National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Lincoln Boyhood National Memorial

Natural Resource Report NPS/LIBO/NRR—2024/2617

ON THE COVER
Mixed hardwood forest, Lincoln Boyhood National Memorial
CSU

Natural Resource Condition Assessment

Lincoln Boyhood National Memorial

Natural Resource Report NPS/LIBO/NRR—2024/2617

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Contents

Contents (continued)

Contents (continued)

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Publisher's Note: Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions. For this report, most or all of the data discovery and analyses occurred during the period of 2013 to 2017. Thus, park conditions reported in this document pertain to that time period. Due to revised publishing requirements and/or scientific delays, this report was not published until 2024.

Executive Summary

The National Park Service (NPS) Natural Resource Condition Assessment (NRCA) Program administered by the NPS Water Resources Division evaluates current conditions for important natural resources and resource indicators using primarily existing information and data. NRCAs also report on trends in resource condition, when possible, identify critical data gaps, and characterize a general level of confidence for study findings. This NRCA complements previous scientific endeavors, is multi-disciplinary in scope, employs a hierarchical indicator framework, identifies and develops reference conditions/values for comparison against current conditions, and emphasizes spatial evaluation of conditions where possible.

Lincoln Boyhood National Memorial (LIBO) was authorized by an act of Congress on February 19, 1962, (Public Law 87-407) to preserve the site associated with the boyhood and family of President Abraham Lincoln, including a portion of the original Tom Lincoln farm and the nearby gravesite of Nancy Hanks Lincoln. The 200-acre memorial commemorates the pioneer farm where Abraham Lincoln lived from the age of 7 to 21.

The NRCA for LIBO employed a scoping process involving Colorado State University, LIBO and other NPS staffs to establish the NRCA framework, identify important park resources, and gather existing information and data. Indicators and measures for each resource were then identified and evaluated. Data and information were analyzed and synthesized to provide summaries and address condition, trend and confidence using a standardized but flexible framework. A total of nine focal resources were examined: four addressing system and human dimensions, one addressing chemical and physical attributes, and four addressing biological attributes. The quality and currentness of data used for the evaluation varied by resource.

Landscape context – system and human dimensions included land cover and land use, natural night skies, soundscape, and climate change. Climate change and land cover/land use were not assigned a condition or trend—they provide important context to the memorial and many natural resources and can be stressors. Some of the land cover and land use-related stressors at LIBO and in the larger region are related to the development of rural land and increases in population/housing over time. The trend in land development, coupled with the lack of significantly sized and linked protected areas, presents significant challenges to the conservation of natural resources of LIBO to also include natural night skies, natural sounds and scenery. Climate change is happening and is affecting resources, but is not considered good or bad per se. The information synthesized in that section is useful in examining potential trends in the vulnerability of sensitive resources and broad habitat types

such as forests. Night skies and soundscapes, significantly altered by disturbance due to traffic, development and urbanization, warrant significant and moderate concern, respectively, and appear to be in decline.

Air quality was the sole resource supporting chemical and physical environment at the memorial. The condition of air quality can affect human dimensions of the park such as visibility and scenery as well as biological components such as the effect of ozone levels on vegetation health. Air quality warrants significant concern and is largely impacted by historical and current land uses outside the memorial boundary.

The floral biological component was examined by assessing native species composition, Mean Coefficient of Conservation, Floristic Quality Assessment Index, invasive exotic plants, forest pests and disease, and forest vulnerability to climate change. Vegetation resources at LIBO have been influenced by historical land uses that have changed the species composition and age structure of these communities. Although large tracts of forests can be found surrounding the park, the majority of forested areas are fragmented, and few areas within and around LIBO exhibit late-successional or old-growth characteristics. Vegetation communities at LIBO have a long history of being impacted by a variety of stressors and threats including noxious and invasive weeds, diseases and insect pests; compounding effects of climate change, air pollution, acid rain/atmospheric chemistry, and past land uses; and impacts associated with overabundant white-tail deer populations. These stressors and threats have collectively shaped and continue to impact plant community condition and ecological succession. The sole metric in good condition was native species composition, while all other indicators and metrics warranted either moderate or significant concern.

The faunal biological components examined included birds, herptiles, and mammals. Birds (unchanging trend) and herptiles (no trend determined) warrant moderate concern, while mammal populations warrant significant concern (no trend determined). The confidence of both herptiles and mammals was low due to length of time since data were last collected. Current forest structure within and surrounding LIBO generally reflects the historical overstory composition but changes in the hardwood forest at LIBO and the surrounding area have resulted in declines in the avian fauna of the region since the 1970s. The decline in woodland bird populations has been caused by multiple factors including the conversion of hardwood forest to other land cover types, habitat fragmentation, and increasing human population growth.

The identification of data gaps during the course of the assessment is an important NRCA outcome. Resource-specific details are presented in each resource section. In some cases, significant data gaps contributed to the resource not being evaluated or low confidence in the condition or trend being assigned to a resource. Primary data gaps and uncertainties encountered were lack of recent survey data, uncertainties regarding reference conditions, availability of consistent long-term data, and the need for more robust or sensitive sampling designs.

Impacts associated with development outside the park will continue to stress some resources. Regionally, the direct and indirect effects of climate change are likely but specific outcomes are uncertain. Nonetheless, within the past several decades, some progress has been made toward restoring the quality of natural resources within the park, most notably the forested environments. Regional and park-specific mitigation and adaptation strategies are needed to maintain or improve the condition of some resources over time. Success will require acknowledging a “dynamic change context” that manages widespread and volatile problems while confronting uncertainties, managing natural and cultural resources simultaneously and interdependently, developing disciplinary and interdisciplinary knowledge, and establishing connectivity across broad landscapes beyond park borders.

Prologue

Publisher’s Note, December 28, 2023

Changes in publishing requirements, and in some cases scientific delays, resulted in several NRCA reports not being published in a timely manner. These publications reported on studies initiated in the 2013–16 timeframe. Since Natural Resource Condition Assessments provide a snapshot-in-time evaluation of park resource conditions, it is important to note that data discovery and analyses for this study was conducted during the period of 2013-2017. Thus, park conditions reported in this document pertain to that time period.

In 2023, the Natural Resource Condition Assessment Program evaluated the content of the information in this report and deemed the information valuable, even though dated. The report received peer review in 2023 and the original principal investigators reengaged to address peer review comments and to assist NRCA in seeing this report through to publication. We did not attempt to update the information to align with the publication date. Thus, we alert the reader that this natural resource condition assessment report is pertinent only to the report timeframe of 2013-2017.

A variety of floristic inventories, survey work and mapping has been undertaken since 2017 when the report was written. The memorial has initiated several projects to improve forest composition and structure relative to the desired condition. Efforts include invasive exotic plant management, mechanical removal of understory woody vegetation, planting of 5,000 oak and sage bark hickory seedlings, and reintroduction of fire to the landscape. Significant progress has been made in focused parts of the park (R. Schier, Superintendent, Lincoln Boyhood National Memorial, pers. comm., 27 December 2023).

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 GIS (map) products;[4]
- Summarize key findings by park areas; and[5]
- 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.

[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.

These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources 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. 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

Introduction

Enabling Legislation/Presidential Proclamation

Lincoln Boyhood National Memorial (hereafter referred to as either LIBO or "the memorial" or "the park") was authorized by an act of Congress on February 19, 1962, (Public Law 87-407) to preserve the site associated with the boyhood and family of President Abraham Lincoln, including a portion of the original Tom Lincoln farm and the nearby gravesite of Nancy Hanks Lincoln. The 200-acre memorial commemorates the pioneer farm where Abraham Lincoln lived from the age of 7 to 21.

Park History[9]

Although no physical traces of the Lincoln farm remained above ground, in the late 1800s, local residents began creating a memorial landscape at this site. It provided an opportunity for visitors to pay their respect to President Lincoln's memory and to learn more about his family's Indiana roots. For many years, the site was known as the Nancy Hanks Lincoln Memorial and was maintained as a local park and picnic area. Because it was often neglected, state agencies became involved during the 1920s. By that time the site featured decorative elements such as ornate gates, concrete sculptures, ornamental plantings, and a picnic area.

Between 1927 and the 1940s the Indiana Department of Conservation led the effort to create a more formal Lincoln memorial. The state hired Olmsted Brothers, a renowned landscape architecture firm, to prepare a design for the memorial. Landscape architect Donald Johnson was hired to supervise the implementation of the Frederick Law Olmsted Jr. design. After completion, the site was maintained and interpreted as Lincoln State Park. Efforts to get President Lincoln's Indiana roots recognized at a national level resulted in the site's 1962 designation as a national memorial. The commemorative designed landscape has since been administered and interpreted by the National Park Service. In 1976 the entire memorial was listed in the National Register of Historic Places.

Geographic Setting

The Lincoln Boyhood National Memorial is located in Spencer County, Indiana, approximately 40 miles east of Evansville, Indiana (117,429 residents as of 2010 Census) and 80 miles west of Louisville, Kentucky (741,096 residents as of 2010 Census) (Figure 1). Spencer County borders the Ohio River in southwest Indiana. Interstate 64 is the approximate northern border of the county. The terrain in the region consists of wooded hills in the eastern and northern sections and agricultural land in the southern and western area. The county is spread over 398.7 square miles with a population of 19,810 as of the 2020 census (U.S. Census Bureau 2020).

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[9] Adapted from NPS (2018a)

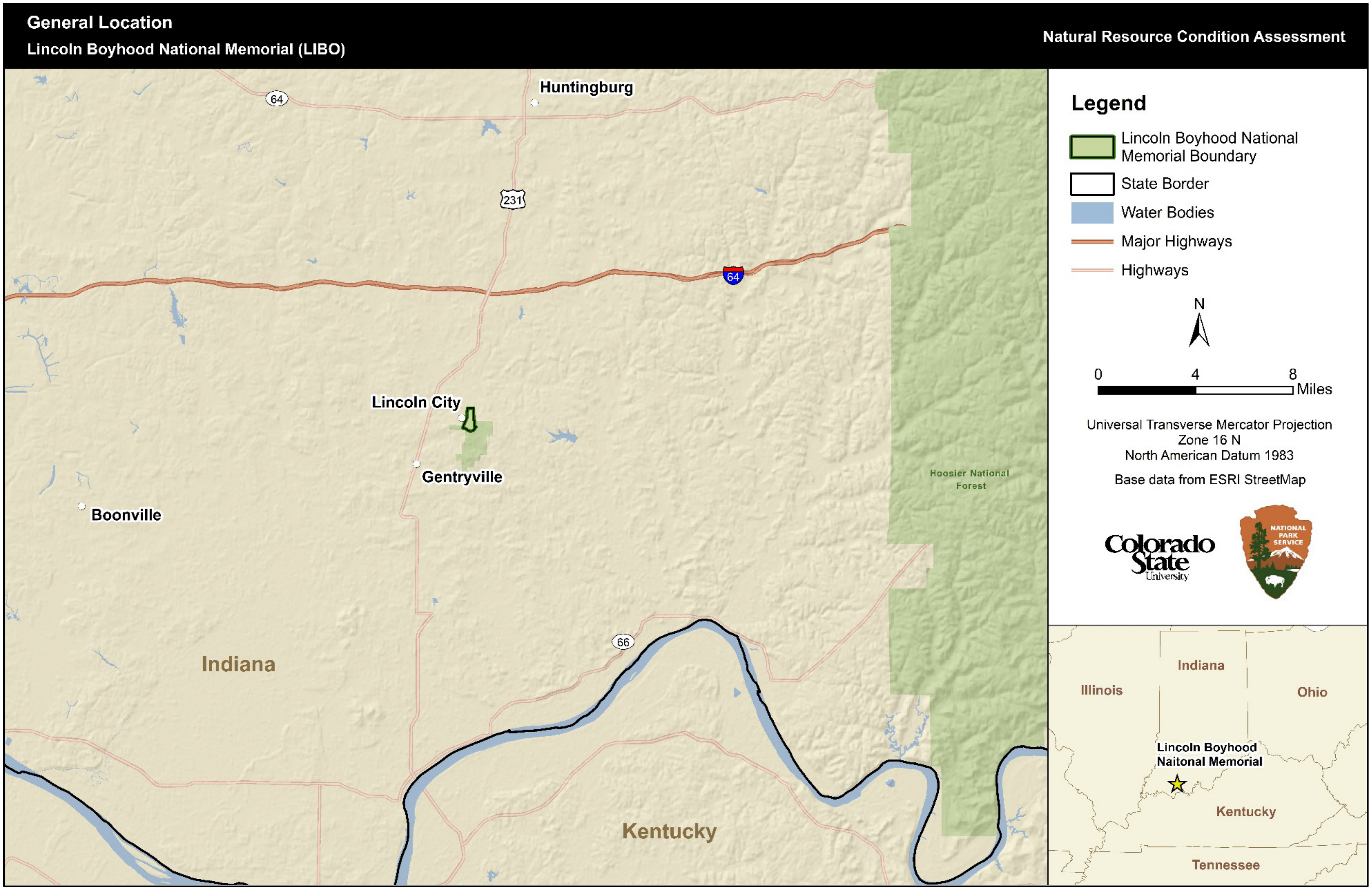


Figure 1. General location of Lincoln Boyhood National Memorial. (Data sources: NPS, ESRI StreetMap.)

Park Significance

Purpose and Significance statements highlighted in the memorial's *General Management Plan/Environmental Impact Statement* (2005) reaffirm the reasons that LIBO was set aside as an NPS unit and capture the essence of the memorial's importance to our country's cultural heritage. The purpose of LIBO is to:

> *Preserve and interpret the site associated with the boyhood and family of President Abraham Lincoln and the grave site of Nancy Hanks Lincoln as a public memorial.* (NPS 2005).

The significance of LIBO is as follows:

> *Lincoln Boyhood National Memorial contains the farm of Thomas Lincoln and the marked gravesite of Nancy Hanks Lincoln and is associated with the formative years of Abraham Lincoln's life from age 7 to 21. Lincoln Boyhood National Memorial was established to nationally commemorate President Abraham Lincoln. The site contains physical expressions of the nation's respect and reverence for President Abraham Lincoln, including formal and informal memorial landscapes.* (NPS 2018a).

Visitation Statistics

Park visitors are a mixture of recreation and non-recreation travelers and local residents. Annual park recreation visitation has decreased steadily since the late-1970s, with a large spike in visitation in 2009 attributed to the 200th birthday of Abraham Lincoln (Figure 2). Mean monthly visitation for the five-year period ending 2017 was 10,096 recreation visitors. Monthly visitation is highest in June and July (Figure 3) (NPS 2018b).

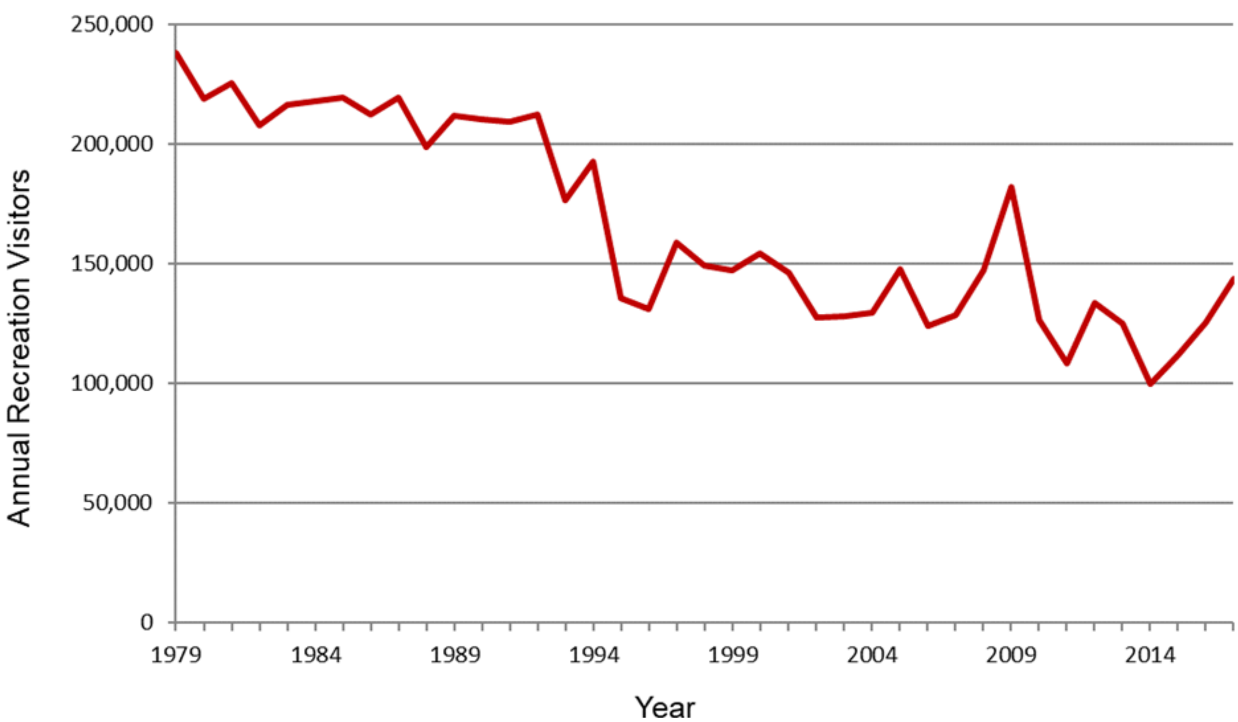


Figure 2. Annual LIBO recreation visitation for 1979–2017. (Data source: NPS 2018b.)

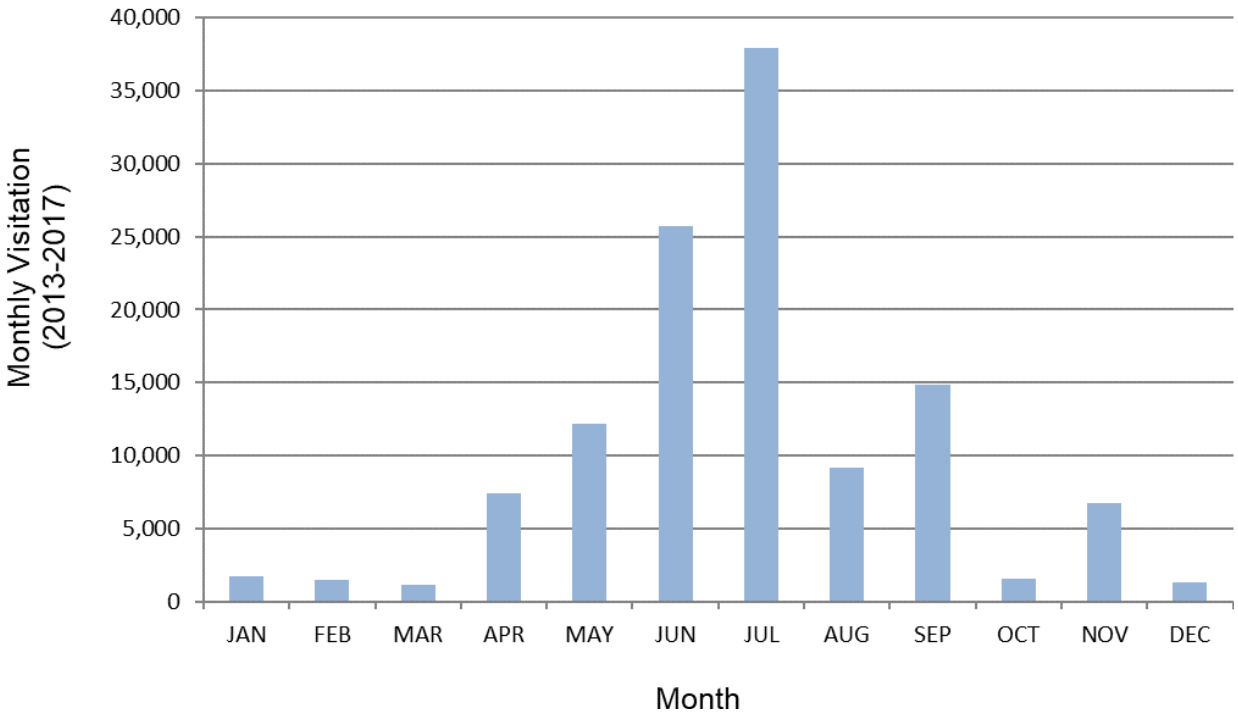


Figure 3. Mean monthly recreation visitation for LIBO for 2013–2017. (Data source: NPS 2018b.)

Natural Resources

Ecological Units

LIBO is located in the Southern Wabash Lowlands Level IV Ecoregion approximately 5 miles from the border between the Interior River Valleys and Hills Level III Ecoregion and the Interior Plateau Level III Ecoregion in southern Indiana (Omernik 1987). The Southern Wabash Lowlands Level IV Ecoregion (72c) is characterized by undulating to rolling topography and wide, shallow valleys. Oak-hickory forests originally grew on well-drained upland soils while mesophytic forests grew in poorly drained areas. Forests in the area have been mostly cleared for agricultural use, including corn, wheat, soybeans, and livestock. Some southern plant species reach their northern distributional limit in the region (Woods et al. 1998).

Resource Descriptions

Climate

The climate at LIBO is continental and characterized by cold winters and hot summers. Summers tend to be hot and humid; winters are cold and snowy; and spring and fall are mild with moderate temperatures (NCDC 2018a). The average annual temperature at LIBO is 13.8° Celsius (C) (56.8° Fahrenheit (F)). The coldest month is January, with an average temperature of 0.9° C (33.7° F). The warmest month is July, with an average temperature of 24.8° C (76.6° F) (Figure 4) (Table 1) (MRCC 2018). The median growing season length at LIBO is 190 days with a last spring frost occurring around April 15 and a first fall frost occurring around October 23 (MRCC 2018). The snow season at LIBO spans October to April and averages 28.5 cm (11.2 in) of snowfall annually (MRCC 2018). The regional climate and projected changes to climate in the vicinity of the memorial are discussed in the section on Climate Change.

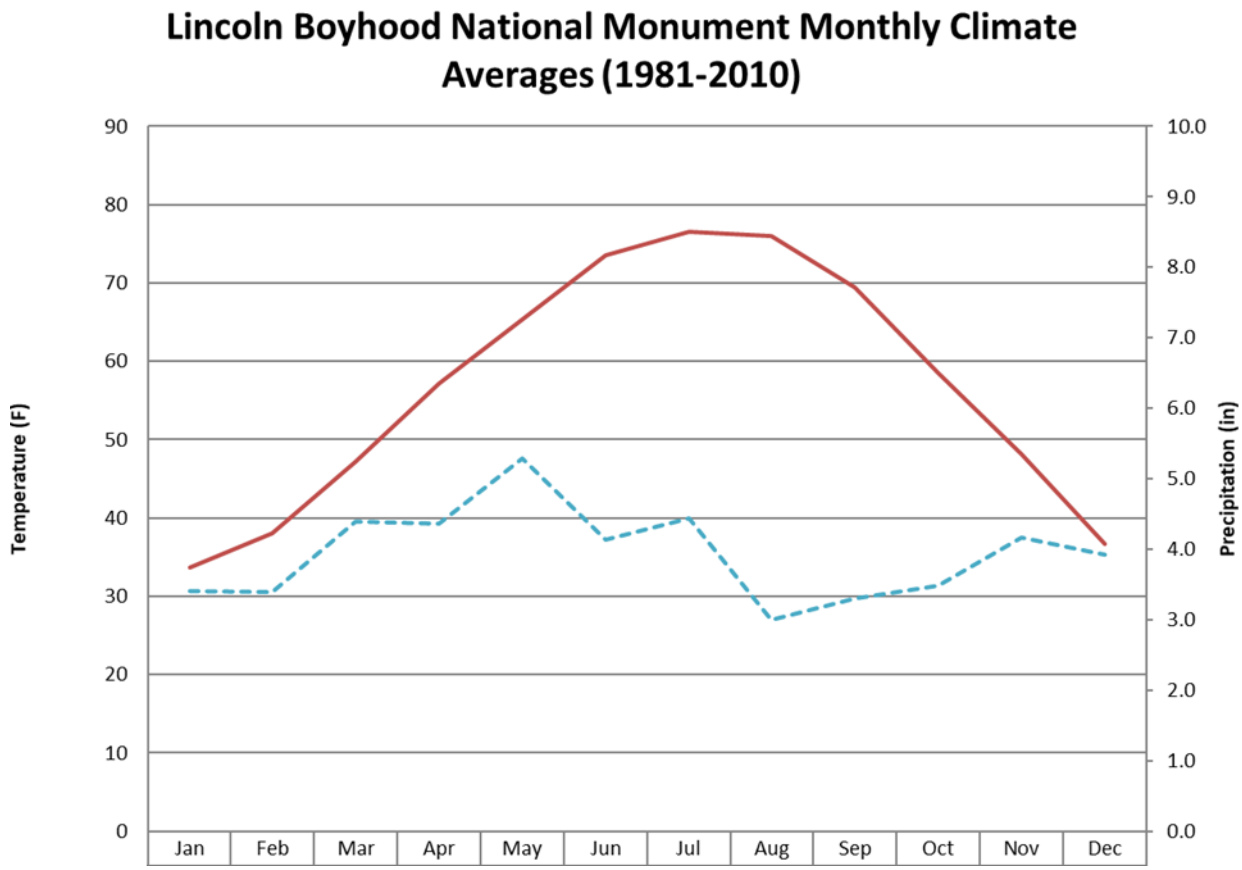


Figure 4. Walter climate diagram near LIBO with 30-year temperature and precipitation averages (1981–2010). (Data source MRCC 2018.)

