National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Chickamauga and Chattanooga National Military Park

Natural Resource Report NPS/CHCH/NRR—2018/1833

ON THE COVER
Wilder Brigade Monument
Photograph courtesy of Jim Szyjkowski, National Park Service

Natural Resource Condition Assessment

Chickamauga and Chattanooga National Military Park

Natural Resource Report NPS/CHCH/NRR—2018/1833

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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 Chickamauga and Chattanooga National Military Park (CHCH) 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 CHCH. The final project framework contains 10 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 CHCH 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 just 1 of the 10 components due to these data gaps.

For those components with sufficient available data, the overall condition varied. Three components were determined to be in good condition: water quality, birds, and herpetofauna. However, water quality was at the edge of the good condition range, and any small decline in conditions could shift it into the moderate concern range. Of the components in good condition, trends could not be assigned for birds or herpetofauna, and water quality is considered stable. Two components (hardwood forest community and wetlands) were of moderate concern with no trends assigned. The remaining four components were of significant concern: limestone cedar glades, cave bats, air quality, and adjacent land cover and use. These components all showed a declining trend, with the exception of air quality, which is improving. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in CHCH. Those of primary concern include invasive exotic species, adjacent land use/development, and climate change. 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 historically significant landscape.

Acknowledgments

We acknowledge Chickamauga and Chattanooga National Military Park and Cumberland Piedmont Inventory and Monitoring Network staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, Jim Szyjkowski, Teresa Leibfreid, Bill Moore, Steven Thomas, Johnathan Jernigan, and Joe Meiman. Their logistical insight and critical review of interim documents was essential to this project's completion. Additional insight and reviews were provided by Rickie White, Tom Govus, Randy Stanley, and Emma Brown. Dale McPherson, Regional NRCA and RSS Coordinator, and Jeff Albright, National NRCA Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

ANC:	Acid Neutralizing Capacity
AOA:	Area of Analysis
AQI:	Air Quality Index
ARD:	Air Resources Division
BBS:	Breeding Bird Survey
CAA:	Clean Air Act
CBC:	Christmas Bird Count
CFU:	Colony Forming Units
CHCH:	Chickamauga and Chattanooga National Military Park
cps:	Cycles per Second
CUPN:	Cumberland Piedmont Network
dB:	Decibels
DBH:	Diameter-at-Breast-Height
DDT:	Dichlorodiphenyltrichloroethane
DO:	Dissolved Oxygen
DOD:	Department of Defense
EPA:	Environmental Protection Agency
Esri:	Environmental Systems Research Institute
GAP:	Gap Analysis Program
GIS:	Geographic Information System
GRSM:	Great Smoky Mountains National Park
HGM:	Hydrogeomorphic
Hz:	Hertz
I&M:	Inventory and Monitoring

Acronyms and Abbreviations (continued)

IMPROVE: Interagency Monitoring of Protected Visual Environments Program

IUCN: International Union for Conservation of Nature

LED: Light-emitting Diodes

MDN: Mercury Deposition Network

MPN: Most Probable Number

MRLC: Multi-Resolution Land Characteristics Consortium

MSPA - Morphological Spatial Pattern Analysis

NAAQS: National Ambient Air Quality Standards

NADP: National Atmospheric Deposition Program

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

NFI: Noise Free Interval

NLCD: National Landcover Dataset

NPS: National Park Service

NRCA: Natural Resource Condition Assessment

NVC: National Vegetation Classification

NWI: National Wetlands Inventory

OMB: Office of Management and Budget

PAD-US: Protected Areas Database of the United States

PM: Particulate Matter

POMS: Portable Ozone Monitoring Station

ppb: Parts per Billion

ppm-hrs: Parts per Million-Hours

SERGoM: Spatially Explicit Regional Growth Model

SOP: Standard Operating Procedure

SpC: Specific Conductance

Acronyms and Abbreviations (continued)

SPL:	Sound Pressure Level
TAA:	Time Above Ambient
TAud:	Time Audible
TDEC:	Tennessee Department of Environment and Conservation
TN-EPPC:	Tennessee Exotic Pest Plant Council
TVA:	Tennessee Valley Authority
USACE:	U.S. Army Corps of Engineers
USCB:	United States Census Bureau
USFWS:	U.S. Fish and Wildlife Service
USGS:	United States Geological Survey
VOCs:	Volatile Organic Compounds
WCS:	Weighted Condition Score
WNS:	White Nose Syndrome

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

Considered the nation's oldest and largest military park, Chickamauga and Chattanooga National Military Park (CHCH) was established on 19 August 1890, by an Act of Congress (Call 1910). It was established (NPS 1987, p. 3)

> *[F]or the purpose of preserving and suitably marking for historical and professional military study the fields of some of the most remarkable maneuvers and most brilliant fighting in the Civil War.*

Being one of the first historic battlefields preserved, CHCH laid the foundation for future national battlefield, memorial, and monument preservation (NPS 1987) . A fairly new addition to CHCH is the Moccasin Bend National Archeological District located across the Tennessee River and within the City of Chattanooga. It came under the management of the NPS in 2003 and brings unique archaeological and ethnographical challenges to CHCH (The Jaeger Company 2014). The area was designated as a national archeological district in 1986, due to its occupation and significant use by Native Americans for approximately 12,000 years. Three prehistoric village sites and a Woodland Indian mound complex have been identified on Moccasin Bend, and it also contains a portion of the Trail of Tears National Historic Trail (The Jaeger Company 2014).

A visitor at Chickamauga Battlefield in the late 19th century (NPS photo, donated by the Museum of St. Albans in the United Kingdom).

2.1.2. Geographic Setting

CHCH is comprised of 18 separate units that, all together, total 3,673 ha (9,077 ac) (NPS 1987, 2015b). The park falls within both Tennessee and Georgia (Figure 1). Of those 18 units, there are four that hold the most significant historic and prehistoric features. The Chickamauga Battlefield, the largest unit at 2,138 ha (5,283 ac), is in Walker and Catoosa counties of Georgia. The second largest unit is Lookout Mountain at 1,354 ha (3,345 ac), which contains Point Park, at an elevation around 640 m (2,100 ft) (NPS 2015a). The majority of Lookout Mountain falls within Hamilton County, Tennessee (Figure 1). Missionary Ridge, with its disjunct reservations, along with Orchard Knob and Signal Point, are all found in Hamilton County, Tennessee as well (NPS 1987). Moccasin Bend National Archeological District is the fourth major unit within CHCH. It can be found across the Tennessee River, in the river bend, from the Lookout Mountain Unit of CHCH. It is a 306-ha (755-ac) area that includes the Trail of Tears National Historic Trail and Union earthworks (soil fortification) that were used during the Battle of Chattanooga (The Jaeger Company 2014).

A winter view of Moccasin Bend and the city of Chattanooga from Lookout Mountain (NPS photo).

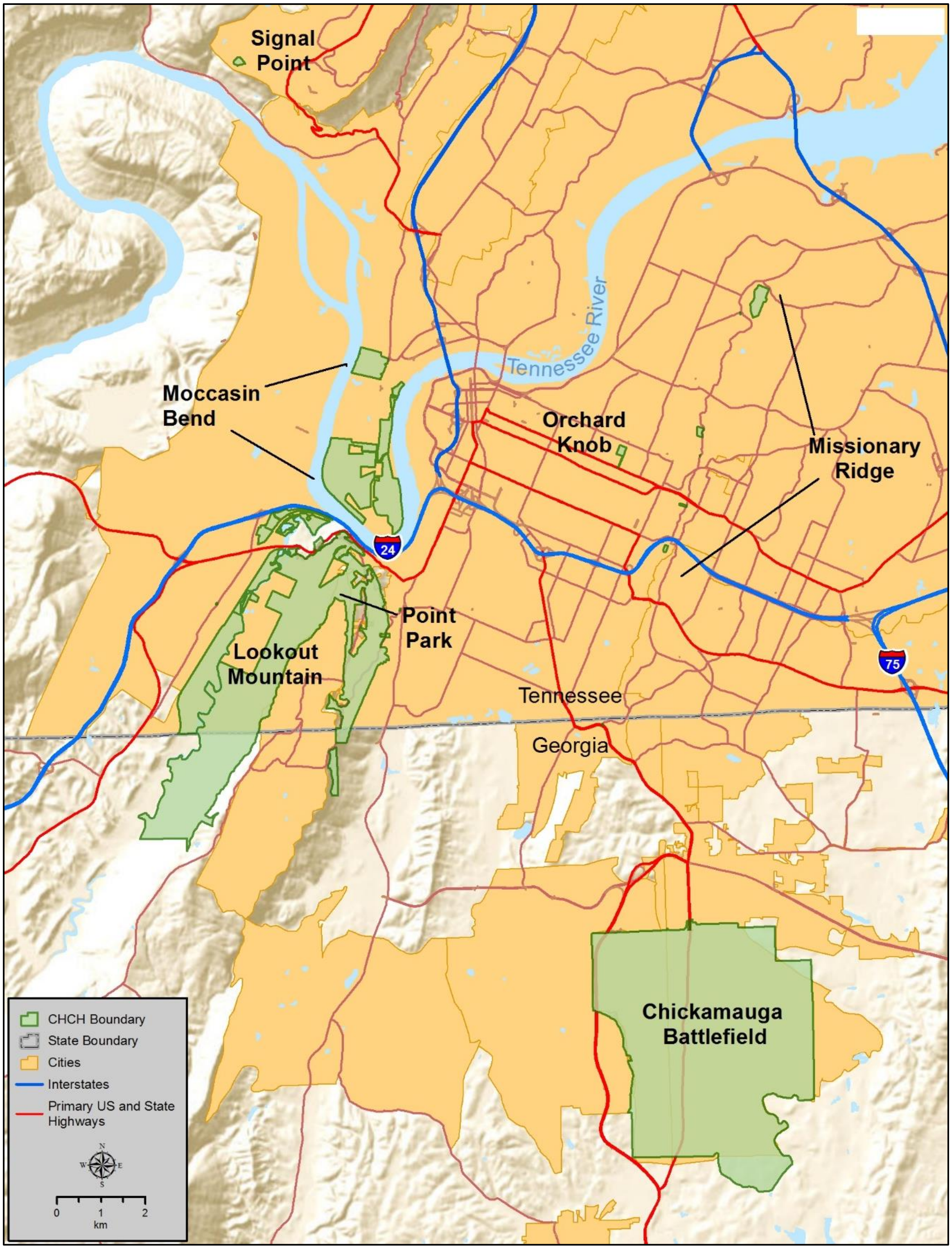

Figure 1. The relative locations of CHCH park units within Tennessee and Georgia.

There are two National Climate Data Center (NCDC) weather stations found in the CHCH area. The Chickamauga Park Larc, GA station is located in the Chickamauga Battlefield (Table 1). The mean annual temperature at this station is 15.1°C (59.1°F). The annual mean high temperature is 22°C (71.6°F), with an average of 37.2 days above 32.2°C (90°F). The average low temperature is 8.1°C (46.6°F), with freezing temperatures (0°C or 32°F or below) occurring an average of 83.8 days per year (NCDC 2015a). The other weather station is the Lookout Mountain, TN station (Table 2). Mean annual temperature at this station is 14.1°C (57.4°F). The annual mean high temperature is 18.9°C (66°F), with an average of 8.1 days above 32.2°C (90°F). The average low temperature is 9.3°C (48.8°F), with freezing temperatures (0°C or 32°F or below) occurring an average 67.1 days per year (NCDC 2015b). The mean annual precipitation around the Chickamauga Park, GA station is 136.7 cm (53.8 in), with January and February being peak seasons (NCDC 2015a). The mean annual precipitation around the Lookout Mountain, TN station is a bit higher at 139.2 cm (54.8 in), with December through February being the peak season (NCDC 2015b).

Table 1. 30-year climate (temperature and precipitation) normals (1981-2010) for the Chickamauga Park Larc, GA weather station in CHCH (NCDC 2015a).

Climate Measure	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg Temp. (°C)	Max	10.1	12.6	17.7	22.6	26.6	30.3	31.6	31.7	28.7	23.4	17.6	11.6	22.0
	Min	-2.4	-1.0	2.8	6.9	11.7	17.1	19.2	18.8	14.8	8.2	2.1	-1.2	8.1
Avg. Precip. (cm)	Total	13.5	13.2	13.0	9.4	11.1	11.1	11.2	9.3	10.7	8.4	12.7	13.1	136.7

Table 2. 30-year climate normal (temperature and precipitation) (1981-2010) for the Lookout Mountain, TN weather station in CHCH (NCDC 2015b).

Climate Measure	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg Temp. (°C)	Max	7.2	9.4	14.7	19.6	23.0	27.2	28.8	28.7	25.0	19.6	14.6	8.8	18.9
	Min	-2.6	-0.6	4.0	8.6	13.7	18.1	19.9	19.8	16.2	10.3	5.2	-0.4	9.3
Avg. Precip. (cm)	Total	13.1	14.6	12.8	10.7	11.2	10.1	10.5	9.1	11.7	8.9	13.0	13.5	139.2

2.1.3. Visitation Statistics

On average, CHCH received 978,673 visitors between 2005 and 2015 (Figure 2) (NPS 2016a), with high traffic at the Chickamauga Battlefield and Lookout Mountain (NPS 1987). There are two visitor centers in CHCH: one at Chickamauga Battlefield and another at Lookout Mountain. A lookout over the Tennessee River Valley is available to visitors at Point Park. Monuments and historic structures are distributed throughout all units of the park. Interpretation of Civil War themes is a major attraction for visitors to CHCH. In one year (2007), four park interpretive staff members led 2,772 formal, on-site interpretive programs and 45 programs off-site (NPCA 2009). During this period, an estimated 116,562 visitors attended some type of interpretive program, such as a living history demonstration (NPCA 2009).

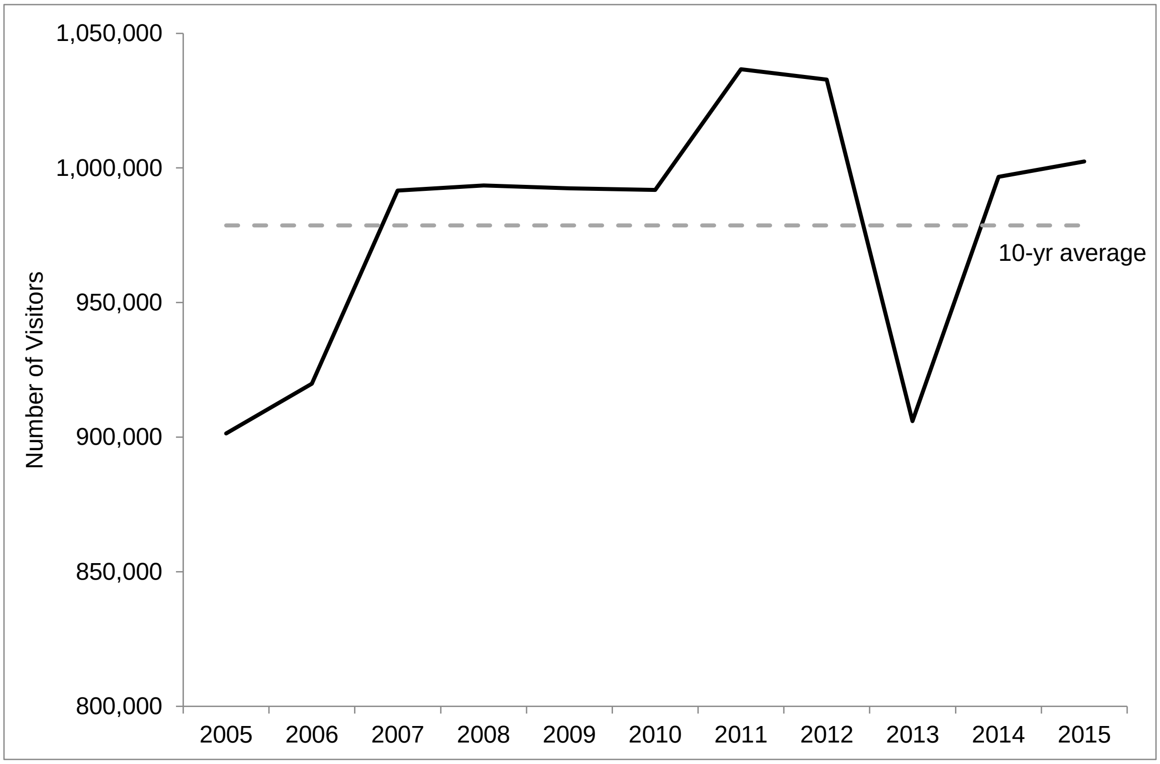

Figure 2. Annual visitor statistics for CHCH between 2005-2015 (NPS 2016a).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

CHCH lies within the Middle Tennessee-Chickamauga Watershed (EPA 2010), which is a part of the Tennessee River Basin. The Tennessee River Basin covers 105,904 km^2 (40,890 mi^2) and eventually drains into the Ohio River (USGS: NAWQA 2001).

CHCH can be found in the Environmental Protection Agency's (EPA) Southwestern Appalachians and Ridge and Valley Level III Ecoregions (Figure 3). The Ridge and Valley Ecoregion, as gathered from the name, is comprised of ridges and valleys that include a variety of heights, widths, and geologic materials. There are an abundance of springs and caves, along with a great diversity of aquatic habitats and fish species (EPA 2013). Presently, about 50% of the ecoregion is forest covered. The Southwestern Appalachians Ecoregion contains a mixture of forest and woodland, along with cropland and pasture. This ecoregion is relatively smooth on the east end, except for a few groves caused from eastward flowing streams, and towards the west the terrain becomes rougher and more crenulated. Coal mining is abundant within this ecoregion (EPA 2013).

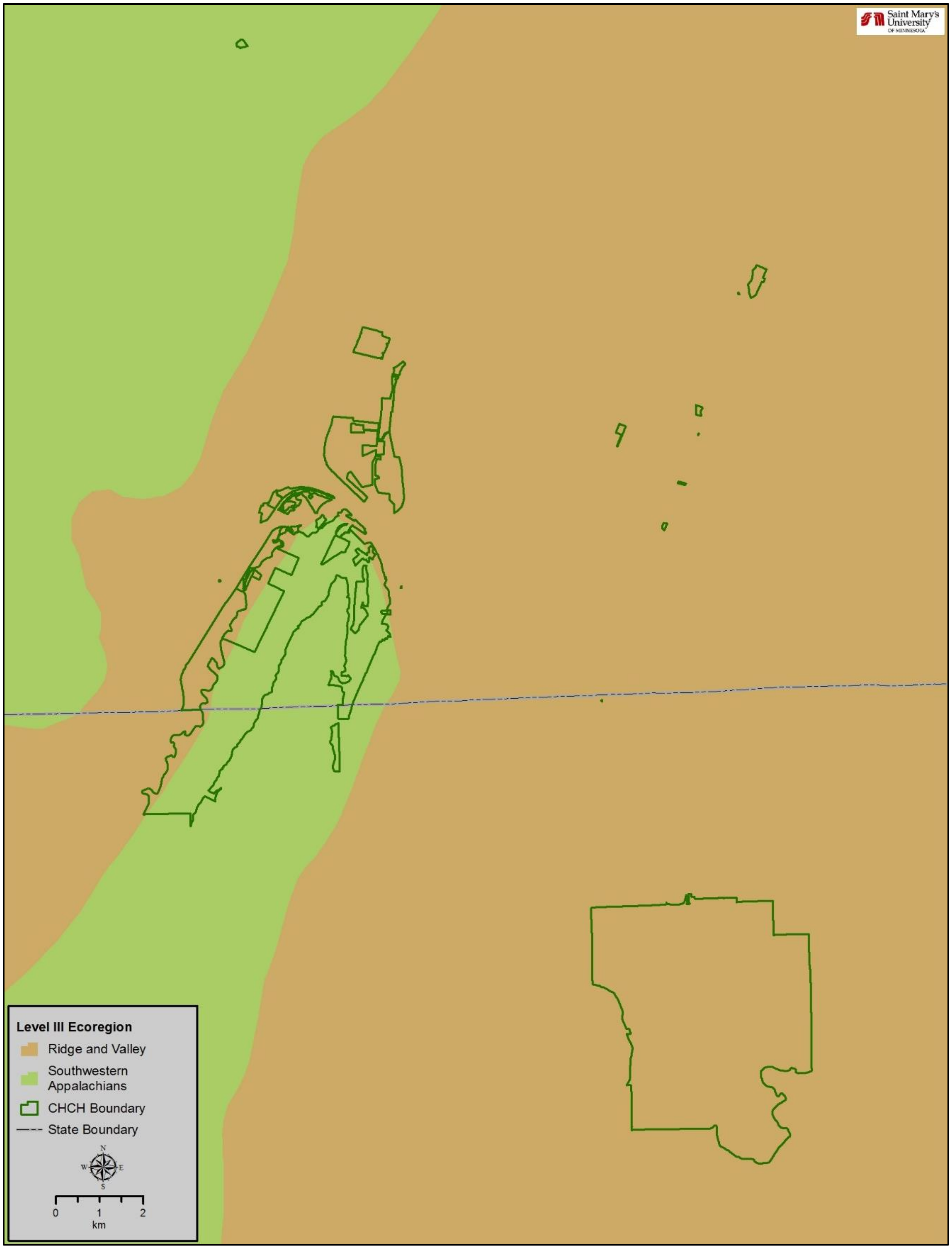

Figure 3. CHCH falls into two Level III Ecoregions: Ridge and Valley, and Southwestern Appalachians (EPA 2013).

2.2.2. Resource Descriptions

Biological Resources

For a park known for its cultural resources, CHCH has a high diversity of ecologically significant community types (Govus et al. 2010). There are three major habitat types found in the park: forests, cedar glades, and fields. The mixed deciduous and coniferous forests comprise over 60% of the park's landscape (Jordan and Madden 2010) and the majority of these forests are at least 70 years in age (Govus et al. 2010). Common tree species include several pines (*Pinus* spp.), oaks (*Quercus* spp.), and hickories (*Carya* spp.) (Govus and White Jr. 2006). These forests support the only federally threatened plant species found within CHCH, the large-flowered skullcap (*Scutellaria montana*) (Govus and White Jr. 2006) (Figure 4). With areas of Moccasin Bend and along Lookout Creek prone to flooding, soils rich in nutrients can be found which support species like silver maple (*Acer saccharinum*), American sycamore (*Platanus occidentalis*), and spicebush (*Lindera benzoin*) (Govus and White Jr. 2006).

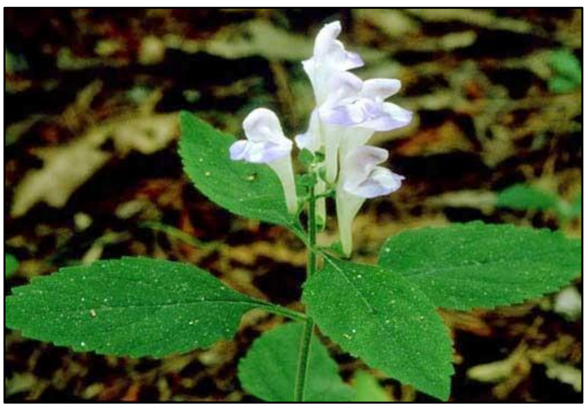

Figure 4. The large-flowered skullcap is a federally threatened species found in CHCH forests (USFS Photo).

The cedar glade communities, characterized by scattered eastern redcedar (*Juniperus virginiana*) trees, are unique to the CHCH area. They are considered the most globally rare community in the park (Govus et al. 2010) (Figure 5). There are at least 28 cedar glades located in the park (Jordan and Madden 2010), containing a number of plant species that are endemic to glade environments (Govus and White Jr. 2006) (Table 3). The final community - the fields - consist of managed grassy areas intended to replicate the Civil War era landscape (Rogers et al. 1993). Also known as "cultivated meadows," these areas are dominated by a mix of native and non-native herbaceous species (Govus and White Jr. 2006).

Figure 5. Cedar glades are unique communities inside CHCH (SMUMN GSS photo by Kathy Allen).

Table 3. Plant species listed that are unique to glade communities (Govus and White Jr. 2006). Listed with each species is their global and state (Georgia) rarity rank.

Scientific name	Common name	GA S-rank[A]	G-rank
Bouteloua curtipendula	sideoats grama	S2	G5
Dalea candida	white prairie clover	S1	G5
Dalea gattingeri	purpletassels	S2S3	G3G4
Eleocharis compressa	flat-stemm spikerush	S2S3	G4
Hypericum dolabriforme	straggling St. Johnswort	S3	G4
Isoetes butleri	Butler's quillwort	S1	G4
Leavenworthia exigua	Tennessee gladecress	S2	G4T3[B]
Pediomelum subacaule	whiterim scurfpea	S2	G4
Spiranthes magnicamporum	Great Plains ladies-tresses	S1	G4
Sporobolus heterolepis	prairie dropseed	S1	G5
Thaspium pinnatifidum	cutleaf meadowparsnip	S1	G3[C]

[A] GA S-rank: Georgia, state rarity rank (1 = very rare to 5 = very common in Georgia), G-rank: global rarity rank (1 = very rare to 5 = very common globally)

[B] T3 represents the Georgia protection status; (E = Endangered, T = Threatened, R = Rare, U = Unusual) (Georgia Department of Natural Resources: Wildlife Resources Division nd)

[C] Inexact numeric rank

According to the NPSpecies list, there are 175 bird species, 50 mammal, 45 amphibian and reptile, 19 fish, and approximately 950 plant species documented at CHCH (NPS 2016b). Common mammals at CHCH include white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), and gray squirrels (*Sciurus carolinensis*) (NPS 2016b). The gray bat (*Myotis grisescens*) and Indiana bat (*M. sodalis*) are two mammals listed as federally endangered that occur within the park boundaries.

The most frequently occurring birds in the park include the northern cardinal (*Cardinalis cardinalis*), Carolina wren (*Thryothorus ludovicianus*), red-eyed vireo (*Vireo olivaceus*), and tufted titmouse (*Baeolopus bicolor*) (Figure 6; Stedman et al. 2006). Commonly seen species of reptiles and amphibians in the area include the American toad (*Anaxyrus americanus americanus*), common garter snake (*Thamnophis sirtalis*), and the eastern box turtle (*Terrapene carolina*) (NPCA 2009).

Figure 6. Three of the most frequently occurring birds in CHCH (left to right): Carolina wren, tufted titmouse, and red-eyed vireo (NPS photos).

2.2.3. Resource Issues Overview

<u>Exotic Species</u>

Exotic plant species are recognized globally as a significant threat to ecosystem stability and are a major concern at CHCH (Govus and White Jr. 2006, NPS 2008). Just over 15% of the plant species found in the park are non-native and some pose a severe or significant threat to the native species in the park (Table 4) (Govus and White Jr. 2006). These species can alter plant community composition and ecological processes (e.g., water and nutrient cycling) and contribute to biodiversity and habitat losses (NPS 2008).

Table 4. Non-native plant species found in CHCH (NPS 2016b) that pose a severe or significant threat to native plant communities, according to the Tennessee Exotic Pest Plant Council (TN-EPPC) (2009).

Common name	Scientific name	Threat rank
tree-of-heaven	*Ailanthus altissima*	severe
silk tree, mimosa	*Albizia julibrissin*	severe
garlic mustard	*Alliaria petiolata*	significant
wild garlic	*Allium vineale*	significant
small carpgrass	*Arthraxon hispidus*	significant
Japanese barberry	*Berberis thunbergii*	significant
Asian bittersweet	*Celastrus orbiculatus*	severe
Chinese yam	*Dioscorea oppositifolia*	severe
thorny olive	*Elaeagnus pungens*	significant
autumn olive	*Elaeagnus umbellata* var. *parvifolia*	severe
creeping charlie	*Glechoma hederacea*	significant
Korean clover	*Kummerowia stipulacea*	severe
Chinese lespeza	*Lespedeza cuneata*	severe
Chinese privet	*Ligustrum sinense*	severe

Table 4 (continued). Non-native plant species found in CHCH (NPS 2016b) that pose a severe or significant threat to native plant communities, according to the Tennessee Exotic Pest Plant Council (TN-EPPC) (2009).

Common name	Scientific name	Threat rank
European privet	*Ligustrum vulgare*	severe
tall fescue	*Schedonorus arundinaceus*	significant
Japanese honeysuckle	*Lonicera japonica*	severe
Amur honeysuckle	*Lonicera maackii*	significant
creeping jenny	*Lysimachia nummularia*	significant
Japanese stiltgrass	*Microstegium vimineum*	severe
wart-removing herb	*Murdannia keisak*	significant
royal paulownia	*Paulownia tomentosa*	severe
white poplar	*Populus alba*	significant
kudzu	*Pueraria montana* var. *lobata*	severe
multiflora rose	*Rosa multiflora*	severe
Johnsongrass	*Sorghum halepense*	severe
Japanese meadowsweet	*Spiraea japonica*	significant
common mullein	*Verbascum thapsus*	significant
bigleaf periwinkle	Vinca major	significant
common periwinkle	Vinca minor	significant

Along with the exotic plants, CHCH may also be impacted by forest pests and diseases like the emerald ash borer (Agrilus planipennis) and hemlock woolly adelgid (Adelges tsugae) (Figure 7) (Keefer 2012, Fisichelli 2015).

Figure 7. Ovisacs of the hemlock woolly adelgid (HWA) are found from late fall to early summer on the underside of eastern hemlock (*Tsuga canadensis*) trees. The white wool-like wax filaments are created to protect the eggs and the insect from predation and drying out (USFS 2005).

Climate Change

The issue of climate change is a significant concern for the Cumberland Piedmont Network (CUPN), which includes CHCH. Climate change can have effects on air and water quality, the spread of invasive plant species, and land-use patterns (Davey et al. 2007). This concern motivated the CUPN to compile a weather and climate inventory that evaluated the weather and climate patterns in the parks and analyzed any changes over time (Davey et al. 2007). Predictions of potential future vulnerabilities for CHCH include (Gonzalez 2015, p. 1):

- Projected changes in rainfall timing and amount, potential evapotranspiration, and other factors may alter river and stream hydrology and reduce water availability (Ingram et al. 2013).
- Continued warming of water temperatures could threaten coldwater fish (TWRA 2009).
- Under high emissions, the region could become more favorable to the growth of the invasive plants kudzu (*Pueraria montana var. lobata*) and Chinese privet (*Ligustrum sinense*) (Bradley et al. 2010).
- Experimental increases of atmospheric carbon dioxide in a North Carolina forest indicate that climate change could increase the growth and toxicity of poison ivy (*Toxicodendron radicans*) (Mohan et al. 2006).

- Under the highest emissions scenario, climate change could shift the ranges of numerous tree species northward, reducing potential densities of red maple (*Acer rubrum*) and white oak (Quercus alba) (Iverson et al. 2008).
- Under continued climate change, longer growing seasons may increase the risk of southern pine beetle (*Dendroctonus frontalis*) outbreaks and expand the range of the beetle northward, increasing forest mortality (McNulty et al. 2013).
- Under continued climate change, increasing winter temperatures may exacerbate hemlock wooly adelgid infestation and increase mortality of hemlock trees (Duke et al. 2009).

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

A general management plan for CHCH was completed in 1987. This plan (NPS 1987, p. 23):

> *[S]eeks to ensure the preservation and protection of park resources and to provide visitors with high-quality experiences. Visitors should leave the park with an understanding of why the battles of Chickamauga and Chattanooga were important, and why the people of the United States have sought to preserve and protect these lands as a unit of the national park system.*

The directives given in the plan include (NPS 1987):

- Try to balance active and passive recreational uses in the park.
- Ensure that all park visitors have access to detached units and that the desires and needs of adjoining or nearby residents are respected.
- Attempt to minimize traffic congestion and noise associated with commercial and commuter traffic on U.S. Highway 27 (pending its relocation) and other park roads within the Chickamauga battlefield unit without unnecessarily interrupting the regional transportation network.

In January 2015, an amendment was made to this 1987 general management plan for the Lookout Mountain Battlefield Unit (NPS 2015a, p. 12). The purpose of this plan amendment was to:

> *…define the desired resource conditions and visitor uses and experiences to be achieved for Lookout Mountain Battlefield, including additional lands recently acquired by the park on the unit's north end.*

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 5 shows the CUPN Vital Signs selected for monitoring in CHCH.

Table 5. CUPN Vital Signs selected for monitoring in CHCH (Leibfreid et al. 2005). An "X" indicates that vital sign was selected.

Category	CUPN Vital Sign	Category 1[A]	Category 2[B]	Category 3[C]	No Monitoring Planned
Air and Climate	Ozone and Ozone Impact	X	–	–	–
	Visibility and Particulates	–	–	–	X
	Atmospheric Deposition	–	–	–	X
	Air Contaminants	–	–	–	X
	Weather	–	X	–	–
Geology and Soils	Stream/River Morphology	–	–	–	X
	Cave Air Quality	–	–	–	X
	Soil Chemistry and Structure	–	–	–	X
	Soil Invertebrates and Associated Predators	–	–	–	X
Water	Water Quality and Quantity	X	–	–	–
	Benthic Macro-invertebrates	–	–	–	X
	Microbes	–	–	–	X
Biological Integrity	Invasive Plants "early detection"	X	–	–	–
	Forest Pests	X	–	–	–
	Amphibians	–	–	–	X
	Birds	–	–	–	X
	Cave Aquatic Fauna	–	–	–	X
	Cave Beetles	–	–	–	X
	Cave Crickets	–	–	–	X
	Cave Entrance Invertebrate Community	–	–	–	X
	Guano-dependent Invertebrate Communities	–	–	–	X
	Vegetation Communities	X	–	–	–
	Mussel Diversity	–	–	–	X
	Fish Diversity	–	–	–	X
	Cave Bats	–	–	–	X
	Deer	–	–	X	–
	Allegheny Woodrats	–	–	–	X
	Plant Species of Concern	–	–	–	X
Human Use	Poached Plants	–	–	–	X
Landscapes (Ecosystem Patterns and Processes)	Adjacent Land Use	X	–	–	–
	Fire	–	X	–	–
	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 CHCH, 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 SMUMN GSS. Project stakeholders include the CHCH resource management team, and CUPN Inventory and Monitoring Program 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 8-10 December 2015. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the CHCH 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 CHCH 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 CHCH 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 CHCH 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 CHCH and CUPN resource staff, the NPS Integrated Resource Management Application (IRMA) website, 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

<u>Selection of Resources and Measures</u>

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), 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 CHCH 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 the park in some way, or are of greatest concern or highest management priority in CHCH. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

<u>Selection of Reference Conditions</u>

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). Key resources for the park 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 April 2016 following acceptance from NPS resource staff. It contains a total of 10 components (Table 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.

Table 6. Chickamauga & Chattanooga National Military Park natural resource condition assessment framework.

Component	Measures (Significance Level)	Stressors	Reference Condition
Chickamauga and Chattanooga National Military Park Natural Resource Condition Assessment Framework			
Biotic Composition			
Ecological Communities			
Hardwood Forest Community	Species richness (native vs. exotic) (3), community extent (area) (2), Invasive/Exotic cover (3), oak regeneration (3), Connectivity (2)	Exotic plant species, forest pests, fire suppression, visitor impacts (e.g., climbing), climate change	NatureServe/Govus and White 2006
Limestone Cedar Glades	Species richness (3), glade area (2), percent woody cover (3), invasive/exotic cover (3)	Exotic/invasive plant species, fire suppression, deer use, climate change	NatureServe (2009) draft metrics
Wetlands	Number and acreage of wetlands (3), plant species richness (2), exotic species cover (3)	Exotic/invasive plant species, climate change (drought, flooding)	No net loss; best professional judgement
Wildlife			
Cave Bats	Species richness (3), summer cave-roosting bat abundance (3), hibernating bat abundance (2)	White-nose syndrome, direct human disturbance (i.e., unmanaged visitation), vegetation structure changes at cave entrances, land use changes, changes in cave air temperature and relative humidity, pesticides, wind energy development, bioaccumulation of heavy metals (e.g., mercury)	Species richness: 3 species (detected using caves during 2012-13 assessments)
Birds	Species richness (3), raptor species richness (2), species abundance (2)	Habitat loss in migratory ranges, climate change	Potentially undefined
Herpetofauna	Amphibian species richness (3), reptile species richness (3)	Disease, pollutants, habitat fragmentation and alteration, climate change	Potentially undefined, use best professional judgment

Table 6 (continued). Chickamauga & Chattanooga National Military Park natural resource condition assessment framework.

Chickamauga and Chattanooga National Military Park Natural Resource Condition Assessment Framework			
Component	**Measures (Significance Level)**	**Stressors**	**Reference Condition**
Environmental Quality			
Water Quality	Temperature (3), pH (3), dissolved oxygen (3), specific conductivity (3), acid neutralizing capacity (3), E. coli bacteria (3)	Upstream agricultural practices, upstream human use, atmospheric deposition, park operations/ maintenance, climate change	State standards, when available; see Meiman (2010)
Air Quality	Nitrogen deposition (3), sulfur deposition (3), mercury deposition (3), ozone (3), visibility (3), particulate matter (3)	Vehicle emissions, industrial and agricultural practices, and pollution from regional metropolitan areas	NPS ARD Standards
Adjacent Land Cover and Use	Change in external land cover/land use (3), total population (2), population density (2), housing development (3), land ownership (3)	Population growth/expansion, adjacent developments, expanding use of white/blue temperature LED lighting, other poor lighting practices	Landscape as it appeared at the time of battle(s)
Soundscape	Sound levels (3), frequency (3), duration of sounds (3)	Firing range and interstate near MOBE, commercial air traffic, vehicle noise from nearby roads	Natural ambient sound level

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 CHCH and CUPN 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 provided by NPS staff. Additional data and literature were also 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 and recommendations from NPS reviewers and sources of expertise including staff from CHCH 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 7. 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. If a measure is given a Significance Level of 1, it is thought to be of low importance when determining the overall condition of the component. For this reason, measures with a Significance Level of 1 are not discussed in detail in the Current Condition and Trends section of a component’s chapter. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 7. Scale for a measure's Significance Level in determining a components 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 8). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 8. 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 **SIGNIFICANT** 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: resource is in good condition (WCS = 0.0 – 0.33); condition warrants moderate concern (WCS = 0.34 - 0.66); and condition warrants significant concern (WCS = 0.67 to 1.00). Table 9 displays and describes the symbology 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 are in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there was currently insufficient data to make a statement about the condition of a component. The border of the circles represents SMUMN GSS's confidence in the assessment of current condition; bold borders indicate high confidence, normal borders indicate medium confidence, and a dashed-border indicates low confidence. 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. An arrow that points to the left and right indicates a stable or unchanging trend and an arrow pointing down indicates a decline 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. An empty circle with no arrow is reserved for situations in which the trend of the component's condition is currently unknown.

Table 9. Description of symbology used for individual component assessments.

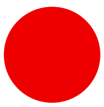
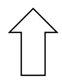
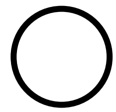
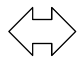
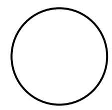
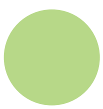
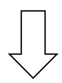
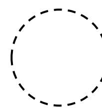
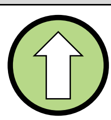
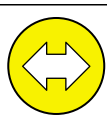
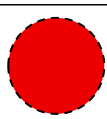
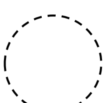
Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Mediu m
	Resource is in Good Condition		Condition is Deteriorating		Low
No color	Current condition is Unknown or Indeterminate	No trend	Trend in condition is Unknown or Not Applicable	–	–

Table 10. Examples of how the symbols should be interpreted.

Symbol Example	Description of Symbol
	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 CHCH 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 or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call 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 CHCH 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 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 in the park. 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 is 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. Sources are listed alphabetically by last name.

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 section'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).

Leibfreid, T. R., R. L. Woodman, and S. C. Thomas. 2005. Vital Signs monitoring plan for the Cumberland Piedmont Network and Mammoth Cave National Park prototype monitoring program: July 2005. National Park Service, Mammoth Cave, Kentucky.

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):1267-127.

Chapter 4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 10 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 (Table 6):

4.1 Hardwood Forest Community

4.2 Limestone Cedar Glades

4.3 Wetlands

4.4 Cave Bats

4.5 Birds

4.6 Herpetofauna

4.7 Water Quality

4.8 Air Quality

4.9 Adjacent Land Cover and Use

4.10 Soundscape and Acoustic Environment

4.1. Hardwood Forest Community

4.1.1. Description

CHCH is primarily known for its historic significance, but the park also contains significant natural resources, including extensive hardwood forests. The slopes of Lookout Mountain and the rolling hills of Chickamauga Battlefield support hardwood forests of varying species composition, depending on topography, soils, and land use history (NPS 1987, 2015a). Oaks (*Quercus* spp.) and hickories (*Carya* spp.) dominate the uplands, with red maple, tulip tree (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), ashes (*Fraxinus* spp.), hackberries (*Celtis* spp.), and elms (*Ulmus* spp.) also present (NPS 1987, 2015a). 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 and Leibfreid 2013).

The hardwood forests of Lookout Mountain also support a federally threatened plant species, the large-flowered skullcap (Figure 8) (Govus and White Jr. 2006, NPS 2015a). The skullcap is a mid-successional species, found in areas where light still reaches the forest floor (NPS 2015a). Two separate populations of skullcap occur on the steep escarpment slopes at Lookout Mountain: one on the west side and one on the east side (NPS 2015a). Four monitoring sites have been established in the park by the NPS; results are reported to the Tennessee Department of Environment and Conservation (TDEC) staff, who track population trends throughout the area. As of 2014, all monitoring locations had flowering plants and juvenile plants (TDEC 2014). Total skullcap numbers have increased or remained stable at two of the four sites over the last decade, but have steadily declined at one west side site (TDEC 2014). The fourth site experienced increased plant numbers through 2008 but has since declined (TDEC 2014), likely due to openings in the canopy cover from storm damage that have allowed new plant growth to compete with the skullcap (Jim Szyjkowski, CHCH Chief of Resource Management, written communication, 21 December 2016).

Vegetation classification and mapping efforts at CHCH identified 16 unique hardwood forest community types and two mixed hardwood/coniferous forest types (excluding bottomland/riparian forests) occurring within park boundaries (Govus and White Jr. 2006). These types (or "associations") and the prominent or characteristic tree species in CHCH stands are presented in Table 11.

Figure 8. Large-flowered skullcaps (a federally threatened plant species) at CHCH (NPS photo).

Table 11. Hardwood forest vegetation associations documented within CHCH (excluding bottomland/riparian forests) and the most prominent hardwood tree species in each (Govus and White Jr. 2006).

Association	Prominent tree species
Cumberland Plateau Dry-Mesic White Oak Forest	white oak, black oak (*Quercus velutina*)
Rich Low Elevation Appalachian Oak Forest	white oak, northern red oak (*Quercus rubra*), mockernut hickory (*Carya alba*), sugar maple (*Acer saccharum*)
Highland Rim White Oak - Tuliptree Mesic Lower Slope Forest	white oak, sweetgum, red maple, black gum (*Nyssa sylvatica*), willow oak (*Quercus phellos*)
Southern Interior Southern Red Oak - Scarlet/Post Oak Forest	southern red oak (*Quercus falcata*), post oak, mockernut hickory, white ash (*Fraxinus americana*)
White Oak - Post Oak Subcalcareous Forest	white oak, post oak (*Quercus stellata*), Florida maple (Acer floridanumA), winged elm (*Ulmus alata*)
Interior Low Plateau Chinquapin Oak - Mixed Oak Forest	southern red oak, chinquapin oak (*Quercus muehlenbergii*), blackjack oak (*Q. marilandica*), post oak, Shumard's oak (*Q. shumardii*), winged elm
Interior Plateau Chinquapin Oak - Shumard Oak Forest	chinquapin oak, Shumard's oak, post oak, pignut hickory (*Carya glabra*), sugarberry (*Celtis laevigata*),

[A] formerly known as *Acer barbatum*

[B] formerly known as *Quercus prinus*

Table 11 (continued). Hardwood forest vegetation associations documented within CHCH (excluding bottomland/riparian forests) and the most prominent hardwood tree species in each (Govus and White Jr. 2006).

Association	Prominent tree species
Interior Low Plateau Chestnut Oak - Mixed Forest	chestnut oak (*Quercus montana*[B]), white oak, black oak, red maple
Dry-Mesic Southern Appalachian White Oak - Hickory Forest	white oak, black oak, mockernut hickory, pignut hickory, sand hickory (*Carya pallida*), red maple
Xeric Ridgetop Chestnut Oak Forest	chestnut oak, scarlet oak (*Q. coccinea*), black oak, red maple, sand hickory
Appalachian Sugar Maple - Chinquapin Oak Limestone Forest	sugar maple, white ash, chinquapin oak, bitternut hickory (*Carya cordiformis*), sugarberry
Central Interior Beech - White Oak Forest	American beech (*Fagus grandifolia*), white oak
Successional Tuliptree Forest (Circumneutral Type)	black cherry (*Prunus serotina*), willow oak
Interior Mid- to Late-Successional Sweetgum - Oak Forest	sweetgum, white oak, southern red oak, tuliptree
Highland Rim Semi-Natural Redcedar – Oak Forest	eastern redcedar, red maple, southern shagbark hickory (*Carya ovata* var. *australis*), southern red oak, blackjack oak
Southern Blue Ridge Escarpment Shortleaf Pine – Oak Forest	shortleaf pine (*Pinus echinata*), southern red oak, black oak, pignut hickory, blackjack oak, post oak

[A] formerly known as *Acer barbatum*

[B] formerly known as *Quercus prinus*

4.1.2. Measures

- Species richness
- Community extent
- Invasive/exotic plant cover
- Oak regeneration
- Connectivity

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 Civil War battles (1863). Historical accounts describe the area as primarily wooded with interspersed fields and farms (NPS 1987, Govus and White Jr. 2006). However, little scientific information regarding the forests is available from this time. It is known that the battle damaged or destroyed some of the forest, and much of Lookout Mountain was clear-cut for lumber to support the war effort (NPS 1987).

The most thorough description available of CHCH's hardwood forest communities is from Govus and White Jr. (2006), which will serve as a reference condition. Rosen et al. (1982) provides some insight into historic exotic plant presence and cover at Lookout Mountain, although that survey was not specific to hardwood forest communities.

4.1.4. Data and Methods

The earliest known vegetation survey of CHCH occurred from 1972-1975 (Van Horn 1981). Vascular plants were collected and inventoried at Chickamauga Battlefield and Lookout Mountain. However, species were not classified by habitat, so it is not possible to determine which plant species were documented specifically in hardwood forest communities.

Rosen et al. (1982) surveyed the roads and trails of the Lookout Mountain Unit for exotic woody plants. The surveyors also rated the impact of each exotic occurrence on the surrounding native plant communities, using a subjective scale from zero (almost no impact) to five (maximum impact, 100% cover) (Rosen et al. 1982). The impact rating was based on two factors: 1) the extent to which the exotic was displacing native plants, and 2) for vines, whether the exotic species was covering or killing native plants (Rosen et al. 1982).

Rogers et al. (1993) completed a vegetation inventory and habitat mapping project at Chickamauga Battlefield for use in a white-tailed deer ecology study. Vegetation sampling took place in April and May of 1991, and included 41 forest survey plots (Rogers et al. 1993). Species composition and relative frequency were recorded by vegetation stratum (e.g., seedling, sapling, shrub, tree) and percent cover of trees were recorded at each forest plot. Habitat mapping, based on 1988 aerial imagery, divided forests into hardwood, conifer, or mixed stands (Rogers et al. 1993).

In August 2002, NatureServe initiated a vascular plant inventory and vegetation classification project at CHCH (Govus and White Jr. 2006). Ecologists sampled a total of 49 1-ha (2.5-ac) circular plots within the park. Twenty-nine of these plots fell within non-bottomland hardwood or mixed hardwood/coniferous forest communities. At each plot, environmental characteristics were recorded and every vascular plant species present was recorded (Govus and White Jr. 2006). Each species was also assigned a cover value by stratum (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 (2007).

The most recent vegetation map of CHCH was completed in 2010 by the University of Georgia Center for Remote Sensing and Mapping Science (Govus et al. 2010, Jordan and Madden 2010). Mapping was based on aerial photos (1:12,000 scale) from October 2001 (Jordan and Madden 2010). This map provides information regarding the extent of various vegetation associations, including several hardwood forest types, at the time of the imagery.

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 and Leibfreid 2013). Survey and data analysis protocols are outlined in White et al. (2011). Forty monitoring plots have been established at CHCH since 2011 (20 at Chickamauga Battlefield, 16 at Lookout Mountain, and four at Moccasin Bend), 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 and Leibfreid 2013, CUPN 2016). Thirty-one of these plots are within non-bottomland hardwood or mixed hardwood/coniferous forest communities. Plots are scheduled to be surveyed every 5 years. Data collected include species presence, frequency, and cover by stratum (tree, sapling, seedling, and herb layers), canopy cover, tree growth and health, coarse woody debris, and evidence of forest pests (Moore and Leibfreid 2013).

For this NRCA, forest connectivity will be analyzed using NPScape metrics, specifically the Pattern Morphology Tool. This tool provides land pattern metrics through the use of Morphological Spatial Pattern Analysis (MSPA) using the National Landcover Dataset (NLCD) as the data input (Monahan et al. 2012). MSPA is a pixel-level analysis of land cover that uses image segmentation to classify individual pixels into a set of pattern types (Monahan et al. 2012). Pattern types are listed in Table 12. The NPScape Pattern Morphology Tool produces output based on the forest and grassland cover types (NPS 2013). It should be noted that the input layer provided by NPScape for this analysis groups all forest cover types together and does not separate out hardwood forests specifically. The tool can produce output for two separate edge definitions, 1-pixel width or 5-pixel widths of core areas (Gross et al. 2009). An edge width of 1-pixel (30 m [98.4 ft] in the NLCD) was used in this analysis, as previous studies on deciduous forests in the eastern U.S. have shown that edge factors generally occur within 5 m (16.4 ft) to 50 m (160 ft) of the core patch (Ranney 1977, Matlack 1993). NPScape recommends the use of a standardized area of analysis (AOA) in landscape analyses (NPS 2015b). For pattern morphology analysis, NPScape recommends the use of a 30-km (18.6-mi) buffer surrounding the park. For CHCH, this buffer was generated around the two primary units of the park. The advantages to using the MSPA are its ability to be applied over large spatial extents and to identify change at the pixel level (Gross et al. 2009). Limitations to this model include sensitivity to pixel level changes, the computational time required to complete large areas, and the fact that it is a relatively new process, with few scientific studies linking results to specific ecological attributes (Monahan et al. 2012).

Table 12. MSPA classifications and definitions (Soille and Vogt 2009, Riiters 2011).

Pattern Type	Definition*
Core	Foreground pixels whose distance to the background is greater than the edge width
Islet	Cluster of foreground pixels that is too small to contain core, and is not a connector or branch
Edge	The exterior perimeter around a cluster of core pixels
Perforated	The interior perimeter around a hole (inclusion) in a cluster of core pixels
Bridge	Cluster of pixels linking two or more edge pixels, or two or more perforated pixels
Loop	Cluster of pixels connected to one edge pixel or one perforated pixel of the same type
Branch	Cluster of pixels connected to one edge pixel or one perforated pixel

* “Foreground” is the analyzed cover type (forest, in this case) and “background” is the complement (shrubland and grassland).

4.1.5. Current Condition and Trend

<u>Species Richness</u>

Over time, approximately 480 total plant species have been documented in CHCH's hardwood forests (Appendix A). The species list for Chickamauga Battlefield forests (not exclusive to hardwood communities) provided by Rogers et al. (1993) included 51 species, only one of which was exotic (Chinese privet) (Appendix A). However, this list focused on woody species (e.g., trees, shrubs) and did not include the herbaceous species and vines observed in forest plots.

The NatureServe (2007) vegetation inventory of CHCH identified 392 plant species in hardwood and mixed forest community sampling plots (Appendix A). Twenty-eight species (7.1%) were exotic. Recent CUPN forest monitoring (2011-2015) has identified 330 plant species in hardwood and mixed forest plots, 27 (8.2%) of which are exotic (CUPN 2016). The slightly lower number of total species observed by the CUPN may be due to a smaller total sampling area than that of the NatureServe (2007) inventory. The 29 NatureServe (2007) inventory plots covered a total of 29 ha (74 ac) while the 31 CUPN monitoring plots cover a total of 1.2 ha (3 ac). Despite this size difference, the CUPN monitoring detected a similar number of exotic plant species for a slightly higher percentage of total species (8.2% exotic by CUPN vs. 7.1% exotic by NatureServe) (NatureServe 2007, CUPN 2016).

<u>Community Extent</u>

The earliest known vegetation mapping effort (Rogers et al. 1993), which was based on 1988 aerial imagery and covered only the Chickamauga Battlefield, identified 831.9 ha (2,056 ac) of hardwood forest and 218.5 ha (540 ac) of mixed forest. This accounted for 37% and 10% of the total area mapped, respectively (Rogers et al. 1993). Hardwood forests occurred throughout the battlefield but were most dominant in its northwest corner (Rogers et al. 1993).

Jordan and Madden (2010) identified a total of 2,277.2 ha (5,627.1 ac) of hardwood and mixed forest within CHCH (Table 13). This included 1,314.9 ha (3,249.1 ac) at Chickamauga Battlefield (Figure 9), 960.4 ha (2,373.2 ac) at Lookout Mountain (Figure 10), and 1.9 ha (4.8 ac) within Moccasin Bend and reservations on Missionary Ridge (Jordan and Madden 2010). These forest extents represent 59%, 71%, and 7% of each unit surveyed, respectively. Across CHCH as a whole, the community with the greatest extent was Southern Interior Southern Red Oak - Scarlet/Post Oak Forest, at just over 1,000 ha (2,471 ac) (Table 13). This forest type also showed the greatest extent at Chickamauga Battlefield, covering over three times as much area as all other forest types combined (Jordan and Madden 2010). Within the Lookout Mountain Unit, Interior Low Plateau Chestnut Oak - Mixed Forest covered nearly twice as much area as all other forest types combined (Table 13). The smallest forest communities, park-wide, were Central Interior Beech - White Oak Forest with just 2.0 ha (5.0 ac) and Appalachian Sugar Maple - Chinquapin Oak Limestone Forest at 3.0 ha (7.4 ac) (Jordan and Madden 2010).

Table 13. Total area of hardwood forest vegetation associations within CHCH units, based on 2001 aerial photography (Jordan and Madden 2010). Areas are given in hectares, with acres in parentheses.

Vegetation Association	Battlefield	Lookout Mt	MB & Res.	Total
Cumberland Plateau Dry-Mesic White Oak Forest	–	154.5 (381.8)	–	154.5 (381.8)
Rich Low Elevation Appalachian Oak Forest	18.9 (46.6)	12.6 (31.1)	–	31.5 (77.7)
Highland Rim White Oak - Tuliptree Mesic Lower Slope Forest	29.0 (71.6)	35.0 (86.5)	–	64.0 (158.1)
Southern Interior Southern Red Oak - Scarlet/Post Oak Forest	1,007.5 (2,489.5)	0.3 (0.8)	–	1,007.8 (2,490.3)
White Oak - Post Oak Subcalcareous Forest	119.3 (294.8)	–	–	119.3 (294.8)
Interior Low Plateau Chinquapin Oak - Mixed Oak Forest	16.8 (41.5)	–	–	16.8 (41.5)
Interior Plateau Chinquapin Oak - Shumard Oak Forest	37.6 (92.9)	–	–	37.6 (92.9)
Interior Low Plateau Chestnut Oak - Mixed Forest	–	631.0 (1,559.3)	–	631.0 (1,559.3)
Dry-Mesic Southern Appalachian White Oak - Hickory Forest	52.4 (129.4)	0.9 (2.3)	–	53.3 (131.7)
Xeric Ridgetop Chestnut Oak Forest	–	111.3 (274.9)	–	111.3 (274.9)
Appalachian Sugar Maple - Chinquapin Oak Limestone Forest	–	1.9 (4.6)	1.1 (2.8)	3.0 (7.4)
Central Interior Beech - White Oak Forest	0.5 (1.3)	1.5 (3.7)	–	2.0 (5.0)
Successional Tuliptree Forest (Circumneutral Type)	2.8 (7.0)	5.7 (14.1)	0.8 (2.0)	9.3 (23.1)
Interior Mid- to Late-Successional Sweetgum - Oak Forest	–	4.3 (10.7)	–	4.3 (10.7)
Highland Rim Semi-Natural Redcedar – Oak Forest	10.0 (24.8)	–	–	10.0 (24.8)
Southern Blue Ridge Escarpment Shortleaf Pine – Oak Forest	20.1 (49.7)	1.4 (3.4)	–	21.5 (53.1)
Totals	**1,314.9** (3,249.1)	**960.4** (2,373.2)	**1.9** (4.8)	**2,277.2** (5,627.1)

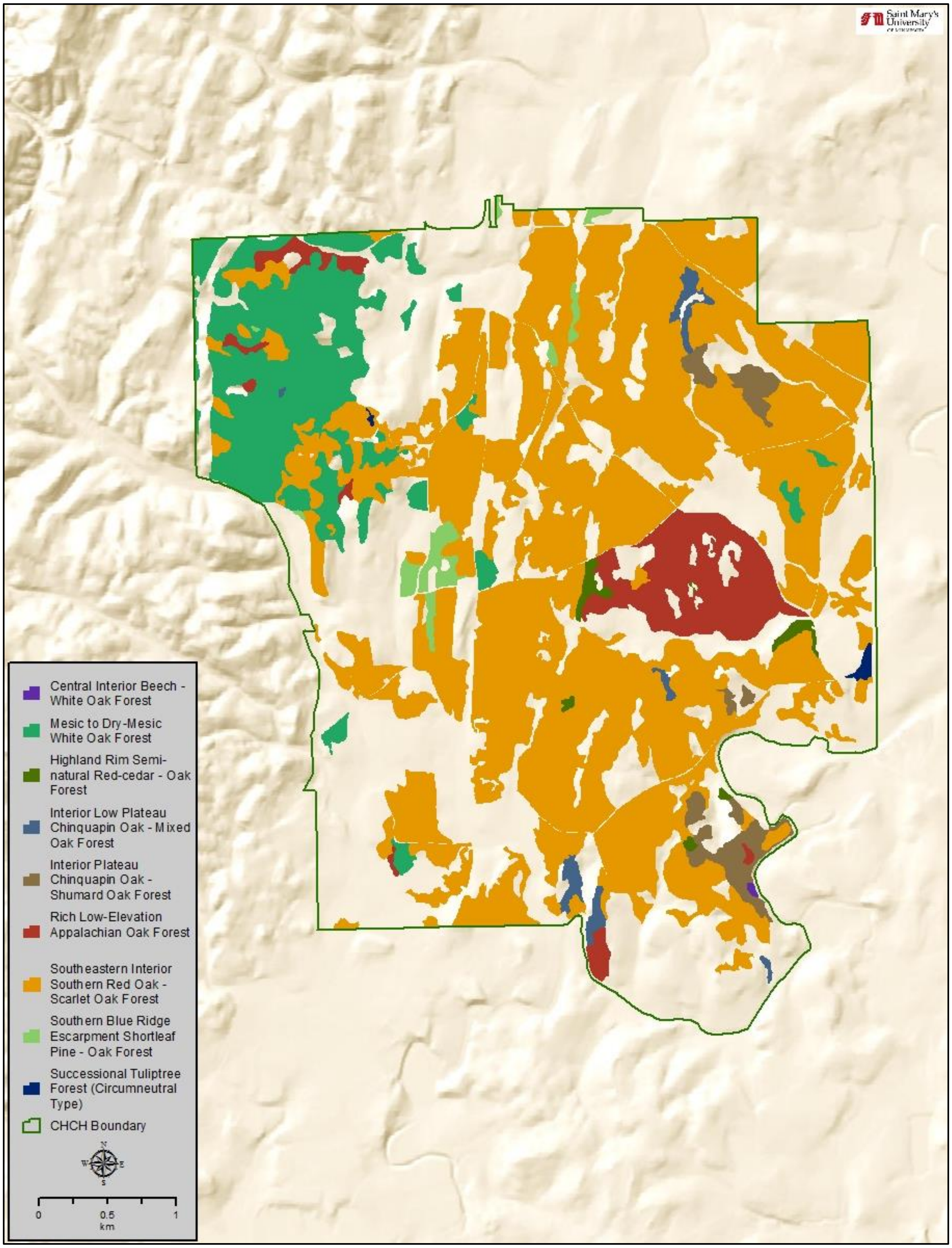


Figure 9. Hardwood and mixed forest community extent at Chickamauga Battlefield (Jordan and Madden 2010).

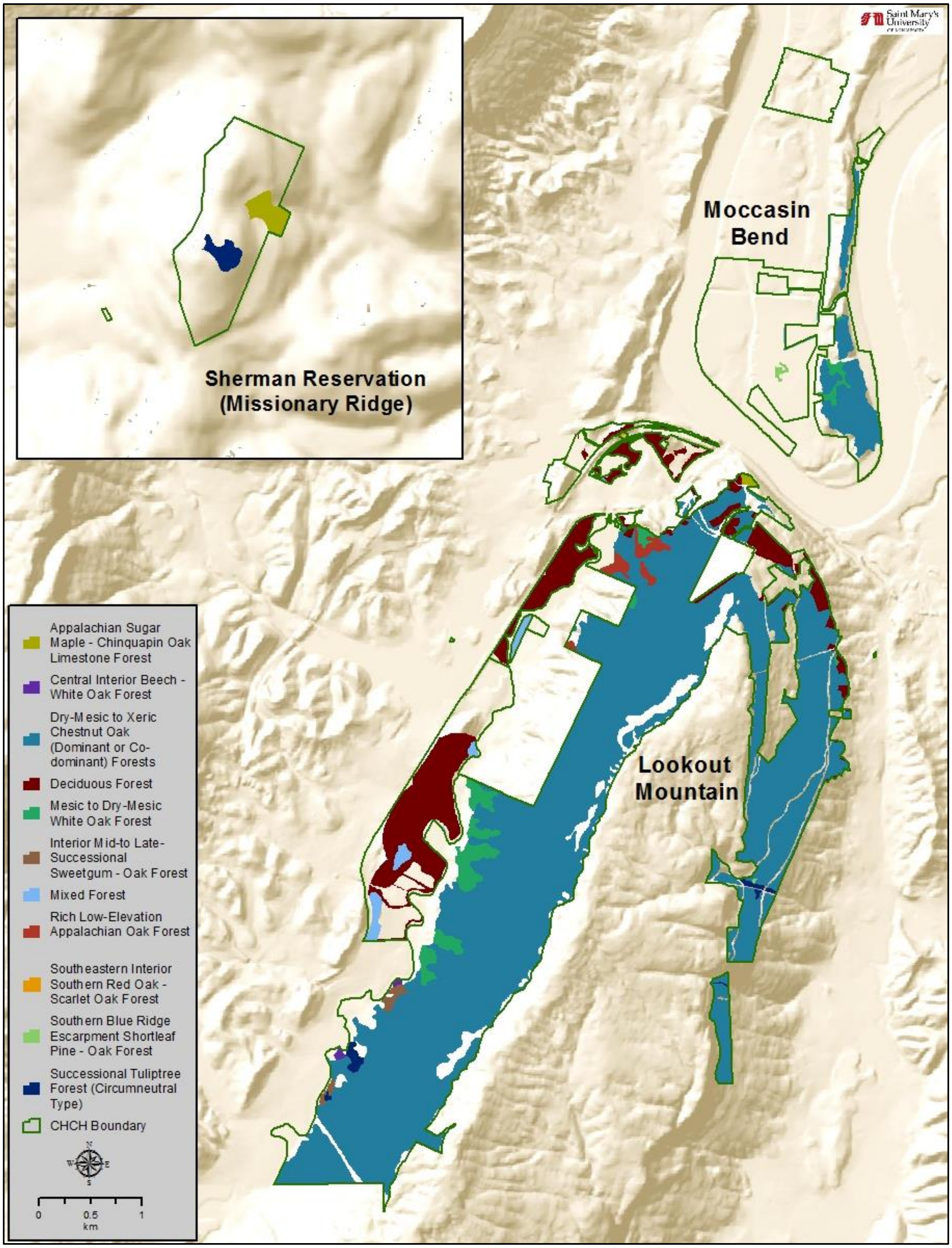


Figure 10. Hardwood and mixed forest community extent in the Lookout Mountain, Moccasin Bend, and Sherman Reservation Units of CHCH (Jordan and Madden 2010).

Invasive/Exotic Plant Cover

In a 1982 survey of roads and trails on Lookout Mountain, Rosen et al. (1982) documented 655 occurrences of exotic woody plants. The most common exotic species included Japanese honeysuckle (*Lonicera japonica*), princess tree (*Paulownia tomentosa*), tree-of-heaven (*Ailanthus altissima*), silk tree (*Albizia julibrissin*), and kudzu (Rosen et al. 1982). At the time, exotic vine species were estimated to cover a total area of 15.2 ha (37.6 ac); cover by species is presented in Table 14. Exotic tree species cover (basal area) totaled 21.0 m^2 (226 ft^2) (Rosen et al. 1982). Basal area by species is shown in Table 15. It should be noted that these results are for the Lookout Mountain Unit as a whole and are not exclusive to hardwood forest communities.

Table 14. Estimated total cover of exotic vine species at Lookout Mountain and mean population size/cover (Rosen et al. 1982). Areas are given in hectares, with acres in parentheses.

Species	Total cover	Mean population size/cover
Japanese honeysuckle	9.3 (22.9)	0.03 (0.08)
kudzu	4.8 (11.8)	0.13 (0.31)
English ivy (*Hedera helix*)	0.8 (2.0)	0.03 (0.07)
common periwinkle (*Vinca minor*)	0.3 (0.8)	0.05 (0.13)

Table 15. Basal area (cover) of exotic tree species at Lookout Mountain (Rosen et al. 1982). Areas are given in m^2 with ft^2 in parentheses.

Species	Basal area
princess tree	16.2 (174.4)
tree-of-heaven	3.9 (42.0)
silk tree (mimosa)	0.9 (9.7)

Of the 29 hardwood forest plots surveyed by NatureServe (2007), exotic species were absent (0% cover) from 11 plots (Appendix B). Species cover was recorded by stratum (e.g., tree, shrub, vine, herbaceous), so that total cover within a plot could exceed 100%, due to stratum overlap. In plots where exotic species were found, total cover per plot ranged from 0.05% to 45.6% (NatureServe 2007). Exotic cover was ≤2% in nine plots and exceeded 25% in only two plots (Appendix B). The overall mean for all plots (including 0% cover plots) was 4.7% (NatureServe 2007).

Thirty-one plots within CHCH's hardwood forest communities were sampled by the CUPN (2016) once each between 2011 and 2015. Exotic plant cover was assigned a range by species rather than an exact value (e.g., trace, 1-2%, 2-5%, 10-25%). Exotic species were absent from four plots: one at Chickamauga Battlefield and three at Lookout Mountain (Appendix B). In the remaining plots, total exotic species cover ranged from a trace to 60% (CUPN 2016). Fourteen of these plots had cover ranges ≤2%, while the top end of cover ranges exceeded 25% in four plots (CUPN 2016). Overall mean cover was difficult to calculate, given the use of ranges and the "trace" category. If "trace" is assigned a numeric value of 0.1 for calculation purposes, the mean minimum exotic species cover was 3.7% and mean maximum cover was 9.1% (with zeroes included as both maximum and minimum for plots with no exotics present).

Oak Regeneration

Studies of tree regeneration, such as the composition and density of the seedling and sapling layers, can provide insight into the future character of the forest (McWilliams et al. 2015). Shifts in the composition of seedlings/saplings may indicate an eventual change in the composition of the forest as a whole, which can impact forest dynamics and wildlife habitat (McWilliams et al. 2015). For several decades, studies have raised concerns that oak-hickory dominated forests are becoming increasingly dominated by more mesic, shade-tolerant species, such as maples (*Acer* spp.) (Christensen 1977, Rose 2008). Research suggests that this may be partially due to poor oak regeneration (Lorimer 1993, Rose 2008). Many factors can inhibit oak regeneration, including low acorn production, acorn consumption by wildlife, animal damage to seedlings, unfavorable spring weather, and increased shade from dense tree/shrub canopies (sometimes attributed to lack of fire disturbance) (Lorimer 1993).

The NatureServe (2007) inventory tracked species presence by vegetation layer and included categories for the herbaceous layer, which would include tree seedlings, and the short shrub layer, which would include many tree saplings. Of the 29 hardwood forest plots surveyed, 26 (89.7%) showed some evidence of oak regeneration (Table 16) (NatureServe 2007). Five plots had oak species present in the herbaceous layer only, 13 had oaks in the short shrub layer only, and eight plots had oaks in both the herbaceous and short shrub layers (NatureServe 2007).

Table 16. Evidence of oak regeneration during NatureServe (2007) vegetation sampling, as indicated by the presence of oak species in the herbaceous layer and short shrub strata. An “x” indicates that regeneration was observed at that plot.

