	-	-	-	-	-	-	-	-	-	1
Aphredoderus sayanus	pirate perch	-	U_{ip}	-	C	-	-	C	-	-	-	-	-	3
Opsopoeodus emiliae	pugnose minnow	-	-	-	C_{ip}	-	-	-	-	-	-	-	-	1
Lepomis microlophus	redear sunfish	-	-	-	C	-	-	U	-	-	-	-	-	2

Appendix H (continued). **A** = abundant, **C** = common, **U** = uncommon, **O** = occasional, **ip** = isolated populations, **- =** not observed. **1** = only one specimen collected, **2** = only two specimen collected, **3** = only three specimen collected

Scientific Name	Common Name	Owl Creek Drainage				Tennessee River Drainage							Owl Creek	Totals
		Tilghman Branch	Shiloh Branch	Picnic Branch	Owl Creek Beaver Ponds	Dill Branch	Mounds Branch	River-bottoms Branch	Hagy Branch	Rogers Branch	Johns-ton Branch	Quarry Branch		
Lythrurus fumeus	ribbon shiner	O[1]	-	-	A	-	-	-	-	-	-	-	A	3
Lythrurus ardens	rosefin shiner	U_{ip}	U_{ip}	-	-	-	-	-	-	-	-	-	-	2
Clinostomus funduloides	rosyside dace	C	A	-	-	-	-	-	-	-	-	-	-	2
Sander canadensis	sauger	-	-	-	-	-	-	O[1]	-	-	-	-	-	1
Phoxinus erythrogaster	southern redbelly dace	A	A	A	-	A	A	-	A	A	A	A	-	9
Cyprinella spiloptera	spotfin shiner	C_{ip}	-	-	A_{ip}	U	A	A	-	-	-	-	A	6
Minytrema melanops	spotted sucker	-	-	-	O[1]	-	-	U	-	-	-	-	-	2
Luxilus chrysocephalus	striped shiner	A	A	-	A	A	A	A	-	A	-	-	A	8
Etheostoma kennicotti	stripetail darter	U	U	-	-	-	-	-	-	-	-	-	O[1]	3
Dorosoma petenense	threadfin shad	-	-	-	O[1]	-	A	A	-	-	-	-	-	3
Lepomis gulosus	warmouth	U	-	-	C	-	U	U	-	-	-	-	-	4
Gambusia affinis	western mosquitofish	C_{ip}	A_{ip}	-	A	A_{ip}	C	C	-	U	-	-	C_{ip}	8

Appendix H (continued). **A** = abundant, **C** = common, **U** = uncommon, **O** = occasional, **ip** = isolated populations, **- =** not observed. **1** = only one specimen collected, **2** = only two specimen collected, **3** = only three specimen collected

		Owl Creek Drainage				**Tennessee River Drainage**								
Scientific Name	**Common Name**	**Tilghman Branch**	**Shiloh Branch**	**Picnic Branch**	**Owl Creek Beaver Ponds**	**Dill Branch**	**Mounds Branch**	**River-bottoms Branch**	**Hagy Branch**	**Rogers Branch**	**Johns-ton Branch**	**Quarry Branch**	**Owl Creek**	**Totals**
Pomoxis annularis	white crappie	-	-	-	C	-	O[1]	U	-	-	-	-	-	3
Ameiurus natalis	yellow bullhead	-	-	-	U	-	-	-	-	-	-	-	-	1
Perca flavescens	yellow perch	-	-	-	-	-	-	U[1]	-	-	-	-	-	1
-	**Totals**	**25**	**21**	**3**	**29**	**14**	**20**	**19**	**2**	**7**	**2**	**3**	**18**	**-**

Appendix I. Herpetofauna species composition in the park.

Species occurrence abbreviations are P=present, PP=probably Present, U=unconfirmed, -= not observed, and “not listed” indicates that NPSpecies does not currently include the species in the database (Pritts 1999, ABC 2006, NPS 2016).

Category	Scientific Name	Common Name	Pritts (1999)	ABC (2006)	NPS (2016)
Frogs and toads	*Acris crepitans*	northern cricket frog	-	X	P
	Acris gryllus	southern cricket frog	-	X	P
	Anaxyrus fowleri	Fowler's toad	X	X	P
	Anaxyrus americanus americanus	American toad	X	X	P
	Gastrophryne carolinensis	eastern narrowmouth toad	-	X	P
	Hyla avivoca	bird-voiced treefrog	-	X	P
	Hyla chrysoscelis	Cope's gray treefrog	-	X	P
	Hyla cinerea	green treefrog	-	X	P
	Hyla gratiosa	barking treefrog	-	X	P
	Hyla versicolor	gray treefrog	X	X	U
	Lithobates clamitans	green frog	X	X	P
	Lithobates capito	gopher frog	-	-	U
	Lithobates catesbeianus	bullfrog	X	X	P
	Lithobates clamitans clamitans	bronze frog	-	X	not listed
	Lithobates sphenocephalus	southern leopard frog	X	X	P
	Pseudacris brachyphona	mountain chorus frog	-	-	PP
	Pseudacris crucifer	spring peeper	X	X	P
	Pseudacris feriarum	upland chorus frog	-	-	PP