Table 1. The 30-year average temperature and precipitation by month shown in the Walker climate diagram in Figure 4 for LIBO (1981–2010). (Data source MRCC 2018.)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature	33.7	38.1	47.2	57.1	63.3	73.6	76.6	76.0	69.4	58.5	48.1	36.7
Precipitation	3.4	3.4	4.4	4.4	5.3	4.1	4.4	3.0	3.3	3.5	4.2	3.9

Geology and Soils[10]

The park is located in the Wabash Lowlands physiographic province of southwestern Indiana in a transition to the Crawford Upland to the east. Elevation in LIBO ranges from about 415 feet to 512 feet above sea level. The land above 450 feet is comprised of steep sloping hills dissected by shallow ravines. Below 450 feet, the landscape is gently undulating. The land is underlain by Pennsylvanian age sedimentary rocks— sandstone, shale, and thin Carbondale Group coals. The lowland surficial material is alluvium derived from weathered shale and sandstone. The upland surficial material is comprised mainly of weathered loess derived from Wabash River outwash from the late Wisconsin glaciations. Soils consist of silt-loams derived from alluvium, loess, and weathered sandstone and

[10] Adapted from Middlemis-Brown and Young (2012)

shale bedrock. Five soil series occur within the park. Well-drained soils occur in the high relief areas in the southern half of LIBO. Poorly drained soils are associated with flat land in the North Forty and ephemeral drainages in the southern property.

Hydrology[2]

The only permanent water source at LIBO is a small, constructed pond. During the spring, the northern one-third of the park contains several ephemeral pools and streams that are not obvious during the remainder of the year. There is insufficient data to determine a current condition or trend for stream geomorphology and water quality, and these resources have been left out of the resource framework for LIBO. Historical data for several water sampling locations in and near the memorial can be found in NPS (1999) and Buszka and Fowler (2005).

Air Quality

Lincoln Boyhood National Memorial, like all the other parks within the Heartland Inventory and Monitoring Network, is designated as a Class II airshed by the Clean Air Act of 1997 (Middlemis-Brown and Young 2012). The designation is based on park size, location and date of origin. As a Class II airshed, air quality within LIBO is protected to a less stringent degree than in some other parks and protected areas around the country. Air quality at LIBO is not directly measured within the park but instead is inferred from instrumentation located within the region.

Air quality parameters estimated for LIBO reflect regional air quality characteristics. For example, the wet deposition of nitrogen and sulfur for LIBO reflects industrial land use from the North and the agricultural character of the region, while ozone concentrations generally mirror regional ones and do not indicate significant ozone concerns. These specific resource issues as well as visibility are addressed later in the document. Consequences for the health and condition of natural communities, human health and the quality of the visitor experience are also described.

Land Use

The lands adjacent to LIBO range from several small towns to cultivated farmlands and deciduous forests surrounding the memorial. The memorial protects small patches of restored hardwood forest (Diamond et al. 2014). The area around LIBO still maintains a mostly rural character. Accelerated land use changes have occurred in the area surrounding LIBO since the mid-1950s. Urbanization and changes in land use have resulted in a regional landscape that has become less rural and more urban. Urbanization, industrial activities and fragmentation of habitats can intensify edge effects and exacerbate the spread of exotic plants within the park (Hansen and Gryskiewicz 2003). Urbanization also degrades the visitor experience and impacts the natural soundscape, visual resources and natural night skies.

Wildlife

A wildlife inventory was conducted in 1996–97. During the inventory, 67 bird species were counted during breeding bird surveys, including 26 neotropical migrants, 26 migrants that winter in the U.S., and 26 resident species. Subsequent monitoring detected 42 species of breeding birds; 21 of the 42 species are year-round residents, with the remaining species being summer residents. Twelve species are of continental importance (Peitz 2011). The most common bird species included northern cardinal (*Cardinalis cardinalis*), Canada goose (*Branta canadensis*), American crow (*Corvus brachyrhynchos*), tufted titmouse (*Parus bicolor*), and blue jay (*Cyanocitta cristata*).

The most comprehensive source of wildlife present at the memorial is NPSpecies (NPS 2018d). The only large mammal present is white-tailed deer (*Odocoileus virginianus)*. Mesocarnivores include coyote (*Canis latrans*), red fox (*Vulpes vulpes*) and common raccoon (*Procyon lotor*), and . Nine small mammal species were documented with mice (*Peromyscus* spp.) being the most frequently recorded. Seven frog and toad, four salamander, two lizard, four turtle, and six snake species have been documented.

Federally listed threatened, endangered, or candidate animal species

No federally listed species occur in LIBO, but there may be suitable summer habitat for the federally-endangered Indiana bat (*Myotis sodalist*), gray bat (*Myotis grisescens*) and threatened (proposed endangered 3/31/2023) northern long eared bat (*Myotis septentrionalis)* within the park.

Indiana state-listed animal species found at LIBO

Indiana's endangered species act covers animals, excluding insects. The act does not require agency consultation. There are three bird species (Mississippi kite (*Ictinia mississippiensis*), cerulean warbler (*Dendroica cerulean*), and hooded warbler (*Wilsonia citrina*)), one reptile (rough green snake (*Opheodrys aestivus*)), and one mammal (eastern red bat (*Lasiurus borealis*)) that are listed as state species of concern that occur in the park.

Vegetation[2]

An analysis of pre-settlement vegetation of Spencer County indicated a mosaic of upland xeric (dry) and mesic oak-hickory forest with patches of mesic mixed-hardwood forest grading into bottomland forests along streams. Mature forest covers approximately 120 acres at LIBO. The forests are largely the result of reforestation by the Civilian Conservation Corps during the Olmstead plan implementation of the 1930s and 1940s, although there are a small number of older, open-grown trees left for ornamental purposes (Pavlovic and White 1989). The mature forest contains a canopy of red oak, black oak (*Quercus velutina*), and white oak, as well as pignut hickory (*Carya glabra*) and shagbark hickory (*Carya ovata*). Other successional uplands that regenerated following land clearing are dominated by tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and sassafras (*Sassafras albidum*). A mixed maple-tulip poplar forest, planted during the 1920s and 1930s, covers much of the southeastern section of the park. Mesic species, such as tulip poplar, sweetgum, and maples dominate the lower elevations of the park. The original bottomlands consisted largely of successional forests with an overstory of sweetgum and red maple. Pin oak (*Quercus palustris*) dominates the remnant mature bottomland forests. Home sites associated with homesteading and farming prior to creation of the memorial supported numerous invasive pasture grasses such as tall fescue (*Schedonorus phoenix*), orchard grass, and bluegrass. The area surrounding LIBO is characterized largely by mosaics of cropland and pasture, with some ruderal and some remnant natural forest, and urbanization is causing habitat loss and fragmentation.

Federally listed threatened, endangered, or candidate plant species

None occur in the park.

Indiana state-listed plant species found at LIBO

Indiana's endangered species act covers only animals, not plants. Nonetheless, the park has documented 13 species of management concern within LIBO. These species are: paper birch (*Betula papyrifera*), northern catalpa (*Catalpa speciose*), coppery St. Johns-wort (*Hypericum denticulatum*), bald cypress (*Taxodium distichum*), eastern white cedar (*Thuja occidentalis*), American chestnut (*Castanea dentate*), butternut (*Juglans cinerea*), purple fringeless orchid (*Platanthera peramoena*), lesser ladies' tresses (*Spiranthes ovalis*), eastern white pine (*Pinus strobus*), marsh bristlegrass (*Setaria geniculate*), goldenseal (*Hydrastis canadensis*), and lanceleaf buckthorn (*Rhamnus lanceolata*).

Resource Issues Overview

Regional ecosystem stressors that can impact park resources and their management include altered disturbance regimes such as fire and flooding, conversion and fragmentation of natural habitats, spread of invasive exotic plants and animals that threaten regional biological diversity, loss of native pollinators, excessive deer browsing, and altered hydrology and channel degradation of streams.

Management concerns highlighted in the memorial's *Draft Foundation Document* (NPS 2018a), *General Management Plan and Environmental Impact Statement* (NPS 2005) and noted by park staff during the scoping process consist of natural and cultural resource-related issues as well as stressors from outside the park. Primary natural resource management concerns in and near the park are briefly described below. The first three items have been identified in the park's *Draft Foundation Document* as fundamental resources and values.

The Historic Farm Site[11]. The farm site owned by Thomas Lincoln where Abraham Lincoln lived, including the spring and the Lincoln Trace on that property. The Lincoln Trace is the route the Lincoln family used to get to their property, and it later became a road.

The Gravesite of Nancy Hanks Lincoln[2]. The approximate site of Nancy Hanks Lincoln's grave in what is known as Pioneer Cemetery.

Memorialization of Abraham Lincoln's Youth[2]. The value of commemorating Abraham Lincoln and the time he spent in Indiana that was formative to his character, including the values and process of remembrance and respect for his mother.

Visitor Experience – traffic and noise[2]. With few historic artifacts and no remaining structures from Thomas Lincoln's homestead, visitors depend on the NPS to effectively interpret Lincoln's boyhood and life and provide educational opportunities at the site of his family farm. Some of the management concerns impacting visitor experience include traffic and noise, and connections with other nearby parks and recreation areas. Train noise and automobile traffic unrelated to memorial visitation and management distract from the park mission and visitor experiences. Local traffic on County Roads 300 and 1625N previously passed directly through the memorial, contributing to noise and increasing

[11] Excerpted from NPS (2018a).

traffic volume, but there is no longer through traffic on County Roads 300 and 1625N and noise and traffic volume have significantly decreased (E. Hilligoss-Volkmann, pers. comm., June 2023).

Because LIBO is directly across a two-lane highway from Lincoln State Park, many visitors have a “disconnect” between the historical and recreational opportunities available in the immediate area. The two Lincoln areas, with entrances directly across from each other, contribute to the confusion of a first-time visitor about which direction to pursue. Each area has a very different mission, although together they provide visitors with a complementary range of opportunities (NPS 2005).

Forest Restoration. Much of the memorial is covered by successional hardwood forest. Restoration of oak-hickory forest and woodland is a goal identified in the Resource Management Plan. A variety of floristic inventories, survey work and mapping has been undertaken over the years. Within the past 10 years, the memorial has initiated a number of projects to improve forest composition and structure relative to the desired condition. Efforts include invasive exotic plant management, mechanical removal of understory woody vegetation, and reintroduction of fire to the landscape. It has proved challenging for the park to make headway with the resources available, but significant progress has been made in focused parts of the park.

Resource Stewardship

Management Directives and Planning Guidance

Each unit in the National Park System is required by the National Park Service Organic Act of 1916 to “conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.” The General Authorities Act in 1970 (as amended) reiterated the provisions of the Organic Act and emphasized that “these areas, though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage.” The General Authorities Act also re-emphasized the importance of “unimpaired” NPS resources for future generations. The enabling legislation establishes park purposes and legislatively authorized uses within a context of cultural and natural resources. The National Park Service Management Policies (NPS 2006) provides Service-wide guidance for Park System planning, land protection, natural and cultural resources management, wilderness preservation and management, interpretation and education, use of the parks, park facilities and commercial visitor services. All management and planning documents developed for the park must adhere to these overarching documents and other laws, Executive Orders and Director’s Orders.

A number of important NPS documents guide the management of natural resources in LIBO. The *General Management Plan and Environmental Impact Statement* (NPS 2005) is the primary planning document for the memorial. This document provides a broad direction for all phases and elements of LIBO management. The implemented management alternative places an emphasis on “Exploring Lincoln’s Indiana,” and on interpreting the history of the Lincoln family in southern Indiana and the natural and socio-political environment at the time (NPS 2005). Other important documents guiding stewardship at LIBO include the *Fire Management Plan* (NPS 2011), numerous historical studies, and various vertebrate and vascular plant inventories. These broad and park-specific documents and management directives provide important information for identifying and characterizing focal resources and articulating resource reference conditions in this natural resource condition assessment.

Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. Much of the supporting baseline survey and monitoring data was collected through the ongoing Heartland Network of the Inventory and Monitoring (I&M) Program initiated in the early 2000s. The Heartland Network also supported requests for geospatial data. Landscape context information and aspects of human dimensions were greatly supported by national program staff such as the Natural Sounds and Night Skies Division (NSNSD), the national NPS Air Quality program, and the NPScape Project within the I&M Program. Additional information and data were provided by the park, published and unpublished reports and articles, and other outside experts noted in the individual resource sections.

Chapter 3. Study Scoping and Design

Preliminary Scoping

The initial phase of the study consisted of a series of meetings, conversations and collaborations between Colorado State University and NPS staff, including the Midwest Regional NPS Office, the Heartland Inventory and Monitoring (I&M) Network, LIBO staff, Water Resources Division (NRCA proponent), and National I&M programs. Initial scoping consisted of reviewing the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program Vital Signs Monitoring Plan (DeBacker et al. 2005) and other documents to begin to understand the management and resource context for the park. Vital signs previously identified and prioritized for the park were the basis for a preliminary list of focal resources to support initial NRCA discussions with park and other NPS staff. A site visit and initial meeting took place July 20, 2017, at LIBO Headquarters. The purpose of the preliminary scoping meetings was to:

- establish contact and begin dialogue with key staff members;
- identify points of contact;
- provide an overview of NRCA purpose and process (for park staff);
- provide an overview of park context, administrative history and management concerns (for cooperators);
- discuss analysis framework, reporting scales/units, and rating system;
- identify and discuss priority/focal resources in support of framework development;
- discuss key NRCA concepts including indicators and measures, threats and stressors, and reference conditions;
- identify and gather available data and information;
- identify sources of expertise inside and outside the NPS; and
- define project expectations and identify constraints.

Key constraints placed on the scope of NRCA development include the following:

- the assessment will provide a snapshot of a subset of park resources, as determined through the scoping process;
- some lower priority resources or those having little supporting data may not be fully examined to allow a more comprehensive analysis of higher-priority resources;
- the assessment will use existing information/data and not modeled or projected data, although limited analysis and data development may be undertaken where feasible (e.g., data to support views/scenery analysis)—future modeled data are used only in the climate change section; and
- assignment of condition ratings may be constrained by insufficient information or inadequately defined reference conditions.

Study Design

Indicator Framework, Focal Resources and Indicators

The NRCA framework used for LIBO is adapted from The Heinz Center (2008) (Table 2). The Heinz structure was identified in the NRCA guidance documents as a relevant framework that organizes indicators under each focal resource within broad groupings of ecosystem attributes related to: landscape context including system and human dimensions; chemical and physical components; biological components; and integrated systems. Although threats and stressors are described for each focal resource, the Land Cover and Land Use and Climate Change sections were added to address broad ecosystem-level processes and stressors affecting multiple resources. A total of nine focal resources were examined and included here: four addressing system and human dimensions, one addressing chemical and physical attributes, and four addressing biological attributes.

Table 2. Lincoln Boyhood National Memorial natural resource condition assessment framework.

Ecosystem Attributes	Focal Resource	Indicators and Measures of Condition
Landscape Context – System and Human Dimensions	Land Cover and Land Use	• Land cover/land use • Population and housing • Conservation/protection status
	Natural Night Skies	• All-sky light ratio (ALR)
	Natural Sounds	• Anthropogenic sources of noise • Traffic volumes on nearby and memorial roads • Anthropogenic sound level impacts (modeled)
	Climate Change	• Modeled temperature and precipitation vs. historical baseline • Aridity – Palmer index (historical) • Frost-free period historical vs. projected
Chemical and Physical	Air Quality	• Level of ozone: human health risk and vegetative health risk • Atmospheric wet deposition of total N and total S • Visibility haze index
Biological – Plants	Vegetation Communities	• Community composition (Native Species Richness) • Invasive exotic plants (%IEP cover) • Floristic Quality Assessment (FQAI) and Coefficient of Conservatism • Forest pests and diseases • Forest vulnerability to climate change
Biological – Animals	Birds	• Native species richness (S) • Bird index of biotic integrity (IBI) • Occurrence and status of bird species of conservation concern
	Herptiles	• Presence of herptile species expected for the park
	Mammals	• Presence of mammal species expected for the park

Some resources identified as important to the memorial and desirable to include in the NRCA during the scoping phase were not included in the assessment due to lack of information or data, poor understanding of their ecological role and significance in the landscape, their absence at the memorial, or other reasons. The latter case for eliminating resources considered to have a lower priority for inclusion also reflected realities related to balancing cooperator budget, breadth of the assessment across many resources and depth of analysis. The following resources were discussed and eliminated from inclusion in the document:

Scenery: Visual resources have not been assessed for the memorial. Some important memorial views may be impacted by inconsistent elements. Viewpoints are somewhat limited in number due to relatively flat topography and the enclosed nature of the mostly forested landscape, but a number of high-quality and important views exist. Some important views are associated with the memorial structures and formal allée, the Nancy Lincoln gravesite, and the re-created historic farm.

Water Quality and Wetlands/Ephemeral Pools: Water resources at the memorial consist of several ephemeral pools and small streams and a small, constructed farm pond. The ephemeral pools may provide breeding habitat for some amphibians.

Species of Concern: little data are available for individual species of concern. The occurrence of rare species has mostly been documented via park-wide faunal and floral surveys.

Terrestrial Invertebrates: the memorial staff is interested in knowing more about insects and other invertebrates, including pollinators. However, no surveys of this faunal group have been completed for the park.

Reporting Areas

The reporting area for all resources varies by resource but is often the entire area within the memorial boundary. In some cases, indicators were analyzed using subsets based on geographic or ecological strata within the memorial, e.g., forests vs. grasslands. The results for each subset were then combined into single memorial-wide condition and trend ratings for the resource. For several resources such as those capturing landscape context, the extent of the analysis extends outside memorial boundaries in a fixed or variable way.

General Approach and Methods

General Approach

This study employed a scoping process involving Colorado State University, memorial and NPS staffs to discuss the NRCA framework, identify important memorial resources, and gather existing literature and data for each of the focal resources. Indicators and measures to be used for each resource were then identified and evaluated. All available data and information were analyzed and synthesized to provide summaries and address condition, trend and confidence. Condition ratings compared the current condition at the memorial to the reference condition when possible. In some cases, due to interrelationships, one focal resource was used to help determine condition and/or trend for another focal resource.

Sources of Information and Data

Non-spatial data, published literature, unpublished reports and other grey literature related to conditions both inside and outside the memorial were obtained from myriad sources. The primary sources for memorial-specific resource data were park staff, the Heartland I&M Network (HTLN) staff, and the public access side of the IRMA (Integrated Resource Management Applications) web portal, which is intended as a "one-stop shop" for data and information on NPS-related resources. Memorial and HTLN staff were an invaluable source of knowledge regarding resources, stressors and management history and activities. State and federal agency reports and data were downloaded using the internet or obtained from the memorial or other agency staff. Spatial data were provided by the memorial, HTLN staff, the NPS Midwest Regional Office and other sources. The NPS I&M Program and Night Skies and Natural Sounds Division (NSNSD) also provided data to support the assessment. Primary data sources are described in each focal resource section. In some cases, existing data were reworked in order to make them more useful for analysis.

Subject Matter Experts

A number of subject matter experts were consulted while developing this assessment. Expert involvement included in-person and telephone meetings, correspondence, and reviews of preliminary resource drafts. The experts consulted for each focal resource are listed in the resource sections in the chapter on Natural Resource Conditions.

Data Analyses and NRCA Development

Data analyses and development of technical sections followed NRCA guidance and recommendations provided by the NPS. Data analyses were tailored to individual resources, and methods for individual analyses are described within each section of the chapter on Natural Resource Conditions. As one of the tenets of the NRCA framework, geospatial analysis and presentation of results is used where possible throughout the assessment. Periodic contact between the authors, memorial and other NPS staff and subject matter experts took place as needed to obtain additional data and information or collaborate on an analysis framework or approach or on the interpretation of results.

Final Assessments

Final drafts followed a process of preliminary draft review and comment by memorial staff and other NPS reviewers. Reviewer comments were incorporate and addressed to improve the analysis within the limits of the NRCA scope, schedule and budget.

Rating Condition, Trend and Confidence

For each focal resource, a reference condition for each indicator is established and a condition rating framework presented. The condition rating framework forms the basis for assigning a current condition to each indicator. In some cases, current condition and trend may be based on data or information that is several or more years old. Condition may be based on qualitative, semi-quantitative or quantitative data. Trend is assigned where data exist for at least two time periods separated by an ecologically significant span or may be based on qualitative assessments using historical information, photographs, anecdotal evidence or professional opinion. It is not uncommon for there to be some correlation among indicators for a particular focal resource. In a few cases, the trend assigned to an indicator may be influenced by the data for a correlated indicator. For example, traffic trend data may influence the trend rating for anthropogenic noise levels.

The level of confidence assigned to each indicator integrates the comfort level associated with the condition and/or trend rating assigned. A lower confidence (i.e., higher uncertainty) may be assigned where modeled data have considerable uncertainty or numerous assumptions, where changes may be small and no quantitative data are available, where statistical inference is poor (e.g., as is often the case where sample sizes are inadequate), where interannual or seasonal variability is very high or unknown, where detectability is difficult when monitoring (e.g., some plants and birds), where only several closely spaced data points are available for trend determination (e.g., invasive exotic plant sampling only several years apart and only 2 periods available), or where a very small proportion of the reference frame or population of interest is sampled (in time or space), which influences the representativeness of the sample (e.g., the timing and length of attended listening data for natural sounds analysis). Lack of information/data may result in an unknown condition rating, which is often associated with unknown trend and low confidence.

Symbology and Scoring[12]

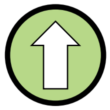
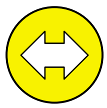
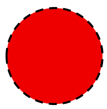
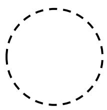
This NRCA uses a standardized set of symbols to represent condition status, trend and confidence in the status and trend assessment (Table 3, Table 4). This standardized symbology provides some consistency with other NPS initiatives and reporting programs.

Table 3. Standardized condition status, trend and confidence symbology used in this NRCA.

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

[12] Adapted from NPS-NRCA Guidance Update dated January 18, 2018 (NPS 2018c).

Table 4. Examples of how condition 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.

The overall assessment of the condition for a focal resource may be based on a combination of the status and trend of multiple indicators and specific measures of condition. A set of rules was developed for summarizing the overall status and trend of a particular resource when ratings are assigned for two or more indicators or measures of condition. To determine the combined condition, each red symbol is assigned zero points, each yellow symbol is assigned 50 points, and each green symbol is assigned 100 points. Open (uncolored) circles are omitted from the calculation. Average scores of 0 to 33 warrant significant concern, average scores of 34 to 66 warrant moderate concern and average scores of 67 to 100 indicate the resource is in good condition. In some cases, certain indicators may be assigned larger weights than others when combining multiple metrics into a condition score. In those cases, the authors provide an explanation for the weights applied.

To determine the overall trend, the total number of down arrows is subtracted from the total number of up arrows. If the result is 3 or greater, the overall trend is improving. If the result is −3 or lower, the overall trend is deteriorating. If the result is between 2 and −2, the overall trend is unchanged. Sideways trend arrows and cases where trend is unknown are omitted from this calculation. Subjective weighting of indicators is sometimes applied.

Organization of Focal Resource Assessments

Background and Importance

This sub-section provides information regarding the relevance of the resource to the memorial and the broader ecological or geographic context. This sub-section explains the characteristics of the resource to help the reader understand subsequent sub-sections of the document. Relevant stressors of the resource and the indicators/measures selected are listed or discussed.

Data and Methods

This sub-section describes the source and type of data used for evaluating the indicators/measures, data management and analysis (including qualitative) methods used for processing or evaluating the data, and outputs supporting the assessment

Reference Conditions

This sub-section describes the reference conditions applied to each indicator and how the reference conditions are cross-walked to a condition status rating for each indicator. NRCAs must use logical and clearly documented forms of reference conditions and values. Reference condition concepts and guidance are briefly described in the NRCA Background Information chapter. A reference condition is “a quantifiable or otherwise objective value or range of values for an indicator or specific measure of condition that is intended to provide context for comparison with the current condition values. The reference condition is intended to represent an acceptable resource condition, with appropriate information and scientific or scholarly consensus” (NPS 2018c). An important characteristic of a reference condition is that it may be revisited and refined over time. The nature of the reference condition prescribed for a particular resource can vary with the status of the resource relative to historical conditions and anticipated future conditions (Figure 5).