Plot	In herbaceous layer	In short shrub layer	None present
CHCH01	–	x	–
CHCH02	x	–	–
CHCH06	x	–	–
CHCH07	x	x	–
CHCH08	–	x	–
CHCH10	–	x	–
CHCH12	–	x	–
CHCH13	–	–	x
CHCH15	x	x	–
CHCH17	x	–	–
CHCH18	–	x	–
CHCH22	–	x	–
CHCH24	x	x	–
CHCH25	–	–	x

Table 16 (continued). Evidence of oak regeneration during NatureServe (2007) vegetation sampling, as indicated by the presence of oak species in the herbaceous layer and short shrub strata. An “x” indicates that regeneration was observed at that plot.

Plot	In herbaceous layer	In short shrub layer	None present
CHCH26	–	x	–
CHCH27	–	x	–
CHCH28	x	x	–
CHCH29	–	x	–
CHCH31	–	x	–
CHCH32	–	x	–
CHCH33	x	x	–
CHCH34	–	x	–
CHCH35	x	x	–
CHCH37	x	x	–
CHCH38	–	x	–
CHCH39	–	–	x
CHCH40	x	–	–
CHCH45	x	x	–
CHCH47	x	–	–

The CUPN has documented seedling and sapling layer composition during their monitoring efforts from 2011-2015. Of the 31 hardwood forest plots surveyed, 28 (90.3%) had oak species present in the seedling and sapling layers (Appendix C) (CUPN 2016). Two of the three plots with no evidence of oak regeneration were at Chickamauga Battlefield and one was in the Lookout Mountain Unit. When oaks were present, the number of seedlings/saplings per plot ranged from one (three plots) to 31, with a mean of 6.8 (Appendix C).

Oaks were most frequently found in the 0-50 cm seedling category (28 of 31 plots) and were rare in all other categories (Table 17) (CUPN 2016). However, the percentage of total seedlings in the 0-50 cm category that were oaks was still low in most plots (<20% at 14 plots) (Appendix C). The most frequently occurring species were black oak (14 of 31 plots), white oak (10 of 31 plots), and chestnut oak (10 of 31 plots, all at Lookout Mountain) (Table 18, Appendix C). Black oak also showed the greatest size range, occurring within all six of the sapling/seedling categories (Table 18) (CUPN 2016).

Table 17. The number of CUPN monitoring plots where oaks were present in each seedling/sapling category (CUPN 2016). Sd = seedling, Sp = sapling; measurements following Sd categories represent heights while measurements following Sp categories are diameter-at-breast-height (DBH).

Seedling/ sapling category	Number of plots present
Sd 5-50 cm	28
Sd 50-137 cm	6
Sp 0-1 cm DBH	8
Sp 1-2.5 cm DBH	4
Sp 2.5-5 cm DBH	5
Sp 5-10 cm DBH	4

Table 18. The number of CUPN monitoring plots where each oak species was present and the number of size categories where it occurred (CUPN 2016). LOM = Lookout Mountain, CHIC = Chickamauga Battlefield.

Oak Species	# of plots present	# of size categories
black oak (*Q. velutina*)	14	6
white oak (*Q. alba*)	10	3
chestnut oak (*Q. montana*)	10 (LOM only)	5
southern red oak (*Q. stellata*)	8 (CHIC only)	4
post oak (*Q. falcata*)	7 (CHIC only)	2
chinquapin oak (*Q. muehlenbergii*)	6	3
northern red oak (*Q. rubra*)	4	4
water oak (*Q. nigra*)	4	3
willow oak (*Q. phellos*)	1 (CHIC only)	1
overcup oak (*Q. lyrata*)	1 (CHIC only)	1

Based on early monitoring data, the relative proportion of oak-hickory species versus upland maple species in the canopy and sapling layers at CHCH suggests that the park's hardwood forest composition may change in coming decades. While oak-hickory species comprise over 40% of the forest canopy, these species make up less than 20% of the sapling layer (Figure 11) (Moore and Leibfreid 2013). In contrast, upland maples comprise very little of the canopy layer, but make up a high percentage of the sapling layer, particularly at Lookout Mountain (Moore and Leibfreid 2013).

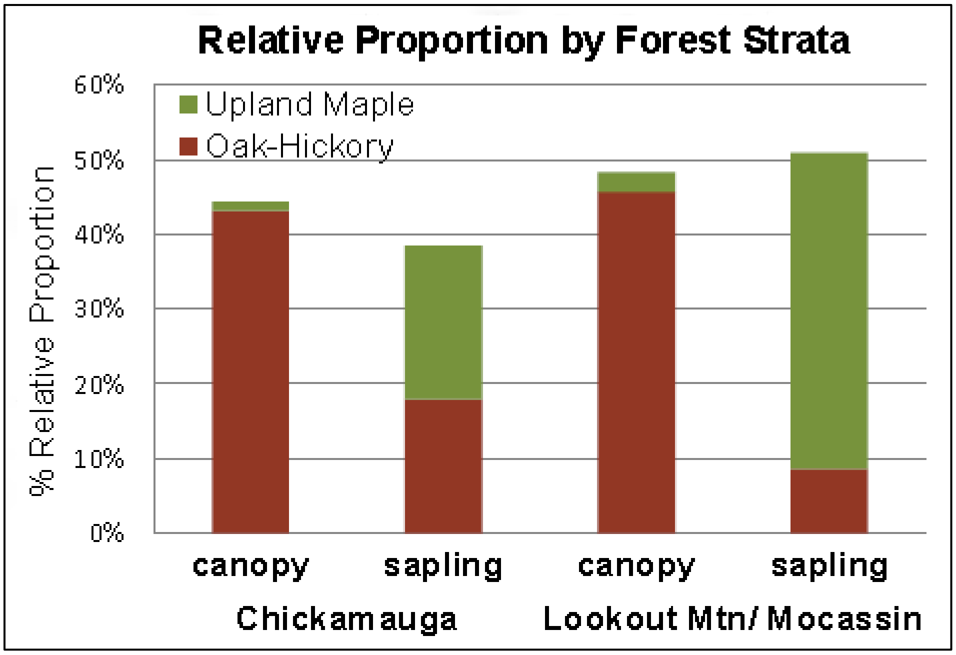


Figure 11. Relative proportion of oak-hickory and upland maple species in the tree canopy and sapling layers of CUPN forest monitoring plots at CHCH (reproduced from Moore and Leibfreid 2013).

Connectivity

Forest fragmentation causes a loss of habitat connectivity for both plants and animals, often contributing to a loss of native plant and wildlife species (Heilman Jr. et al. 2002, Honnay et al. 2005). Fragmentation makes dispersal between habitat patches more difficult, which can decrease population sizes and gene flow, potentially contributing to local extinctions (Heilman Jr. et al. 2002, Honnay et al. 2005). Fragmentation also can make forests more vulnerable to exotic species invasions, as smaller patches have more habitat "edges" than large, intact forests (Yates et al. 2004, Honnay et al. 2005).

The NPScape Pattern Morphology Tool was used to provide core and edge habitat data for forest patches in and around CHCH. It should again be noted that this habitat dataset includes all forest cover types, not exclusively hardwood forests. Core and edge areas, based on the 30-m (98.4-ft) edge definition, along with all MSPA class types for forested patches within the AOA, are given in Table 19.

Table 19. MSPA class types for forest patches within the AOA as derived by the NPScape analysis of 2011 NLCD (Fry et al. 2011).

Pattern type	Area (km^2)	Percent of total area (%)	Percent of forested area (%)
Core	1,777.9	41.5	73.1
Edge	398.5	9.3	16.4
Islet	33.9	0.8	1.4

* "Background" pattern is any non-forested habitat type

Table 19 (continued). MSPA class types for forest patches within the AOA as derived by the NPScape analysis of 2011 NLCD (Fry et al. 2011).

Pattern type	Area (km^2)	Percent of total area (%)	Percent of forested area (%)
Perforated	57.3	1.3	2.4
Bridge	30.6	0.7	1.3
Loop	17.3	0.4	0.7
Branch	115.1	2.7	4.7
Background*	1,855.6	43.3	–

* “Background” pattern is any non-forested habitat type

Based on this analysis, about 56% of the selected AOA (a 30-km buffer around the two major park units) is forested (i.e., all class types that are not “background”) (Table 19). Of this forested area, 73% is “core” habitat and should be buffered from detrimental edge effects (Figure 12). As seen in Figure 13 and Figure 14, the proportion of forest within the park boundaries that is core habitat appears to be even higher. In comparing the two areas, there is more core forest habitat near but outside the Lookout Mountain Unit boundary than around Chickamauga Battlefield.

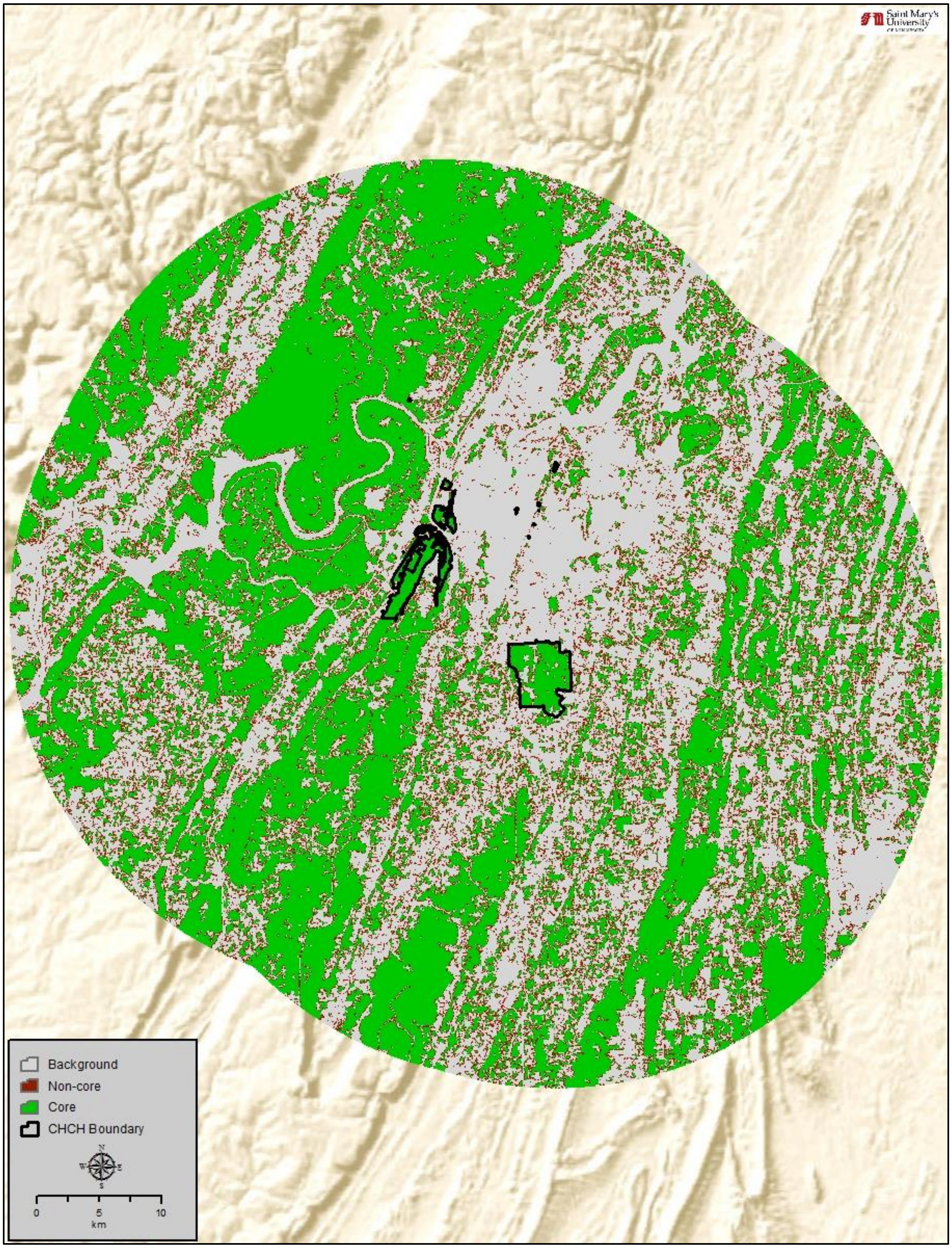


Figure 12. Core and non-core forested areas in the AOA surrounding CHCH (data from NPScape).

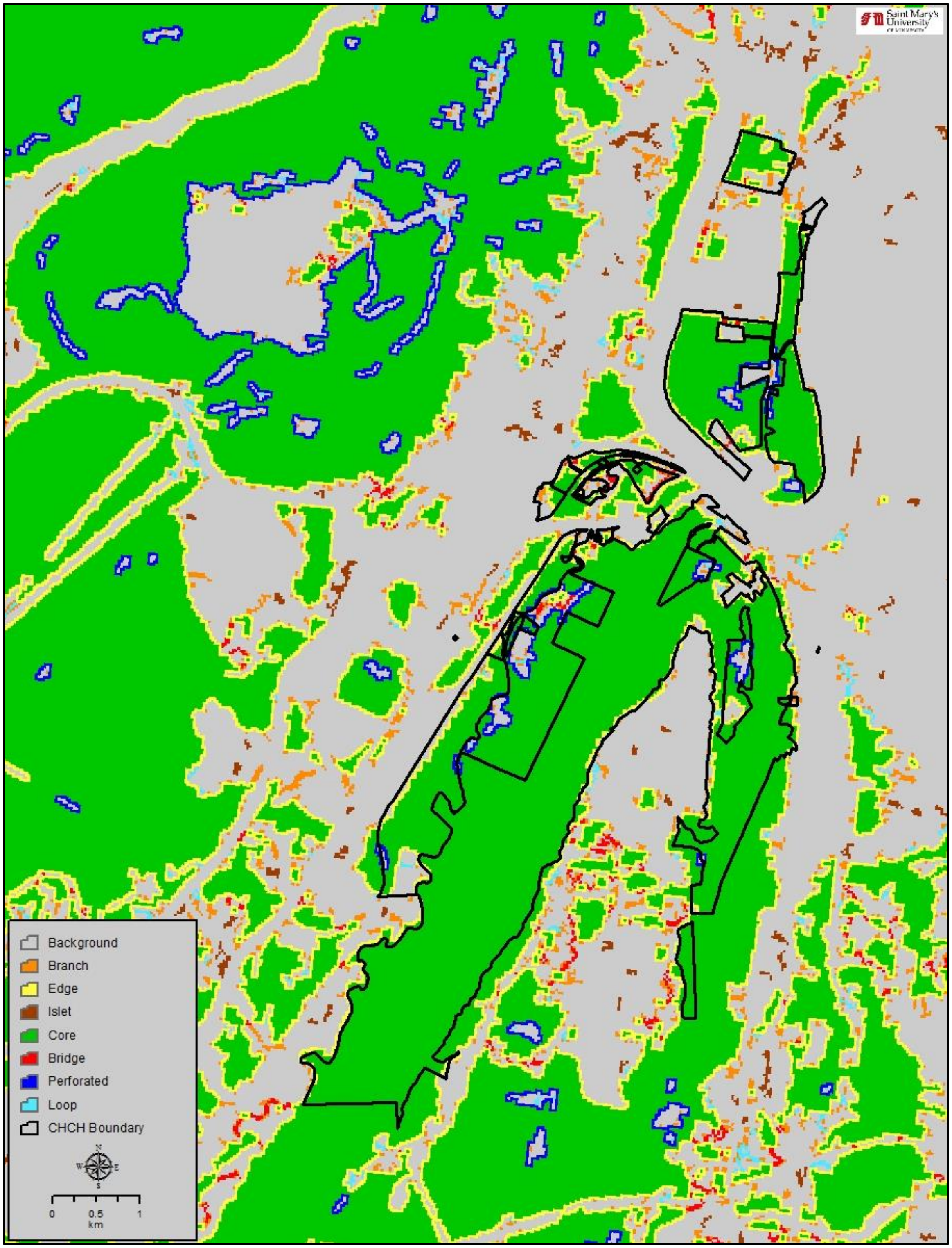


Figure 13. Pattern type of forested patches in and around the Lookout Mountain and Moccasin Bend Units of CHCH (data from NPScape).

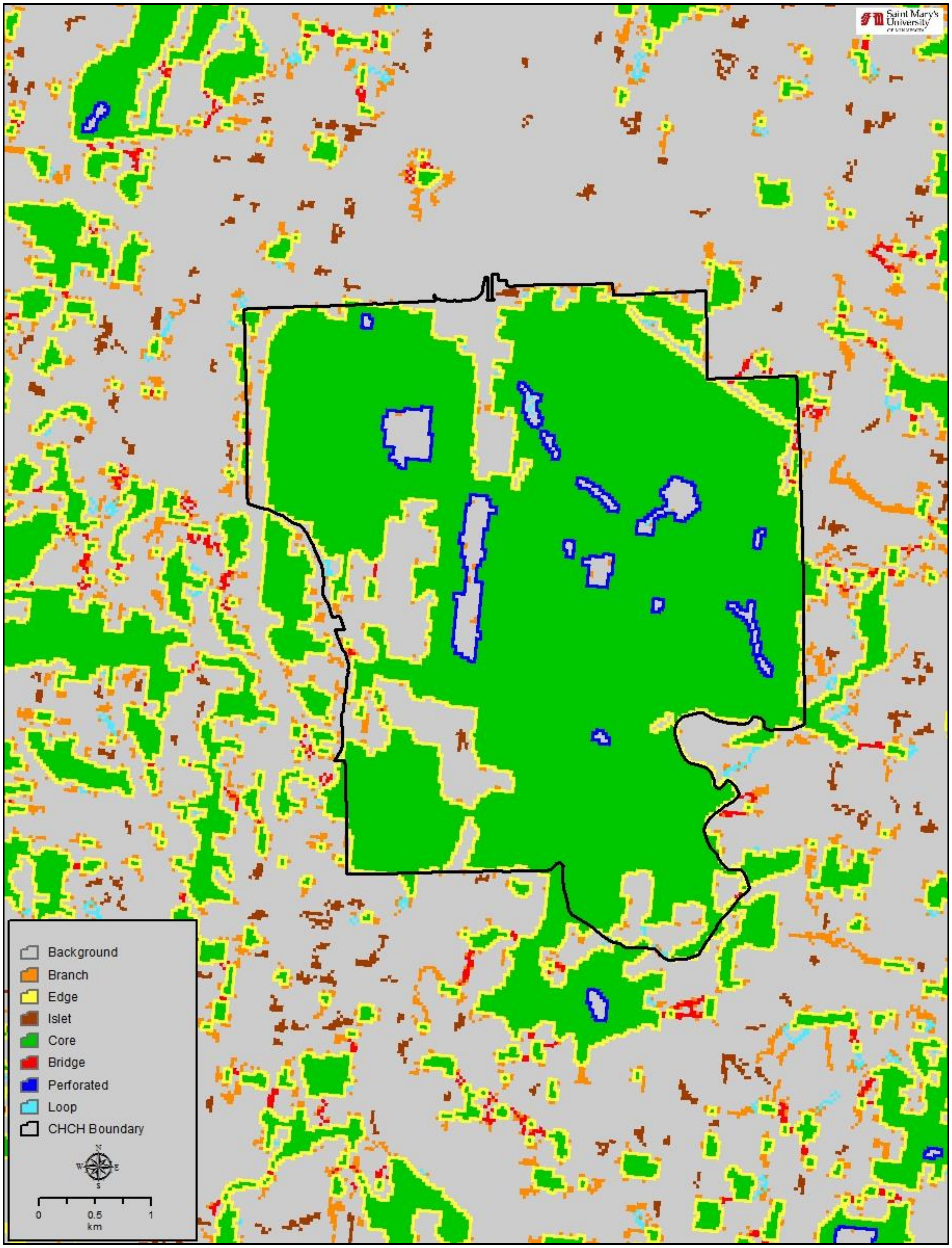


Figure 14. Pattern type of forested patches in and around the Chickamauga Battlefield Unit of CHCH (data from NPScape).

Threats and Stressor Factors

Threats to CHCH's hardwood forest communities include exotic plant species, forest pests and diseases, fire suppression, visitor impacts, and climate change. Exotic, invasive plants are among the greatest threats to forests worldwide, including at CHCH. The roads and trails that crisscross CHCH, as well as surrounding developments, serve as potential vectors for the spread of invasive plants and pests (Mack 2003, Keefer et al. 2014). To date, a total of 43 exotic plant species have been confirmed in CHCH's hardwood forests (Appendix A). However, only 24 of these are considered invasive by the Tennessee Exotic Pest Plant Council (TN-EPPC), and 12 species are considered a severe threat to native communities (Table 20) (TN-EPPC 2009). These aggressive species can outcompete and replace native forest plants (Govus and White Jr. 2006, Moore and Leibfreid 2013). This is already happening at CHCH, where invasive plants such as Chinese privet and bush honeysuckles (*Lonicera* spp.) are changing the site's character by reducing visibility through the forest understory (Figure 15) (NPS 2015a).

Table 20. Exotic invasive plant species confirmed in CHCH's hardwood forests and considered a "severe threat" in Tennessee (TN-EPPC 2009).

Scientific name	Common name	Growth form
Ailanthus altissima	tree-of-heaven	tree
Albizia julibrissin	silktree, mimosa	tree
Celastrus orbiculatus	Asian bittersweet	vine
Dioscorea oppositifolia	Chinese yam	vine
Elaeagnus umbellata var. parvifolia	autumn olive	shrub
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
Pueraria montana var. lobata	kudzu	vine
Rosa multiflora	multiflora rose	shrub

Figure 15. Exotic shrubs (green) invading a forest at Chickamauga Battlefield (SMUMN GSS photo by Kathy Allen).

Native and exotic insect, fungal, and bacterial pests pose serious threats to forests across the southeastern U.S., including the hardwood communities at CHCH (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 exotic insect threats to CHCH's hardwood forests include the gypsy moth (Lymantria dispar) and emerald ash borer (Figure 16), although neither of these species has yet been found in the park (Keefer 2012, Keefer et al. 2014). Emerald ash borer infests and kills only ash tree species. It was detected in Hamilton County, Tennessee (where Lookout Mountain is located) in 2013 and in northwest Georgia in 2014 (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 south-central Tennessee in 2012 (CERIS 2016).

Figure 16. Emerald ash borers, which are potential exotic insect threats to CHCH's hardwood forests (NPS photo by J. S. Keefer).

Diseases that may impact CHCH's hardwood trees include oak wilt and butternut canker. Oak wilt, caused by the fungal pathogen *Ceratocystis fagacearum*, is considered one of the most serious tree diseases in the eastern U.S. (O'Brien et al. 2011). It can kill thousands of oaks throughout the region annually. The species most commonly killed by oak wilt include black oak, northern red oak, Shumard's oak, blackjack oak, and southern red oak (O'Brien et al. 2011). Butternut canker (*Sirococcus clavigignenti- juglandacearum*), another fungal disease, is currently decimating butternut (*Juglans cinerea*) populations throughout their range and may have already extirpated the species in some southern states (Schlarbaum et al. 1998). The decline has been so severe that the U.S. Fish and Wildlife Service (USFWS) has listed butternut as a species of federal concern (Schlarbaum et al. 1998).

Prior to European settlement, fires were common in much of the eastern U.S., and helped to maintain the open character of oak-dominated hardwood forests that still remained at the time of the Civil War (Nowacki and Abrams 2008). However, fire has largely been suppressed across all park units since its establishment in 1890 (Govus and White Jr. 2006, NPS 2015a). As a result, the park's forests are much denser now than they were during the battles, to the point that views of Lookout Mountain from Point Park are obscured (NPS 2015a). This increased density has caused a buildup of fuels in many places, which increases the vulnerability of the forests to severe fires, if ignition were to occur. The increased density, particularly in the understory, also likely inhibits oak regeneration and may be reducing native herbaceous plant species diversity (Lorimer 1993, Govus and White Jr. 2006). Unfortunately, the use of prescribed fire as a management tool at Lookout Mountain has been extremely difficult due to the proximity of residential development to the park (NPS 2015a).

Visitor use, particularly hiking and rock climbing, has the potential to negatively impact CHCH's hardwood forests (Sutter et al. 1994, NPS 2015a). Increased hiking may lead to widening of trails, creation of unauthorized trails (e.g., shortcuts or switchbacks), and increased erosion (NPS 2015a). Rock climbing has increased at Lookout Mountain over the past several decades, particularly at Sunset Rock (Sutter et al. 1994). Sunset Rock provides a 30-m (100-ft) cliff face for climbers and stunning views for both climbers and hikers. Sutter et al. (1994) found that human use had greatly affected the vegetation and soils in the areas above and below the cliff. Impacts include damage to mature trees (from climbing equipment), a decline in younger trees, decreases in shrub and herbaceous cover, and increased soil erosion and compaction (Sutter et al. 1994).

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 CHCH's hardwood forests (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 and forest pests to expand their ranges and potentially their impact, as well as alter 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 estimated forest change for CHCH (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 CHCH's key hardwood species are shown in Table 21. The large-flowered skullcap is also considered vulnerable to climate change, due to its narrow habitat specificity and susceptibility to disturbance (Bruno et al. 2012). Habitat suitability modeling by Bruno et al. (2012, p. 75) predicted that CHCH "will not contain climatically suitable skullcap habitat by 2050."

Table 21. Potential change in habitat suitability by 2100 for select CHCH hardwood species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific name	Common name	Least change scenario	Major change scenario
Acer floridanum	Florida maple	extirpated	extirpated
Acer rubrum	red maple	small decrease	small decrease
Acer saccharum	sugar maple	large decrease	large decrease
Aesculus flava	yellow buckeye	extirpated	extirpated
Carya glabra	pignut hickory	small decrease	small decrease
Fagus grandifolia	American beech	small decrease	small decrease
Juglans nigra	black walnut	small decrease	large decrease
Liriodendron tulipifera	yellow-poplar	large decrease	large decrease
Quercus coccinea	scarlet oak	large decrease	large decrease
Quercus muehlenbergii	chinkapin oak	large decrease	small decrease
Celtis laevigata	sugarberry	small increase	large increase
Liquidambar styraciflua	sweetgum	small increase	small increase
Platanus occidentalis	sycamore	small increase	small increase
Quercus marilandica	blackjack oak	large increase	large increase
Quercus nigra	water oak	large increase	large increase
Quercus stellata	post oak	large increase	large increase
Ulmus alata	winged elm	small increase	large increase
Carya illinoinensis	pecan	–	new habitat
Quercus texana	Nuttall's oak	–	new habitat
Ulmus crassifolia	cedar elm	new habitat	new habitat

<u>Data Needs/Gaps</u>

Additional study of oak and other hardwood regeneration is needed to better understand this process and how it will impact the future composition of CHCH's hardwood forest communities (Moore and Leibfreid 2013). If oak regeneration is below desirable levels, the causes will need to be investigated, as well as strategies for improving regeneration. For example, the feasibility of using prescribed fire as a management tool could perhaps be revisited.

Little is known about large-flowered skullcap biology (NPS 2015a). The healthy populations at CHCH provide an opportunity for researchers to better understand this rare species, in order to protect it from current and future threats.

<u>Overall Condition</u>

Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3. The hardwood forests of CHCH are very diverse, supporting over 450 native plant species (

). Of the 200 sampling plots surveyed by the CUPN across network parks in 2011-2012, the most diverse plot occurred near the base of Lookout Mountain (Moore and Leibfreid 2013). However, there is some concern over the increasing percentage of plant species that are exotic. During the NatureServe (2007) inventory, 7.1% of the species documented were exotic, while during more recent CUPN monitoring (2011-2015), 8.2% of plant species were exotic (CUPN 2016). Therefore, this measure is of low concern (*Condition Level* = 1).

Community Extent

This measure was assigned a *Significance Level* of 2. According to the most recent vegetation map for CHCH, hardwood and mixed hardwood/coniferous forests cover 2,277 ha (5,627 ac) of the park (Jordan and Madden 2010). These forest communities cover 71% of the Lookout Mountain Unit and 59% of Chickamauga Battlefield (Jordan and Madden 2010). This extent for the Battlefield Unit is slightly higher than what was mapped by Rogers et al. (1993), based on 1988 aerial imagery. As a result, community extent is currently of no concern (*Condition Level* = 0).

Invasive/Exotic Plant Cover

The project team assigned a *Significance Level* of 3 for this measure. Exotic plant species, particularly woody species, have been present and of concern at CHCH for at least several decades (Van Horn 1981, Rosen et al. 1982). During NatureServe (2007) vegetation sampling, exotic plant species were present in 18 of 29 plots (62%). Cover ranged from 0.05% to 45.6%, with a mean of 4.7% (including zeroes for plots where exotics were absent) (NatureServe 2007). During more recent CUPN (2016) sampling, exotic plants were present in 27 of 31 plots (87%). Cover ranged from a trace to 60%, with a mean range of 3.7%-9.1% (CUPN 2016). A comparison of these two surveys suggests that exotic plant cover is expanding within the park, making this measure of moderate concern (*Condition Level* = 2).

Oak Regeneration

The oak regeneration measure was also assigned a *Significance Level* of 3. Oak regeneration is of interest at CHCH because studies have raised concerns that oak-hickory dominated forests are becoming increasingly dominated by more mesic, shade-tolerant species (Christensen 1977, Rose 2008). During both the NatureServe (2007) inventory and CUPN (2016) monitoring, approximately 90% of hardwood and mixed forest sample plots showed evidence of oak regeneration. However, in CUPN monitoring plots, oaks were very rare in the sapling layer and comprised a small percentage (<20%) of seedlings at half the sites (CUPN 2016). As a result, this measure was assigned a *Condition Level* of 2, indicating moderate concern.

Connectivity

This measure was assigned a *Significance Level* of 2. An analysis using the NPScape Pattern Morphology tool showed that 73.1% of the forested area within the AOA surrounding CHCH is classified as core habitat (Table 18, Figure 12). Within park boundaries, especially at Lookout Mountain, the proportion of forested area classified as core is even higher. At this time, connectivity is of low concern (*Condition Level* = 1) for CHCH’s forests.

Weighted Condition Score

The *Weighted Condition Score* for CHCH's hardwood forests is 0.44, indicating moderate concern. An overall trend could not be assigned; while some measures appear to be stable (e.g., species richness, community extent), others are thought to be declining (e.g., exotic plant cover, oak regeneration).

Table 22. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's hardwood forest community.

Measures	Significance Level	Condition Level	WCS = 0.44
Species Richness	3	1	
Community Extent	2	0	
Exotic Plant Cover	3	2	
Oak Regeneration	3	2	
Connectivity	2	1	

4.1.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Rickie White, NatureServe Ecologist
- Jim Szyjkowski, CHCH Chief of Resource Management

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4.2. Limestone Cedar Glades

4.2.1. Description

Limestone cedar glades are flat or rolling open areas with exposed rock and shallow soil that support plant communities dominated by herbaceous species, with scattered small trees and/or shrubs (Sutter et al. 1994, Baskin and Baskin 2003). They are interspersed within forests or woodlands and are known for containing a high number of endemic plant species, many of which require high light levels for survival (Sutter et al. 1994). At CHCH, limestone cedar glades are found only at the Chickamauga Battlefield Unit (Figure 17) and make up a relatively small percentage of the unit's total area (Rogers et al. 1993, Jordan and Madden 2010). They have been called, "without question the most biologically significant feature of Chickamauga Battlefield" (Govus and White Jr. 2006, p. 22). These glades are the best remaining example of this community type in Georgia and are the only known locations of several plant species within the state (Sutter et al. 1994). The park's protected glades have become even more important over time, as unprotected glades are degraded or eliminated by agriculture and human development throughout their range (Sutter et al. 1994, Govus and Lyons 2009). CHCH's cedar glades are separated from the primary range of this community type by the Cumberland Plateau; as a result, the Battlefield's glades may have a unique plant species composition and some plant species may be genetically distinct from other populations (Sutter et al. 1994). The cedar glades are actually mentioned in several accounts of the Battle of Chickamauga, as open areas within the woods where skirmishers from the two armies met (Scott 1890, as cited in Sutter et al. 1994).

Figure 17. A limestone cedar glade at Chickamauga Battlefield (SMUMN GSS photo by Kathy Allen).

Limestone cedar glades appear to maintain their open nature through their shallow soils (typically <25 cm [9.8 in]) with extreme fluctuations in moisture conditions (Sutter et al. 1994, Baskin and Baskin 2003). During the winter, when the majority of precipitation occurs in these areas, glade soils become saturated and standing water may even occur. Then in the summer, when precipitation is infrequent and evaporation rates are high, glade soils become extremely dry (Sutter et al. 1994). Due to these extremes, glade communities are often dominated by one set of herbaceous plant species in the spring, while winter moisture remains, and another set of species during the drier summer and fall (Sutter et al. 1994).

Plant species composition and distribution can be very diverse both within and between limestone cedar glades, due to slight microhabitat differences (e.g., amount of sun exposure, bedrock exposure, soil depth) (Govus and White Jr. 2006). Nearly all glades at CHCH include sparse eastern redcedar, with other scattered small trees. A sparse, patchy low shrub layer is also typically present (Govus and White Jr. 2006). The herbaceous layer ranges from around 50% to 90% cover, often dominated by grasses. Dominant grasses include little bluestem (*Schizachyrium scoparium*) and annual dropseeds (*Sporobolus* spp.). All glades have some bare rock, which may support a thin cover of moss, lichen, or algae (e.g., *Nostoc* sp.) (Govus and White Jr. 2006). The cedar glade complexes at CHCH are comprised of three unique vegetation associations; the Central Limestone Glade association is most prevalent, with just small areas of Southern Ridge and Valley Annual Grass Glade on the shallowest soils and Limestone Seep Glade where water seepage reaches the surface (Table 23) (Govus and White Jr. 2006).

Table 23. Cedar glade-associated vegetation associations documented within CHCH and the most prominent plant species in each (Govus and White Jr. 2006).

Association	Prominent plant species
Central Limestone Glade	eastern redcedar, little bluestem, additional native grasses (e.g., *Sporobolus* spp., *Andropogon* spp.) and endemic forbs
Limestone Seep Glade	Crawe's sedge (*Carex crawei*), flat-stem spike-rush (*Eleocharis compressa*), crowposion (*Nothoscordum bivalve*), nodding onion (*Allium cernuum*)
Southern Ridge and Valley Annual Grass Glade	poverty dropseed (*Sporobolus vaginiflorus*), whorled milkweed (*Asclepias verticillata*), croton (*Croton* spp.), straggling St. Johnswort (*Hypericum dolabriforme*), fluxweed (*Trichostema brachiatum*), pasture heliotrope (*Heliotropium tenellum*)

4.2.2. Measures

- Species richness
- Glade area
- Percent woody cover
- Exotic cover

4.2.3. Reference Conditions/Values

As with hardwood forests, the ideal reference condition for limestone cedar glades would be their appearance and condition at the time of the Civil War battles. However, no scientific information on the glades is available for this period. In 2009, NatureServe (2009) drafted a series of metrics for assessing the ecological integrity of cedar glades at CHCH and Stones River National Battlefield in central Tennessee. The three selected metrics were size (glade area), vegetation structure (woody percent cover of plants >1 m [3.3 ft]), and invasive exotic plant presence/cover. Both glade area and woody percent cover are known to be associated with the number of endemic plant species supported by a glade, while invasive plants are a threat to many native species (NatureServe 2009). Endemic plant species richness tends to increase with glade area but decreases as woody percent cover increases (NatureServe 2009). Each metric would be assigned a rating from A (excellent) to D (poor), which then provides an overall ecological integrity rating (NatureServe 2009). The draft rating categories for each metric are outlined in Table 24. These three metrics were selected by the NRCA project team as measures for this component. For the purposes of this assessment, the reference condition will be a rating of excellent (A) or good (B) for the glade area measure and a rating of excellent for the woody cover and exotic cover measures.

Table 24. Draft rating categories for the three cedar glade ecological integrity assessment metrics, as outlined by NatureServe (2009).

Metric	Excellent (A)	Good (B)	Fair (C)	Poor (D)
Size	Glade area >1,200 m^2	Glade area 400-1,200 m^2	Glade area 200-400 m^2	Glade area <200 m^2
Vegetation structure	Woody plant cover <10%	Woody plant cover 10-25%	Woody plant cover 25-50%	Woody plant cover >50%
Invasive exotic plants	No invasive exotic plants present	Invasive exotic plant cover <2%	Invasive exotic plant cover 2-10%	Invasive exotic plant cover >10%

4.2.4. Data and Methods

Sutter et al. (1994) conducted baseline monitoring of CHCH's limestone cedar glades. The objectives were to: 1) update the plant species list for CHCH's cedar glades as a whole and to develop a species list for each individual glade (23 total), 2) establish baseline monitoring of woody vegetation in selected glades, and 3) establish baseline monitoring of herbaceous vegetation (plants less than 0.5 m [1.6 ft] in height) in a subset of selected glades (Sutter et al. 1994). Nine glades were selected for woody vegetation monitoring, and permanent baseline transects were established. The line intercept method was utilized to measure woody cover (Sutter et al. 1994). Herbaceous vegetation was also monitored in six of the nine selected glades, using the line intercept method to measure cover and 1 m (3.3 ft) wide belt transects to collect density data (Sutter et al. 1994).

During 2006 and 2008, the CUPN (Rutledge 2006) and NatureServe relocated and resampled the majority of Sutter's (1994) glade transects (Figure 18) (Govus and Lyons 2009, Sutter et al. 2011). Woody cover was resampled at all nine of the original glades, while herbaceous cover was resampled at five of the six original glades (one transect could not be relocated) (Sutter et al. 2011). Additional glades were revisited for a brief, qualitative assessment to provide a snapshot of each glade's condition at that time (Govus and Lyons 2009).

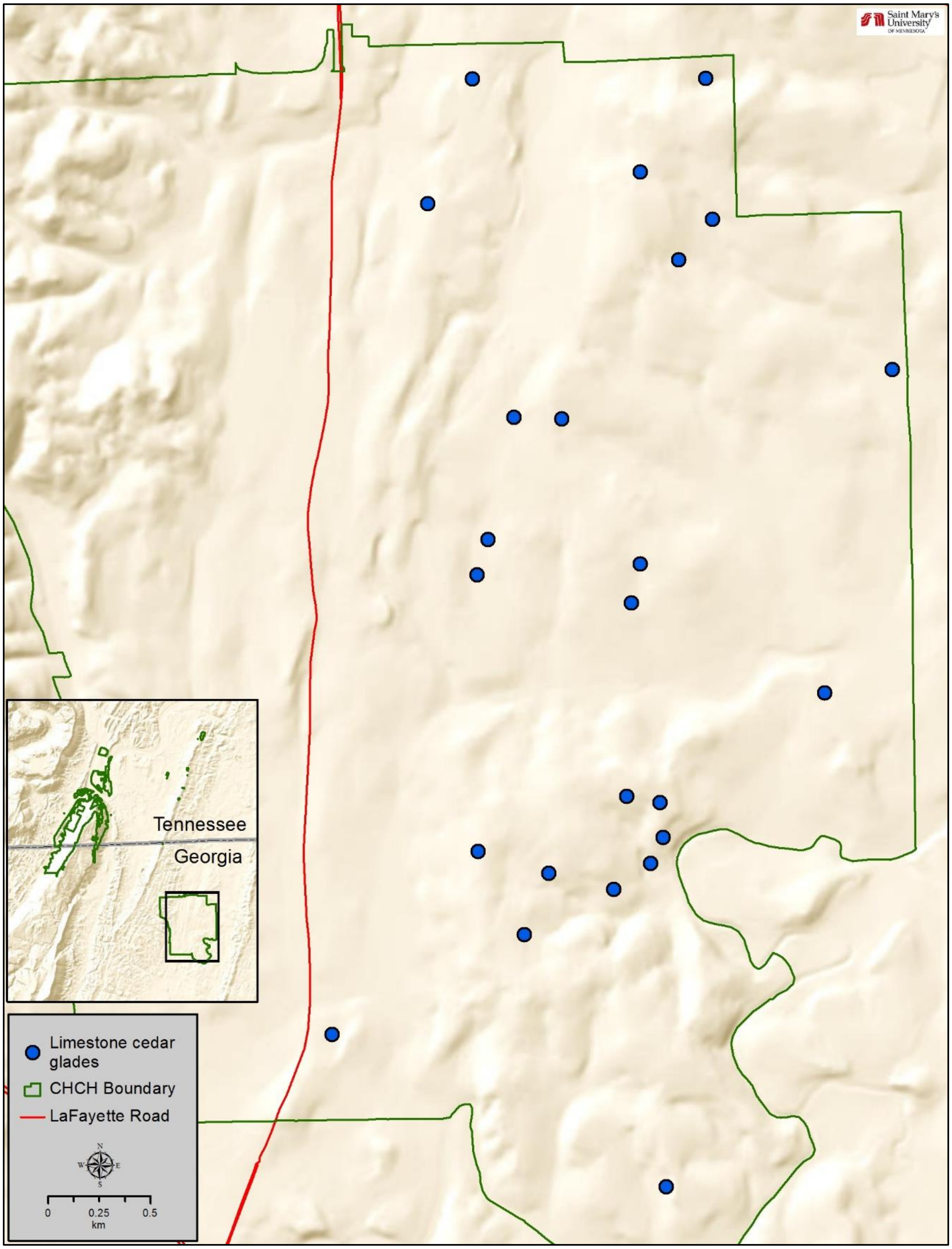

Figure 18. Limestone cedar glades at Chickamauga Battlefield relocated by the CUPN (Rutledge 2006) and sampled by NatureServe (Govus and Lyons 2009, Sutter et al. 2011).

Several sources described in the previous chapter were also utilized for this component. These are the Rogers et al. (1993) vegetation inventory and habitat mapping project at Chickamauga Battlefield, the NatureServe park-wide vegetation inventory and classification (Govus and White Jr. 2006), and the University of Georgia vegetation mapping (Jordan and Madden 2010). Only four of the plots sampled during the NatureServe inventory fell within limestone cedar glades (NatureServe 2007).

4.2.5. Current Condition and Trend

Species Richness

Together, multiple surveys of CHCH's cedar glades over time have documented a total of just over 275 species (Appendix D). Some of these species are not found in any other vegetation communities at the park. Thirteen of the plant species documented are considered endemic to cedar glades and 22 species (~8%) are exotic (Appendix D).

Glade Area

According to Sutter et al. (2011, p. 164), comparisons to a historical map of the Battlefield created by Edward Betts in 1892 and 1930s aerial photos "make it apparent that the areal extent of limestone glades at CHCH has become greatly reduced." However, no scientific data are currently available to support this conclusion. In the initial glade baseline survey, Sutter et al. (1994) did not measure total glade areas. However, baseline transect lengths were reported for the cedar glades where woody cover was sampled, along with lengths for sampling transects running perpendicular to the baseline. By multiplying the baseline length and the lengths of the shortest and longest sampling transects, an approximate range for the area of each glade can be found (Table 25). These may be slight overestimates, as some baseline transects stretched into the woods surrounding the glades to reach trees to mark the ends of the transects.

Table 25. Approximate glade area ranges, calculated from baseline length (in m) and shortest and longest sampling transect lengths (in m), for cedar glades sampled by Sutter et al. (1994). Area minimums were all rounded down to the nearest whole number and maximums were rounded up to the nearest whole number.

Glade	Baseline length	Shortest transect	Longest transect	Area range (m^2)
Glade 2	119.0	19	35	2,261-4,165
Glade 3A	54.4	9	35	489-1,904
Glade 3B	84.1	13	32	1,093-2,692
Glade 6	59.1	15	26	886-1,537
Glade 8A	115.2	12	36	1,382-4,148
Glade 8B	141.6	13	33	1,840-4,673
Glade 11	56.4	14	31	789-1,749
Glade 13 (first)	61.0	50	87	3,050-5,307
Glade 13 (second)	37.6	26	35	977-1,316
Glade 13 total	–	–	–	4,027-6,623
Glade 14	99.4	12	51	1,192-5,070

Table 25 (continued). Approximate glade area ranges, calculated from baseline length (in m) and shortest and longest sampling transect lengths (in m), for cedar glades sampled by Sutter et al. (1994). Area minimums were all rounded down to the nearest whole number and maximums were rounded up to the nearest whole number.

Glade	Baseline length	Shortest transect	Longest transect	Area range (m^2)
Glade 21	49.9	10	37	499-1,847
Glade 24A	86.0	34	62	2,924-5,332
Glade 24B	201.2	24	56	4,828-11,268

Estimated minimum areas ranged from 489-4,828 m^2 (0.1-1.2 ac). The largest estimated maximum area was 11,268 m^2 (2.8 ac). Although these are rough estimates, they may be compared to the NatureServe (2009) draft metric categories to provide some insight into glade condition. All of the cedar glades sampled by Sutter et al. (1994) had minimum areas in the good (400-1,200 m^2) or excellent (>1,200 m^2) categories. However, it is important to keep in mind that these are only a subset of the glades at the Battlefield, and no area information was provided by Sutter et al. (1994) for 14 additional glades. During later relocation efforts, Rutledge (2006) provided qualitative size descriptions for seven of the remaining glades. Although these descriptions cannot be assessed using the NatureServe (2009) metrics, they are presented below in Table 26.

Table 26. Qualitative size descriptions for unsampled cedar glades at Chickamauga Battlefield, according to Rutledge (2006).

Glade	Size	Glade	Size
Glade 1	medium	Glade 16	medium
Glade 4	small	Glade 17	medium
Glade 7	small	Glade 18	medium
Glade 9	small	Glade 19	small
Glade 10	small	Glade 20	small
Glade 12	small	Glade 22	medium
Glade 15	small (2 glades)	–	–

Some information on glade area may also be gleaned from park-wide vegetation mapping efforts. Completed in 2010, the most recent vegetation map is based on 2001 aerial imagery (Jordan and Madden 2010). According to this map, the Central Limestone Glade vegetation association covered 4.8 ha (11.8 ac) of the park (Jordan and Madden 2010). Individual mapped glade polygons ranged from 0.04 to 0.65 ha (0.10-1.6 ac, or 405-6,475 m^2) with a mean of 0.17 ha (0.42 ac, or 1,700 m^2). The extent of Central Limestone Glade vegetation, as mapped by Jordan and Madden (2010), is shown in Figure 19.

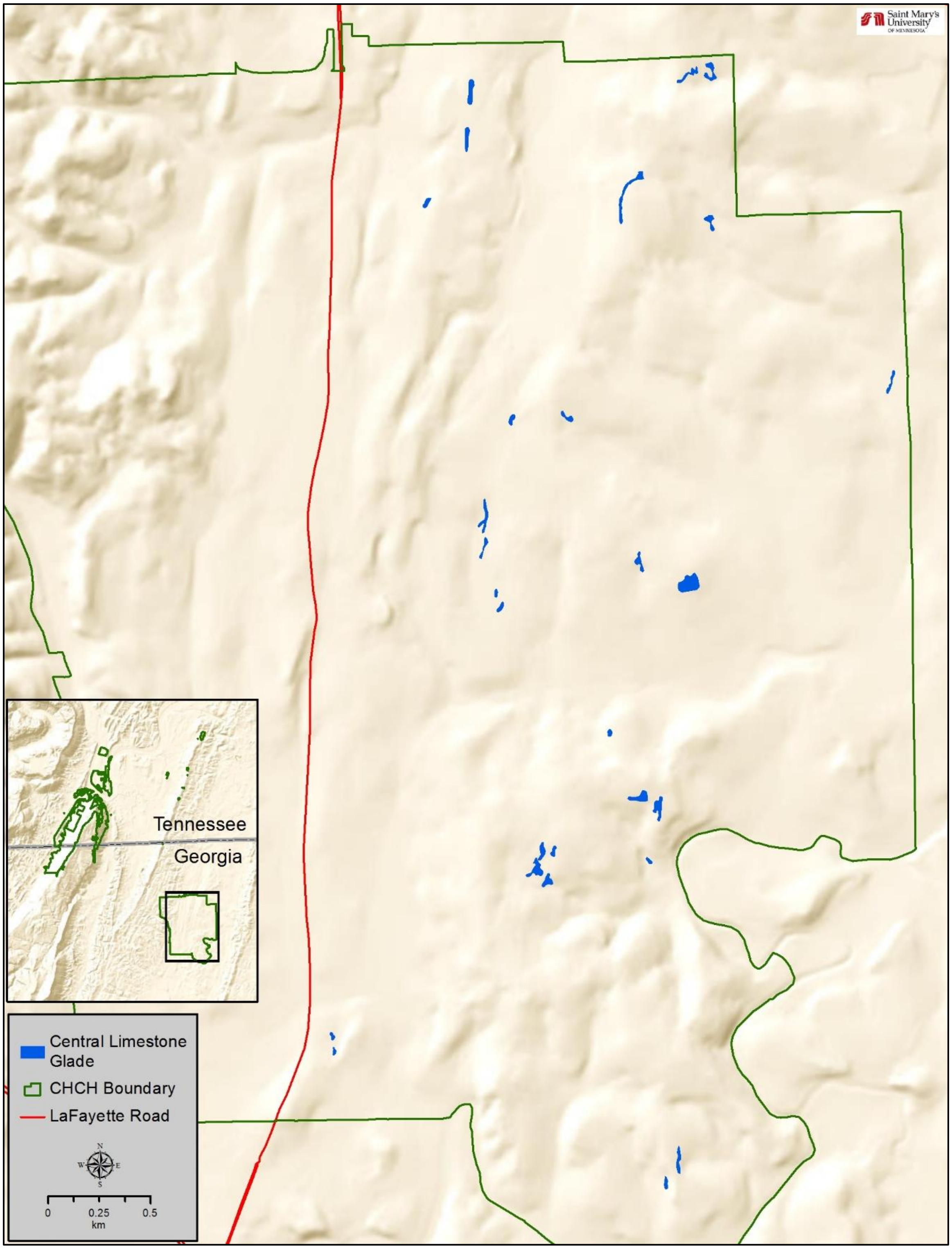

Figure 19. Central Limestone Glade vegetation, as mapped by Jordan and Madden (2010).

Percent Woody Cover

Percent woody cover was recorded along the same transects at CHCH with the same methodology in 1993 (Sutter et al. 1994) and 2006 (Govus and Lyons 2009, Sutter et al. 2011). Over this time period, woody percent cover of plants >1 m tall showed a statistically significant increase, with an average of 26% across the 11 glades sampled (Govus and Lyons 2009). The largest increase in an individual glade was just over 50%; only one glade experienced a slight decline (<1%) in percent woody cover (Table 27). Based on NatureServe's (2009) draft metrics, in 1993 the majority of sampled cedar glades (8 of 11) fell within the fair category (woody cover 25-50%). Only two glades were in the good category (woody cover 10-25%), with one glade in the poor category (woody cover >50%). By 2006, no glades remained in the good category. Only two were in the fair category and the remaining nine fell in the poor category.

Table 27. Change in mean percent woody cover by glade (modified from Govus and Lyons 2009; 1993 data were gathered by Sutter et al. 1994).

Glade	Mean percent cover 1993	Mean percent cover 2006	%change
Glade 2	44.21	83.55	39.34
Glade 3A	26.41	77.19	50.78
Glade 3B	58.85	77.31	18.46
Glade 6	44.1	43.65	-0.46
Glade 8A	45.86	80.67	34.81
Glade 8B	40.34	56.93	16.59
Glade 11	34.36	45.24	10.88
Glade 13	25.37	50.49	25.12
Glade 14	19.8	59.25	39.44
Glade 21	21.92	52.74	30.77
Glade 24A	40.97	59.85	18.87

The greatest increase by a single woody species was observed for eastern redcedar, with a mean increase across all glades of 11.37% (Table 28). The greatest increase in redcedar cover in an individual glade was 28.19%, which brought total redcedar cover in that glade to over 39% (Govus and Lyons 2009). Mean percent increases in additional species are shown in Table 28.

Table 28. Mean change in woody percent cover of plants >1 m from 1993-2008, by species (reproduced from Govus and Lyons 2009).

Species	# of glades present	Mean change in % cover
Juniperus virginiana	11	11.37
Ligustrum sinense	9	4.63
Cercis canadensis	6	2.76
Frangula caroliniana	8	2.26
Rhus aromatica	10	2.22
Pinus taeda	10	1.94
Ulmus alata	8	1.64
Fraxinus americana	7	1.62
Quercus stellata	8	0.75
P. echinata	4	0.68
P. virginiana	10	-0.28

Exotic Cover

Quantitative data on exotic plant cover in CHCH's cedar glades are somewhat limited. Only four NatureServe (2007) sampling plots fell within central limestone glade vegetation communities. While several exotic species were observed in the vicinity of these plots, exotics were not present within two of the four plots. In the remaining two plots, just one exotic species was observed, accounting for <0.1% cover (Table 29).

Table 29. Exotic species cover within NatureServe (2007) sampling plots in limestone cedar glades. Cover was recorded by strata: H = herbaceous, S = shrub.

Plot	Species	% cover (by strata)
CHCH16	*Nandina domestica* (H)	0.05
CHCH19	*Ligustrum sinense* (S)	0.05
CHCH21	None	0
CHCH51	None	0

In documenting woody cover along sampling transects, Sutter et al. (1994) and Govus and Lyons (2009) captured data on several exotic plant species. Between 1993 and 2006, the average increase in Chinese privet woody cover across all transects was 4.6%, with changes ranging from a slight decrease (-0.1%) to increases over 10% (Table 30) (Govus and Lyons 2009). Percent cover of this one exotic species alone exceeded 10% in three different glades. Based on NatureServe's (2009) exotic plants metrics and 2006 data, these three glades would fall in the poor category (exotic cover >10%). Four glades would fall in the fair category (exotic cover 2-10%), two in the good category (exotic cover <2%), and two in the excellent category (no exotics present).

Table 30. Mean change in percent cover of woody exotic species (>1 m tall) from 1993-2008 (modified from Govus and Lyons 2009; 1993 data were gathered by Sutter et al. 1994).

Glade	Species	Mean percent cover 1993	Mean percent cover 2006	% change
Glade 2	*Ligustrum sinense*	0.51	3.62	3.11
Glade 3A	*Ligustrum sinense*	0.14	0	-0.14
Glade 3B	*Ligustrum sinense*	0	2.37	2.37
Glade 6	*Ligustrum sinense*	0	4.28	4.28
Glade 8A	*Ligustrum sinense*	2.08	10.90	8.82
Glade 8B	*Ligustrum sinense*	2.32	3.78	1.46
Glade 11	*Ligustrum sinense*	4.11	14.27	10.16
Glade 13	None	0	0	0
Glade 14	*Lonicera japonica*	0	0.10	0.10
Glade 21	*Ligustrum sinense*	0	1.16	1.16
Glade 24A	*Ligustrum sinense*	3.72	14.20	10.48

Rutledge (2006) and Govus and Lyons (2009) reported qualitative descriptions of exotic species cover for additional glades at CHCH (Table 31). From these reports, it is clear that exotics are present within or around at least a half-dozen more glades, with populations at two glades (glades 1 and 10) that would likely put them in the fair or poor categories.

Table 31. Qualitative descriptions of exotic plant species presence for unsampled cedar glades at Chickamauga Battlefield, according to Rutledge (2006) and/or Govus and Lyons (2009).

Glade	Exotics
Glade 1	Substantial privet population
Glade 4	Japanese honeysuckle present
Glade 7	Small amount of privet on perimeter
Glade 9	Some pressure from exotics
Glade 10	Choked with privet
Glade 12	Not under pressure from exotics
Glade 15	Small amount of privet
Glade 16	Privet on edges and in middle
Glade 17	Surrounded by large, aggressive privet stand
Glade 18	Privet on edges and in middle
Glade 19	Not under pressure from exotics
Glade 20	Some pressure from exotics
Glade 22	Not under pressure from exotics

Threats and Stressor Factors

The NRCA project team identified the following threats and stressors to the park's limestone cedar glades: invasive/exotic species, fire suppression, climate change, and deer populations. The shallow soils and extreme moisture fluctuations of cedar glades have protected them from invasion by many plants, both exotic and native woody species (Sutter et al. 1994, Govus and White Jr. 2006). As recently as the early 1990s, the establishment of exotics in undisturbed glades was considered rare (Sutter et al. 1994). However, exotic species such as Chinese privet (Figure 20) have increased within and around cedar glades in recent decades and appear to pose the greatest threat to the integrity of these unique communities (Govus and White Jr. 2006, Govus and Lyons 2009).

Figure 20. Chinese privet, an exotic species that poses the greatest threat to the integrity of cedar glades in CHCH (NPS photo).

Aggressive exotic species can outcompete native plants in the glades and alter ecological functions (NatureServe 2009). Chinese privet has increased to the point that as of 2008, it was the third most abundant woody species by percent cover in sampled CHCH glades (Govus and Lyons 2009). Exotic species may be inadvertently introduced to the cedar glades through trails (a horse trail passes through at least one glade in the park) and other visitor traffic, as visitors often find the open nature of the glades appealing (Barnett-Lawrence et al. 1994, Sutter et al. 1994). To date, 22 exotic species have been documented in CHCH's cedar glades; thirteen are considered invasive and six are ranked as a severe or significant threat to native plant communities (Table 32) (TN-EPPC 2009).

Table 32. Exotic invasive plant species confirmed in CHCH's hardwood forests and considered a severe or significant threat in Tennessee (TN-EPPC 2009).

Scientific name	Common name	Growth form	Threat
Albizia julibrissin	silktree, mimosa	tree	severe
Lespedeza cuneata	Chinese lespedeza	forb	severe
Ligustrum sinense	Chinese privet	shrub	severe
Lonicera japonica	Japanese honeysuckle	vine	severe
Sorghum halepense	Johnson grass	grass	severe
Verbascum thapsus	common mullein	forb	significant

The encroachment of both exotic and native woody species upon many of the park's cedar glades is most likely related to fire suppression (Sutter et al. 1994, Govus and White Jr. 2006). It is believed that, prior to European settlement, the glades and surrounding woodlands would have burned occasionally (approximately once every 13-25 years), which would help maintain the open appearance of the glades and surrounding woodlands (Govus and White Jr. 2006, Govus and Lyons 2009). Fire would help to reduce woody cover, decrease plant litter, and stimulate growth of grasses and forbs in cedar glade communities (Sutter et al. 1994). It could also discourage woody encroachment from surrounding woodlands, particularly of eastern redcedar, which is very sensitive to fire (Tom Govus, NatureServe Botanist/Vegetation Ecologist, written communication, 29 August 2016). Since the establishment of CHCH over a century ago, fire has largely been suppressed throughout the park (Govus and Lyons 2009). This is likely contributing to the increase in woody cover within glades, which has been linked to declines in herbaceous glade endemic species (Sutter et al. 1994, Govus and Lyons 2009). The reintroduction of fire has been recommended to improve and maintain habitat quality and overall condition of the Battlefield's cedar glades (Govus and Lyons 2009).

During the 1990s, Rogers (1996) concluded that negative impacts from deer were not evident in CHCH's cedar glade vegetation. However, evidence of browsing was observed on seven glade endemic species, with deer appearing to favor legume species (Rogers 1996). Given the recently increased threats to glade endemics from encroaching woody cover and exotic species, it is possible that deer browsing may now have more serious impacts. A re-investigation of this possibility is warranted, particularly given the current high deer densities at Chickamauga Battlefield (Govus, written communication, 29 August 2016).

Climate, in the form of extreme moisture conditions, has played a key role in the formation and maintenance of limestone cedar glade communities (Sutter et al. 1994, Baskin and Baskin 2003). Over the next century, temperatures are projected to increase across the southeast as a result of global climate change (Carter et al. 2014), which may influence precipitation patterns, water availability, and other aspects of the hydrological cycle (Bates et al. 2008). Projections of future precipitation patterns in the southeast under climate change are uncertain; some areas may experience wetter conditions, others drier conditions, and some little change (Carter et al. 2014). If seasonal moisture conditions become more extreme (e.g., more heavy precipitation in the winter and more droughts in the summer), this may favor the cedar glades over encroaching woodlands. However, if seasonal precipitation patterns were to shift so that conditions are occasionally wetter in the summer or drier in the winter, cedar glades could be negatively impacted. Warmer temperatures may also allow invasive plants and other pests (e.g., insects, diseases) to expand their ranges and potentially their impact.

Data Needs/Gaps

The digital mapping and measurement of the park's limestone cedar glades in a GIS would facilitate a more accurate assessment of glade areas. This would also allow for the easy detection of changes in area over time. Consistent monitoring of CHCH glades is needed to investigate the rate and impacts of woody succession (Sutter et al. 1994), as well as levels of exotic species invasion. A better understanding of succession and woody species encroachment will help in making management decisions regarding cedar glade maintenance and protection. Govus and Lyons (2009) suggested the creation of a management plan to address the habitat degradation currently occurring in glades, as well as a photo monitoring program, which would provide a quick and inexpensive way to document general glade condition.

Monitoring of glade endemics and other rare plants would help to identify any trends in the populations and better protect these species (Sutter et al. 1994). Given the existence of these unique plant species in the glades, surveys should be conducted for rare and unique invertebrates and other organisms (Sutter et al. 1994). This could provide a clearer picture of the role glades play within the larger ecosystem.

Overall Condition

Species Richness

The *Significance Level* for species richness was assigned a 3. Over time, survey and sampling efforts in CHCH's cedar glades have identified just over 275 total plant species. Some of these are found nowhere else in the park, and several are endemic to limestone cedar glades. Currently, there is no evidence that species richness is declining, resulting in a *Condition Level* of 1 for low concern. However, changes in vegetation structure (e.g., increasing woody cover) appear to be threatening many glade endemic species populations (Govus and Lyons 2009), and concern over this measure is likely to grow if woody species encroachment continues.

Glade Area

The *Significance Level* for glade area was assigned a 2. The area of CHCH's cedar glades appears to have declined over the past century (Sutter et al. 2011), but there are currently no hard data available to support this conclusion. According to rough estimates using baseline and transect lengths from Sutter et al. (1994), sampled glades ranged in size from approximately 489 to 11,268 m^2 (0.5-2.8 ac). Based on these estimates, the sampled glades would all have fallen in the NatureServe's (2009) excellent or good categories. However, these estimates are over 20 years old, and woody encroachment may be reducing their size. Since no more recent information is available regarding glade area, a *Condition Level* cannot be assigned for this measure at this time.

Percent Woody Cover

The *Significance Level* for percent woody cover was assigned a 3. Between 1993 and 2006, percent woody cover of plants >1 m tall showed a statistically significant increase, averaging 26% across the sampled glades (Govus and Lyons 2009). Govus and Lyons (2009) found a clear correlation between the increase in woody cover and a decline in glade endemic species density. As of 2006, woody cover exceeded 50% at nine of 11 sampled glades, and was over 75% at four of these glades (Govus and Lyons 2009). Based on NatureServe's (2009) draft metrics, nine of the CHCH sampled glades fell in the poor category with only two in the fair category. As a result, this measure is of high concern (*Condition Level* = 3).

Invasive/Exotic Cover

The *Significance Level* for invasive/exotic cover was also assigned a 3. Historically, the shallow soils and extreme moisture fluctuations of cedar glades largely protected them from invasion by exotic plants (Sutter et al. 1994, Govus and White Jr. 2006). However, the re-sampling of Sutter et al.'s (1994) glade transects by Govus and Lyons (2009) showed that at least one exotic species, Chinese privet, has increased dramatically in many of CHCH's cedar glades (Table 29). While further investigation of additional glades and for other exotic species would provide more insight into the condition of this measure, the increase in privet alone is enough to warrant moderate concern (*Condition Level* = 2).

Weighted Condition Score

The *Weighted Condition Score* for CHCH's limestone cedar glades is 0.67, indicating moderate concern. Given the increases in woody cover and Chinese privet detected by Govus and Lyons (2009), the condition of this resource is considered to be declining. Since information is limited for some measures (e.g., glade area) and the most recent sampling of glade transects occurred in 2008, a moderate confidence border has been applied.

Table 33. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's limestone cedar glades.

Measures	Significance Level	Condition Level	WCS = 0.67
Species Richness	3	1	
Glade Area	2	N/A	
Percent Woody Cover	3	3	
Invasive/Exotic Cover	3	2	

4.2.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Rickie White, NatureServe Ecologist
- Tom Govus, NatureServe Botanist/Vegetation Ecologist

4.2.7. Literature Cited

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4.3. Wetlands

4.3.1. 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). Wetlands provide critical ecosystem functions, including surface water storage, groundwater recharge, nutrient cycling, and sediment trapping (Roberts and Morgan 2009). Wetlands also provide valuable habitat for a variety of plants and wildlife, contributing greatly to overall biodiversity (Roberts and Morgan 2009). At CHCH, temporary/ephemeral wetlands are particularly important for amphibian breeding habitat and as water sources for other wildlife (Govus and White Jr. 2006, Roberts and Morgan 2009). Despite their critical role in biodiversity and ecosystem functions, 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).

A wetland near Alexander's Bridge at Chickamauga Battlefield (SMUMN GSS photo by Kathy Allen).

The majority of wetlands at CHCH are forested, with common tree species including sweetgum, red maple, willow oak, and green ash (*Fraxinus pennsylvanica*) (Roberts and Morgan 2009). Floodplain forests that receive regular flooding have nutrient-rich soils that support a diverse herbaceous layer (Roberts and Morgan 2009). An excellent example of this at CHCH is the large wetland complex (63.5 ha [157 ac]) in the southwest corner of Chickamauga Battlefield, the majority of which lies between Wilder and Glen-Viniard Roads. The Battlefield also contains a rare wetland type known as a "willow oak pond" near Alexander's Bridge (Govus and White Jr. 2006). Some of the old-growth willow oaks here were likely present during the Civil War battle in 1863 (Barnett-Lawrence et al. 1994). This wetland type is associated with ponds that form as a result of natural subsidence (i.e., sinking of the ground) in limestone or sandstone substrates (NPS 1987, Govus and White Jr. 2006).

Vegetation classification and mapping efforts at CHCH identified 10 wetland vegetation community types that occur within park boundaries (Govus and White Jr. 2006). These types (or "associations") and the prominent or characteristic species in CHCH stands are presented in Table 34.

Table 34. Wetland vegetation associations documented within CHCH and the most prominent plant species in each (Govus and White Jr. 2006).

Association	Prominent plant species
Cumberland Plateau Willow Oak Pond	willow oak, green ash, sweetgum, possumhaw (*Ilex decidua*), smallspike false nettle (*Boehmeria cylindrica*), southern waxy sedge (*Carex glaucescens*)
Box-elder Floodplain Forest	box-elder (*Acer negundo*), Chinese privet
Sycamore - Silver Maple Calcareous Floodplain Forest	American sycamore, box-elder, silver maple, spicebush (*Lindera benzoin*), possumhaw, sedges (*Carex* spp.)
Rich Levee Mixed Hardwood Bottomland Forest	sugarberry, American sycamore, American hornbeam (*Carpinus caroliniana*), Indian wood-oats (*Chasmanthium latifolium*)
Southern Interior Oak Bottomland Forest	Shumard's oak, southern shagbark hickory, sweetgum, Virginia creeper (*Parthenocissus quinquefolia*), poison ivy
Black Willow Riparian Forest	black willow (*Salix nigra*)
Successional Sweetgum Floodplain Forest	sweetgum
Piedmont Small Stream Sweetgum Forest	sweetgum, tulip tree
Chinese Privet Temporarily Flooded Shrubland	Chinese privet
Smartweed-Cutgrass Beaver Pond	smartweeds (*Persicaria* spp.), blunt spikesedge (*Eleocharis obtusa*), rice cutgrass (*Leersia oryzoides*), marsh seedbox (*Ludwigia palustris*)

4.3.2. Measures

- Number and acreage of wetlands
- Plant species richness
- Exotic species cover

4.3.3. Reference Conditions/Values

As with previous components, the ideal reference condition would be the appearance and condition of wetlands at the time of the Civil War battles. However, little information is available regarding wetlands at that time. The park and NPS as a whole has an objective of no net loss of wetlands (NPS 2016). The information presented here can serve as a baseline for future assessments; best professional judgment will be used to assess current condition at this time.

4.3.4. Data and Methods

Roberts and Morgan (2009) conducted a baseline wetlands inventory at CHCH from 2005-2007. 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 2009). 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 2009).

Additional sources for this component already described in previous chapters are the NatureServe vegetation inventory and classification (Govus and White Jr. 2006), the University of Georgia vegetation mapping (Jordan and Madden 2010), and CUPN forest vegetation monitoring (Moore and Leibfreid 2013, CUPN 2016). Only seven of the plots sampled by NatureServe (2007) and six plots established by the CUPN fell within wetland communities.

4.3.5. Current Condition and Trend

Number and Acreage of Wetlands

Prior to the 2005-2007 baseline wetlands inventory, Roberts and Morgan (2009) conducted a preliminary investigation of National Wetlands Inventory (NWI) data for CHCH. According to the NWI database, approximately 18 wetlands occurred within park boundaries (Roberts and Morgan 2009). 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, NWI classification is more accurate in open landscapes (Roberts and Morgan 2009) and can have difficulties identifying forested wetlands, such as those common in CHCH. Also, wetlands smaller than 0.4 ha (1 ac) are commonly missed due to the scale of the imagery used by the NWI (Roberts and Morgan 2009).

Roberts and Morgan (2009) identified a total of 179 wetlands across CHCH's units, totaling an estimated 113 ha (279 ac) (Table 35, Figure 21, Figure 22). The large wetland complex in the southwest corner of Chickamauga Battlefield accounted for 63.5 ha (157 ac) of this total area (Roberts and Morgan 2009). With this complex included, the average wetland size for CHCH is 0.63 ha (1.56 ac); excluding the complex, average wetland size falls to 0.28 ha (0.69 ac) (Roberts and Morgan 2009). The majority of wetlands (76%) were forested, with a small number of herbaceous (emergent vegetation), shrub, and riverine wetlands (Table 35) (Roberts and Morgan 2009).