Appendix I (continued). Species occurrence abbreviations are P=present, PP=probably Present, U=unconfirmed, -= not observed, and "not listed" indicates that NPSpecies does not currently include the species in the database (Pritts 1999, ABC 2006, NPS 2016).

Category	Scientific Name	Common Name	Pritts (1999)	ABC (2006)	NPS (2016)
Salamanders and newts	*Ambystoma maculatum*	spotted salamander	X	X	P
	Ambystoma opacum	marbled salamander	X	-	PP
	Ambystoma talpoideum	mole salamander	X	-	PP
	Ambystoma texanum	smallmouth salamander	-	-	PP
	Ambystoma tigrinum	eastern tiger salamander	-	-	U
	Desmognathus conanti	spotted dusky salamander	X	X	P
	Eurycea cirrigera	southern two-lined salamander	-	X	P
	Eurycea guttolineata	three-lined salamander	X	X	P
	Eurycea bislineata	two lined salamander	X	-	not listed
	Gyrinophilus porphyriticus	spring salamander	-	-	U
	Notophthalmus viridescens	eastern newt	-	-	P
	Notophthalmus viridescens louisianensis	central newt	X	-	not listed
	Notophthalmus viridescens viridescens	red spotted newt	X	X	not listed
	Plethodon dorsalis	northern zigzag salamander	-	X	P
	Plethodon mississippi	(Mississippi) slimy salamander	X	X	P
	Pseudotriton ruber vioscai	southern red salamander	-	X	not listed
	Pseudotriton ruber ruber	red salamander	X	-	P
Snakes	*Agkistrodon contortrix*	copperhead	X	X	P
	Agkistrodon piscivorus	cottonmouth	X	X	P

Appendix I (continued). Species occurrence abbreviations are P=present, PP=probably Present, U=unconfirmed, -= not observed, and “not listed” indicates that NPSpecies does not currently include the species in the database (Pritts 1999, ABC 2006, NPS 2016).

Category	Scientific Name	Common Name	Pritts (1999)	ABC (2006)	NPS (2016)
Snakes (continued)	*Carphophis amoenus*	worm snake	-	X	P
	Cemophora coccinea	scarlet snake	-	-	U
	Coluber constrictor priapus	black racer	X	X	P
	Diadophis punctatus	ringneck snake	X	X	P
	Elaphe guttata	corn snake	-	X	P
	Elaphe spiloides	gray rat snake	-	X	not listed
	Elaphe obsoleta	rat snake	-	X	P
	Heterodon platirhinos	eastern hognose snake	X	-	PP
	Lampropeltis getula	kingsnake	-	-	U
	Lampropeltis triangulum	milk snake	-	-	PP
	Nerodia rhombifer	diamondback water snake	-	-	PP
	Nerodia erythrogaster flavigaster	yellowbelly water snake	-	X	P
	Nerodia sipedon pleuralis	midland water snake	X	X	P
	Opheodrys aestivus	rough green snake	-	-	PP
	Storeria dekayi	brown snake	X	-	PP
	Storeria occipitomaculata	redbelly snake	X	-	PP
	Tantilla coronata	southeastern crowned snake	-	-	U
	Thamnophis sirtalis	eastern garter snake	-	X	P

Appendix I (continued). Species occurrence abbreviations are P=present, PP=probably Present, U=unconfirmed, -= not observed, and "not listed" indicates that NPSpecies does not currently include the species in the database (Pritts 1999, ABC 2006, NPS 2016).

Category	Scientific Name	Common Name	Pritts (1999)	ABC (2006)	NPS (2016)
Lizards and skinks	*Sceloporus undulatus*	eastern fence lizard	X	X	P
	Eumeces anthracinus	coal skink	-	X	P
	Eumeces fasciatus	five-lined skink	X	X	P
	Eumeces inexpectatus	southeastern five-lined skink	-	X	P
	Eumeces laticeps	broadhead skink	-	-	PP
	Scincella lateralis	ground skink	X	X	P
	Cnemidophorus sexlineatus	six-lined racerunner	-	X	P
Turtles	*Apalone spinifera*	spiny softshell turtle	X	-	PP
	Chelydra serpentina	common snapping turtle	-	X	P
	Kinosternon subrubrum	eastern mud turtle	-	X	P
	Macrochelys temminckii	alligator snapping turtle	-	-	U
	Terrapene carolina	eastern box turtle	X	X	P
	Trachemys scripta elegans	red-eared slider	X	X	P

Appendix J. The 2001-2011 external landcover change inside the 10-digit watershed areas surrounding SHIL.