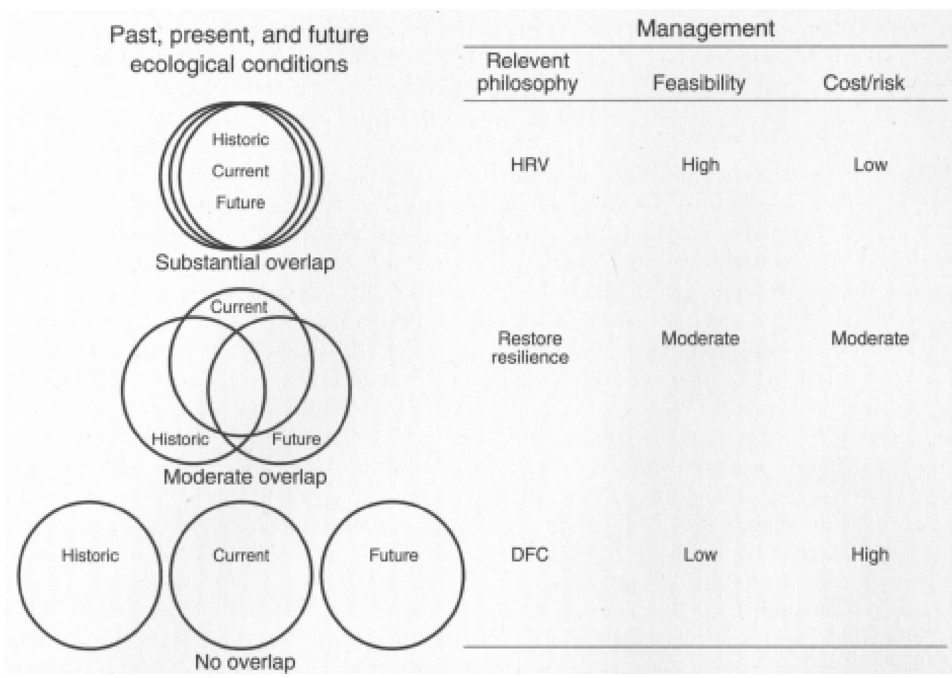


Figure 5. Illustration of three possible cases of the extent to which current ecosystem conditions in a place differ from historical conditions and from projected future conditions. Circles denote the range of variability for each time period. Also shown are the expected management criteria for each case. Abbreviations are HRV, historical range of variability and DFC, desired future conditions (Hansen et al. 2014).

Several sub-sections, namely the *Climate Change* and *Land Cover and Land Use* sub-sections, are included for their contextual value and do not assign reference conditions or condition/trend ratings.

For example, moderate overlap may exist for forest vegetation or natural night skies; little or no overlap may exist for nonnative invasive plants. Reference conditions can be particularly difficult to define where presettlement or period of significance conditions or range of variability are unknown, and/or where little inventory and monitoring data exist.

Condition and Trend
This sub-section provides a summary of the condition for each indicator/measure based on available literature, data, and expert opinions. A condition status, trend and confidence designation for each indicator/measure is assigned and accompanying rationale is provided. Where multiple indicators or metrics are used, a single rating is consolidated for each resource using the condition rating scoring framework described earlier in this chapter.

Uncertainty and Data Gaps
This sub-section briefly highlights information and data gaps and uncertainties related to assessment of the focal resources.

Sources of Expertise
Individuals who were consulted or provided preliminary reviews for the focal resource are listed in this sub-section.

Chapter 4. Natural Resource Conditions

Land Cover and Land Use

Background and Importance

This section places LIBO resources and management concerns within a local and regional context of land cover and land use and examines implications related to population and resource conservation. Using several metrics, it characterizes conditions and dynamics of the surrounding areas, highlights the potential effects of related landscape-scale stressors on memorial resources, and underscores the conservation value of LIBO to the surrounding region. The synthesis of national data uses a series of straightforward spatial analyses for areas within and surrounding the memorial. Condition and trend ratings are not assigned to these landscape context metrics. In some cases, long-term data are not available and for the most part LIBO has little influence over activities occurring outside memorial boundaries. Longer-term data are available for some population and housing metrics.

Indicators of landscape context applied here include a variety of metrics for land cover and land use, population and housing, and land conservation status. Due to the relatively small size of LIBO, the overwhelmingly non-natural status of surrounding lands, and the lack of significant regional migration by terrestrial fauna of concern, road densities and habitat fragmentation and connectivity both within the park and outside the park are not examined.

<u>Threats and Stressors</u>

Land use is intensifying around many protected areas including parks, monuments, and memorials (Wittemyer et al. 2008, Wade and Theobald 2010, Davis and Hansen 2011, Hansen et al. 2014). Many parks in the region are concerned with the ecological consequences of habitat loss associated with urbanization outside park boundaries, conversion of surrounding areas to non-natural uses, as well as the effects of runoff from impermeable surfaces on hydrologic flows through the parks (Hansen and Gryskiewicz 2003). Farmland acreage around LIBO declined by over 20% between 1950 and 2000 (Hansen and Gryskiewicz 2003). The growth of housing adjacent to protected areas can create a patchwork of land use that degrades the conservation impact of high-value protected areas on adjacent parcels and within the region (Radeloff et al. 2010). Protected areas are most effective when they conserve habitat within their boundaries and are connected with other protected areas via intact corridors (Radeloff et al. 2010). According to the Radeloff et al. study, the main threat to protected areas in the U.S. is housing density, which is highly correlated with population density. The adverse effects of development also impact the quality of the natural environment and visitor experience related to natural night skies, natural soundscapes and viewscapes/scenery.

Linkages between land use change and ecological functioning at LIBO were explored by Hansen and Gryskiewicz (2003) as part of a broader examination of land use change within the Heartland Network region. Their findings for LIBO are summarized below:

> *LIBO has been part of an agricultural landscape for centuries, so ecosystems within the park most likely adapted long ago to rural human settlements and moderate levels of human activity. However, in recent decades the region around the park has been transforming from*

rural to more urban (housing densities have increased 339% since 1950), and landscape characteristics reflect this. The park landscape experiences water quality that is moderately altered by human-caused pollution, has high levels of hydrologic modification, and a significant industrial presence (the highest of all Heartland parks, with one industrial site every 17 square miles). Consequently, park managers are concerned about how this transformation from a rural agricultural landscape to one that is more urban will impact park natural resources.

LIBO is a relatively small, largely terrestrial park, and park management priorities focus on preserving and restoring forest health and associated wildlife populations. Because the park is located within a fragmented landscape, land use changes that disrupt habitat connectivity and further isolate the park from external remnant forest tracts (especially those to the northwest and east), may be an important focus for establishing land use change monitoring priorities. Urban development which eliminates unique habitats such as corridors, source habitats, and seasonal habitats may significantly influence park ecological functioning, and may hinder efforts to restore wildlife populations within the park. Additionally, increases in human population and residential settlements around the park may intensify edge effects and exacerbate the spread of exotic plants within the park, as well as increase recreational use and human disturbance inside of the park.

<u>Indicators and Measures</u>

- Land cover and use
- Extent of Anderson Level II classes
- Extent of natural vs. converted land cover
- Extent of impervious surface area
- Human population and housing
- Housing density
- Historical population: total and density
- Population: current and projected total and density
- Conservation status
- Protected area (ownership) extent
- Biodiversity conservation status (level of protection)

Data and Methods

Spatial data for land cover, human population, and housing used for condition and trend analysis were provided by the NPS NPScape Program and follow protocols described in Monahan et al. (2012). Sources of other data are noted below.

<u>Defining Areas of Interest</u>

Landscape context elements within and adjacent to the memorial were compared to resource conditions in the area surrounding the memorial. Landscape attributes important to park resources often vary with scale or spatial extent. Relevant scales or areas of analysis (AOAs) include the landscape within the park itself (i.e., the reporting unit used for many focal resources in this report), the "boundary" area immediately adjacent to the park (i.e., 3 km buffer), the local area surrounding a park (i.e., within 30 km of the park boundary), and nearby counties. Areas of analysis used for the different landscape context indicators and metrics are based on recommendations from Monahan et al. (2012) (Table 5) and serve to capture a variety of scales to facilitate examination of the integrated effects of human activities. The memorial is relatively small, regional topography is very gentle, and climate is fairly uniform throughout the areas of interest.

Table 5. Areas of analysis used for land cover and land use measures. An "X" indicates that parameter was used, and an endash ("–") indicates that it was not used in the analysis.

<table>
<tr><th>Indicators</th><th>Measures</th><th>3 km buffer around park</th><th>Park + 30-km buffer</th><th>Counties overlapping with park + 30-km buffer</th></tr>
<tr><td rowspan="3">Land Cover and Use</td><td>Anderson Level II</td><td>X</td><td>X</td><td>–</td></tr>
<tr><td>natural vs. converted land cover</td><td>X</td><td>X</td><td>–</td></tr>
<tr><td>impervious surfaces</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td rowspan="3">Human Population and Housing</td><td>population total and density by census block group (historical and projected)</td><td>–</td><td>X</td><td>–</td></tr>
<tr><td>historical population totals by county</td><td>–</td><td>–</td><td>X</td></tr>
<tr><td>housing density 1970–2010</td><td>–</td><td>X</td><td>–</td></tr>
<tr><td>Conservation Status</td><td>Protected areas (ownership) and biodiversity conservation status</td><td>X</td><td>X</td><td>–</td></tr>
</table>

Land Cover

United States Geological Survey (USGS) National Land Cover Dataset (NLCD) data for 2011 were used to characterize current/recent conditions. NLCD data products are derived from Landsat Thematic Mapper (TM) imagery with a 30 m pixel resolution. NLCD summaries employ a well-documented, consistent procedure that is highly repeatable over time. Although NLCD data date back to 1992, differences in classification and analysis methods do not favor comparison of the 1992 data with 2011 data (Monahan et al. 2012). Procedures for the summarization of data for the following indicators are from NPS (2014a).

Anderson land cover/land use classes: NLCD data were interpreted and classified using Anderson Level II land cover classes (Table 6) for the areas of analysis listed in Table 5.

Acreage of natural vs. converted land cover: The NLCD Anderson Level I “developed” and “agriculture” classes were reclassified as “converted” (Table 6) and analyzed using the areas of analysis listed in Table 5. Other classes were classified as “natural.”

Table 6. Anderson land cover/land use classes (Anderson et al. 1976) and rules for reclassifying Anderson land cover as natural vs. converted land cover.

Anderson Level I	Anderson Level II	Natural/Converted
Open Water	–	Natural
Developed	–	Converted
Barren/Quarries/Transitional	–	Natural
Forest	–	Natural
Shrub/Scrub	–	Natural
Grassland/Herbaceous	–	Natural
Agriculture	pasture/hay vs. cultivated agriculture	Converted
Wetlands	–	Natural

Human Population and Housing

Housing Density

Change from 1970 to 2010 and projected changes to 2050 were examined. The NPScape housing density metrics used here are based on the Spatially Explicit Regional Growth Model (SERGoM v3) (Theobald 2005). Housing densities are categorized into 11 non-uniform development classes and then reclassified as described by Theobald (2005): rural (0–0.0618 units/ha), exurban (0.0618–1.47 units/ha), suburban (1.47–10.0 unit/ha), and urban (> 10.0 units/ha). The non-uniform ranges permit a much finer delineation of areas of low-density housing than is common for non-ecological studies (Monahan et al. 2012).

Total Population and Population Density

Historical data were derived from county-level population totals for all counties overlapping with the 30-km park buffer, and U.S Census Bureau block data from 1990, 2000 and 2010 for population density. Population density (number of people per square kilometer) classes follow NPScape guidance (NPS 2014b).

Conservation Status

For our region of interest, the two primary sources of protected areas data were the Protected Areas Database-US (PAD-US) Version 2 (Conservation Biology Institute 2013) and the National Conservation Easement Database (NCED 2013). The two databases are designed to be used together to show comprehensive protection status for areas of interest while using compatible database attributes such as ownership type and agency.

Ownership

Land ownership greatly influences the level of conservation protection. The PAD-US (CBI Edition) Version 2 is a national database of protected fee lands in the United States. It portrays the United

States protected fee lands with a standardized spatial geometry with valuable attribution on land ownership, management designations, and conservation status (using national GAP coding systems). The National Conservation Easement Database (NCED) Version III (July 2013) is a voluntary national geospatial database of conservation easement information that compiles records from land trusts and public agencies throughout the United States. It is a collaborative partnership by the Conservation Biology Institute, Defenders of Wildlife, Ducks Unlimited, NatureServe, and the Trust for Public Land (NCED 2013). As of August 2018, the acreage of publicly-held easements is considered to be 42% complete for Indiana; the accounting of the acreage of NGO-held easements in Indiana is currently estimated at approximately >96% complete (NCED 2018).

Level of Protection

The USGS Gap Analysis Program (GAP) uses a scale of I to IV to categorize the degree of biodiversity protection for each distinct land unit (Scott et al. 1993). A status of "I" denotes the highest, most permanent level of maintenance, and "IV" represents no biodiversity protection or areas of unknown status. The PAD-US (CBI Version 2) database includes the coded GAP biodiversity protection status of each parcel. The NCED database is designed to accommodate the GAP protection status field, but most parcels have not been assigned a GAP conservation value. The four status categories are described below.

Status I: These areas have permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, and intensity) are allowed to proceed without interference or are mimicked through management. Most national parks, Nature Conservancy preserves, some wilderness areas, Audubon Society preserves, some USFWS National Wildlife Refuges and Research Natural Areas are included in this class.

Status II: These areas have permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive use or management practices that degrade the quality of existing natural communities. Some national parks, most wilderness areas, USFWS Refuges managed for recreational uses, and BLM Areas of Critical Environmental Concern are included in this class.

Status III: These areas have permanent protection from conversion of natural land cover for the majority of the area but may be subject to extractive uses of either a broad, low-intensity type or localized intense type. This class also confers protection to federally-listed endangered and threatened species throughout the area. Most non-designated public lands, including USFS, BLM and state park land are included in this class.

Status IV: These areas lack irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types. This class allows for intensive use throughout the tract and includes those tracts for which the existence of such restrictions or sufficient information to establish a higher status is unknown. Most private lands fall into this category by default.

Protected areas data from the two databases was examined by owner type and by easement protection status within a 30-km buffer of the park boundary. GAP biodiversity protection values were summarized for NCED and PAD-US parcels by ownership type within the 30-km buffer areas of interest. There is some spatial overlap between the PAD-US and NCED databases due to the existence of easements on some lands owned by federal, state and local agencies. Where easements existed on these public (i.e., protected) lands, the acreages were reported by owner only to avoid double counting in the number of protected acres.

Condition and Trend

Land Cover and Use

Extent of Anderson Level II Classes 2011

In the immediate vicinity of LIBO (3 km buffer) over 47% of land acreage is deciduous forest, and 35% is cultivated crops (predominantly to the north) (Table 7, Figure 6). Less than 8% of the land area within 3 km of LIBO is developed. Within the 30-km buffer, over 37% of the acreage is cultivated crops and over 36% is deciduous forest. Although the forests surrounding LIBO are fairly patchy and lack a high degree of connectivity, the patches are much larger than those surrounding other federal and state parks in the region (Figure 6). Within 30 km of the memorial boundary, there is less forest and more hay pasture compared to the boundary area.

Table 7. Anderson Level II land cover classes within 3 km and 30 km of the LIBO park boundary.

	3 km Buffer		Park + 30km Buffer	
Anderson Level 2 Classes	**Acres**	**% of Area**	**Acres**	**% of Area**
Barren Land	24	0.24%	1,272	0.17%
Cultivated Crops	3,583	35.05%	273,185	37.49%
Deciduous Forest	4,876	47.69%	265,425	36.43%
Developed, High Intensity	15	0.15%	1,497	0.21%
Developed, Low Intensity	60	0.59%	6,832	0.94%
Developed, Medium Intensity	160	1.56%	3,266	0.45%
Developed, Open Space	504	4.93%	40,437	5.55%
Emergent Herbaceous Wetlands	8	0.08%	2,843	0.39%
Evergreen Forest	259	2.53%	15,361	2.11%
Hay/Pasture	541	5.29%	84,641	11.62%
Herbaceous	54	0.52%	11,702	1.61%
Mixed Forest	0	0.00%	112	0.02%
Open Water	94	0.92%	14,346	1.97%
Perennial Snow/Ice	0	0.00%	0	0.00%
Shrub/Scrub	3	0.03%	554	0.08%
Unclassified	0	0.00%	0	0.00%
Woody Wetlands	43	0.42%	7,129	0.98%
Total	10,223	–	728,602	–

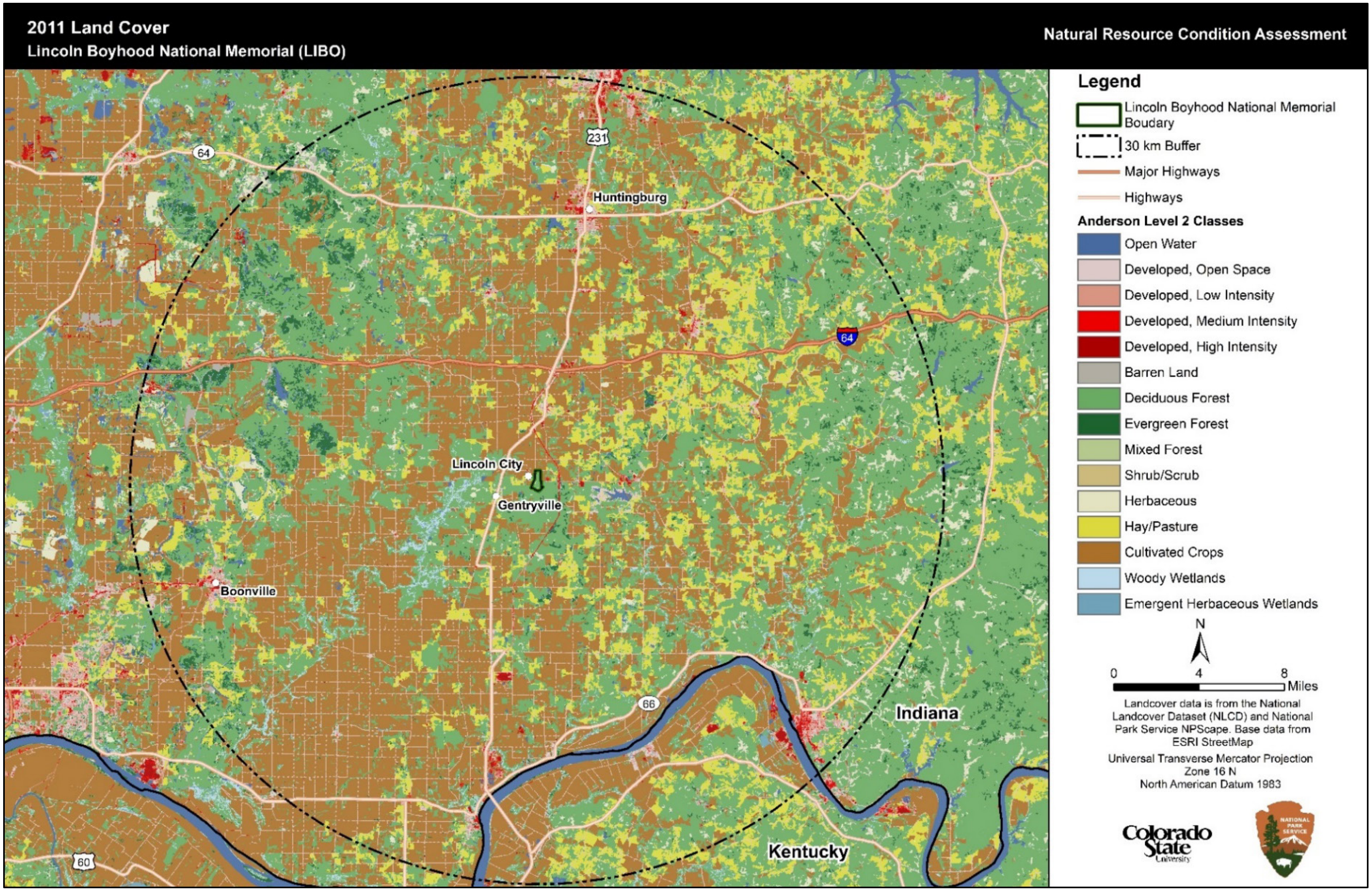


Figure 6. Anderson Level II land cover classes within 3 km and 30 km of the LIBO boundary. (Data source: National Land Cover Dataset provided by NPS NPScape Program, ESRI StreetMap.)

Natural vs. Converted Land Cover

Change in natural land cover is possibly the most basic indication of habitat condition (O'Neill et al. 1997). Knowing the ratio of natural land cover area to converted land area provides a general indication of overall landscape condition, offering insight into potential threats and opportunities for future conservation.

The proportion of converted acreage surrounding LIBO is comparable to the surrounding region (Table 8, Figure 7). Within 30 km of the memorial boundary, over 56% of the area is classified as converted (Figure 7).

Table 8. Natural vs. converted acreage within 3 km and 30 km of the park boundary.

	Natural		Converted	
AOA	**Acres**	**% of Area**	**Acres**	**% of Area**
3 km	5,360	52.43%	4,863	47.57%
Park + 30-km Buffer	318,743	43.75%	409,857	56.25%

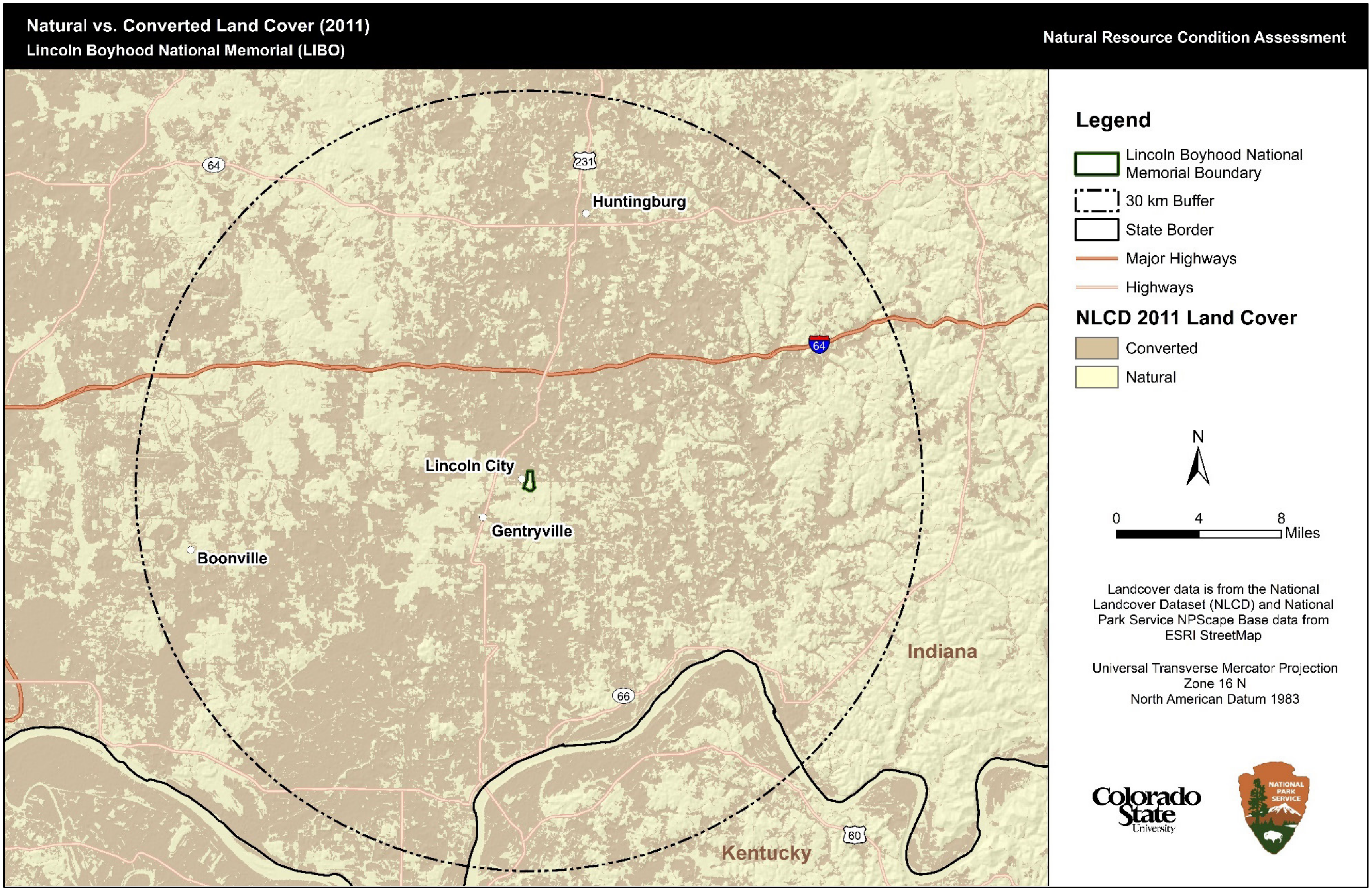


Figure 7. Natural vs. converted land cover classes within 3 km and 30 km of the park boundary. (Data sources: 2006 National Land Cover Dataset provided by NPS NPScape Program, ESRI StreetMap.)

Population and Housing

Historical and Projected Population

High human population density has been shown to adversely affect the persistence of habitats and species (Kerr and Currie 1995, Woodroffe 2000, Parks and Harcourt 2002, Luck 2007). Conversion of natural landscapes to agriculture, suburban, and urban landscapes is generally permanent, and this loss of habitat is a primary cause of biodiversity declines (Wilcove et al. 1998). Human conversion of landscapes can alter ecosystems and reduce biodiversity by replacing habitat with non-habitable cover types and structures, fragmenting habitat, reducing availability of food and water, increasing disturbance by people and their animals, altering vegetation communities, and increasing light, noise, and pollution.

Population density within 30 km of LIBO's boundary is low, with most of the area within this 30-km radius having a density of 1–75 people/km^2 (Table 9, Figure 8). Historically, population has increased in the region, with an accelerated increase since the 1970s (Figure 9).

Table 9. Population density classes and acreage for 1990, 2000, and 2010 by census block group for the park and surrounding 30-km buffer (U.S. Census Bureau 2010).