Table 35. Wetland area in hectares within CHCH boundaries by type (Roberts and Morgan 2009). Abbreviations in parentheses represent Cowardin wetland classification codes used in the Roberts and Morgan (2009) report.

Wetland type	Number	Approx. area
Forested (PFO)	136	108.26
Shrub (PSS)	4	0.09
Emergent (PEM)	23	4.46
Riverine (R4)	16	0.18
Total wetlands	**179**	**112.99**

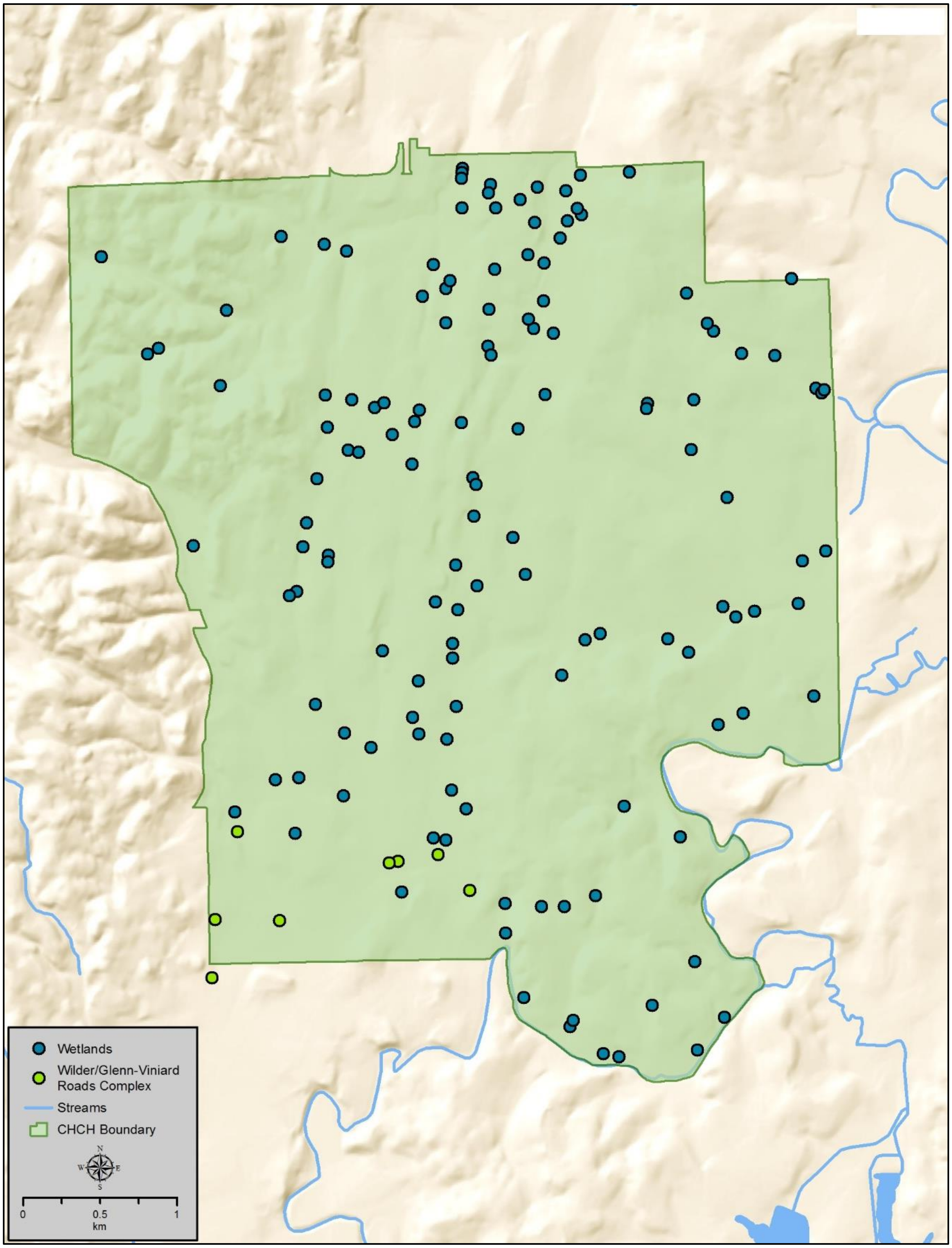

Figure 21. Locations of wetlands documented at Chickamauga Battlefield during the baseline survey by Roberts and Morgan (2009). Green circles indicate wetlands that are part of the larger Wilder/Glenn-Viniard Roads complex in the park's southwest corner.

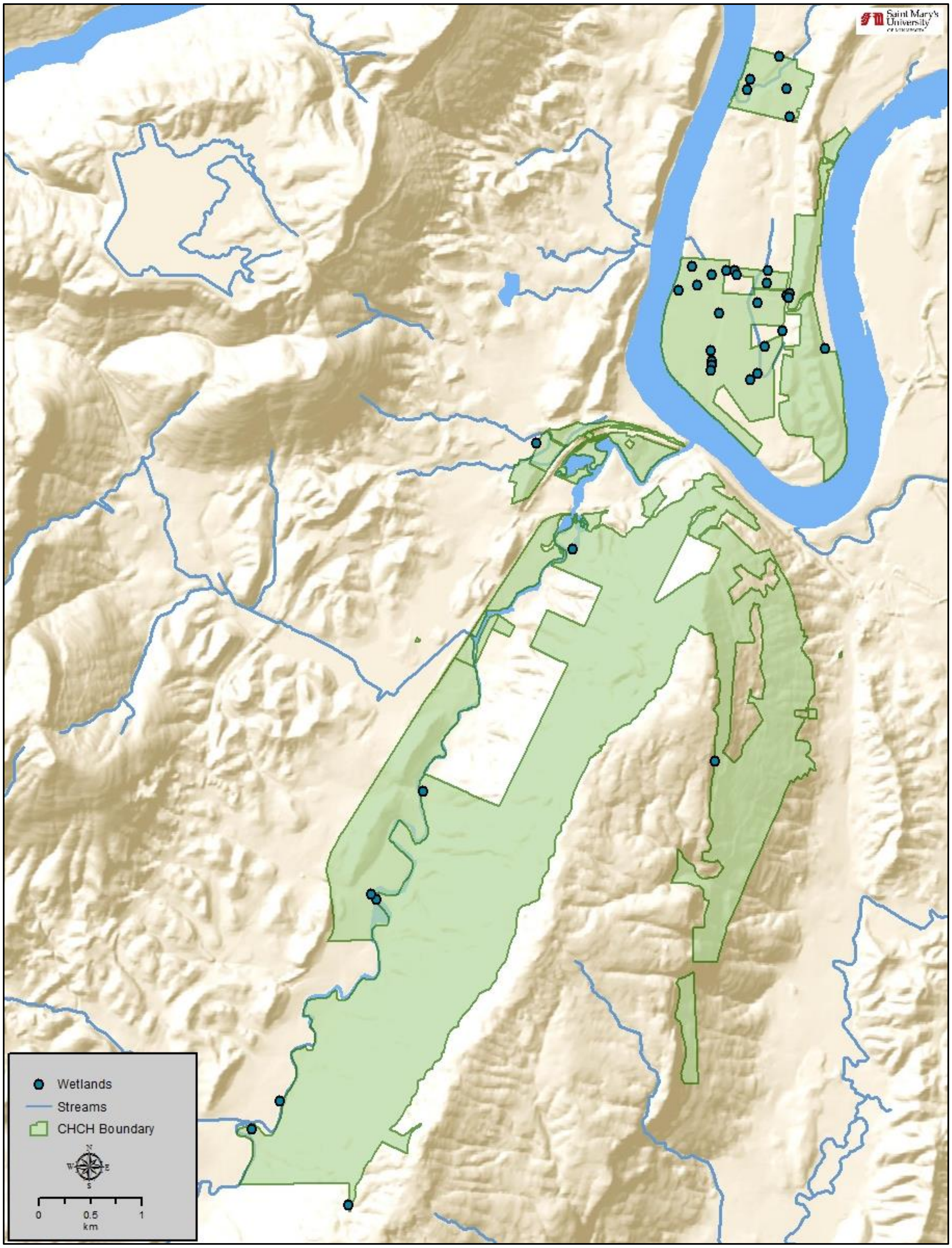

Figure 22. Locations o f wetlands documented at Lookout Mountain and Moccasin Bend during the baseline survey by Roberts and Morgan (2009).

Plant Species Richness

During the baseline wetlands inventory of CHCH, Roberts and Morgan (2009) recorded 85 plant species in park wetlands (Appendix E); nine (10.6%) of the species identified were exotic (Roberts and Morgan 2009). NatureServe (2007) documented 150 plant species in seven sampling plots within wetland vegetation communities, with an average of 33.1 species per 1-ha plot (0.3 species/100 m^2). Only eight of these species (3.6%) were exotic. Lastly, CUPN (2016) monitoring has identified 123 plant species in six forest plots that would be considered wetlands, with 17 of those species (13.8%) being exotic. The average number of species per 400-m^2 plot was 42.0, which is equivalent to 10.5 species/100 m^2 (CUPN 2016). Between all three surveys, a total of just under 250 plant species have been documented in CHCH's wetlands (Appendix E); 25 species (10%) are considered exotic species.

Exotic Species Cover

Roberts and Morgan (2009) documented exotic species presence at each wetland but did not record percent cover. Of the 179 wetlands identified at CHCH, only 21 had no exotic species present (i.e., 0% cover) (Table 36). The most common exotic species, Chinese privet, was found at 117 of 179 wetlands (Roberts and Morgan 2009), which suggests it is widespread in the park's wetlands.

Table 36. Exotic plant species documented in CHCH wetlands, along with the number of wetlands where each was found (Roberts and Morgan 2009).

Species	# of wetlands
Chinese privet	117
Japanese stiltgrass	42
Japanese honeysuckle	24
tall fescue (*Schedonorus arundinaceus*)	11
barnyard grass (*Echinochloa crus-galli*)	2
kudzu	1
Chinese lespedeza (*Lespedeza cuneata*)	1
Asiatic dayflower (*Commelina communis*)	1
No exotic species	21

Of the six NatureServe (2007) plots for which species cover was recorded, exotic species were absent from two (Table 37). In plots where exotic species were found, total exotic cover per plot ranged from 2% to 15% (NatureServe 2007). The overall mean for all plots (including 0% cover plots) was 4.9%.

Table 37. Exotic species cover within NatureServe (2007) sampling plots in wetland communities. Cover was recorded by strata: H = herbaceous, S = shrub, V = vine.

Plot	Species	% cover (by strata)	Total % cover
CHCH03	*Ligustrum sinense* (S)	1.5%	–
	Persicaria hydropiper (H)	0.5%	**2%**
CHCH36	*Ligustrum sinense* (S)	1.5%	–
	Euonymus fortunei (S)	0.5%	–
	Poa annua (H)	0.5%	**2.5%**
CHCH46	*Ligustrum sinense* (S)	7.5%	–
	Microstegium vimineum (H)	1.5%	–
	Lespedeza cuneata (H)	0.5%	–
	Lonicera japonica (V)	0.5%	**10%**
CHCH52	None	0%	**0%**
CHCH53	None	0%	**0%**
CHCH54	*Ligustrum sinense* (S)	7.5%	–
	Microstegium vimineum (H)	7.5%	**15%**

During forest vegetation monitoring, the CUPN (2016) recorded estimated percent cover for each species present per plot. Multiple exotic species were present in all of the six plots within wetland forest communities (Table 38). Total exotic species cover per plot ranged from 26% to 170% (totals above 100% are possible due to the presence of exotics in different vegetation strata) (CUPN 2016). Exotic cover range was below 50% in just one plot and exceeded 100% in three plots (Table 38). Mean minimum cover across all plots was 72.8% and mean maximum was 102.3%.

Table 38. Exotic species cover within CUPN (2016) monitoring plots in wetland communities, 2011-2015.

Plot	Species	% cover (by strata)	Total % cover
LOOK001	*Ligustrum sinense*	50-75%	–
	Lonicera japonica	0-1%	–
	Microstegium vimineum	trace	–
	Poa annua	trace	–
	Euonymus fortunei	trace	**50-76%**
LOOK002	*Ligustrum sinense*	25-50%	–
	Microstegium vimineum	1-2%	–
	Lonicera japonica	0-1%	–
	Lonicera maackii	0-1%	–
	Cardamine hirsuta	trace	–
	Celastrus orbiculatus	trace	**26-54%**

Table 38 (continued). Exotic species cover within CUPN (2016) monitoring plots in wetland communities, 2011-2015.

Plot	Species	% cover (by strata)	Total % cover
LOOK007	*Ligustrum sinense*	75-95%	–
	Microstegium vimineum	10-25%	–
	Stellaria media	1-2%	–
	Lonicera japonica	0-1%	–
	Lonicera maackii	0-1%	–
	Persicaria posumbu	trace	–
	Celastrus orbiculatus	trace	–
	Geranium dissectum	trace	**86-124%**
LOOK014	*Ligustrum sinense*	50-75%	–
	Euonymus fortunei	75-95%	–
	Persicaria posumbu	trace	–
	Dioscorea oppositifolia	trace	–
	Microstegium vimineum	trace	–
	Murdannia keisak	trace	**125-170%**
CHIC001	*Ligustrum sinense*	95-100%	–
	Albizia julibrissin	1-2%	–
	Lonicera japonica	2-5%	–
	Nandina domestica	0-1%	–
	Rosa multiflora	1-2%	**99-110%**
CHIC003	*Ligustrum sinense*	50-75%	–
	Lonicera japonica	1-2%	–
	Microstegium vimineum	0-1%	–
	Duchesnea indica	0-1%	–
	Rumex crispus	0-1%	**51-80%**

Threats and Stressor Factors

Threats to CHCH's wetlands include exotic plant species and climate change. Roberts and Morgan (2009) documented exotic species in 158 of CHCH's 179 wetlands. A total of 25 exotic plant species have been confirmed in CHCH's wetland communities to date (Appendix E). Fourteen of these are considered invasive by TN-EPPC, and ten species are considered a severe threat to native communities (Table 39) (TN-EPPC 2009). These aggressive species can outcompete and replace native plants (Figures 23 & 24) (Govus and White Jr. 2006, Moore and Leibfreid 2013). Research from a southern Tennessee forest suggests that dense coverage of Japanese stiltgrass (*Microstegium vimineum*), one of the more common exotic species in CHCH wetlands, can inhibit woody species regeneration and may impact woody species richness (Oswalt et al. 2007). Invasive exotic plants can also alter ecological processes (e.g., nutrient cycling, hydrology, fire regimes) (Mack et al. 2000).

Table 39. Exotic invasive plant species confirmed in CHCH's hardwood forests and considered a "severe threat" in Tennessee (TN-EPPC 2009).

Scientific name	Common name	Growth form
*Albizia julibrissin**	silktree, mimosa	tree
Celastrus orbiculatus	Asian bittersweet	vine
Dioscorea oppositifolia	Chinese yam	vine
*Lespedeza cuneate**	Chinese lespedeza	forb
Ligustrum sinense	Chinese privet	shrub
Ligustrum vulgare	European/common privet	shrub
Lonicera japonica	Japanese honeysuckle	vine
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	grass
Pueraria montana var. *lobate**	kudzu	vine
Rosa multiflora	multiflora rose	shrub

* These species are primarily dominant in uplands and may not impact wetlands (Rickie White, NatureServe Ecologist, written communication, 29 August 2016).

Figure 23. Chinese privet invading CHCH wetlands (photo from Roberts and Morgan 2009).

Figure 24. Japanese stiltgrass invading CHCH wetlands (photo from Roberts and Morgan 2009).

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, which threaten CHCH's wetland 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 or temporary wetlands is strongly influenced by weather events and climate, they are particularly sensitive to climate change (Brooks 2009). With warming temperatures, it is likely that these wetlands 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 ephemeral pools and other small wetlands. For further discussion of climate change's potential impacts on trees, which would affect forested wetlands, see the threats and stressors section of Chapter 4.1.5.

<u>Data Needs/Gaps</u>

The majority of wetlands at CHCH are small (<0.5 ha), and small wetlands have received little research attention (Roberts and Morgan 2009). Many of these wetlands also lie within an upland landscape; the value of these wetlands to wildlife, particularly during extended dry periods, should be further investigated (e.g., with remote cameras, live trapping, and/or track counts).

The willow oak pond communities that occur at CHCH are somewhat rare and should be monitored to prevent any damage or decline in these areas (Govus and White Jr. 2006). These and other high-quality wetland community examples at the park (e.g., the Wilder/Glen-Viniard Roads complex, Sycamore - Silver Maple floodplain forests at Lookout Creek) provide excellent opportunities for research in a variety of wetland topics, from hydrology and soils to vegetation and wildlife (Govus and White Jr. 2006, Roberts and Morgan 2009).

Overall Condition

Number and Acreage of Wetlands

The project team assigned this measure a *Significance Level* of 3. A comprehensive baseline survey of CHCH identified a total of 179 wetlands across park units, totaling an estimated 113 ha (279 ac) (Roberts and Morgan 2009). Given the wetland losses that have occurred throughout the U.S. since European settlement (Dahl 1990, 2000), it is likely that the number and acreage of wetlands within CHCH today is lower than at the time of the Civil War battles. However, a remarkable number of wetlands still occur within CHCH, given its history and location. This measure is currently of low concern (*Condition Level = 1*).

Plant Species Richness

A *Significance Level* of 2 was assigned for this measure. A total of just under 250 plant species have been documented during various surveys of CHCH's wetlands (Appendix E). Less than 10% of these are exotic species. At this time, there is no evidence to suggest that a loss in overall species richness is a concern for park wetlands. However, the most recent monitoring (2011-2015) by the CUPN (2016) found a higher percentage of exotic plant species (13.8%) than earlier surveys (9.5% by Roberts and Morgan [2009], 3.6% by NatureServe [2007]). Therefore, this measure is currently of low concern (*Condition Level = 1*).

Exotic Species Cover

This measure was assigned a *Significance Level* of 3. Roberts and Morgan (2009) found that exotic plant species were widespread in CHCH wetlands. In NatureServe (2007) sampling plots within wetland communities, exotic species cover was relatively low, ranging from 2-15%. However, CUPN (2016) monitoring from 2011-2015 found exotic species cover ranges in forested wetland plots ranging from 26-170%, with the maximum end of these ranges exceeding 100% in three of six monitoring plots. While NatureServe (2007) and CUPN (2016) data cannot be directly compared due to slight differences in methodologies and sampling locations, the large difference in exotic cover between the two surveys is a serious cause for concern. As a result, this measure is assigned a *Condition Level* of 3.

Weighted Condition Score

The *Weighted Condition Score* for CHCH's wetlands is 0.58, which indicates moderate concern. This level of concern is primarily due to the apparent increase in exotic species cover within park wetlands. Although the exotic species measure appears to be showing a decline, an overall trend could not be assigned for this component due to a lack of historical wetland data that would allow for detection of changes in the number and acreage of wetlands over time.

Table 40. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's wetlands.

Measures	Significance Level	Condition Level	WCS = 0.58
Number and Acreage of Wetlands	3	1	
Plant Species Richness	2	1	
Exotic Species Cover	3	3	

4.3.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager
- Rickie White, NatureServe Ecologist

4.3.7. Literature Cited

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4.4. Cave Bats

4.4.1. Description

Bat species represent excellent bioindicators of an ecosystem's overall health (O'Shea et al. 2003). Additionally, bats play integral roles in terrestrial and subterranean ecosystems, as they serve as pollinators, aid in the control of insect populations, and transfer vital surface nutrients to caves (Baker et al. 2015, Thomas 2015). According to Boyles et al. (2011, p. 42), "bats are among the most overlooked, yet economically important, nondomesticated animals in North America, and their conservation is important for the integrity of ecosystems and in the best interest of both national and international economies." Bats play a critical role in controlling nocturnal insect populations, and their foraging efforts are responsible for reducing several agricultural and forest pest populations (Thomas 2015), thus saving farmers and foresters money that would otherwise need to be spent on pest-control applications (Boyles et al. 2011). Recent threats to bat populations, particularly the sudden arrival of white-nose syndrome (WNS) and its rapid spread across the Eastern U.S., have been well publicized. Unfortunately, the disease is still poorly understood and continues to spread west across North America, reaching as far west as Washington State in 2016 (NPS 2016b). While the impacts of WNS are far-reaching, fluctuations in bat populations in the past decade have not been caused by WNS exclusively. Fluctuations in bat populations can be also be tied to climate change, changes in water quality, agricultural intensification, loss and fragmentation of forests, fatalities at wind turbines, disease, and pesticide use (Jones et al. 2009).

Species with specialized roosting requirements are important to monitor, as they are particularly vulnerable to habitat loss and local extirpation. Cave-roosting bats, in particular, are vitally important to nutrient-poor cave ecosystems, as these species are responsible for importing large amounts of organic material into the cave ecosystem they roost or hibernate in. These organic materials aid in supporting other cave communities and populations; the specialized cave invertebrate community is one group of organisms that rely heavily on the organic materials that bats bring into caves (Thomas 2015).

CHCH has several locations that provide cave-roosting and hibernating bats with necessary habitats (Figure 25); this also includes surface habitats (e.g., tree roosts). Cave bats were selected by the CUPN as a high priority Vital Sign for long-term monitoring, primarily due to their high importance to the cave ecosystems, their role in controlling insect populations, and because many of the cave bat species in the CUPN are species of conservation concern (Leibfreid et al. 2005). Monitoring of these caves during both the summer roosting season and the winter hibernation period provides managers with critically important information that provides insight regarding current condition and that will help understand long-term trends in the future.

Figure 25. A hibernating cluster of Indiana bats observed in a CUPN park (NPS Photo by Steve Thomas).

4.4.2. Measures

- Species richness
- Summer cave-roosting bat abundance
- Hibernating bat abundance

4.4.3. Reference Conditions/Values

Due to the varying metrics chosen for this assessment, there cannot be a single reference condition for the component as a whole. The reference condition for the species richness measure will be the presence of four species, as this is the number of species that has been observed during CUPN monitoring in the park from 2013-present. The species that have been detected in CHCH during these monitoring efforts are the tricolored bat (*Perimyotis subflavus*; formerly the eastern pipistrelle [*Pipistrellus subflavus*]), northern long-eared bat (*Myotis septentrionalis*), the Indiana bat, and the gray bat.

The reference conditions for the summer cave-roosting bat and hibernating bat abundance measures are currently undefined, as those measures are actively being monitored and studied in order to gain a better understanding of the current cave bat population. When several years of data become available after quality assurance and quality control checks, an approximate reference condition can be assigned to these measures.

4.4.4. Data and Methods

Ford et al. (2004) conducted bat surveys in CHCH during the summer and fall of 2002 and the spring of 2003 in order to: document what bat species were in the park, observe what foraging habitats were utilized, quantify the value that park caves had as hibernacula, and to provide presence and absence data on bat species in northwest Georgia. Survey methodologies included acoustical surveys (using Anabat II acoustical detectors), mist-netting, and harp trapping. Anabat II survey sites in the summer of 2002 included 11 riparian sites, 12 upland forest sites, and 11 upland field sites, and each site was surveyed for one 20-minute period between sunset and midnight (Ford et al. 2004). Additional acoustical surveys were conducted at cave entrances in the fall of 2002 and again during the spring of 2003. Mist-netting occurred at five riparian locations in CHCH during the summer of 2002 and two cave entrances in the fall of 2002. Harp trapping occurred at six cave entrances during the fall of 2002; all species that were captured using mist nets or harp traps were sexed, assigned an age estimate, and identified to species (Ford et al. 2004).

CUPN researchers conducted 2 years of "pre-monitoring" assessments in order to determine preliminary levels of bat use in selected CUPN locations and to determine the feasibility of using those locations for long-term monitoring. Secondarily, these pre-monitoring efforts provided initial surveillance in network locations for WNS; pre-monitoring efforts in 2012 provided the first confirmed instance of WNS in CHCH (NPS 2012). The CUPN used the results of the pre-monitoring efforts when the network initiated a formal monitoring program for cave dwelling bats in 2014 (Steven Thomas, CUPN Monitoring Program Leader, written communication, 2016).

Thomas et al. (2016) represents the cave bat monitoring protocol for all network parks. Several locations in CHCH were selected for monitoring in the summer, winter, or both seasons. Summer cave roosting surveys typically occur between mid-May and the end of July, and begin at 8:45 pm eastern time zone. Sampling at each location consists of a direct emergence count (e.g., night vision goggles used near entrance/exit of a roost), and/or passive counting methods (e.g., night vision camera with external infrared illuminators, thermal infrared video camera methods that allow for analysis of data at a later date) (Thomas et al. 2016). Researchers document the total number of bats exiting and entering the roost, and estimate species abundance. Summer surveys were completed during the 2014, 2015, and 2016 seasons, but have not yet gone through quality assurance and quality control checks. In all instances where a cave bat researcher is required to enter a cave, rigorous safety and decontamination protocols are followed to minimize the risk of injury and spreading WNS. The CUPN researchers follow the most recent national guidance, which is available at www.whitenosesyndrome.org.

Winter surveys are completed in CHCH biennially, and were conducted during both the 2014 and 2016 seasons; results of these surveys have gone through a quality assurance and quality control check. CUPN researchers document the total number of bats counted of each species (or an estimate of this number), and determine abundance and spatial distribution within a location when possible (Thomas et al. 2016). Hibernating bats are censused using direct visual counts, photography, or a combination of the two methods (Thomas et al. 2016).

4.4.5. Current Condition and Trend

<u>Species Richness</u>

NPS Certified Species List (NPS 2016)

The NPS Certified Mammal Species List identifies 12 bat species in CHCH (Table 41). Of the 12 species identified by NPS (2016a), nine species are confirmed in the park and three species (Rafinesque's big-eared bat [*Corynorhinus rafinesquii*], silver-haired bat [*Lasionycteris noctivagans*], eastern small-footed bat [*Myotis leibii*]) are identified as 'probably present' in CHCH or the nearby area. Currently, three of the 12 bat species identified by NPS (2016a) are federal species of conservation concern. There are two federally-listed endangered species identified by NPS (2016a): the gray bat (confirmed in park) and the Indiana bat (confirmed in park). These are the only two species of animals occurring in CHCH that are federally-listed as endangered. The northern long-eared bat (also referred to as the northern bat) is federally-listed as a threatened species.

Table 41. Bat species documented on the NPS Certified Species List (NPS 2016).

Common Name	Scientific Name	Status in Park
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*	Probably Present
big brown bat	*Eptesicus fuscus*	Present
silver-haired bat	*Lasionycteris noctivagans*	Probably Present
eastern red bat	*Lasiurus borealis*	Present
hoary bat	*Lasiurus cinereus*	Present
gray bat	*Myotis grisescens*	Present
eastern small-footed bat	*Myotis leibii*	Probably Present
little brown bat	*Myotis lucifugus*	Present
northern bat (northern long-eared bat)	*Myotis septentrionalis*	Present
Indiana bat	*Myotis sodalis*	Probably Present*
evening bat	*Nycticeius humeralis*	Present
tricolored bat	*Perimyotis subflavus*	Present

* While not noted in NPS (2016), this species was documented in the park during CUPN monitoring in 2016.

Ford et al. (2004)

During monitoring at CHCH in 2002 and 2003, Ford et al. (2004) documented eight species of bats. Seven species were captured using mist-netting and harp-trapping techniques throughout riparian and cave/well sampling sites in the park (Table 42). An additional species, the big brown bat, was detected only during acoustic Anabat II surveys at cave and well entrances in CHCH in October and March 2003.

Table 42. Species detected during mist-net and harp-trap bat captures in CHCH from August and October, 2002 (based on Ford et al. 2004). Unk. = Unknown, *N* = number of individuals.

Riparian or Cave and Well Location	Location	Date	Species Captured	Age	Sex	*N*	Method
Riparian Locations	Jay's Mill Road	22-Aug-02	–	–	–	–	mist-net
	Two Bridges	25-Aug-02	eastern pipistrelle (tricolored bat)	Adult	Male	2	mist-net
	Two Bridges	25-Aug-02	eastern red bat	Adult	Male	5	mist-net
	Two Bridges	25-Aug-02	eastern red bat	Adult	Female	3	mist-net
	Two Bridges	25-Aug-02	eastern red bat	Unk.	Unk.	1	mist-net
	Two Bridges	25-Aug-02	little brown bat	Adult	Male	1	mist-net
	Brotherton Field	25-Aug-02	eastern pipistrelle (tricolored bat)	Adult	Male	2	mist-net
	Brotherton Field	25-Aug-02	eastern red bat	Adult	Male	1	mist-net
	Brotherton Field	25-Aug-02	eastern red bat	Adult	Female	5	mist-net
	Brotherton Field	25-Aug-02	evening bat	Adult	Male	1	mist-net
	Brotherton Field	25-Aug-02	hoary bat	Adult	Female	1	mist-net
	Brotherton Field	25-Aug-02	little brown bat	Adult	Male	2	mist-net
	W. Chickamauga (Dalton's Ford)	27-Aug-02	eastern pipistrelle (tricolored bat)	Adult	Male	1	mist-net
	W. Chickamauga (Dalton's Ford)	27-Aug-02	gray bat	Adult	Female	1	mist-net
	Visitor Center Creek	28-Aug-02	eastern red bat	Adult	Male	2	mist-net
	Visitor Center Creek	28-Aug-02	eastern red bat	Adult	Female	2	mist-net
	Visitor Center Creek	28-Aug-02	eastern red bat	Juvenile	Female	1	mist-net
Cave and Well Locations	Location 1*	4-Oct-02	eastern pipistrelle (tricolored bat)	Adult	Male	1	harp-trap
	Location 2*	4-Oct-02	eastern pipistrelle (tricolored bat)	Adult	Male	1	mist-net
	Location 2*	4-Oct-02	eastern pipistrelle (tricolored bat)	Adult	Female	1	mist-net
	Location 3*	5-Oct-02	eastern red bat	Adult	Female	1	harp-trap
	Location 4*	6-Oct-02	–	–	–	–	harp-trap
	Location 5*	6-Oct-02	eastern pipistrelle (tricolored bat)	Adult	Male	1	harp-trap

* Indicates generic cave name that is used to protect the location of the roosting and hibernating bats.

Table 42 (continued). Species detected during mist-net and harp-trap bat captures in CHCH from August and October, 2002 (based on Ford et al. 2004). Unk. = Unknown, *N* = number of individuals.

Riparian or Cave and Well Location	Location	Date	Species Captured	Age	Sex	*N*	Method
Cave and Well Locations (continued)	Location 6*	7-Oct-02	northern long-eared bat	Adult	Male	–	harp-trap
	Location 7*	7-Oct-02	eastern pipistrelle (tricolored bat)	Adult	Male	–	harp-trap
	Location 8*	8-Oct-02	–	–	–	–	harp-trap

* Indicates generic cave name that is used to protect the location of the roosting and hibernating bats.

Ford et al. (2004) noted that the eastern pipistrelle (now identified as the tricolored bat), eastern red bat (*Lasiurus borealis*), the gray bat, and the big brown bat were the most commonly encountered species in the park during 2002 and 2003 survey efforts. While not observed during the study, Ford et al. (2004) suggested that the Rafinesque's big-eared bat and the eastern small-footed bat could likely occur in the park but were missed during the inventory. The silver-haired bat, a species not observed during the survey but identified as probably present in the park by NPS (2016a), is migratory and if it was to be found in the park, Ford et al. (2004) suggests that it would be a seasonal or limited winter species.

CUPN Pre-monitoring Efforts (2012-2013)

As part of the planning process for an annual cave monitoring program in CHCH, network researchers visited several locations in CHCH during both the summer and winter months in order to see which sites would be best served by annual summer visits, winter visits, or both. These preliminary efforts resulted in the detection of three species: the tricolored bat, northern long-eared bat, and the gray bat. The northern long-eared bat and the tricolored bat were observed directly, while the gray bat was detected via acoustic survey.

CUPN Annual Monitoring (2014-present)

Following the conclusion of the pre-monitoring efforts in 2012 and 2013, the CUPN initiated an annual monitoring program for cave bats, with several locations selected for monitoring in the summer, winter, and some locations that are monitored in both seasons. During the annual monitoring efforts at CHCH between 2014-2016, two species have been observed directly: the tricolored bat and the Indiana bat, both of which were documented during the winter surveys.

<u>Summer Cave-roosting Bat Abundance</u>

The summer cave-roosting bat abundance measure represents a data gap at this time in CHCH. The CUPN implemented an annual monitoring program in 2014 that includes this metric. While some limited data exist from these initial surveys, the data have not gone through quality assurance and quality control checks, and are not ready to be summarized in this NRCA. It is likely that these data will be available for analysis in the near future. Until these data are analyzed, the current condition of this measure will remain undefined.

While not used to inform the current condition in this assessment, there are some limited data available from an initial summer site visit to CHCH locations during the CUPN's pre-monitoring efforts in 2012. Most of the data collected during these pre-monitoring efforts are not comparable to the data collected by the CUPN monitoring program from 2014-present, and are presented here for reference only. Of the many methods used during the 2012 field season, only the external emergence counts were selected for use in the long-term monitoring program that began in 2014.

Summer internal and external surveys were completed between 16-18 July at 10 different caves within the park. Survey efforts identified 270 individuals of three species (Table 43), with the gray bat being the most abundant of the three species. It should be noted that the gray bat was detected exclusively by goggle exit counts at Cave #3, which were then confirmed by acoustic detectors. All other species were observed directly. Night vision goggle exit counts at Cave #8 identified 12 individuals of unknown species (Table 43). Only one location had both tricolored bats and northern long-eared bats (Location #1).

Table 43. Bat abundance as observed 16-18 July 2012 CUPN pre-monitoring efforts in CHCH (NPS unpublished data). The results obtained during these surveys were the product of several different methodologies, and because of this they are not comparable to the results that will be produced by the CUPN annual monitoring program.

Location	PESU[A]	MYSE[A]	MYGR[A]	UNK[A]
Cave #1	1	2	0	0
Cave #2	2	0	0	0
Cave #3	0	0	255[B]	0
Cave #4	0	0	0	0
Cave #5	0	0	0	0
Cave #6	0	0	0	0
Cave #7	0	0	0	0
Cave #8	0	0	0	12[C]
Cave #9	0	10	0	0
Cave #10	0	0	0	0
Total	**3**	**12**	**255**	**12**

[A] PESU =*Perimyotis subflavus*; tricolored bat; MYSE = *Myotis septentrionalis*; northern long-eared bat; MYGR = *Myotis grisenscens*; gray bat; UNK = Unknown species

[B] Individuals detected via vision goggle exit count and species confirmed via acoustic detectors

[C] Individuals detected via night vision goggle exit count

Hibernating Bat Abundance

Following the completion of CUPN pre-monitoring efforts at CHCH in 2013, hibernating bat abundance has been documented biennially in the park at six locations. The initial surveys conducted in 2012-2013 used the same methodology as current biennial monitoring, although several additional sites were visited and some visits occurred in April (current biennial monitoring is done during a January-February window). For this assessment, only the data from February 2013 that were collected from four of the six sites that are monitored biennially are included. The 2013 data have not gone through the detailed quality assurance and quality control checks that the data from 2014 and 2016 have, so their results should be interpreted with caution.

In 2013, 561 bats were observed across four locations in CHCH; Cave #2 and #8 were not surveyed due to unfavorable conditions. Cave #3 had the highest number of bats, with 497 tricolored bats and one northern long-eared bat (the only individual of this species observed between 2013 and 2016) (Table 44). In general, hibernating bat abundance at the surveyed locations in CHCH has declined in each survey year. Location #3, which had the highest tricolored bat abundance in both 2013 (497 individuals) and 2014 (306 individuals), had just 15 tricolored bats in 2016, a 95% decline between 2014 and 2016, and a 97% decline since 2013 (Table 44). While the annual abundance at each cave has varied during CUPN monitoring, all locations with 2 years of data exhibited tricolored bat abundance declines of approximately 50% or greater between 2014 and 2016 (Table 44). With just 2 years of CUPN data, it is difficult to determine if these declines are natural temporal variations, are caused by external threats (e.g., WNS), or are due to another factor. Continued monitoring of these locations will provide park and network managers with a much greater time series to determine long-term trends and to better understand the impact that WNS is having on the local and regional bat populations. Additionally, continued monitoring will provide greater winter abundance estimates for species of conservation concern, such as the Indiana bat, which was confirmed for the first time in the park in 2016.

Table 44. Hibernating bat abundance in CHCH locations as observed during CUPN winter hibernacula counts (NPS unpublished data).

	25-27 February 2013[A]		24-26 February 2014	23-25 February 2016		% Decline from 2014 to 2016
Location	**PESU[B]**	**MYSE[B]**	**PESU[B]**	**PESU[B]**	**MYSO[B]**	**PESU[B]**
Location #1	4	–	27	11	–	-59.3
Location #2	N/A[C]	N/A[C]	31	N/A[C]	N/A[C]	–
Location #3	497	1	306	15	1	-95.1
Location #8	N/A[C]	N/A[C]	49	25	–	-49.0
Location #9	26	–	10	1	–	-90.0
Location #12	34	–	8	3	–	-62.5

[A] Year in which the data were not subjected to the same quality assurance and quality control checks as the 2014 and 2016 data.

[B] PESU =*Perimyotis subflavus*; tricolored bat; MYSE = *Myotis septentrionalis*; northern long-eared bat; MYSO = *Myotis sodalis*; Indiana bat

[C] N/A = Site was not surveyed due to unfavorable conditions.

<u>Threats and Stressor Factors</u>

White-nose syndrome, caused by the fungus *Pseudogymnoascus destructans*, has emerged as the greatest threat to bats in North America in the past decade (Blehert et al. 2008, Castle and Cryan 2010, Cryan et al. 2010). First detected in upstate New York in 2006, WNS has spread rapidly across the U.S., reaching as far west as Oklahoma and Nebraska in just 10 years (an isolated case was confirmed in Washington State in 2015-2016; it is unknown how the disease traversed to the west coast and affected only an isolated county) (Figure 26) (NPS 2016b). Affected bats exhibit a white fungal growth on their external body surface, usually around the muzzle, ears, or wings, and experience frequent winter arousal when hibernating. These arousals deplete the bat’s body fat prematurely and cause them to experience dehydration, wing damage, starvation, and frequently, death (Foley et al. 2011, Thomas 2015). It is estimated that WNS has killed more than 6 million bats in the eastern U.S. and Canada since 2006 (Baker et al. 2015). Transmission primarily occurs from bat-to-bat during the winter months, as the fungus that causes the disease thrives in cold temperatures; it is unknown, however, how long the fungal spores can persist. Anthropogenic spread of WNS is also possible, as contaminated caving gear, clothing, or recreational equipment (e.g., cameras, hiking gear) may facilitate spread of the fungus.

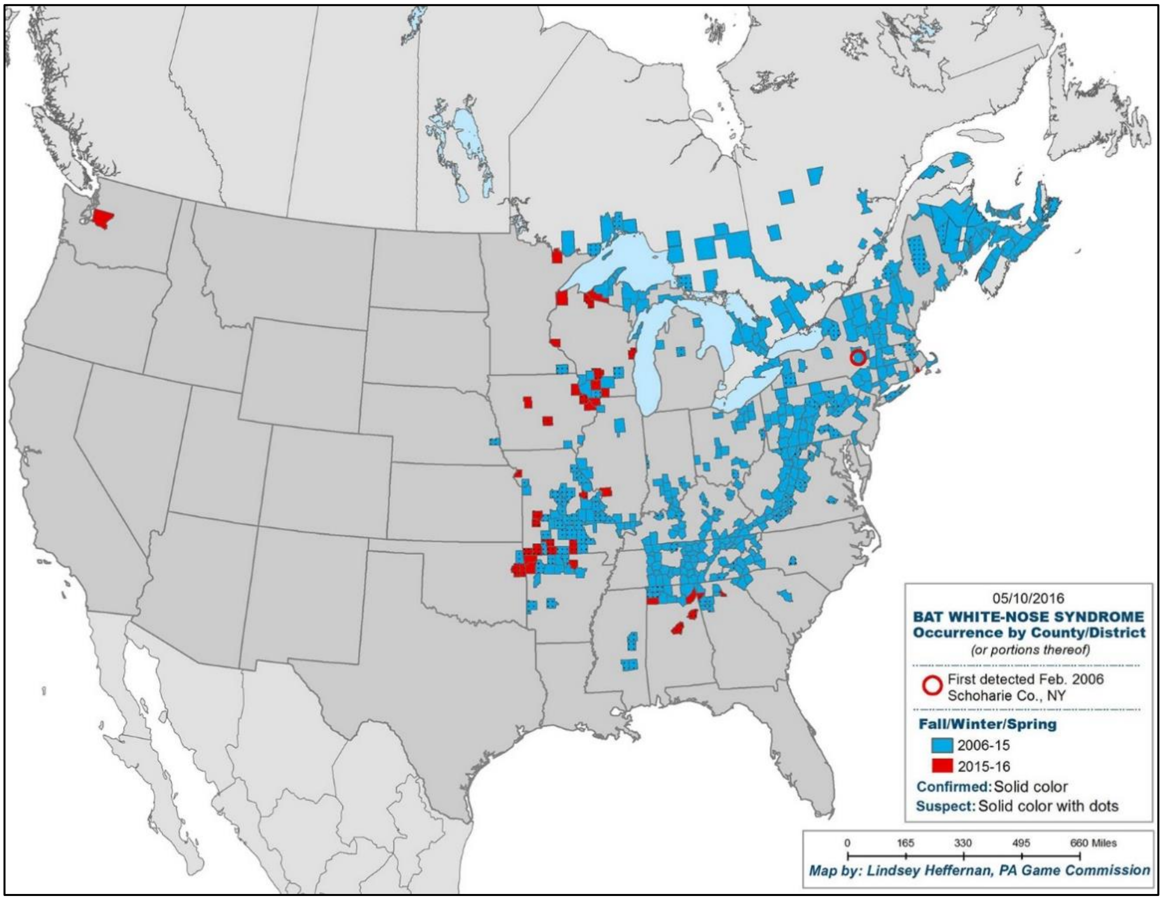


Figure 26. Counties and districts across the continental U.S. and Canada where white-nose syndrome has been confirmed or is suspected. Counties in red indicate a county where the disease was first detected in 2015-2016. (Figure reproduced from NPS 2016b).

White-nose syndrome has been confirmed in four parks in the CUPN (CHCH, Cumberland Gap National Historical Park, Russell Cave National Monument, and Mammoth Cave National Park) and was first verified in CHCH in 2012 when a tricolored bat collected from a park cave tested positive for the disease (NPS 2012). Annual monitoring of hibernating cave bats has detected signs of WNS at all six locations in CHCH, with all affected bats being tricolored bats (Table 45). The overall percentage of bats visibly affected by WNS at CHCH has varied by location, with some locations having up to 50% of all bats with WNS symptoms (Location #12, February 2014). Preliminary trend analysis from just 2 years of CUPN survey data appears to indicate declining abundance at all locations in CHCH (Table 46). These trends, combined with the relatively high rates of WNS occurrence, warrant significant concern for park managers. Continued monitoring of population trends and the number of bats with WNS symptoms is needed to better understand the continued trajectory of the disease and, if feasible, to help initiate preventative measures in the park.

Table 45. White-nose syndrome occurrence at CHCH locations as observed during CUPN winter bat monitoring efforts (NPS unpublished data).

Location	25-27 February 2013[A]		24-26 February 2014		23-25 February 2016	
	WNS Count	% WNS	WNS Count	% WNS	WNS Count	% WNS
Location #1	0	0	2	7.4	4	36.4
Location #2	N/A[B]	N/A[B]	7	22.6	N/A[B]	22.6
Location #3	15	3	2	0.7	5	33.3
Location #8	N/A[B]	N/A[B]	6	12.2	7	28
Location #9	3	11.5	2	20	0	0
Location #12	11	32	4	50	1	33.3

[A] Year in which the data were not subjected to the same quality assurance and quality control checks as the 2014 and 2016 date were.

[B] N/A = Site was not surveyed due to unfavorable conditions.

As alluded to previously, direct human disturbance represents a threat to bats. Following the discovery of WNS at CHCH in 2012, access to all of the park's caves was restricted (NPS 2012). However, CUPN researchers have noted a couple instances of unauthorized use of caves in the park since 2012. Unmanaged access and visitation to these caves, especially during the winter months, could facilitate additional spread of fungal spores to caves, resulting in increased WNS rates in the park. Additionally, human disturbance to hibernating bats could awaken them from torpor and cause the bats unnecessary stress/energy expenditure. Bats typically hibernate in large groups (although tricolored bats in CHCH usually roost singly), and a single disturbance event could affect a large part of a cave's total hibernating bat population. Alterations within caves used by hibernating bats could also reduce annual bat abundance, although these alterations may be caused by natural forces (e.g., rockfalls at entrances) and not exclusively by humans.

Conversion of land from natural habitat to agriculture and other anthropogenic development is impacting bats throughout the world (Medlin et al. 2010). Habitat fragmentation, as well as reduction in habitat patch size and density, has been shown to reduce both the abundance and richness of bat communities (Medlin et al. 2010). Further, vegetation changes near cave entrances, such as an overgrowth of an exotic species (e.g., kudzu), or loss of a native species due to climate change, could change the temperature of the cave. Temperature and relative humidity are the primary drivers of cave ecosystems, and bats typically have very specific temperature requirements for hibernation. Shifts in a cave's temperature or relative humidity could affect overall hibernating bat abundance (USFWS 2016).

Changes in the subsurface air temperatures could be directly related to climate change, as relatively stable zones in some cave systems are correlated with local mean annual surface temperatures (Thomas, written communication, 30 November 2017). Some bats roost in variable temperature zones that typically exchange air with the surface (described often as caves "breathing" in and out). If local surface temperatures rise during the winter, then warmer air could enter the caves and potentially affect airflow between the subsurface and surface (Thomas, written communication, 30

November 2016). Warming global temperatures are predicted to range from 1.1°C to 6.4°C (2.0-11.5°F) over the next century (Saunders et al. 2008, Adams 2010), and changes to the surface air temperatures would likely elevate the subsurface temperatures in certain portions of caves. While the southeastern U.S. did not experience the same degree of warming trends as the western U.S. in the last century, the highest emissions scenario predicts that there will be 20-25 more days per year with temperatures exceeding 35°C (95°F) (Walsh et al. 2014).

Summer habitat loss is also an issue for bats, as anthropogenic development has removed large numbers of trees which are used for summer roosting sites and foraging areas. The loss and fragmentation of forested habitats in the CHCH area would likely have an effect on the overall bat population of the area. Tracking the rate of anthropogenic development in the area around CHCH, along with continued regular monitoring and inventory of the bat community in the park, would help managers make informed decisions on bat conservation strategies.

Recent efforts to develop alternative energy sources have resulted in more wind farm development across the planet (de Lucas et al. 2008). The turbines that are becoming increasingly common upon the landscape are known to be responsible for the direct mortality of large numbers of bats (Kunz et al. 2007). Bat mortality related to wind turbines has been especially prominent with utility-scale wind turbines located along forested ridges (Kunz et al. 2007). Migratory bat species have been the most impacted, and this mortality has become a major threat, meriting multi-year monitoring and research (Kunz et al. 2007). Kunz et al. (2007) estimate that between 33,000 and 111,000 bats will be killed by wind turbines in the mid-Atlantic highlands of the U.S. by the year 2020.

All species of bats in the CUPN are insectivores that consume many species commonly regarded as ‘pests’. These pests are often managed by using pesticides. Some bat species can consume up to their body weight in insects in a single day, and this daily metabolic rate makes bats particularly vulnerable to the accumulative effects of pesticides and environmental contaminants (Brunet-Rossini and Wilkinson 2009). Additional research into bioaccumulation in bats is needed, as Yates et al. (2013) found that bats in the northeastern U.S. showed highly elevated levels of mercury in both their fur and blood. The exact effects that mercury or other contaminants has on bats is understudied, but warrants concern especially due to the risk of transmission of contaminants to pups through breastmilk.

Pesticides that are used to control insect populations have been shown to negatively impact bat populations across several ranges and species (Clark 1981). The effects of modern pesticide use are still being studied, but historic use of DDT and other organophosphates resulted in the decline of bat populations across the U.S. (Eidels et al. 2007). DDT use was linked to bat population declines in Carlsbad Caverns National Park, New Mexico, and organophosphate usage has been tied to deaths of the Indiana bat, an endangered species (Eidels et al. 2007).

Data Needs/Gaps

In general, bats have been understudied and many aspects of their life history, behavior, and population dynamics are not well described (Reeder and Moore 2013). Similarly, the impacts from the two most pressing threats to bat populations in North America, WNS and wind turbines (Boyles et al. 2011), are also not fully understood. Rapid research has been ongoing into the ecology, transmission dynamics, and epidemiology of the WNS fungus, but there is still no effective strategy to control the outbreak (Reeder and Moore 2013). While often fatal, some bats affected by WNS can survive, and further research is needed to understand why and how some bat species are affected less by WNS. Additional research is needed regarding the two aforementioned threats, especially with WNS having been confirmed in several CHCH caves and Tennessee's largest wind farm being constructed approximately 145 km (90 mi) north of the park. Continued monitoring of WNS-related mortality and annual bat abundance at park locations is also needed.

While not provided here, data which would provide abundance estimates for summer cave-roosting bats have been collected during CUPN monitoring. These data need to undergo vigorous quality assurance and quality control checks before they can be published or distributed. These data should be available in 2017, and will allow for a more accurate assessment of that measure's current condition. Continued monitoring of summer cave-roosting bats is needed in order to establish more reliable trend estimates, and to help identify any threats that may affect the abundance of roosting bats. Additionally, biennial surveys of hibernating bat abundance are needed in order to obtain more reliable long-term trends, and to identify any fluctuations in the bat population of CHCH. A longer data series will help researchers and managers determine just how significant the impacts of WNS are on the local bat population.

Overall Condition

Species Richness

The species richness measure was assigned a *Significance Level* of 3 during project scoping. NPS (2016a) identifies nine bat species as confirmed in the park, and an additional three species that are probably present in the park or area (Table 41). An inventory in 2002 and 2003 documented eight species, and captured seven of those species via mist netting and harp trapping. The most recent CUPN survey and monitoring efforts in the park has documented four species, including the Indiana bat, which is a federally endangered species. It should be noted, however, that Ford et al. (2004) and NPS (2016a) include species of bats not typically described as "cave bats". The methodology of Ford et al. (2004) included mist-netting, harp trapping, and acoustical surveys, which were focused on all bat species (including tree bats). This methodology was very different from the CUPN monitoring which focused on cave species and utilized only internal cave surveys and external exit counts. It is likely that if the CUPN monitoring was expanded to look at all bat species, and included methods similar to Ford et al. (2004), that more than four species would be observed (Thomas, written communication, 30 November 2016).

Nine of the 12 species suspected of occurring in the area are species of conservation concern, with two cave bat species being federally endangered (Indiana and gray bats) and one species being federally listed as threatened (northern long-eared bat). While the survey efforts in the park in the last 20 years have met the reference condition for species richness of cave bat species (four species), the fact that so many species of concern exist in the park, combined with the confirmed presence of WNS in many of the park's hibernacula, is cause for significant concern. Should any of these populations experience local extirpations, the total species richness estimate for the park could be reduced. Because of these concerns a *Condition Level* of 2 (moderate concern) was assigned to this measure.

Summer Cave-roosting Bat Abundance

CHCH staff assigned a *Significance Level* of 3 to the summer cave-roosting bat abundance measure. The CUPN has surveyed summer cave-roosting abundance during annual monitoring efforts from 2014 through 2016; however, the data obtained during these efforts are not yet available for analysis as they need to go through a similar quality assurance and quality check procedures that the winter data went through. Until these data become available, a *Condition Level* cannot be assigned to this measure.

Hibernating Bat Abundance

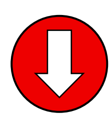
Hibernating bat abundance was assigned a *Significance Level* of 3 during project scoping. The CUPN monitoring effort has observed downward trends in the 3 years of monitoring data available. While limited in temporal scope, bat abundance at the surveyed locations in CHCH has declined each year. Location #3, which had the highest tricolored bat abundance in both 2013 (497 individuals) and 2014 (306 individuals), had just 15 tricolored bats in 2016, a 95% decline between 2014 and 2016 (Table 43). While bat abundance at each cave has varied during CUPN monitoring, five locations exhibited tricolored bat abundance declines of approximately 50% or greater between 2014 (Location #2 had only 1 year of data) and 2016 (Table 44).

These declining trends, combined with the fact that WNS has been confirmed at multiple locations in the park, indicate high levels of concern for this measure. A *Condition Level* of 3, indicating significant concern, was assigned to hibernating bat abundance.

Weighted Condition Score

A *Weighted Condition Score* of 0.83, indicating significant concern, was assigned for CHCH's cave bats. While trend data are limited and exist for only 3 years, the regional bat population trends, especially as they relate to WNS, appears to be declining. Confidence in this overall assessment was determined to be medium, but continued monitoring of bat population trends will strengthen overall confidence in this assessment.

Table 46. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's cave bats.

Measures	Significance Level	Condition Level	WCS = 0.83
Species Richness	3	2	
Summer Cave-roosting Abundance	3	N/A	
Hibernating Bat Abundance	3	3	

4.4.6. Sources of Expertise

- Steven Thomas, CUPN Monitoring Program Leader

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4.5. Birds

4.5.1. 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 2010). Despite being recognized more for the historic nature of the park, CHCH is home to several unique habitat types. The Chickamauga Battlefield Unit of CHCH is the largest unit of the park and is mainly forested, with some tracts of bottomlands and mowed fields also present. The southern portion of this unit is also home to ponds recently created by American beavers (*Castor canadensis*). These areas are bordered by willows (*Salix* spp.) and have several standing dead trees along the waterways (Stedman et al. 2006). The pond areas are home to a great blue heron (*Ardea herodias*) rookery, a large population of red-headed woodpeckers (*Melanerpes erythrocephalus*), and several wetland-dependent avian species (Stedman et al. 2006). Additionally, the Bewick's wren (*Thryomanes bewickii*) (Figure 27) has been documented breeding in the open scrub habitat of CHCH (Stedman et al. 2006). This species is an endangered species in the State of Tennessee, a federal species of management concern, and its presence in the park highlights the importance of CHCH's habitats for many critical avian species.

Figure 27. Bewick's wren perched on a lichen covered twig (NPS Photo).

CHCH has confirmed the presence of 174 bird species within the park (Appendix F), and another eight species have been identified as either unconfirmed or not currently in the park but likely occurred historically within the general area of the park (NPS 2016). It is likely that additional species frequent the park throughout the year, as Calhoon (2013) identified 327 species as present in the greater Chattanooga area, with 127 of those species identified as nesting species. Continued monitoring of avian species and their habitats provides managers with an accurate depiction of the current health of the bird community and the habitats which they frequent, and also provides the opportunity to document new species as they occur in the park.

4.5.2. Measures

- Species Richness
- Raptor Species Richness
- Species Abundance

4.5.3. Reference Conditions/Values

The reference condition for this component is undefined at this time. Stedman et al. (2006) represents perhaps the most comprehensive and recent avian-related study to take place within CHCH boundaries. Further, Calhoon (2013) compiled an expected bird species list for the greater Chattanooga area; however, this list was not specific to CHCH and likely included species that frequent habitat types not found within the boundaries of the park.

While Stedman et al. (2006) could likely serve as a suitable reference condition, there are not enough recent data collected within the park to provide a meaningful comparison. Future assessments of condition that take place after more data have been collected within CHCH should use Stedman et al. (2006) as a baseline reference condition.

4.5.4. Data and Methods

Research regarding the avian communities in CHCH has been extremely limited, as Stedman et al. (2006) represents the only avian-specific inventory effort to occur within the park. This inventory took place from 2005-2006 and utilized five different survey methodologies in an effort to identify as many bird species as possible within the park. The most standardized survey methodology utilized during Stedman et al. (2006) was the point count technique. Forty point count locations were established in the park and were surveyed twice a year from late-May to early June. Observers stood at a point (the center of a 100m [328 ft] diameter circular plot) for 10 minutes and identified all birds heard or seen; 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 et al. (2006) was a migration walk. Observers took between eight and ten walks during the spring and fall seasons of 2005 and 2006. These walks lasted between 1 and 3 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 et al. (2006) also conducted raptor-specific surveys in CHCH. 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 route along many of the roads of CHCH (about 35 km [22 mi]). All raptor species that were seen or heard were documented by observers.

The fourth survey type utilized by Stedman et al. (2006) was a nighttime survey. These surveys were mostly informal, and were particularly 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 et al. (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 attempted to document evidence of breeding for all suspected breeding species, and categorized these as confirmed, probable, or possible breeders. All of the species that were seen or heard during these searches were recorded.

An annual Christmas Bird Count (CBC) is centered outside of CHCH boundaries and has been completed almost every year since 1980. The Chattanooga CBC is part of the International CBC effort, which started in 1900 and is coordinated by the Audubon Society. Data from the Chattanooga CBC are available for 35 years (1980-2014). Multiple volunteers survey 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 at the Chickamauga Dam near 34.104016ºN, -85.229184ºW (Figure 28). 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 is recorded each year.

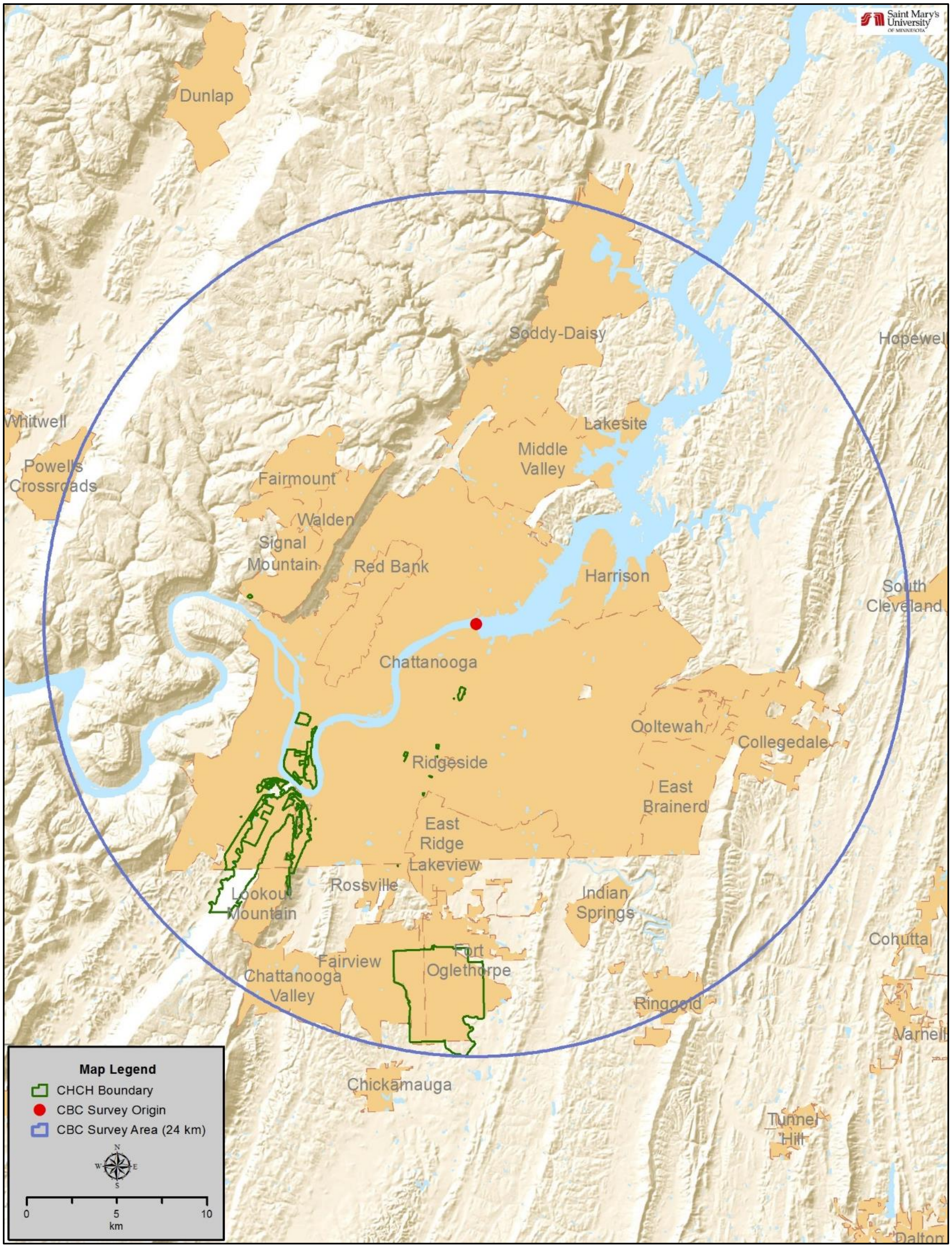

Figure 28. The count area of the annual Chattanooga Christmas Bird Count. The 24-km (15-mi) count diameter includes all of the many CHCH units.

4.5.5. Current Condition and Trend

<u>Species Richness</u>

NPS Certified Species List (NPS 2016)

The NPS Certified Bird Species List contains 174 species confirmed in the park (Appendix F). This list also includes species that may be present in the area but have not been confirmed within the park's boundaries. Eight species were identified as either unconfirmed or not currently in the park by NPS (2016): Bachman's sparrow (*Peucaea aestivalis*), Henslow's sparrow (*Ammodramus henslowii*), peregrine falcon (*Falco peregrinus*), pine siskin (*Spinus pinus*), red-cockaded woodpecker (*Picoides borealis*), rock wren (*Salpinctes obsoletus*), ruffed grouse (*Bonasa umbellus*), and the white-crowed sparrow (*Zonotrichia leucophyrs*). 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 et al. (2006). A detailed discussion of that study is provided below. One species included on the NPS Certified Bird Species List that was not documented by Stedman et al. (2006) was the Bewick's wren. This species is a state-listed endangered species in the State of Tennessee, and park staff and other observers had observed breeding evidence in the park prior to the Stedman et al. (2006) inventory, but it was not documented during the inventory, it is likely the park still supports breeding habitat for the species.

Stedman et al. (2006)

During 2005 and 2006 surveys and inventories in CHCH, Stedman et al. (2006) identified 173 species (Appendix F). Point count surveys by Stedman et al. (2006) yielded 74 unique avian species in CHCH. Point counts in 2005 identified 67 avian species, while point counts in 2006 identified 63 avian species (Appendix G). The species richness results of the other various survey techniques (e.g., raptor search, nighttime survey) were not reported in Stedman et al. (2006).

In addition to documenting all species that were observed during their inventory efforts, Stedman et al. (2006) also documented possible, probable, and confirmed breeding species in the park. Forty-three species were confirmed as breeding within CHCH, with an additional 29 species identified as probably breeding in the park. Fourteen species were documented as having possible breeding sites within CHCH (Appendix F).

Chattanooga Christmas Bird Count (1980-2014)

The Chattanooga CBC survey area encompasses CHCH (Figure 26). Counts such as the CBC (or other index counts, e.g., breeding bird surveys) are neither censuses nor density estimates (Link 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 1998); these biases may influence how many individuals are observed in a given year, and may potentially explain the annual variation observed in species richness each year. Because of these biases, the results of the Chattanooga CBC are interpreted with a degree of caution; when possible, results are presented with the approximate number of observers that participated in the

Chattanooga CBC in order to provide some degree of clarity regarding annual observer effort from year to year.

During the 35 years of CBC efforts for the entire Chattanooga count circle, 161 avian species have been observed (Appendix F). The lowest number of avian species observed in a given year was 92 (1987: 27 observers; 2008: 22 observers), while the highest number of species observed was 112 (1997: 34 observers) (Figure 29). The average number of avian species observed during the Chattanooga CBC was 99.3, and the average number of observers per year was 29.

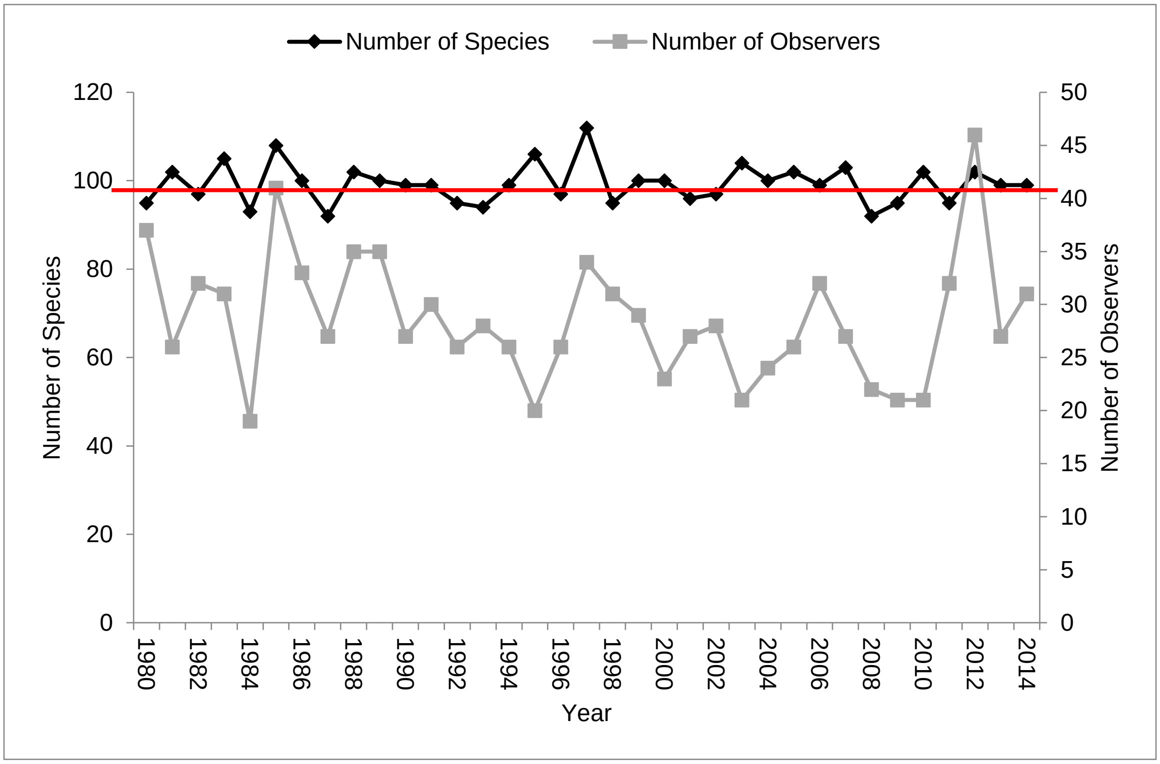

Figure 29. Number of bird species and observers during the Chattanooga CBC between 1980 and 2014. The solid red line represents the average number of species observed per year (99.2). Note that data include all count circle results and is not specific to only observations within CHCH boundaries. Data retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx#.

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 rates of reproductive success subsequently increased following this ban (Fischer 2000). Species especially affected by the use of organochlorines, such as the peregrine falcon, 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 CHCH (e.g., grasslands, hardwood forests, wetland and riparian areas) can support a variety of different raptor species. Observed raptor species in CHCH 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 CHCH includes 16 raptor species, with one of those species represented by unconfirmed historical occurrences (i.e., peregrine falcon; Appendix F).

Stedman et al. (2006)

Stedman et al. (2006) identified 15 raptor species during 2005 and 2006 searches of CHCH (Appendix F). According to Stedman et al. (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 year-round. Notably absent from the field habitat in the winter were short-eared owls (*Asio flammeus*) and northern harriers (*Circus cyanus*) (Stedman et al. 2006). Stedman et al. (2006) noted that the mowing regime present in many of the fields and grasslands of CHCH likely contributed to the low number of grassland raptor species.

Additional surveys of the park, preferably raptor-specific, are needed in order to establish a more accurate current condition of raptor species richness in CHCH. 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. Additionally, the timing of breeding bird surveys (late-May through early-July) will miss many species of raptors that use the park during fall migration. Until more recent and specific raptor species richness data exists for CHCH, it will not be possible to determine an accurate current condition for this measure.

Chattanooga Christmas Bird Count (1980-2014)

From 1980-2014, 20 raptor species have been observed during the Chattanooga CBC. The number of raptor species observed on the CBC is higher than the total number of raptor species that have been confirmed in CHCH, this may be due to the larger survey area of the CBC and potentially due to the longer period of survey data and more observers during each survey. The highest number of raptor species observed in a given year was 15 (1998: 34 observers), while the lowest number of species observed was eight (1984: 19 observers) (Figure 30). The average number of raptor species observed during the Chattanooga CBC was 11.3.