The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	Area (hectares)
Open Water to Developed, Open Space	1.17
Open Water to Developed, Low Intensity	0.72
Open Water to Developed, Medium Intensity	0.09
Open Water to Barren Land	1.44
Open Water to Deciduous Forest	8.01
Open Water to Evergreen Forest	17.82
Open Water to Mixed Forest	0.36
Open Water to Shrub/Scrub	12.87
Open Water to Grassland/Herbaceous	8.90
Open Water to Pasture/Hay	2.34
Open Water to Cultivated Crops	7.92
Open Water to Woody Wetlands	23.49
Open Water to Emergent Herbaceous Wetlands	2.25
Developed, Open Space to Developed, Low Intensity	28.08
Developed, Open Space to Developed, Medium Intensity	31.59
Developed, Open Space to Developed, High Intensity	2.25
Developed, Low Intensity to Developed, Open Space	4.59
Developed, Low Intensity to Developed, Medium Intensity	30.96
Developed, Low Intensity to Developed, High Intensity	6.84
Developed, Low Intensity to Deciduous Forest	0.09
Developed, Low Intensity to Pasture/Hay	0.18
Developed, Medium Intensity to Developed, Open Space	0.63
Developed, Medium Intensity to Developed, Low Intensity	12.51
Developed, Medium Intensity to Developed, High Intensity	3.33
Developed, High Intensity to Developed, Low Intensity	0.09

Appendix J (continued). The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	**Area (hectares)**
Developed, High Intensity to Developed, Medium Intensity	3.24
Barren Land to Open Water	3.33
Barren Land to Developed, Open Space	0.72
Barren Land to Developed, Low Intensity	3.96
Barren Land to Developed, Medium Intensity	3.87
Barren Land to Developed, High Intensity	1.08
Barren Land to Deciduous Forest	0.63
Barren Land to Shrub/Scrub	0.09
Barren Land to Grassland/Herbaceous	0.18
Deciduous Forest to Open Water	11.16
Deciduous Forest to Developed, Open Space	7.11
Deciduous Forest to Developed, Low Intensity	1.80
Deciduous Forest to Developed, Medium Intensity	0.99
Deciduous Forest to Developed, High Intensity	0.63
Deciduous Forest to Barren Land	4.50
Deciduous Forest to Evergreen Forest	309.69
Deciduous Forest to Mixed Forest	3.24
Deciduous Forest to Shrub/Scrub	459.45
Deciduous Forest to Grassland/Herbaceous	626.49
Deciduous Forest to Pasture/Hay	72.27
Deciduous Forest to Cultivated Crops	31.95
Deciduous Forest to Woody Wetlands	8.46
Evergreen Forest to Open Water	0.27
Evergreen Forest to Developed, Open Space	6.48
Evergreen Forest to Developed, Low Intensity	2.61
Evergreen Forest to Developed, Medium Intensity	2.52
Evergreen Forest to Developed, High Intensity	0.72
Evergreen Forest to Barren Land	4.23

Appendix J (continued). The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	**Area (hectares)**
Evergreen Forest to Deciduous Forest	124.65
Evergreen Forest to Mixed Forest	5.94
Evergreen Forest to Shrub/Scrub	1,130.76
Evergreen Forest to Grassland/Herbaceous	1,444.86
Evergreen Forest to Pasture/Hay	81.72
Evergreen Forest to Cultivated Crops	50.67
Evergreen Forest to Woody Wetlands	1.71
Mixed Forest to Open Water	0.36
Mixed Forest to Developed, Open Space	3.96
Mixed Forest to Developed, Low Intensity	0.72
Mixed Forest to Developed, Medium Intensity	0.27
Mixed Forest to Developed, High Intensity	0.54
Mixed Forest to Barren Land	0.63
Mixed Forest to Deciduous Forest	26.64
Mixed Forest to Evergreen Forest	97.29
Mixed Forest to Shrub/Scrub	261.45
Mixed Forest to Grassland/Herbaceous	252.27
Mixed Forest to Pasture/Hay	29.52
Mixed Forest to Cultivated Crops	6.57
Mixed Forest to Woody Wetlands	0.81
Shrub/Scrub to Open Water	5.13
Shrub/Scrub to Developed, Open Space	14.49
Shrub/Scrub to Developed, Low Intensity	5.67
Shrub/Scrub to Developed, Medium Intensity	5.13
Shrub/Scrub to Developed, High Intensity	1.17
Shrub/Scrub to Barren Land	13.59
Shrub/Scrub to Deciduous Forest	739.71
Shrub/Scrub to Evergreen Forest	2,203.92