	1990		2000		2010	
Population Density (#/km2)	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
1–20	581,539	79.82%	515,852	70.80%	473,730	65.02%
21–75	118,133	16.21%	185,913	25.52%	228,179	31.32%
76–150	14,770	2.03%	17,112	2.35%	17,091	2.35%
151–300	9,669	1.33%	3,743	0.51%	4,394	0.60%
301–750	2,236	0.31%	4,541	0.62%	3,314	0.45%
751–1200	926	0.13%	522	0.07%	1,266	0.17%
1201–1500	817	0.11%	483	0.07%	485	0.07%
1501–2000	512	0.07%	438	0.06%	144	0.02%
2001–3000	0	0.00%	0	0.00%	0	0.00%
>3000	0	0.00%	0	0.00%	0	0.00%

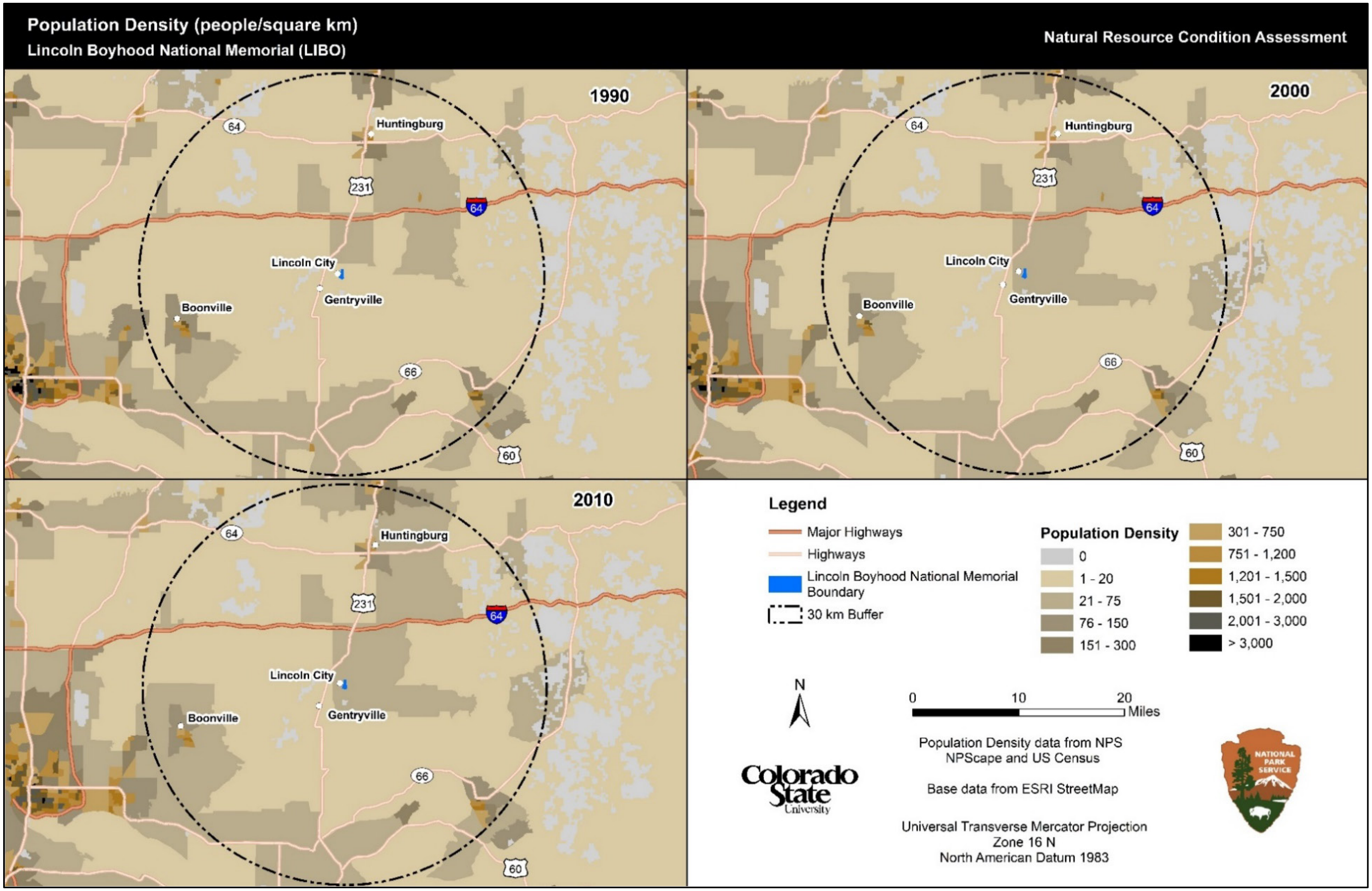


Figure 8. Population density for 1990, 2000, and 2010 by census block group for the park and surrounding 30-km buffer. Population density in # people per square kilometer. (Data sources: U.S. Census data provided by NPS NPScape Program, ESRI StreetMap.).

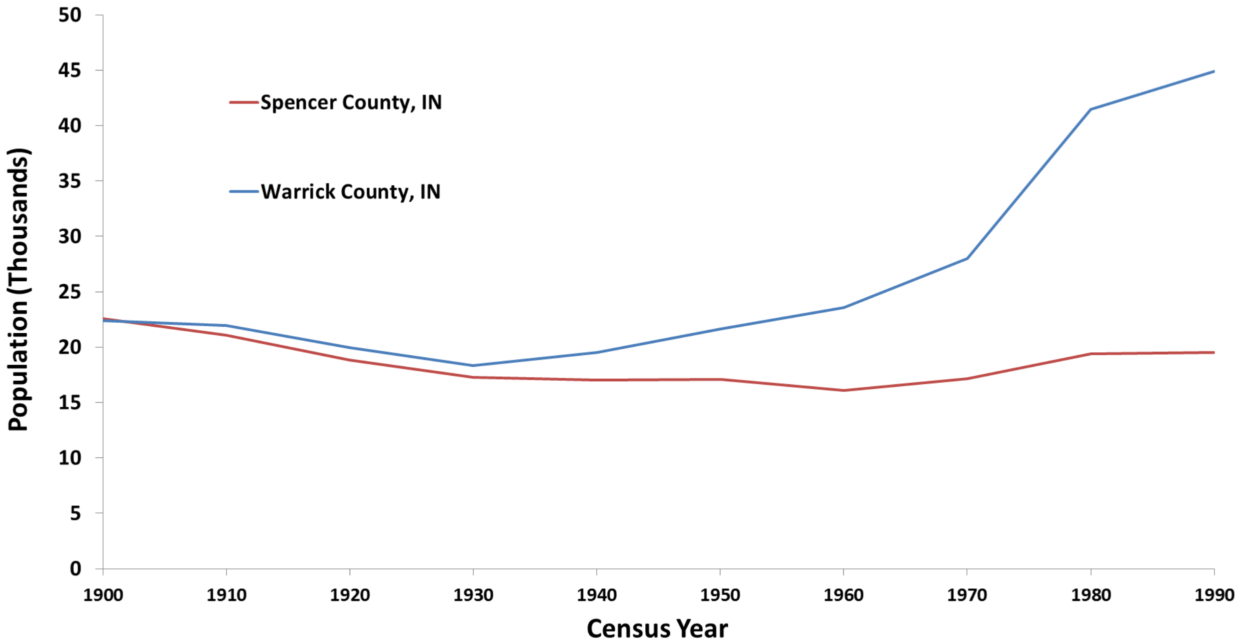


Figure 9. Historical population by decade for counties within 30 km of LIBO (U.S. Census Bureau 2010).

Housing Density

Housing density in the region surrounding the park shows an increase in exurban development and corresponding decrease in rural development between 1970 and 2010 (Table 10, Figure 10). Areas shown in white in Figure 10 are primarily state and federal wildlife areas.

Table 10. Historical housing density by decade for 1970–2020 for the park and surrounding 30-km buffer (U.S. Census Bureau 2010). Urban housing density was <0.1% of the area for all periods.

Census Year	Rural (0–0.0618 units/ha)		Exurban (0.0618–1.47 units/ha)		Suburban (1.47–10.0 units/ha)	
	Acres	% of Area	Acres	% of Area	Acres	% of Area
1970	666,326	96.40%	13,913	2.02%	3,007	0.44%
1980	655,733	94.87%	23,610	3.42%	3,934	0.57%
1990	645,930	93.45%	32,588	4.71%	4,702	0.68%
2000	626,841	90.57%	51,316	7.41%	5,859	0.85%
2010	619,129	89.52%	58,537	8.46%	5,856	0.85%
2020	617,135	89.24%	60,523	8.75%	5,864	0.85%

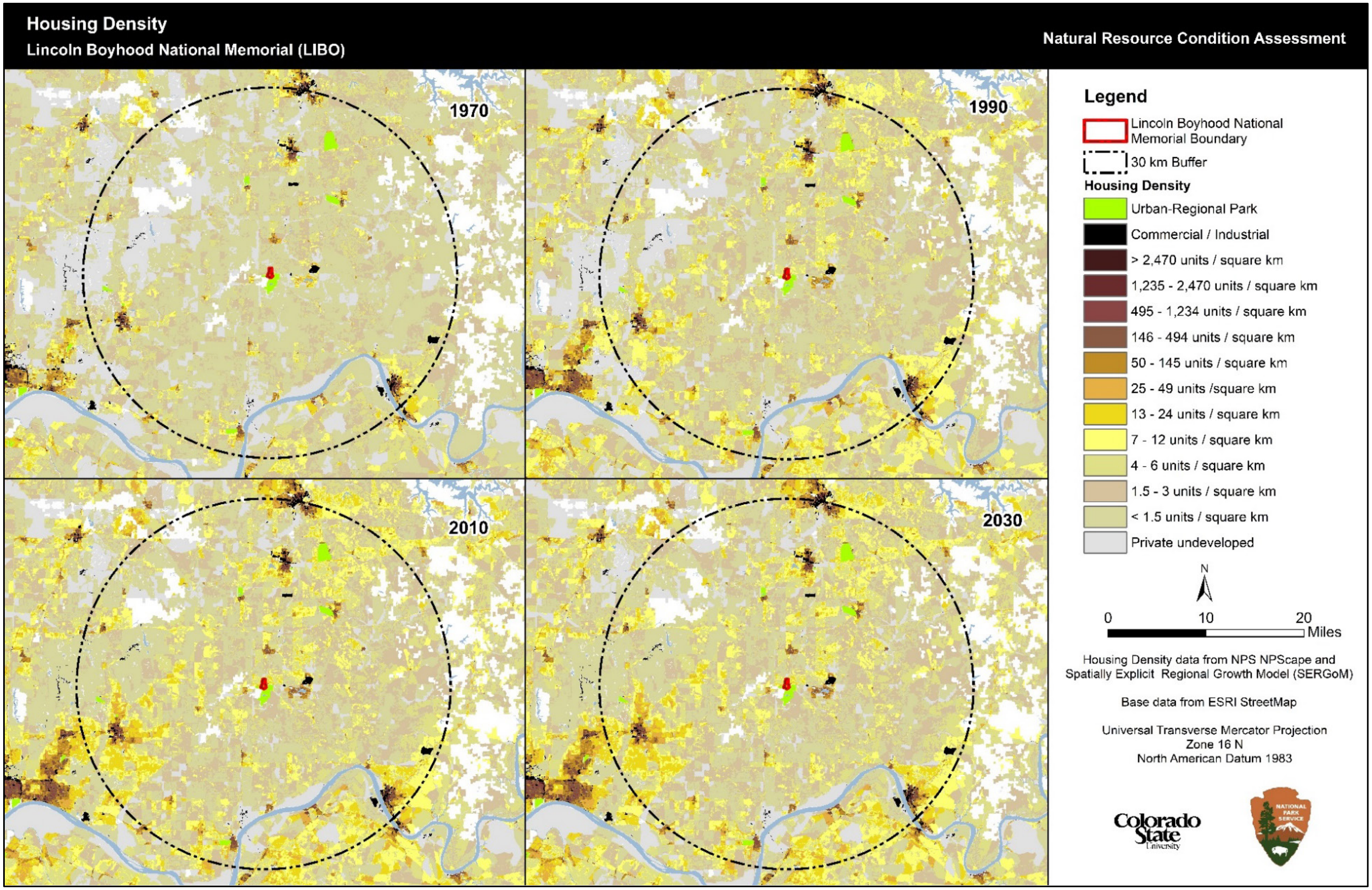


Figure 10. Historical and projected housing density for 1970, 1990, 2010 and 2030 for LIBO and the surrounding 30-km buffer. Areas of no data (white) represent protected lands (especially publicly owned and including some private lands with conservation easements) (NPS 2013). (Data sources: SERGoM data provided by NPS NPScape Program, ESRI StreetMap).Level of Protection

Within 30 km of the memorial, less than 4% of the acreage has some level of protection (Level I-III; Table 11; Figure 11). Most of the protected land is in Status II (Table 12). More than 96% of land area surrounding the memorial is not protected, which highlights the importance of LIBO and other occasional parcels that do provide biodiversity protection in the region. Moreover, in protected areas such as LIBO natural processes and disturbance regimes are more likely to occur, support a greater degree of biodiversity, and provide critical linkages to the surrounding natural landscape.

Table 11. Acreage of lands within 30 km of the boundary of LIBO with some level of protection. Percentages are the proportion of total AOA area. (PAD-US and NCED data).

	Park + 30-km Buffer	
Ownership	**Acres**	**% of Area**
Federal	3,252	0.45%
Native American	0	0.00%
State	23,369	3.21%
City and County	0	0.00%
Private Conservation	898	0.12%
Joint Ownership/Unknown	4	<0.01%
Total	**27,523**	**3.78%**

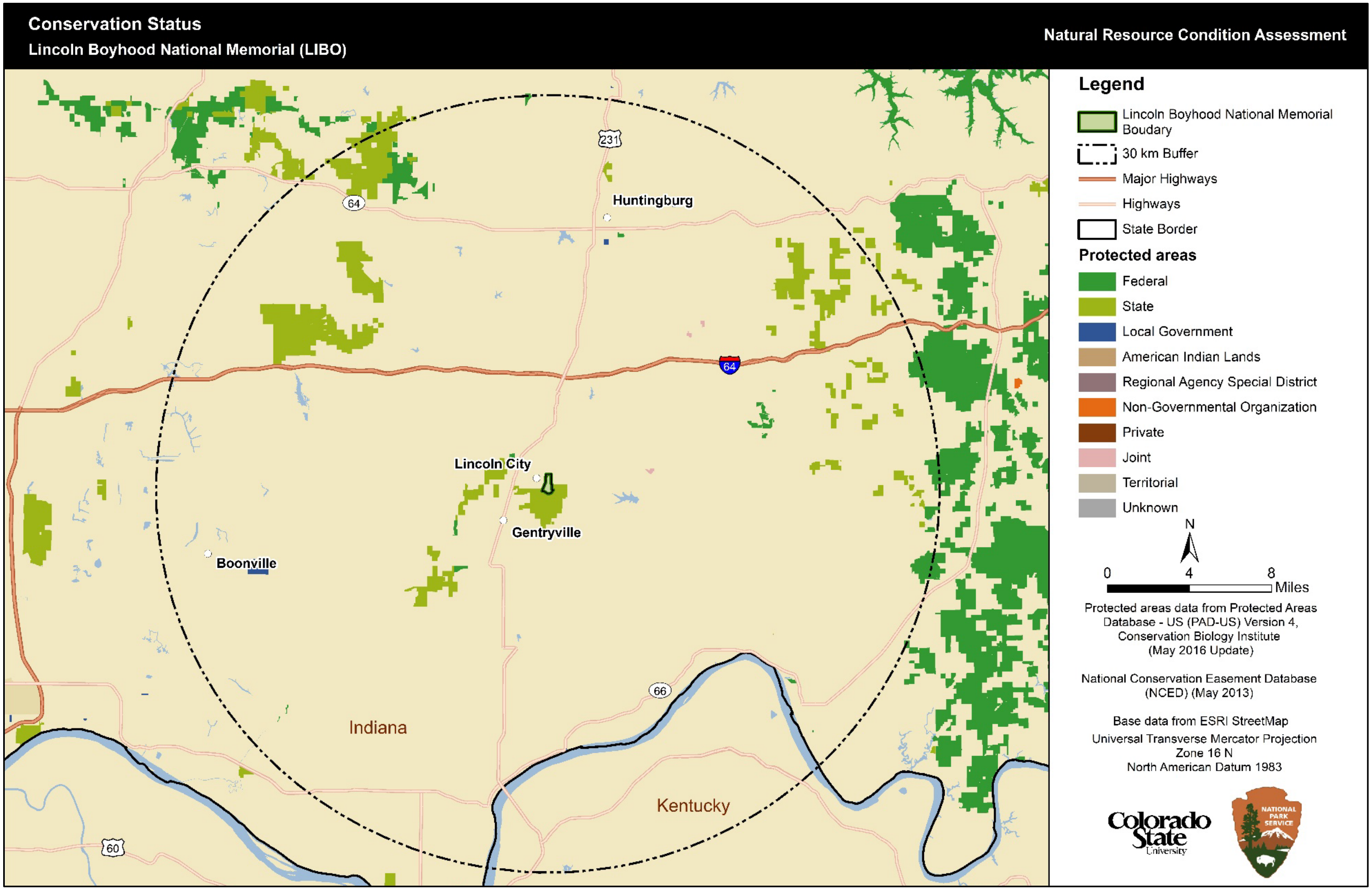


Figure 11. Conservation status of lands within 30 km of the LIBO boundary. (Data sources: Protected Areas Database – US Version 4, Conservation Biology Institute, National Conservation Easement Database, ESRI StreetMap).

Table 12. Biodiversity protection status of lands within 30 km of the park boundary (PAD-US and NCED data). Percentages are the proportion of total AOA area.

	Park + 30-km Buffer	
Protection Level	**Acres**	**% of Area***
I (highest)	2,381	0.33%
II	17,324	2.38%
III	2,944	0.40%
IV (lowest/status unknown)	4,874	0.67%
Total	**27,523**	**3.78%**

* The remaining acreage within the area of analysis is comprised of private lands with no known conservation protection.

Land Cover and Land Use Summary

Specific reference conditions are not defined for the metrics examined, and NRCA condition ratings are therefore not assigned. The general idea is that conditions and trends showing degraded or deteriorating levels of naturalness, increasing human development/disturbance, and increasing human populations are undesirable as they tend be correlated with reduced ecosystem function and diversity and can also impact the visitor experience.

Indicator summaries are presented in Table 13. Overall, the memorial is within a semi-natural landscape with a high proportion of cropland and deciduous forest. Significant changes in land cover and population/housing over the past several decades are well documented. The lack of substantial and well-connected protected areas outside the memorial makes it more difficult to maintain a diversity of native plants and animals within LIBO. Overall, the status and degree of these threats and stressors on LIBO are relatively low in comparison to other parks in the region. Nonetheless, the effects of urbanization and fragmentation impact ecological functioning, increase undesirable edge effects on vegetation and wildlife, and exacerbate the spread of exotic plants within the park. Natural night skies and park soundscape are significantly impacted by increasing urbanization and population densities. This summary of land cover and land use metrics provides a useful context of known stressors, supports resource planning and management within the park, and provides a foundation for collaborative conservation with other landowners in the surrounding area.

Table 13. Summary for land cover and land use indicators, Lincoln Boyhood National Memorial.

Indicator	Measure	Summary Notes Integrating Results for 3 km and 30 km Areas of Interest
Land Cover	Extent of Anderson Level II classes	Most of the acreage surrounding LIBO is deciduous forest and cultivated crops.
	Extent of natural vs. converted land cover	The proportion of converted acreage surrounding LIBO is moderate and comparable to the surrounding region.
Population and Housing	Historical and projected population total and density	Population density within 30 km of the memorial's boundary is low, with most of the area within this 30-km radius having a density of 1–75 people/km2. The low population density of the area is attributable to the prevalence of forest and cropland surrounding LIBO. Historically, the population of Spencer County has been increasing since 1930.
	Housing density	Within a 30-km radius of the park, the most notable trend is an increase in exurban areas and a corresponding decrease in rural acreage. The major change in housing density is associated with the existing urban center of Evansville, Indiana. However, there is also a pattern of increasing exurban housing density in unincorporated areas, including areas close to major roads.
Conservation Status	Protected area extent and biodiversity protection status	Only a very small portion of the acreage in the region surrounding the park is protected through ownership or conservation easements. The rarity of protected lands within the region underscores the value of the memorial as a conservation island within a heavily agricultural region.

Uncertainty and Data Gaps

The primary source of uncertainty is associated with assumptions regarding the relationships between land ownership and conservation status. Although information about ownership and protection status can be useful, the degree to which biodiversity is represented within the existing network of protected areas is largely unknown (Pressey at al. 2002). Protection status and extent must be combined with assessments of conservation effectiveness (e.g., location, design, and progress toward conservation objectives) to achieve more meaningful results (Chape et al. 2005).

Sources of Expertise

- Bill Monahan, Ph.D., NPS Inventory and Monitoring Division, Fort Collins, Colorado. Dr. Monahan provided NPScape data summaries and consulted on the selection and use of various metrics.

Natural Night Skies

Background and Importance

National parks serve as refuges for the endangered resource of natural darkness and starry night skies. Existing studies from the NPS Midwest Region since 2000 found that natural night skies are rated as "extremely" or "very" important by 57% of visitor groups (Kulesza et al. 2013). The National Park Service recognizes the significance of naturally dark night skies to humans and many wildlife species and aims to protect the night skies of parks just like other important natural resources. With nearly half of all species being nocturnal and requiring naturally dark habitat, the presence of excessive artificial light can cause significant impacts to these species (Rich and Longcore 2005). For humans, there is cultural, scientific, economic, and recreational value associated with high-quality night skies. NPS *Management Policies* state that the NPS "will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light" (NPS 2006). The *Management Policies* also provide specific actions that the NPS will take to prevent the loss of dark conditions and natural night skies: restricting the use of artificial lighting where safety and resource requirements allow, utilizing minimal-impact lighting techniques, and providing shielding for artificial lighting (Peel 2000, NPS 2006).

The National Park Service defines a natural lightscape as the resources and values that exist in the absence of human-caused light at night. Natural lightscapes are critical for nighttime scenery and nocturnal habitat. There are many species that depend on natural patterns of light and dark for navigation, predation and other natural processes. Light pollution is the introduction of artificial light either directly or indirectly into the natural environment. Light pollution can have a negative effect on the organisms within a park and can also reduce the enjoyment of park visitors; it degrades the view of the night sky by reducing the contrast between faint extraterrestrial objects and the background of the luminous atmosphere. An example of light pollution is sky glow, sometimes referred to as artificial sky glow, light domes or fugitive light, which is the brightening of the night sky from human-caused light scattered into the atmosphere. Another form of light pollution is glare, which is the direct shining of light. Both of these forms of light pollution impact the human perception of nighttime, natural landscapes and features of the night sky (NPS 2016a).

Excessive artificial light pollution in NPS units threatens to adversely impact natural and cultural resources and the quality of visitor experiences. It is important to document with reliable data existing baseline conditions of the lightscapes in national park units so that monitoring of long-term changes can be implemented, and management actions taken to restore natural conditions, where necessary (NPS 2016a). Poor air quality in combination with light pollution can dim the stars and other celestial objects and lead to reduced ability to see starry skies. Poor air quality also "scatters" artificial light, resulting in parks near cities and other significant light sources having a greater "sky glow" than if pollution was not present (Kulesza et al. 2013). The NPS has clearly declared its commitment to protecting natural night skies for the benefit of natural ecosystems and the enjoyment of current and future generations of park visitors.

Threats and Stressors

The relatively small size of Lincoln Boyhood National Memorial (LIBO) makes it more vulnerable to the effects of anthropogenic light sources on adjacent lands, which are predominantly private. The memorial is surrounded mainly by cropland and deciduous forest (Haack-Gaynor 2014) but is impacted by anthropogenic light sources nearby and from the larger region. The most immediate sources of artificial light impacting natural night skies are small cities like Lincoln City, Dale, and Gentryville. However, anthropogenic light can often be perceived several miles away from where it is originated (Falchi et al. 2016). Other sources of light pollution, including the sky glow from Evansville, Indiana (population 118, 930), Jasper, Indiana (population 15,519), and Owensboro, Kentucky, (population 59,404), could also be degrading natural night skies at LIBO. Light originating from modern transportation and development within and beyond the memorial's boundaries and from artificial lighting in the memorial also represents a distinct threat to the natural and historical natural dark skies of the memorial and to the quality of visitor experiences. Streetlamps and lights from vehicles on U.S Route 231, State Route 162, and other local roads could be significant sources of artificial light affecting visitor experience and the integrity of night skies inside the memorial.

A comprehensive examination of landscape context related to land cover/land use, population and housing, all of which are correlated with light pollution, was performed for the area surrounding LIBO and is presented in the *Land Cover and Land Use* section. Landscape context parameters can be highly correlated with ambient light levels. Therefore, changes in these factors can have significant impacts on the night sky of the park.

Indicators and Measures

- All-sky light pollution ratio (ALR)
- Artificial night sky brightness

Data and Methods

The NPS Natural Sounds and Night Skies Division (NSNSD) recommends modeled all-sky light pollution ratio (ALR) as a metric for assessing the condition of the night skies (Moore et al. 2013). NSNSD developed a nation-wide spatial model (calibrated to ground-based measurements) of median sky brightness levels; comparing the modeled brightness values to average natural night sky luminance yields the ALR. Modeling was applied to all NPS units, including the entire area of LIBO and the surrounding region. In addition, a geospatial data layer from Falchi (2016) provided data for artificial night sky brightness levels in the park and the surrounding region. Although the Falchi brightness values are not directly comparable with ALR, they are related and supplement the ALR data.