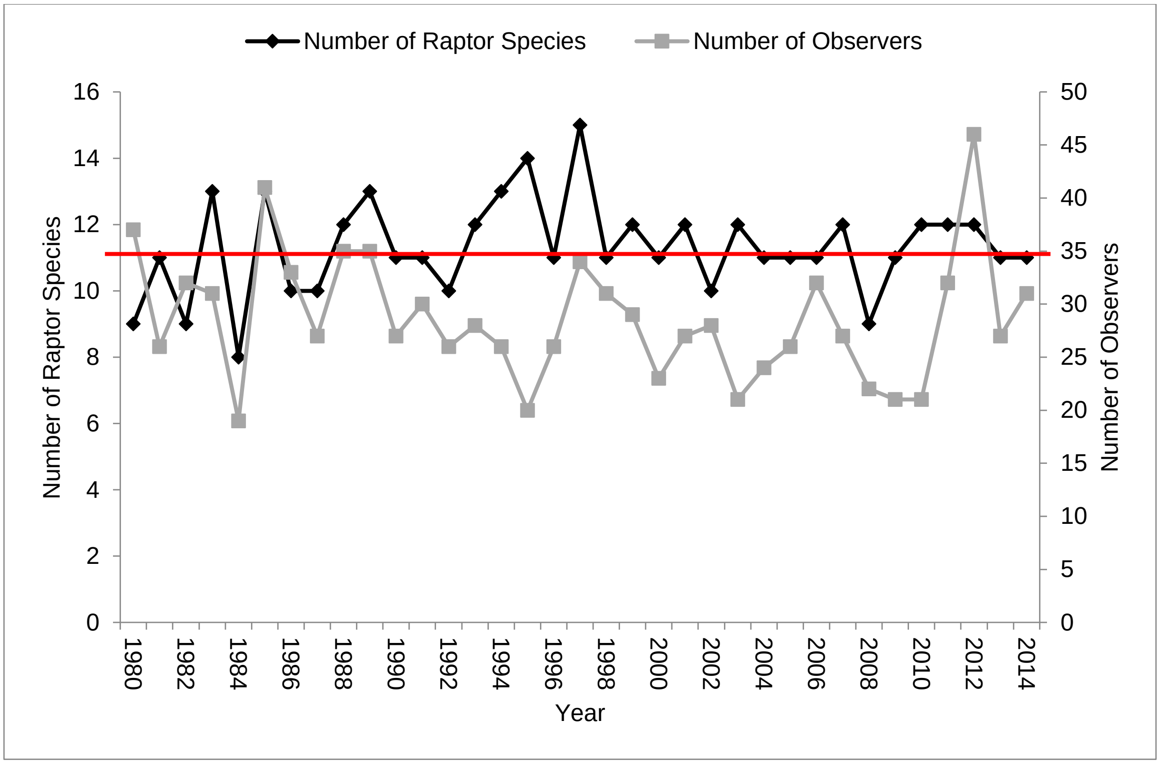

Figure 30. Number of raptor species and the number of observers during the Chattanooga CBC from 1980-2014. The solid red line represents the average number of raptor species observed per year (11.3). Note that data include all count circle results and are not specific to only observations within CHCH boundaries. Data retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx#.

Species Abundance

Species abundance refers to how many individuals are documented in a given survey/monitoring period. It needs to be noted, however, that all species have different detection probabilities, and measures of abundance reported here should be considered "naïve" estimates as they do not account for these variable detection probabilities.

Stedman et al. (2006)

Of the five survey methodologies utilized by Stedman et al. (2006) only the point count efforts resulted in estimates of the total abundance of bird species that were observed. Stedman et al. (2006) observed 1,812 individuals of 74 species via point count efforts in CHCH during the 2005 and 2006 seasons (Appendix G). The total number of individuals observed each year was nearly identical, with 909 individuals observed in 2005 and 903 individuals observed in 2006 (Appendix G). The most abundant species (i.e., most numerous) during the two field seasons were the northern cardinal, Carolina wren, red-eyed vireo, tufted titmouse, and the American crow (*Corvus brachyrhynchos*). These species accounted for over 38% of all individuals observed by Stedman et al. (2006) (Appendix G). They were also the most common species, being detected at more than 81% of all point count locations in the park (Table 47). The northern cardinal was observed at all 40 point count locations in CHCH in 2005 (Table 47), and had the highest total abundance estimates of all observed species (Appendix G). The Carolina wren was the most numerous species in 2006, and was observed at 38 of the 40 point count locations (Appendix G).

Table 47. Frequency of occurrence (proportion of survey points observed) for bird species observed at 40 point count locations during Stedman et al. (2006).

Common Name	Frequency (proportion of points) 2005	Frequency (proportion of points) 2006
northern cardinal	1.00	0.85
Carolina wren	0.85	0.95
red-eyed vireo	0.83	0.88
tufted titmouse	0.83	0.83
Carolina chickadee	0.70	0.58
red-bellied woodpecker	0.68	0.63
American crow	0.58	0.60
pine warbler	0.50	0.33
blue-gray gnatcatcher	0.48	0.35
scarlet tanager	0.48	0.50
eastern towhee	0.45	0.43
blue jay	0.43	0.68
indigo bunting	0.40	0.15
American goldfinch	0.35	0.20
white-breasted nuthatch	0.33	0.48
wood thrush	0.33	0.23
summer tanager	0.33	0.35
mourning dove	0.30	0.23
pileated woodpecker	0.30	0.40
chimney swift	0.25	0.20
yellow-billed cuckoo	0.20	0.30
great crested flycatcher	0.20	0.30
downy woodpecker	0.15	0.35
yellow-throated vireo	0.15	0.25
eastern bluebird	0.15	0.05

Chattanooga Christmas Bird Count (1980-2014)

The average number of individuals observed during the Chattanooga CBC between 1980 and 2014 was 20,156 birds/year; the maximum number of individuals was 66,636 in 1997 (34 observers), while the minimum number of individuals observed was 11,483 in 1989 (35 observers) (Figure 31). The number of individuals observed per year has been below average for nine of the past 10 years (Figure 31). However, for the duration of the count effort most estimates of abundance have been in the 17,000-19,000 individuals/year range. There have been several years of exceptionally high abundance that likely skew the average towards a higher estimate (see 1997 and 2005 in Figure 31).

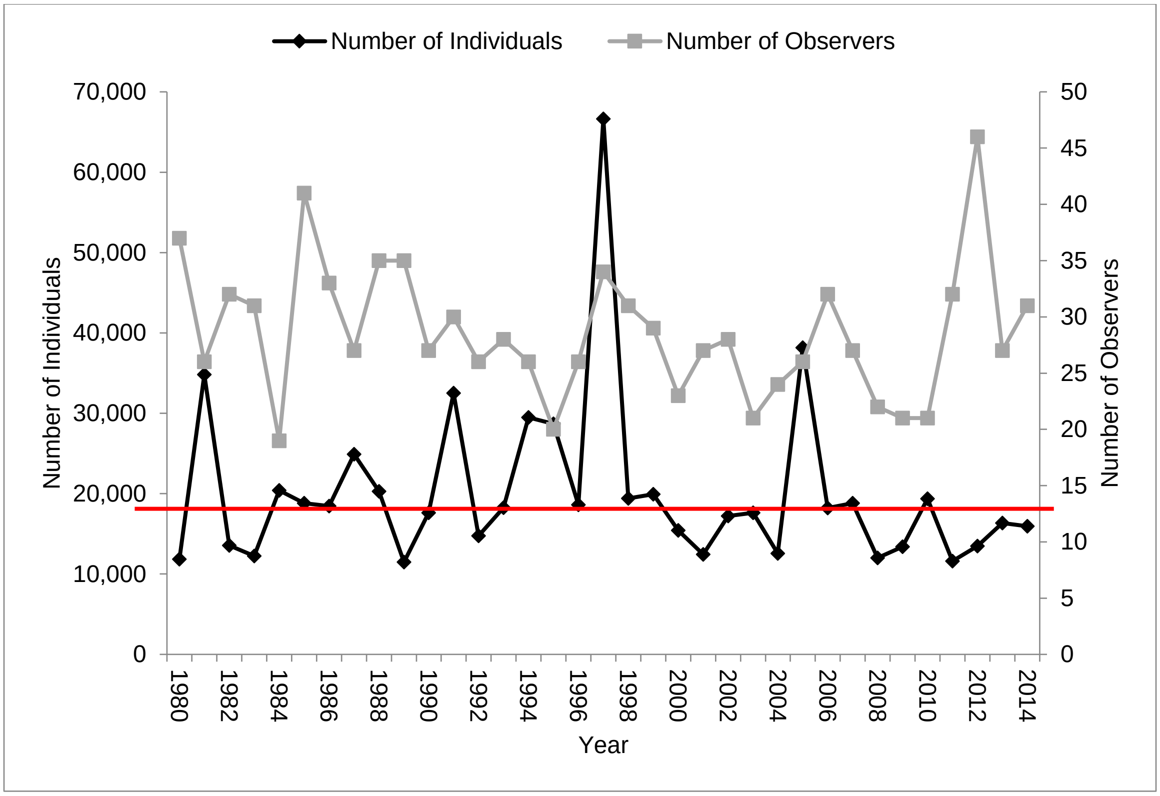

Figure 31. Total number of individual birds observed during the Chattanooga CBC efforts from 1980-2014. The solid red line represents the average number of bird individuals observed per year (20,156). Data retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx#.

Because the CBC takes place over the winter months when many migratory and breeding species are no longer present in the area, the abundance estimates often look very different when compared to breeding season surveys. For the average number of individuals of a particular species per year from 1980-2014, the European starling (*Sturnus vulgaris*) had the highest annual average abundance with 4,913 individuals/year (Table 48). This was almost three times as great as the next most abundant species, the ring-billed gull (*Larus delawarensis*) (Table 48). In 1997, 44,852 individual European starlings were observed during the CBC. This is a stark comparison to the Stedman et al. (2006) breeding surveys, as only three individuals were observed in the park in 2005 and 2006 combined; this may be attributed to a variety of factors, including season of sampling and the type of habitats and urban settings that were sampled in the CBC. Other abundant bird species during the Chattanooga CBC included the common grackle (*Quiscalus quiscula*), American coot (*Fulica americana*), rock pigeon (*Columba livia*), and the American robin (*Turdus migratorius*) (Table 48).

Table 48. Average annual abundance for the 10 most frequently observed species during the Chattanooga CBC from 1980-2014.

Species	Average # of Individuals/ Year
European starling	4,913.37
ring-billed gull	1,781.94
common grackle	1,472.63
American coot	1,174.12
rock pigeon	1,077.89
American robin	1,012.57
red-winged blackbird	625.43
cedar waxwing	566.09
American crow	520.29
mourning dove	512.23

Threats and Stressor Factors

Stedman et al. (2006) identified the present mowing regime in CHCH as an area in need of critical management attention. The grassland habitats of CHCH were found to support low numbers of grassland obligate species and foraging raptor species during the 2005 and 2006 field seasons. Stedman et al. (2006, p. 13-14) recommended major changes to the park's mowing regime:

1. For fields that remain moist or wet except in the driest months of late summer (and for any that are out of sight of the public from roads), mow only once a year in late July or August, so as to encourage a wider diversity of wildlife to use them during the fall, winter, and spring. Snodgrass Field, Dyer Field, Viniard Field, and Glenn Field, to name some specific examples, could all be shifted to a once-per-annum mow cycle with great benefit to the grassland wildlife using the park.
2. Leave a buffer zone about 30 m (100 ft) wide between forests and fields, allowing this buffer to develop several years of growth before it is mowed or bush-hogged; mow or bush-hog this buffer strip in different years for different fields, so that they are not all in the same growth condition at the same time.
3. The Lookout Mountain Land Trust has been removing exotic shrubs and trees from the edges of the Hardy and Guild trails in the battlefield park. It would be [a] worthy goal to remove exotics from the successional areas on the slopes beside and below the Cravens House Compound although the cost and time to do this would make it a daunting task.

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 (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 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 or house sparrow (*Passer domesticus*), to move in and outcompete native bird species. Grassland and shrub-scrub dependent species in CHCH, 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 CHCH.

As urban areas continue to develop and grow, modern alterations to the landscape (land use changes) 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). Marzluff (2001, p. 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 CHCH, and include species such as rock pigeon, Eurasian collared-dove (*Streptopelia decaocto*), European starling, and house sparrow (Stedman et al. 2006).

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 (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.

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 CHCH. 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 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins 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 2010).

<u>Data Needs/Gaps</u>

The establishment of an annual bird monitoring program in CHCH 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 and update the park's species list. Other survey methodologies, such as winter surveys (e.g., Chattanooga CBC surveying a portion or the entirety of the park), raptor road surveys, targeted survey efforts designed to document species listed as unconfirmed or uncommon/historic, 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. With the potential presence of the Bewick's wren in the park, area searches and the determination of areas of potential nesting habitat would be highly beneficial. Additionally, expanded research and survey efforts in unique habitats of the park, such as the cedar glades or the beaver ponds, could yield additional species that have not yet been identified in the park.

<u>Overall Condition</u>

Species Richness

The CHCH project team assigned the species richness measure a *Significance Level* of 3 during project scoping. Species richness values based on Stedman et al. (2006) indicated a high level of diversity that was about what was to be expected based on the size of the park, although not as many grassland obligate species were observed as were expected. Several unexpected results were noted by Stedman et al. (2006), for example, a relatively large great blue heron rookery in the park, a high density of Chuck-will's-widow (*Caprimulgus carolinensis*), and the general lack of grassland and shrub-scrub species. The observation of a Bewick's wren in the Chickamauga Battlefield Unit before the inventory began indicated that the park provides suitable habitat for that, and likely other, species of conservation concern.

The Chattanooga CBC effort has species richness results dating back to 1980, and in general, the number of species observed has remained relatively consistent (Figure 27). The CBC samples the area's bird population outside of the breeding season, and detects some species that are not otherwise observed in the park during traditional monitoring seasons (Appendix F).

Stedman et al. (2006) is now over 10 years old, so it is difficult to accurately predict what the current condition of birds is in CHCH using those data. A *Condition Level* of 1, indicating low concern, was assigned to this measure, albeit with low confidence due to the lack of current data. Updated surveys, inventories, and area searches are needed to elevate the confidence in this condition designation; updated surveys are especially needed to determine the current status of the state-endangered Bewick's wren.

Raptor Species Richness

The raptor species richness measure was assigned a *Significance Level* of 2 during project scoping. Stedman et al. (2006) noted low overall raptor species richness levels in the park during monitoring from 2005-2006, and raptors that depended on the grassland habitats of the park were either not observed (e.g., northern harriers, short-eared owls), or observed in low numbers (e.g., American kestrels [*Falco sparverius*]). The sharp-shinned hawk (*Accipiter striatus*) and Cooper's hawk (*Accipiter cooperii*; Figure 32) were observed as likely nesters in the park, and the broad-winged, red-shouldered (*Buteo lineatus*), and red-tailed hawks were confirmed as nesting species in the park.

Figure 32. A pair of Cooper's hawks perched in a tree in early spring (NPS Photo).

The number of raptor species observed during the Chattanooga CBC from 1980-2014 averaged about 11 species per year, with most years fluctuating between 11-12 species (Figure 30). Similar to the broad species richness measure discussed previously, the CBC largely samples areas and habitats found outside of CHCH; additionally, the timing of sampling captures more resident raptor species. Because of this timing, species richness values are generally lower for raptors in the winter, as many raptor species migrate to the south in the winter.

A *Condition Level* was not assigned to the raptor species richness measure. While Stedman et al. (2006) and the annual CBC efforts have captured a small picture regarding the raptor species richness in the park, no study has specifically investigated the raptor population of the area. The lack of a raptor-specific inventory or breeding survey, combined with the now outdated Stedman et al. (2006), make an assessment of current condition unreliable. Expansion of previous monitoring efforts, and a focus specifically on the raptor population and breeding in the park would provide managers with a better idea of what raptor species may utilize the park throughout the year.

Species Abundance

The species abundance measure was assigned a *Significance Level* of 2 during project scoping. Abundance estimates obtained during Stedman et al. (2006) were very similar between 2005 and 2006, with the majority of observations coming from five of the same species each year (Table 47). CBC efforts in Chattanooga have also been steady, with several years of extremely high abundance levels (Figure 31). As has been discussed previously, the now 10-year-old Stedman et al. (2006) report is out of date, and the data presented by that study may not be completely reliable in the assessment of current condition. With this in mind, a Condition Level of 0 indicating no current concern was assigned to this measure. As with the species richness measure, this assessment is assigned with low confidence, and future surveys are needed to more accurately assess the current condition of this measure in CHCH.

Weighted Condition Score

A *Weighted Condition Score* of 0.20, indicating good current condition, was assigned to the birds component. Due in large part to the lack of a recent (<10 years old) data source specific to the birds in the park, the overall confidence in this assessment is low. A current trend was not assigned due to the lack of recent trend data.

Table 49. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's birds.

Measures	Significance Level	Condition Level	WCS = 0.20
Species Richness	3	1	
Raptor Species Richness	2	N/A	
Species Abundance	2	0	

4.5.6. Sources of Expertise

This component relied upon the best professional judgement of park and network staff.

4.5.7. Literature Cited

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4.6. Herpetofauna

4.6.1. Description

Herpetofauna species are considered critical components of terrestrial and aquatic ecosystems, and are often used as indicator species in assessments of environmental health (Accipiter Biological Consultants 2006). Reptile and amphibian taxa are frequently understudied in protected areas, and have become a focal topic as the shift to protecting biodiversity has become a critical goal in cultural-based NPS units (Scott and Seigel 1992). Recent inventory efforts, largely instigated by the CUPN, have targeted the herpetofaunal species in the park. CHCH consists of several disjunct units, with the Tennessee River flowing between the Lookout Mountain Battlefield and the Moccasin Bend Unit. Much of the park has suitable reptile and amphibian habitat, and over 30 species of herpetofauna have been documented within both the terrestrial and aquatic areas of the park (Accipiter Biological Consultants 2006, NPS 2016).

The slimy salamander (*Plethodon glutinosus*) is one of many amphibians found at CHCH (NPS Photo).

4.6.2. Measures

- Amphibian species richness
- Reptile species richness

4.6.3. Reference Conditions/Values

Only one herpetofauna inventory has been conducted in the park (Accipiter Biological Consultants 2006), and this sole source of actual on-the-ground data for the park's reptile and amphibian taxa will serve as the reference condition (Accipiter Biological Consultants 2006). While a lack of more recent data will prevent actual comparisons to this report, the identification of this reference condition may be useful for future assessments of condition.

4.6.4. Data and Methods

Accipiter Biological Consultants (2006) 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. 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 (Accipiter Biological Consultants 2006, p. 2).

Accipiter Biological Consultants (2006) targeted 11 major communities during their herpetofauna inventory in CHCH from 2003 to 2005; these communities are identified in Table 50. Surveys were conducted in the three largest units of the park: Chickamauga Battlefield (Figure 33), Lookout Mountain (Figure 34), and the Sherman Reservation (not shown, but contains just two plot areas where only hand collection was conducted) (Accipiter Biological Consultants 2006). A total of six field methods were utilized in the park, including general collecting, minnow traps, random plots (i.e., cover boards and area-constrained searches), frog breeding surveys, road surveys, and drift fences (Accipiter Biological Consultants 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 (Accipiter Biological Consultants 2006). Individuals captured through sampling were identified to species, sexed (if possible), measured in length (mm), weighed (g), and checked for reproductive condition.

Table 50. Habitat communities sampled during the Accipiter Biological Consultants (2006) herpetofauna inventory of CHCH.

Community	Description
Mixed hardwood forest	Dominated by oaks, ash, beech, and maple. Found on higher slopes than other forest types.
Mixed mesic hardwood forest	Red and white oaks, few beech, basswood, and buckeye. Found in lower areas near streams/springs
Juniper/hardwood forest	Juniper and hardwood species found in patches throughout park.
Pine/hardwood forest	Mixed pines and hardwoods found in drier slopes and ridges.
Open fields	Open grassy areas (e.g., mowed fields).
Cedar glades	Open areas of limestone substrate dominated by grasses and forbs.
Rock faces	Rock faces with no sources of water.
Ponds	Manmade lakes, beaver ponds, and other natural water bodies.
Springs	Areas of ground water discharging to the surface.
Streams	Flowing water of ephemeral, intermittent, or perennial nature.
Ephemeral pools	Pools of water that exist due to rainfall or runoff.

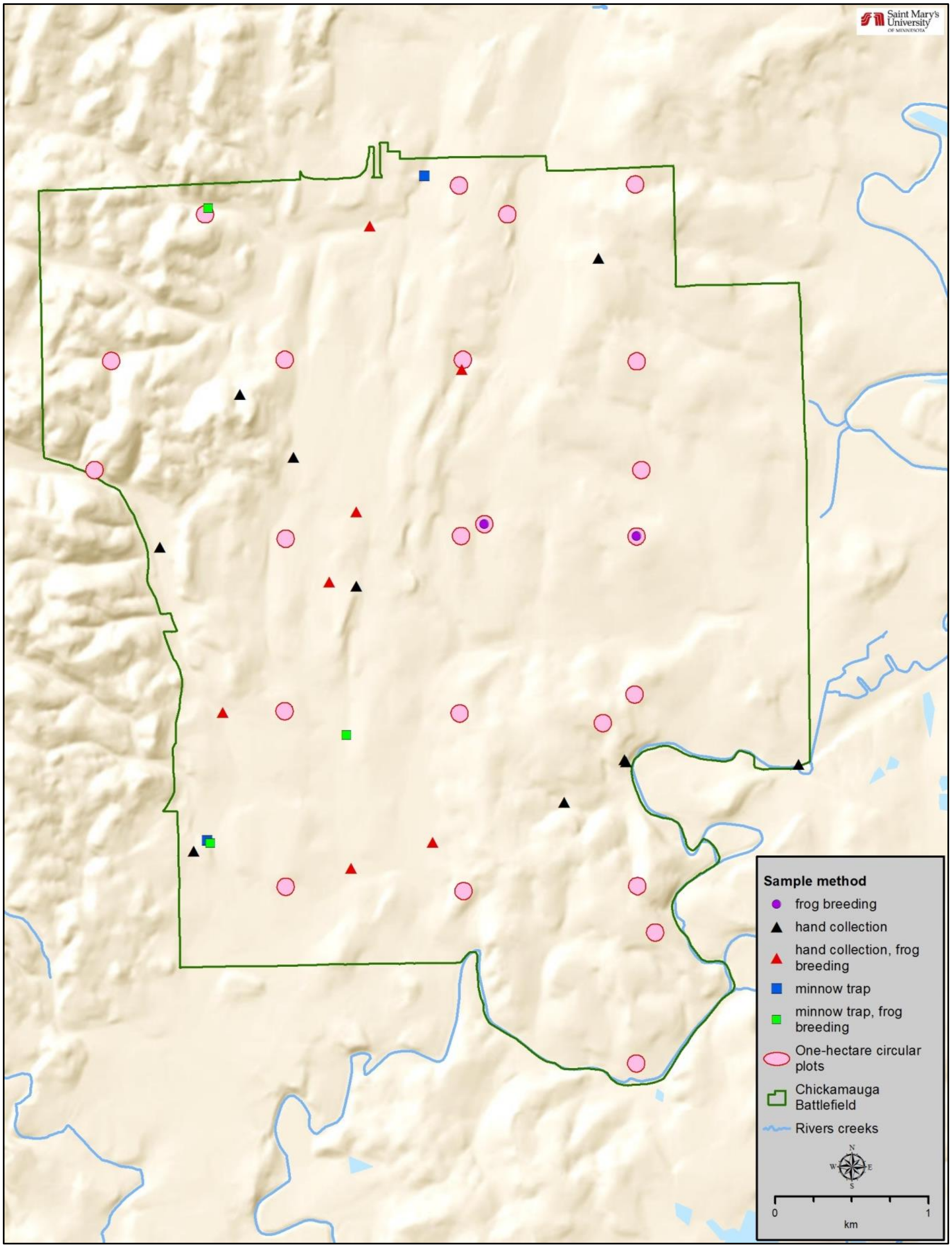

Figure 33. Sampling areas utilized by Accipiter Biological Consultants (2006) in the Chickamauga Battlefield Unit of CHCH.

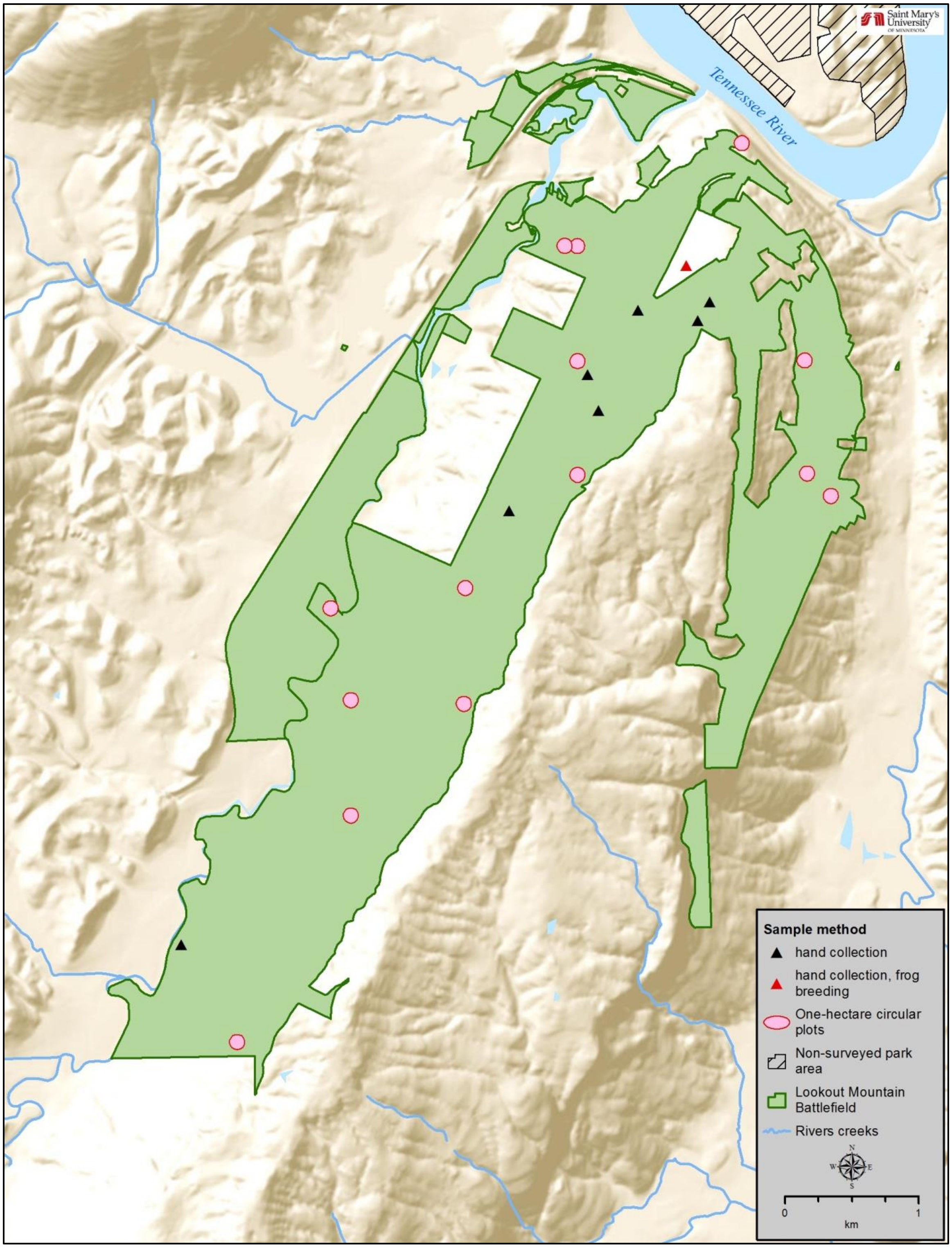

Figure 34. Sampling areas utilized by Accipiter Biological Consultants (2006) in the Lookout Mountain Battlefield Unit of CHCH.

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. "Probably present" is assigned to species that are highly likely to occur in the park but verifiable evidence is not current; "unconfirmed" is assigned for species with low or high likelihood of occurrence where evidence is not current or is insufficient (NPS 2011). These designations are determined largely through on-the-ground documentation by researchers/NPS staff during an inventory or survey. CHCH's Certified Species List was compiled primarily from the results of Accipiter Biological Consultants (2006), and it has not been reviewed or certified since 2007 (Bill Moore, CUPN Ecologist/Data Manager, written communication, 7 July 2016).

4.6.5. Current Condition and Trend

Amphibian Species Richness

NPS Certified Species List (2016)

The NPS Certified Species List (NPS 2016) identifies 36 amphibian species in CHCH as either present, probably present, or unconfirmed (Appendix H). When excluding unconfirmed species from the total, the number of amphibian species in CHCH drops to 23. Among amphibian species included for CHCH are 11 frog and toad species listed as present and three as unconfirmed. Ten species of salamanders and newts are listed as present, two probably present, and ten unconfirmed (Appendix H) (NPS 2016).

Accipiter Biological Consultants (2006)

Accipiter Biological Consultants (2006) reported 21 amphibian species (11 frogs and toads, 10 salamanders and newts) during inventory efforts from 2003-2005 (Appendix H). As part of their preparation for the 2003-2005 inventory, Accipiter Biological Consultants (2006) compiled a list of expected amphibian species based on the historic ranges and habitat requirements of the species. From this list, only three species (Tennessee cave salamander [*Gyrinophilus palleucus*], marbled salamander [*Ambystoma opacum*], and the red-spotted newt [*Notophthalmus viridescens viridescens*]) were not detected during the CHCH inventory. The Tennessee cave salamander is a state-threatened species that was historically documented in Lookout Mountain Cave within the park (Hay 1903, as cited in Hobbs 1994). The red-spotted newt and marbled salamander may be rare in CHCH, as Accipiter Biological Consultants (2006) concluded that little suitable habitat currently exists at the park.

Reptile Species Richness

NPS Certified Species List (NPS 2016)

The NPS Certified Species List (NPS 2016) identifies 40 reptile species (nine turtles, eight lizards and skinks, and 23 snakes) in CHCH as either present, probably present, or unconfirmed. When excluding unconfirmed species from the total, the number of reptile species in CHCH drops to 22 (Appendix I). Among reptile species included for CHCH are three turtle species listed as present and six unconfirmed; three species of lizards and skinks are listed as present, one probably present, and four unconfirmed; nine species of snakes are listed as present, six probably present, and eight unconfirmed (NPS 2016) (Appendix I).

Accipiter Biological Consultants (2006)

Accipiter Biological Consultants (2006) reported 15 reptile species (three turtles, three lizards and skinks, and nine snakes) during inventory efforts from 2003-2005 (Appendix I). There were seven reptile species that were not observed that had been identified on the expected reptile species list compiled by Accipiter Biological Consultants (2006) prior to survey efforts. All expected turtle species were documented during the time of Accipiter Biological Consultants (2006) inventory. The eastern musk turtle (*Sternotherus odoratus*) was not documented by the authors, but anecdotal evidence exists for this species in the park, with reports from visitors and park staff occurring throughout the inventory. However, the species is still considered unconfirmed due to the lack of formal documentation.

Six expected snake species were not documented by Accipiter Biological Consultants (2006). The species not documented included: northern pine snake (*Pituophis melanoleucus melanoleucus*), brown snake (*Storeria dekayi*), red-bellied snake (*Storeria occipitomaculata*), corn snake (*Elaphe guttata*), mole kingsnake (*Lampropeltis calligaster rhombomaculata*), and the southeastern crowned snake (*Tantilla coronata*). The eastern hognose snake (*Heterodon platirhinos*), northern black racer (*Coluber constrictor constrictor*), and timber rattlesnake (*Crotalus horridus*) were absent during the inventory, but similar to the absent turtle species, Accipiter Biological Consultants (2006) reported several anecdotal observations reported to the authors by park visitors and staff during the time of the inventory. The authors suggested that snakes may have been more prevalent in the park than the survey detected, and that there is appropriate habitat for these three species. Three of the four expected skink and lizard species were detected during the inventory, and only the broad-headed skink (*Eumeces laticeps*) was not observed. It is possible that this species, along with some of the undocumented snake species, could be found at the park with additional survey efforts (Moore, written communication, 11 July 2016).

<u>Threats and Stressor Factors</u>

Climate change has enormous threat potential for herpetofauna, depending on how it will impact the hydrology and local weather patterns in the region where CHCH is located. 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, as well as degrading water quality (Bates et al. 2008). These events can cause losses in biodiversity due to disruptions in the timing of seasonal events for animal reproduction and food sources (Bates et al. 2008, Carter et al. 2014). This is particularly true for amphibians since they spend a portion of their life cycle in water. An overall increase in global temperatures contributes to extended periods of drought, which have a combined effect on biota by causing by temperature and water stress (Bates et al. 2008).

Under stress, herpetofauna tend to be more susceptible to diseases, such as ranavirus, 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); ranaviruses have been associated with die-offs of more than 20 species of amphibians and turtles in over 25 states across the U.S. (USGS 2016). Mortality due to ranaviruses occurs mostly in larval amphibians, true frogs, and chorus frogs. Infected individuals my exhibit subtle or severe hemorrhages in ventral skin, often appearing as an irregular rash; onset of illness is sudden and often affects most individuals in a wetland (up to or exceeding 90%) (USGS 2016). Observed outbreaks have often been within wetland environments and cause mass die-off of frogs and salamanders, with the highest mortality rates occurring in juveniles (USGS 2016).

Chytrid fungus, specifically *Batrachochytrium dendrobatidis*, is a pathogen of amphibians that could potentially affect amphibian populations in CHCH. 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 zoosporic 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 of 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 individuals to high temperatures may kill the fungus (Woodhams et al. 2003). Neither ranaviruses nor chytrid fungus infection have been detected in CHCH to date, but they may greatly impact amphibian populations if the disease reaches the park.

Pollutants are a threat to herpetofaunal species, particularly in aquatic environments where contamination often accumulates from agricultural, municipal, and industrial activities within the catchment basin of an aquatic system (Gibbons et al. 2000). These can include pesticides, herbicides, cosmetics, metals, and excess nutrients which can be toxic to herpetofauna. Amphibians are thought to be especially sensitive to pollutants because their permeable skin and gelatinous eggs allow contaminants to enter their bodies and disrupt embryo formation (Marco et al. 1999). Some contaminants act as endocrine disrupters and have been known to alter natural sex-determination in turtle species exposed to them (Guillette Jr et al. 1996).

Habitat loss, fragmentation, and alteration are considered a primary threat to herpetofauna populations. Riparian vegetation serves as habitat structure and regulates water temperature by shading the water surfaces; any loss in riparian vegetation may reduce critical herpetofauna habitats in the park (Sung 2000). Potential loss of aquatic habitat is a grave concern for the park herpetofauna, particularly in regard to the many amphibian species that rely on aquatic habitat to carry out their life cycle. In North America, losses in area of freshwater wetlands (mostly from land development), an important aquatic habitat, have been substantial (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 (e.g., forests, meadows, and aquatic areas).

Data Needs/Gaps

The only park herpetofauna inventory is now over 10 years old and does not allow for an accurate assessment of current condition for herpetofaunal species that occur in the park. However, it does serve as an important baseline and has laid the groundwork for continued monitoring programs that are intended to promote long-term health of the park's herpetofauna (Accipiter Biological Consultants 2006). A more current study and long-term monitoring of amphibians and reptiles are needed to assess any trends that may be occurring within the park. Efforts should also be made to document additional species which were potentially missed during the 2006 inventory effort in order to fully document the parks biodiversity. Herpetofauna can be extremely difficult to inventory and follow-up efforts are often needed (Moore, written communication, 11 July 2016). Expansion of survey efforts into the recently acquired Moccasin Bend Unit may be warranted, especially if any NPS-related development is to occur on that property.

Overall Condition

Amphibian Species Richness

The amphibian species richness measure was assigned a *Significance Level* of 3 by the project team. The NPS Certified Species List includes 23 amphibian species as present or probably present at CHCH (NPS 2016); 21 of these species were observed by Accipiter Biological Consultants (2006). At this time, Accipiter Biological Consultants (2006) represents the only on-the-ground source of data for this component; however, it is over 10 years old, which makes assessing the current condition of this measure difficult. Due in large part to the fact that the majority of the expected amphibian species were present in CHCH during the Accipiter Biological Consultants (2006) inventory, this measure has been assigned a *Condition Level* of 0, indicating no concern at present.

Reptile Species Richness

The reptile species richness measure was assigned a *Significance Level* of 3 by the project team. Twenty-two reptile species are included on The NPS Certified Species List as present or probably present at CHCH (NPS 2016). Thirteen of these were observed during Accipiter Biological Consultants' (2006) inventory. Compared to amphibians, there were more reptile species considered "probably present" that were not observed in CHCH by Accipiter Biological Consultants (2006). Six species of snakes could not be confirmed within the park. While CHCH is at the extreme end of the northern pine snake's range and may be unlikely to support this species, CHCH does provide suitable habitat for the other five species that were not observed. It is very likely that additional snake-focused surveys would yield higher species richness results, especially for species such as the red-bellied snake and southeastern crowned snake, which spend the majority of their life underground. A *Condition Level* of 1, indicating low concern, was assigned to this measure, primarily due to the continued lack of documentation/confirmation for several "probably present" snake species.

Weighted Condition Score

The *Weighted Condition Score* for the herpetofauna component was 0.17, indicating good current condition. The overall confidence in this assessment is low, due mainly to the fact that there are no data available from the past 10 years and the current assessment of condition is based only on one data source. Monitoring and additional inventories of amphibians and reptiles in CHCH are needed to determine a more accurate current condition for the park. The work of Accipiter Biological Consultants (2006) serves as an excellent baseline for herpetofauna species richness in CHCH that other inventories should use as a basis of comparison.

Table 51. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's herpetofauna.

Measures	Significance Level	Condition Level	WCS = 0.17
Amphibian Species Richness	3	0	
Reptile Species Richness	3	1	

4.6.6. Sources of Expertise

- Bill Moore, CUPN Ecologist/Data Manager

4.6.7. Literature Cited

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4.7. Water Quality

4.7.1. Description

Water quality and quantity have been identified as high-priority Vital Signs for all parks in the CUPN, including CHCH (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; CHCH 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 surface water resources of CHCH include perennial streams (e.g., Lookout Creek, West Chickamauga Creek), perennial springs, and small ponds. In addition, the newest unit of the park, Moccasin Bend, is bordered by the Tennessee River. Several water bodies hold a cultural significance to the park; West Chickamauga Creek (Figure 35), for example, is where the first skirmishes of the Battle of Chickamauga occurred as the confederates tried to cross the creek from the southeast (Hanson and Blythe 1999).

Figure 35. West Chickamauga Creek at the site of Alexander's Bridge (SMUMN GSS photo by Kathy Allen).

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 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 in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2015).

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 atmospheric oxygen 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 2005).

NPS water quality data collection at Lookout Creek in CHCH (NPS photo by Beth Meiman).

Acid Neutralizing Capacity

Acid neutralizing capacity (ANC) is the ability of solutes and particulates in an unfiltered water sample to buffer acids, measured in mg/l as $CaCO_3$ (Meiman 2005). Waters with low ANC are more at risk of reductions in pH due to acid deposition, such as from acid rain (Meiman 2005).

E. coli Bacteria

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 2011a). 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. It is tested by counting colonies that grow on micron filters placed in an incubator for 22-24 hours. High concentrations of certain fecal coliform, such as *E. coli*, can cause serious illness in humans (USGS 2011a).

4.7.3. Reference Conditions/Values

The reference conditions for water quality will be the Tennessee and Georgia state standards for water bodies with a "fish and aquatic life" designated use (Table 52). However, there is an additional qualification in Tennessee water quality standards 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 52. Tennessee and Georgia state water quality standards for the fish and aquatic life designated use (unless otherwise noted) (Meiman 2010, 2016).

Parameter	TN standards	GA standards
Water temperature	not to exceed 30.5°C (86.9°F)	not to exceed 32.2°C (89.0 °F)
pH	6.0 - 9.0	6.0 - 8.5
Dissolved oxygen	not less than 5.0 mg/l	not less than 4.0 mg/l
E. coli bacteria	**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.	No standard

Since Georgia has not established a standard for E. coli, NPS monitoring at CHCH has adopted the EPA standard for "Single Sample Infrequently Used Full Contact Recreation" of <576 cfu/100 ml (Meiman 2010). 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 CHCH because they vary with the size and source of the water body. West Chickamauga and Lookout Creeks are part of larger watersheds that include areas outside the park, and are therefore subject to different influences than the smaller, upland springs fully contained within the park (Joe Meiman, NPS Hydrologist, email communication, 29 August 2016). Based on available data from CUPN monitoring, the natural SpC range for water bodies at CHCH appears to be 80-300 µS/cm. Natural ANC ranges are approximately 40-150 mg/l as CaCO3 for Cave and Skyuka Springs and the two creeks, but 1-40 mg/l as $CaCO_3$ for the remaining Lookout Mountain springs (Meiman 2005). 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-2000) water quality data are limited for CHCH. Hobbs (1994) recorded some water quality parameters during a survey of Lookout Mountain caves during 1992. Additional data exist from limited sampling along Lookout Creek (near but not within park boundaries) between 1995-1998 and for two locations on West Chickamauga Creek, one sampled in 1972 and the other in 1980 (NPS 2001). Measurements taken included water temperature, pH, DO, and SpC. Locations for which some historical water quality data are available are shown in Figure 36.

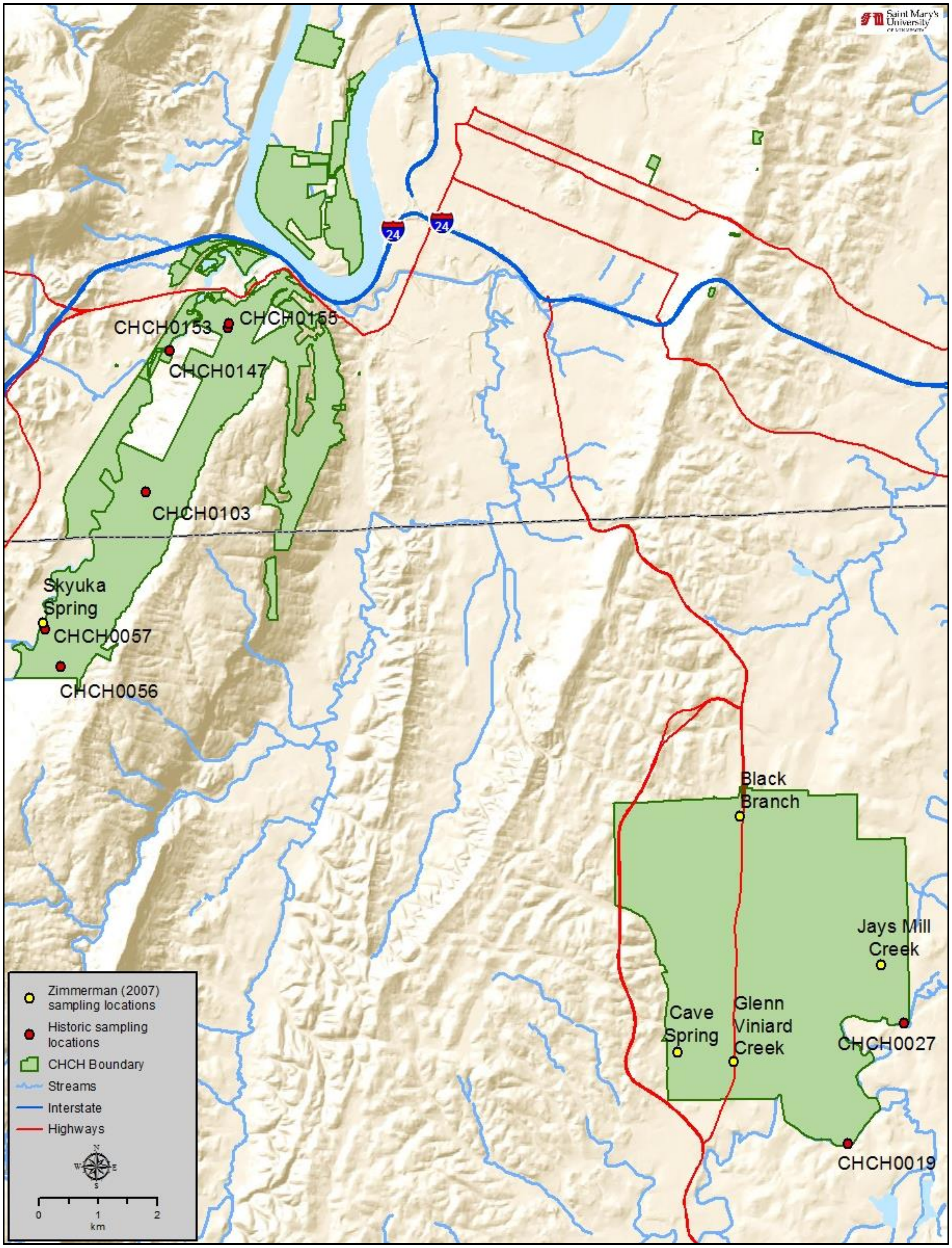


Figure 36. Locations of historic water quality sampling in or near CHCH (NPS 2001, Zimmerman 2007).

In 2002, the CUPN initiated a water quality monitoring program at CHCH. Monitoring takes place every month for two years, followed by a break of five years (Meiman 2010). Based on the limited nature of previous data and information, the first round of data collection can essentially be considered a baseline inventory (Meiman 2005). Monthly sampling was conducted from November 2002 through September 2004 at seven sites across both major units of the park (Figure 24), for a total of 23 sampling events per site (Meiman 2005). Parameters recorded included water temperature, pH, DO, SpC, ANC, and fecal coliform bacteria. 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 37.

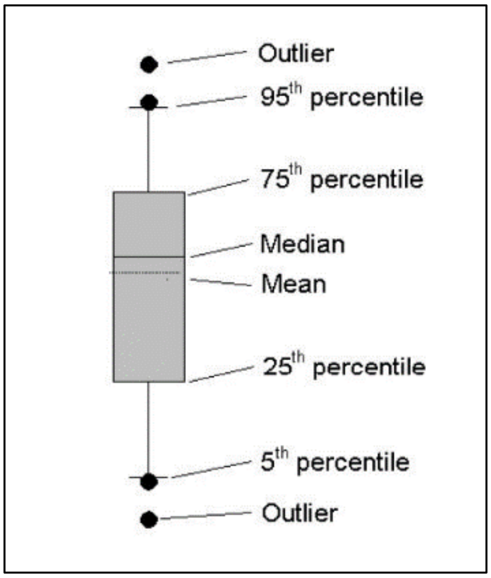


Figure 37. A guide for interpreting box-plot results (reproduced from Meiman 2007).

The CUPN repeated water quality sampling at the seven CHCH sampling sites from 2008-2010 (Meiman 2010). At this time, the bacteria parameter was changed from fecal coliform to *E. coli* bacteria specifically. Another round of sampling began in October 2015 and will continue through September 2017 (Teresa Leibfreid, CUPN Program Manager, email communication, 2 August 2016). During this most recent round, one additional sampling site was added on the Black Branch near the Chickamauga Battlefield Visitor Center (Meiman, email communication, 26 September 2016).

Zimmerman (2007) collected water quality data at five CHCH sites (Figure 38), all in Georgia, during a study of fish assemblages at four southeastern parks. Parameters measured included water temperature, pH, DO, SpC, and discharge. Samples were taken once each in the summer and fall of 2005 and during the spring of 2006 (Zimmerman 2007).

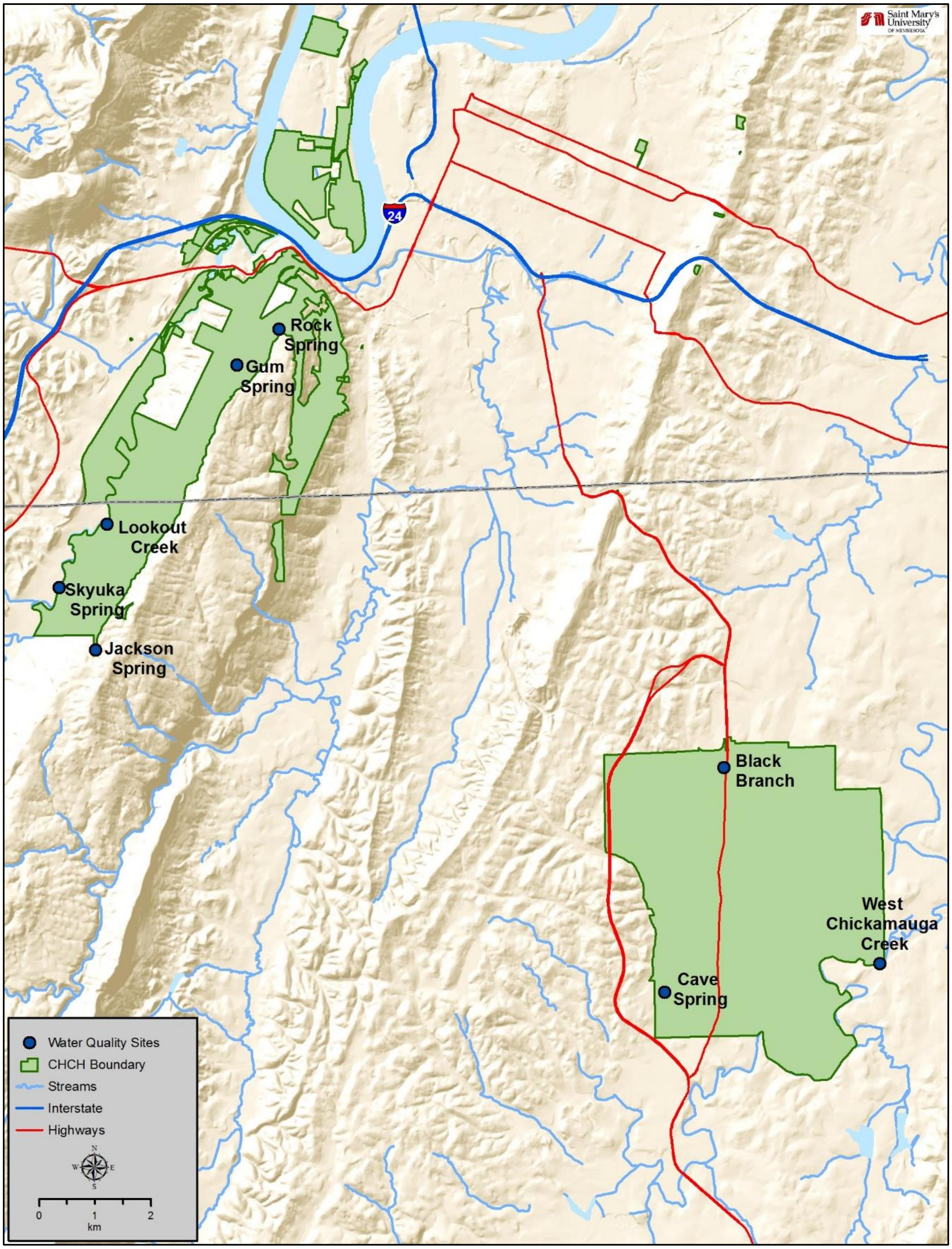


Figure 38. Locations of CUPN water quality monitoring sites within CHCH.

4.7.5. Current Condition and Trend

<u>Temperature</u>

The limited number of historical water temperature observations for CHCH suggest that waters generally range from 8-10°C (46-50°F) in colder months to above 20°C (68°F) during warmer months (Table 53) (NPS 2001). The ranges for locations with multiple observations were well within state standards, which serve as the reference condition for this assessment.

Table 53. Historical (pre-2000) water temperature (°C) observations (°C) for CHCH sampling locations (NPS 2001).

Site	Year(s)	Observations	Mean	Range
CHCH0019	Oct. 1972	3	17.5	–
CHCH0027	1967-1980	20	17.3	7.0-27.5
CHCH0056	Dec. 1992	1	10.3	–
CHCH0057	Sept. 1992	1	14.2	–
CHCH0103	Dec. 1992	1	12.1	–
CHCH0147	1995-1998	5	12.3	8.2-23.5
CHCH0153	Dec. 1992	1	13.9	–
CHCH0155	Dec. 1992	1	11.1	–

Zimmerman (2007) observed water temperatures ranging from 12.9-20.0°C (55.2-68.0°F) (Table 54). Temperatures at two sampling sites (Cave and Skyuka Springs) were relatively stable across seasons, due to their groundwater source and high canopy cover at each site (Zimmerman 2007). Temperatures were more seasonally variable at the remaining three sites because of variations in flow/discharge (i.e., temperatures increase during low flow periods) and/or lack of canopy cover (Zimmerman 2007). All observations were well within the state water temperature standards.

Table 54. Water temperatures (°C) at CHCH sampling locations in summer and fall of 2005 and spring of 2006 (table modified from Zimmerman 2007).

Site	Summer	Fall	Spring
Black Branch	13.4	20.0	17.3
Jays Mill Creek	12.9	16.2	16.3
Glen Viniard Creek	14.9	15.1	19.3
Cave Spring	15.2	15.0	15.1
Skyuka Spring	14.1	14.5	13.7

Water temperatures recorded during the initial round of CUPN monitoring (2002-2004) ranged from approximately 5-25°C (41-77°F), also within state standards (Figure 39) (Meiman 2005). Temperature ranges were wider for the two creeks, reflecting natural seasonal variation, and narrower for springs recharged by groundwater with long underground retention times (e.g., Skyuka Spring) (Meiman 2005).

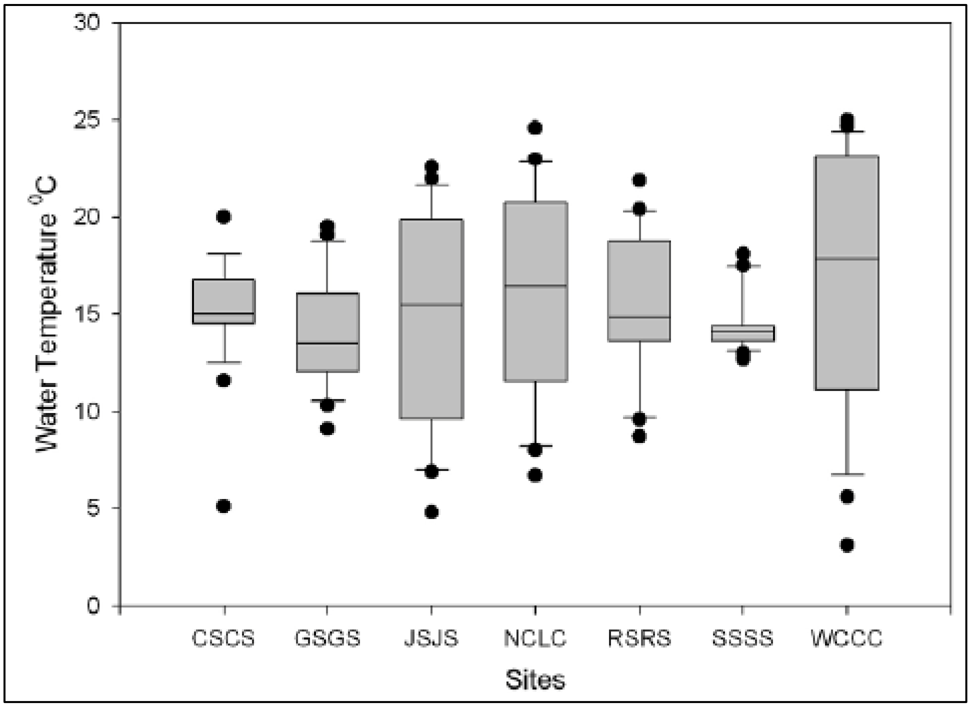


Figure 39. Water temperature measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005). CSCS = Cave Spring, GSGS = Gum Spring, JSJS = Jackson Spring, NCLC = Lookout Creek, RSRS = Rock Spring, SSSS = Skyuka Spring, WCCC = West Chickamauga Creek.

Results from CUPN sampling during 2008-2010 and in 2015-2016 also showed temperatures within both state standards (Figure 40). Maximum temperatures for the two creeks during the 2008-2010 sampling period were slightly higher than during the initial monitoring, but the most recent temperature measurements were well within the initial range (Meiman 2016). As with previous results, the two creeks (NCLC and WCCC) show greater temperature ranges than spring sites.

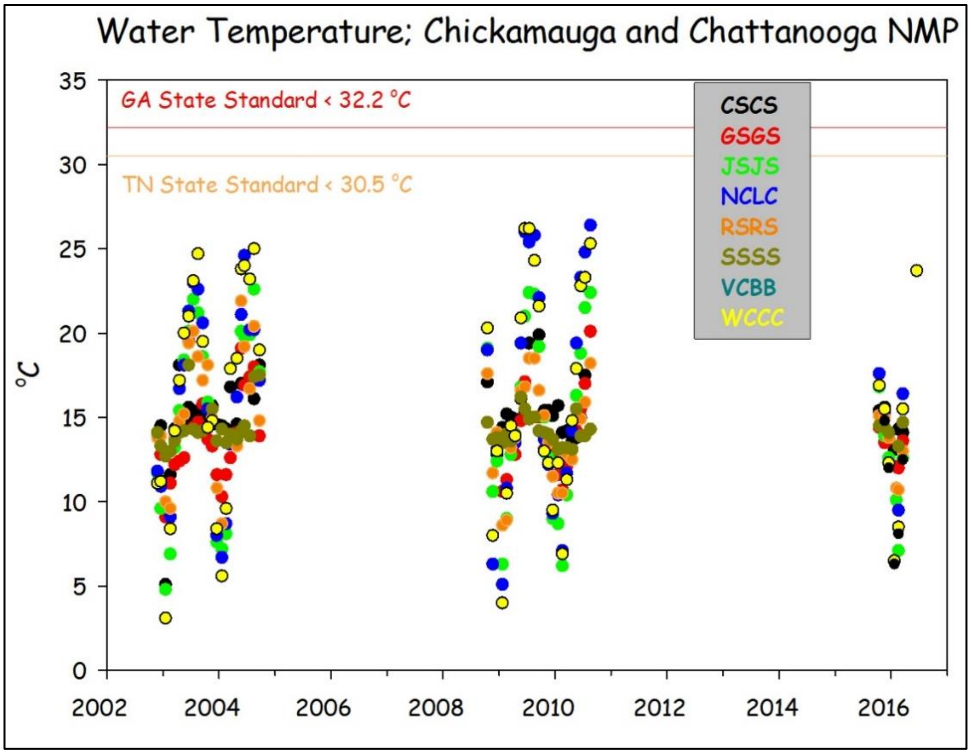


Figure 40. Water temperature measurements for CHCH sampling sites, 2002-2016 (graph provided by Joe Meiman, 26 September 2016). VCBB = Black Branch near the Visitor Center.

<u>pH</u>

Historical pH measurements from CHCH water bodies ranged from 7.0 to 8.8, with most values falling between 7.5 and 8.4 (Table 55) (NPS 2001). Nearly all values fall within state standards, with the exception of the maximum from West Chickamauga Creek at Alexander's Bridge (CHCH0027), which exceeded the Georgia standard range of 6.0-8.5.

Table 55. Historical (pre-2000) pH observations for CHCH sampling locations (NPS 2001).

Site	Year(s)	Observations	Mean	Range
CHCH0027	1967-1980	5	7.64	7.0-8.8
CHCH0056	Dec. 1992	1	8.35	–
CHCH0057	Sept. 1992	1	7.63	–
CHCH0103	Dec. 1992	1	8.18	–
CHCH0147	1995-1998	5	7.71	7.3-8.2
CHCH0153	Dec. 1992	1	7.81	–
CHCH0155	Dec. 1992	1	8.31	–

During 2005-2006 sampling, Zimmerman (2007) recorded pH values between 6.1 and 8.8 (Table 56). All but two readings (both from spring 2006) fell within Georgia state standards.

Table 56. pH values at CHCH sampling locations in summer and fall of 2005 and spring of 2006 (table modified from Zimmerman 2007).

Site	Summer	Fall	Spring
Black Branch	6.9	6.1	8.4
Jays Mill Creek	7.4	6.8	8.3
Glen Viniard Creek	7.3	7.2	8.8
Cave Spring	6.4	6.4	7.5
Skyuka Spring	7.4	6.2	8.6

During initial CUPN monitoring, pH values at the seven sampling sites ranged from approximately 5.0-8.0 (Figure 41) (Meiman 2005). All measurements fell within the upper limit of respective state standards (8.5 or 9.0), and five of seven sites were within the lower limit (6.0). Two Lookout Mountain springs (Rock and Gum) yielded some readings below this lower limit. However, these lower pH levels are likely due to the composition of the rock through which these springs are recharged, and are therefore considered within the natural range and not of concern at this time (Meiman 2005).

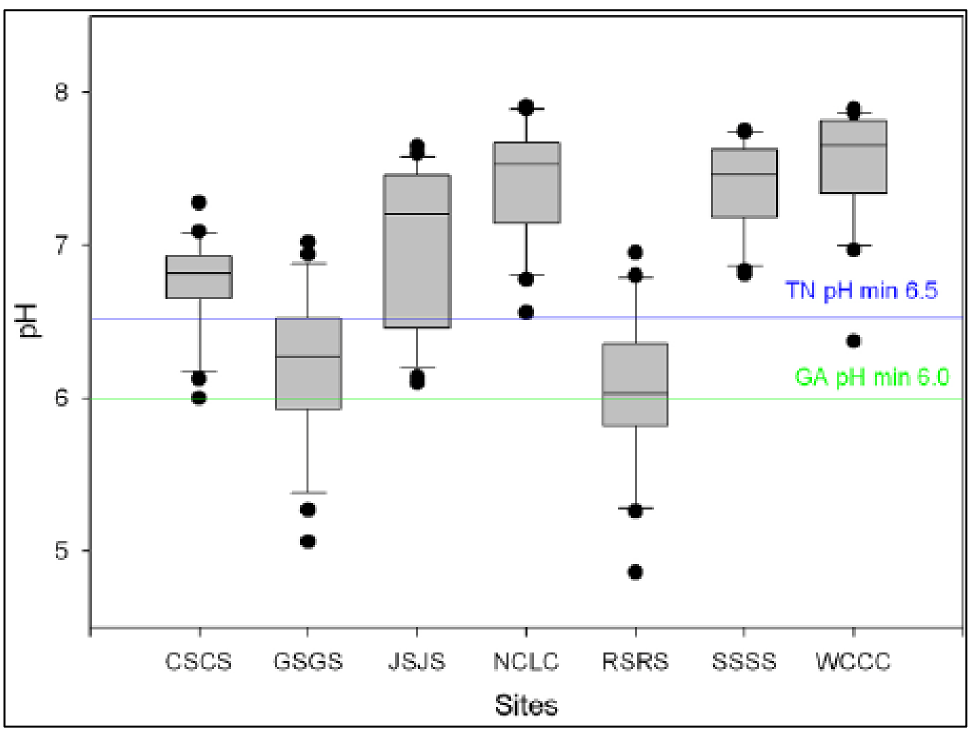


Figure 41. pH measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005). Note that the **current** lower limit used by Tennessee and utilized as a reference condition in this assessment is 6.0, not the 6.5 shown in this graph.

During 2008-2010 CUPN sampling, all measurements fell within the upper pH limits, with multiple readings from the two Lookout Mountain springs below the lower limit (Figure 42). During 2015-

2016 sampling, however, all measurements were within both the upper and lower limits (Meiman 2016).

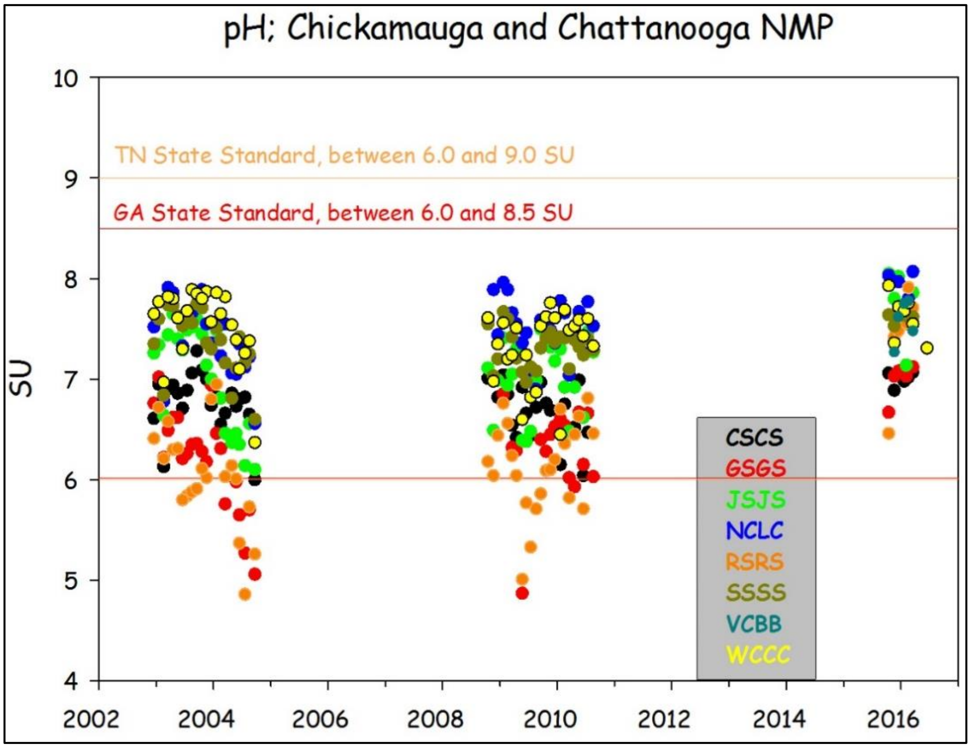


Figure 42. pH measurements for CHCH sampling sites, 2002-2016 (graph provided by Joe Meiman, 26 September 2016).

<u>Dissolved Oxygen</u>

The limited historical observations of DO from CHCH waters suggest that levels generally range from 5-10 mg/l (Table 57) (NPS 2001). However, the minimum reading from West Chickamauga Creek (CHCH0027) was well below this and outside the Georgia state standard of >4.0 mg/l.

Table 57. Historical (pre-2000) DO observations (mg/l) for CHCH sampling locations (NPS 2001).

Site	Year(s)	Observations	Mean	Range
CHCH0019	Oct. 1972	3	5.7	5.2-5.9
CHCH0027	1967-1980	20	5.1	0.05-10.5
CHCH0057	Sept. 1992	1	9.2	–
CHCH0147	1995-1998	5	8.2	5.7-10.4

Zimmerman (2007) documented DO levels in CHCH waters ranging from 2.0-8.9 mg/l, with lows typically occurring in the fall (Table 58). Two of these low values (Black Branch and Cave Spring) did not meet the Georgia state standard. However, it is worth noting that discharge during these times was zero (Zimmerman 2007), meaning there was no flow to refresh and aerate the waters.

Table 58. Dissolved oxygen levels (mg/l) at CHCH sampling locations in summer and fall of 2005 and spring of 2006 (table modified from Zimmerman 2007).

Site	Summer	Fall	Spring
Black Branch	5.0	2.9	6.1
Jays Mill Creek	5.1	4.2	5.2
Glen Viniard Creek	8.0	5.2	5.8
Cave Spring	4.7	2.0	4.9
Skyuka Spring	7.9	8.7	8.9

The majority of dissolved oxygen levels during the initial round of CUPN monitoring ranged from approximately 5-12 mg/l, with a couple lower outlying values from Cave Spring (Figure 43) (Meiman 2005). The low values at Cave Spring may be related to natural geological conditions at the spring, although these readings were also taken during low flow conditions, when surface waters were not being adequately recharged/aerated (Meiman 2005).

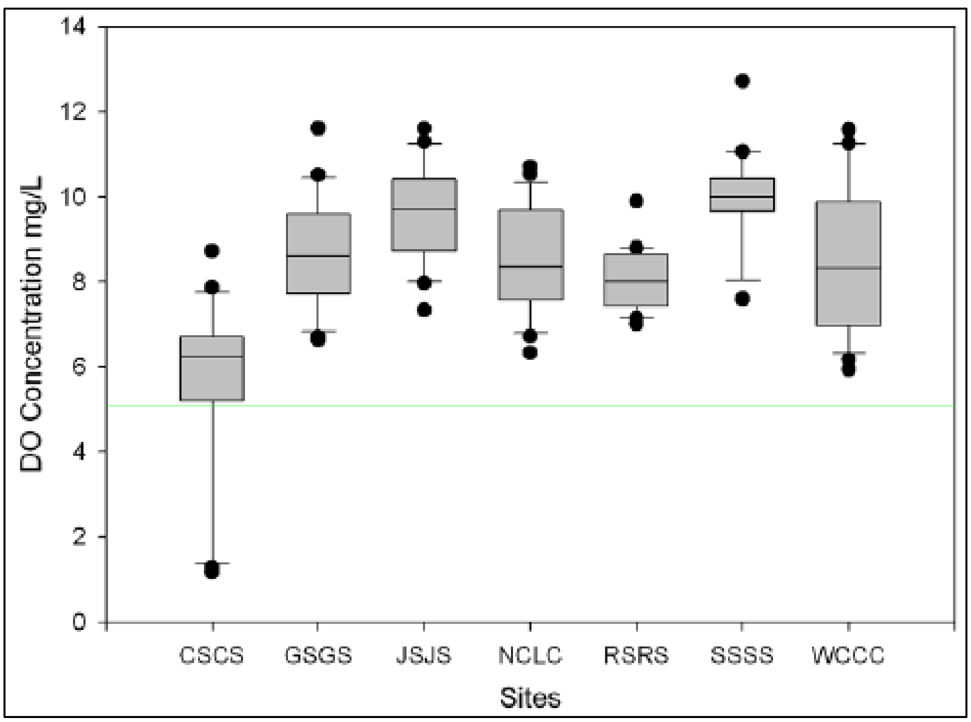


Figure 43. DO measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005). The green line represents the state standards at the time of 5 mg/l; the current state standards are >4 mg/l.