Appendix J (continued). The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	Area (hectares)
Shrub/Scrub to Mixed Forest	12.24
Shrub/Scrub to Grassland/Herbaceous	257.31
Shrub/Scrub to Pasture/Hay	56.34
Shrub/Scrub to Cultivated Crops	31.23
Shrub/Scrub to Woody Wetlands	11.43
Grassland/Herbaceous to Developed, Open Space	0.09
Grassland/Herbaceous to Developed, Low Intensity	0.36
Grassland/Herbaceous to Developed, Medium Intensity	1.08
Grassland/Herbaceous to Developed, High Intensity	0.45
Grassland/Herbaceous to Barren Land	1.80
Grassland/Herbaceous to Deciduous Forest	36.27
Grassland/Herbaceous to Evergreen Forest	50.49
Grassland/Herbaceous to Mixed Forest	0.90
Grassland/Herbaceous to Shrub/Scrub	3.51
Grassland/Herbaceous to Pasture/Hay	0.09
Grassland/Herbaceous to Cultivated Crops	2.16
Grassland/Herbaceous to Woody Wetlands	2.88
Pasture/Hay to Open Water	18.45
Pasture/Hay to Developed, Open Space	37.80
Pasture/Hay to Developed, Low Intensity	28.17
Pasture/Hay to Developed, Medium Intensity	20.97
Pasture/Hay to Developed, High Intensity	6.48
Pasture/Hay to Barren Land	0.81
Pasture/Hay to Deciduous Forest	121.14
Pasture/Hay to Evergreen Forest	270.18
Pasture/Hay to Mixed Forest	6.03
Pasture/Hay to Shrub/Scrub	93.78
Pasture/Hay to Grassland/Herbaceous	84.42

Appendix J (continued). The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	Area (hectares)
Pasture/Hay to Cultivated Crops	132.48
Pasture/Hay to Woody Wetlands	37.08
Pasture/Hay to Emergent Herbaceous Wetlands	7.38
Cultivated Crops to Open Water	15.03
Cultivated Crops to Developed, Open Space	19.71
Cultivated Crops to Developed, Low Intensity	15.21
Cultivated Crops to Developed, Medium Intensity	17.46
Cultivated Crops to Developed, High Intensity	7.20
Cultivated Crops to Barren Land	4.23
Cultivated Crops to Deciduous Forest	184.05
Cultivated Crops to Evergreen Forest	283.86
Cultivated Crops to Mixed Forest	1.17
Cultivated Crops to Shrub/Scrub	77.22
Cultivated Crops to Grassland/Herbaceous	90.00
Cultivated Crops to Pasture/Hay	60.66
Cultivated Crops to Woody Wetlands	66.42
Cultivated Crops to Emergent Herbaceous Wetlands	7.83
Woody Wetlands to Open Water	35.37
Woody Wetlands to Developed, Open Space	10.62
Woody Wetlands to Developed, Low Intensity	6.57
Woody Wetlands to Developed, Medium Intensity	2.70
Woody Wetlands to Developed, High Intensity	0.09
Woody Wetlands to Barren Land	0.18
Woody Wetlands to Deciduous Forest	17.64
Woody Wetlands to Evergreen Forest	142.83
Woody Wetlands to Shrub/Scrub	37.17
Woody Wetlands to Grassland/Herbaceous	66.42
Woody Wetlands to Pasture/Hay	31.86

Appendix J (continued). The table shows what the landcover was in 2001 and what it changed to in 2011. This appendix is associated with Figure 57 of this document.

Land Cover Change (2001-2011)	**Area (hectares)**
Woody Wetlands to Cultivated Crops	39.60
Woody Wetlands to Emergent Herbaceous Wetlands	34.29
Emergent Herbaceous Wetlands to Open Water	16.11
Emergent Herbaceous Wetlands to Developed, Open Space	2.52
Emergent Herbaceous Wetlands to Developed, Low Intensity	2.07
Emergent Herbaceous Wetlands to Developed, Medium Intensity	0.18
Emergent Herbaceous Wetlands to Deciduous Forest	9.90
Emergent Herbaceous Wetlands to Evergreen Forest	26.46
Emergent Herbaceous Wetlands to Shrub/Scrub	3.60
Emergent Herbaceous Wetlands to Grassland/Herbaceous	22.14
Emergent Herbaceous Wetlands to Pasture/Hay	8.91
Emergent Herbaceous Wetlands to Cultivated Crops	16.11
Emergent Herbaceous Wetlands to Woody Wetlands	52.11
Total Landcover Change	**11,069.63**

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