Two impact criteria were established by the NPS to address the issue of non-urban (Level 1) and urban (Level 2) park night sky resources (Table 14). Parks outside of designated urban areas are considered more sensitive to the impact of anthropogenic light and are assessed using lower thresholds of impact. Parks within urban areas, as designated by the U.S. Census Bureau, are considered less sensitive to the impact of anthropogenic light and are assessed using less stringent thresholds of impact. According to the U.S. Census Bureau, LIBO is categorized as non-urban, or more sensitive (U.S. Census Bureau 2010). Condition ratings correspond to the ALR level that exists in at least half of the park's landscape (i.e., the median condition). At such a condition, it is probable that a visitor will be able to experience the specified night sky quality. It is also probable that most wildlife and habitats found within the park will exist under the specified night sky quality.

Table 14. Condition thresholds for Level 1 (non-urban) and Level 2 (urban) parks.

Indicator	Threshold for Level 1 Parks—Non-Urban	Threshold for Level 2 Parks—Urban	NRCA Condition Rating
All-sky Light Pollution Ratio (At least half of park area should meet criteria)	ALR < 0.33	ALR < 2.00	Good condition
	ALR 0.33–2.0	ALR 2.0–18.0	Warrants moderate concern
	ALR > 2.0	ALR > 18.0	Warrants significant concern

Reference Conditions

The reference condition for the night sky in LIBO is one in which the intrusion of artificial light into the night scene is minimal. Natural sources of light (such as moonlight, starlight, and the Milky Way) will be more visible from the memorial than anthropogenic sources. During the period of significance associated with the memorial (early 1800s), there were no sources of artificial light beyond cooking and heating fires, candles and kerosene lamps. To help the park achieve its cultural mission, it is important that the night sky of the site retain its historic character. Condition ratings correspond to the ALR level that exists in at least half of the park's landscape (i.e., the median condition) (Table 14). At such a condition, it is probable that a visitor will be able to experience the night sky quality expected for a non-urban park. It is also probable that the majority of wildlife and habitats found within the memorial can successfully exist under such conditions.

Condition and Trend

The modeled ALR values within LIBO ranged from 1.28 to 2.56, indicating degraded night skies (Figure 12). According to the rating criteria for non-urban parks, these ALR levels correspond to a photic environment considered to warrant moderate to significant concern (Table 15). At these light levels, the Milky Way is visible but has typically lost some of its detail and is not visible as a complete band. Zodiacal light (or "false dawn," which is a faint glow at the horizon just before dawn or just after dusk) is rarely seen. Anthropogenic light likely dominates light from natural celestial features and shadows due to distant lights may be seen (Moore et al. 2013). Cities such as Evansville (30 miles from LIBO), Owensboro (24 miles from LIBO), and Huntingburg and Jasper (19 miles from LIBO) could be some of the main sources of anthropogenic light degrading LIBO night skies. Louisville, Kentucky is a significant source of light to the east.

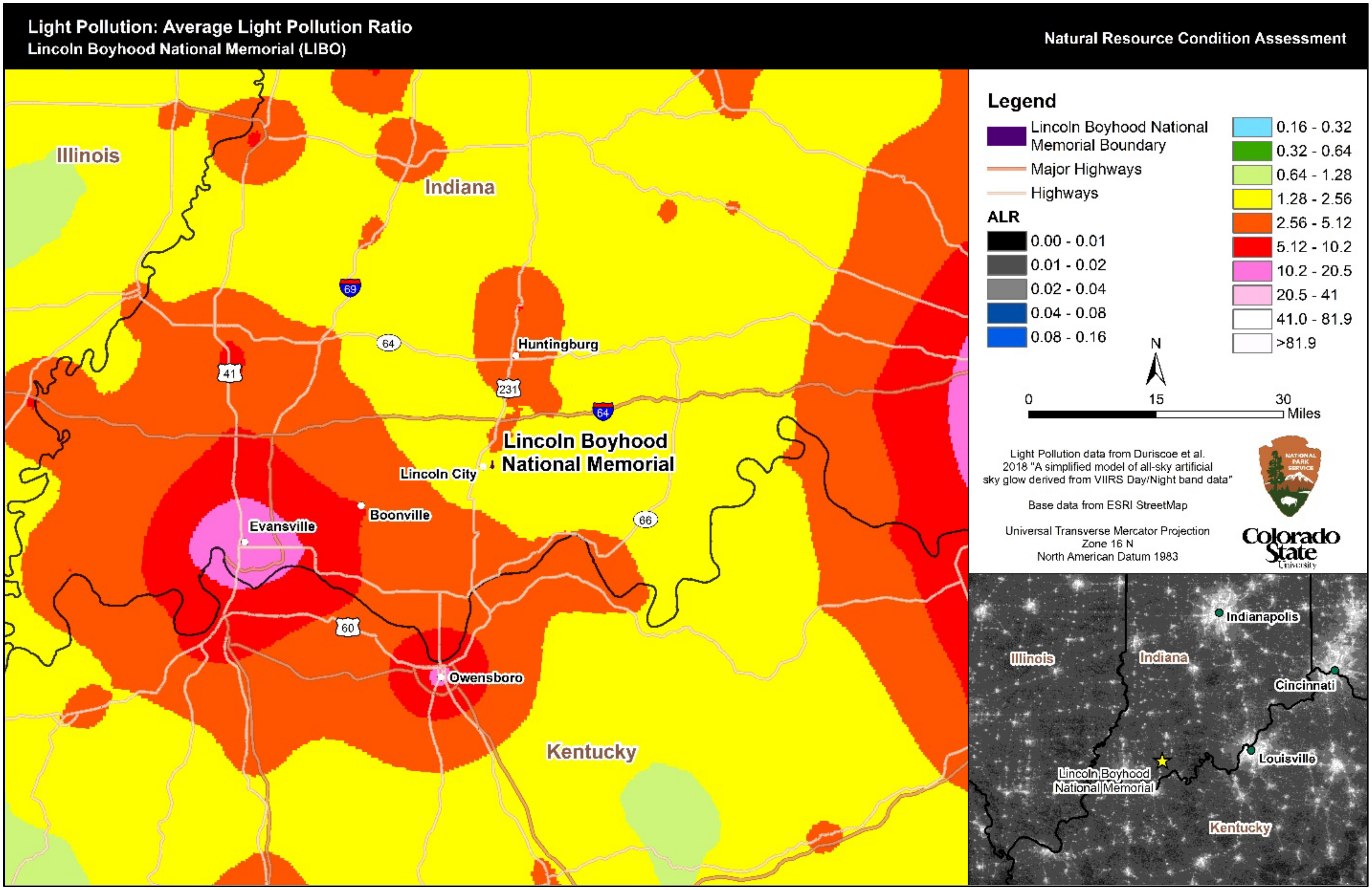


Figure 12. All-sky Light Pollution Ratio (ALR) values for LIBO and its surrounding area. (Data sources: Duriscoe et al. 2018, ESRI StreetMap).

Table 15. Condition and trend summary for natural night skies at Lincoln Boyhood National Memorial.

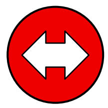
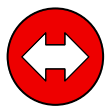
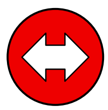
Indicator	Condition Status/Trend	Rationale
All-sky light pollution ratio		ALR values for LIBO are between 1.28 and 2.56, indicating moderate to significant management concern.
Artificial Night Sky Brightness		Several nearby urban areas produce significant light pollution that degrades the quality of LIBO's night skies. Local and regional populations and development are expected to increase slowly over time.
Natural Night Skies overall		**The condition of natural night skies warrants significant concern with an unchanging near-term trend. Confidence in the assessment is medium.**

Figure 13 displays values of artificial night sky brightness for LIBO and its surrounded area taken from the New World Atlas of Artificial Sky Brightness (Falchi et al. 2016). The overall pattern is similar to the modeled ALR data (Figure 12), in that urban centers degrade the dark skies. The Falchi data provides finer resolution for towns such as Lincoln City, Santa Claus and Dale, and their influence on conditions at LIBO.

Based on the values of modeled ALR and artificial night sky brightness, the condition of natural night skies at LIBO warrants significant concern (Table 14). Anthropogenic light is tightly linked to population densities and housing classes. From 1970–2010, there was significant growth in exurban development as farmland and rural acreage became more settled and developed (see Land Cover and Land Use section). However, a leveling off of population growth is forecast for the surrounding counties (U.S. Census Bureau 2010). For this reason, we estimate an unchanging trend in resource condition into the near future. Confidence in the condition is high but overall confidence in the condition and trend is medium, due to the modeled nature of population growth projections. Over the long term, it is likely that the resource will be further degraded.

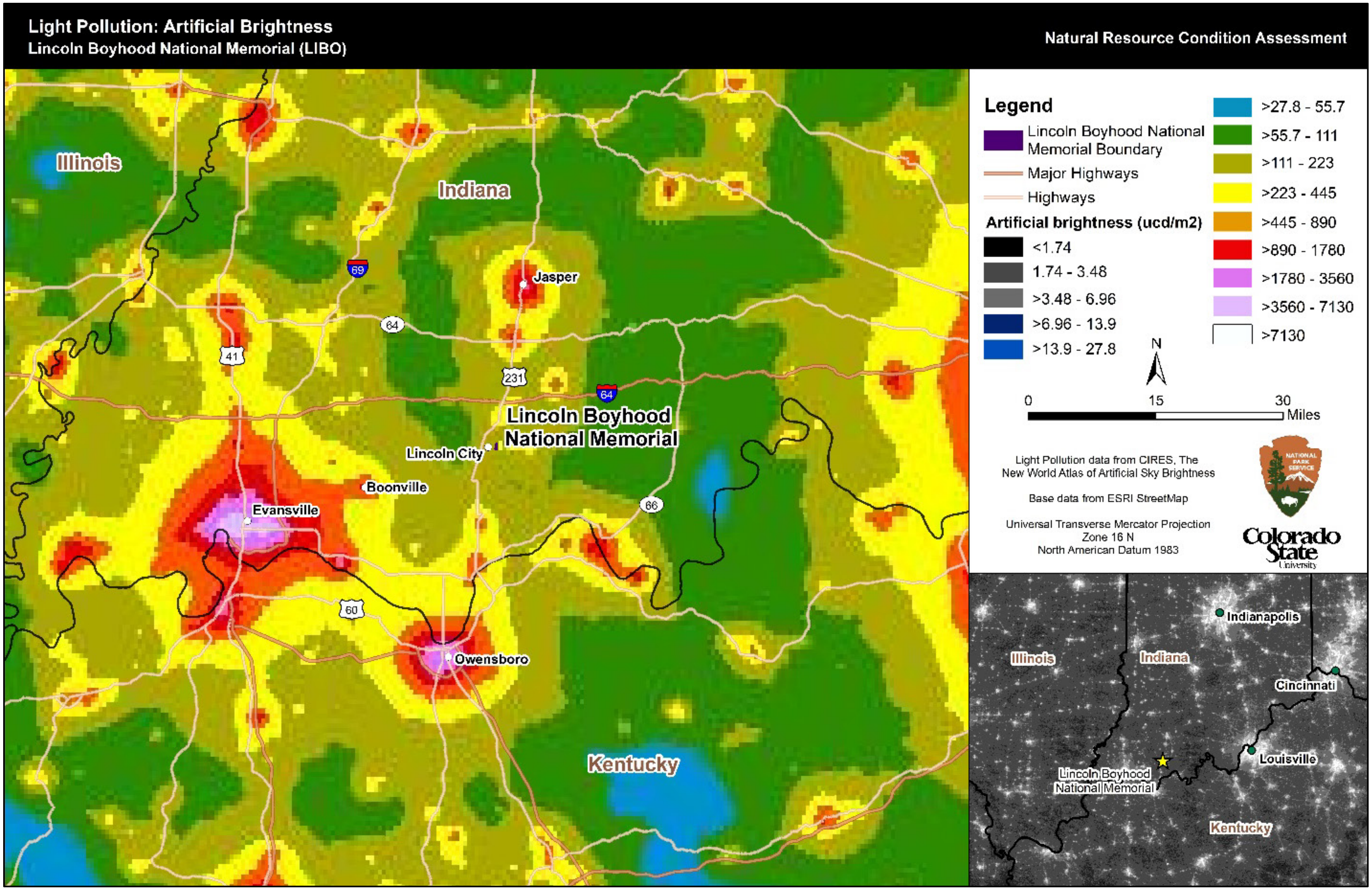


Figure 13. Regional artificial night sky brightness values for LIBO. (Data sources: Falchi et al. 2016, ESRI StreetMap.)

Uncertainty and Data Gaps

No on-site night sky monitoring studies have been conducted by the NPS or NSNSD in LIBO. Additional measures for night skies could include Bortle Dark Sky Scale assessments, assessment of sky brightness using a charged couple device (CCD), and Unihedron Sky Quality Meter (SQM).

Sources of Expertise

- Jeremy White, NPS Natural Sounds and Night Skies Division.
- Sharolyn Anderson, NPS Natural Sounds and Night Skies Division.

Natural Sounds

Background and Importance

Park natural soundscape resources encompass all the natural sounds that occur in parks, including the physical capacity for transmitting those natural sounds and the interrelationships among park natural sounds of different frequencies and volumes (NPS 2006). Visitors to national parks are often highly motivated to experience natural quiet and the sounds of nature (McDonald et al. 1995). Most visitors prefer to hear sounds that are intrinsic to the natural and cultural settings of the parks they are visiting. A growing body of research also documents the biological and behavioral impacts of unnatural and unusual noise on a variety of wildlife (Barber et al. 2010; Shannon et al. 2016). Many species depend on natural soundscape conditions—free from anthropogenic noise intrusions—to successfully reproduce and survive (Rabin et al. 2006; Habib et al. 2007).

In 2000 the NPS issued *Director's Order #47: Soundscape Preservation and Noise Management* "to articulate National Park Service operational policies that will require, to the fullest extent practicable, the protection, maintenance, or restoration of the natural soundscape resource in a condition unimpaired by inappropriate or excessive noise sources" (Peel 2000). The order established guidelines for monitoring and planning to preserve park soundscapes.

New NPS management policies introduced in 2006 included several directives related to soundscapes, including the affirmation that "The Service will preserve, to the greatest extent possible, the natural soundscapes of parks. The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise) and will protect natural soundscapes from unacceptable impacts" (NPS 2006). Excessive anthropogenic noise in NPS units threatens to adversely impact natural and cultural resources and the quality of visitor experiences. The NPS has clearly declared its commitment to protecting intrinsic soundscapes for the enjoyment of current and future generations of park visitors.

Lincoln Boyhood National Memorial preserves the farm site where Abraham Lincoln's family lived from 1816 to 1830. One goal for this site is to provide visitors the opportunity to experience a natural environment as close as possible to what Lincoln's family experienced. However, the memorial's relatively small size with little to no buffer between it and the surrounding landscape could present challenges to preserving the natural soundscape. The main sources of anthropogenic noise affecting visitors and wildlife in the area may be aerial traffic, terrestrial traffic, and agricultural operations. In this section we analyze some of the main elements that could be affecting the natural soundscape at LIBO.

<u>Threats and Stressors</u>

The primary threat to the natural soundscape in LIBO, like in many other NPS sites, is noise originating from modern transportation within and beyond the memorial's boundaries, including motorized park management activities and traffic associated with commercial, industrial, urban and exurban development. Aircraft noise is typically one of the most pervasive threats to natural sounds in NPS units; LIBO is no exception. Nearby airports include Evansville Regional Airport, Huntingburg Municipal Airport, Owensboro-Daviess County Regional Airport, and Owensboro-

Daviess County Regional Airport in Kentucky. However, most of the air traffic in the area is associated with the Louisville International Airport in Kentucky (FlightAware 2018). There are at least three major air ways (V512, T325, and Q29) near the memorial. Satellite images also show at least eight smaller airports or airstrips within 10 miles of LIBO, which could contribute to the airplane noise (Google Earth Pro 2018).

There is a complex with a middle and high school that contributes significantly to noise levels at the park. Heritage Hills Middle and High schools (the high school is closer and has more activity) are located northeast of the park. Sporting events, band practice, and other events at the school impact the sound environment at the memorial (E. Hilligoss-Volkmann, pers. comm., June 2023). There is a train that runs directly through the park twice a day. The noise from the train and its horn impact the noise environment in the park (E. Hilligoss-Volkmann, pers. comm., June 2023).

Government reports indicate that air and vehicle traffic are projected to significantly increase at regional and national scales (VFR MAP n.d.). While noise associated with park management activities could be minimized over time using noise-conscious management practices, transportation noise sources are a distinct threat to the natural and historic soundscape of LIBO and to the quality of visitor experiences.

Farming activities near the memorial also impact the memorial's soundscape. Farming requires prolonged operation of machinery that could be an important contributor to the anthropogenic noise in the area (Franklin et al. 2006). A middle school northwest of the memorial also could contribute to the anthropogenic component of the memorial's soundscape. Studies have shown that school activities can be loud (Silva et al. 2016), but the impact of the school is not analyzed in this assessment due to a lack of data.

A comprehensive examination of landscape context related to landcover and land use, population and housing, which can all affect the soundscape, was performed for the area surrounding the memorial and is presented in the Land Cover and Land Use section. These factors can be highly correlated with ambient sound levels and, therefore, can have significant impacts on the memorial's soundscape.

Indicators and Measures

- Anthropogenic sources of noise: relative noise level
- Anthropogenic sound level impacts (modeled): median and maximum impacts

Data and Methods

Anthropogenic Sources of Noise

Qualitative data from LIBO staff were used to assess anthropogenic sources of noise. Staff members were asked to identify natural and human-caused (extrinsic or intrinsic to the memorial's values) sounds present at LIBO. Staff members were also asked to describe the desired soundscape conditions for LIBO, including anthropogenic cultural sounds that could be considered appropriate for the memorial's mission and purpose. In addition, forecasts from the NPS (Hansen and Gryskiewicz 2003), Indiana Department of Transportation (2018), and FAA (2017) were used to assess trends for anthropogenic sources of noise.

Anthropogenic Sound Level Impacts

The condition of the soundscape at LIBO was evaluated based on data provided by the NPS Natural Sounds and Night Skies Division (NSNSD). The NSNSD provided results from nationwide modeling of ambient sound levels (Mennitt et al. 2013). Modeling was applied to all NPS units, including the entire area of LIBO and the surrounding region. This analysis permitted estimation of the impact of anthropogenic noise on natural sound levels in the memorial.

Another study for a related metric that examined noise pollution in protected areas across the continental United States (Buxton et al. 2017) calculated how much anthropogenic noise exceeds natural noise levels. The researchers used a metric known as "noise exceedance," which is the difference between the predicted A-weighted sound levels (defined below) and predicted sound levels in the absence of anthropogenic noise. In other words, noise exceedance is the amount that anthropogenic noise raises sound levels above natural levels. The researchers did not calculate noise exceedance for LIBO, but they did for nearby areas, allowing us to give more context to the soundscape of the memorial.

Decibel Scale

Sound pressure levels are often represented in the logarithmic decibel (dB) scale. In this scale, 0 dB is equivalent to the lower threshold of human hearing at a frequency of 1 kHz. This scale can be adjusted to account for human sensitivity to different frequencies of sound, a correction known as A-weighting. A-weighted sound pressure levels are represented in the dBA scale. Examples of common sound sources (both within and outside of park environments) and their approximate dBA values are shown in Table 16 (Lynch 2009).

Table 16. Sound pressure level examples from NPS and other settings (Lynch 2009).

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (Haleakala National Park)	Human breathing at 3m	10
Leaves rustling (Canyonlands National Park)	Whispering	20
Crickets at 5m (Zion National Park)	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 above ground level (Yukon-Charley Rivers National Preserve)	Train horn at 1m	120

Reference Conditions

Anthropogenic Sources of Noise

The reference condition for the soundscape in LIBO is one dominated by natural and cultural sounds that are intrinsic to the park, including elements of the agricultural soundscape of the early 1800s when Lincoln's family lived in the area. Natural quiet, or the absence of sound, was identified by park managers as a desired natural soundscape condition, but most likely no longer occurs in the memorial due to anthropogenic noise intrusion. Natural sounds for the reference condition include birds, wind, rain, and insects. A condition rating system for the soundscape indicators incorporating guidance from NSNSD and the authors is presented in Table 17.

Table 17. Reference condition rating framework for soundscape indicators at LIBO.

Indicator	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Anthropogenic Sources of Noise (subjective, NPS staff opinion)	Infrequent, low, or inaudible levels of anthropogenic noise. Annoyance level of visitors low. Recognizable natural and historic farming sounds.	Moderately frequent and audible anthropogenic noise. Annoyance level of visitors moderate.	Frequent and highly audible anthropogenic noise. Annoyance level of visitors high.
Anthropogenic Sound Level Impacts	• Median impact ≤ 3 dB • Maximum impact ≤ 7.5 dB	• 3 dB < Median impact < 5 dB • 7.5 dB < Maximum impact < 10 dB	• Median impact ≥ 5 dB • Maximum impact ≥ 10 dB

Anthropogenic Sound Level Impacts

The reference conditions for anthropogenic sound level impacts are listed in Table 17. For reference in translating sound level impacts into functional effects for human visitors and resident wildlife, an increase in background sound level of 3 dB produces an approximate decrease in listening area of 50%. In other words, by raising the sound level in LIBO by just 3 dB, the ability of listeners to hear the sounds around them is effectively cut in half. Furthermore, an increase of 7 dB leads to an approximate decrease in listening area of 80%, and an increase of 10 dB decreases listening area approximately 90%.

Condition and Trend

Anthropogenic Sources of Noise

Some common sources of anthropogenic noise that could adversely affect the natural soundscape at LIBO is traffic noise from roads outside and inside the park, noise from modern mechanized farming on adjacent lands, and aviation noise. Within the Heartland I&M region, from 1950 to 2000 housing density (houses/mi^2) increased 339% and farm acreage decreased 22%, indicating that development could become a concern in the future (Hansen and Gryskiewicz 2003). Nonetheless trends in development and population densities over the past several decades are largely flat, other than some increases in exurban development (see the Land Cover and Land Use section). Based on the sources of anthropogenic noise currently reported at the memorial, it is possible that most anthropogenic noise sources originating outside the memorial, primarily air and land traffic, may slowly increase in the coming years (FAA 2017; Indiana Department of Transportation 2018), but not currently or in the near term. The condition of this indicator is good, with an unchanging trend and a medium confidence level.

Anthropogenic Sound Level Impacts

At LIBO, the median modeled LA50 sound level impact was 4.8 dBA and the maximum impact value was 5.2 dB (Table 18). Modeled mean impacts in the area immediately surrounding LIBO are shown in Figure 14. Based on the references condition framework in Table 17, the modeled median sound level impact indicates moderate concern and the modeled maximum sound level impact indicates good condition. On the conservative side, the results for indicate moderate concern, with an unchanging trend and a medium confidence level.

Table 18. Anthropogenic sound level impacts in dBA for LIBO (Mennitt 2013).

Minimum	1st quartile	Median	3rd quartile	Maximum
4.1 dBA	4.7	4.8	5.1	5.2

The noise exceedance levels calculated more recently by Buxton et al. (2017) on areas around LIBO are low; however, no data are available within the memorial. The areas around Lincoln City and Gentryville, Indiana, have noise exceedance levels close to 0 dB, indicating anthropogenic noise is low around the memorial (Figure 15). Nevertheless, levels of noise exceedance east of LIBO and north of Interstate 64 (yellow areas in Figure 15) are concerning because they show high levels of noise exceedance that could expand and reach the memorial in the future.

The condition of this indicator warrants moderate concern with a medium confidence level given the lack of on-site acoustical data and the modeled nature of the data.