Dissolved oxygen measurements during 2008-2010 CUPN sampling were similar to initial monitoring results, but with several more measurements from Cave Spring and one measurement from Lookout Creek falling below state standards (Figure 44). However, during 2015-2016 sampling, all DO measurements met state standards (Meiman 2016).

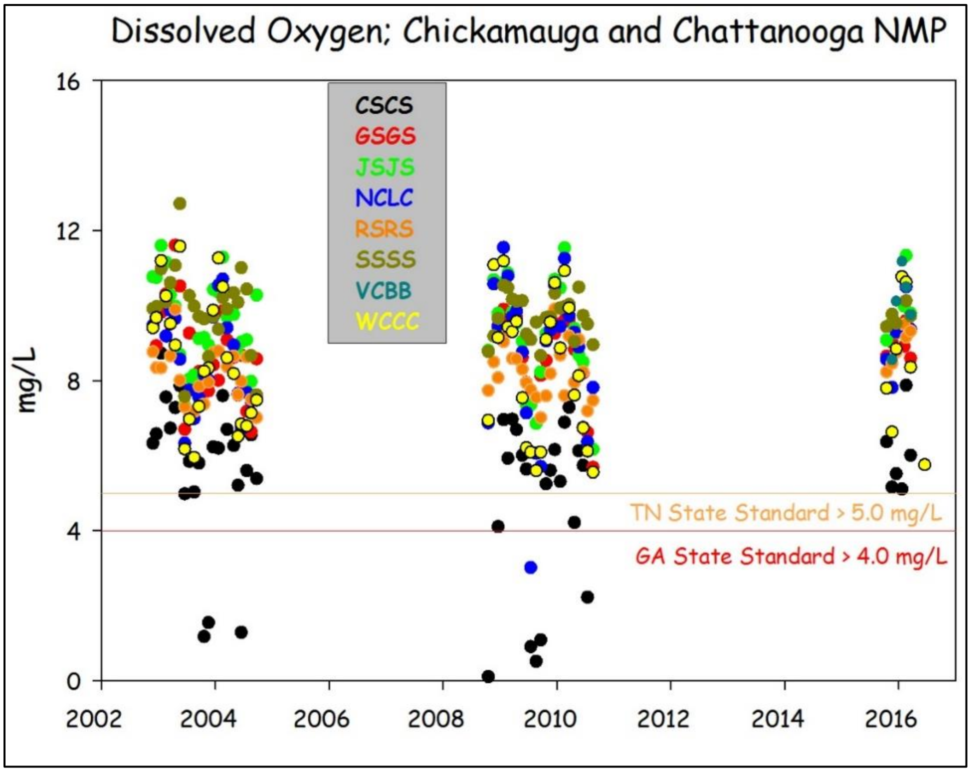


Figure 44. DO measurements for CHCH sampling sites, 2002-2016 (graph provided by Joe Meiman, 26 September 2016).

<u>Specific Conductance</u>

Historical observations of SpC at CHCH ranged from 141-300 µS/cm (Table 59) (NPS 2001). These values fall within the informal reference range identified for this NRCA of 80-300 µS/cm.

Table 59. Historical (pre-2000) SpC observations (µS/cm) for CHCH sampling locations (NPS 2001).

Site	Year(s)	Observations	Mean	Range
CHCH0027	1980	4	292.5	280-300
CHCH0056	Dec. 1992	1	227	–
CHCH0057	Sept. 1992	1	141	–
CHCH0103	Dec. 1992	1	211	–
CHCH0147	1995-1998	6	182.8	141-281
CHCH0153	Dec. 1992	1	282	–
CHCH0155	Dec. 1992	1	225	–

During 2005-2006 sampling, Zimmerman (2007) observed SpC values between 103 and 425 µS/cm, with highest values in the summer or fall (Table 60). Higher values in the fall at Black Branch and Cave Spring are likely related to low flow conditions (Zimmerman 2007).

Table 60. Specific conductance measurements (µS/cm) at CHCH sampling locations in summer and fall of 2005 and spring of 2006 (table modified from Zimmerman 2007).

Site	Summer	Fall	Spring
Black Branch	282.2	423.2	223.7
Jays Mill Creek	425.8	324.0	348.4
Glen Viniard Creek	385.0	293.2	323.3
Cave Spring	248.0	304.9	286.8
Skyuka Spring	134.1	171.6	103.5

The SpC ranges documented during initial CUPN sampling varied among the seven sampling sites, largely due to differences in site lithology (i.e., physical characteristics of underlying rocks) (Meiman 2005). Measurements for the two streams and Cave Spring (at Chickamauga Battlefield) generally covered wider ranges, from approximately 150 to 300 µS/cm (Figure 45). The highest values for Cave Spring were during periods of low flow (Meiman 2005). The ranges for the Lookout Mountain springs were narrower and lower, from around 80 to just below 200 µS/cm.

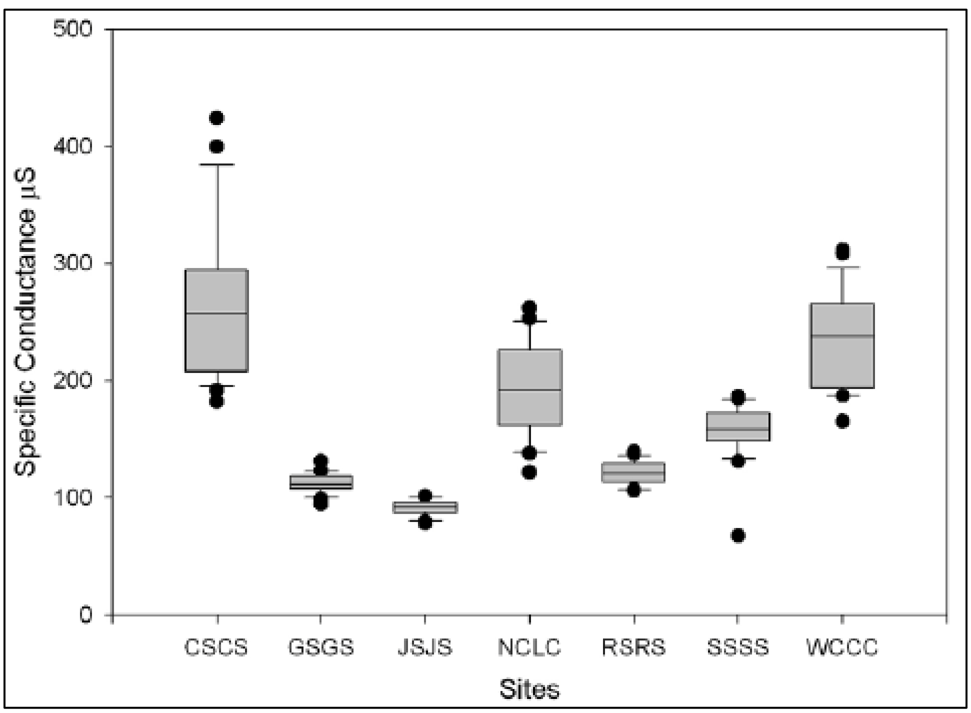


Figure 45. SpC measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005).

During 2008-2010 CUPN sampling, SpC ranges were similar to initial monitoring data, with the two streams and Cave Spring showing higher values and wider ranges (Figure 46). Several measurements from Cave Spring and West Chickamauga Creek were above the informal reference range of 80-300 µS/cm. During the most recent 2015-2016 sampling, maximum readings were lower, with nearly all measurements falling within the reference range (Meiman 2016).

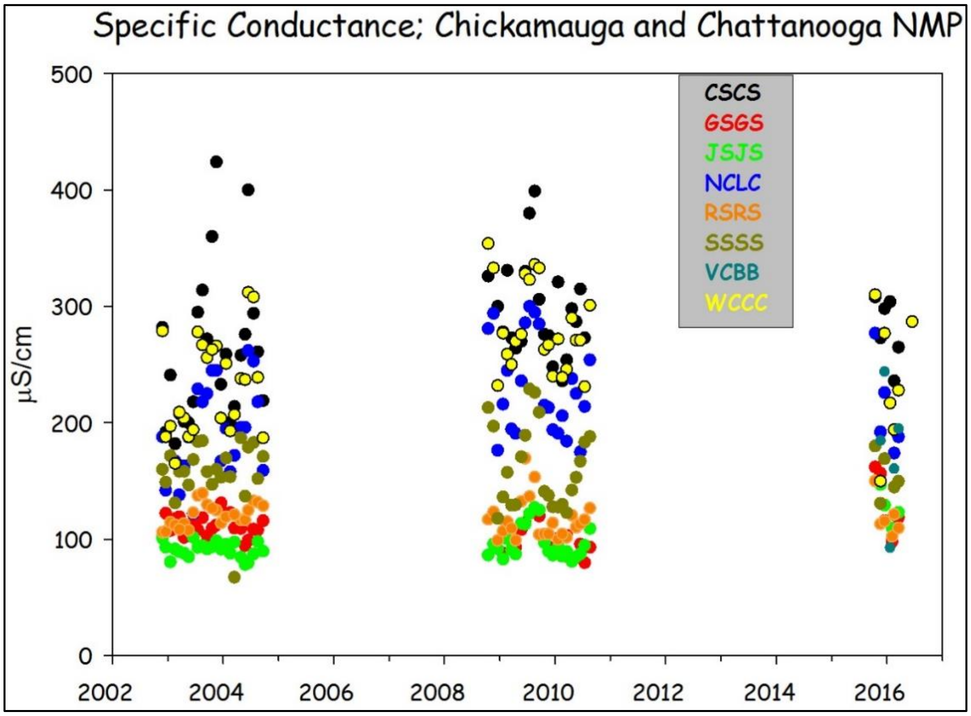


Figure 46. SpC measurements for CHCH sampling sites, 2002-2016 (graph provided by Joe Meiman, 26 September 2016).

<u>Acid Neutralizing Capacity</u>

As with SpC, ANC levels at CHCH sampling sites varied during initial CUPN sampling due to differences in site lithology (Meiman 2005). The two streams and Cave Spring generally ranged from 50-150 mg $CaCO_3$/l, with some higher values at Cave Spring (Figure 47). The Skyuka Spring range was slightly lower, from approximately 40-80 mg $CaCO_3$/l. The remaining Lookout Mountain springs, which recharge through sandstone, showed lower and much narrower ranges, from just above zero to around 30 mg $CaCO_3$/l (Meiman 2005).

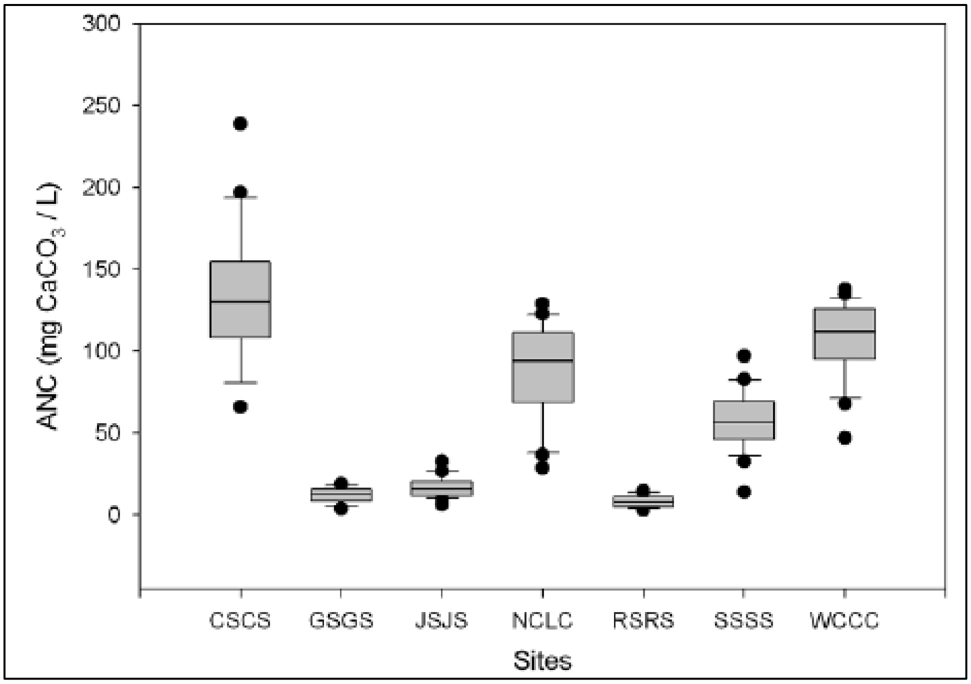


Figure 47. ANC measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005).

During subsequent CUPN monitoring efforts, ANC has been measured at just three Lookout Mountain sites: Gum Spring, Jackson Spring, and Rock Spring. During 2008-2010 sampling, Rock Spring ANCs were typically in the 5-10 mg $CaCO_3$/l, and nearly all Gum Spring readings were in the 10-20 mg $CaCO_3$/l range (Figure 48). Jackson Spring showed the highest values and widest range, from approximately 20 to just over 40 mg $CaCO_3$/l. During 2015-2016 sampling, Rock Spring ANC values were slightly higher, in the 10-15 mg $CaCO_3$/l range (Meiman 2016). The Gum Spring ANC readings were similar to prior sampling, but the Jackson Spring results showed a narrower range, with the majority of readings in the vicinity of 30-35 mg $CaCO_3$/l (Figure 48).

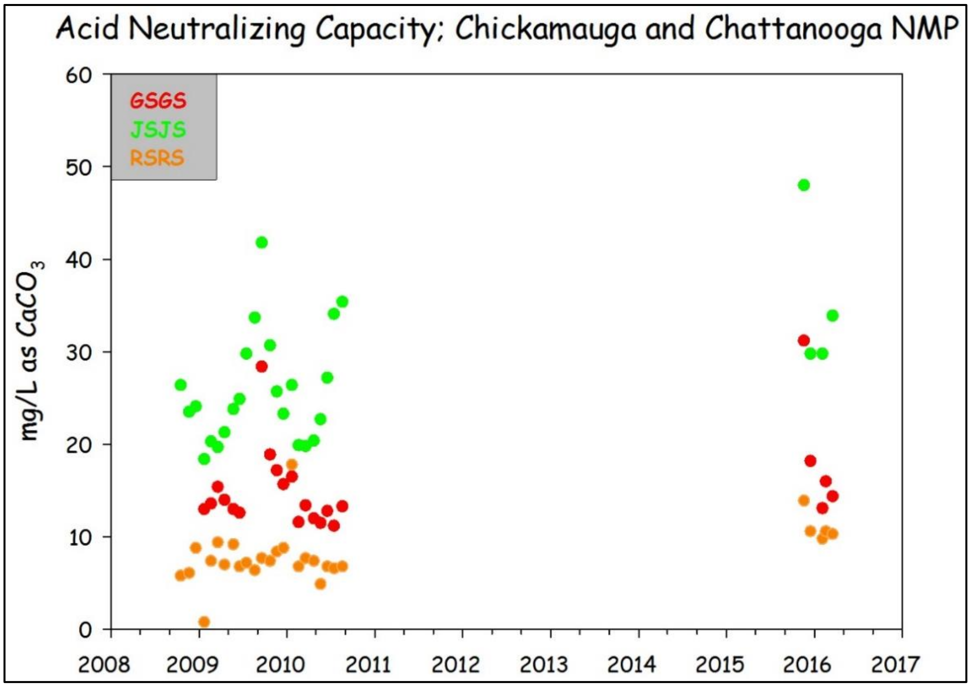


Figure 48. ANC measurements for CHCH sampling sites, 2008-2016 (graph provided by Joe Meiman, 26 September 2016).

E. coli Bacteria

Prior to 2008, bacteria data were gathered as total fecal coliform, not specifically *E. coli*. As a result, earlier bacteria measurements are not directly comparable to more recent CUPN monitoring data. Historical fecal coliform data are limited to just two stations at CHCH, on West Chickamauga and Lookout Creeks (Table 61).

Table 61. Historical (pre-2000) fecal coliform measurements (CFU/100 ml) for CHCH sampling locations (NPS 2001).

Site	Year(s)	Observations	Mean	Range
CHCH0027	1967-1992	13	729.5	50-7,100
CHCH0147	1995-1998	6	348.7	24-1,090

Initial CUPN sampling for fecal coliform showed that bacteria levels were generally low in CHCH water bodies (Meiman 2005). One or two readings from nearly all sites exceeded the Georgia "summer" limit of 200 col/100 ml, but only one extreme outlier from Cave Spring exceeded the "winter" limit of 1,000 col/100 ml (Figure 49).

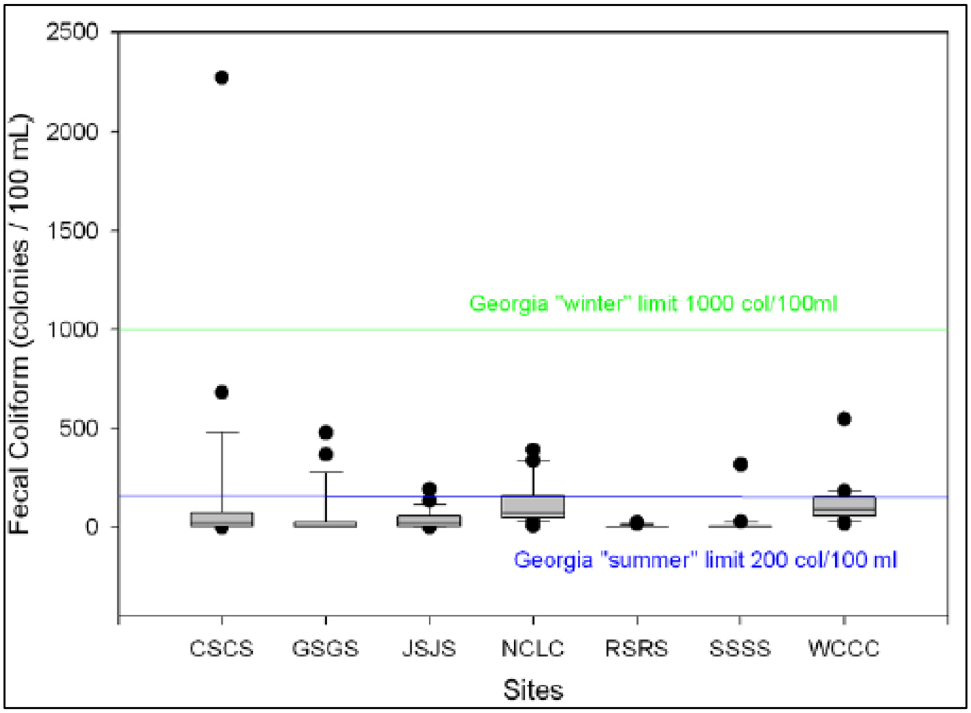


Figure 49. Fecal coliform bacteria measurements for CHCH sampling sites, November 2002-September 2004 (reproduced from Meiman 2005). Note that the state standards shown are for fecal coliform, not specifically *E. coli*, and are therefore no longer used as a standard for CUPN monitoring.

For the 2008-2010 round of CUPN monitoring, bacteria sampling switched and specifically measured *E. coli*. The majority of measurements were very low, particularly at Skyuka, Rock, and Jackson Springs (Figure 50). However, single measurements from four different sites exceeded the Tennessee state standard and the EPA standard of <576 cfu/100 ml, with one reading from Gum Spring around 2,400 MPN/100 ml (MPN is a statistical calculation roughly equivalent to cfu) (Meiman 2016). Higher values most likely occur during high flow periods, when fecal contaminants are washed into streams by runoff (Meiman 2005). During 2015-2016, several more readings have exceeded the EPA standard, including multiple samples from West Chickamauga Creek and Black Branch. Three of these measurements were at or near the upper quantification limit for sampling of 2,420 MPN/100 ml (Figure 50).

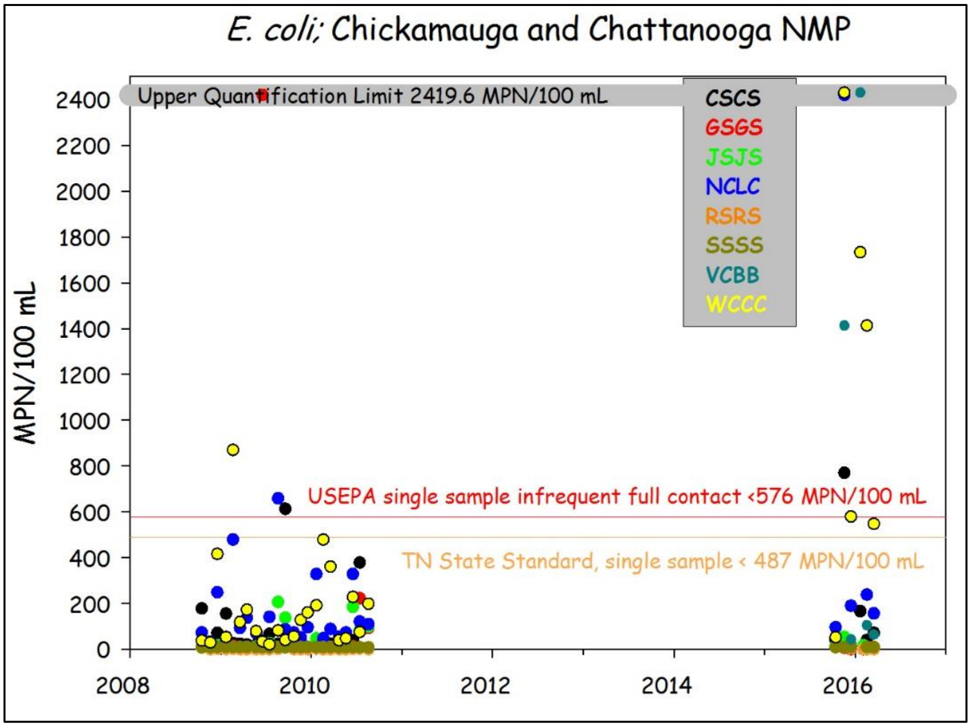


Figure 50. *E. coli* bacteria measurements for CHCH sampling sites, 2008-2016 (graph provided by Joe Meiman, 26 September 2016). MPN = most probable number, a statistical calculation that is theoretically equivalent to cfu (Meiman, written communication, 2 December 2016).

Threats and Stressor Factors

Threats to CHCH's water quality include upstream agricultural practices and human use, atmospheric deposition, climate change, and park operations/grounds maintenance. Much of the land south and east of Chickamauga Battlefield was still in agricultural use as of 2011, as pasture/hay or cultivated crops (Figure 51). Some of these lands have likely been altered through tiling, draining, and channelization, which may impact hydrological patterns (e.g., run off, stream flow, groundwater recharge) in the area. Fertilizers, animal wastes, and other chemicals may also run off into streams from agricultural lands. Additional human development upstream of the park could contribute trash, pollutants, and/or excess nutrients to the park's ground and surface waters. For example, relatively high nitrate levels observed at Rock Spring may be related to the nearby residential development on Lookout Mountain (Meiman 2005). 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, 29 August 2016).

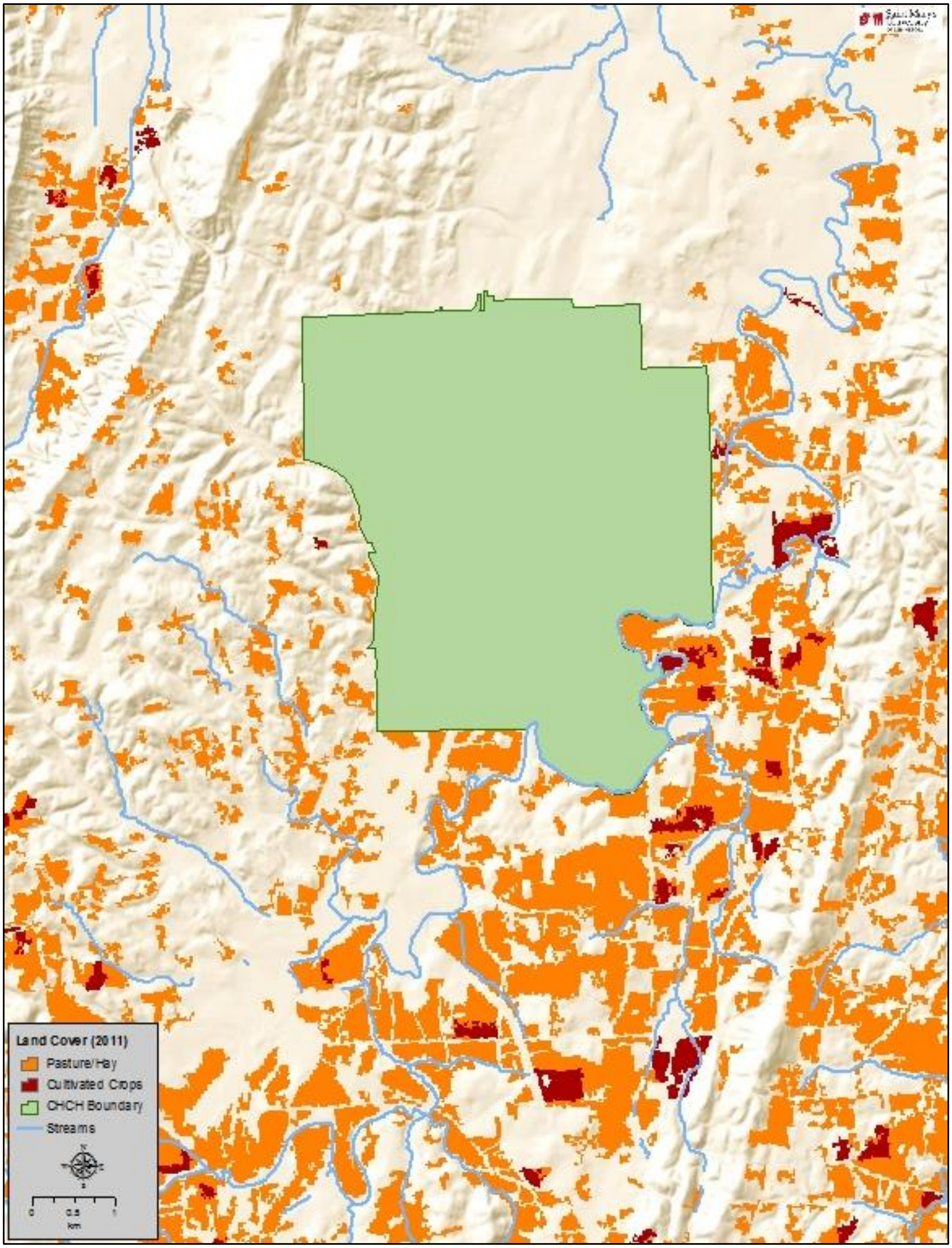


Figure 51. Agricultural land cover (as of 2011) surrounding Chickamauga Battlefield, according to the NLCD (USGS 2011b).

Atmospheric wet deposition (e.g., rain, snow, fog) in the region around CHCH is likely acidic. The mean annual pH of wet deposition measured near Crossville, AL (approximately 93 km [58 mi] southwest of CHCH) from 2012-2014 was between 5.2-5.3 (Figure 52) (NADP 2016a). pH means are similar at a station 164 km (102 mi) east of the park near Otto, NC (NTN Site NC25) (NADP 2016b). Because of the low acid neutralizing capacity of some of CHCH's water bodies, the low pH of precipitation/deposition may be retained in the park's surface waters (Meiman 2005, 2013). It is unclear if the acidic nature of regional wet 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).

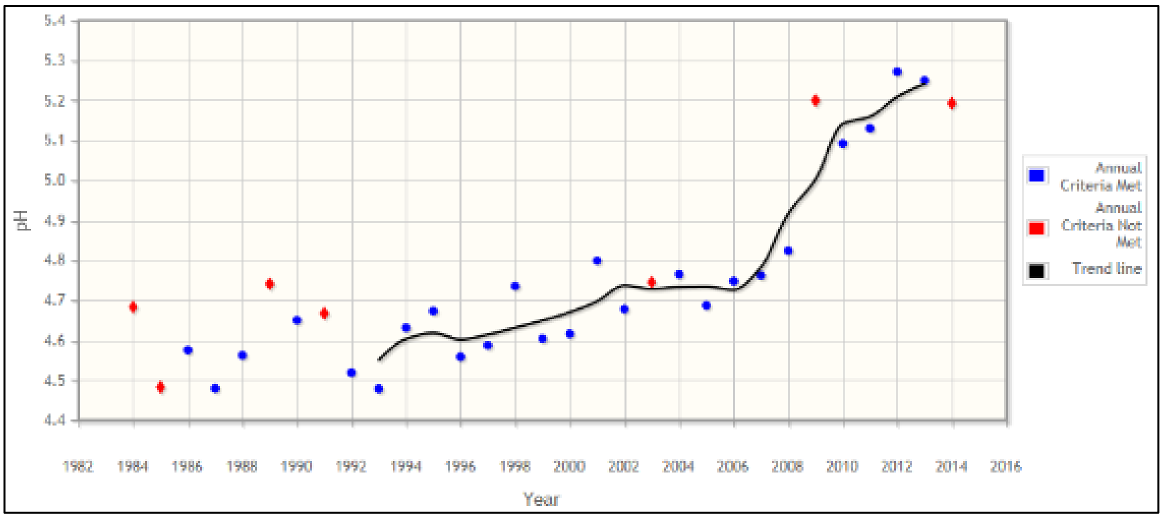


Figure 52. Annual mean pH of wet atmospheric deposition at NTN Site AL99, Sand Mountain Research and Extension Center (approximately 93 km [58 mi] southwest of CHCH) (NADP 2016a). Red diamonds represent years when NADP's data completeness criteria (valid samples and precipitation amounts for 75% of time 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).

<u>Data Needs/Gaps</u>

Adequate 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. Further investigation to identify the sources contributing to recent high *E. coli* levels in several water bodies may be warranted.

Overall Condition

Temperature

The NRCA project team assigned this measure a *Significance Level* of 3. All water temperature measurements taken at CHCH have met the state standards of both Tennessee and Georgia. As a result, temperatures in park waters are considered within the range to support aquatic life (Meiman 2005). Therefore, this measure is currently of no concern (*Condition Level* = 0).

pH

This measure was also assigned a *Significance Level* of 3. The majority of pH measurements since CUPN monitoring began in 2002 have fallen within respective state standards (Meiman 2005, Zimmerman 2007). Two readings by Zimmerman (2007) were just above the Georgia standard, and several readings from Lookout Mountain springs during the first two rounds of CUPN sampling have fallen below state standards. However, the low values at the springs are considered natural, given the site's lithology, and are not a particular concern at this time. Therefore, a *Condition Level* of 1 is assigned.

Dissolved Oxygen

A *Significance Level* of 3 was assigned for the DO measure. During the first two rounds of CUPN monitoring (2002-2005, 2008-2010) the majority of DO measurements met state water quality standards (Meiman 2005, 2016). Exceptions were potentially related to natural geological conditions (e.g., at Cave Spring) and also likely occurred during low flows. Measurements during 2015-2016 CUPN sampling have all met state standards. As a result, this measure is of low concern (*Condition Level* = 1).

Specific Conductance

This measure was assigned a *Significance Level* of 3. No state standards are in place for SpC, but based on historical observations and available data from initial CUPN monitoring, an informal reference condition range of 80-300 µS/cm was used for this assessment. Several observations by Zimmerman (2007) and during early CUPN sampling exceeded this range, primarily at Cave Spring and Chickamauga Battlefield streams (Meiman 2005, 2016). Many of these high readings were likely during low flow conditions, when less water was available to dilute the conductive solutes. During 2015-2016 sampling, only a few SpC measurements were at or just above the upper end of the informal reference range. A *Condition Level* of 1, indicating low concern, is assigned for this measure.

Acid Neutralizing Capacity

The ANC measure was assigned a *Significance Level* of 3. State standards are also not available for ANC, but an informal reference range of 1-40 mg $CaCO_3$/l for three Lookout Mountain springs and 40-150 mg $CaCO_3$/l for the remaining sample sites was used for this assessment. After initial CUPN sampling (2002-2005), ANC was determined to be of little concern at all but the three Lookout Mountain springs with the lowest readings (Gum, Rock, and Jackson) (Meiman, email communication, 26 September 2016). Subsequent monitoring has occurred only at these sites. Sampling results from 2008-2010 and 2015-2016 were fairly consistent, with slightly higher ANC values during the most recent round (Meiman 2016). This may suggest a small improvement in the water's ability to buffer acid inputs. Therefore, this measure is currently of low concern (*Condition Level* = 1).

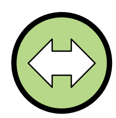
E. coli Bacteria

The NRCA project team assigned this measure a *Significance Level* of 3. The majority of *E. coli* readings from CHCH waters are very low. However, during 2008-2010 CUPN monitoring, three measurements from different water bodies exceeded the EPA standard for contact recreation of <576 cfu/100 ml (Meiman 2016). In more recent sampling (2015-2016), even more measurements exceeded this standard, with three readings near the upper quantification limit of 2,400 cfu/100 ml (Figure 50). As a result, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Weighted Condition Score

The *Weighted Condition Score* for CHCH's water quality is 0.33, which falls at the top edge of the good condition range. Any slight deterioration in conditions could shift water quality to moderate concern. A comparison of results from the three rounds of CUPN sampling shows that park water quality is relatively stable.

Table 62. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's water quality.

Measures	Significance Level	Condition Level	WCS = 0.33
Temperature	3	0	
pH	3	1	
Dissolved Oxygen	3	1	
Specific Conductivity	3	1	
Acid Neutralizing Capacity	3	1	
E. coli	3	2	

4.7.6. Sources of Expertise

- Joe Meiman, National Park Service Hydrologist

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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 CHCH. 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 its impacts as a Vital Sign for all network parks, including CHCH (Figure 53) (Leibfreid et al. 2005).

Figure 53. Portable ozone monitor at Lookout Mountain within CHCH (NPS photo).

4.8.2. Measures

- Nitrogen deposition
- Sulfur deposition
- Mercury deposition
- Ozone
- Visibility
- Particulate matter

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, 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).

Ozone

Ozone (O_3) 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 CHCH that are known to be sensitive to ozone include green ash, white ash (*Fraxinus americana*), tulip tree, eastern redbud (*Cercis canadensis*), 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 concentrations.

Particulate Matter and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It 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 or less in diameter; 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 63 and Table 64.

Table 63. 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_{25} (ppb)	Visibility (dv* above natural conditions)
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 64. National Park Service Air Resources Division air quality assessment matrix for mercury status (mercury wet deposition rating) (NPS 2015c). Green = Good Condition, yellow = Moderate Concern, and red = Significant Concern.

Predicted Methylmercury Concentration 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 3-year average 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 average 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 63) to determine park-specific mercury/toxics status (NPS 2015c).

Particulate Matter

The PM 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 98^{th}-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 PM nonattainment areas, EPA AQI breakpoints for 24-hour average (µg/m^3) are used to assign a PM condition (NPS 2015c). $PM_{2.5}$ concentrations ≥35.5 ppb are assigned a *Significant Concern*. $PM_{2.5}$ 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 2013b). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier (NPS 2013b). 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 40^{th} and 60^{th} 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

Monitoring in the Park

Air quality monitoring in the park has been limited. Ozone was monitored by the CUPN from 7 April to 3 November 2010 using a portable ozone monitoring station (POMS) on Lookout Mountain in Point Park (Jernigan et al. 2011). The CUPN monitors ozone at two network parks each year, resulting in a 6-year sampling rotation for each park (Jernigan et al. 2012). Sensitive plants were also checked for ozone foliar injury at one location in the park (Jernigan et al. 2011). CHCH is being monitored again in 2016, with the POMS deployed at the same Lookout Mountain location (Johnathan Jernigan, CUPN Physical Scientist, email communication, 11 August 2016). Atmospheric deposition, $PM_{2.5}$, and visibility have never been measured within CHCH.

NPS Data Resources

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 CHCH. 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 condition data for CHCH 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 near-enough representative monitors for such an assessment of 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 visibility monitoring locations meet these criteria for CHCH.

Other Air Quality Data Resources

The EPA Air Trends Database provides annual average summary data for ozone and $PM_{2.5}$ concentrations near CHCH (EPA 2016a). The nearest $PM_{2.5}$ monitor is located in Rossville, GA (Site ID: 13-295-0002) and is operated by the Georgia Air Protection Branch Ambient Monitoring Program (Figure 54). This station, which has collected data from 2000–2015, is located approximately 5 km (3 mi) northwest of Chickamauga Battlefield and 4 km (2.5 mi) east of Lookout Mountain. The nearest active ozone monitor is on the northeast side of Chattanooga (Site ID 47-065-4003), around 18-20 km (11-12.5 mi) northeast of CHCH’s two main units, and has been active since 2004 (Figure 54).

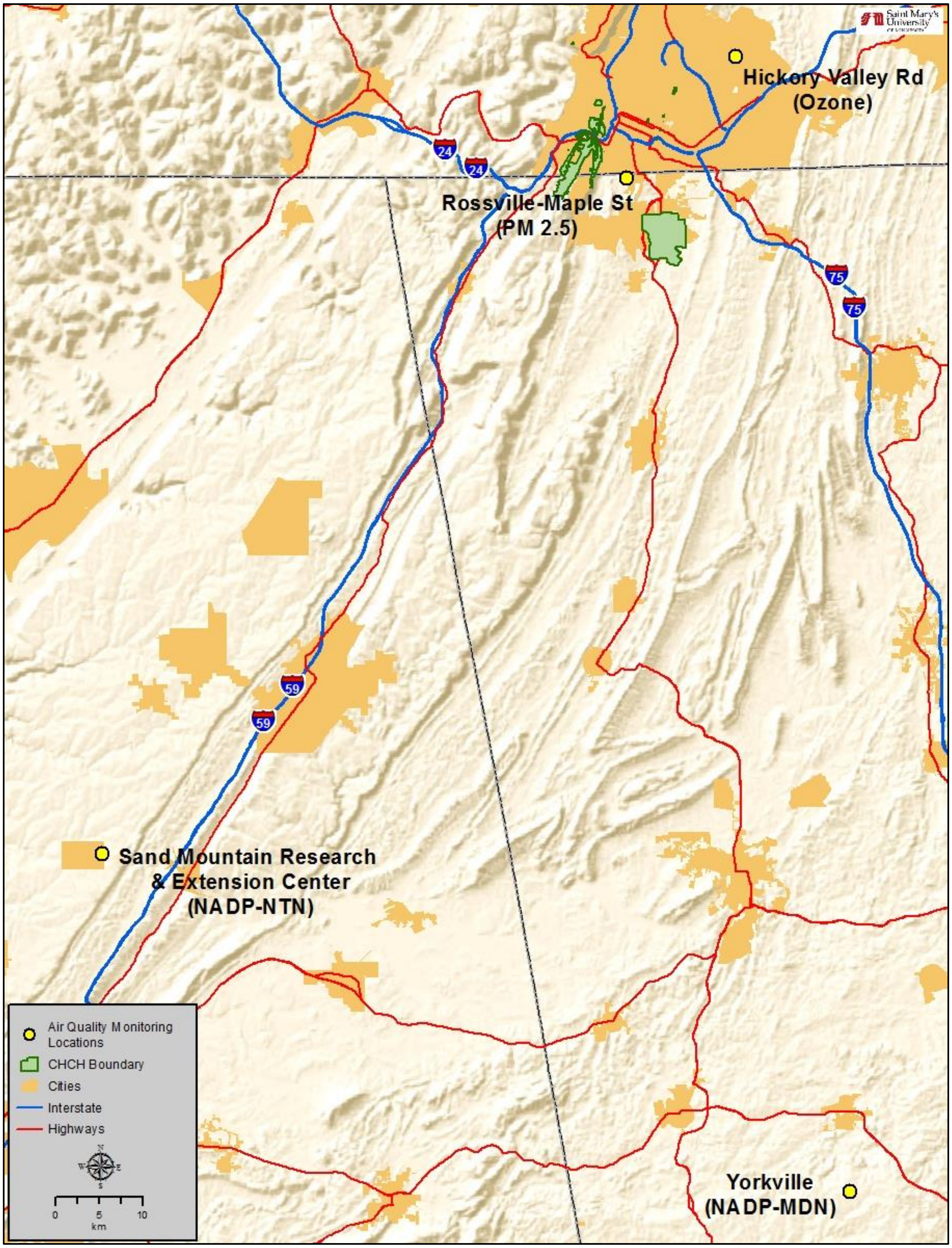

Figure 54. Air quality monitoring locations in relation to CHCH.

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 CHCH is located at Sand Mountain Research and Extension Center, in northeastern Alabama (site ID: AL99), just over 90 km (56 mi) southwest of CHCH (Figure 54). 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 CHCH is in Yorkville, GA, nearly 110 km (68 mi) southeast of Chickamauga Battlefield (NADP 2016a) (Figure 54). 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).

Special Air Quality Studies

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.

Sullivan et al. (2011a, 2011b) 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. 2011b).

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

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 CHCH is 4.1 kg/ha/yr (NPS 2015b). Based on the NPS ratings for air quality conditions (see Table 54), this falls in the *Significant Concern* range. A comparison to previous 5-year estimates shows that nitrogen deposition has decreased slightly over recent years (Figure 55).

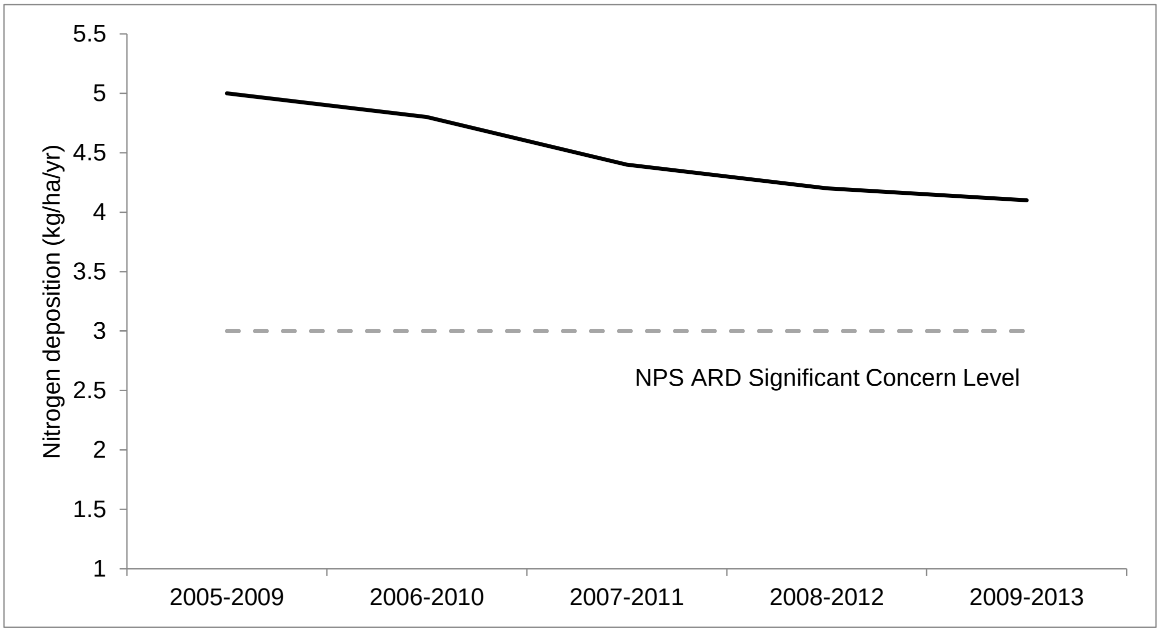

Figure 55. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at CHCH (NPS 2015b).

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 CHCH 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 CHCH of 4.1 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. (2011b) ranked CHCH as at moderate risk of nutrient enrichment from nitrogen deposition, due to very high pollutant exposure but very low levels of ecosystem sensitivity.

Concentrations (mg/L) of nitrogen compounds in wet deposition can also 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 56 shows that nitrate concentrations increased slightly during the 1980s, remained relatively stable through the 1990s, and then decreased during the 2000s (NADP 2016b). Ammonium concentrations also increased during the 1980s, stabilized during the 1990s, but then increased during the mid-2000s, peaking in 2006 (Figure 57). Concentrations decreased in recent years, returning to early 2000s levels (NADP 2016b).

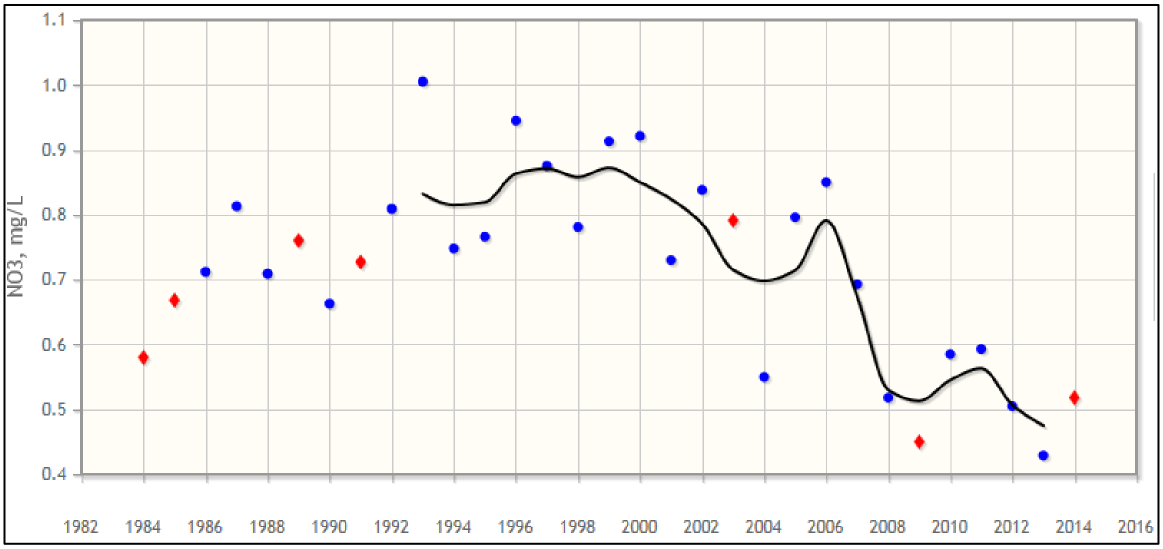

Figure 56. Annual weighted mean concentration of nitrate in wet deposition from Sand Mountain Research and Extension Center (NTN Site AL99) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

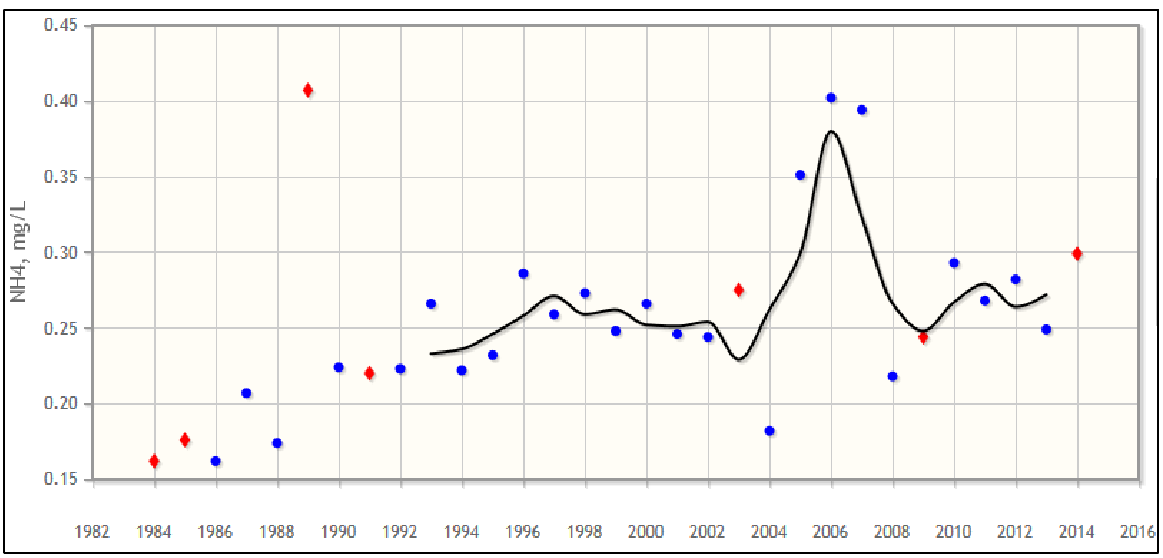

Figure 57. Annual weighted mean concentration of ammonium in wet deposition from Sand Mountain Research and Extension Center (NTN Site AL99) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

In contrast to the nutrient enrichment assessment discussed previously, Sullivan et al. (2011a) ranked CHCH as at very high risk of acidification from acidic (nitrogen and sulfur) deposition, due to very high pollutant exposure and very high levels of ecosystem sensitivity.

Sulfur 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 CHCH is

3.3 kg/ha/yr (NPS 2015b). This falls in the *Significant Concern* range. A comparison to previous estimates suggests that sulfur deposition is decreasing at CHCH (Figure 58).

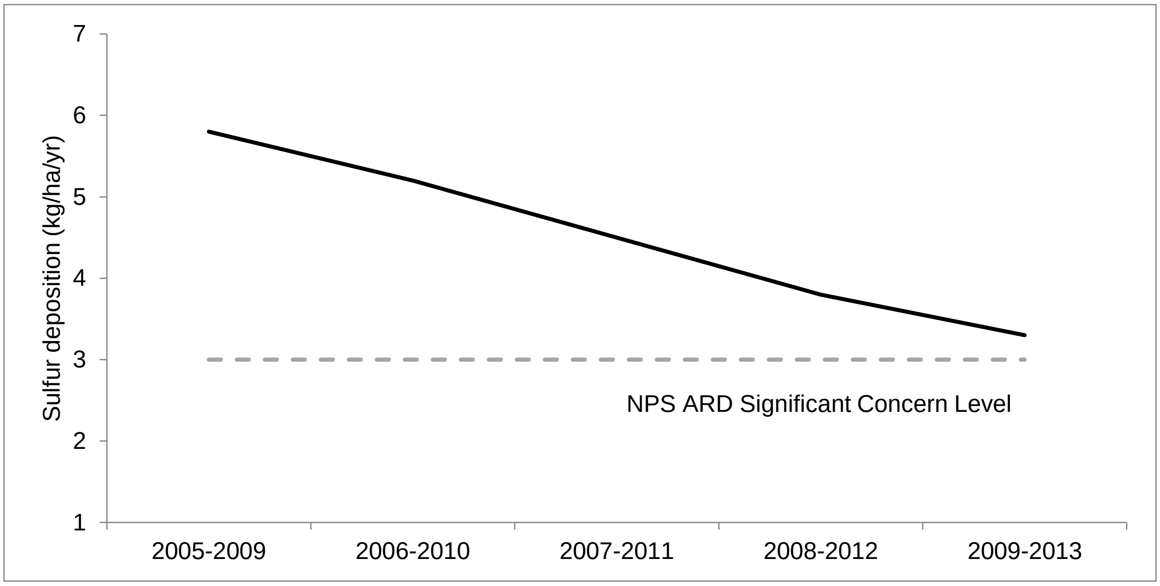

Figure 58. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at CHCH (NPS 2015b).

As with nitrogen, concentrations (mg/L) of sulfur compounds in wet deposition can also be used to evaluate overall trends in deposition. Figure 59 shows that the sulfate concentration in the CHCH region has declined over time, recently dropping below 0.7 mg/L (NADP 2016b).

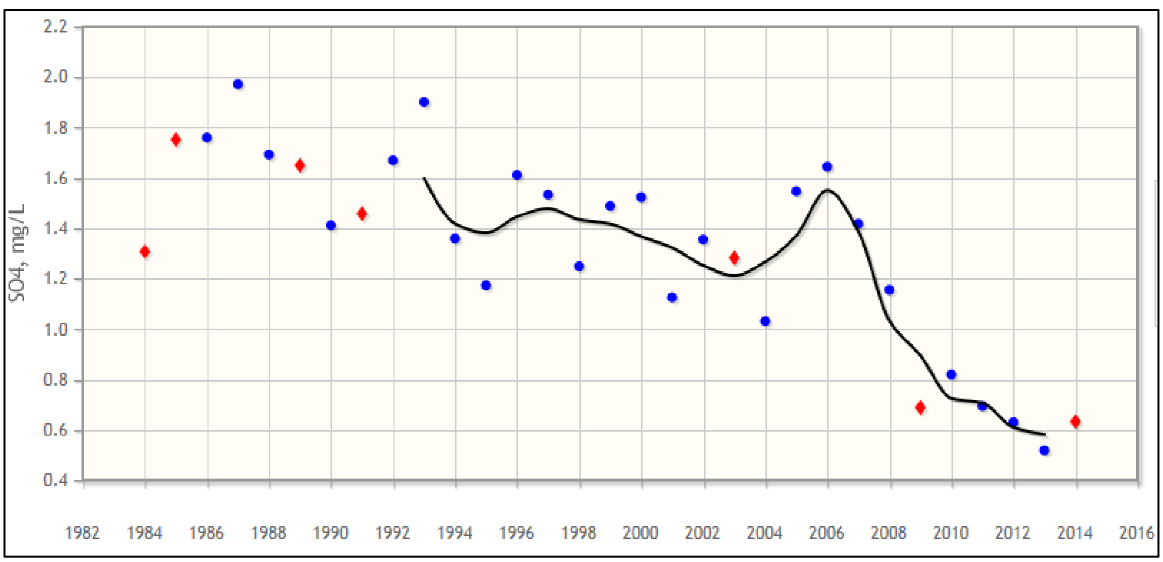

Figure 59. Annual weighted mean concentration of sulfate in wet deposition from Sand Mountain Research and Extension Center (NTN Site AL99) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

Mercury Deposition

The 2012-2014 wet mercury deposition estimate is very high for CHCH, ranging from 12.2-14.4 μg/m^2/yr, but predicted methylmercury concentrations in surface waters are low, estimated at 0.05 ng/l (NPS 2016a). When compared to the NPS ARD mercury status assessment matrix (Table 63), these estimates result in a condition of *Moderate Concern*.

Total mercury deposition at the monitor nearest to CHCH (Yorkville, GA) is somewhat high, measuring 12.9 μg/m^2 in 2014 (Figure 60) (NADP 2014). Based on interpolations by the MDN, deposition levels in the CHCH area in 2014 were likely in the 10-15 μg/m^2 range (Figure 60).

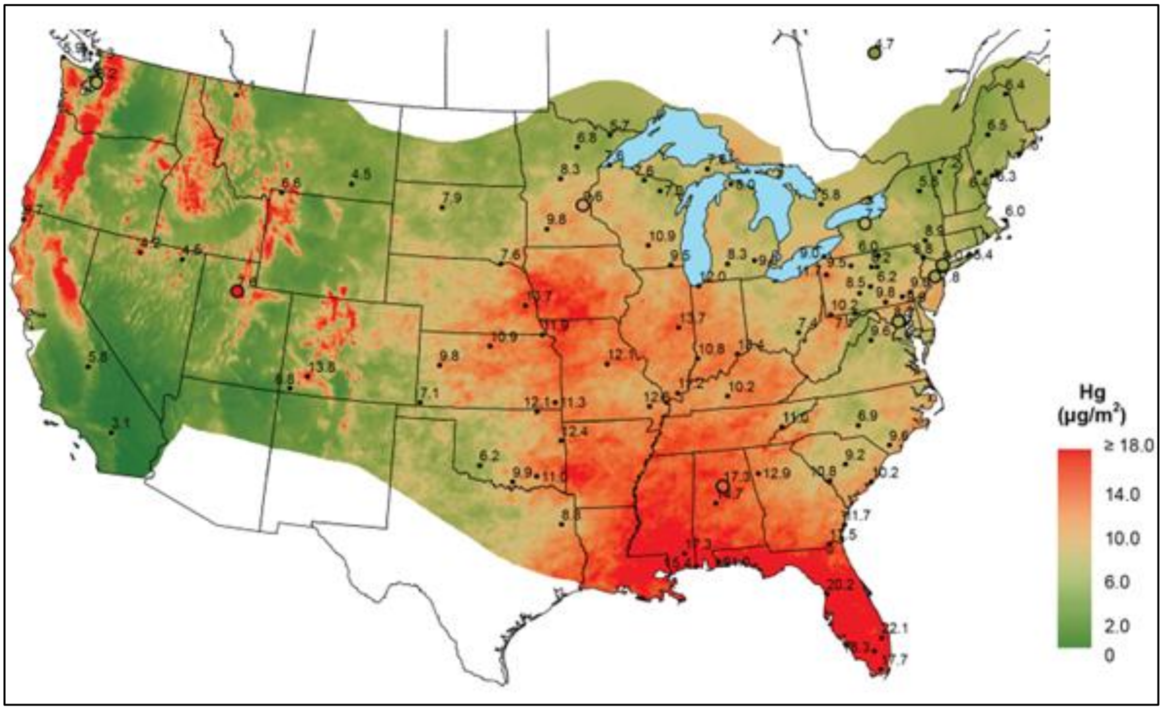

Figure 60. Total annual mercury wet deposition in 2014 (NADP 2014).

Mercury concentrations are also somewhat high at the Yorkville, GA monitoring station, with a value of 10.1 ng/L in 2014 (Figure 61) (NADP 2014). Based on interpolations displayed in Figure 61, total mercury concentrations in the CHCH area were likely 9-11 ng/L (NADP 2014).

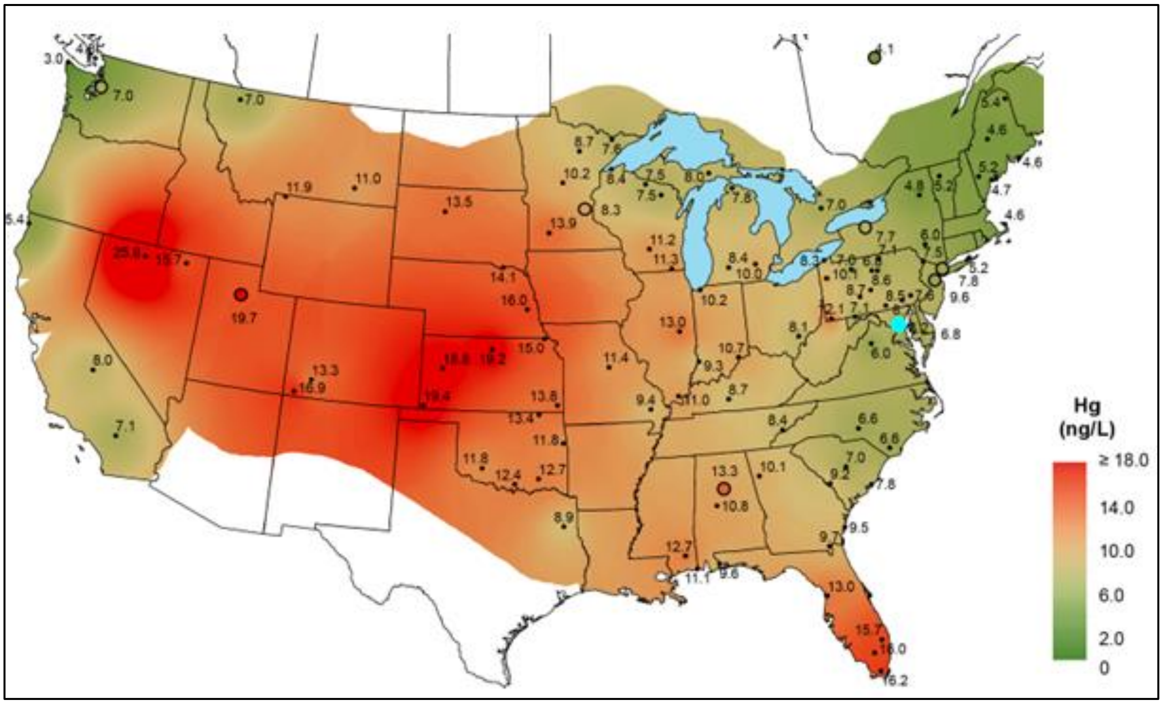

Figure 61. Total mercury concentrations in 2014 (NADP 2014).

The NPS ARD has measured mercury wet deposition at 16 parks across the U.S. (NPS 2013a). The location closest to CHCH where monitoring has occurred is Great Smoky Mountains National Park (GRSM), approximately 130 km (80 mi) northeast of Chickamauga Battlefield. According to an analysis of mercury concentrations in precipitation, concentrations at GRSM have been significantly improving, decreasing by 0.29 ng/l/yr from 2000-2009 (NPS 2013a).

Ozone

Historically, ozone has been a concern in the CHCH region. Kohut (2007) determined that the risk of ozone exposure at the park was high, with concentrations estimated (through kriging) to exceed 100 ppb many times annually from 1995-1999. During these same years, the estimated W126 value remained above 30 ppm-hrs, and exceeded 50 ppm-hrs in 1998 and 1999 (Kohut 2007).

Ozone was monitored during the growing season at CHCH's Lookout Mountain Unit from 7 April to 3 November 2010 (Jernigan et al. 2011). During this period, ozone concentrations ranged widely from approximately 10-100 ppb (Figure 62). Levels exceeded 80 ppb multiple times, mostly in August and September. The W126 metric yielded a value of 15.0 ppm-hrs, which is in the *Significant Concern* category outlined by the NPS ARD (>13 ppm-hrs) (Jernigan et al. 2011). However, no foliar injury was detected during sampling of sensitive plant species (eastern redbud, American sycamore, winged sumac [*Rhus copallinum*]) on 5 August 2010 (Jernigan et al. 2011). This may have been partly due to a limited number of suitable sampling sites and available plants (Jernigan et al. 2011).

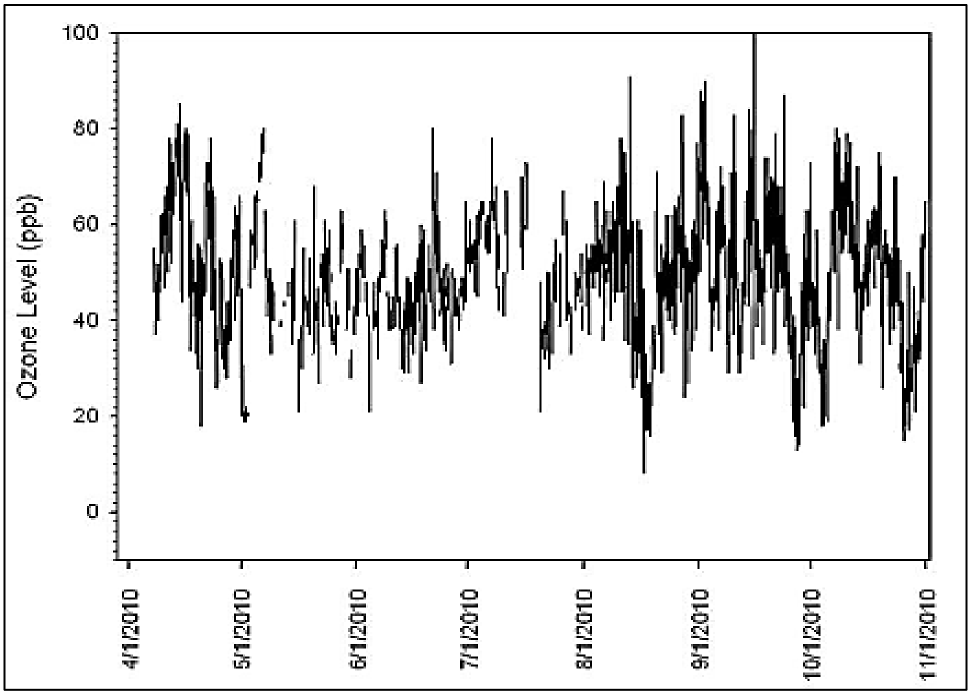

Figure 62. Ozone concentrations at Lookout Mountain, April to November 2010 (reproduced from Jernigan et al. 2011).

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 2013b). The most recent 5-year (2009–2013) estimated average for 4^{th}-highest 8-hour ozone concentration at CHCH is 70.9 ppb (NPS 2015b). This is within the *Moderate Concern* range, but only 0.1 ppb below the *Significant Concern* level (Figure 63). A comparison to previous estimates suggests that ozone conditions are improving at CHCH, as 5-year average estimates have declined annually from a high of 78.5 ppb for 2005-2009 (NPS 2015b).

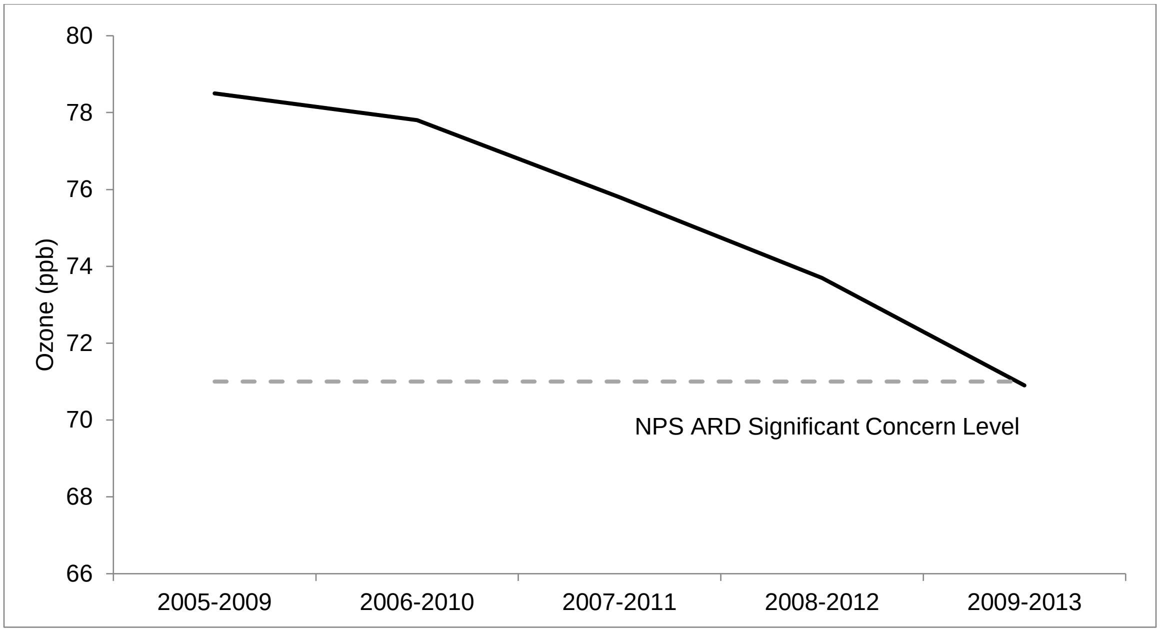

Figure 63. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for CHCH (NPS 2015b).

This suggested improvement is supported by data from the nearest year-round ozone monitor (in Chattanooga, TN), which show ozone concentrations fluctuating over time but with an overall decreasing trend (Figure 64) (EPA 2016a).

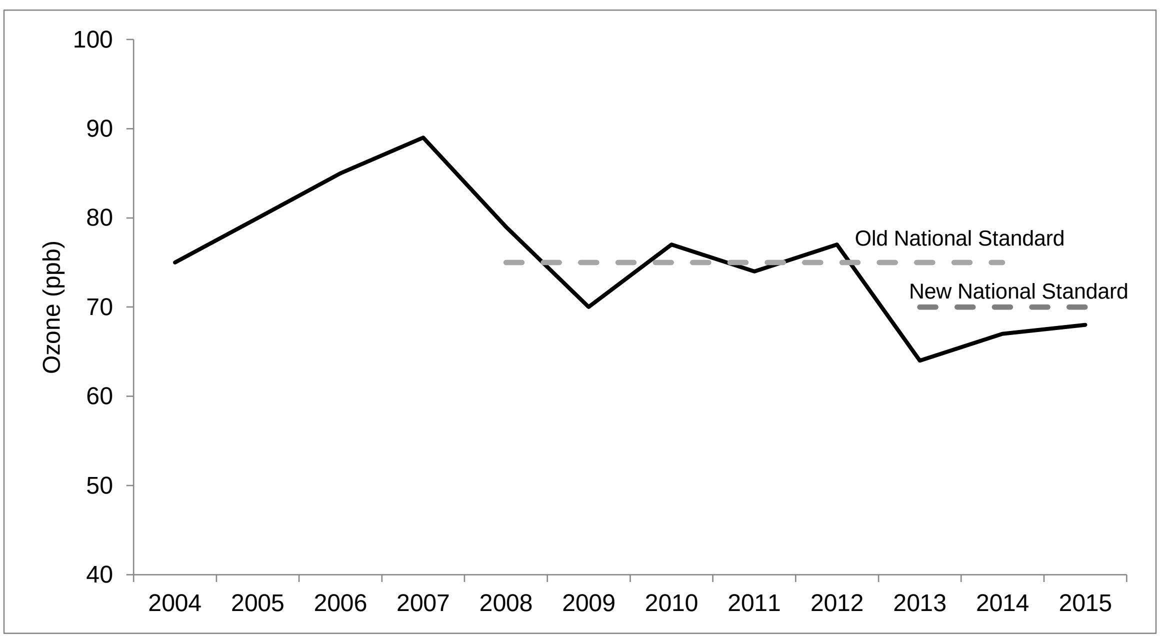

Figure 64. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Hickory Valley Road monitoring site in Chattanooga (Site ID 47-065-4003), 2004-2015 (EPA 2016a).