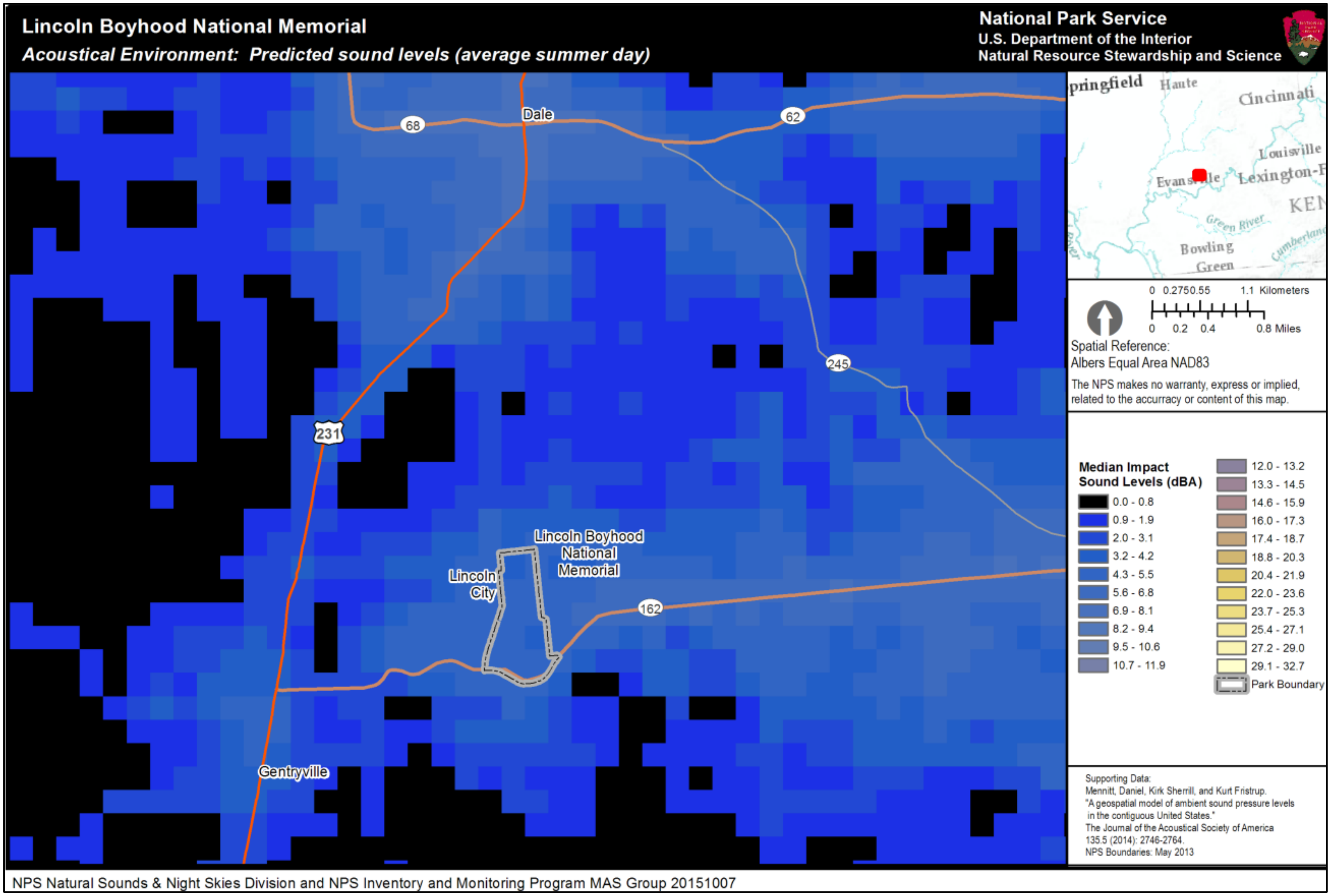


Figure 14. Modeled median anthropogenic sound level impacts in the area immediately surrounding LIBO. Graphic provided by NSNSD (October 2015).

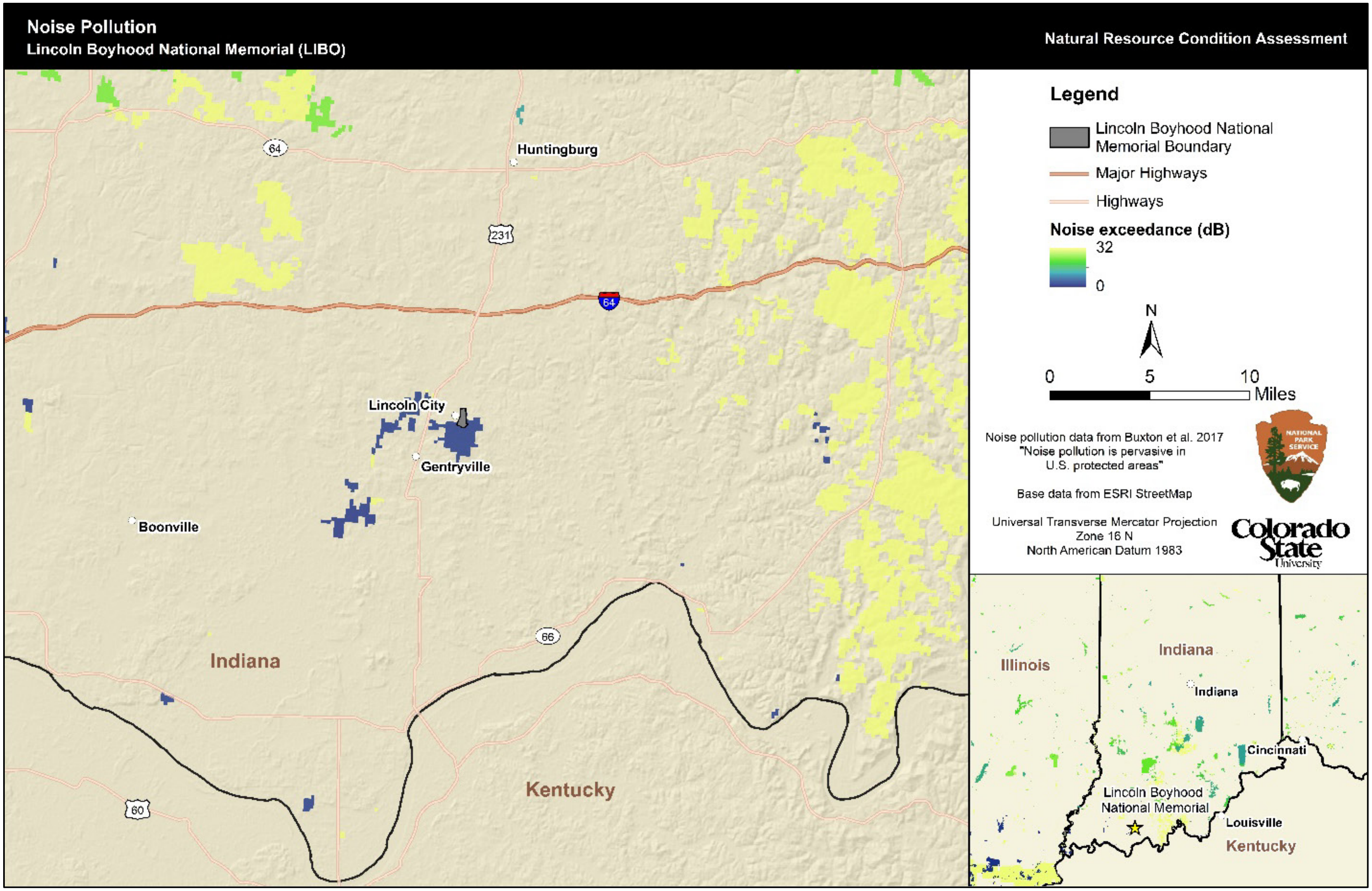
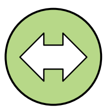
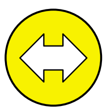
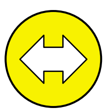


Figure 15. Noise exceedance levels in the immediate surroundings of LIBO (Buxton et al. 2017). Noise levels around LIBO (location in grey) are close to 0 indicating low levels of noise exceedance. (Data sources: Buxton et al 2017, ESRI StreetMap.)

Overall Condition

The data presented above suggest that the condition of the soundscape at LIBO warrants moderate concern, with an unchanging trend based on recent trend in landcover and population densities (Table 19). Future trend may deteriorate if road and air traffic. For example, air traffic is projected to increase in the area over time (FAA 2017). Nationwide modeling of anthropogenic sound level impacts indicates that modern noise intrusions are substantially increasing the existing ambient sound level above the natural ambient sound level of the park. If noise from the adjacent highway and park management activities remains stable in the park, the condition of the soundscape will likely remain the same in the near term. The confidence associated with these ratings is medium due to the use of qualitative and modeled data, and the lack of data for LIBO proper.

Table 19. Condition and trend summary for the soundscape at Lincoln Boyhood National Memorial.

Indicator	Condition Status/Trend	Rationale
Anthropogenic Sources of Noise		Noises from anthropogenic sources are present but possibly they don't represent a significant source of Noise. Air and terrestrial traffic noise hasn't been acoustically assessed for LIBO.
Modeled L_{A50} Sound Level Impacts		Anthropogenic noise is increasing the ambient sound level above the natural ambient sound level of the memorial. The median value was 4.8dB, indicating moderate concern, and the maximum value was 5.2 dB, indicating good condition.
Soundscape overall		**Condition warrants moderate concern with an unchanging trend. Confidence in the assessment is medium.**

Uncertainty and Data Gaps

Acoustical monitoring studies to measure ambient sound levels and audibility of different intrinsic and extrinsic sound sources have not been conducted within LIBO. Likewise, evaluative research to determine the social impacts of existing soundscape conditions on visitor experiences has not been done at LIBO. Natural sounds have not been inventoried at LIBO, making it difficult to assess what natural sounds are threatened or missing and thus decreasing visitors' enjoyment of the memorial.

Sources of Expertise

- Emma Lynch, Acoustical Resource Specialist, NPS Night Skies and Natural Sounds Division.
- Megan McKenna, Acoustical Resource Specialist, NPS Night Skies and Natural Sounds Division.

Climate Change

Background and Importance

Climate change is increasingly recognized as a major stressor of biological taxa, communities and ecological systems. Understanding the magnitude and effects of changing climate is essential within the NPS to "manage for change while confronting uncertainty" while developing new management and adaptation strategies (National Park System Advisory Board Science Committee 2012) and is a significant scientific component of the NPS *Climate Change Response Strategy* (NPS 2010). Numerous species at LIBO are vulnerable to climate change; in particular, northern catalpa (*Catalpa speciosa*), eastern white pine (*Pinus strobus*), and swamp white oak (*Quercus bicolor*) may become extirpated from the memorial even under relatively minor changes in climate (Fisichelli 2015).

The climate suitable for temperate deciduous forest is expected to remain relatively stable with some expansion to the north into the Canadian Taiga (Rehfeldt et al. 2012). Increasing carbon dioxide tends to increase plant growth and water use efficiency, but such increases may be limited by water and nutrient availability. Transpiration rates usually decline as carbon dioxide increases, while, in many plants, photosynthesis and growth increase. Growth response to carbon dioxide is usually higher in rapidly-growing plants and in plants with the C3 photosynthetic pathway (e.g., most woody plants and "cool-season" grasses) than in plants that use the C4 pathway (e.g., most "warm-season" grasses); therefore, increasing levels of carbon dioxide could lead to an increase in the growth rates of tree species prevalent at LIBO (Schramm and Loehman 2011).

Overall climate change vulnerability for a particular resource is estimated using a combination of exposure, sensitivity and adaptive capacity (Glick et al. 2011). The synopsis of potential changes to LIBO's climate presented here characterizes the "exposure" component of resource vulnerability. Climate change is examined here using modeled future climate scenarios, but potential resource vulnerability and management implications are based on the relative amounts and directions of changes rather than specific magnitudes or thresholds of change. Although the memorial can do its part to mitigate greenhouse gas emissions and optimize the efficiency of park operations to reduce greenhouse gas emissions, climate change and its associated effects on park resources are largely out of the control of park managers. The impacts of climate change are already being observed and will require an evaluation of the vulnerability of park resources. Moreover, specific and diverse adaptation measures for some park resources may be necessary to mitigate effects of climate change and transition to future climatic conditions.

Threats and Stressors

Increases in atmospheric greenhouse gases are resulting in changes in global, regional and local climates. Changes in the amounts and patterns of temperature and precipitation have numerous direct and indirect effects on environmental conditions and biota. An increase in the frequency of extreme weather is also anticipated under climate change.

Indicators and Measures

- Temperature changes from baseline: minimum, mean, and maximum temperatures (monthly)
- Precipitation changes from baseline: annual and seasonal; very heavy events

- Palmer Drought Severity Index (PSDI): historical period of record
- Observed and projected changes in frost-free period

Data and Methods

We applied a variety of data and analysis approaches to characterize the climate during the historical period of record and examine possible changes in climate for the memorial. A combination of site-specific and regional results is presented. Historical climate and modeled future climate change were examined for the area extending approximately 30 km from the memorial boundary. Because LIBO is small and has relatively little elevation change within its boundaries, climatic variation within the memorial is minimal; monthly values were therefore averaged across the area of interest.

Consolidation of future modeled climates and comparisons with historical baseline and graphic representation of results was supported by the USGS North Central Climate Science Center (NCCSC). Future climate projections for the NCCSC products are presented for several scenarios of future greenhouse gas concentrations (i.e., emission scenarios); representative concentration pathway (RCP) 8.5 represents the high emissions scenario and RCP 4.5 represents a moderate emissions scenario. Walsh et al. (2014a) present a comparison of RCP emission scenarios and the scenarios presented in the 2000 Special Report on Emission Scenarios (SRES).

Examination of historical climate data used PRISM (4 km) data (PRISM Climate Group 2014). Climate projections for non-spatial graphics use CMIP5 downscaled data (CMIP5 Modeling Groups 2014). CMIP5 downscaling procedures are described in Maurer et al. (2002).

Approximately 35 general circulation models (GCMs) that use quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice were used for the NCCSC summaries. Because the variability in results among models makes interpreting results problematic, ensemble summaries were used to combine the simulations of multiple GCMs and quantify the range of possibilities for future climates under the different emission scenarios. Using ensemble median values based on the results from many GCMs provides a more robust climate simulation versus using results of individual models (Girvetz et al. 2009). Seasonal summaries use the following groupings: winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; and autumn = September, October, and November.

The Palmer Drought Severity Index (PDSI) uses temperature and precipitation data to calculate water supply and demand while incorporating soil moisture (Palmer 1965, USDA 2014). Long-term drought is cumulative, so the intensity of drought during a point in time is dependent on the current weather patterns plus the cumulative patterns of the previous period. The Index is used widely by the U.S. Department of Agriculture and other agencies. PSDI values range between −4.00 or less (extreme drought) and +4.00 or greater (extreme moisture). A value of 0 is considered “normal”; a value of −1.5 is considered drought. The Palmer Index is most effective in determining long term drought (i.e., lasting at least several months). Monthly PSDI values were obtained from the National Climatic Data Center (NCDC 2018b). Assumptions of the PSDI regarding the relationship between temperature and evaporation may give biased (i.e., overestimated evaporation) results in the context of climate change (Sheffield et al. 2012). However, examination of historical PSDI does appear to corroborate known drought periods and we do not use the PSDI approach to model future drought.

The length of the frost-free period, which corresponds with the area's growing season, is an important determinant in which plants will grow and flourish in a particular region (Walsh 2014b). These observed climate changes are correlated with increases in satellite-derived estimates of the length of the growing season (Jeong et al. 2011). The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has been gradually increasing since the 1980s (EPA 2012). The length of the frost-free period can alter plant phenology. Increases in temperature are responsible for plants flowering earlier in the spring and the delayed onset of dormancy in autumn. This affects not only synchrony between plants, pollinators and complex evolutionary adaptation, but can shorten (or lengthen) a plant's growing season. Phenology also plays an important role in the amount of water released to the atmosphere via evapotranspiration, sequestration of carbon in new growth, and the amount of nitrogen utilized from the soil (Ibanez et al. 2010).

Reference Conditions

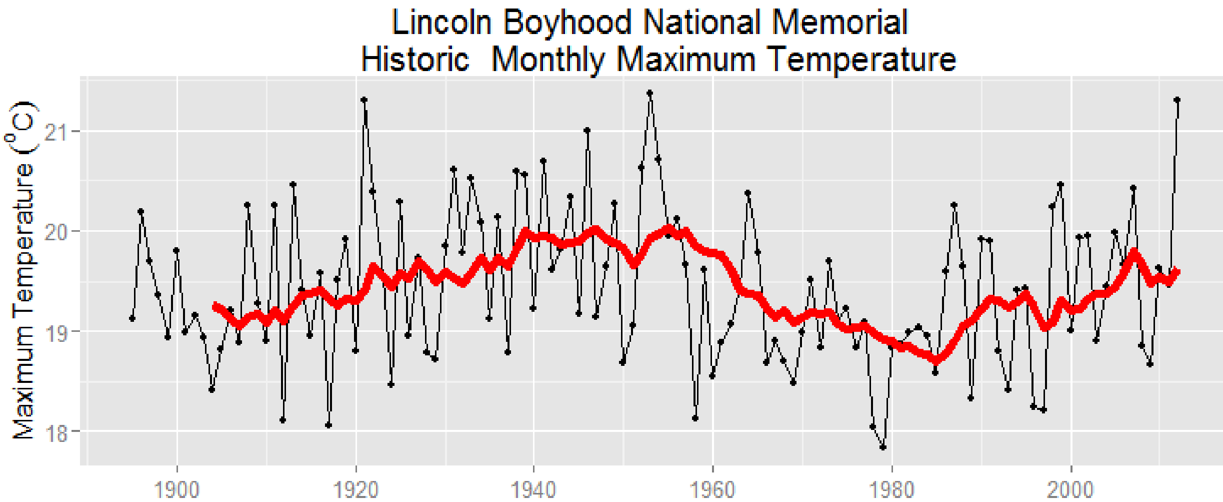
For most indices, the reference condition for this assessment is an 85-year period from about 1895, when meteorological data was first collected, to 1980, when a significant change in many climate indices began. Although there may be some changes occurring during this period, the long reference period avoids bias associated with wet, dry, warm and cold periods or extreme events such as prolonged or severe drought. Some analyses of historical data use a 1950–1980 baseline because of limited dates associated with downscaled CMIP5 data. For frost-free season length, the baseline period was 1901–1960.

Historical Conditions, Range of Variability and Modeled Changes

<u>Temperature</u>

Historical Trends

A linear model was fit to average minimum and average maximum monthly temperature for 1895–1980 and 1980–2012 in the vicinity of LIBO (Figure 16). The earlier period corresponds to a timeframe that is generally associated with no change in climate or a slower rate of change compared to 1980 or later. The model results for mean monthly maximum temperature over time were not statistically significant for the 1895–1980 period but were for the 1980–2012 period ($p=0.37$ and <0.05, respectively). In contrast, mean minimum monthly temperatures increased significantly over time during 1895–1980 ($p<0.01$), and during 1980–2012 ($p<0.01$).



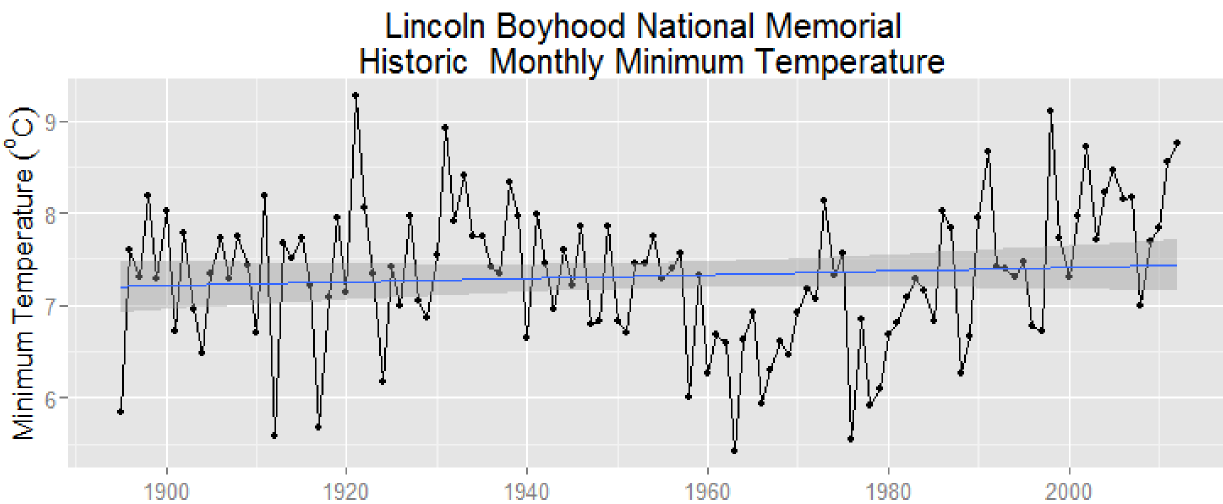


Figure 16. Historical average maximum temperature with a five-year lag running mean (top) and average minimum temperature showing significant linear model fit (bottom) for Lincoln Boyhood National Memorial. (Data and graphic prepared by NCCSC.)

Trends in monthly maximum and minimum temperatures over time are further illustrated in graphical representations of the data (Figure 17), which normalize differences between a baseline period of 1895 to 1980 with individual monthly values. For example, relative to the baseline period, cooler minimum temperatures across most months are evident in the period before 1980 compared to more recent years (Figure 17, bottom). High temperatures associated with severe droughts that occurred in the 1930s, 1950s, and 2010s are clearly shown in Figure 17 (top). An anomaly plot showing the difference between mean monthly minimum temperature for each year and a baseline (the average of mean monthly minimum temperatures from 1895–1980) further illustrates changes during the recent past, with mean monthly minimum temperatures for most years since 1980 being 0.5–2.0 °C above the long term average (Figure 18).

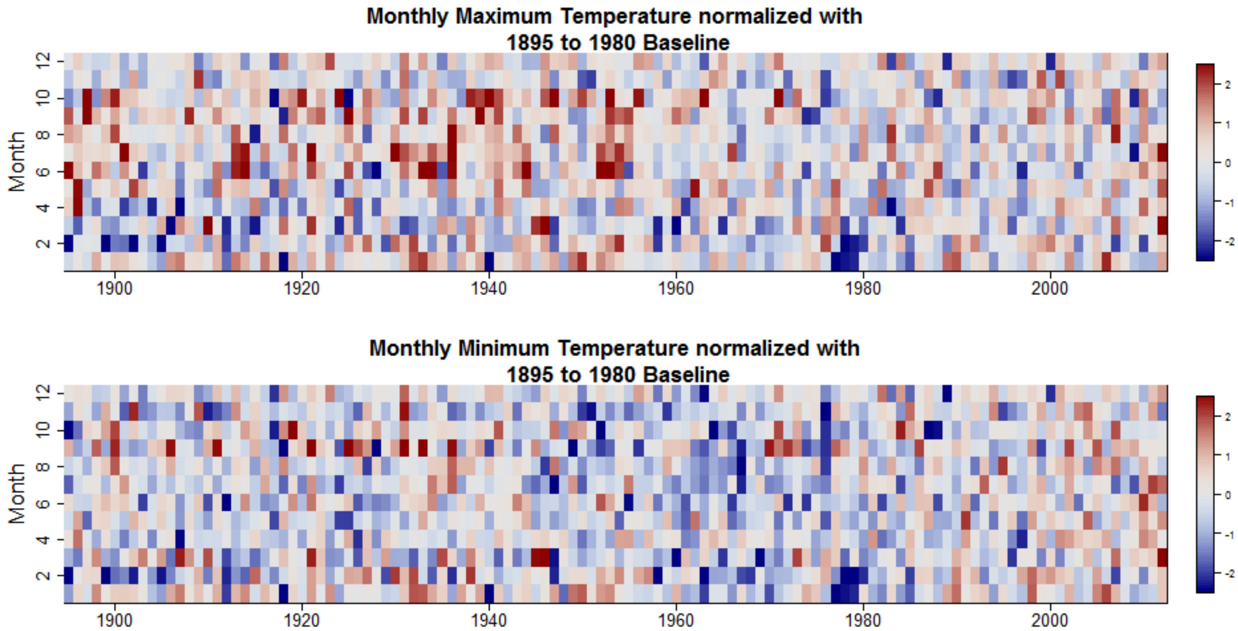


Figure 17. Deviation of monthly maximum temperature (top) and monthly minimum temperature (bottom) from a normalized baseline at Lincoln Boyhood National Memorial. The baseline for each month is the average maximum or minimum temperature for that month for 1895–1980. The pixel colors range from ± 2.5 standard deviations from the mean for that month during the baseline period. Red cells are warmer than baseline, while blue cells are cooler than baseline. (Data and graphic prepared by NCCSC.)

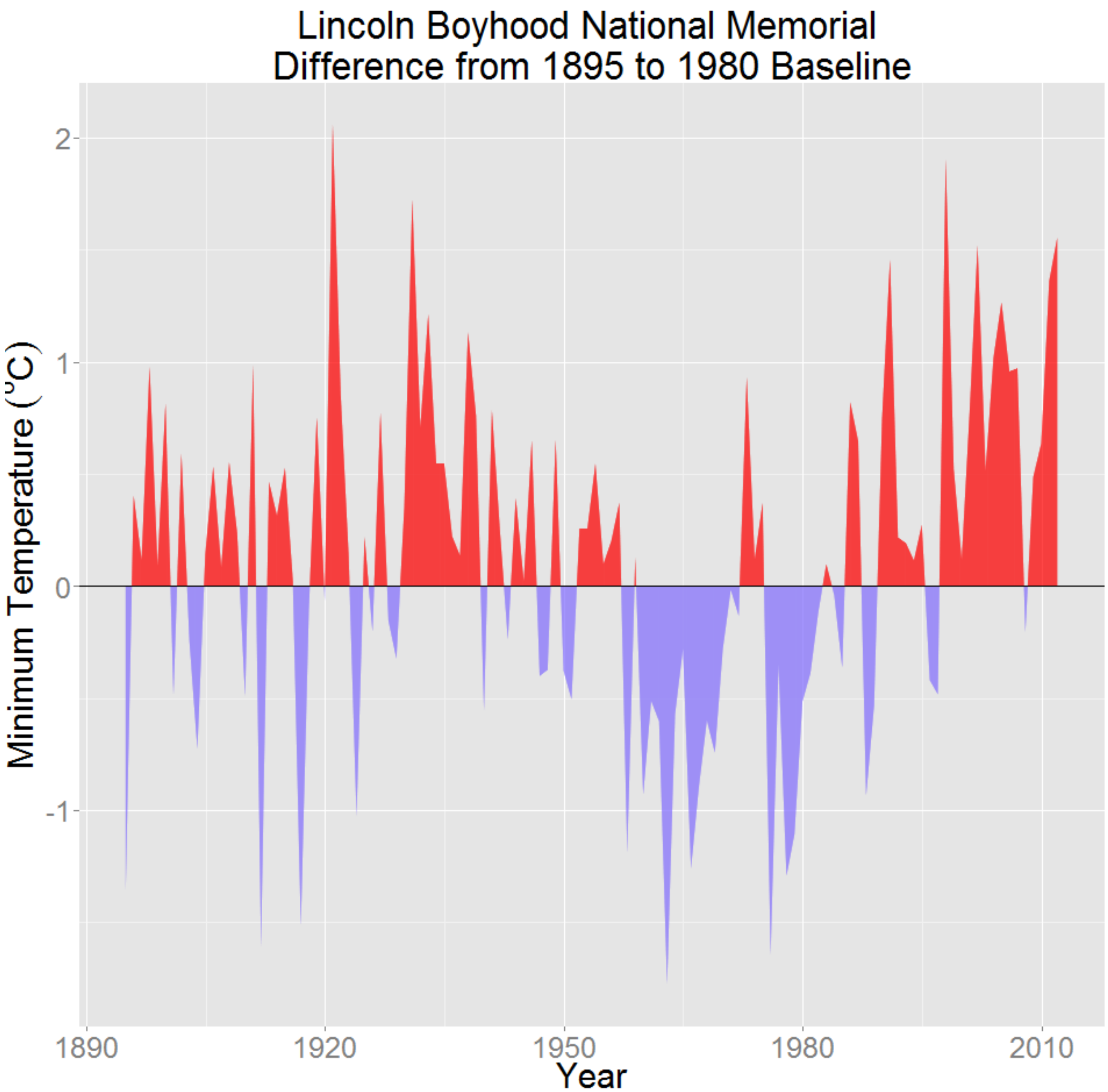


Figure 18. Anomaly plot for monthly mean minimum temperature showing the difference between individual years from 1895 to 2012 and a baseline (the average of mean monthly minimum temperatures from 1895 to 1980) for Lincoln Boyhood National Memorial. (Data and graphic prepared by NCCSC.)

Modeled Future Changes

Models prepared by the NCCSC indicate that temperatures at the memorial will rise significantly under climate change (Figure 19). According to median ensemble estimates, minimum, maximum, and mean temperatures are expected to increase by approximately 1.5–2.0 ºC by 2050, and by approximately 2.0–6.5 ºC by 2100, depending on the scenario (Figures 20 through 22).

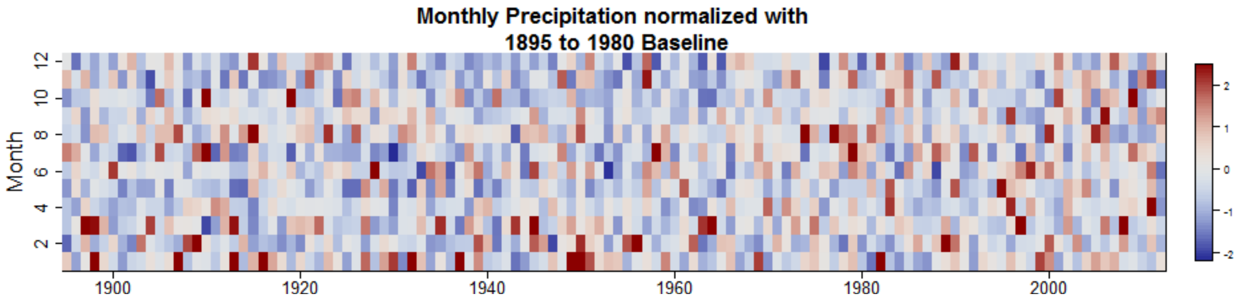


Figure 19. Deviation of mean monthly precipitation from a normalized baseline period at Lincoln Boyhood National Memorial. The baseline for each month is the precipitation during that month, averaged over 1895–1980. The pixel colors range from ± 2.5 standard deviations from the mean for that month during the baseline period. Red pixels indicate more precipitation and blue pixels represent less. (Data and graphic prepared by NCCSC.)

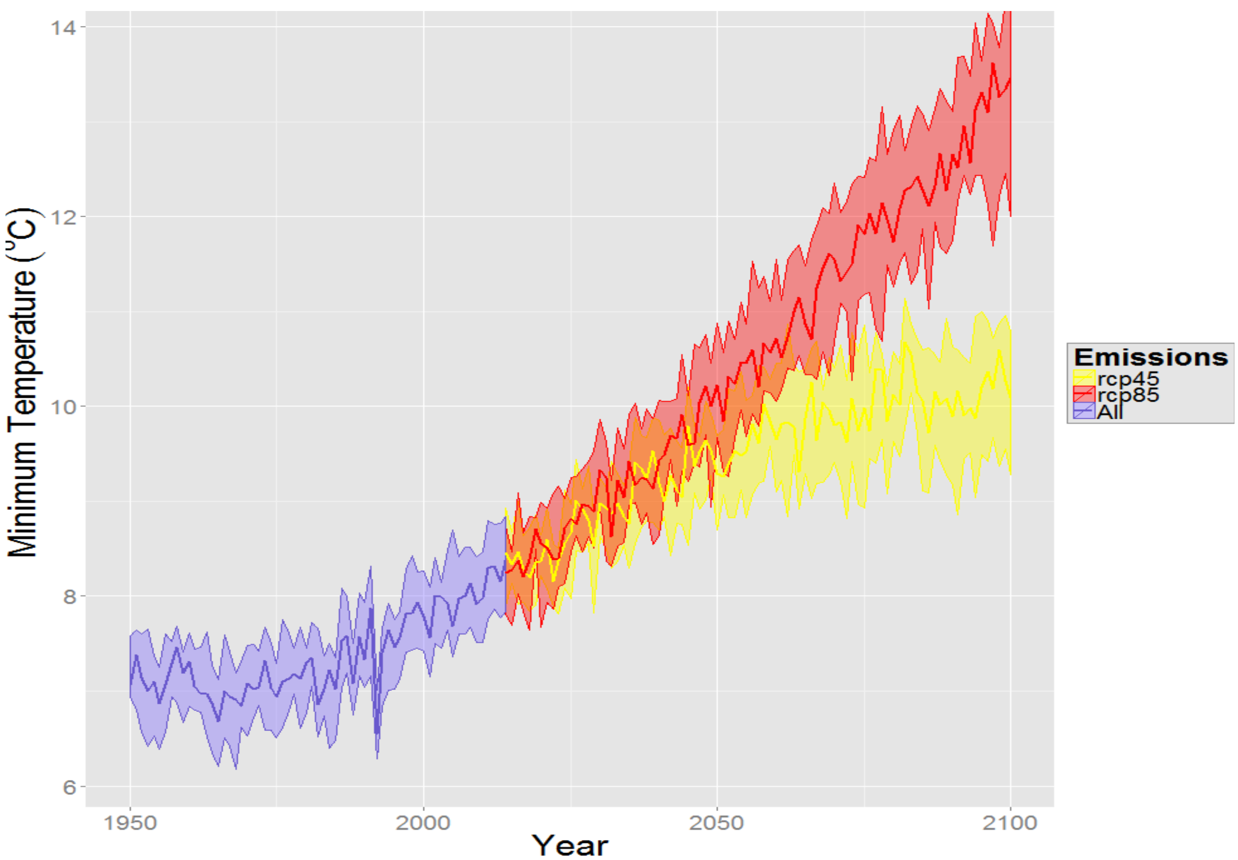


Figure 20. Projections for annual minimum temperature with median, 25 and 75% quantiles grouped by emissions scenario for Lincoln Boyhood National Memorial. (Data and graphic prepared by NCCSC.)

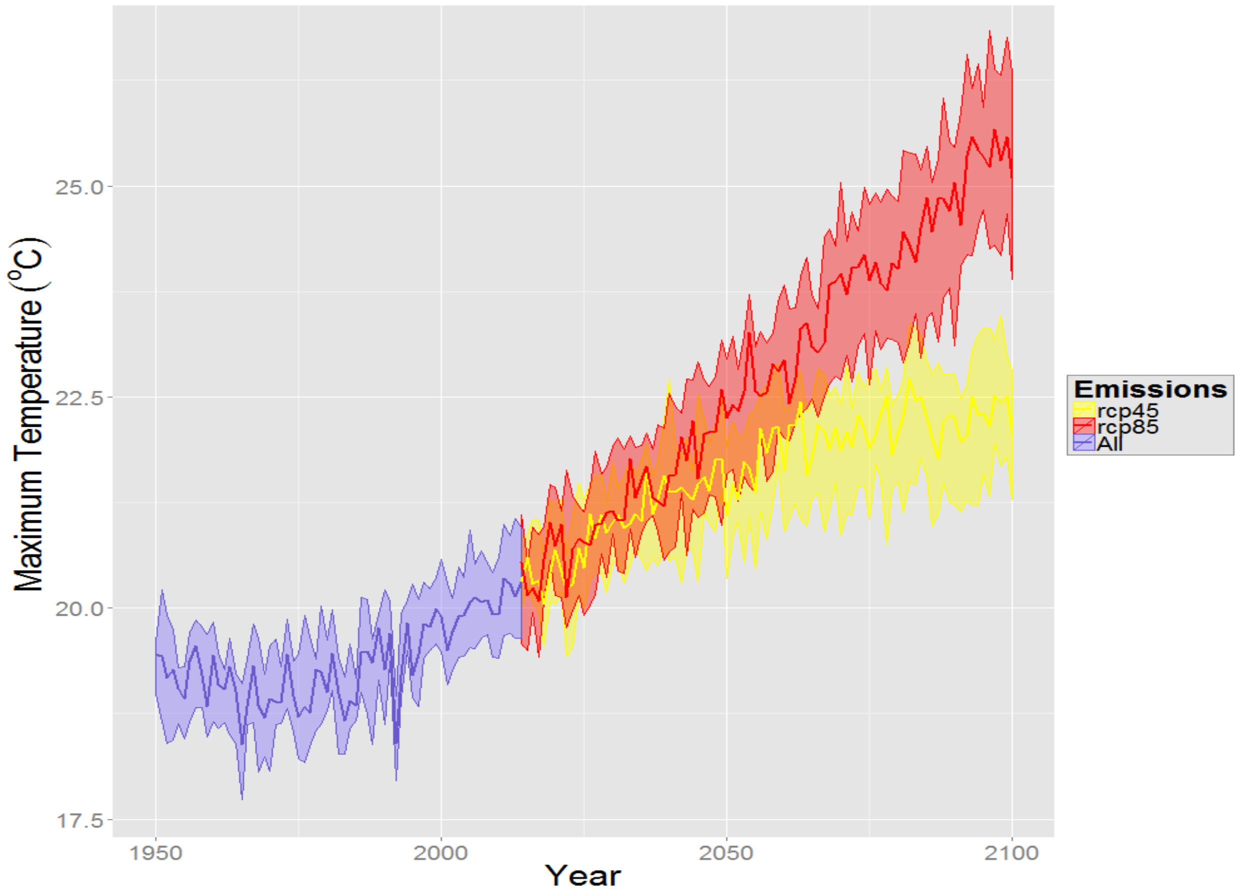


Figure 21. Projections for annual maximum temperature with median, 25 and 75% quantiles grouped by emissions scenario for Lincoln Boyhood National Memorial. (Data and graphic prepared by NCCSC.)

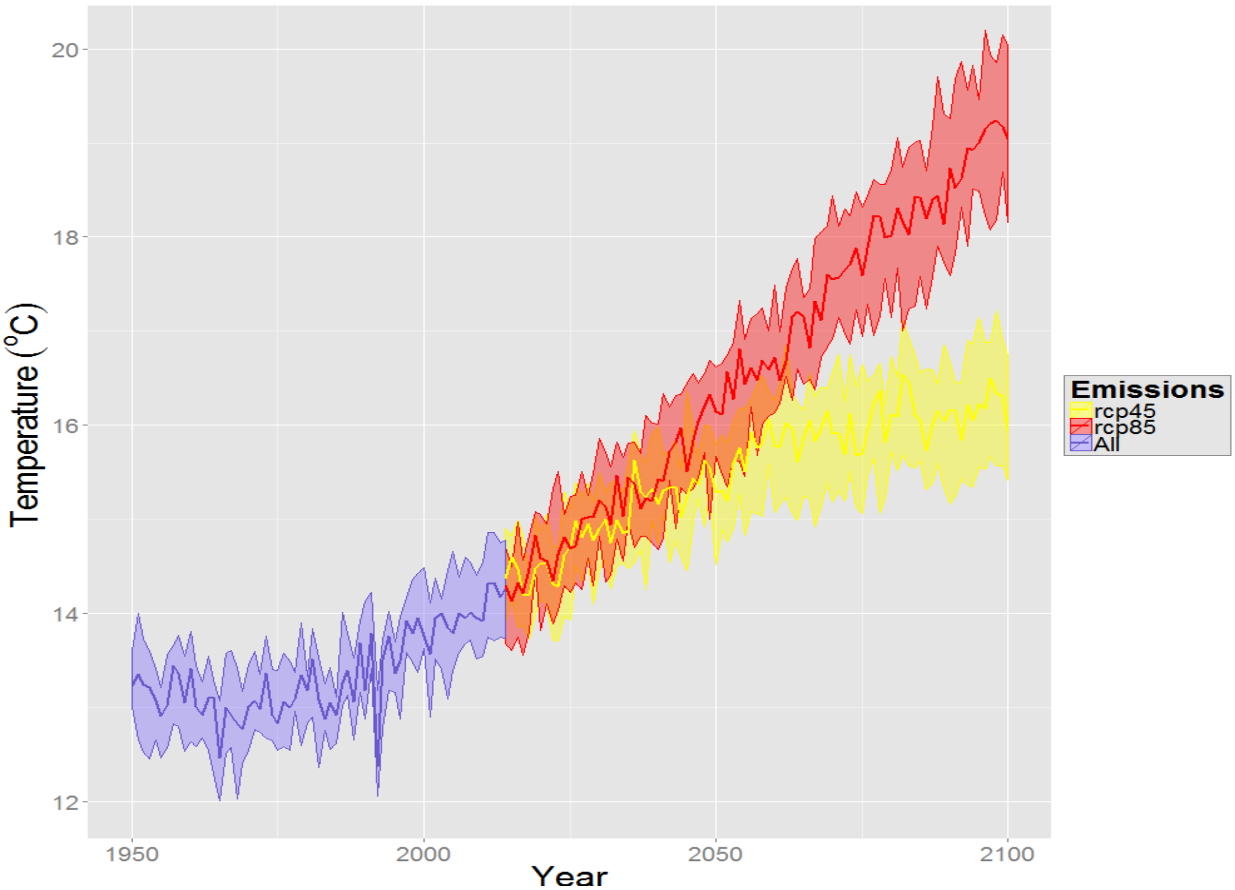


Figure 22. Projections for annual mean (lower) temperature with median, 25 and 75% quantiles grouped by emissions scenario for Lincoln Boyhood National Memorial. (Data and graphic prepared by NCCSC.)

Precipitation

Historical Trends

Historical trends in monthly and annual precipitation for 1895–2012 were examined to understand patterns and variability. Patterns of seasonality are not clear (Figure 19). The linear regression of mean monthly precipitation over time was not significant for the 1895–1980 period (p=0.338) or the 1980–2012 period (p=0.206) (Figure 23). Variability in annual (Figure 24) precipitation is relatively high.

In recent decades the United States has experienced increased amounts of precipitation falling in very heavy events, defined as the heaviest 1% of all daily events from 1901 to 2012 (Walsh et al. 2014b). The largest regional increases have been in the Midwest and Northeast when compared to the 1901–1960 average (Walsh et al. 2014b). Data for the Midwest region, which includes LIBO, indicate an increase of 20 to 30% or more in the annual amount of precipitation falling in very heavy events over the past few decades (Figure 24).

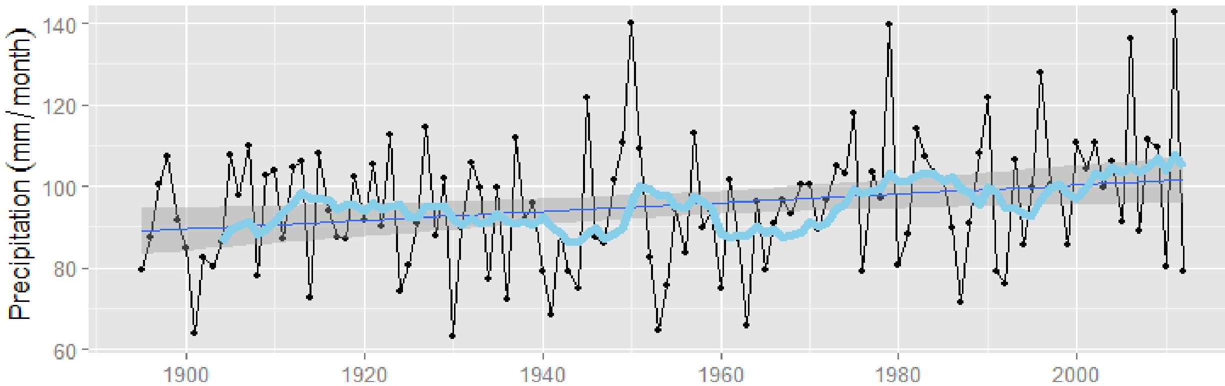


Figure 23. Historical PRISM mean monthly precipitation at Lincoln Boyhood National Memorial showing linear model fit and a five-year lag running mean. (Data and graphic prepared by NCCSC.)

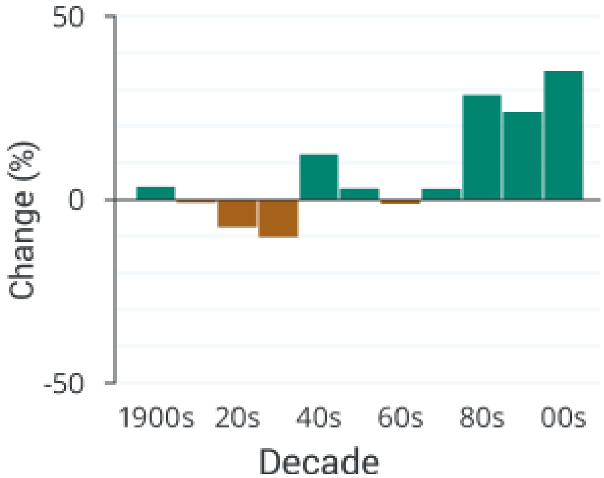


Figure 24. Percent change in the annual amount of precipitation falling in very heavy events by decade compared to the 1901–1960 average for the Midwest region. A very heavy event is defined as the heaviest 1% of all daily events from 1901 to 2012. The far-right bar is for 2001–2012 (Walsh et al. 2014b).

Modeled Future Changes

Modeled climate through the year 2100 projects increasing mean monthly precipitation under both moderate (RCP 4.5) and high (RCP 8.5) emission scenarios (Figure 25). Both the medium and high emission scenarios are projected to lead to higher mean monthly precipitation compared to the baseline period, with increases of approximately 1–4 mm (0.04–0.16 inches) per month or approximately 12–48 mm (0.48–1.92 inches) per year by the 2040s and 1–7 mm (0.04–0.28 inches) per month or approximately 12–84 mm (0.48–3.36 inches) per year by the 2080s.

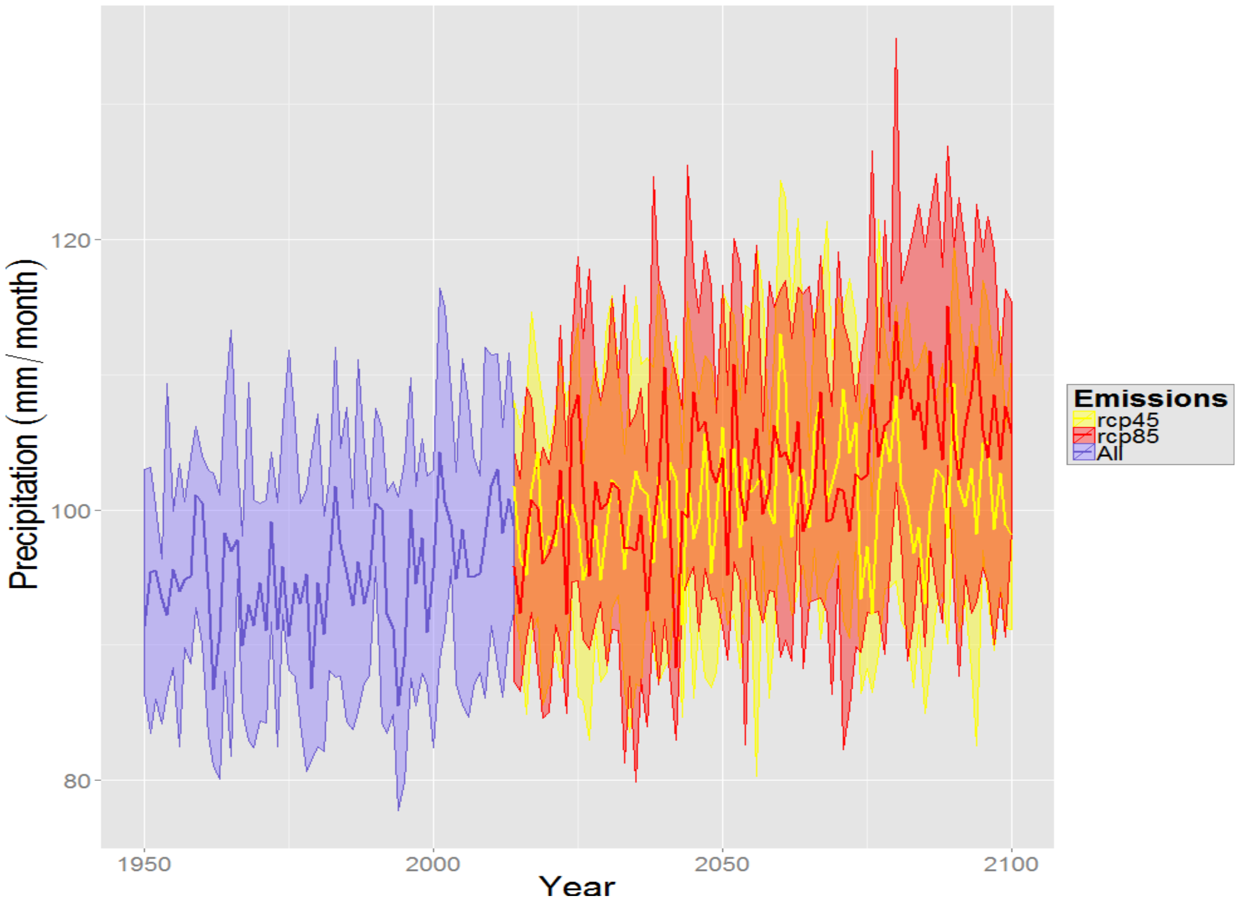


Figure 25. Projections for monthly precipitation at Lincoln Boyhood National Memorial, showing mean, 25% and 75% quantiles for two emissions scenarios. (Data and graphic prepared by NCCSC.)

Aridity

Aridity and moisture availability were examined using the Palmer Drought Severity Index (Palmer 1965) for 1895–2017. No modeled future events were considered for aridity due to a lack of well-supported tools to examine this indicator's potential for change.

Historical Trends

Palmer Drought Severity Index (PDSI) values were calculated for the period from 1895 to 2017 (Figure 26). For 1895–2017, LIBO PDSI values show periodic moderate drought lasting 2–5 years occurring approximately every 15–20 years until about 1970. Since then, droughts have become less frequent and severe.