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 9.7 ppm-hrs falls in the *Moderate Concern* category (NPS 2015b). Again, a comparison to previous estimates suggests that ozone conditions are improving, having transitioned from significant to moderate concern in recent years (Figure 65).

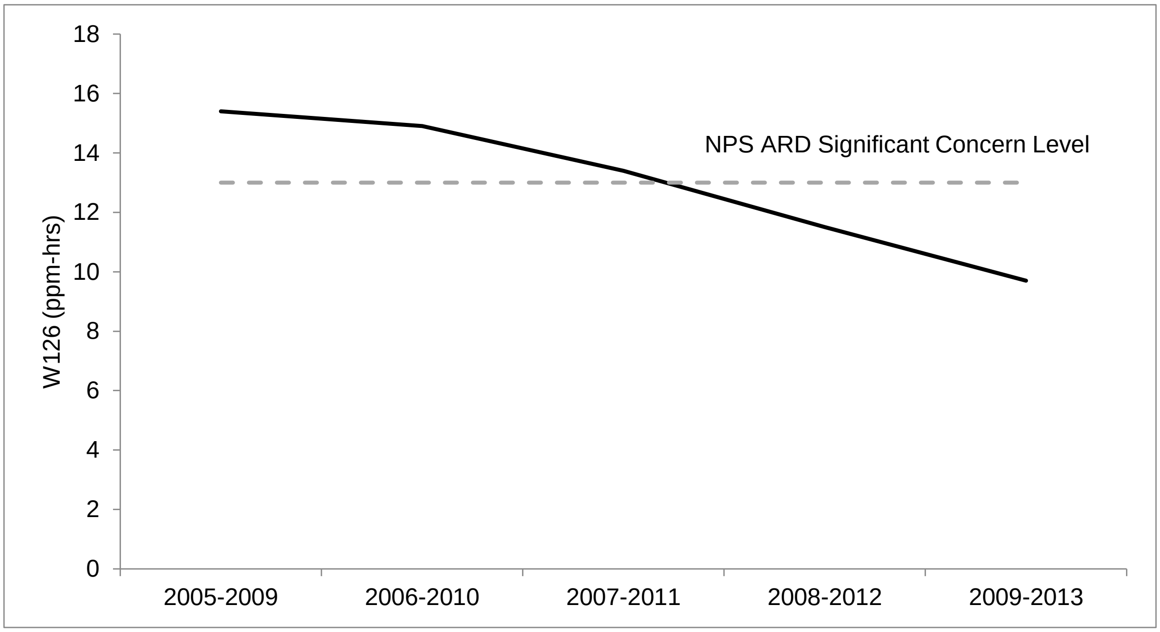

Figure 65. Estimated 5-year averages of the W126 ozone metric for CHCH (NPS 2015b).

<u>Visibility</u>

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 CHCH was 9.6 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 3.7 dv above natural conditions on the 20% clearest days and 15.4 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 CHCH. The 2005-2009 estimated visibility was 12.6 dv above estimated natural conditions, but the 5-year average has declined every year since, although it is still above the significant concern threshold (>8 dv) (Figure 66).

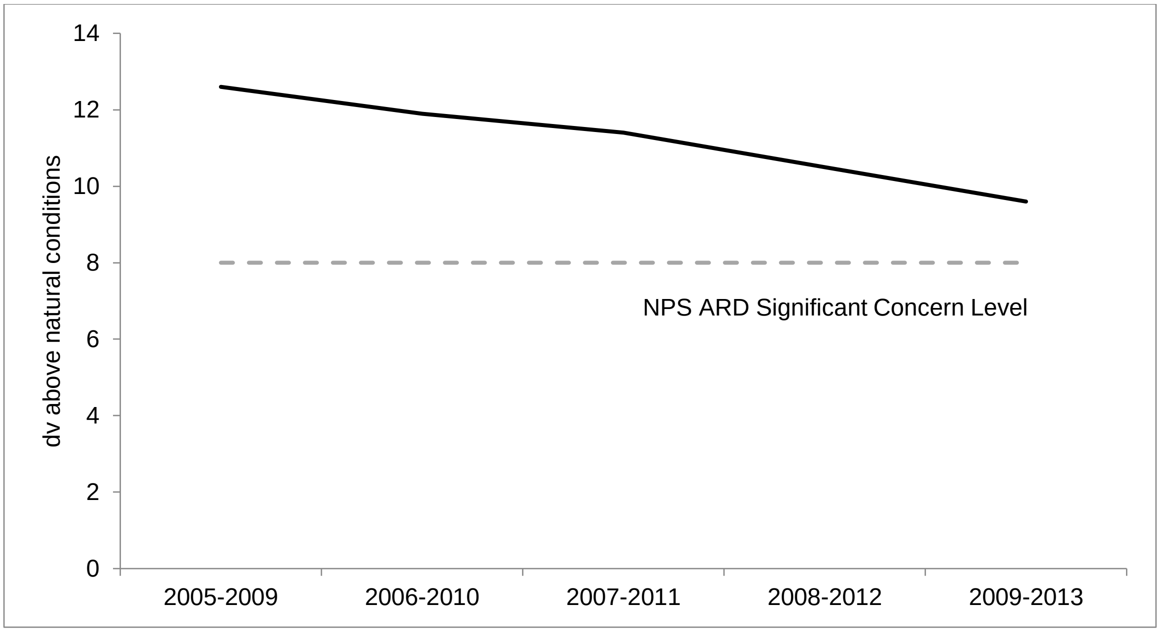

Figure 66. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at CHCH (NPS 2015b).

Particulate Matter

Annual average 24-hour $PM_{2.5}$ concentrations are available from a station in Rossville, GA for 2000-2015. This station is located between the Lookout Mountain and Chickamauga Battlefield Units of CHCH. These observations suggest that $PM_{2.5}$ concentrations have decreased in the region, and are currently within the EPA standards for levels that are protective of human health (35 $\mu g/m^3$) (Figure 67) (EPA 2016d). However, the most recent 3-year average (2013-2015) 98^{th} percentile 24-hour $PM_{2.5}$ concentration of 21.2 μ/m^3 falls in the NPS ARD's *Moderate Concern* range.

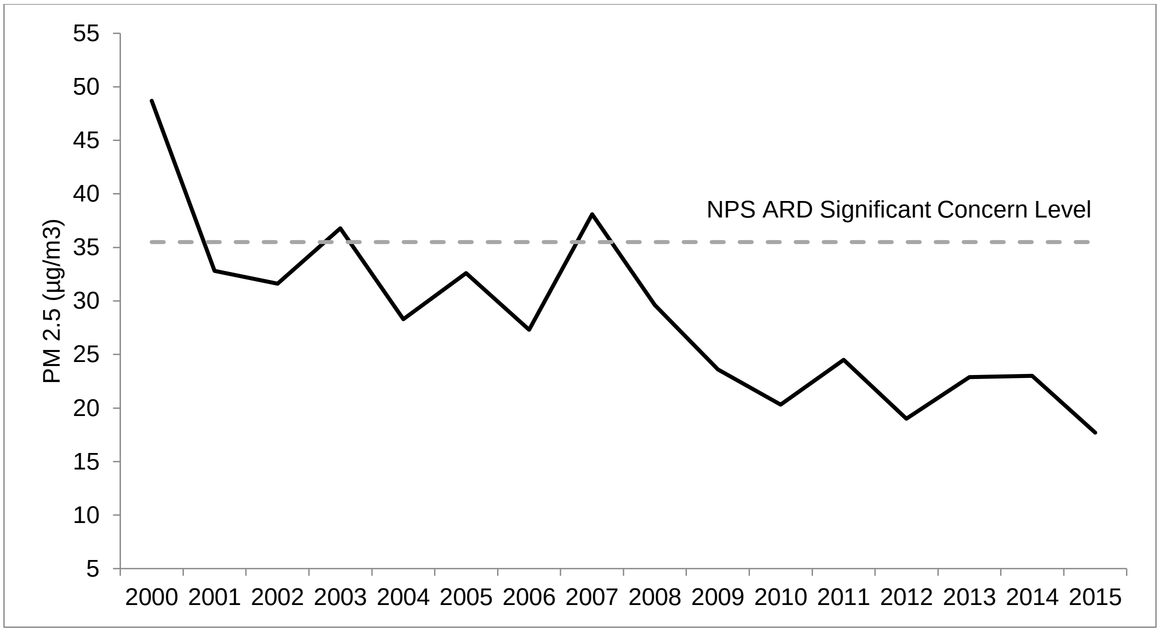

Figure 67. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) for the CHCH region, 2000-2015 (EPA 2016a). The monitoring station is located in Rossville, GA (Site ID: 13-295-0002).

Threats and Stressor Factors

Threats to CHCH'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. U.S. Highway 27 passes along and through the west side of Chickamauga Battlefield and Interstate 24 passes just below Point Park at the foot of Lookout Mountain, allowing for a relatively high level of traffic around CHCH. Also, the NPS has created a self-guided auto tour route through Chickamauga Battlefield with stops at various historically significant locations (NPS 2016b). This route and the associated stops may encourage additional vehicle travel (and idling at stops) in the park.

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).

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.

Data Needs/Gaps

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

Overall Condition

Nitrogen Deposition

The project team assigned this measure a *Significance Level* of 3. The most recent 5-year (2009–2013) estimate for nitrogen deposition at CHCH is 4.1 kg/ha/yr, which falls in the *Significant Concern* range identified by the NPS ARD (NPS 2015b). Although deposition estimates and concentrations suggest that conditions are improving, current levels are still high enough that they may be damaging sensitive vegetation. Therefore, this measure is of significant concern (*Condition Level* = 3).

Sulfur Deposition

Sulfur deposition was also assigned a *Significance Level* of 3. As with nitrogen, the most recent 5-year (2009–2013) estimate for sulfur wet deposition at CHCH of 3.3 kg/ha/yr also falls in the *Significant Concern* range (NPS 2015b). Conditions appear to be improving, but this measure is assigned a *Condition Level* of 3 as well, indicating significant concern.

Mercury Deposition

A *Significance Level* of 3 was assigned for mercury deposition. While the 2012-2014 wet mercury deposition estimate for CHCH is very high, ranging from 12.2-14.4 $\mu g/m^2/yr$, predicted methylmercury concentrations in surface waters are low, estimated at 0.05 ng/l (NPS ARD 2016a). Overall, mercury deposition is considered of *Moderate Concern*, according to NPS ARD standards. As a result, this measure is assigned a *Condition Level* of 2.

Ozone

The project team also assigned this measure a *Significance Level* of 3. Until recently, ozone concentrations were a serious concern in the CHCH region (Kohut 2007, Jernigan et al. 2011). However, the most recent 5-year (2009–2013) estimated average for 4^{th}-highest 8-hour ozone concentration at CHCH decreased, falling in the very top of the NPS ARD *Moderate Concern* range at 70.9 ppb (NPS 2015b). The 2009–2013 estimated W126 metric of 9.7 ppm-hrs also falls in the *Moderate Concern* category (NPS 2015b). Ozone is therefore assigned a *Condition Level* of 2 for moderate concern.

Visibility

Visibility was assigned a *Significance Level* of 3. The 2009–2013 estimated visibility on mid-range days for CHCH was 9.6 dv above estimated natural conditions, or within the *Significant Concern* category identified by the NPS ARD (NPS 2015b). Even on the 20% clearest days, estimated visibility falls in the *Moderate Concern* range. As a result, this measure is assigned a *Condition Level* of 3, indicating significant concern.

Particulate Matter

A *Significance Level* of 3 was also assigned for this measure. As with previous measures, $PM_{2.5}$ conditions have been improving in recent years. However, the most recent 3-year average (2013-2015) 98^{th} percentile 24-hour $PM_{2.5}$ concentration of 21.2 μ/m^3 (from a monitoring location between the park's two main units) falls in the NPS ARD's *Moderate Concern* range. This measure is therefore assigned a *Condition Level* of 2.

Weighted Condition Score

The *Weighted Condition Score* for CHCH's air quality is 0.83, indicating significant concern. However, it is important to note that the causes of poor air quality in and around the park are largely beyond the control of park management. Data suggest that most of the selected measures are improving, some more slowly than others, so an improving trend has been assigned for the component as a whole. Because much of the air quality information for CHCH is based on interpolations from monitors some distance away rather than on-site measurements, a medium confidence border is applied.

Table 65. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's air quality.

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

4.8.6. Sources of Expertise

- Johnathan Jernigan, CUPN Physical Scientist

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4.9. Adjacent Land Cover and Use

4.9.1. Description

The fragmented units of CHCH sit at the southern end of the Appalachian Mountains, scattered amongst natural valleys and developed urban areas. Major developments in the area were first established through the railroad and agricultural industry in the early 1800s (Hanson and Blythe 1999), and urban areas like Chattanooga, Tennessee became thriving areas of commerce by 1860 (NPCA 2009). This development and urbanization now comprises most of the landscape surrounding CHCH (See Figure 1 in Chapter 2). In 2010, the City of Chattanooga, Tennessee had a population of 167,674 (USCB 2016) and was considered the fourth largest city in Tennessee (City of Chattanooga Tennessee 2016a) (Figure 68).

Figure 68. View of the City of Chattanooga, Tennessee from the Phelps Monument on Missionary Ridge (NPS Photo).

The city of Fort Oglethorpe, Georgia, located just 8 km (5 mi) south of Chattanooga, had a population of 9,263 in 2010 (USCB 2016) and is located just north of the Chickamauga Battlefield. In addition to the potential impacts from nearby urban development, agricultural land and transportation corridors around the park threaten many different natural resources including the quality of dark night skies, external viewscape, and the overall continuity of the landscape. The preservation of natural features surrounding the park, such as the wooded landscape, provides visitors with a better understanding of the struggles Civil War armies endured while fighting. According to Sullivan (1956, p. 20):

> *Neither army knew the exact position of the other as they maneuvered for position during the night. The densely wooded area, covered with tangled undergrowth, brambles and cedar thickets, prevented easy movement or good observation, and many of the officers had difficulty keeping in touch with their own commands.*

4.9.2. Measures

- Change in external land cover/land use
- Total population
- Population density
- Housing development
- Land ownership

4.9.3. Reference Conditions/Values

The reference condition for this component was defined as the landscape as it appeared at the time of the 1863 battles. While there is some information available to quantify what the landscape looked like during battle, Hanson and Blythe (1999, p. 5) provide a good description of what the soldiers encountered before and during battle:

> *Prior to the battles in 1863, the land that today comprises the national military park* [CHCH] *was dotted with small farms and settlements scattered among a wooded landscape. The wooded landscape conveys a sense of the natural obstacles that made fighting so difficult*.

4.9.4. 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 2014a). These landscape metrics are collectively called NPScape and include the following datasets: population, housing, roads, land cover, landscape patterns, climate, and conservation status (NPS 2014a). The NPScape data for this particular component were analyzed at the census block group level (herein after study area); this study area covers approximately 352,000 ha (870,000 ac) (Figure 69).

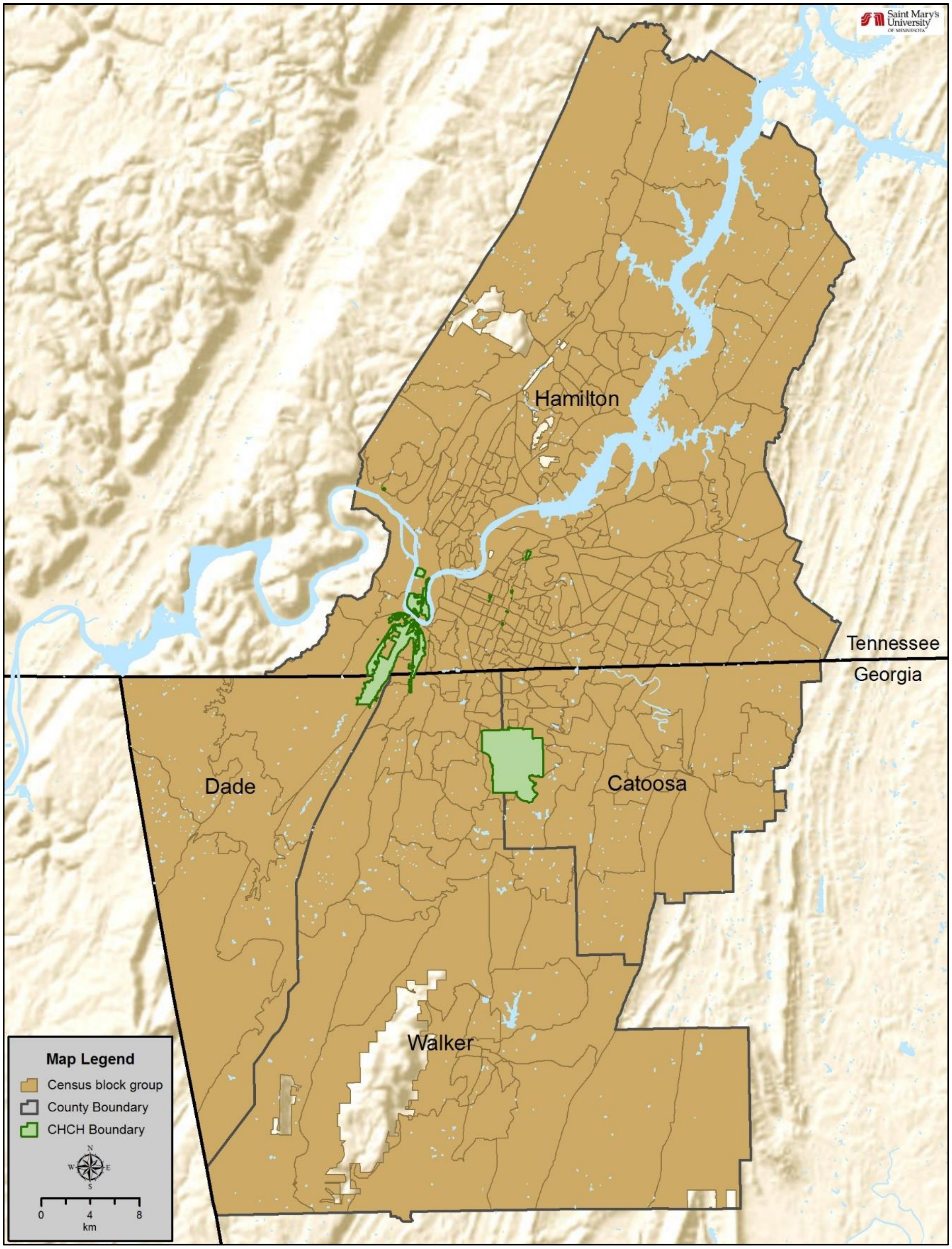


Figure 69. The scale for this component's analysis is at the census block group level and extends out to the following four counties: Hamilton (TN), Dade, Catoosa, and Walker (GA).

National Land Cover Dataset

The NLCD is created by the U.S. Geological Survey (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). The 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 land cover 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 land cover change. The 2001 to 2011 land cover 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 2014b); data can be obtained for 1990, 2000, 2010, historic (1790-1990), and projected (2000-c.2050) census years (NPS 2014a).

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 are likely to change (NPS 2013).

Protected Area Database

The Protected Area Database of the United States (PAD-US) provides information on publicly-owned land, along with voluntarily provided protected areas (e.g., Nature Conservancy preserves), that focus on conservation management (USGS 2012a). 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 level categories which provide a measurement of management intent for long term biodiversity conservation;
- International Union for Conservation of Nature (IUCN) category for protected areas (USGS 2012a).

4.9.5. Current Condition and Trend

Change in External Land Cover/Land Use

From indigenous populations to European settlers, the area surrounding modern-day CHCH was known as a "haven for settlement" (Paige and Greene 1983). By 1860, Chattanooga had a population of 2,535 people and was considered the "Key to East Tennessee" or the "Gateway to the deep South" (Sullivan 1956). It had grown to become the principal Southern rail center with lines going in all directions (Paige and Greene 1983). Today, the land development around CHCH is a potential threat to the park's natural resources. Suburban sprawl (e.g., strip malls, housing developments) is approaching the Chickamauga Battlefield, heavily traveled highways leading to many tourist attractions and single family homes are located around Lookout Mountain, a golf course and water treatment plant share boundaries with Moccasin Bend, and small units of Missionary Ridge and Orchard Knob (Figure 70) are found within populated neighborhoods (See Figure 1 in Chapter 2) (NPCA 2009).

Figure 70. A view of Orchard Knob, a small piece of protected land included in CHCH that is found inside a Chattanooga neighborhood (NPS Photo) (NPCA 2009).

According to the 2001-2011 NLCD, 5.4% (18,999 ha [46,947 ac]) of the external land cover within the study area has changed from 2001 to 2011 (Figure 71). Of this external land cover, 1.5% (5,117 ha [12,645 ac]) started out in a non-developed state (e.g., open water, barren land, forest, cultivated, etc.) and ended up in a developed state (open space, low intensity, medium intensity, high intensity) by 2011. The largest change was to developed, open space at 2,183 ha (5,396 ac). The development land cover 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.

Due to the large study area, the legend provided for Figure 71 below only displays the colors associated with what the land cover changed *to* by the year 2011. Please see Appendix J for a full detailed list of the 2001-2011 land cover change for the entire analyzed area.

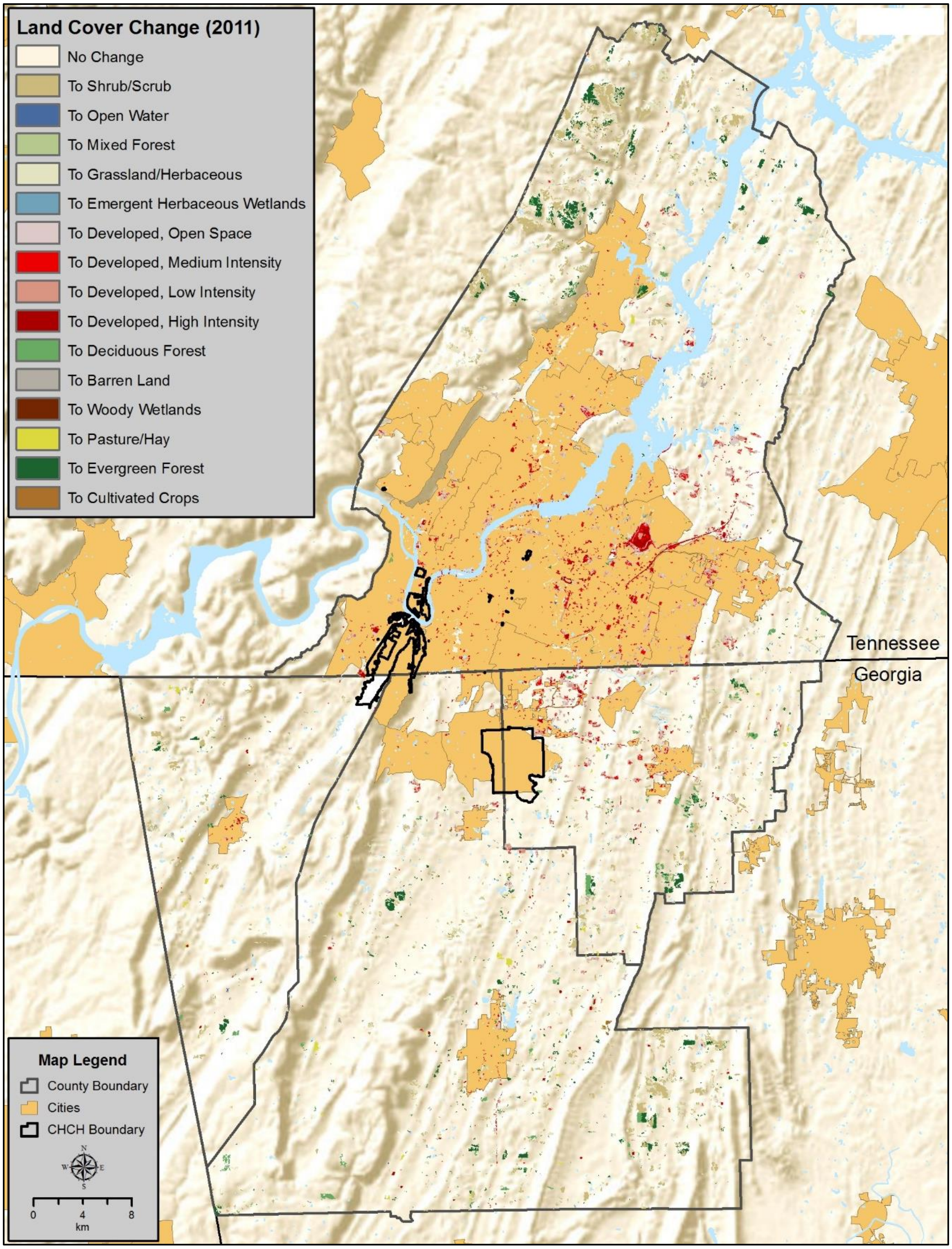


Figure 71. External land cover change from 2001-2011 within the study area. Minimal land cover change has occurred (~5%) over the past ten years. Due to the large study area, the legend provided in the figure only displays what the land cover changed to by 2011. See Appendix J for more detail on what the original land cover type was.

As mentioned previously, the presence of a wooded landscape could have cultural importance for CHCH as the woods played a large role in the 1863 battles. There are four NLCD categories that could be used to describe this wooded landscape; they are defined as follows (USGS 2011):

- Deciduous Forest = Areas dominated by trees generally greater than 5 meters [16 ft] tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest = Areas dominated by trees generally greater than 5 meters tall, and greater than 20% total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
- Mixed Forest = Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
- Shrub/Scrub = Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Of the 18,999 ha (46,947 ac) of external land cover change for CHCH, 37% (7,011 ha [17,324 ac]) started out in one of the aforementioned wooded landscape categories and changed to a non-wooded land cover class by 2011 (Figure 72); almost half (46%) changed to one of the developed (open space, low, medium, high intensity) categories mentioned above. Out of the four wooded landscape NLCD categories, the greatest loss occurred in the deciduous forest land cover (3,049 ha [7,533 ac] lost by 2011). By 2011, 21% of the deciduous forest land cover changed to "Developed, Open Space," while.47% changed to the "Grassland/Herbaceous" land cover category, which is defined as "Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing" (USGS 2011).

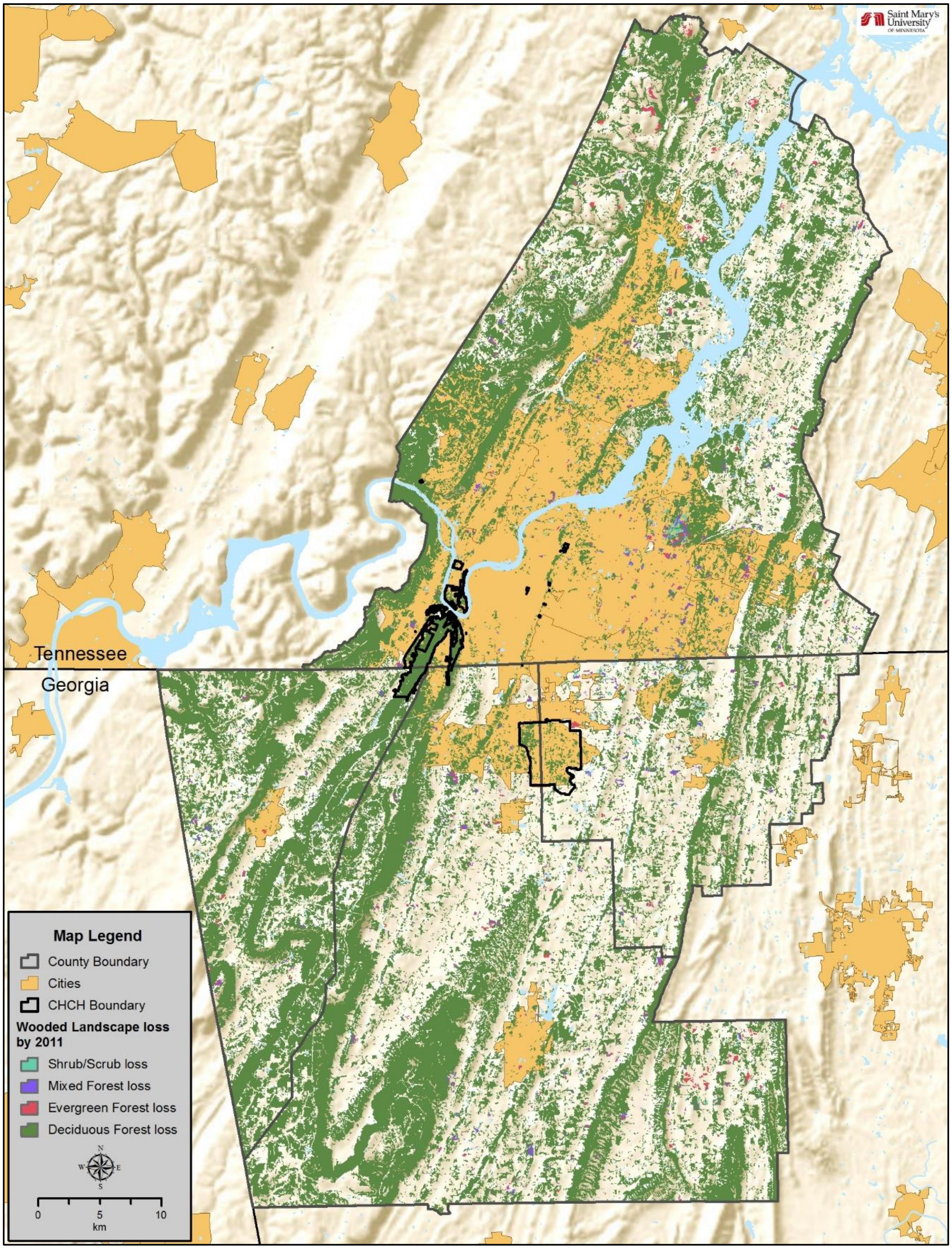


Figure 72. From 2001 - 2011, 37% of the wooded landscape was lost to other non-wooded land cover categories (i.e., developed, pasture, crop, etc.). Above shows the areas that lost a particular wooded landscape land cover by 2011.

Total Population

Following the War of 1812, an influx of Europeans settled in the Tennessee-Georgia area, with much of the land being utilized for crop cultivation. Populations expanded through the 1820s and 1830s, and by the 1860s places like Chattanooga and Atlanta had become thriving communities known for their commercial activities (Paige and Greene 1983). Total population has varied between the four counties that CHCH lies within since 1860, but have generally had an increasing trend (Figure 73) (USCB 1996, 2014). Of the three counties in Georgia, Walker County's population levels have ranged from 10,082 (1860) to 38,756 (2010), with an average annual growth rate of 4% from 1860-2010. Dade County's population levels have ranged from 3,069 (1860) to 16,633 (2010), with an average annual growth rate of 3% from 1860-2010 (USCB 1996, 2014). Catoosa County has had the largest average annual growth rate out of the three Georgia counties; populations ranged from 5,082 in 1860 to 63,942 in 2010, which translates to an 8% average annual growth rate (USCB 1996, 2014). Hamilton County, Tennessee population grew the most out of all four counties over the years (16% average annual growth rate), with levels ranging from 13,258 (1860) to 336,463 (2010) (USCB 1996, 2014). Overall, Hamilton County, Tennessee has been steadily growing since the 1860s, while Walker, Catoosa, and Dade County, Georgia has only seen more significant increases since the 1950s.

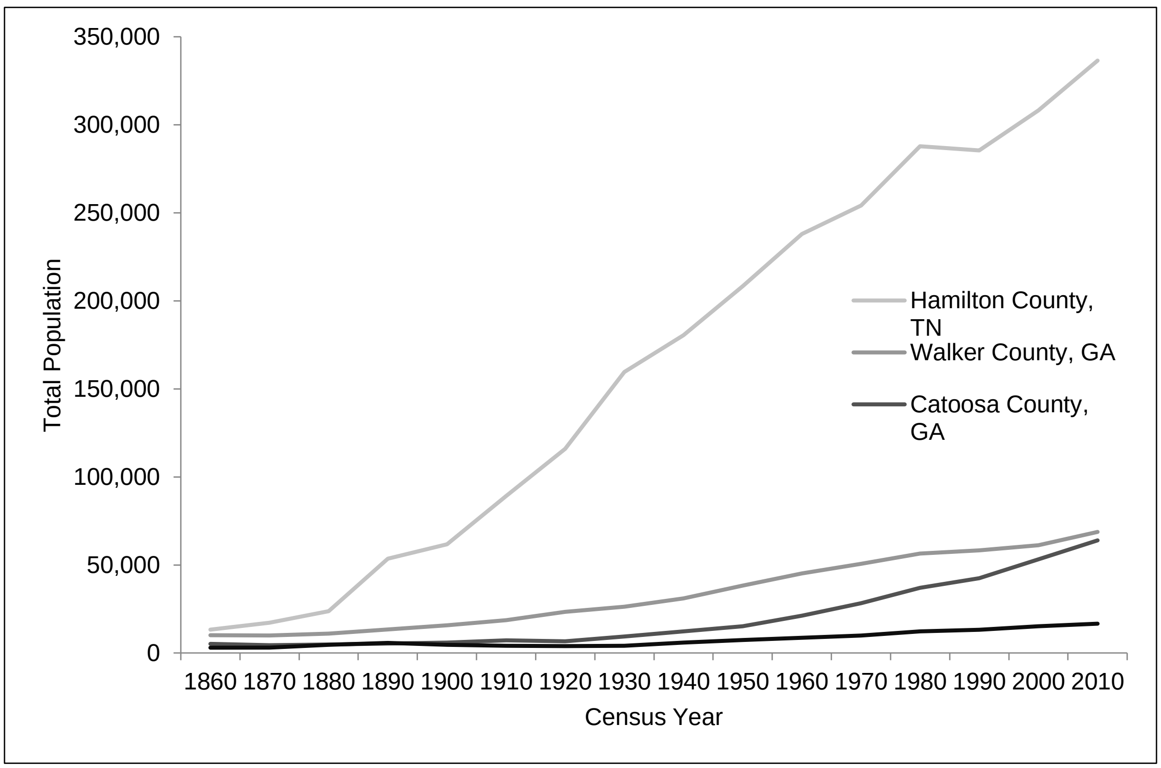


Figure 73. This graph articulates total population for all four counties in the study area: Hamilton County, TN, Walker County, Catoosa County, and Dade County in Georgia (USCB 2014).

Population information at the census block group level surrounding the park is provided in Figure . Again, the general trend is that population inside the study area is increasing, especially southwest of

Lookout Mountain and southeast of the Chickamauga Battlefield. Figure 74 shows growth for all four counties combined is occurring, albeit at a slow rate with a 1% increase between 1990 and 2000, and between 2000 and 2010.

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). Figure 75 shows that population density north of CHCH in the City of Chattanooga, Tennessee, has spread out, as is indicated by the light to dark orange color. The U.S. Office of Management and Budget (OMB) defines and delineates 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. All four counties in the study area are considered a metro area (Wilson et al. 2012) due to the presence of Chattanooga, Tennessee.

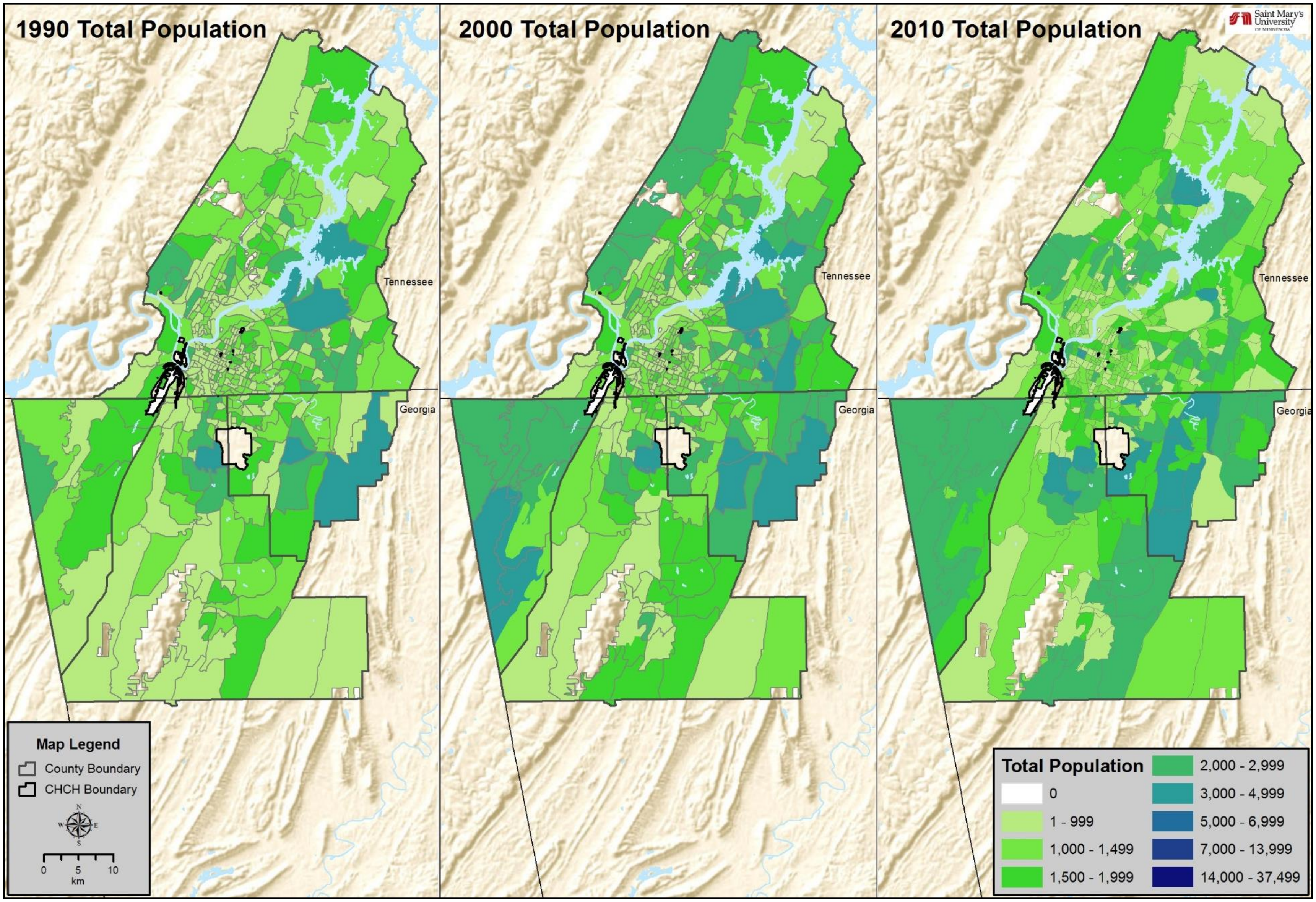


Figure 74. Total population per census block group (1990, 2000, 2010) for all four counties in the study area (USCB 2014).

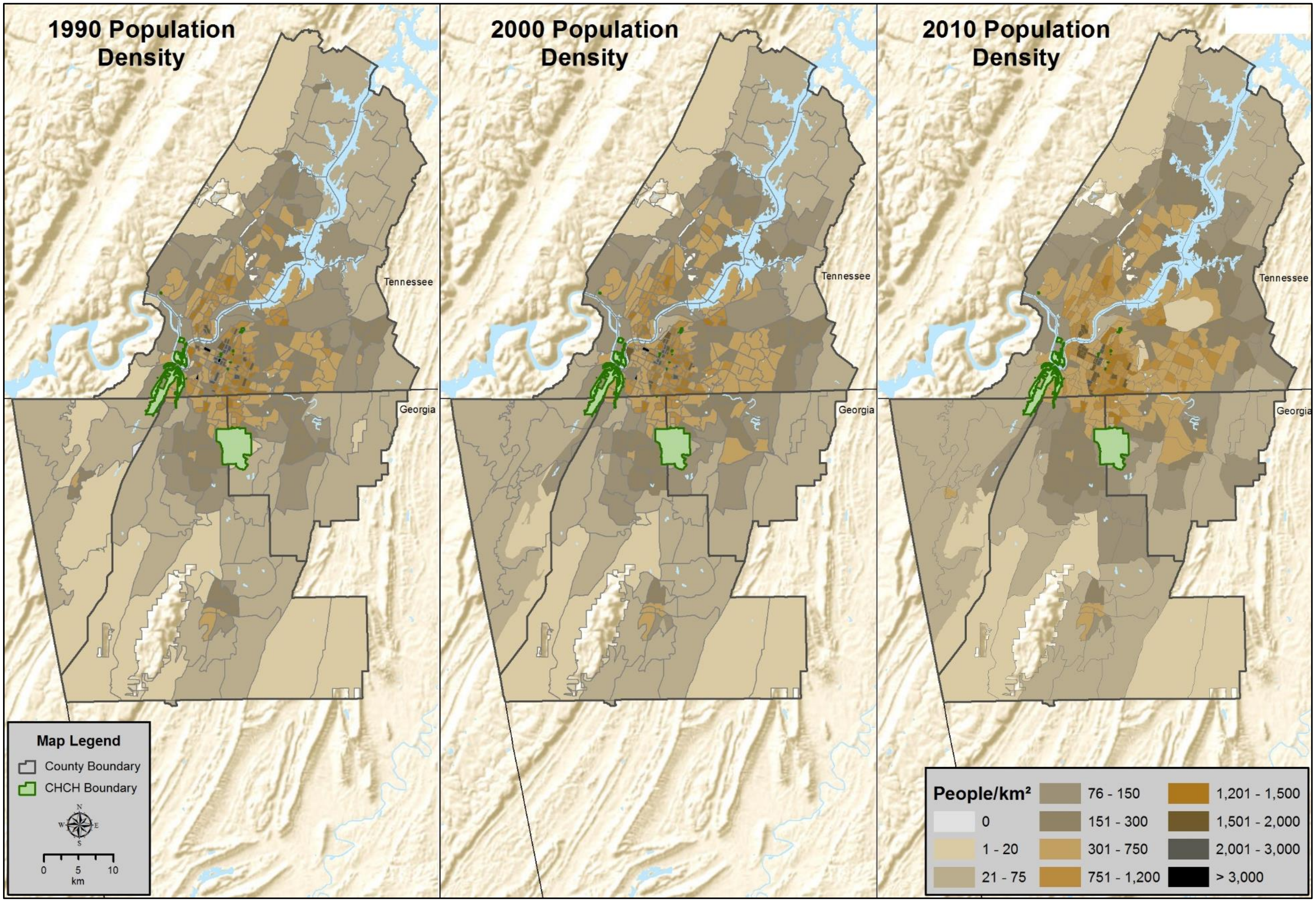


Figure 75. Total population density (people/km²) for census block groups for the four counties in the study area (USCB 2014).

From 2000 to 2010, approximately 92% of the U.S. population growth occurred in metro areas (Wilson et al. 2012). The majority of growth occurred in metro areas with populations ranging from one to five million (e.g., Chicago, Illinois), while metro areas with a population of 250,000 or less (e.g., Chattanooga, Tennessee) experienced a 11% growth rate from 2000 to 2010 (Wilson et al. 2012). Table 66 provides the average densities for each county in the study area. The population density of Hamilton County, Tennessee and Dade County, Georgia decreased between 1990 and 2010, while Catoosa County and Walker County, Georgia increased.

Table 66. Average population densities (people/km²) for all four counties in the study area (USCB 2014).

County	1990 average density	2000 average density	2010 average density
Hamilton County, TN	757	702	636
Dade County, GA	67	44	46
Walker County, GA	253	271	271
Catoosa County, GA	316	370	393

<u>Housing Development</u>

As populations are increasing in the region around CHCH, more homes or dwellings are being built 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, housing development surrounding CHCH increased from 1970-2010 (Table 67). In 1970, the largest area of land (78,371 ha [193,659 ac]) had a housing density of less than 1.5 units per km², and by 2010 the largest area of land (58,287 ha [144,030 ac]) had a housing density of 13 to 24 units per km². Figure 76 illustrates this increased housing development, with expansion primarily occurring north and northeast of the park.

Table 67. The total area of varying housing densities (hectares, with acres in parentheses) from 1970, 1990, and 2010 for the combined area of all four counties surrounding CHCH (NPS 2013).

Housing density	1970 area	1990 area	2010 area
< 1.5 units/squared km	78,371 (193,659)	36,095 (89,193)	26,633 (65,811)
1.5-3 units/squared km	45,409 (114,679)	35,240 (87,080)	30,589 (75,587)
4-6 units/squared km	54,308 (134,198)	41,823 (103,347)	32,485 (80,272)
7-12 units/squared km	35,997 (88,950)	51,878 (128,193)	44,043 (108,833)
13-24 units/squared km	23,412 (57,852)	44,646 (110,323)	58,287 (144,030)
25-49 units/squared km	16,387 (40,493)	27,226 (67,277)	42,193 (104,261)
50-145 units/squared km	14,748 (36,443)	28,434 (70,262)	38,281 (94,594)
146-494 units/squared km	7,946 (19,635)	14,720 (36,374)	19,405 (47,951)
495-1,234 units/squared km	2,498 (6,173)	4,385 (10,836)	5,725 (14,147)
1,235-2,470 units/squared km	623 (1,539)	1,139 (2,815)	1,429 (3,531)
>2,470 units/squared km	152 (376)	232 (573)	283 (699)
Total	**279,851 (693,997)**	285,818 (706,273)	**299,353 (739,716)**

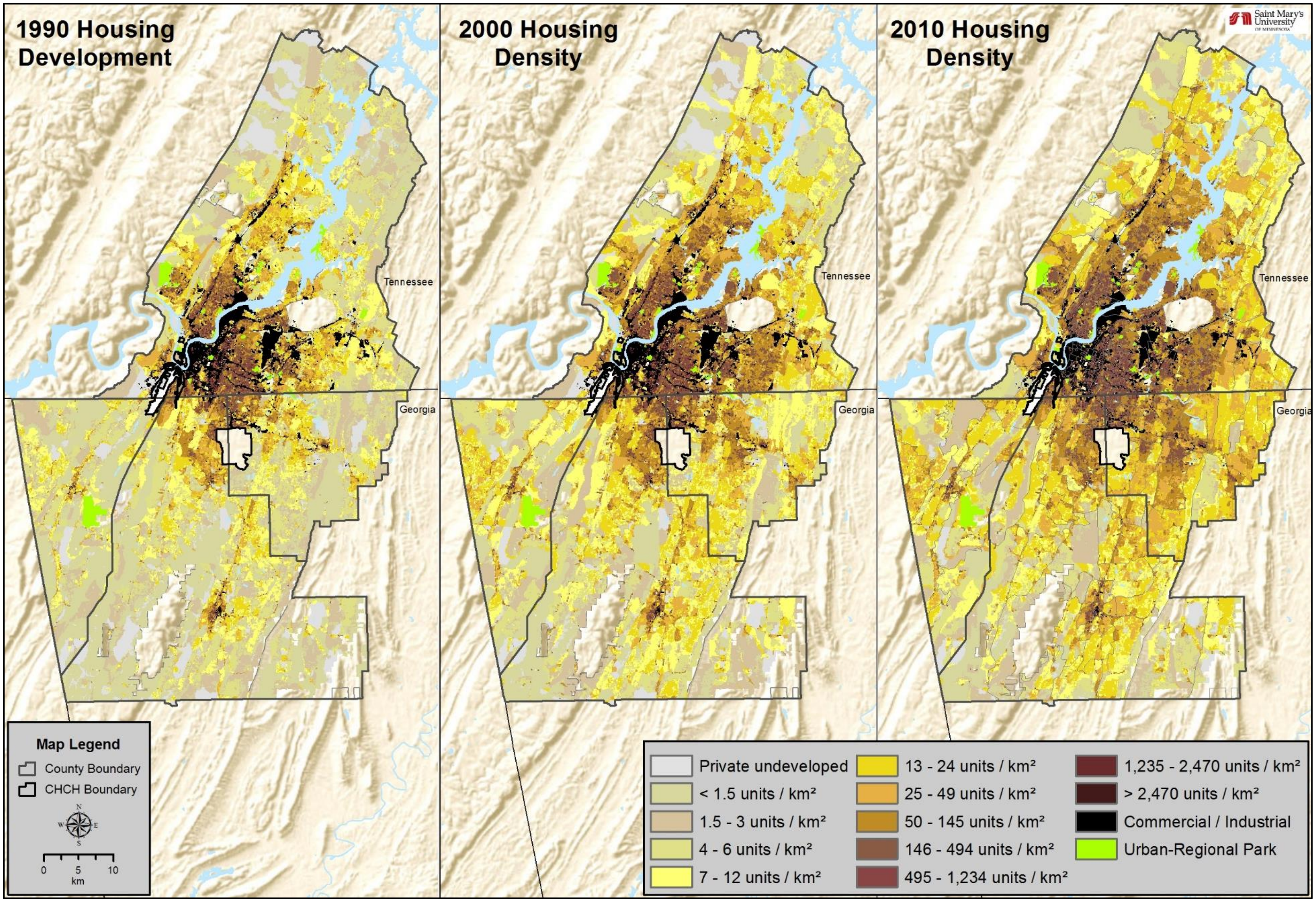


Figure 76. Housing densities (units/km²) in 1970, 1990, and 2010 for all four counties in the study area (NPS 2013).

Land Ownership

When looking at land ownership outside CHCH boundaries and to the extent of the study area (Hamilton, TN; Walker, Dade, and Catoosa, GA), PAD-US data show that there are 30,585 ha (75,577 ac) of protected land surrounding the park, or 9% of the total study area (Figure 77) (USGS 2012b). Of that protected land, the largest areas are owned by state fish and wildlife (8,215 ha [20,300 ac]) and the U.S. Forest Service (USFS) (7,559 ha [18,678 ac]). Private entities own 3,442 ha (8,506 ac), while federal agencies such as the Department of Defense (DOD) (652 ha [1,611 ac]), the NPS (3,330 ha [8,228 ac]), and Tennessee Valley Authority (TVA) (3,474 ha [8,585 ac] own 24% of this protected land. Other state agencies own the following: state parks and recreation owns 1,462 ha (3,614 ac), and state cultural affairs owns 1,759 ha (4,346 ac). An ownership category titled 'joint, other, or unknown land' accounts for 2% (692 ha [1,709 ac]) of this protected land. According to the USGS (2012a) PAD-US metadata, this represents an ownership-related data gap between the agency and owner name of that particular piece of land.

The two largest units of CHCH, Chickamauga Battlefield and Lookout Mountain Battlefield, are the only units out of the entire park that are included in the PAD-US dataset; this is due to the broad, more generalized nature of the PAD-US data and the fact that Moccasin Bend was acquired by the NPS after the PAD-US dataset was created for this particular area. According to the data, these two units have restricted public access, meaning access is granted through either a permit or allowed at variable times (USGS 2012a). In terms of GAP status, which is a "measure of management intent to conserve biodiversity" (USGS 2012a), the two aforementioned units in CHCH have a Status 3 management measure. This is defined as:

> *…permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging, OHV recreation) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area* (USGS 2012a).

The IUCN management category is unassigned for the two units in CHCH due to the GAP status 3 measure. IUCN defined a protected area as:

> *A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.*

Despite CHCH not having a recognized IUCN category assigned, it is suggested that a local assignment and review is preferred (USGS 2012a).

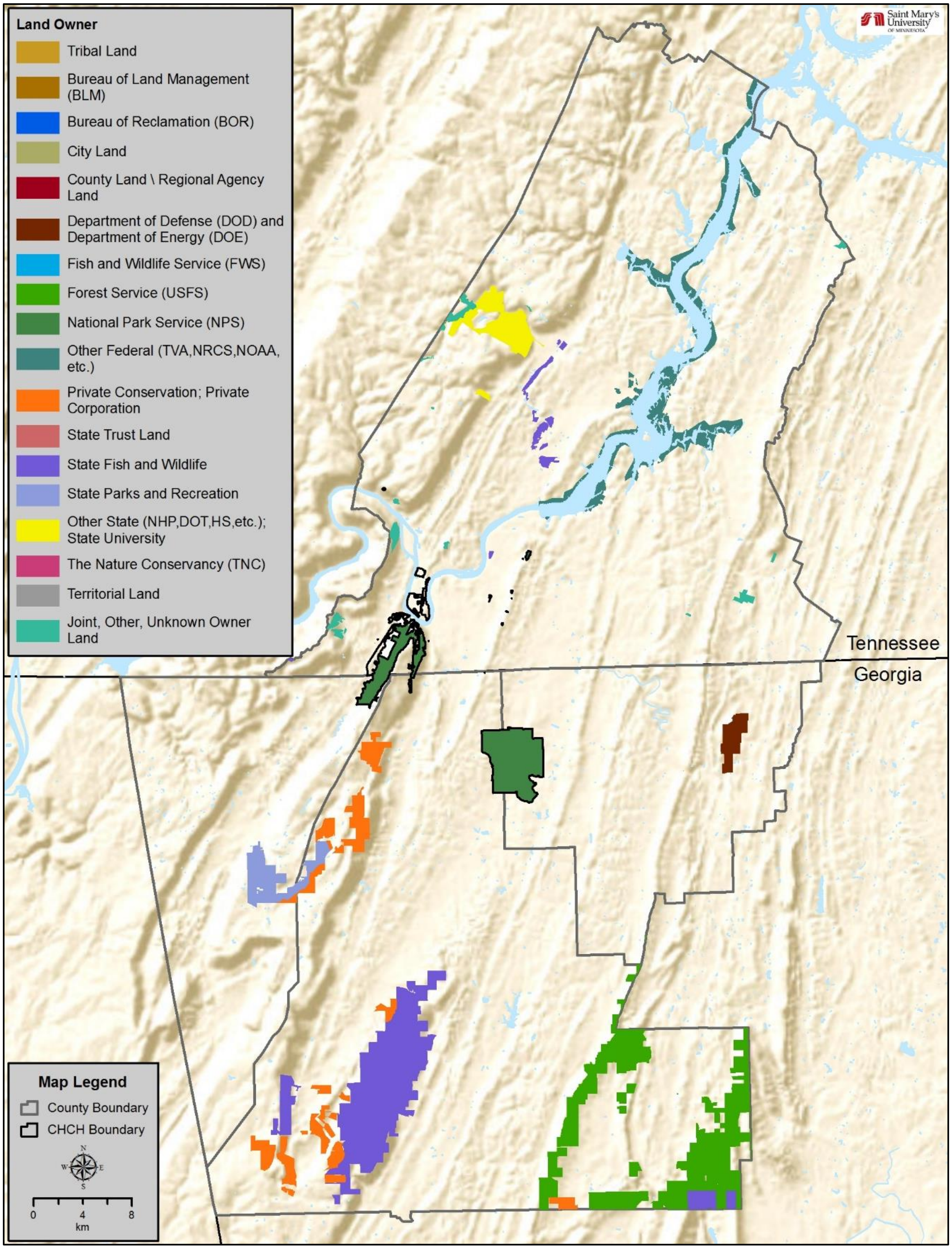


Figure 77. Land ownership of protected lands outside of CHCH boundaries (USGS 2012b).

Threats and Stressor Factors

For this particular component, the park staff identified the following threats and stressors to the park: population growth and expansion, adjacent development, LED light expansion leading to temperature and brightness variations, and poor lighting practices (i.e., unshielded houses, over-lighting for tasks). According to the USCB (2014) total population estimation for 2015, both Hamilton County, Tennessee and Catoosa County, Georgia had increased projected populations for 2015, while Dade County and Walker County, Georgia decreased (Figure 78).

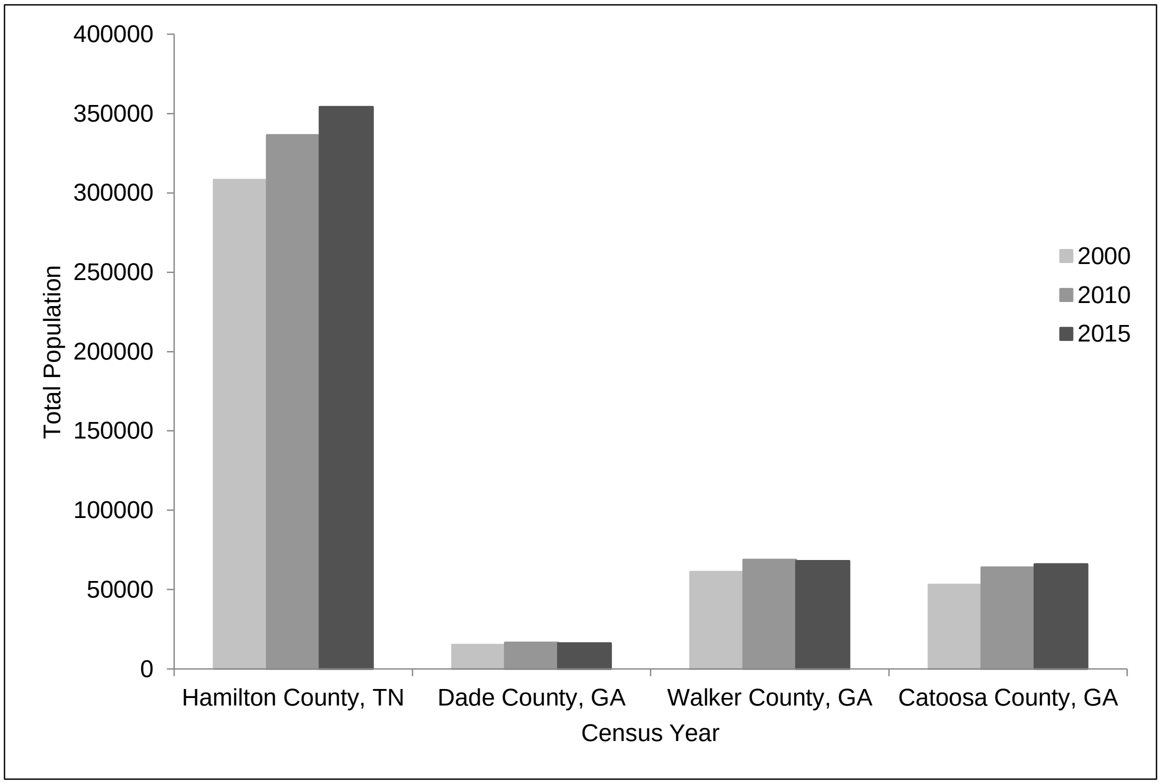


Figure 78. Projected 2015 populations for all four counties in the analysis extent (USCB 2014).

A positive correlation has been found between land development and proximity to national parks (also known as protected areas), as rates of development are often greater in areas with proportionately more protected land (Davis and Hansen 2011). According to Radeloff et al. (2009), from 1940 to 2000, the number of housing units within a 50 km (31 mi) buffer of U.S. national parks had increased on average 57% every decade. Along with population growth and residential communities, transportation corridors have increased (Hanson and Blythe 1999). Not only does transportation infrastructure impact wildlife biodiversity, decrease air and water quality, and increase human access to previously remote places (White et al. 2007), noise from traffic can negatively impact the overall visitor experience. Refer to Chapter 4.10 for a detailed discussion regarding CHCH's soundscape. Because CHCH lies within a metro area (as defined by OMB), interstates, highways, and other roads are common around and even within the park, as seen in Figure 79.

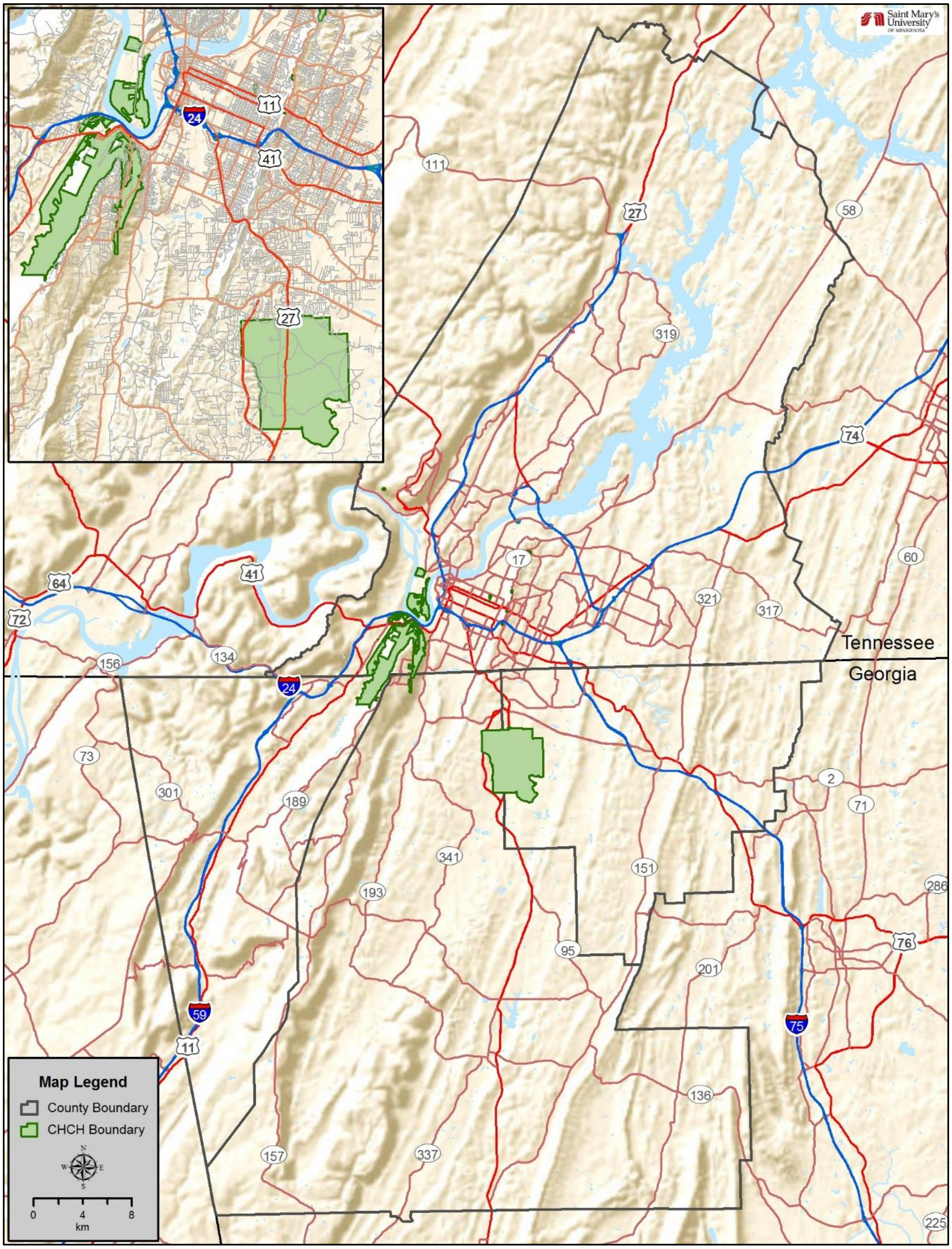


Figure 79. The road network in and around CHCH includes Interstate 24 and 75, along with U.S., state, and county highways.

Along with land development adjacent to CHCH potentially affecting the surrounding wildlife, air and water quality, and the park's soundscape, it can negatively affect a visitor's viewscape from inside the park. A viewscape analysis can help determine which features or parts of a landscape viewers can be seen from a selected set of observation points (e.g., what the view will be from the lookout point) (Esri 2014a). The Visibility Tool created by the Environmental Systems Research Institute (Esri) was used to determine the park's viewscape (Esri 2014b). Three observation points were selected for CHCH's viewscape analysis: Point Park, Sunset Rock, and the Wilder Brigade Monument (Figure 80). These three locations were chosen due to their popularity and easy access. Figure 81 displays one of many views from Point Park; this particular picture is a view of Moccasin Bend. Figure 82 displays the Wilder Brigade Monument where visitors can climb stairs to the top to get a view, and Figure 83 displays a panoramic view from Sunset Rock.

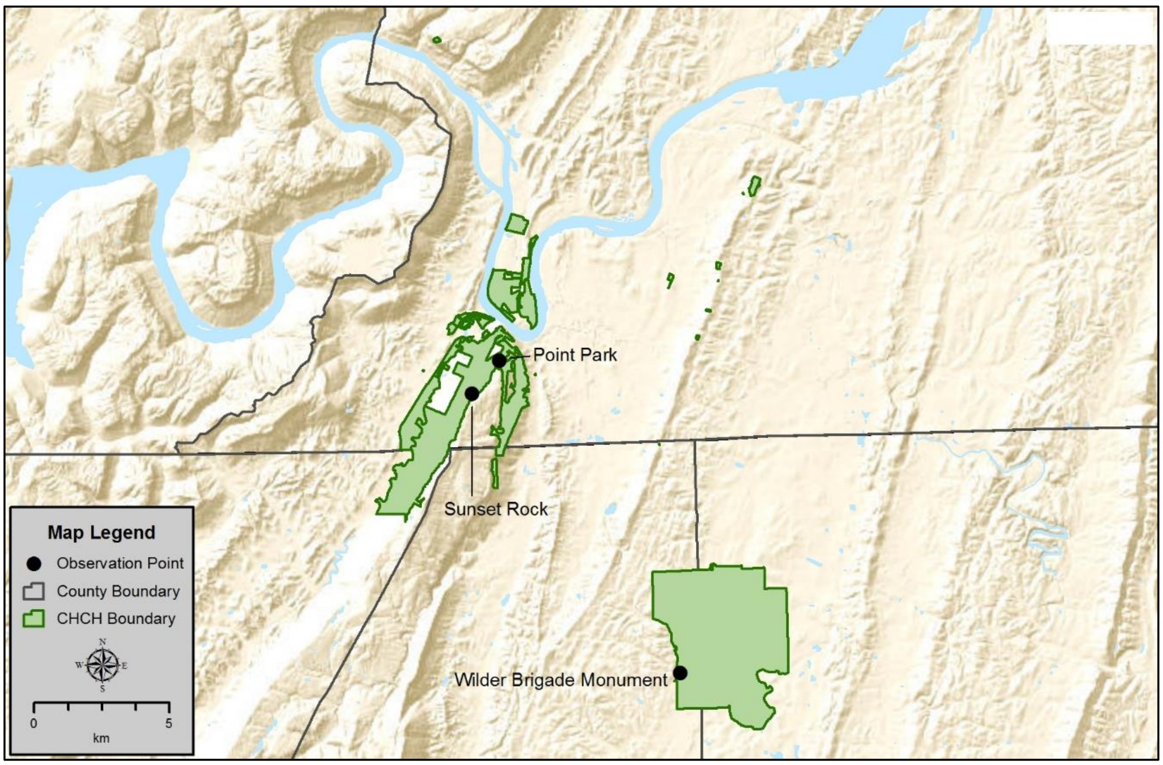


Figure 80. Three observation points were used for the viewscape analysis: Point Park, Sunset Rock, and the Wilder Brigade Monument (NPS unpublished data).

Figure 81. The view of Moccasin Bend from Point Park, located on Lookout Mountain (NPS Photo).

Figure 82. The Wilder Brigade Monument found in the Chickamauga Battlefield Unit is 25.9 m (85 ft) tall (NPS Photo).

Figure 83. Composite panoramic photo from Sunset Rock constructed using six NPS-provided photos.

In order to replicate as accurately as possible the view as seen by a person standing at these points, a 1.7 m (5.5 ft) observer offset was applied to Point Park and Sunset Rock (CDC 2012), while a 27.6 m (90.5 ft) observer offset was applied to the Wilder Brigade Monument to account for the height of the viewer plus the height of the monument (25.9 m [85 ft]) (CDC 2012, NPS 2016). According to the viewscape analysis, out of the study area (352, 000 ha [870,000 ac]), 60,611 ha (149,774 ac) can be seen externally from the aforementioned observation points; this equates to approximately 17% of the external landscape. Due to the ridges and valleys in the area, the viewscape from each observation point varies across the landscape (Figure 84). Each observation point has its own area of visibility (or visibility range), but as seen in Figure 84, there is some overlap between observation points (e.g., when inside Point Park and looking southwest, the same landscape can be seen from Sunset Rock looking northwest).

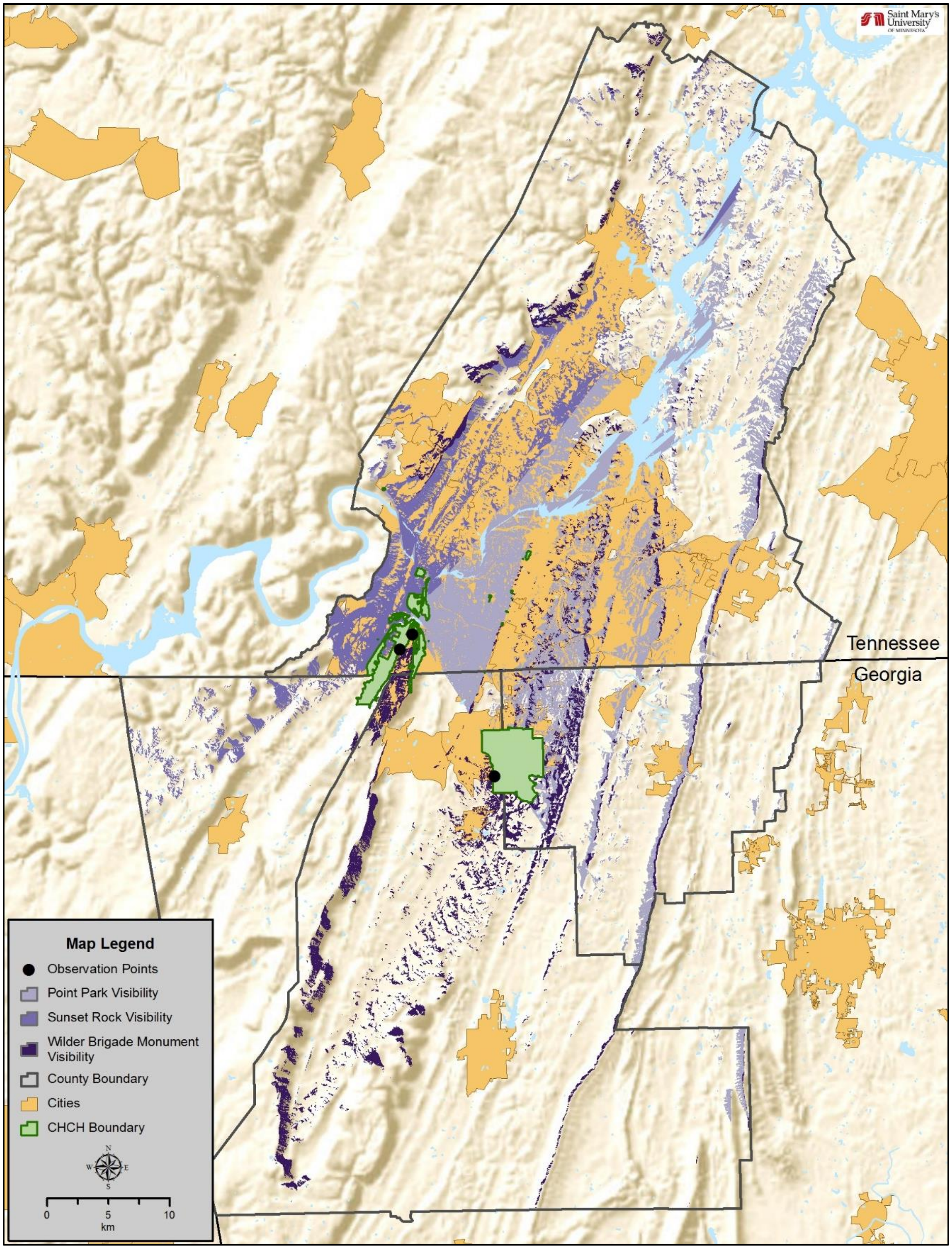


Figure 84. The park's viewscape from three different prime observation points (Figure 83). Each observation point has its own visibility range, but overlap does occur.

Another factor that can influence a visitor's viewscape experience is artificial light; this is also known as a lightscape. According to the NPS (2015), 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. There are many reasons that understanding a park's lightscape is important. 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 (NPS 2015).

A type of artificial lighting that can be found throughout many lightscapes is called light-emitting diodes, or LEDs. LEDs are known for their energy-efficiency and ability to confine light (International Dark Sky Association 2016) but this light source can also cause harm to the surrounding ecological landscape, increase reflection and glare for drivers and pedestrians, and depending on the amount of emitted blue light, can increase the surrounding temperature (Pawson and Bader 2014, International Dark Sky Association 2016) (Figure 85). International Dark Sky Association (2016) describes the Jevons Paradox, which is an economics concept explaining that when the price of producing or distributing a product goes down (i.e., reduced energy costs with LED lights), there is a tendency to use more of that product versus less (e.g., keep LED lights on longer or increase LED lighting infrastructure).

Figure 85. Image of Milan at night after a transition to LED technology. An increase in LED lighting occurred at the center of the city (articulated by the white center), while non-LED lights are used in the suburbs (yellow/orange hue) (Photo by Samantha Cristoforetti, NASA/ESA) (International Astronomical Union 2016).

Some sort of lightscape management plan could help provide standards of lighting within and around CHCH. At this time, CHCH does not have any sort of lightscape management plan in place. Also, the City of Chattanooga does not require specifications or regulations on indoor or outdoor lighting (City of Chattanooga Tennessee 2016b). The State of Tennessee initiated an increase in the amount of LED lighting in outdoor public spaces; the goal was to replace over 1.5 million lighting fixtures by May 2016; the sole energy provider for Chattanooga, Tennessee (Electric Power Board) participated in this initiative (TDEC 2014).

Lorenz and Danko (2015) created a light pollution map that displays levels of light pollution occurring in and around the park (Figure 86). The Bortle Dark Sky Scale (Bortle 2001) is used in this light pollution map as a semi-quantitative measure of night sky and anthropogenic sky glow. Visual observations 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). Inside CHCH boundaries, the Bortle Scale ranges from class 5 to class 9; this translates to the dark sky falling under a suburban sky (class 5) to inner-city sky (class 9). Inside the study area used for this component, the lowest class reached is class 4 (highlighted in neon green in Figure 86), meaning the dark sky represents rural/suburban transition.

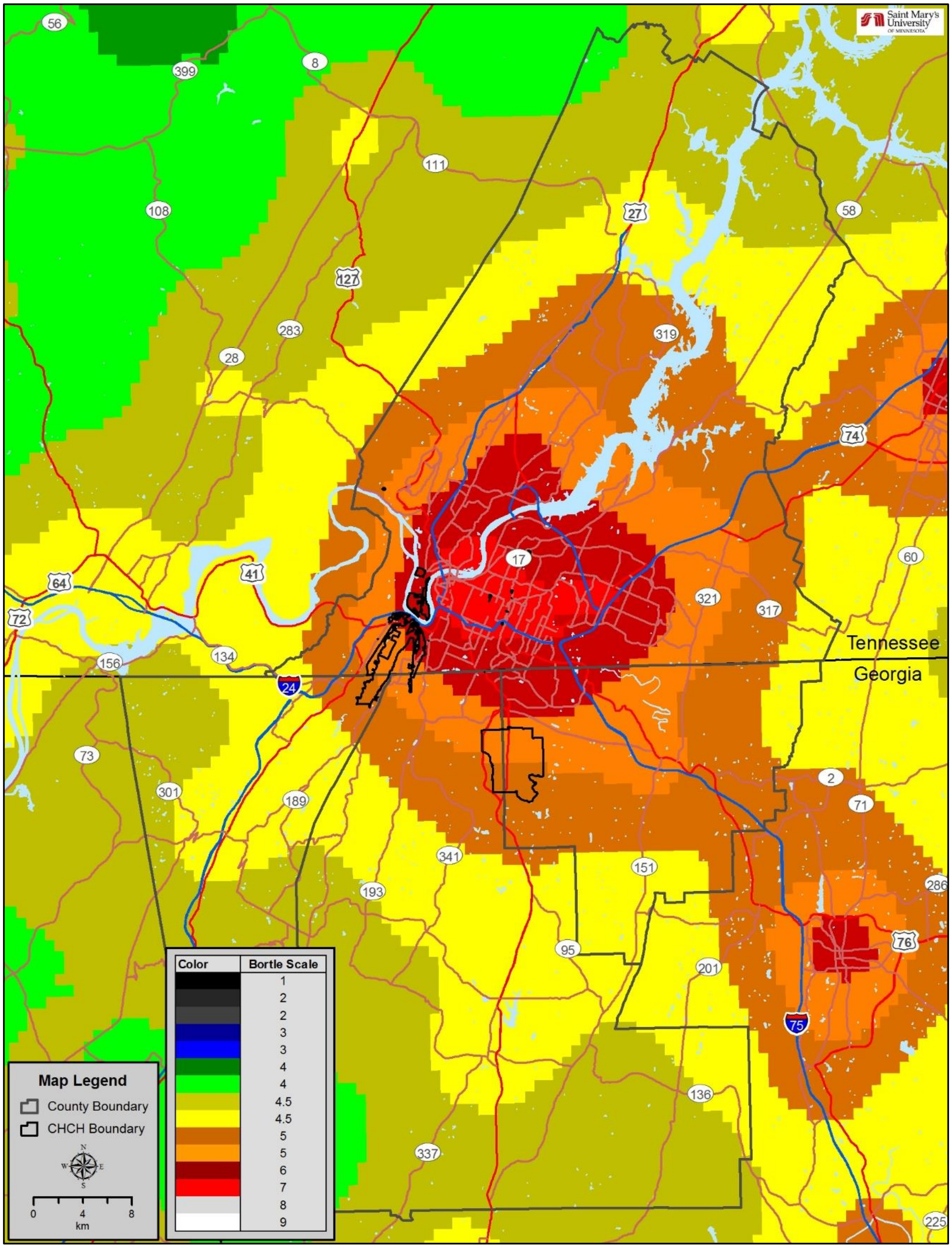


Figure 86. The levels of light pollution in and around CHCH according to the Bortle Scale (2001), based on 2016 data.

Data Needs/Gaps

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) and the impact of lights used in and around the park may help managers better assess the threats posed by such uses and infrastructure.

Overall Condition

Change in External Land Cover/Land Use

The *Significance Level* for this measure was assigned a 3. Despite only 5% of the external land cover surrounding CHCH changing from 2001 to 2011 and of that 5%, only 1% converted from a non-developed to a developed land cover class, CHCH still sits in a fairly urbanized area. Due to the fact that since the time of the battle(s) (1863), the adjacent land cover and land use around the park has changed dramatically, thus a *Condition Level* of 3, meaning high concern, was assigned for this measure.

Total Population

A *Significance Level* of 2 was assigned for total population. The land around CHCH has been populated for over two centuries, especially in Hamilton County due to the City of Chattanooga. According to the USCB (2014), population estimates for 2015 predicted that both Hamilton County, Tennessee and Catoosa County, Georgia would become more populated, while Dade and Walker County, Georgia will stay fairly consistent. Due to the potential for population growth around the park, a *Condition Level* of 2, or moderate concern, was assigned for this measure.

Population Density

Population density was also assigned a *Significance Level* of 2. Both Catoosa County and Walker County, Georgia showed an increase in population density from 1990 to 2010, while Hamilton County, Tennessee and Dade County, Georgia showed a decrease. With Hamilton County's population increasing and its population density decreasing, this could imply that populations are spreading out. Also, with population increasing in Catoosa County, Georgia and its population density increasing, this likely indicates that people are moving into the area. Despite population densities varying between counties in the study area, the increasing density in Catoosa County warrants some concern, and therefore a *Condition Level* of 2 was assigned for this measure.

Housing Development

The *Significance Level* for this measure was assigned a 3. Along with population increasing, SERGoM data suggests that housing developments and densities (units/km^2) are also increasing around CHCH. This measure was assigned a *Condition Level* of 2, or moderate concern, due to housing development increasing in the area.

Land Ownership

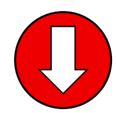
A *Significance Level* of 3 was also assigned for this measure. According to the PAD-US data, only 8.69% of the land in the study area is considered protected. Since the other parcels of land are owned by entities that would not necessarily manage their lands in support of park management goals, a

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 is 0.67, implying that adjacent land cover and land use is currently in significant condition. Despite land development being relatively slow over a recent 10-year period (2001-2011), since the time of the battle(s) (1863), adjacent land cover and land use has increased dramatically. Also, a combination of increased populations, changes in population densities, and increases in housing developments 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 a visitor's overall experience (i.e., viewscape, soundscape, and cultural experience). Due to the combination of population change, housing developments, and overall external land cover/land use change (i.e., loss of wooded landscape), a deteriorating trend was applied with medium confidence in the overall assessment.

Table 68. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's adjacent land cover/land use.

Measures	Significance Level	Condition Level	WCS = 0.67
Change in External Land Cover/Land Use	3	3	
Total Population	2	2	
Population Density	2	2	
Housing Development	3	2	
Land Ownership	3	1	

4.9.6. Sources of Expertise

- Jim Szyjkowski, CHCH Chief of Resource Management

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4.10. Soundscape and Acoustic Environment

4.10.1. 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 2014). The acoustic environment is the combination of all the acoustic resources within a given area, natural sounds and human-caused sounds (NPS 2014). 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 2014). Soundscape is the component of the acoustic environment that can be perceived by humans (NPS 2014). The character and quality of the soundscape influence human perceptions of an area, providing a sense of place that differentiates from other places (NPS 2014). 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 2014). 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 2014). 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 2014).

A cannon sits atop Lookout Mountain, looking over the Tennessee River and the City of Chattanooga. Visible in this photo are several sources of anthropogenic noise sources, including the city, Interstate 24 (visible in lower right), and Moccasin Bend (west of the river; location of an active shooting range) (NPS Photo).

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, 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 (NPS 1994, 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. 2016).

4.10.2. Measures

Sound measures may be classified in terms of amplitude, frequency, or duration, as described below. Additional details are provided in Chapter 4.10.4.

- Sound pressure levels (in decibels [dB], a logarithmic unit) - the most common measure of sound amplitude, and especially A-weighted sound levels (in A-weighted decibels [dBA])
- Frequency - 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.

4.10.3. 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 EPA (1974) in order to maintain the integrity of interpretive programs at the park outdoor background conversation should not exceed 55 dB.

4.10.4. Data and Methods

Sound Science

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 2014).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave (NPS 2014). 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 2014). 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, humans also perceive the amplitude (or level) of a sound (NPS 2014). 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 2014). This also means that small variations in sound pressure level can have significant effects on the acoustic environment (NPS 2014). Sound pressure level is commonly summarized in terms of dBA (A-weighted decibels) (NPS 2014). Table 69 provides examples of A-weighted sound levels measured in national parks.

Table 69. Examples of sound levels measured in national parks (NPS 2014) 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 2014):

- 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.

4.10.5. 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 (see Figure 87). 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).

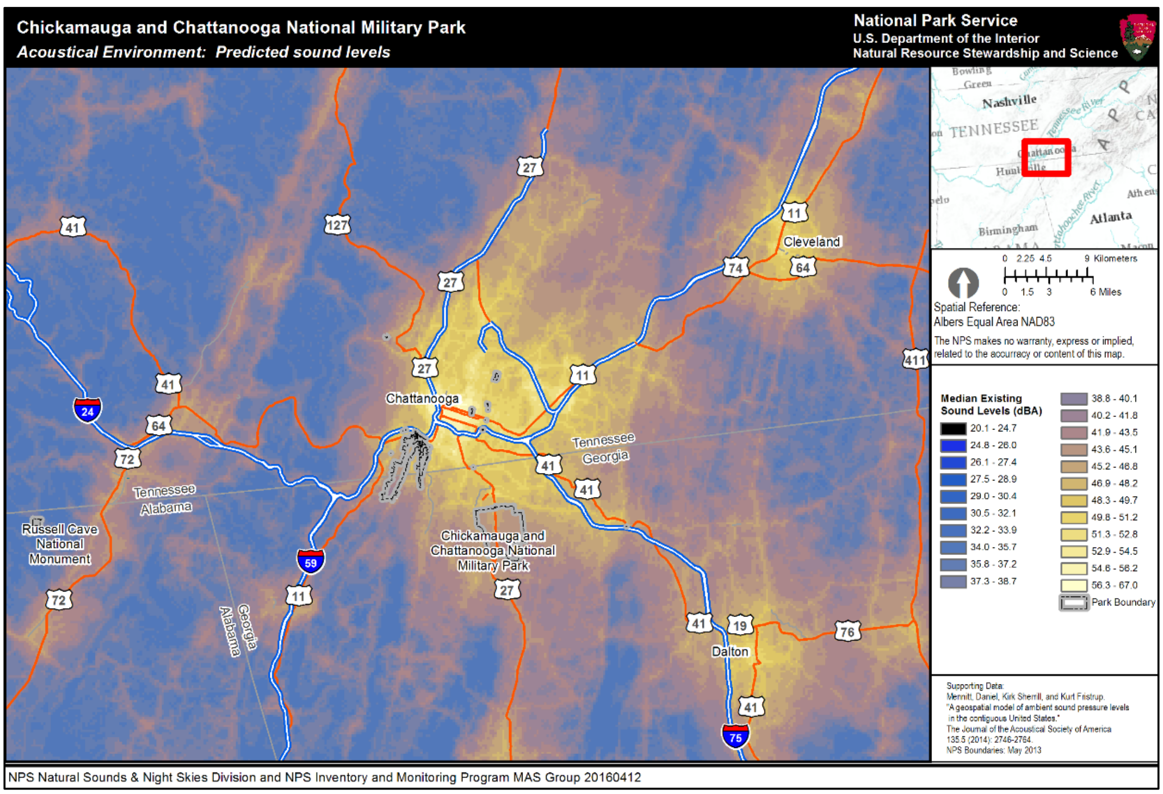

Figure 87. Map displaying predicted median existing sound levels (L_{50}) in dBA (figure provided by NPS).

The model shows that predicted median existing daytime sound levels (L_{50}) within CHCH are moderately high, ranging from 40.7 to 51.1 dBA. In addition to predicting these two ambient sound levels, the model also calculates the difference between the two metrics which provides a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting metric (L_{50} dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location (Figure 88). Predicted impacts due to anthropogenic sources are moderate in CHCH, and range from 4.1 to 15.3 dBA. No on-the-ground data have been collected in CHCH, and the modeled sound levels are currently the only source of acoustic data that exist for the park.

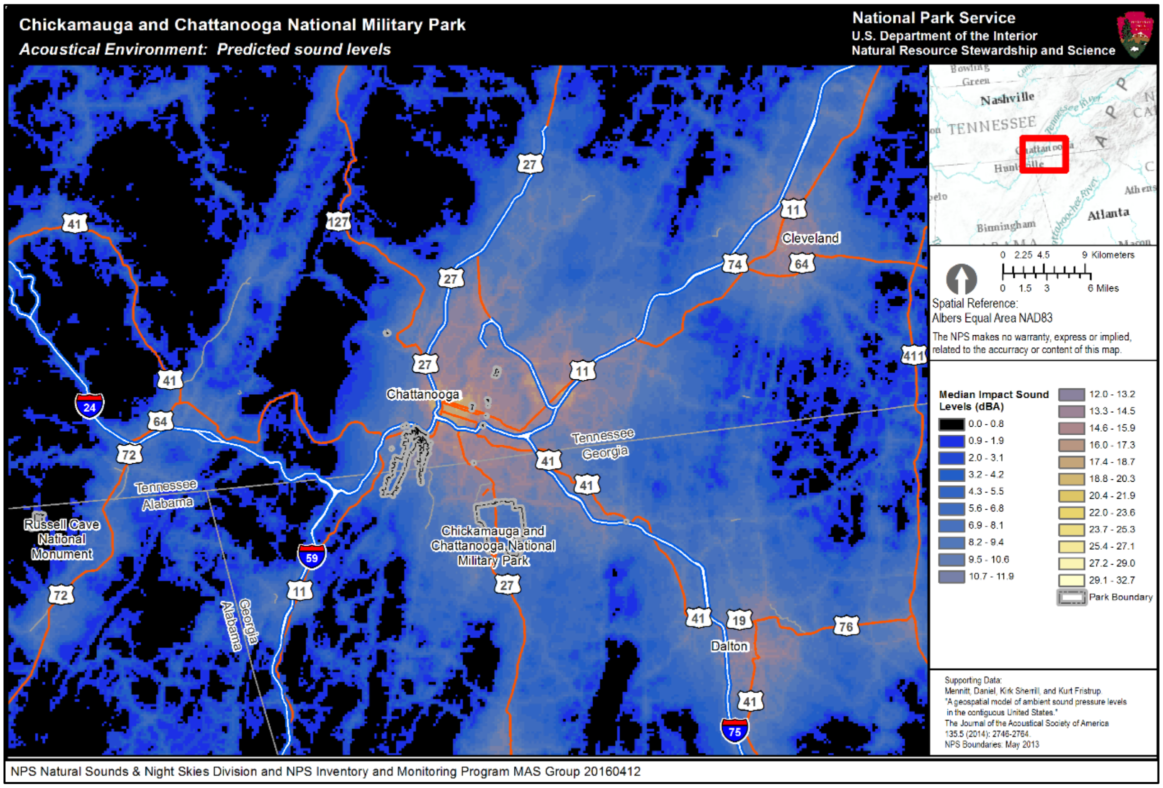

Figure 88. Map displaying modeled 2016 L_{50} dBA impact levels in CHCH (figure produced and provided by NPS NSNSD).

Threats and Stressor Factors

Multiple factors can increase anthropogenic sounds inside a park; anything from park maintenance equipment to noisy visitors (NPS 2016). A study investigating sound and its impacts was completed in Muir Woods National Monument and found that anthropogenic noise from visitors, disruptive behaviors, and other related sounds created the most distractions and interruptions to the quality of a visitor's experience in the park (NPS 2016). While visitors and their associated noises are certainly present in CHCH, there are several threats and stressors to the acoustical environment of CHCH that are of a higher magnitude. These threats include the nearby law enforcement firing range, automobile traffic, and commercial air traffic.

The Chattanooga Police Department operates a firing range and training facility near the Moccasin Bend Archeological District (Figure 89). The noise generated from this facility can be heard throughout the Moccasin Bend Archeological District, and it may potentially be heard from locations outside of this district. While there have been discussions to re-locate or abandon the current firing range on Moccasin Bend, it appears likely that the facility will continue to remain operational for the near future.

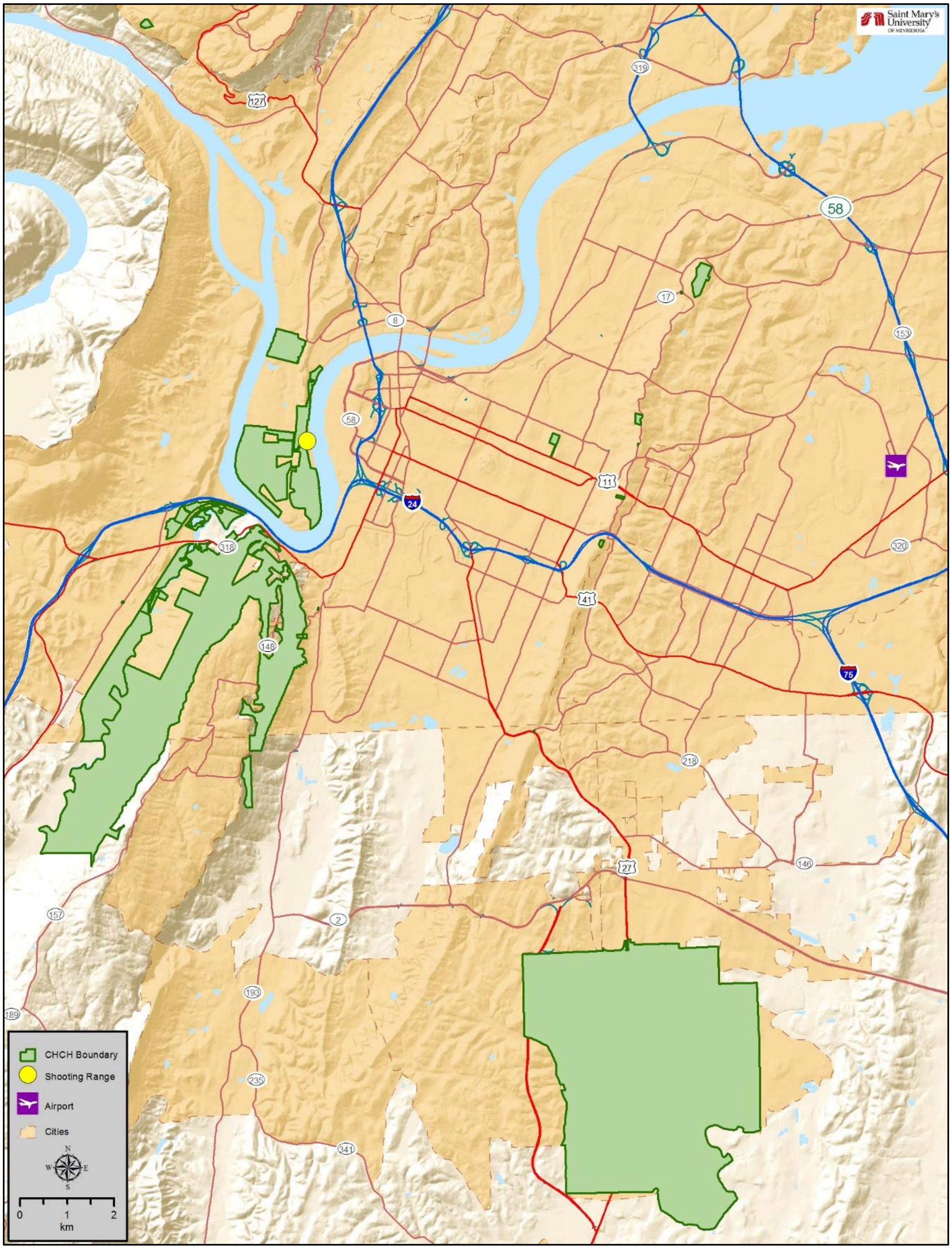

Figure 89. Location of the major roads and the Chattanooga Police Department's shooting range in relation to the Moccasin Bend and Lookout Mountain Battlefield units.

Another threat that is unlikely to be alleviated in the near future is automobile traffic. As a primarily urban park with units scattered throughout the City of Chattanooga (e.g., Lookout Mountain, Moccasin Bend, Orchard Knob, Chattanooga National Cemetery, and the six reservations scattered along Missionary Ridge), road noise has an almost constant impact on the acoustic environment of the park. U.S. Interstate 24 is located in close proximity to both the Lookout Mountain Battlefield Unit and the Moccasin Bend Archeological District (Figure 89). This stretch of interstate is heavily travelled, with an average of nearly 72,000 vehicles passing through in a 24-hour period (TDOT 2016). 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."

Air travel creates additional non-natural sounds that may disrupt a visitor's enjoyment of the park. The Chattanooga Metropolitan Airport, also known as Lovell Field, is located near CHCH in eastern Chattanooga (Figure 89). Flights over CHCH land are frequent; in 2015, the total number of airport operations numbered 51,386, which breaks down to an average of 141 flights a day (FAA 2016).

Data Needs/Gaps

At this time, there are no soundscape data for CHCH. Implementing an annual monitoring program of sound levels and sound recordings is essential for the management of the park's soundscape. There are plans for on-the-ground NPS-led sound monitoring to take place in the park in the summer of 2016, however, these data were not available for this assessment at the time of publication.

Overall Condition

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 moderately high noise impacts within the park, a lack of on the ground data makes it difficult to accurately understand current condition. CHCH is unique in that anthropogenic noise was present during the time of battle, and reenactments and interpretive programs often recreate some of the battle's noises. These noises 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 CHCH 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 even bother park visitors (NPS 2016). Implementing soundscape monitoring inside CHCH 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 have to adapt 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-caused 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.

Table 70. Significance levels and condition levels used to calculate the weighted condition score (WCS) for CHCH's 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	

4.10.6. 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

4.10.7. 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 71 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 71. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Hardwood Forest Community	• Additional study of oak and other hardwood regeneration to better understand this process and how it will impact the future composition of CHCH's hardwood forest communities • If oak regeneration is below desirable levels, investigate the causes, as well as strategies for improving regeneration • Healthy populations of large-flowered skullcap at CHCH provide an opportunity for researchers to better understand this rare species
Limestone Cedar Glades	• Digital mapping and measurement of the park's limestone cedar glades in a GIS would facilitate a more accurate assessment of glade areas • Consistent monitoring of CHCH glades to investigate the rate and impacts of woody succession, as well as levels of exotic species invasion • Creation of a management plan to address the habitat degradation currently occurring in glades, and a photo monitoring program, which would provide a quick and inexpensive way to document general glade condition • Monitoring of glade endemics and other rare plants to help identify any trends in the populations and better protect these species
Wetlands	• Further investigation of the value of small wetlands within an upland landscape, particularly to wildlife • Monitoring and research in rare willow oak pond communities and other high-quality wetland community examples at the park (e.g., the Wilder/Glen-Viniard Roads complex)
Cave Bats	• Continued monitoring of annual bat abundance (summer-roosting and hibernating) and WNS-related mortality at park locations • Additional research into impacts of WNS and wind turbines on bat populations.

Table 71 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Birds	• Establishment of an annual bird monitoring program, potentially including point counts during the breeding or migratory seasons, winter surveys (e.g., CBC), raptor road surveys, and/or targeted survey efforts designed to document species listed as unconfirmed or uncommon/historic • Research regarding potential detrimental effects of mowing or pesticides on grassland species • Area searches for Bewick's wren and the determination of areas of potential nesting habitat for the species • Expanded research and survey efforts in unique habitats of the park, such as the cedar glades or the beaver ponds
Herpetofauna	• Updated inventory, with efforts to document additional species which were potentially missed during the 2006 inventory • Regular monitoring, including the recently acquired Moccasin Bend Unit, to assess any trends that may be occurring within the park
Water Quality	• Continuation of the CUPN monitoring program to detect any changes or trends in water quality over time
Air Quality	• On-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury) and visibility, as budget and personnel limitations allow • Studies of mercury concentrations in park waters and wildlife (e.g., fish, birds, bats) to identify any impacts this contaminant may be having on the park
Adjacent Land Cover and Use	• Additional information regarding specific land use immediately adjacent to park boundaries (e.g., types of agriculture or other development) and the impact of lights used in and around the park
Soundscape	• Implementation of an annual monitoring program of sound levels and sound recordings

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, cave bats). However, many of the identified data gaps for CHCH center on the need for the establishment of an annual (or at least standardized) monitoring or inventory effort (e.g., birds, herpetofauna). Many of the existing data sets for these resources are outdated, while components such as dark night skies, air quality, and soundscape, do not have data specific to CHCH, 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 72 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Table 73 following Table 72). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 72) 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), or even current information.

Table 72. Summary of current condition and condition trend for featured NRCA components.

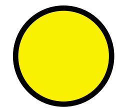
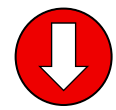
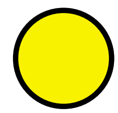
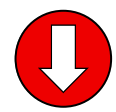
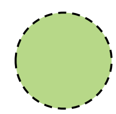
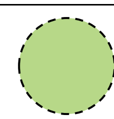
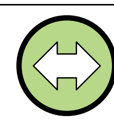
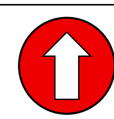
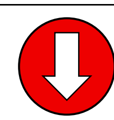
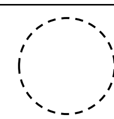
Category	Sub-category	Component	WCS	Condition
Biotic Composition	Ecological communities	Hardwood Forest Community	0.44	
		Limestone Cedar Glades	0.67	
		Wetlands	0.58	
	Wildlife	Cave Bats	0.83	
		Birds	0.20	
		Herpetofauna	0.17	
Environmental Quality	–	Water Quality	0.33	
	–	Air Quality	0.83	
	–	Adjacent Land Cover and Use	0.67	
	–	Soundscape	N/A	

Table 73. Description of symbology used for individual component assessments.

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
No color	Current condition is Unknown or Indeterminate	No trend	Trend in condition is Unknown or Not Applicable	–	–

Table 74. Examples of how the symbols should be interpreted.

Symbol Example	Description of Symbol
	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.

For featured components with available data and fewer data gaps, assigned conditions varied. Three components were considered to be in good condition: birds, herpetofauna, and water quality. However, water quality was at the edge of the good condition range, and any small decline in conditions could shift it into the moderate concern range. Of the components in good condition, trends could not be assigned for birds or herpetofauna, and water quality is considered stable. Two components (hardwood forest community and wetlands) were of moderate concern with no trends assigned. The remaining four components were of significant concern: limestone cedar glades, cave bats, air quality, and adjacent land cover and use. These components all showed a declining trend, with the exception of air quality, which is improving.

5.3. Park-wide Condition Observations

Despite the variety of habitats at CHCH, many of the 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 the nation's oldest and largest National Military Park, and the threats/stressors, data needs, and priority habitats of CHCH are critical to park managers in order to fully understand the many ecosystems present in the park.

5.3.1. Ecological Communities

While CHCH is primarily recognized for its military significance during the Civil War, the park possesses tremendous ecological values as well. The native vegetative communities of CHCH are vital resources for the park, providing habitat for wildlife and performing critical ecological functions. The extensive hardwood forests in CHCH, especially along the slopes of Lookout Mountain and the rolling hills of Chickamauga Battlefield, can be divided into 16 unique hardwood forest community types, with an additional two mixed conifer/hardwood forest types as well (Govus and White Jr. 2006). These forests provide habitat for many plant species, with almost 500 species documented within these areas (Appendix A). Perhaps most notably, these hardwood forests provide a microhabitat for the federally threatened large-flowered skullcap, a mid-successional plant species that is found in forest areas where light can still reach the forest floor (Govus and White Jr. 2006, NPS 2015a).

Interspersed within the hardwood forests and woodlands of the Chickamauga Battlefield are unique areas called limestone cedar glades. These areas are typically flat or rolling open areas with exposed rock and shallow soil, and can support endemic or unique plant communities that are typically dominated by herbaceous species or small trees and shrubs (Sutter et al. 1994, Baskin and Baskin 2003). The cedar glades are a biologically significant area, not just in the park, but in the southeastern U.S.; the glades found in the Chickamauga Battlefield unit are the best example of this community type in Georgia and represent the only known location in Georgia for several plant species. To date, over 275 plant species have been documented in CHCH's limestone cedar glades (Appendix D).

The majority of the wetlands that occur in CHCH are forested and support a diverse herbaceous layer. Additionally, the large wetland complex in the southwest corner of the Chickamauga Battlefield Unit contains a rare wetland type known as a willow oak pond and is a biologically and culturally important area in the park. Many of the old-growth willows and oaks in this area were likely present during the Civil War battle in 1863 (Barnett-Lawrence et al. 1994).

The current condition of the park's vegetation communities varied. Both the hardwood forest and wetland components had current conditions of moderate concern with an unknown trend, while the limestone cedar glades component was determined to be of significant concern with a declining trend. The hardwood forest and wetland communities had relatively high species richness levels, and the total extent of these areas was of relatively low concern. However, the continued threat of exotic species expansion in these areas was a major concern for both components. Exotic species cover in the forested wetlands of CHCH ranged from 26-170% during monitoring from 2011-2015, and cover ranged from a trace to almost 60% in the hardwood forest community during the same period. Comparisons between the NatureServe (2007) survey and the CUPN monitoring from 2011-2015 appears to indicate expansion of exotic plant cover during that short time, and warrants significant concern for park managers. Another pressing concern, especially in the hardwood forest community, is that oak regeneration continues to be an issue and represents a major threat to the persistence of this community in CHCH. Continued research in both of these communities is needed in order to allow for a long-term trend analysis and to observe 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.

The limestone cedar glades of CHCH were determined to be of significant concern, although the overall Weighted Condition Score fell very close to the upper threshold of the moderate concern range. While the species richness of these areas is currently of low concern to park managers, the current area (acreage) of these areas is unknown, as no update to the total glade size in CHCH has occurred since 1994. While Sutter et al. (2011) suggests that the area of the glades has declined in the last century, there is no hard data to support this notion.

Two areas that represent areas of more pressing concern to the cedar glades in CHCH are the percent of woody cover and the cover of invasive/exotic species. Between 1993 and 2006, percent woody cover of plants >1 m tall showed a statistically significant increase, averaging 26% across the sampled glades (Govus and Lyons 2009). As of 2006, woody cover exceeded 50% at nine of 11 sampled glades, and was over 75% at four of these glades (Govus and Lyons 2009). Based on NatureServe's (2009) draft metrics, nine of the CHCH sampled glades fell in the poor category with only two in the fair category. Historically, the shallow soils and extreme moisture fluctuations of cedar glades largely protected them from invasion by exotic plants (Sutter et al. 1994, Govus and White Jr. 2006). However, the re-sampling of Sutter et al.'s (1994) glade transects by Govus and Lyons (2009) showed that at least one exotic species, Chinese privet, has increased dramatically in many of CHCH's cedar glades. While further investigation of additional glades and for other exotic species would provide more insight, the increase in privet alone is of concern to park managers.

5.3.2. Wildlife

Animals featured as NRCA components included cave bats, birds, and amphibians and reptiles (under the herpetofauna component). Both the birds and herpetofauna components were determined to be in good current condition. However, the available data for these components were sparse, and these assessments relied heavily upon the best professional judgement of managers. Because of the limited data for these two components, the overall confidence in condition assessment was low, as indicated in Table 71.

Avian species richness values based on Stedman et al. (2006) indicated a high level of diversity that was about what was to be expected based on the size of the park, although not as many grassland obligate species were observed as were expected. The observation of a Bewick's wren in the Chickamauga Battlefield Unit before the Stedman et al. (2006) inventory began indicates that the park provides suitable habitat for that, and likely other, species of conservation concern. Abundance estimates for bird species obtained during Stedman et al. (2006) were very similar between 2005 and 2006, with the majority of observations coming from five of the same species each year. Expanded monitoring of the bird community in CHCH is needed in order to obtain a more reliable estimate of current condition. The presence of the Bewick's wren, which is an endangered species in the State of Tennessee and a federal species of management concern, highlights the importance of CHCH's habitats for many critical avian species.

Reptile and amphibian taxa are frequently understudied in protected areas, and have become a focal topic as the shift to protecting biodiversity has become a critical goal in cultural-based NPS units (Scott and Seigel 1992). Only one herpetofauna inventory has been conducted in the park (Accipiter Biological Consultants 2006), and an expansion of research is needed regarding this priority wildlife community. Species richness levels for both amphibians and reptiles in CHCH were determined to be of low concern, as the majority of the herptile species that were expected to occur in the park were documented during the most recent inventory. The NPS Certified Species List includes 23 amphibian species as present or probably present at CHCH (NPS 2016); 21 of these species were observed by Accipiter Biological Consultants (2006). Twenty-two reptile species are included on The NPS Certified Species List as present or probably present at CHCH (NPS 2016), and 13 of these were observed during Accipiter Biological Consultants' (2006) inventory. While the number of species observed looks low compared to the expected number of species, survey design (i.e., search methods, timing) and the elusiveness of some species (e.g., snakes) likely contributed to this low number. Without an expansion of the early inventory work, overall confidence in the current condition of these resources will remain low.

The park's cave bat population was determined to be of significant concern. Recent threats to cave bat populations, particularly the sudden arrival of WNS and its rapid spread across the Eastern U.S., have been well publicized but are poorly understood. It is estimated that WNS has killed more than 6 million bats in the eastern U.S. and Canada since 2006 (Baker et al. 2015). While the impacts of WNS are far-reaching, fluctuations in bat populations over the past decade have not been caused by WNS exclusively. These fluctuations can also be tied to climate change, changes in water quality, agricultural intensification, loss and fragmentation of forests, fatalities at wind turbines, and pesticide use (Jones et al. 2009). White-nose syndrome was confirmed in CHCH in 2012 when a tricolored bat collected from a park cave tested positive for the disease (NPS 2012). Part of the continued monitoring in CHCH's caves has focused on documenting the spread and effects of the disease in CHCH.

Current species richness estimates for cave bats in CHCH were on par with what would be expected for the area. However, the continued decline in bat species across their ranges, combined with the presence of two cave bat species of conservation concern (Indiana bat and gray bat) indicate that this measure may be at risk in the future. Echoing those concerns, CUPN monitoring efforts have observed downward trends in hibernating cave bat abundance during the 3 years of monitoring. While bat abundance at each survey cave has varied during CUPN monitoring, five locations exhibited tricolored bat abundance declines of approximately 50% or greater between 2014 and

2016. Trend data are limited and exist for only 3 years, but the regional bat population trends, especially as they relate to WNS, appear to be declining. Continued monitoring of bat population trends will strengthen overall confidence in this component's condition assessment.

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 determined to be of significant concern in CHCH, largely due to high levels of nitrogen and sulfur deposition and poor visibility in the area. The most recent 5-year (2009-2013) estimate for sulfur wet deposition at CHCH was 3.3 kg/ha/yr, which falls into the *Significant Concern* range as defined by the NPS ARD (NPS 2015b). Similarly, the most recent 5-year (2009–2013) estimate for nitrogen deposition at CHCH was 4.1 kg/ha/yr, also in the *Significant Concern* range identified by the NPS ARD (NPS 2015b).

Until recently, ozone concentrations were a serious concern in the CHCH region (Kohut 2007, Jernigan et al. 2011). However, the most recent 5-year (2009–2013) estimated average for 4th-highest 8-hour ozone concentration at CHCH decreased, falling in the very top of the NPS ARD *Moderate Concern* range at 70.9 ppb (NPS 2015b). Visibility continues to be a concern in the CHCH region, as even on the 20% clearest days, estimated visibility fell into the NPS ARD's *Moderate Concern* range.

The water quality of the many perennial streams and springs, small ponds, and rivers of CHCH was determined to be in good condition, although the overall weighted condition score was at the upper threshold of the good category. Confidence in the assessment of current condition was high, as sampling efforts initiated by the CUPN occur on a rotating basis, and provide an adequate baseline for comparison. Several metrics of water quality investigated in this assessment were documented as being of low concern throughout the monitoring in the park. All water temperature measurements taken at CHCH met the state standards of both Tennessee and Georgia, and never exceeded the range to support aquatic life (Meiman 2005). The only measure of water quality determined to be of moderate concern was *E. coli* bacteria. The majority of *E. coli* readings from CHCH waters were very low. However, during 2008-2010 CUPN monitoring, three measurements from different water bodies exceeded the EPA standard for contact recreation of <576 cfu/100 ml (Meiman 2016). In more recent sampling (2015-2016), even more measurements exceeded this standard, with three readings near the upper quantification limit of 2,400 cfu/100 ml.

The soundscape of CHCH is unique in that anthropogenic noise was present during the time of battle, and reenactments and interpretive programs often recreate some of the battle's noises. In contrast to many NPS units, these noises and actions are allowed within the park's enabling legislation, and are not considered significant detractions from the managed condition of the park. The current condition of the park's soundscape is unknown at this time. The many units of CHCH are situated in largely urban environments, with much of the Lookout Mountain Battlefield, Moccasin Bend, and Orchard Knob Units lying in or just around the city of Chattanooga, Tennessee. Modelling of the expected soundscape around CHCH suggests that there are moderately high noise impacts in the park, but an on the ground survey is needed to verify/counter these projections.

5.3.4. Park-wide Threats and Stressors

Several threats and stressors are affecting multiple resources within the park. Two of the most significant are climate change and non-native species. 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 threaten CHCH's priority resources as well (Davey et al. 2007). Because 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 accelerate with 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 to sensitive plant species.

Throughout the CUPN, distinct seasonal variations in precipitation levels are evident (Davey et al. 2007). In the western portion of the network, 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 contributed to water quality degradation (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 closely tied to water. These patterns, along with warming temperatures, have the potential to affect nearly every plant and animal population inside CHCH (Wathen et al. 2015).

Non-native invasive plants are among the greatest threats to forests worldwide, including those in CHCH. The majority of the units of CHCH are situated in urban or near-urban environments, and some are near a major interstate highway corridor. The many roads, trails, and waterways of this area, combined with the nearby residential and urban developments, serve as potential vectors for the spread of invasive plants and pests (Mack 2003, Keefer et al. 2014). To date, 43 non-native plant species have been confirmed in CHCH's hardwood forests. Twenty-four of these are considered invasive by the TN-EPPC, with 12 species being considered a severe threat to native communities (TN-EPPC 2009). In the park's forested 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 (2009) documented non-native plant species in 79% of all wetlands and riparian areas that were sampled. These aggressive species can outcompete and replace native forest and wetland plants (Govus and White Jr. 2006, Moore and Leibfreid 2013). Invasive plants, such as

Chinese privet and bush honeysuckles (*Lonicera* spp.), are changing the character of many sites in CHCH by reducing visibility through the forest understory and represent a major threat to several ecological communities in the park.

Non-native species in CHCH are not confined only to plant species, however, as several mammal and avian non-native species are present in the park. Feral cats represent one of the largest causes of bird and herpetofauna 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). Non-native avian species present in CHCH include the rock pigeon, Eurasian collared-dove, European starling, and house sparrow. 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, p. 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.*

5.3.5. Overall Conclusions

CHCH is unique in that it possesses incredible cultural, historic, and ecological importance across many scattered units in Tennessee and Georgia. While the park is renowned primarily for its preservation of Civil War battlefields, the federal protection mandated in 1890 has allowed many of the ecosystems in the park to remain true to what should be expected in this region. The lands surrounding CHCH have largely been developed, being converted to various urban-associated infrastructure (i.e., transportation, residential, and commercial structures), yet the units of CHCH remain islands of protected forests, wetlands, and Civil War monuments. Continued monitoring of the park's priority resources, combined with management efforts directed at minimizing disturbance potential, will aid many of these natural communities and ensure their continued presence in the park. Additional monitoring in regards to the many shared threats and stressors in the area, particularly climate change, will strengthen park manager's overall understanding of the interrelated nature of the ecosystems and communities in CHCH. CHCH possesses tremendous opportunity for scientific study, and continuing advancements in the scientific understanding of CHCH's resources will not only benefit the park, but also other locales in the southeast with shared resources.

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Appendix A. Plant species documented in hardwood forest communities during vegetation surveys of CHCH.

Table A.1. Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An “x” donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Acalypha gracilens	–	x	–
Acalypha rhomboidea	–	x	–
Acer floridanum (*A. barbatum*)	–	x	x
Acer negundo	x	x	x
Acer rubrum	x	x	x
Acer saccharum	–	x	x
Actaea racemosa (*Cimicifuga racemosa*)	–	x	x
Adiantum pedatum	–	x	x
Aesculus pavia	–	x	–
Agalinis setacea	–	x	–
Ageratina altissima	–	x	x
Agrimonia sp.	–	x	x
Agrimonia gryposepala	–	x	–
Agrimonia pubescens	–	x	x
Agrimonia rostellata	–	x	–
Agrostis sp.	–	x	–
Agrostis hyemalis	–	–	x
Ailanthus altissima[A]	–	x	–
Albizia julibrissin[A]	–	x	–
Allium canadense	–	–	x
Allium vineale	–	x	–
Ambrosia artemisiifolia	–	x	x
Ambrosia psilostachya	–	x	–
Ambrosia trifida	–	x	–
Amelanchier arborea	–	x	x
Amelanchier spicata (*A. stolonifera*)	–	–	x
Amorpha sp.	–	–	x
Amorpha fruticosa	–	x	–
Amphicarpaea bracteata	–	x	x
Amsonia tabernaemontana	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Andropogon sp.	–	–	x
Andropogon virginicus	–	x	–
Anemone acutiloba (*Hepatica nobilis* var. *acuta*)	–	x	–
Anemone americana (*Hepatica nobilis* var. *obtusa*)	–	x	–
Anemone quinquefolia	–	x	x
Anemone virginiana	–	x	x
Angelica venenosa	–	x	x
Antennaria plantaginifolia	–	x	x
Anthoxanthum odoratum[A]	–	–	x
Apocynum cannabinum	–	x	x
Aralia spinosa	–	x	x
Arisaema triphyllum	–	–	x
Aristolochia serpentaria	–	x	x
Arnoglossum atriplicifolium	–	x	x
Asclepias quadrifolia	–	x	–
Asimina parviflora	x	–	–
Asimina triloba	–	x	x
Asplenium bradleyi	–	x	–
Asplenium platyneuron	–	x	x
Astranthium integrifolium	–	x	–
Athyrium filix-femina	–	x	x
Aureolaria sp.	–	–	x
Aureolaria virginica	–	x	–
Avenella flexuosa	–	x	–
Berberis thunbergii[A]	–	x	–
Berchemia scandens	–	x	x
Betula lenta	–	x	x
Bidens frondosa	–	x	–
Bignonia capreolata	–	x	x
Blephilia hirsuta	–	x	–
Boehmeria cylindrica	–	x	x
Botrychium biternatum	–	x	–
Botrychium virginianum	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Brachyelytrum erectum	–	x	x
Bromus commutatus[A]	–	–	x
Bromus pubescens	–	x	–
Calycanthus floridus	–	x	x
Campanula divaricata	–	x	–
Campsis radicans	–	x	x
Cardamine bulbosa	–	–	x
Cardamine dissecta	–	x	x
Cardamine hirsuta	–	x	–
Carex abscondita	–	–	x
Carex amphibola	–	x	–
Carex annectens	–	x	–
Carex blanda	–	x	x
Carex caroliniana	–	x	–
Carex cherokeensis	–	x	x
Carex complanata	–	x	x
Carex flaccosperma	–	–	x
Carex gracilescens	–	–	x
Carex hirsutella	–	–	x
Carex laxiculmis	–	x	–
Carex muehlenbergii var. enervis	–	x	–
Carex nigromarginata	–	x	x
Carex oxylepis	–	–	x
Carex kraliana	–	–	x
Carex pensylvanica	–	–	x
Carex retroflexa	–	x	–
Carex rosea	–	x	–
Carex styloflexa	–	–	x
Carex swanii	–	–	x
Carex virescens	–	x	x
Carex willdenowii	–	x	–
Carpinus caroliniana	x	–	x
Carya cordiformis	–	x	x
Carya glabra	x	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Carya laciniosa	–	x	–
Carya ovalis	–	x	x
Carya ovata	x	–	–
Carya ovata var. *australis* (*C. carolinae-septentrionalis*)	–	x	x
Carya pallida	–	x	x
Carya tomentosa (*C. alba*)	x	x	x
Castanea dentata	–	x	–
Celastrus orbiculatus[A]	–	x	x
Celtis laevigata	–	x	x
Celtis occidentalis	x	x	x
Celtis tenuifolia	–	x	x
Cerastium glomeratum[A]	–	–	x
Cerastium nutans	–	x	–
Cercis canadensis	x	x	x
Chaerophyllum tainturieri	–	x	–
Chamaecrista fasciculata	–	x	–
Chamaecrista nictitans	–	x	–
Chamaelirium luteum	–	x	–
Chasmanthium latifolium	–	x	x
Chasmanthium laxum	–	x	x
Chasmanthium laxum ssp. *sessiliflorum* (*C. sessiliflorum*)	–	x	x
Chimaphila maculata	–	x	x
Chionanthus virginicus	–	x	x
Cirsium sp.	–	–	x
Claytonia virginica	–	x	x
Clematis terniflora	–	x	–
Clitoria mariana	–	x	x
Cocculus carolinus	–	x	x
Collinsonia canadensis	–	x	x
Collinsonia verticillata	–	x	x
Commelina communis[A]	–	x	x
Conopholis americana	–	x	x
Conyza canadensis	–	–	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Coreopsis major	–	x	x
Cornus florida	x	x	x
Corylus cornuta	–	x	–
Crataegus sp.	–	x	x
Crataegus marshallii	–	x	x
Cryptotaenia canadensis	–	x	–
Cynoglossum virginianum	–	x	x
Cyperus retrofractus	–	x	–
Cypripedium acaule	–	x	–
Danthonia compressa	–	–	x
Danthonia spicata	–	x	x
Delphinium carolinianum	–	–	x
Desmanthus illinoensis	–	x	–
Desmodium glutinosum	–	x	x
Desmodium laevigatum	–	x	–
Desmodium nudiflorum	–	x	x
Desmodium paniculatum	–	x	–
Desmodium rotundifolium	–	x	x
Dichanthelium sp.	–	x	x
Dichanthelium boscii	–	x	x
Dichanthelium commutatum	–	x	x
Dichanthelium dichotomum	–	x	x
Dichanthelium laxiflorum	–	x	x
Dichanthelium sphaerocarpon	–	x	x
Dichondra carolinensis	–	x	–
Diervilla rivularis	–	x	–
Dioscorea oppositifolia[A] (*D. polystachya*)	–	x	x
Dioscorea villosa (*D. quaternata*)	–	x	x
Diospyros virginiana	x	x	x
Doellingeria umbellata var. *umbellata*	–	x	–
Dryopteris marginalis	–	x	x
Elaeagnus umbellata[A]	–	x	–
Elephantopus carolinianus	–	x	x
Elephantopus tomentosus	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Elymus hystrix	–	x	–
Elymus virginicus	–	x	x
Erechtites hieraciifolius	–	x	x
Erigeron sp.	–	–	x
Erigeron annuus	–	x	–
Erigeron philadelphicus	–	x	x
Erigeron pulchellus	–	x	–
Euonymus alatus[A]	–	–	x
Euonymus americanus	–	x	x
Euonymus atropurpureus	–	x	–
Euonymus fortunei[A]	–	x	x
Eupatorium serotinum	–	–	x
Euphorbia corollata	–	x	x
Euphorbia mercurialina	–	x	x
Euphorbia pubentissima	–	x	–
Eurybia divaricata	–	x	x
Eutrochium purpureum	–	x	x
Fagus grandifolia	x	x	x
Festuca subverticillata	–	x	–
Fragaria virginiana	–	x	–
Frangula caroliniana (*Rhamnus caroliniana*)	–	x	x
Fraxinus americana	x	x	x
Fraxinus pennsylvanica	x	–	x
Galactia volubilis	–	x	–
Galium aparine	–	x	x
Galium circaezans	–	x	x
Galium obtusum	–	–	x
Galium obtusum ssp. *filifolium*	–	x	–
Galium pilosum	–	–	x
Galium triflorum	–	x	x
Gamochaeta purpurea	–	–	x
Gelsemium sempervirens	–	–	x
Geranium maculatum	–	x	x
Geum canadense	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Geum vernum	–	x	–
Geum virginianum	–	–	x
Gillenia stipulata (*Porteranthus stipulatus*)	–	x	–
Glechoma hederacea	–	x	–
Gleditsia triacanthos	–	x	x
Glyceria melicaria	–	x	–
Glyceria sp.	–	–	x
Glyceria striata	–	x	–
Goodyera pubescens	–	–	x
Halesia carolina	–	x	–
Hamamelis virginiana	–	x	–
Hedera helix[A]	–	x	–
Helianthus divaricatus	–	x	–
Helianthus microcephalus	–	x	x
Heuchera americana	–	x	x
Hexastylis arifolia	–	x	x
Hieracium venosum	–	x	–
Houstonia caerulea	–	x	x
Houstonia purpurea	–	–	x
Hydrangea arborescens	–	x	x
Hydrangea cinerea	–	x	x
Hypericum hypericoides ssp. *hypericoides*	–	x	–
Hypericum hypericoides ssp *multicaule*	–	x	–
Hypericum punctatum	–	–	x
Hypoxis hirsuta	–	x	x
Ilex ambigua	–	x	x
Ilex cornuta[A]	–	x	–
Ilex decidua	x	x	x
Ilex montana	–	x	x
Ilex opaca	–	x	x
Impatiens capensis	–	x	–
Ipomoea pandurata	–	x	x
Juglans nigra	x	x	x
Juncus sp.	–	–	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Juncus coriaceus	–	–	x
Juncus tenuis	–	x	x
Juniperus virginiana	x	x	x
Kalmia latifolia	–	x	–
Krigia biflora	–	x	–
Krigia virginica	–	–	x
Kummerowia stipulacea[A] (*Lespedeza stipulacea*)	–	x	–
Lactuca sp.	–	–	x
Lactuca canadensis	–	x	–
Lactuca floridana	–	x	x
Lespedeza cuneata[A]	–	x	–
Lespedeza procumbens	–	x	x
Lespedeza repens	–	–	x
Lespedeza violacea	–	–	x
Lespedeza virginica	–	–	x
Leucanthemum vulgare[A]	–	x	–
Ligusticum canadense	–	–	x
Ligustrum sinense[A]	x	x	x
Lindera benzoin	x	x	x
Liquidambar styraciflua	x	x	x
Liriodendron tulipifera	x	x	x
Lithospermum canescens	–	x	x
Lobelia inflata	–	x	–
Lobelia puberula	–	–	x
Lobelia spicata	–	x	–
Lonicera flava	–	x	x
Lonicera fragrantissima[A]	–	x	x
Lonicera japonica[A]	–	x	x
Lonicera maackii[A]	–	x	x
Lonicera morrowii[A]	–	–	x
Lonicera sempervirens	–	x	x
Luzula echinata	–	x	x
Lycopus sp.	–	–	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Lysimachia ciliata	–	x	x
Lysimachia quadrifolia	–	x	x
Lysimachia tonsa	–	x	x
Maclura pomifera	–	x	–
Macrothelypteris torresiana[A]	–	x	–
Magnolia grandiflora	–	x	–
Maianthemum racemosum ssp. *racemosum*	–	x	x
Malus angustifolia	–	–	x
Manfreda virginica	–	x	x
Matelea sp.	–	x	x
Melica mutica	–	x	x
Microstegium vimineum[A]	–	x	x
Minuartia patula	–	x	–
Mitchella repens	–	–	x
Monarda fistulosa	–	x	x
Morus alba[A]	–	x	–
Morus rubra	x	x	x
Mosla dianthera[A]	–	x	–
Muhlenbergia sp.	–	–	x
Muhlenbergia schreberi	–	–	x
Muhlenbergia sobolifera	–	x	–
Myosotis macrosperma	–	x	x
Nandina domestica[A]	–	x	–
Nothoscordum bivalve	–	x	x
Nyssa sylvatica	x	x	x
Ophioglossum engelmannii	–	x	–
Ostrya virginiana	–	x	x
Oxalis dillenii	–	–	x
Oxalis stricta	–	x	x
Oxalis violacea	–	x	x
Oxydendrum arboreum	x	x	x
Packera anonyma	–	x	x
Packera obovata	–	x	–
Packera paupercula	–	–	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Panax quinquefolius	–	–	x
Panicum sp.	–	x	–
Panicum flexile	–	–	x
Parthenium integrifolium	–	x	–
Parthenocissus quinquefolia	–	x	x
Paspalum dilatatum[A]	–	x	–
Passiflora lutea	–	x	x
Penstemon laevigatus	–	x	–
Penthorum sedoides	–	x	–
Phegopteris hexagonoptera	–	x	–
Philadelphus hirsutus	–	–	x
Phlox amoena	–	–	x
Phlox carolina	–	x	–
Phlox divaricata	–	–	x
Phryma leptostachya	–	x	x
Physalis virginiana	–	–	x
Phytolacca americana	–	x	x
Pinus echinata	x	x	x
Pinus taeda	x	x	x
Pinus virginiana	x	x	x
Piptochaetium avenaceum	–	x	x
Plantago sp.	–	x	–
Platanus occidentalis	x	–	x
Pleopeltis polypodioides	–	x	x
Pleopeltis polypodioides var. *michauxiana*	–	x	–
Poa annua[A]	–	x	x
Poa autumnalis	–	x	x
Podophyllum peltatum	–	x	x
Polygonatum biflorum	–	x	x
Polygonatum pubescens	–	x	–
Polygonum virginianum	–	x	x
Polypodium appalachianum	–	x	–
Polystichum acrostichoides	–	x	x
Potentilla canadensis	–	–	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Potentilla simplex	–	x	x
Prenanthes altissima	–	x	–
Prenanthes serpentaria	–	–	x
Prenanthes trifoliolata	–	x	–
Prosartes lanuginosa	–	x	–
Prunella vulgaris	–	x	–
Prunus americana	–	x	–
Prunus serotina	x	x	x
Pseudognaphalium obtusifolium	–	–	x
Ptelea trifoliata	–	x	x
Pteridium aquilinum	–	x	–
Pueraria montana var. *lobata*[A]	–	x	–
Pycnanthemum pycnanthemoides	–	x	x
Pycnanthemum tenuifolium	–	–	x
Pyrus calleryana[A]	–	–	x
Pyrus communis[A]	–	x	–
Quercus alba	x	x	x
Quercus coccinea	–	–	–
Quercus falcata	x	x	x
Quercus lyrata	x	–	x
Quercus marilandica	x	x	–
Quercus montana (*Q. prinus*)	x	x	x
Quercus muehlenbergii	x	x	x
Quercus nigra	x	x	x
Quercus pagoda	–	–	x
Quercus phellos	x	x	x
Quercus prinoides	x	–	–
Quercus rubra	x	x	x
Quercus shumardii	x	x	x
Quercus stellata	x	x	x
Quercus velutina	–	x	x
Ranunculus abortivus	–	x	–
Ranunculus bulbosus[A]	–	–	x
Ranunculus fascicularis	–	x	–

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Ranunculus hispidus	–	x	–
Ranunculus recurvatus	–	x	–
Ratibida pinnata	–	x	–
Rhamnus caroliniana	x	–	–
Rhododendron calendulaceum	x	x	–
Rhododendron canescens	–	x	x
Rhododendron periclymenoides	–	–	x
Rhus aromatica	x	x	x
Rhus copallinum	x	–	–
Rhus glabra	–	x	–
Ribes rotundifolium	–	x	–
Robinia pseudoacacia	–	x	x
Rosa sp.	–	x	x
Rosa carolina	–	–	x
Rosa multiflora[A]	–	–	x
Rubus allegheniensis	x	x	–
Rubus argutus	–	x	x
Rubus flagellaris	–	x	x
Rubus trivialis	–	–	x
Rudbeckia sp.	–	–	x
Rudbeckia hirta	–	x	–
Ruellia caroliniensis	–	x	x
Ruellia strepens	–	x	–
Sabatia sp.	–	–	x
Salvia lyrata	–	x	x
Salvia urticifolia	–	x	x
Sambucus nigra ssp. *canadensis*	–	x	x
Sanguinaria canadensis	–	x	–
Sanicula sp.	–	–	x
Sanicula canadensis	–	x	x
Sanicula smallii	–	x	x
Sanicula trifoliata	–	x	–
Sassafras albidum	x	x	x
Schizachyrium scoparium	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Scleria sp.	–	x	x
Scleria oligantha	–	x	x
Scutellaria elliptica	–	x	x
Scutellaria elliptica var. *hirsuta*	–	x	–
Scutellaria incana	–	–	x
Scutellaria integrifolia	–	x	–
Scutellaria montana	–	x	–
Scutellaria ovata	–	x	x
Scutellaria pseudoserrata	–	x	–
Sedum pulchellum	–	x	–
Sedum ternatum	–	x	x
Senna marilandica	–	x	x
Sericocarpus asteroides	–	x	–
Sherardia arvensis[A]	–	–	x
Sideroxylon lanuginosum	–	x	–
Silene stellata	–	x	–
Silene virginica	–	–	x
Silphium asteriscus var. *dentatum*	–	x	–
Silphium trifoliatum	–	x	–
Sisyrinchium albidum	–	x	–
Sisyrinchium mucronatum	–	x	x
Smilax bona-nox	–	x	x
Smilax glauca	–	x	x
Smilax herbacea	–	x	x
Smilax rotundifolia	–	x	x
Smilax tamnoides	–	x	–
Solanum carolinense	–	x	–
Solanum ptychanthum	–	x	–
Solidago arguta	–	x	x
Solidago caesia	–	x	x
Solidago canadensis	–	x	x
Solidago curtisii	–	x	x
Solidago erecta	–	x	–
Solidago flexicaulis	–	x	–

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An "x" donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Solidago juncea	–	x	–
Solidago odora	–	x	–
Sonchus asper[A]	–	–	x
Spigelia marilandica	–	x	x
Stellaria media[A]	–	x	x
Stellaria pubera	–	x	–
Stylosanthes biflora	–	x	–
Symphoricarpos orbiculatus	–	x	x
Symphyotrichum sp.	–	–	x
Symphyotrichum cordifolium	–	x	x
Symphyotrichum lateriflorum	–	x	–
Symphyotrichum patens	–	x	x
Taraxacum officinale[A]	–	x	x
Thalictrum dioicum	–	x	x
Thalictrum thalictroides	–	x	x
Thaspium trifoliatum	–	x	x
Tiarella cordifolia	–	x	–
Tipularia discolor	–	x	x
Toxicodendron radicans	–	x	x
Tradescantia subaspera	–	x	x
Tragia urticifolia	–	x	–
Tridens flavus	–	x	–
Trifolium campestre[A]	–	–	x
Trillium cuneatum	–	x	x
Trillium luteum	–	x	x
Ulmus alata	x	x	x
Ulmus americana	–	x	x
Ulmus rubra	x	x	x
Uvularia perfoliata	–	x	x
Uvularia sessilifolia	–	x	x
Vaccinium arboreum	–	x	x
Vaccinium corymbosum (*V. atrococcum*)	x	x	x
Vaccinium pallidum	–	x	x
Vaccinium stamineum	–	x	x

[A] Exotic species

Table A.1 (continued). Plant species documented in hardwood forest communities during vegetation surveys of CHCH. Note that Rogers et al. (1993) covered only Chickamauga Battlefield and the species list provided for forests included only woody species (e.g., trees and shrubs). An “x” donotes that the species was observed in the park by that source.

Species	Rogers et al. (1993)	NatureServe (2007)	CUPN (2016)
Verbesina occidentalis	–	x	x
Verbesina virginica	–	x	–
Vernonia sp.	–	–	x
Vernonia flaccidifolia	–	x	x
Vernonia gigantea	–	–	x
Veronica sp.	–	x	–
Viburnum spp.	x	–	–
Viburnum acerifolium	–	x	x
Viburnum rufidulum	–	x	x
Vicia caroliniana	–	–	x
Vicia sativa[A]	–	–	x
Vinca minor[A]	–	–	x
Viola sp.	–	–	x
Viola palmata	–	x	x
Viola pubescens var. *scabriuscula*	–	x	–
Viola sororia	–	x	x
Viola tripartita	–	x	x
Vitis aestivalis	–	x	x
Vitis cinerea	–	–	x
Vitis rotundifolia	–	x	x
Vitis vulpina	–	–	x
Vulpia myuros[A]	–	–	x
Youngia japonica[A]	–	–	x
Zizia aurea	–	–	x
Total	**51**	**392**	**330**
Exotics	**1**	**28**	**27**

[A] Exotic species

Appendix B. Exotic plant species cover in CHCH hardwood forests.

Table B-1. Exotic species cover within NatureServe (2007) hardwood forest sampling plots. Cover was recorded by strata: H = herbaceous, S = shrub, V = vine, T = tree.

Plot	Species	% cover (by stratum)
CHCH01	*Ligustrum sinense* (S)	1.5
	Lonicera japonica (H)	3.5
	Microstegium vimineum (H)	0.5
	Total	**5.5**
CHCH02	*Ligustrum sinense* (S)	0.5
	Lonicera japonica (V)	1.5
	Total	**2**
CHCH06	None	0
CHCH07	*Leucanthemum vulgare* (H)	0.05
	Ligustrum sinense (S)	0.5
	Microstegium vimineum (H)	0.05
	Total	**0.6**
CHCH08	None	0
CHCH10	*Ligustrum sinense* (S)	1.5
	Lonicera japonica (V)	0.05
	Total	**1.55**
CHCH12	*Ligustrum sinense* (S)	3.5
CHCH13	None	0
CHCH15	None	0
CHCH17	None	0
CHCH18	*Ligustrum sinense* (S)	0.05
	Lonicera japonica (H)	0.05
	Microstegium vimineum (H)	0.05
	Total	**0.15**
CHCH22	None	0
CHCH24	*Celastrus orbiculatus* (V)	0.05
CHCH25	*Poa annua* (H)	0.5
CHCH26	*Celastrus orbiculatus* (V)	1.5
CHCH27	None	0
CHCH28	None	0
CHCH29	None	0

Table B-1 (continued). Exotic species cover within NatureServe (2007) hardwood forest sampling plots. Cover was recorded by strata: H = herbaceous, S = shrub, V = vine, T = tree.

Plot	Species	% cover (by stratum)
CHCH31	*Berberis thunbergii* (S)	0.5
	Celastrus orbiculatus (V)	0.05
	Lonicera japonica (H)	1.5
	Total	**2.05**
CHCH32	*Lonicera maackii* (S)	1.5
	Nandina domestica (S)	0.5
	Total	2
CHCH33	*Lonicera maackii* (S)	3.5
	Pueraria montana var. *lobata* (V)	3.5
	Total	7
CHCH34	None	0
CHCH35	*Ligustrum sinense* (S)	0.5
	Lonicera japonica (V)	0.5
	Lonicera maackii (S)	3.5
	Total	**4.5**
CHCH37	*Albizia julibrissin* (S)	0.5
CHCH38	*Ligustrum sinense* (T)	11
	Lonicera fragrantissima (S)	1.5
	Lonicera japonica (V)	1.5
	Total	**14**
CHCH39	*Ailanthus altissima* (S)	0.5
	Celastrus orbiculatus (S)	0.05
	Hedera helix (H)	0.05
	Ligustrum sinense (S)	7.5
	Lonicera maackii (S)	37.5
	Total	**45.6**
CHCH40	*Ailanthus altissima* (S)	0.5
	Hedera helix (V)	0.5
	Lonicera japonica (V)	17.5
	Total	**18.5**
CHCH45	None	0
CHCH47	*Ligustrum sinense* (S)	3
	Lonicera japonica (V)	7.5
	Microstegium vimineum (H)	17.5
	Total	28

Table B-2. Exotic species cover within CUPN (2016) hardwood forest community monitoring plots, 2011-2015.

Plot	Species	% cover
CHIC002	None	0%
CHIC005	*Ligustrum sinense*	2-5%
	Lonicera japonica	2-5%
	Total	**4-10%**
CHIC006	*Ligustrum sinense*	1-2%
	Lonicera japonica	0-1%
	Lonicera maackii	trace
	Pyrus calleryana	trace
	Taraxacum officinale	trace
	Total	**1-3%**
CHIC007	*Ligustrum sinense*	0-1%
	Lonicera japonica	0-1%
	Total	**0-2%**
CHIC008	*Anthoxanthum odoratum*	0-1%
	Bromus commutatus	trace
	Cerastium glomeratum	trace
	Ligustrum sinense	0-1%
	Lonicera japonica	0-1%
	Sherardia arvensis	trace
	Sonchus asper	trace
	Taraxacum officinale	trace
	Trifolium campestre	0-1%
	Vicia sativa	trace
	Vulpia myuros	trace
	Youngia japonica	trace
	Total	trace-4%
CHIC009	*Ligustrum sinense*	25-50%
	Lonicera japonica	5-10%
	Microstegium vimineum	trace
	Ranunculus bulbosus	trace
	Total	**30-60%**
CHIC012	*Ligustrum sinense*	0-1%
	Lonicera japonica	0-1%
	Total	0-2%

Table B-2 (continued). Exotic species cover within CUPN (2016) hardwood forest community monitoring plots, 2011-2015.

Plot	Species	% cover
CHIC013	*Ligustrum sinense*	0-1%
	Lonicera japonica	0-1%
	Lonicera maackii	0-1%
	Microstegium vimineum	0-1%
	Rosa multiflora	trace
	Stellaria media	trace
	Total	**trace-4%**
CHIC014	*Ligustrum sinense*	1-2%
	Lonicera japonica	1-2%
	Nandina domestica	0-1%
	Total	**2-5%**
CHIC015	*Ligustrum sinense*	10-25%
	Lonicera japonica	5-10%
	Total	**15-35%**
CHIC016	*Ligustrum sinense*	5-10%
	Lonicera japonica	0-1%
	Microstegium vimineum	0-1%
	Total	**5-12%**
CHIC017	*Ligustrum sinense*	0-1%
CHIC019	*Ligustrum sinense*	trace
	Lonicera japonica	trace
CHIC023	*Ligustrum sinense*	1-2%
	Lonicera japonica	trace
	Poa annua	trace
CHIC026	*Ligustrum sinense*	trace
	Lonicera japonica	trace
CHIC028	*Ligustrum sinense*	0-1%
	Lonicera japonica	0-1%
	Microstegium vimineum	trace
	Total	**trace-2%**
LOOK003	*Celastrus orbiculatus*	1-2%
	Euonymus fortunei	1-2%
	Ligustrum sinense	0-1%
	Lonicera japonica	1-2%
	Lonicera maackii	2-5%
	Lonicera morrowii	2-5%
	Total	**7-17%**

Table B-2 (continued). Exotic species cover within CUPN (2016) hardwood forest community monitoring plots, 2011-2015.

Plot	Species	% cover
LOOK004	None	0%
LOOK005	*Celastrus orbiculatus*	0-1%
	Euonymus fortunei	0-1%
	Lonicera japonica	1-2%
	Lonicera maackii	0-1%
	Microstegium vimineum	0-1%
	Total	**1-6%**
LOOK006	*Celastrus orbiculatus*	trace
	Ligustrum sinense	trace
	Lonicera japonica	trace
	Lonicera morrowii	0-1%
	Total	**trace-1%**
LOOK009	*Commelina communis*	0-1%
	Dioscorea oppositifolia	0-1%
	Euonymus alata	0-1%
	Lonicera maackii	1-2%
	Microstegium vimineum	0-1%
	Vinca minor	5-10%
	Total	**6-16%**
LOOK010	None	0%
LOOK011	*Lonicera japonica*	0-1%
	Lonicera maackii	trace
	Stellaria media	trace
	Total	**trace-1%**
LOOK012	*Euonymus alata*	0-1%
	Lonicera maackii	0-1%
	Total	**0-2%**
LOOK013	*Lonicera maackii*	trace
LOOK015	*Celastrus orbiculatus*	trace
	Ligustrum sinense	trace
	Lonicera japonica	trace
	Lonicera morrowii	trace
LOOK017	None	0%
LOOK019	*Euonymus alata*	trace
	Lonicera maackii	2-5%
	Lonicera morrowii	10-25%
	Total	**12-30%**

Table B-2 (continued). Exotic species cover within CUPN (2016) hardwood forest community monitoring plots, 2011-2015.

Plot	Species	% cover
LOOK021	*Euonymus fortunei*	0-1%
	Ligustrum sinense	trace
	Lonicera japonica	0-1%
	Total	**trace-2%**
LOOK025	*Microstegium vimineum*	0-1%
LOOK026	*Euonymus fortunei*	trace
	Ligustrum sinense	trace
	Lonicera fragrantissima	25-50%
	Lonicera japonica	2-5%
	Rosa multiflora	trace
	Total	**27-55%**

Appendix C. Oak species in the seedling and sapling layer of CUPN hardwood forest monitoring plots, 2011-2015 (CUPN 2016).

Table C.1. Oak species in the seedling and sapling layer of CUPN hardwood forest monitoring plots, 2011-2015 (CUPN 2016). The total number of seedling and saplings in each category is also presented in the "all species" row. Sd = seedling, Sp = sapling; measurements following Sd categories represent heights while measurements following Sp categories are DBH.

Plot	Species	Sd 5-50 cm	Sd 50-137 cm	Sp 0-1 cm DBH	Sp 1-2.5 cm DBH	Sp 2.5-5 cm DBH	Sp 5-10 cm DBH
CHIC002 (1 oak)	*Q. muehlenbergii*	1	–	–	–	–	–
	All species	39	0	0	0	2	4
CHIC005 (3 oaks)	*Q. alba*	1	–	–	–	–	–
	Q. phellos	1	–	–	–	–	–
	Q. velutina	1	–	–	–	–	–
	All species	42	2	5	2	6	2
CHIC006 (2 oaks)	*Q. muehlenbergii*	1	–	–	–	–	–
	Q. stellata	1	–	–	–	–	–
	All species	99	3	8	6	5	3
CHIC007 (1 oak)	*Q. falcata*	1	–	–	–	–	–
	All species	25	0	0	2	5	2
CHIC008 (4 oaks)	*Q. alba*	1	–	–	–	–	–
	Q. falcata	1	–	–	–	–	–
	Q. stellata	2	–	–	–	–	–
	All species	17	0	0	0	0	0
CHIC009 (6 oaks)	*Q. nigra*	–	–	–	–	2	1
	Q. stellata	3	–	–	–	–	–
	All species	206	3	8	3	4	5
CHIC012	No oaks	–	–	–	–	–	–
	All species	12	0	0	0	0	0
CHIC013	No oaks	–	–	–	–	–	–
	All species	89	0	7	2	1	6
CHIC014 (8 oaks)	*Q. falcata*	–	2	–	1	–	–
	Q. muehlenbergii	1	–	–	–	–	–
	Q. rubra	2	–	–	–	–	–
	Q. velutina	1	–	1	–	–	–
	All species	174	4	10	16	1	1
CHIC015 (2 oaks)	*Q. stellata*	2	–	–	–	–	–
	All species	104	8	25	9	2	3

Table C.1 (continued). Oak species in the seedling and sapling layer of CUPN hardwood forest monitoring plots, 2011-2015 (CUPN 2016). The total number of seedling and saplings in each category is also presented in the “all species” row. Sd = seedling, Sp = sapling; measurements following Sd categories represent heights while measurements following Sp categories are DBH.

Plot	Species	Sd 5-50 cm	Sd 50-137 cm	Sp 0-1 cm DBH	Sp 1-2.5 cm DBH	Sp 2.5-5 cm DBH	Sp 5-10 cm DBH
CHIC016 (31 oaks)	*Q. falcata*	–	–	1	–	–	–
	Q. muehlenbergii	–	–	1	–	–	–
	Q. stellata	1	–	–	2	–	–
	Q. velutina	6	1	9	5	3	2
	All species	189	3	20	8	6	5
CHIC017 (4 oaks)	*Q. alba*	3	–	–	–	–	–
	Q. falcata	1	–	–	–	–	–
	All species	16	2	7	3	2	3
CHIC019 (6 oaks)	*Q. falcata*	3	–	–	–	–	–
	Q. muehlenbergii	–	–	–	–	–	1
	Q. stellata	2	–	–	–	–	–
	All species	83	4	1	2	3	8
CHIC023 (9 oaks)	*Q. falcata*	7	–	–	–	–	–
	Q. lyrata	1	–	–	–	–	–
	Q. velutina	1	–	–	–	–	–
	All species	101	1	1	0	0	2
CHIC026 (16 oaks)	*Q. alba*	8	–	–	–	–	–
	Q. rubra	1	–	–	–	–	–
	Q. velutina	7	–	–	–	–	–
	All species	26	1	5	9	5	0
CHIC028 (2 oaks)	*Q. falcata*	1	–	–	–	–	–
	Q. stellata	1	–	–	–	–	–
	All species	60	1	0	1	0	1
LOOK003 (5 oaks)	*Q. muehlenbergii*	1	–	–	–	–	–
	Q. montana	3	–	–	–	–	–
	Q. velutina	–	–	1	–	–	–
	All species	8	0	2	4	4	5
LOOK004 (4 oaks)	*Q. montana*	4	–	–	–	–	–
	All species	26	3	6	2	6	1
LOOK005 (2 oaks)	*Q. alba*	1	–	–	–	–	–
	Q. velutina	–	–	1	–	–	–
	All species	28	3	13	16	4	3
LOOK006	No oaks	–	–	–	–	–	–
	All species	0	0	6	6	8	2

Table C.1 (continued). Oak species in the seedling and sapling layer of CUPN hardwood forest monitoring plots, 2011-2015 (CUPN 2016). The total number of seedling and saplings in each category is also presented in the "all species" row. Sd = seedling, Sp = sapling; measurements following Sd categories represent heights while measurements following Sp categories are DBH.

Plot	**Species**	**Sd 5-50 cm**	**Sd 50-137 cm**	**Sp 0-1 cm DBH**	**Sp 1-2.5 cm DBH**	**Sp 2.5-5 cm DBH**	**Sp 5-10 cm DBH**
LOOK009 (5 oaks)	*Q. montana*	1	2	–	–	–	–
	Q. rubra	1	–	–	–	1	–
	All species	4	4	0	0	4	1
LOOK010 (7 oaks)	*Q. montana*	5	–	–	–	–	–
	Q. velutina	2	–	–	–	–	–
	All species	17	1	3	2	1	2
LOOK011 (14 oaks)	*Q. alba*	2	–	–	–	–	–
	Q. montana	9	–	–	–	–	1
	Q. velutina	2	–	–	–	–	–
	All species	15	0	0	0	3	2
LOOK012 (11 oaks)	*Q. alba*	1	–	–	–	–	–
	Q. velutina	10	–	–	–	–	–
	All species	31	1	4	2	0	1
LOOK013 (7 oaks)	*Q. alba*	1	–	–	–	–	–
	Q. montana	1	–	1	–	–	–
	Q. rubra	1	–	1	–	–	–
	Q. velutina	–	1	1	–	–	–
	All species	12	4	4	3	2	1
LOOK015 (1 oak)	*Q. montana*	1	–	–	–	–	–
	All species	8	0	4	3	4	0
LOOK017 (13 oaks)	*Q. nigra*	2	–	–	–	–	–
	Q. montana	10	–	–	–	–	–
	Q. velutina	1	–	–	–	–	–
	All species	35	0	2	3	1	0
LOOK019 (8 oaks)	*Q. montana*	3	1	1	1	–	–
	Q. rubra	–	–	–	1	–	–
	Q. velutina	–	–	–	–	1	–
	All species	5	4	10	8	2	0
LOOK021 (5 oaks)	*Q. alba*	–	–	–	1	–	–
	Q. nigra	3	–	–	–	–	–
	Q. velutina	1	–	–	–	–	–
	All species	34	1	0	2	0	1

Table C.1 (continued). Oak species in the seedling and sapling layer of CUPN hardwood forest monitoring plots, 2011-2015 (CUPN 2016). The total number of seedling and saplings in each category is also presented in the "all species" row. Sd = seedling, Sp = sapling; measurements following Sd categories represent heights while measurements following Sp categories are DBH.

Plot	Species	Sd 5-50 cm	Sd 50-137 cm	Sp 0-1 cm DBH	Sp 1-2.5 cm DBH	Sp 2.5-5 cm DBH	Sp 5-10 cm DBH
LOOK025 (7 oaks)	*Q. alba*	–	1	–	–	–	–
	Q. montana	3	–	–	–	–	–
	Q. velutina	1	1	1	–	–	–
	All species	17	4	8	3	4	0
LOOK026 (5 oaks)	*Q. nigra*	1	–	–	–	–	–
	Q. rubra	1	–	1	–	2	–
	All species	6	1	5	4	7	3

Appendix D. Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH.

Table D.1. Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An “X” donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Acalypha gracilens	–	–	–	X	–
Acer floridanum (*A. barbatum*)	–	–	–	–	X
Acer rubrum	–	–	X	X	–
Acer saccharum	–	–	X	X	–
Achillea millefolium	–	–	–	X	–
Albizia julibrissin[A]	–	–	X	–	X
Allium canadense	–	X	–	–	–
Allium cernuum	–	–	X	X	–
Allium vineale	–	–	–	X	–
Amelanchier arborea	–	–	–	–	X
Andropogon sp.	–	–	X	–	–
Andropogon gerardii	–	–	–	X	–
Andropogon gyrans	–	–	–	X	–
Anemone virginiana	X	–	–	–	–
Antennaria sp.	–	–	X	–	–
Antennaria plantaginifolia	–	–	–	X	–
Apocynum cannabinum	–	–	–	X	–
Aristida purpurascens	–	–	X	X	–
Aristolochia serpentaria	–	–	–	X	–
Asclepias tuberosa	–	–	X	–	–
Asclepias verticillata	–	–	X	X	–
Asclepias viridiflora	–	–	X	X	–
Asclepias viridis	–	–	X	X	–
Asparagus officinalis	X	–	–	–	–
Asplenium platyneuron	–	X	–	–	–
Aster sp.	–	–	X	–	–
Astranthium integrifolium	–	–	X	–	–
Baptisia australis	–	X	X	–	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An “X” donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Berchemia scandens	–	X	X	X	–
Bignonia capreolata	–	–	–	X	–
Blephilia ciliata	–	–	–	X	–
Botrychium virginianum	–	X	–	–	–
Bouteloua curtipendula	–	–	X	X	–
Brickellia eupatorioides	–	–	–	X	–
Campsis radicans	–	–	–	X	–
Carduus sp.	–	–	X	–	–
Carex spp.	–	X	–	–	–
Carex blanda	–	–	–	X	–
Carex caroliniana	X	–	X	X	–
Carex cherokeensis	–	–	X	X	–
Carex crawei	X	–	X	X	–
Carex meadii	–	–	X	–	–
Carya sp.	–	–	–	–	X
Carya glabra	–	–	X	x	–
Carya ovalis	–	–	X	–	–
Carya ovata	–	–	X	–	–
Carya ovata var. *australis* (*C. carolinae-septentrionalis*)	–	–	–	X	–
Carya pallida	–	–	X	–	X
Carya tomentosa (*C. alba*)	–	–	X	X	–
Celtis laevigata	–	–	X	X	–
Celtis occidentalis	–	–	X	X	X
Celtis tenuifolia	–	–	–	–	X
Cercis canadensis	–	–	X	X	X
Chamaecrista fasciculata	–	–	–	X	–
Cirsium sp.	–	–	–	X	–
Cirsium carolinianum (*Carduus carolinianus*)	X	–	X	–	–
Cocculus carolinus	–	–	–	X	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An “X” donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Coleataenia anceps (*Panicum anceps*)	–	–	X	X	–
Coreopsis sp.	–	–	X	–	–
Coreopsis major	–	–	–	X	–
Cornus florida	–	X	X	X	X
Crataegus marshallii	–	–	X	–	–
Croton capitatus	–	–	X	X	–
Croton monanthogynus	X	–	X	X	–
Cynodon dactylon[A]	–	–	–	X	–
Dalea candida	–	–	X	–	–
Dalea gattingeri[B]	–	–	X	X	X
Danthonia sp.	–	–	X	–	–
Danthonia spicata	–	–	–	X	–
Daucus carota[A]	–	X	X	X	–
Delphinium carolinianum	–	–	X	X	–
Delphinium carolinianum ssp. *virescens*[B]	–	–	–	–	X
Desmanthus illinoensis	–	–	X	X	–
Desmodium sp.	–	–	X	–	–
Desmodium paniculatum	–	–	–	X	–
Desmodium rotundifolium	–	–	–	X	–
Dichanthelium acuminatum var. *acuminatum* (*Panicum villosissimum*)	X	–	X	–	–
Dichanthelium acuminatum var. *fasciculatum*	–	–	–	X	–
Dichanthelium boscii (*Panicum boscii*)	–	–	X	–	–
Dichanthelium commutatum	–	–	X	–	–
Dichanthelium depauperatum	–	–	–	X	–
Dichanthelium dichotomum	–	–	X	–	–
Dichanthelium laxiflorum	–	–	X	–	–
Dichanthelium scabriusculum	–	X	–	–	–
Dichanthelium sphaerocarpon	–	–	–	X	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Diospyros virginiana	–	–	X	X	X
Draba verna[A]	X	–	–	–	–
Eleocharis spp.	–	X	–	–	–
Eleocharis compressa	–	–	X	X	–
Eleocharis tricostata	X	–	–	–	–
Elephantopus carolinianus	–	–	–	X	–
Elymus virginicus	–	–	–	X	–
Eragrostis capillaris	–	–	–	X	–
Eragrostis spectabilis	–	–	–	X	–
Erigeron strigosus	–	–	X	X	–
Eryngium yuccifolium	–	–	–	X	–
Euonymus americanus	–	–	–	X	–
Euphorbia sp.	–	–	X	–	–
Euphorbia corollata	–	–	X	–	–
Euphorbia maculata	X	–	–	–	–
Euphorbia pubentissima	–	–	–	X	–
Eurybia hemispherica	–	–	–	X	–
Festuca sp.	–	–	X	X	–
Fragaria virginiana	–	–	X	–	–
Frangula caroliniana (*Rhamnus caroliniana*)	–	–	–	X	X
Fraxinus sp.	–	–	X	–	–
Fraxinus americana	–	–	X	X	X
Galactia volubilis	–	–	–	X	–
Galium aparine	–	–	–	X	–
Galium circaezans	–	–	–	X	–
Galium pilosum	–	–	X	X	–
Gentiana sp.	–	–	X	–	–
Geum canadense	–	–	–	X	–
Gleditsia triacanthos	–	–	–	X	–
Helianthus divaricatus	–	–	–	X	–
Helianthus hirsutus	–	–	X	–	–
Helianthus microcephalus	–	–	–	X	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An “X” donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Heliotropium tenellum	–	–	X	–	–
Hemerocallis fulva[A]	X	–	–	–	–
Houstonia spp.	–	X	X	–	–
Houstonia longifolia	X	–	X	X	–
Hypericum spp.	–	X	–	–	–
Hypericum dolabriforme[e]	–	–	X	X	X
Hypoxis sp.	–	X	–	–	–
Hypoxis hirsuta	–	–	X	–	–
Hypoxis wrightii	–	–	–	X	–
Ipomoea sp.	–	–	X	–	–
Ipomoea pandurata	–	–	–	X	–
Isoetes butleri	–	–	X	–	–
Juglans nigra	–	–	X	–	X
Juniperus virginiana	–	X	X	X	x
Kummerowia striata[A]	–	–	–	X	–
Leavenworthia exigua[B]	–	X	X	–	X
Lespedeza spp.	–	X	–	–	–
Lespedeza cuneata[A]	–	–	X	–	–
Lespedeza procumbens	–	–	–	X	–
Lespedeza repens	–	–	X	X	–
Lespedeza virginica	–	–	–	X	–
Leucanthemum vulgare[A]	–	–	X	X	–
Liatris squarrosa var. *squarrosa*	–	–	X	–	–
Ligustrum sinense[A]	–	X	X	X	X
Lindernia dubia	–	–	X	–	–
Linum sulcatum	–	–	–	X	–
Linum virginianum	–	–	X	–	–
Liquidambar styraciflua	–	–	–	–	X
Lithospermum canescens	X	X	X	X	–
Lobelia puberula	–	–	–	X	–
Lobelia spicata	X	–	X	X	–
Lonicera japonica[A]	–	X	–	–	X

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An “X” donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Luzula sp.	X	–	–	–	–
Lycopus sp.	–	–	–	X	–
Maclura pomifera	–	–	–	X	–
Manfreda virginica	–	–	X	X	–
Matelea sp.	–	–	–	X	–
Matelea obliqua	–	–	X	–	–
Mecardonia acuminata	X	–	X	X	–
Melica mutica	–	–	X	–	–
Melilotus officinalis (*M. alba*)[A]	X	–	X	–	–
Minuartia patula[B]	–	X	X	–	X
Monarda fistulosa	–	–	–	X	–
Morus rubra	–	–	X	–	X
Mosla dianthera[A]	–	–	–	X	–
Nandina domestica[A]	–	–	–	X	X
Narcissus pseudonarcissus[A]	X	–	–	–	–
Nothoscordum bivalve	–	–	X	–	–
Onosmodium bejariense var. *occidentale*	X	–	–	–	–
Ophioglossum engelmannii[B]	–	–	X	X	X
Opuntia humifusa	–	–	X	X	–
Oxalis stricta	–	–	X	X	–
Packera anonyma (*Senecio anonymus*)	–	X	–	X	–
Packera obovata (*Senecio obovatus*)	X	–	–	–	–
Packera paupercula[B]	–	–	–	X	X
Packera plattensis	–	–	X	–	–
Panicum flexile	–	–	–	X	–
Panicum virgatum	–	X	–	X	–
Parthenocissus quinquefolia	–	X	–	–	–
Paspalum laeve	–	–	–	X	–
Passiflora lutea	–	–	–	X	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Pediomelum subacaule (*Psoralea subacaulis*)[e]	–	X	X	X	X
Phlox spp.	–	X	–	–	–
Phlox amoena	–	–	X	X	–
Physalis virginiana	–	–	–	X	–
Pinus echinata	–	–	–	–	X
Pinus taeda	–	–	X	X	X
Pinus virginiana	–	X	X	–	X
Piptochaetium avenaceum	–	–	X	X	–
Plantago lanceolata	X	X	–	X	–
Plantago rugelii	–	–	–	X	–
Plantago virginica	X	–	X	–	–
Pleopeltis polypodioides	–	X	–	X	–
Pleurochaete squarrosa (moss)	–	–	X	–	–
Poa autumnalis	–	–	–	X	–
Polygala verticillata var. *isocycla*	–	–	–	X	–
Potentilla recta	X	X	–	–	–
Potentilla simplex	–	–	X	X	–
Prunus sp.	–	–	X	–	–
Prunus serotina	–	–	–	X	X
Pseudognaphalium obtusifolium	X	–	–	–	–
Pycnanthemum sp.	–	–	X	–	–
Pycnanthemum tenuifolium	–	–	–	X	–
Quercus spp.	–	X	–	–	–
Quercus alba	–	–	X	–	X
Quercus falcata	–	–	X	X	X
Quercus marilandica	–	–	X	X	X
Quercus montana (*Q. prinus*)	–	–	X	–	X
Quercus muehlenbergii	–	–	X	X	X
Quercus nigra	–	–	X	–	X

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Quercus phellos	–	–	X	X	X
Quercus rubra	–	–	–	–	X
Quercus shumardii	–	–	X	X	X
Quercus stellata	–	–	X	X	X
Quercus velutina	–	–	–	X	X
Ranunculus bulbosus[A]	–	X	–	X	–
Ranunculus fascicularis	–	–	–	X	–
Ratibida pinnata[e]	–	–	X	X	X
Rhamnus caroliniana	–	X	X	–	–
Rhus aromatic	–	X	X	X	X
Rhus copallinum	–	–	X	X	X
Rhus glabra	–	–	–	–	X
Rhynchosia tomentosa	X	–	–	–	–
Rosa sp.	–	–	X	–	–
Rosa carolina	–	–	–	X	–
Rubus spp.	–	X	X	X	–
Rubus argutus	–	–	–	X	X
Rubus bifrons[A]	–	–	–	–	X
Rubus flagellaris	–	–	–	X	–
Rubus occidentalis	–	–	–	–	X
Rudbeckia fulgida	–	–	X	X	–
Rudbeckia hirta	–	X	X	X	–
Ruellia caroliniensis	–	–	–	X	–
Ruellia humilis[e]	–	–	X	X	X
Ruellia strepens	–	–	–	X	–
Sabatia angularis	X	–	X	–	–
Salvia lyrata	–	X	X	X	–
Salvia urticifolia	X	–	X	X	–
Sanicula canadensis	–	–	X	X	–
Sanicula smallii	–	–	–	X	–
Schizachyrium scoparium	–	X	X	X	–
Scirpus sp.	–	–	X	–	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Scleria oligantha	–	–	X	–	–
Scleria triglomerata	–	–	–	X	–
Scutellaria elliptica var. *hirsuta*	–	–	–	X	–
Scutellaria parvula var. *missouriensis* (*S. leonardii*)[e]	–	–	X	X	X
Sedum pulchellum	X	–	X	–	–
Senna marilandica	–	–	–	X	–
Sericocarpus linifolius	–	–	–	X	–
Setaria parviflora	–	–	–	X	–
Sideroxylon lycioides	–	–	X	X	X
Silene virginica	–	–	X	–	–
Silphium terebinthinaceum var. pinnatifidum[B]	–	–	X	X	X
Sisyrinchium sp.	–	–	X	–	–
Sisyrinchium albidum	–	X	–	X	–
Sisyrinchium mucronatum	–	X	–	–	–
Smilax sp.	–	–	X	–	–
Smilax bona-nox	–	–	–	X	–
Smilax rotundifolia	–	–	–	X	–
Solanum carolinense	–	–	–	X	–
Solidago sp.	–	–	X	–	–
Solidago arguta	–	–	–	X	–
Solidago juncea	–	–	–	X	–
Solidago nemoralis	–	–	–	X	–
Solidago ptarmicoides	–	–	X	–	–
Solidago rigida	X	–	–	–	–
Sorghastrum nutans	–	–	X	–	–
Sorghum halepense[A]	–	X	X	–	–
Sphenopholis intermedia	X	–	–	–	–
Spiranthes cernua	–	–	–	X	–
Spiranthes lacera var. *gracilis*	–	–	–	X	–
Sporobolus clandestinus	–	–	–	X	–
Sporobolus heterolepis	–	–	X	X	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Sporobolus vaginiflorus	–	–	X	X	–
Strophostyles umbellata	X	–	X	–	–
Stylosanthes biflora	–	–	–	X	–
Symphoricarpos orbiculatus	–	–	X	X	X
Symphyotrichum cordifolium	–	–	–	X	–
Symphyotrichum patens	–	–	–	X	–
Symphyotrichum undulatum	–	–	–	X	–
Tephrosia virginiana	–	–	X	X	–
Thaspium barbinode	–	–	–	X	–
Thaspium pinnatifidum	–	–	X	–	X
Toxicodendron radicans	–	X	X	X	–
Tragia urticifolia	–	–	X	X	–
Trichostema brachiatum (*Isanthus brachiatus*)	–	–	X	X	–
Tridens flavus	–	–	–	X	–
Trifolium campestre[A]	–	X	–	–	–
Trifolium repens[A]	X	–	–	X	–
Triosteum angustifolium	–	–	–	X	–
Ulmus alata	–	X	X	X	X
Urtica sp.	–	–	X	–	–
Vaccinium spp.	–	X	–	–	–
Vaccinium stamineum	–	–	X	–	–
Valerianella sp.	–	–	X	–	–
Valerianella radiata	X	–	–	–	–
Verbascum thapsus[A]	–	–	X	–	–
Verbena simplex	–	–	X	–	–
Verbesina occidentalis	–	–	X	–	–
Vernonia flaccidifolia	–	–	–	X	–
Vernonia noveboracensis	–	–	X	–	–
Viburnum acerifolium	–	–	–	X	–
Viburnum rufidulum	–	–	–	X	–
Vicia sativa ssp. *nigra*[A]	–	X	–	–	–
Viola sp.	–	X	–	–	–

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Table D.1 (continued). Plant species documented in limestone cedar glades during vegetation and glade surveys of CHCH. Total species numbers are not calculated for Van Horn (1980), as this source was only documenting new species occurrences within the cedar glades and did not include a comprehensive species list. An "X" donotes that the species was observed in the park by that source.

Species	Van Horn (1980)	Rogers et al. (1993)	Sutter et al. (1994)	NatureServe (2007)	Govus & Lyons (2009)
Viola egglestonii[B]	–	X	X	X	X
Viola pedata	–	–	X	–	–
Vitis rotundifolia	–	X	–	X	X
Vulpia myuros[A] (*Festuca myuros*)	X	–	–	–	–
Total	**–**	**47**	**156**	**180**	**56**
Exotics	**–**	**7**	**7**	**9**	**5**

[A] Exotic species

[B] Endemic cedar glade species, as identified by Sutter et al. 1994 and/or Govus and Lyons 2009

Appendix E. Plant species documented in wetland areas at CHCH.

Appendix F.1. Plant species documented in wetland areas at CHCH. An “X” donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Acer floridanum (Acer barbatum)	X	–	–
Acer negundo	X	X	X
Acer rubrum	X	X	X
Acer rubrum var. *trilobum*	X	–	–
Acer saccharinum	X	–	X
Acer saccharum	–	X	–
Agrimonia pubescens	X	–	–
Agrostis sp.	–	X	–
Agrostis perennans	X	–	–
Albizia julibrissin[A]	X	–	X
Allium canadense	X	–	X
Ambrosia artemisiifolia	X	–	X
Ambrosia psilostachya	–	–	X
Andropogon virginicus	–	X	–
Arisaema dracontium	X	–	X
Arisaema triphyllum	–	–	X
Arundinaria gigantea	X	–	X
Asimina triloba	X	X	–
Asplenium platyneuron	X	–	X
Aster sp.	–	X	–
Berchemia scandens	X	–	–
Bidens frondosa	X	–	–
Bignonia capreolata	X	–	X
Boehmeria cylindrica	X	X	X
Botrychium biternatum	X	–	X
Botrychium virginianum	X	–	–
Brunnera macrophylla	X	–	–
Campsis radicans	X	X	X
Cardamine pensylvanica	X	–	–
Cardamine bulbosa	X	–	X

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Cardamine hirsuta[A]	–	–	X
Carex abscondita	–	–	X
Carex amphibola	X	–	X
Carex blanda	X	–	–
Carex caroliniana	–	–	X
Carex cherokeensis	–	–	X
Carex crinita	–	X	–
Carex cumberlandensis	–	–	X
Carex gigantea	–	X	–
Carex glaucescens	X	–	–
Carex grayi	X	–	–
Carex intumescens	X	X	–
Carex louisianica	–	–	X
Carex lupulina	X	–	–
Carex tribuloides	–	X	–
Carex typhina	X	–	–
Carex vulpinoidea	–	X	–
Carpinus caroliniana	X	X	X
Carya cordiformis	–	X	X
Carya glabra	X	–	–
Carya ovata	–	X	–
Carya ovata var. *australis*	X	–	–
Carya tomentosa (*C. alba*)	X	–	–
Ceanothus americanus	X	–	–
Celastrus orbiculatus[A]	–	–	X
Celtis laevigata	X	X	X
Celtis occidentalis	X	–	X
Cercis canadensis	X	X	–
Chaerophyllum tainturieri	X	–	–
Chasmanthium latifolium	X	X	X
Chasmanthium laxum	–	X	–
Cinna arundinacea	X	–	–
Cirsium altissimum	X	–	–

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Cirsium carolinianum	X	–	–
Claytonia virginica	X	–	–
Cocculus carolinus	X	–	X
Coleataenia longifolia ssp. *rigidula* (*Panicum rigidulum*)	–	X	–
Commelina communis	–	X	–
Commelina virginica	X	–	X
Conoclinium coelestinum	–	X	–
Cornus sp.	–	X	–
Cornus amomum	X	–	–
Cornus florida	X	–	X
Corydalis flavula	–	–	X
Cryptotaenia canadensis	X	–	X
Cyperus sp.	–	X	–
Cyperus strigosus	–	X	–
Desmodium sp.	X	–	–
Dichanthelium clandestinum	–	X	–
Diodella teres (*Diodia teres*)	–	X	–
Diodia virginiana	X	X	–
Dioscorea oppositifolia[A] (*D. polystachya*)	–	–	X
Diospyros virginiana	X	X	X
Duchesnea indica[A]	–	–	X
Echinochloa sp.	X	–	–
Echinochloa crus-galli[A]	–	X	–
Eclipta prostrata	X	–	–
Eleocharis linearis	–	X	–
Eleocharis obtusa	X	–	–
Elephantopus carolinianus	X	–	X
Elymus virginicus	X	–	X
Erigeron philadelphicus	–	–	X
Euonymus americanus	–	–	X
Euonymus fortunei[A]	X	–	X
Eupatorium perfoliatum	X	X	–
Euphorbia pubentissima	X	–	–

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Eurybia divaricata	X	–	–
Fagus grandifolia	–	X	–
Frangula caroliniana	X	–	X
Fraxinus americana	X	–	–
Fraxinus pennsylvanica	X	X	X
Galium aparine	X	–	X
Galium circaezans	–	–	X
Galium obtusum ssp. *obtusum*	X	–	–
Geranium dissectum[A]	–	–	X
Geum canadense	X	–	X
Gleditsia triacanthos	X	–	–
Helenium flexuosum	X	–	–
Hibiscus moscheutos	–	X	–
Hymenocallis occidentalis (*H. caroliniana*)	X	–	–
Hypericum mutilum	X	–	–
Hypericum punctatum	–	–	X
Ilex decidua	X	–	X
Ilex opaca	–	X	–
Impatiens sp.	–	–	X
Impatiens capensis	X	X	–
Ipomoea pandurata	X	–	–
Juglans nigra	X	–	X
Juncus effusus	X	X	X
Juncus tenuis	–	–	X
Juniperus virginiana	X	X	X
Laportea canadensis	X	–	X
Leersia oryzoides	X	X	–
Leersia virginica	–	–	X
Lemna sp.	–	X	–
Lespedeza cuneata[A]	X	–	–
Ligustrum sinense[A]	X	–	X
Ligustrum vulgare[A]	–	X	–
Lindera benzoin	X	–	X
Liquidambar styraciflua	X	X	X

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Liriodendron tulipifera	X	–	X
Lobelia cardinalis	X	–	–
Lolium sp.	–	X	–
Lonicera japonica[A]	X	X	X
Lonicera maackii[A]	–	–	X
Ludwigia palustris	X	–	–
Lycopus sp.	–	X	–
Lycopus rubellus	X	–	–
Maclura pomifera	–	–	X
Mecardonia acuminata	X	–	–
Menispermum canadense	X	–	X
Microstegium vimineum[A]	X	X	X
Mimulus alatus	–	X	–
Morus rubra	X	–	–
Murdannia keisak[A]	–	–	X
Myosotis macrosperma	–	–	X
Nandina domestica[A]	–	–	X
Nemophila aphylla	–	–	X
Nyssa sylvatica	–	X	–
Ophioglossum engelmannii	–	–	X
Ostrya virginiana	X	–	–
Oxalis sp.	–	–	X
Packera glabella	X	–	X
Panicum sp.	–	X	–
Panicum philadelphicum	X	–	–
Parthenium integrifolium	X	–	–
Parthenocissus quinquefolia	X	–	X
Paspalum sp.	–	X	–
Passiflora lutea	–	–	X
Penthorum sedoides	X	–	–
Persicaria hydropiper (*Polygonum hydropiper*)[A]	–	X	–
Persicaria hydropiperoides	X	X	–
Persicaria posumbu[A] (*Polygonum caespitosum*)	–	–	X
Persicaria punctata (*Polygonum punctatum*)	X	–	–

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An “X” donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Physalis sp.	–	–	X
Pilea pumila	–	–	X
Pinus taeda	X	X	X
Pinus virginiana	X	–	–
Plantago cordata	–	X	–
Platanus occidentalis	X	X	X
Pleopeltis polypodioides	X	–	X
Pluchea camphorata	X	–	–
Poa annua[A]	X	–	X
Poa pratensis[A]	X	–	–
Poa sylvestris	–	–	X
Polygonum virginianum	X	X	X
Polystichum acrostichoides	X	–	X
Proserpinaca sp.	–	X	–
Prunus serotina	X	–	X
Pueraria montana var. *lobata*	–	X	–
Pycnanthemum tenuifolium	X	–	–
Quercus alba	X	X	–
Quercus falcata	X	–	–
Quercus lyrata	X	X	–
Quercus muehlenbergii	X	–	–
Quercus nigra	X	X	X
Quercus phellos	X	X	X
Quercus shumardii	X	–	X
Quercus stellata	X	–	–
Quercus velutina	X	–	X
Ranunculus sp.	–	X	–
Ranunculus pusillus	–	–	X
Ranunculus sardous	X	–	–
Rhus aromatica	X	–	–
Rhus copallinum	X	–	–
Rosa multiflora	–	–	X
Rubus sp.	–	X	–
Rubus argutus	X	–	X

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Rudbeckia hirta	X	–	–
Rudbeckia laciniata	X	–	–
Ruellia strepens	–	–	X
Rumex crispus[A]	–	X	X
Salix nigra	X	X	–
Salvia lyrata	X	–	–
Sambucus nigra ssp. *canadensis*	X	–	X
Sanicula sp.	–	–	X
Sanicula canadensis	X	–	–
Sanicula odorata	X	–	X
Sassafras albidum	X	–	X
Saururus cernuus	–	X	–
Schedonorus arundinaceus[A] (*Festuca arundinacea*)	–	X	–
Schoenoplectus tabernaemontani	–	X	–
Scirpus atrovirens	–	X	–
Scirpus cyperinus	–	X	–
Scirpus polyphyllus	X	–	–
Sicyos angulatus	–	–	X
Sideroxylon lycioides	–	–	X
Smilax bona-nox	X	X	X
Smilax glauca	–	–	X
Smilax rotundifolia	X	X	X
Smilax tamnoides	–	–	X
Solanum carolinense	–	X	–
Solidago sp.	–	–	X
Sparganium americanum	X	–	–
Sphagnum sp[B]	–	X	–
Staphylea trifolia	X	–	–
Stellaria media[A]	–	–	X
Symphoricarpos orbiculatus	–	–	X
Symphyotrichum sp.	–	–	X
Symphyotrichum lanceolatum var. *lanceolatum*	–	X	–
Symphyotrichum lateriflorum	X	–	–

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix E.1 (continued). Plant species documented in wetland areas at CHCH. An "X" donotes that the species was observed in the park by that source.

Species	NatureServe (2007)	Roberts and Morgan (2009)	CUPN (2016)
Teucrium canadense	–	–	X
Thaspium trifoliatum var. aureum	X	–	–
Toxicodendron radicans	X	X	X
Tragia urticifolia	X	–	–
Trillium sp.	–	–	X
Trillium cuneatum	X	–	–
Trillium lancifolium	X	–	–
Triosteum angustifolium	–	–	X
Typha latifolia	–	X	–
Ulmus alata	X	–	X
Ulmus americana	X	X	X
Ulmus rubra	X	X	X
Vaccinium sp.	–	X	–
Vaccinium arboreum	X	–	–
Verbesina occidentalis	–	–	X
Verbesina virginica	–	–	X
Vernonia flaccidifolia	–	–	X
Viola sp.	–	–	X
Viola sororia	X	–	–
Viola striata	–	–	X
Vitis sp.	–	X	–
Vitis rotundifolia	X	–	X
Vitis vulpina	–	–	X
Total	**150**	**85**	**123**
Non-native	**8**	**9**	**17**

[A] Exotic species.

[B] Sphagnum is a non-vascular plant and surveys other than Roberts and Morgan (2009) focused on vascular plants. It may have been present during other surveys but was not recorded.

Appendix G. Bird species confirmed within and near CHCH

Table H.1. Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
Acadian flycatcher[B]	X	X	–
American bittern	–	–	X
American crow[D]	X	X	X
American goldfinch[D]	X	X	X
American kestrel[A]	**X**	**X**	**X**
American pipit	X	X	X
American redstart	X	X	–
American robin[D]	X	X	X
American white pelican	–	–	X
American woodcock[C]	X	X	X
Bachman's sparrow	N	–	–
bald eagle[A]	**X**	**X**	**X**
Baltimore oriole	X	X	X
bank swallow	X	X	–
barn owl[A]	–	–	**X**
barn swallow[D]	X	X	–
barred owl[A,C]	**X**	**X**	**X**
bay-breasted warbler	X	X	–
belted kingfisher[B]	X	X	X
Bewick's wren[D]	X	–	–
black scoter	–	–	X
black vulture[A,D]	**X**	**X**	**X**
black-and-white warbler[D]	X	X	–
black-billed cuckoo	X	X	–
black-chinned hummingbird	–	–	X
black-crowned night-heron	–	–	X
blackburnian warbler	X	X	–
blackpoll warbler	X	X	–

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
black-throated blue warbler	X	X	–
black-throated green warbler	X	X	–
blue grosbeak[D]	X	X	–
blue jay[D]	X	X	X
blue-gray gnatcatcher[D]	X	X	X
blue-headed vireo[B]	X	X	X
blue-winged teal	–	–	X
blue-winged warbler[E]	X	X	–
Bobolink	X	X	–
Bonaparte's gull	X	X	X
Brewer's blackbird	X	X	X
broad-winged hawk[A,D]	**X**	**X**	**X**
brown creeper	X	X	X
brown thrasher[D]	X	X	X
brown-headed cowbird[D]	X	X	X
brown-headed nuthatch[C]	X	X	X
Bufflehead	–	–	X
Canada goose[C]	X	X	X
Canada warbler	X	X	–
Canvasback	–	–	X
Cape May warbler	X	X	–
Caribbean coot	–	–	X
Carolina chickadee[D]	X	X	X
Carolina wren[D]	X	X	X
cedar waxwing[B]	X	X	X
cerulean warbler	X	X	–
chestnut-sided warbler	X	X	–
chimney swift[D]	X	X	–
chipping sparrow	X	X	X
chuck-will's-widow[C]	X	X	–

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
cliff swallow	X	X	–
common goldeneye	–	–	X
common grackle[C]	X	X	X
common loon	X	X	X
common merganser	–	–	X
common nighthawk	X	X	X
common yellowthroat	X	X	X
connecticut warbler	X	X	–
Cooper's hawk[A,B]	**X**	**X**	**X**
dark-eyed junco	X	X	X
double-crested cormorant	X	X	X
downy woodpecker[D]	X	X	X
Dunlin	–	–	X
eastern bluebird[D]	X	X	X
eastern kingbird[D]	X	X	–
eastern meadowlark[D]	X	X	X
eastern phoebe[D]	X	X	X
eastern screech-owl[A,B]	**X**	**X**	**X**
eastern towhee	X	X	X
eastern wood-pewee[B]	X	X	–
eurasian collared-dove[B]	X	X	X
European starling[D]	X	X	X
evening grosbeak	–	–	X
field sparrow	X	X	X
fish crow	X	X	X
Forster's tern	–	–	X
fox sparrow	X	X	X
Gadwall	–	–	X
golden-crowned kinglet	X	X	X
golden-winged warbler[E]	X	X	–

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A "Brewster's warbler" was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster's warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
grasshopper sparrow	X	X	X
gray catbird	X	X	X
gray-cheeked thrush	X	X	–
great blue heron[D]	X	X	X
great crested flycatcher[C]	X	X	X
great egret	X	X	X
great horned owl[A,B]	**X**	**X**	**X**
greater scaup	–	–	X
greater yellowlegs	X	X	X
green heron[C]	X	X	X
hairy woodpecker[D]	X	X	X
Henslow's sparrow	U	–	–
hermit thrush	X	X	X
herring gull	X	X	X
hooded merganser	X	X	X
hooded warbler	X	X	–
horned grebe	–	–	X
horned lark	X	X	X
house finch[B]	X	X	X
house sparrow[B]	X	X	X
house wren	X	X	X
Iceland gull	–	–	X
indigo bunting[D]	X	X	X
Kentucky warbler	X	X	–
killdeer[D]	X	X	X
lapland longspur	–	–	X
Le Conte's sparrow	–	–	X
least flycatcher	X	X	–
least sandpiper	–	–	X
lesser scaup	X	X	X

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
Lincoln's sparrow	X	X	X
loggerhead shrike	–	–	X
long-eared owl[A]	–	–	**X**
long-tailed duck	–	–	X
Louisiana waterthrush	X	X	–
magnolia warbler	X	X	–
mallard[C]	X	X	X
marsh wren	X	X	X
merlin[A]	**X**	**X**	**X**
mourning dove[D]	X	X	X
mourning warbler	X	X	–
mute swan	–	–	X
Nashville warbler	X	X	–
northern bobwhite	X	X	X
northern cardinal[D]	X	X	X
northern flicker[C]	X	X	X
northern goshawk[A]	–	–	**X**
northern harrier[A]	**X**	**X**	**X**
northern mockingbird[D]	X	X	X
northern parula[C]	X	X	–
northern pintail	–	–	X
northern rough-winged swallow[C]	X	X	–
northern shoveler	–	–	X
northern waterthrush	X	X	–
olive-sided flycatcher	X	X	–
orange-crowned warbler	X	X	X
orchard oriole[C]	X	X	–
osprey[A]	**X**	**X**	**X**
ovenbird	X	X	X
palm warbler	X	X	X

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
peregrine falcon[A]	**U**	–	**X**
philadelphia vireo	X	X	–
pied-billed grebe	–	–	X
pileated woodpecker[C]	X	X	X
pine siskin	U	–	X
pine warbler[D]	X	X	X
prairie warbler	X	X	X
prothonotary warbler	X	X	–
purple finch	X	X	X
purple martin[D]	X	X	–
red crossbill	–	–	X
red-bellied woodpecker[D]	X	X	X
red-breasted merganser	–	–	X
red-breasted nuthatch	X	X	X
red-cockaded woodpecker	N	–	–
red-eyed vireo[D]	X	X	–
red-headed woodpecker[D]	X	X	X
red-necked grebe	–	–	X
red-shouldered hawk[A,D]	**X**	**X**	**X**
red-tailed hawk[A,C]	**X**	**X**	**X**
red-throated loon	–	–	X
red-winged blackbird[C]	X	X	X
redhead	–	–	X
ring-billed gull	X	X	X
ring-necked duck	–	–	X
rock pigeon	X	X	X
rock wren	N	–	–
rose-breasted grosbeak	X	X	–
Ross's goose	–	–	X
rough-legged hawk[A]	–	–	**X**

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
ruby-crowned kinglet	X	X	X
ruby-throated hummingbird[D]	X	X	–
ruddy duck	–	–	X
ruffed grouse	N	–	X
rusty blackbird	X	X	X
sandhill crane	X	X	X
savannah sparrow	X	X	X
scarlet tanager	X	X	–
sedge wren	X	X	X
sharp-shinned hawk[A]	**X**	**X**	**X**
snow goose	–	–	X
song sparrow	X	X	X
sora	X	X	–
spotted sandpiper	X	X	X
summer tanager	X	X	–
surf scoter	–	–	X
Swainson's thrush	X	X	–
Swainson's warbler	X	X	–
swamp sparrow	X	X	X
Tennessee warbler	X	X	–
tree swallow[B]	X	X	–
tufted titmouse[D]	X	X	X
turkey vulture[A,B]	**X**	**X**	**X**
veery	X	X	–
vesper sparrow	X	X	X
Virginia rail	–	–	X
western grebe	–	–	X
whip-poor-will	X	X	–
white-breasted nuthatch[C]	X	X	X

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Table F.1 (continued). Bird species confirmed within and near CHCH. X = observed, U = unconfirmed, N = not in park.

Common Name	NPS (2016)	Stedman et al. (2006)	CBC (1980-2014)
white-crowned sparrow	U	–	X
white-eyed vireo[C]	X	X	X
white-throated sparrow	X	X	X
white-winged scoter	–	–	X
wild turkey[D]	X	X	X
Wilson's snipe	X	X	X
Wilson's warbler	X	X	–
winter wren	X	X	X
wood duck[D]	X	X	X
wood thrush[C]	X	X	–
worm-eating warbler	X	X	–
yellow warbler	X	X	–
yellow-bellied flycatcher	X	X	–
yellow-bellied sapsucker	X	X	X
yellow-billed cuckoo[C]	X	X	–
yellow-breasted chat	X	X	X
yellow-crowned night-heron	–	–	X
yellow-rumped warbler	X	X	–
yellow-throated vireo[D]	X	X	–
yellow-throated warbler[C]	X	X	X
Species Richness	**174**	**173**	**161**
Raptor Species Richness	**15**	**15**	**20**

[A] Raptor species (also shown in bold text).

[B] possible breeding evidence noted by Stedman et al. (2006).

[C] probable breeding evidence noted by Stedman et al. (2006).

[D] confirmed breeding evidence noted by Stedman et al. (2006).

[E] A “Brewster’s warbler” was observed by Stedman et al. (2006). This species is not included in the total number of species observed by that study as the Brewster’s warbler is a hybrid of the blue-winged and golden-winged warblers and is not a distinct species.

Appendix I. Species abundance estimates recorded during point count efforts of Stedman et al. (2006) during the 2005 and 2006 field seasons.

Table J.1. Species abundance estimates recorded during point count efforts of Stedman et al. (2006) during the 2005 and 2006 field seasons. There were 40 point count locations (stops) sampled during each season, and each site was sampled for 10 minutes. Inds =number of individuals; Stops = number of point count locations where the species was observed (Appendix reproduced from Table 3 in Stedman et al. 2006).

	2005		2006	
Species	**Stops**	**Inds**	**Stops**	**Inds**
wood duck	1	2	0	0
wild turkey	2	6	4	9
northern bobwhite	1	1	0	0
great blue heron	3	8	3	7
green heron	0	0	1	1
turkey vulture	1	3	0	0
Cooper's hawk	0	0	1	1
red-shouldered hawk	1	1	2	2
broad-winged hawk	1	1	2	2
red-tailed hawk	1	1	0	0
killdeer	0	0	1	1
mourning dove	12	14	9	11
yellow-billed cuckoo	8	11	12	12
barred owl	3	3	2	3
chimney swift	10	23	8	14
ruby-throated hummingbird	1	1	3	3
belted kingfisher	0	0	1	1
red-headed woodpecker	3	3	4	4
red-bellied woodpecker	27	33	25	36
downy woodpecker	6	6	14	17
hairy woodpecker	3	4	5	5
northern flicker	1	1	2	2
pileated woodpecker	12	13	16	22
eastern wood-pewee	2	2	3	3
Acadian flycatcher	4	6	3	3
eastern phoebe	2	2	0	0
great crested flycatcher	8	10	12	15
white-eyed vireo	3	3	2	2

Table G.1 (continued). Species abundance estimates recorded during point count efforts of Stedman et al. (2006) during the 2005 and 2006 field seasons. There were 40 point count locations (stops) sampled during each season, and each site was sampled for 10 minutes. Inds =number of individuals; Stops = number of point count locations where the species was observed (Appendix reproduced from Table 3 in Stedman et al. 2006).

	2005		2006	
Species	**Stops**	**Inds**	**Stops**	**Inds**
yellow-throated vireo	6	7	10	11
blue-headed vireo	1	1	0	0
red-eyed vireo	33	69	35	74
blue jay	17	29	27	49
American crow	23	43	24	55
purple martin	3	5	3	7
northern rough-winged swallow	0	0	1	1
barn swallow	2	9	2	5
Carolina chickadee	28	47	23	39
tufted titmouse	33	52	33	53
white-breasted nuthatch	13	18	19	28
brown-headed nuthatch	1	2	4	6
Carolina wren	34	73	38	87
blue-gray gnatcatcher	19	27	14	14
eastern bluebird	6	10	2	2
wood thrush	13	17	9	12
American robin	6	8	7	10
northern mockingbird	5	5	0	0
brown thrasher	1	1	2	3
European starling	1	3	0	0
cedar waxwing	0	0	1	1
northern parula	2	2	1	1
yellow-throated warbler	3	4	4	4
pine warbler	20	30	13	19
black-and-white warbler	1	1	2	3
worm-eating warbler	2	3	2	2
ovenbird	2	2	0	0
Kentucky warbler	6	6	9	11
common yellowthroat	1	2	2	4
hooded warbler	4	4	6	6
yellow-breasted chat	0	0	1	1
summer tanager	13	17	14	20

Table G.1 (continued). Species abundance estimates recorded during point count efforts of Stedman et al. (2006) during the 2005 and 2006 field seasons. There were 40 point count locations (stops) sampled during each season, and each site was sampled for 10 minutes. Inds =number of individuals; Stops = number of point count locations where the species was observed (Appendix reproduced from Table 3 in Stedman et al. 2006).

	2005		2006	
Species	**Stops**	**Inds**	**Stops**	**Inds**
scarlet tanager	19	22	20	29
eastern towhee	18	31	17	30
chipping sparrow	1	1	5	5
grasshopper sparrow	3	3	1	1
song sparrow	1	1	1	1
northern cardinal	40	105	34	81
blue grosbeak	2	2	2	3
indigo bunting	16	30	6	10
red-winged blackbird	1	1	0	0
eastern meadowlark	2	6	2	7
common grackle	4	12	4	7
brown-headed cowbird	5	9	10	14
orchard oriole	1	1	0	0
American goldfinch	14	30	8	11
Total Species Richness	**–**	**–**	**–**	**74**
Species Richness	**–**	**67**	**–**	**63**
Total Abundance	**–**	**909**	**–**	**903**

Appendix K. Amphibian species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list.

Table L.1. Amphibian species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list (NPS 2016). X = Observed; P = Present; PP = Probably Present; and U = Unconfirmed.

Scientific name	Common name	Accipiter Biological Consultants (2006)	NPS (2016)
Acris crepitans	northern cricket frog	X	P
Anaxyrus americanus americanus	American toad	X	P
Anaxyrus fowleri	Fowler's toad	X	P
Gastrophryne carolinensis	eastern narrowmouth toad	X	P
Hyla chrysoscelis	Cope's gray treefrog	X	P
Hyla gratiosa	barking treefrog	–	U
Lithobates palustris	pickerel frog	X	P
Lithobates catesbeianus	bullfrog	X	P
Lithobates clamitans clamitans	green frog	X	P
Lithobates sphenocephalus	southern leopard frog	X	P
Pseudacris brachyphona	mountain chorus frog	–	U
Pseudacris crucifer	spring peeper	X	P
Pseudacris feriarum	upland chorus frog	X	P
Scaphiopus holbrookii	eastern spadefoot	–	U
Ambystoma maculatum	spotted salamander	X	P
Ambystoma opacum	marbled salamander	–	PP
Ambystoma tigrinum	eastern tiger salamander	–	U
Aneides aeneus	green salamander	–	U
Cryptobranchus alleganiensis	eastern hellbender	–	U
Desmognathus conanti	spotted dusky salamander	X	P
Desmognathus fuscus	northern dusky salamander	–	U
Desmognathus monticola	seal salamander	–	U
Desmognathus ocoee	Ocoee salamander	–	U
Eurycea cirrigera	southern two-lined salamander	X	P
Eurycea longicauda	longtail salamander	X	P
Eurycea lucifuga	cave salamander	X	P

Table H.1 (continued). Amphibian species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list (NPS 2016). X = Observed; P = Present; PP = Probably Present; and U = Unconfirmed.

Scientific name	Common name	Accipiter Biological Consultants (2006)	NPS (2016)
Gyrinophilus palleucus	Tennessee cave salamander	–	U
Gyrinophilus porphyriticus	spring salamander	X	P
Hemidactylium scutatum	four-toed salamander	–	U
Necturus maculosus	common mudpuppy	–	U
Notophthalmus viridescens	eastern newt	–	PP
Plethodon dorsalis	northern zigzag salamander	X	P
Plethodon glutinosus	slimy salamander	X	P
Plethodon serratus	southern redback salamander	X	P
Pseudotriton diastictus	midland mud salamander	–	U
Pseudotriton ruber	red salamander	X	P

Appendix M. Reptile species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list

Table N.1. Reptile species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list (NPS 2016). X = Observed; P = Present; PP = Probably Present; and U = Unconfirmed.

Scientific Name	Common Name	ABC (2006)	NPS (2016)
Apalone spinifera	spiny softshell turtle	–	U
Chelydra serpentina	common snapping turtle	X	P
Chrysemys picta	painted turtle	–	U
Kinosternon subrubrum	eastern mud turtle	–	U
Pseudemys concinna concinna	eastern river cooter	X	P
Sternotherus minor	loggerhead musk turtle	–	U
Sternotherus odoratus	common/eastern musk turtle	–	U
Terrapene carolina	eastern box turtle	X	P
Trachemys scripta	red-eared slider	–	U
Anolis carolinensis	green anole	–	U
Cnemidophorus sexlineatus	six-lined racerunner	–	U
Eumeces fasciatus	five-lined skink	X	P
Eumeces inexpectatus	southeastern five-lined skink	–	U
Eumeces laticeps	broad-headed skink	–	PP
Ophisaurus attenuatus	eastern slender glass lizard	–	U
Sceloporus undulatus	eastern fence lizard	X	P
Scincella lateralis	ground skink	X	P
Agkistrodon contortrix	copperhead	X	P
Carphophis amoenus	worm snake	X	P
Cemophora coccinea	scarlet snake	–	U
Coluber constrictor	black racer	X	PP
Crotalus horridus	timber rattlesnake	–	PP
Diadophis punctatus	ringneck snake	X	P
Elaphe guttata	corn snake	–	U
Elaphe spiloides	rat snake	X	P
Heterodon platirhinos	eastern hognose snake	–	PP
Lampropeltis calligaster	mole kingsnake	–	U

Table I.1 (continued). Reptile species observed during Accipiter Biological Consultants (2006) inventory of CHCH and the species identified by the NPS certified species list (NPS 2016). X = Observed; P = Present; PP = Probably Present; and U = Unconfirmed.

Scientific Name	Common Name	ABC (2006)	NPS (2016)
Lampropeltis getula	kingsnake	–	P
Lampropeltis triangulum	milk snake/ scarlet kingsnake	–	PP
Masticophis flagellum	eastern coachwhip	–	U
Nerodia sipedon	midland water snake	X	P
Opheodrys aestivus	rough green snake	X	P
Pituophis melanoleucus	northern pine snake	–	U
Regina septemvittata	queen snake	–	U
Storeria dekayi	brown snake	–	PP
Storeria occipitomaculata	redbelly snake	–	PP
Tantilla coronata	southeastern crowned snake	–	U
Thamnophis sauritus	eastern ribbon snake	–	U
Thamnophis sirtalis	eastern garter snake	X	P

Appendix O. The 2001-2011 external landcover change inside the four-county extent surrounding CHCH.

Table P.1. The 2001-2011 external landcover change inside the four-county extent surrounding CHCH. The table shows what the landcover was in 2001 and what it changed to by 2011. This appendix is associated with Figure of this document.

Land Cover Change (2001-2011)	Area (hectares)
Open Water to Developed, Open Space	18.45
Open Water to Developed, Low Intensity	8.55
Open Water to Developed, Medium Intensity	8.46
Open Water to Developed, High Intensity	6.66
Open Water to Barren Land	5.49
Open Water to Deciduous Forest	1.26
Open Water to Evergreen Forest	0.99
Open Water to Shrub/Scrub	1.08
Open Water to Grassland/Herbaceous	6.12
Open Water to Pasture/Hay	2.43
Open Water to Emergent Herbaceous Wetlands	7.20
Developed, Open Space to Developed, Low Intensity	222.30
Developed, Open Space to Developed, Medium Intensity	561.15
Developed, Open Space to Developed, High Intensity	145.26
Developed, Open Space to Barren Land	0.09
Developed, Open Space to Deciduous Forest	0.63
Developed, Open Space to Evergreen Forest	0.54
Developed, Open Space to Mixed Forest	0.18
Developed, Open Space to Shrub/Scrub	1.17
Developed, Open Space to Grassland/Herbaceous	0.54
Developed, Low Intensity to Developed, Open Space	74.52
Developed, Low Intensity to Developed, Medium Intensity	501.12
Developed, Low Intensity to Developed, High Intensity	238.59
Developed, Low Intensity to Deciduous Forest	0.09
Developed, Low Intensity to Evergreen Forest	0.54
Developed, Low Intensity to Shrub/Scrub	0.36
Developed, Low Intensity to Grassland/Herbaceous	0.27
Developed, Low Intensity to Woody Wetlands	0.09
Developed, Medium Intensity to Developed, Open Space	3.51
Developed, Medium Intensity to Developed, Low Intensity	15.39
Developed, Medium Intensity to Developed, High Intensity	49.95
Developed, Medium Intensity to Grassland/Herbaceous	0.09

Table J.1 (continued). The 2001-2011 external landcover change inside the four-county extent surrounding CHCH. The table shows what the landcover was in 2001 and what it changed to by 2011. This appendix is associated with Figure of this document.

Land Cover Change (2001-2011)	Area (hectares)
Developed, High Intensity to Developed, Open Space	0.18
Developed, High Intensity to Developed, Low Intensity	0.54
Developed, High Intensity to Developed, Medium Intensity	34.92
Barren Land to Open Water	4.68
Barren Land to Developed, Open Space	9.72
Barren Land to Developed, Low Intensity	11.25
Barren Land to Developed, Medium Intensity	16.47
Barren Land to Developed, High Intensity	11.79
Barren Land to Deciduous Forest	6.21
Barren Land to Evergreen Forest	27.72
Barren Land to Mixed Forest	1.08
Barren Land to Shrub/Scrub	2.70
Barren Land to Grassland/Herbaceous	19.35
Barren Land to Pasture/Hay	3.06
Deciduous Forest to Open Water	12.24
Deciduous Forest to Developed, Open Space	632.88
Deciduous Forest to Developed, Low Intensity	414.27
Deciduous Forest to Developed, Medium Intensity	231.03
Deciduous Forest to Developed, High Intensity	86.49
Deciduous Forest to Barren Land	99.45
Deciduous Forest to Evergreen Forest	122.67
Deciduous Forest to Mixed Forest	15.84
Deciduous Forest to Shrub/Scrub	1,134.09
Deciduous Forest to Grassland/Herbaceous	1.435.59
Deciduous Forest to Pasture/Hay	110.52
Deciduous Forest to Cultivated Crops	15.39
Deciduous Forest to Woody Wetlands	0.45
Deciduous Forest to Emergent Herbaceous Wetlands	10.35
Evergreen Forest to Open Water	4.77
Evergreen Forest to Developed, Open Space	221.31
Evergreen Forest to Developed, Low Intensity	173.79
Evergreen Forest to Developed, Medium Intensity	102.15
Evergreen Forest to Developed, High Intensity	36.81
Evergreen Forest to Barren Land	30.87
Evergreen Forest to Deciduous Forest	29.61
Evergreen Forest to Mixed Forest	64.26

Table J.1 (continued). The 2001-2011 external landcover change inside the four-county extent surrounding CHCH. The table shows what the landcover was in 2001 and what it changed to by 2011. This appendix is associated with Figure of this document.

Land Cover Change (2001-2011)	Area (hectares)
Evergreen Forest to Shrub/Scrub	2,508.66
Evergreen Forest to Grassland/Herbaceous	953.10
Evergreen Forest to Pasture/Hay	81.00
Evergreen Forest to Cultivated Crops	8.10
Evergreen Forest to Emergent Herbaceous Wetlands	0.27
Mixed Forest to Open Water	2.70
Mixed Forest to Developed, Open Space	393.48
Mixed Forest to Developed, Low Intensity	263.88
Mixed Forest to Developed, Medium Intensity	140.94
Mixed Forest to Developed, High Intensity	63.81
Mixed Forest to Barren Land	36.72
Mixed Forest to Deciduous Forest	26.73
Mixed Forest to Evergreen Forest	135.63
Mixed Forest to Shrub/Scrub	631.62
Mixed Forest to Grassland/Herbaceous	649.89
Mixed Forest to Pasture/Hay	61.56
Mixed Forest to Cultivated Crops	13.95
Mixed Forest to Emergent Herbaceous Wetlands	5.40
Shrub/Scrub to Open Water	4.95
Shrub/Scrub to Developed, Open Space	211.32
Shrub/Scrub to Developed, Low Intensity	146.61
Shrub/Scrub to Developed, Medium Intensity	85.77
Shrub/Scrub to Developed, High Intensity	50.58
Shrub/Scrub to Barren Land	38.79
Shrub/Scrub to Deciduous Forest	339.57
Shrub/Scrub to Evergreen Forest	1,040.31
Shrub/Scrub to Mixed Forest	68.49
Shrub/Scrub to Grassland/Herbaceous	130.41
Shrub/Scrub to Pasture/Hay	27.99
Shrub/Scrub to Cultivated Crops	14.49
Shrub/Scrub to Woody Wetlands	0.72
Shrub/Scrub to Emergent Herbaceous Wetlands	6.21
Grassland/Herbaceous to Open Water	11.34
Grassland/Herbaceous to Developed, Open Space	104.85
Grassland/Herbaceous to Developed, Low Intensity	85.41
Grassland/Herbaceous to Developed, Medium Intensity	51.39

Table J.1 (continued). The 2001-2011 external landcover change inside the four-county extent surrounding CHCH. The table shows what the landcover was in 2001 and what it changed to by 2011. This appendix is associated with Figure of this document.

Land Cover Change (2001-2011)	Area (hectares)
Grassland/Herbaceous to Developed, High Intensity	27.18
Grassland/Herbaceous to Barren Land	38.16
Grassland/Herbaceous to Deciduous Forest	385.74
Grassland/Herbaceous to Evergreen Forest	843.03
Grassland/Herbaceous to Mixed Forest	28.62
Grassland/Herbaceous to Shrub/Scrub	172.62
Grassland/Herbaceous to Pasture/Hay	0.54
Grassland/Herbaceous to Cultivated Crops	6.30
Grassland/Herbaceous to Emergent Herbaceous Wetlands	13.14
Pasture/Hay to Open Water	6.12
Pasture/Hay to Developed, Open Space	501.30
Pasture/Hay to Developed, Low Intensity	400.23
Pasture/Hay to Developed, Medium Intensity	183.78
Pasture/Hay to Developed, High Intensity	59.31
Pasture/Hay to Barren Land	16.20
Pasture/Hay to Deciduous Forest	131.04
Pasture/Hay to Evergreen Forest	167.49
Pasture/Hay to Mixed Forest	11.25
Pasture/Hay to Shrub/Scrub	47.16
Pasture/Hay to Grassland/Herbaceous	58.77
Pasture/Hay to Cultivated Crops	2.88
Pasture/Hay to Woody Wetlands	1.80
Pasture/Hay to Emergent Herbaceous Wetlands	4.41
Cultivated Crops to Open Water	0.18
Cultivated Crops to Developed, Open Space	59.85
Cultivated Crops to Developed, Low Intensity	46.35
Cultivated Crops to Developed, Medium Intensity	36.99
Cultivated Crops to Developed, High Intensity	13.86
Cultivated Crops to Barren Land	1.44
Cultivated Crops to Deciduous Forest	70.38
Cultivated Crops to Evergreen Forest	57.15
Cultivated Crops to Mixed Forest	2.52
Cultivated Crops to Shrub/Scrub	23.40
Cultivated Crops to Grassland/Herbaceous	20.97
Cultivated Crops to Pasture/Hay	1.35
Cultivated Crops to Emergent Herbaceous Wetlands	0.63

Table J.1 (continued). The 2001-2011 external landcover change inside the four-county extent surrounding CHCH. The table shows what the landcover was in 2001 and what it changed to by 2011. This appendix is associated with Figure of this document.

Land Cover Change (2001-2011)	**Area (hectares)**
Woody Wetlands to Open Water	2.70
Woody Wetlands to Developed, Open Space	28.53
Woody Wetlands to Developed, Low Intensity	12.24
Woody Wetlands to Developed, Medium Intensity	5.76
Woody Wetlands to Developed, High Intensity	0.63
Woody Wetlands to Barren Land	0.54
Woody Wetlands to Deciduous Forest	0.36
Woody Wetlands to Mixed Forest	0.81
Woody Wetlands to Shrub/Scrub	1.17
Woody Wetlands to Grassland/Herbaceous	3.24
Woody Wetlands to Emergent Herbaceous Wetlands	80.64
Emergent Herbaceous Wetlands to Developed, Open Space	1.80
Emergent Herbaceous Wetlands to Developed, Low Intensity	0.09
Emergent Herbaceous Wetlands to Developed, Medium Intensity	1.98
Emergent Herbaceous Wetlands to Developed, High Intensity	0.27
Emergent Herbaceous Wetlands to Barren Land	0.18
Emergent Herbaceous Wetlands to Deciduous Forest	0.72
Emergent Herbaceous Wetlands to Grassland/Herbaceous	0.54
Emergent Herbaceous Wetlands to Pasture/Hay	0.18
Total Landcover Change	**18,998.73**

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National Park Service
U.S. Department of the Interior

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