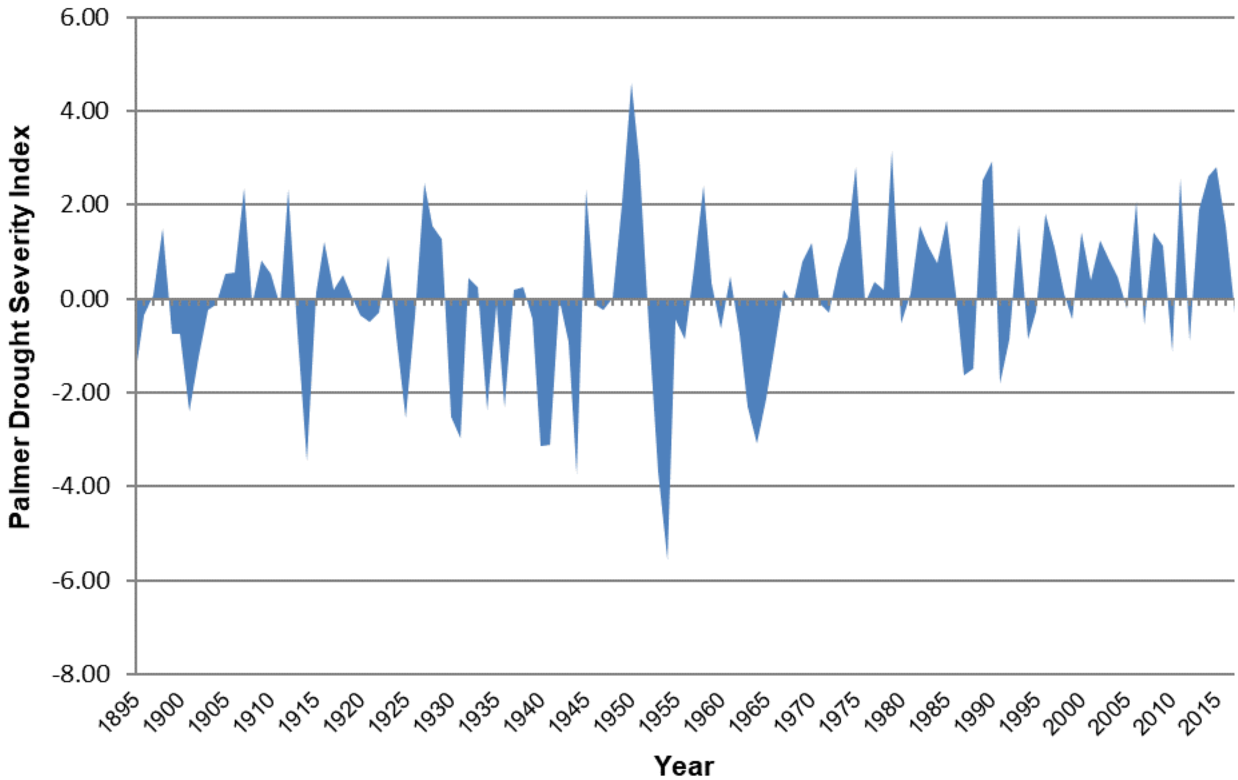


Figure 26. Palmer Drought Severity Index from 1895 –2017 for Lincoln Boyhood National Memorial. Negative values represent dry conditions and positive values represent moist conditions (NCDC 2018b).

<u>Frost-Free Period</u>

Historical Trends

The last frost in the spring has been occurring earlier in the year, and the first frost in the fall has been happening later. In the Midwest region, the average frost-free season for 1991–2011 was about 9 days longer than during 1901–1960 (Walsh et al. 2014b).

Modeled Future Changes

By 2070–2099, the frost-free season for the Midwest is projected to rise significantly as emissions of heat-trapping gases continue to grow. Melillo et al. (2014) project an increase of 20–30 days under a lower emissions (B1) SRES scenario and 40–50 days under a higher (A2) SRES emissions scenario, compared to the 1971–2000 baseline period (Melillo et al. 2014).

<u>Overall Assessment</u>

The data indicate that the climate in the region of LIBO has already become warmer, possibly wetter, and potentially more prone to more frequent and extreme weather events. Trends in the indicators are projected to continue or accelerate by the end of the 21st century. Because these changes in the environment are beyond the control of park managers and climate is not a conventional resource to be managed, climate change is not evaluated using the condition status and trend framework applied elsewhere in this condition assessment. Research and monitoring related to climate change, the anticipated vulnerability of specific resources vis-a-vis climate change, and its associated effects on resources and interactions with other ecological processes can be informed by this broad overview of the magnitude of climate change in the Midwest.

Management and Ecological Implications

Changing climate is anticipated to impact Midwestern forests in a number of ways and is likely to compound the effects of existing stressors and increase the vulnerability of forests to pests, invasive species and loss of native species (NFWPCAP 2012). Species ranges and ecological dynamics are already responding to recent climate shifts, and current reserves including NPS units will be unable to support all species, communities and ecosystems (Heller and Zavaleta 2009), some of which form the core of their park mission. Some of the key anticipated ecological impacts and potential management implications of climate change in the eastern deciduous forest region and at LIBO include:

- Increasing temperatures cause an increase in evaporation, which will take place mostly in the summer, potentially increasing the vulnerability of organisms in the region to drought in combination with other factors including altered precipitation, runoff, and soil moisture (Hayhoe 2007).
- Less predictable winter temperature and precipitation patterns interposed by warm spells could cause trees and other plants to bud and leaf out earlier, increasing their vulnerability to late-season freezes (Hayhoe et al. 2007).
- Higher temperatures could affect phenological events such as flowering, fruit set, and seed production. Longer growing seasons could increase wood production at the expense of root and foliar mass (Hayhoe et al. 2007).
- Warmer temperatures may increase the negative effects of ozone pollution on forest growth and health and increase vulnerability to disease (USDA 2001).
- An interruption in the timing of lifecycles between predators and prey may have a large impact on wildlife (Parmesan 2006).
- Bird species of eastern forests have a higher vulnerability to climate change than birds in western, boreal, or subtropical forests. Approximately 75% of eastern forest bird species that live in a single forest type are moderately or highly vulnerable to climate change (NABCI 2010).
- Increased temperatures can increase the metabolism, reproductive rates, and survival of nuisance species (Dukes et al. 2009), including the black-legged tick (*Ixodes scapularis*), which is a carrier of the bacteria that causes Lyme disease (Gatewood et al. 2009).
- An increase in the growth, reproduction, dispersal, transmission, infection phenology, and overwinter survival of some forest pathogens could be increased by climate change (Schramm and Loehman 2011).
- A longer growing season could increase carbon sequestration in plants (Peñuelas et al. 2009) and increase competition from invasive exotic plants (NFWPCAP 2012).
- Extreme events such as heat waves and heavy rains are expected to happen more frequently (Karl et al. 2009), and the likelihood of flooding in the wetter, northern portions of the Midwest is expected to increase (Walsh 2014b).

- Native species and communities may have a limited ability to adapt; the relatively gentle local relief increases vulnerability to climate change because species and habitats would need to migrate long distances northward to compensate for temperature shifts. This challenge is exacerbated by the highly fragmented and altered landscape in the region (Schramm and Loehman 2011).
- Climate change is likely to exacerbate existing stressors related to anthropogenic disturbances at landscape scales including energy development and agriculture that fragment the landscape and hinder species adaptation (Bagne et al. 2013, Shaeffer et al. 2014).

It is increasingly clear that given significant shifts in climatic variables, adaptation efforts will need to emphasize managing for inevitable ecological changes and concurrently adjusting some management objectives or targets (Stein et al. 2013). In a review of articles examining biodiversity conservation recommendations in response to climate change, Heller and Zavaleta (2009) synthesized conservation recommendations with regard to regional planning, site-scale management, and modification of existing conservation plans. They found that most recommendations offer general principles for climate change adaptation but lack the specificity needed for implementation. Specific adaptation tools and approaches will undoubtedly help park managers with these challenges. Adaptation approaches need to be intentional, context-specific and based on a deliberative process, rather than selected from a generic menu of options (Stein et al. 2014).

While climate change cannot be controlled by the memorial, managers can take steps to minimize the severity of exposure to these changes and help conserve sensitive resources as the transition continues. Existing condition analyses and summaries developed by this NRCA will be useful for subsequent park-level climate change studies and planning efforts.

Uncertainty and Data Gaps

Climate change projections have inherently high uncertainty. Confidence is higher in modeled temperature dynamics and lower for modeled precipitation totals and seasonal patterns. The largest uncertainty in projecting climate change beyond the next few decades is the level of heat-trapping gas emissions (Walsh et al. 2014a). Information needed to help manage resources and understand the repercussions of climate change to the park includes: 1) more specific, applied examples of adaptation principles that are consistent with uncertainty about the future; 2) a practical adaptation planning process to guide selection and integration of recommendations into existing policies and programs; and 3) greater integration of social science and extension of adaptation approaches beyond park boundaries (Heller and Zavaleta 2009).

Sources of Expertise

- Jeffrey Morisette (Director, DOI North Central Climate Science Center). Provided data and expertise regarding modeled climate and metrics.
- Marian Talbert, Biostatistician, DOI North Central Climate Science Center. Provided data and expertise regarding modeled climate and metrics.

- John Gross, Climate Change Ecologist, NPS Inventory and Monitoring Program National Office. Provided expertise regarding modeled climate and metrics.

Air Quality

Background and Importance

The NPS Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1977, and its subsequent amendments, protect and regulate the air quality of the National Parks within the United States. The NPS is responsible for protecting air quality and related issues that may be impacted by air pollution. Many resources in parks can be affected by air pollution. For example, scenic vistas require good visibility and low haze. Human-made pollution can harm ecological resources, including water quality, plants and animals. Air pollution can also cause or intensify respiratory symptoms for visitors and employees at NPS areas. Ozone, in particular, causes problems for human health, including difficulty breathing, chest pain, coughing, inflamed airways, and making lungs more susceptible to infection (EPA 2012). Because of these many links, poor and/or declining air quality can impact park visitation. A synthesis of seven visitor studies conducted in the NPS Midwest Region found that clean air was ranked as *extremely important* or *very important* by 88% of visitor groups (Kulesza et al. 2013).

National Park Service properties fall under two different classifications for air quality protection. Class I airsheds are defined as national parks over 6,000 acres (2,428 ha), national wilderness areas, national memorial parks over 5,000 acres (2,023 ha), or international parks in existence as of August 7, 1977 (NPS ARD 2013). Class II airsheds are areas of the country protected under the CAA but identified for somewhat less stringent protection from air pollution damage than a Class I area, except in specified cases (NPS ARD 2013). Based on these classifications of airsheds, Lincoln Boyhood National Memorial (LIBO) falls under the Class II area of protection.

Air quality can have a significant impact on the vegetation and ecology of an area. The NPS Air Resources Division describes ground-level ozone as having a larger effect on plants than all other air pollutants combined. In addition to being a concern for the health of park staff and visitors, long-term exposures to ground-level ozone can cause injury to ozone-sensitive plants. There are 30 plant species identified within LIBO that are sensitive to ozone (NPS ARD 2017b). Ozone is able to enter leaves through stomata and causes chlorosis and necrosis of leaves (Figure 27), among other problems. Soil moisture plays a big role in the uptake of ambient ozone, as moist soils allow plants to transpire and increase stomatal conductance which, in turn, increases ozone uptake (Panek and Ustin 2004). A risk assessment concluded that plants in LIBO were at high risk for ozone damage (Kohut 2007).

While there are no data documenting adverse environmental effects of air pollution at LIBO (Sullivan 2016), nitrogen (ammonia—NH_4) and sulfur (sulfate—SO_3) deposition can cause acidification of water bodies, while excess nitrate (NO_3) can lead to nutrient effects on biodiversity. Decreased visibility from haze does not affect the ecology of an area so much as it affects the human element through decreased viewing opportunities of the protected lands within NPS units.

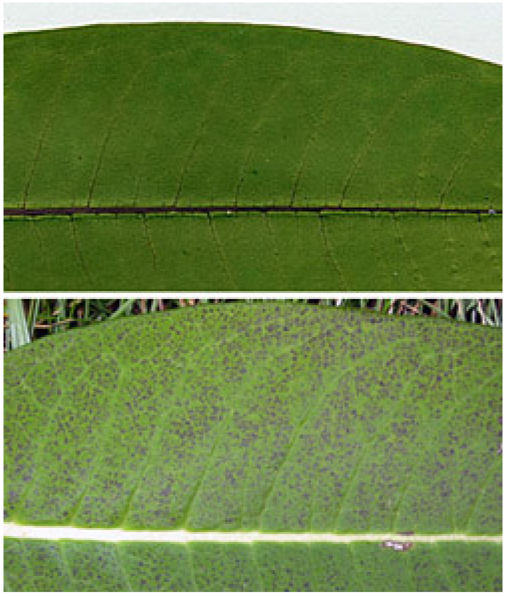


Figure 27. *Asclepias syriaca* normal leaf (top) and ozone-injured leaf (bottom). (Photo: NPS ARD.)

As of June 2018, the LIBO area was not listed by EPA as a non-attainment or maintenance area for ozone levels (EPA 2018). The memorial experiences “Very High” exposure to atmospheric nitrogen (N) enrichment and has been described as being at moderate risk from N enrichment (Sullivan et al. 2011a). LIBO also has “Very High” exposure to acidic deposition from sulfur (S) and N emissions and has been described as being at moderate risk from acidic deposition (Sullivan et al. 2011b).

Threats/ Stressors

Although Spencer County, Indiana, is in attainment for all regulated criteria pollutants, Veale and Washington Townships near Spencer County are designated as Nonattainment Areas for sulfur dioxide. Spencer County was previously listed as a Nonattainment Area for $PM_{2.5}$ until a change in federal standards in 2016 lifted this designation (IDEM 2018). LIBO is located in the southern part of Indiana and is mostly rural and exurban in nature, but coal-fired power plants in the region still continue to affect its air quality.

Indicators and Measures

- Ozone: human health risk
- Ozone: vegetation health risk
- Atmospheric wet deposition of nitrogen
- Atmospheric wet deposition of sulfur
- Visibility haze index

Data and Methods

The condition of air quality within LIBO was assessed using methodology developed by the NPS ARD for use in Natural Resource Condition Assessments (Taylor 2017). The ARD uses all available data from NPS, EPA, state, and/or tribal monitoring stations to interpolate air quality values, with a specific value assigned to the maximum value within each park. Even though the data are derived from all available monitors, data from the closest stations are more heavily weighted.

Trends are computed from data collected over a 10-year period at on-site or nearby representative monitors. Trends are calculated for sites that have at least six years of annual data and an annual value for the end year of the reporting period. There are no representative monitoring stations for ozone, wet deposition, or visibility located on or near LIBO to assess 10-year trends. Therefore, available monitoring data for the memorial are interpolated from regional monitoring stations. Ozone is monitored at two stations in the region in Boonville, Indiana (15 miles west of LIBO) and in Perry County, Indiana (15 miles northeast of LIBO). Wet deposition is monitored in Frickton, Indiana (55 miles northwest of the memorial) (NPS ARD 2001). There is an Interagency Monitoring of Protected Visual Environments (IMPROVE) visibility monitoring station 70 miles northeast of the memorial in Livonia, Indiana (CIRA 2018).

Conditions and trends data were retrieved from the NPS Air Quality Conditions and Trends by Park database (NPS ARD 2017a).

Reference Conditions

Reference conditions are based on regulatory standards, best available scientific knowledge, or NPS ARD recommendations/guidance (Taylor 2017). A summary of reference conditions and condition class rating for air quality indicators is shown in Table 20. Condition assessments for U.S. parks occupying a single contiguous land parcel use the Inverse Distance Weighted (IDW) interpolation method. This method is used to estimate 5-year average (2011–2015) values. Trend analyses use 10 years (2006–2015) of data from on-site or nearby monitors (NPS ARD 2017a).

Table 20. Reference condition framework for air quality indicators (Taylor 2017).

Air Quality Indicator	Specific Measure	Good Condition	Moderate Condition (Warrants Moderate Concern)	Poor Condition (Warrants Significant Concern)
Ozone	Human Health: Annual 4th-highest 8hr concentration	≤ 54 ppb	55–70 ppb	≥ 71 ppb
	Vegetation Health: 3-month maximum 12hr W126 index	< 7 ppm-hrs	7–13 ppm-hrs	> 13 ppm-hrs
Nitrogen	Wet Deposition	<1 kg/ha/yr	1–3 kg/ha/yr	> 3 kg/ha/yr
Sulfur	Wet Deposition	<1 kg/ha/yr	1–3 kg/ha/yr	> 3 kg/ha/yr
Visibility	Haze Index	< 2 deciviews	2–8 deciviews	> 8 deciviews

Ozone: Human Health Risk

The primary National Ambient Air Quality Standard (NAAQS) for ground-level ozone is set by the EPA and is based on human health effects. The NAAQS was set to 70 parts per billion (ppb) in October 2015, which strengthened the previous standard of 75 ppb. The NPS ARD benchmarks for the human health risk from ozone status are based on the updated Air Quality Index (AQI) breakpoints.

The status for human health risk from ozone is based on the estimated 5-year average of the 4th-highest daily maximum 8-hour average ozone concentration compared to benchmarks. Ozone concentrations greater than or equal to 71 ppb warrant significant concern (Poor Condition). Ozone concentrations from 55–70 ppb warrant moderate concern (Moderate Condition). A resource is considered to be in Good Condition when ozone concentrations are less than or equal to 54 ppb (Table 20) (Taylor 2017).

Ozone: Vegetation Health Risk

The W126 index is a biologically relevant measure that focuses on plant response to ozone exposure. The equation used to calculate the W126 index preferentially weights the higher ozone concentrations that are more likely to cause plant damage. It sums all of the weighted concentrations during daylight hours when the majority of gas exchange occurs between the plant and the atmosphere. The highest 3-month period that occurs during the growing season is reported in parts per million-hours (ppm-hrs).

The status for vegetation health risk from ozone is based on the estimated 5-year average of the 3-month 12-hour W126 index compared to benchmarks. For the NRCA, a W126 index greater than 13 ppm-hrs warrants significant concern (Poor Condition), an index from 7–13 ppm-hrs warrants moderate concern (Moderate Condition), and a W126 index less than 7 ppm-hrs indicates Good Condition (Table 20) (Taylor 2017).

Wet Nitrogen Deposition

The NPS ARD (Taylor 2017) considers parks that receive less than 1 kg/ha/yr of nitrogen as being in "Good Condition". Parks receiving between 1–3 kg/ha/yr are ranked as "Moderate Condition". Those parks that receive greater than 3 kg/ha/yr are ranked as "Poor Condition" (Table 20) (Taylor 2017).

Wet Sulfur Deposition

The NPS ARD (Taylor 2017) considers parks that receive less than 1 kg/ha/yr of sulfur as being in "Good Condition". Parks receiving between 1–3 kg/ha/yr are ranked as "Moderate Condition". Those parks that receive greater than 3 kg/ha/yr are ranked as "Poor Condition" (Table 20) (Taylor 2017).

Visibility

Visibility is measured using the Haze Index in deciviews (dv). Visibility conditions are the difference between the mid-range day visibility and estimated average natural visibility (7.4 dv at LIBO), where the mid-range days natural visibility is the mean between the 40th and 60th percentiles (Taylor 2017). Five-year interpolated averages are used in the contiguous U.S. Visibility is considered to be in “Good Condition” if visibility is less than 2 dv, “Moderate Condition” if between 2–8 dv, and “Poor Condition” if greater than 8 dv (Table 20) (Taylor 2017).

Condition and Trend

Ozone: Human Health Risk

From 2011–2015, LIBO experienced a 4th highest 8-hr ozone average concentration of 70.3 ppb (NPS ARD 2017a). No trend information is available because there are not sufficient on-site or nearby ozone monitoring data (NPS ARD 2017a). Available data indicate moderate condition for ozone levels with an unknown trend and medium confidence due to the use of interpolated data from more distant ozone monitors (NPS ARD 2017a).

Ozone: Vegetation Health Risk

The 2011–2015 estimated W126 metric is 9.8 ppm-hrs. This value indicates moderate concern for the impact of ozone on vegetation (NPS ARD 2017a). No trend information is available (NPS ARD 2017a). Overall, the vegetation health risk from ground-level ozone is in moderate condition with unknown trend and medium confidence due to on the use of interpolated data from more distant ozone monitors (NPS ARD 2017a). Also, a risk assessment (Kohut 2007) concluded that plants at LIBO were at high risk for ozone damage

Wet Nitrogen Deposition

Based on the 2011–2015 estimated wet nitrogen deposition of 5.2 kg/ha/yr, wet nitrogen deposition is in poor condition (warrants significant concern) with medium confidence due to the regional and modeled nature of the data. No trend information is available because there are not sufficient on-site or nearby deposition monitoring data (NPS ARD 2017a).

Wet Sulfur Deposition

Based on the 2011–2015 estimated wet sulfur deposition of 3.7 kg/ha/yr, wet sulfur deposition falls in the poor condition category with medium confidence due to the regional and modeled nature of the data. No trend information is available because there are not sufficient on-site or nearby deposition monitoring data (NPS ARD 2017a).

Visibility

Based on the 2011–2015 estimated visibility on mid-range days of 9.8 dv, the visibility condition falls in the poor condition category with medium confidence due to the regional and modeled nature of the data. No trend information is available because there are not sufficient on-site or nearby visibility monitoring data (NPS ARD 2017a).

Overall Condition

Based on the evaluation of air quality indicators, air quality condition warrants significant concern, with no discernable trend (Table 21). Confidence in the assessment is medium. As there are no large-scale industrial sources nearby, impacts to air quality appear to be largely from distant sources that are affecting regional air quality.

Table 21. Condition assessment interpretation for air quality at Lincoln Boyhood National Memorial.

Indicator	Measure	Condition Status/Trend	Rationale
Ozone	Human Health: Annual 4th-highest 8hr concentration		Human health risk from ground-level ozone warrants moderate concern at LIBO. Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated ozone of 70.3 ppb.
	Vegetation Health: 3-month maximum 12hr W126 index		Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated W126 index of 9.8 parts per million-hours (ppm-hrs) and warrants moderate concern. The W126 index relates plant response to ozone exposure.
Nitrogen	Wet Deposition		Wet nitrogen deposition warrants significant concern based on NPS Air Resources Division benchmarks and the 2011–2015 estimated wet nitrogen deposition of 5.2 kg/ha/yr. Nitrogen deposition may disrupt soil nutrient cycling and affect biodiversity of some plant communities, including grasslands and wetlands.
Sulfur	Wet Deposition		Wet sulfur deposition warrants significant concern based on NPS Air Resources Division benchmarks and the 2011–2015 estimated wet sulfur deposition of 3.7 kg/ha/yr.
Visibility	Haze Index		Visibility warrants significant concern at LIBO. Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated visibility on mid-range days of 9.8 deciviews (dv) above estimated natural conditions.
Air Quality overall	–		**The condition of air quality indicators warrants significant concern with no trend determined due to insufficient on-site or nearby monitoring data. Confidence in the assessment is medium because estimates are based on interpolated data from more distant monitoring stations.**

Uncertainty and Data Gaps

Monitoring stations are needed nearby or within LIBO to better understand the specific air quality conditions at the memorial. Estimated values based on geospatial interpolations are valuable but can misrepresent local conditions due to modeling errors. Monitoring of air quality conditions within LIBO or nearby would reduce uncertainty from the interpolations for all indicators.

Sources of Expertise

The NPS ARD manages the national air resource management program for the NPS. They, along with NPS regional offices and memorial staff, provided air quality analysis and expertise.

Vegetation Communities

Background and Importance

The Eastern Deciduous Forest ecosystem once covered almost a million square miles of the eastern United States stretching from the Atlantic seaboard west to the eastern portions of Minnesota, Iowa, Illinois, Missouri, Texas, and Oklahoma (Delcourt and Delcourt 2000). Stretching across 26 states, including most of Indiana, this ecosystem included vast stretches of unbroken forest that persisted for thousands of years (NPS 2016b), covering all of southern Indiana, including what is now Lincoln Boyhood National Memorial (LIBO)(Figure 28). The landscape was almost completely dominated by oak (*Quercus* spp.)/hickory (*Carya* spp.) forest communities (Woodall et al. 2011).

Figure 28. Forest community at LIBO (CSU Photo).

Southern Indiana was an untamed wilderness that was largely unsettled when the Lincoln family arrived in 1816 (NPS 2017). The area around LIBO in Spencer County, Indiana, was a mosaic of xeric and mesic upland oak-hickory forest with patches of mixed-hardwood mesic forest grading into bottomland forests along the streams (Pavlovic and White 1989; Middlemis-Brown and Young 2013). The forests were dominated by native hardwood trees such as hickory, walnut (*Juglans* spp.), white oak (*Q. alba*), tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), Eastern redbud (*Cercis canadensis*), sweet gum (*Liquidambar styraciflua*), ash (*Fraxinus* spp.), and wild cherry (*Prunus serotine*). This area was quickly cleared and cultivated by settlers, and by the time Lincoln left in 1830, the LIBO area was no longer considered wilderness (NPS 2017) (Figure 29). By the mid-1800s, a majority of the current LIBO property had been cleared and several buildings were erected as part of the development of Lincoln City.

Figure 29. Hauling a large log to the mill, 1908, in Dale, Indiana, a few miles from the memorial. (Photo courtesy of Lincoln Boyhood National Memorial Historic Photograph Collection, reproduced with permission from Capps and Ammeson 2008.)

The history of LIBO as a protected park began when a state park was created in the 1920s to preserve the place where Abraham Lincoln grew to manhood. Early park managers recognized that the natural environment at LIBO had played a significant role in shaping Lincoln's character. Therefore, they were determined to work towards the restoration of the forest at LIBO as it was their belief that seeing a landscape similar to what Lincoln had known as a boy would help visitors to gain insight into the man that he became (NPS 2017). Through planned forest restoration efforts and succession over time, most of what is now LIBO has changed significantly from the predominantly agricultural landscape that existed in the early 1900s (Figure 30). When the memorial was authorized by an Act of Congress in 1962, the intent was to "preserve the site in the State of Indiana associated with the boyhood and family of Abraham Lincoln," the "original Tom Lincoln Farm," and "the nearby gravesite of Nancy Hanks Lincoln" (Public Law 87-407, 28 FR 8379; Pavlovic and White 1989).

A long history of anthropogenic disturbances, including forest clearing, intensive agricultural use, grazing, and fire suppression have impacted cultural and natural resources at LIBO (Pavlovic and White 1989). The memorial has been reclaimed to some degree but impacts to vegetation communities are still prevalent. When the park was established, much of the land had been abandoned to natural succession. Mature forest now covers approximately 120 acres at LIBO with these forests largely being the result of reforestation efforts by the Civilian Conservation Corps during the implementation of the Olmstead plan in the 1930s and 1940s (Pavlovic and White 1989). A few larger/older trees also exist on the property as they had been left for ornamental purposes (Pavlovic and White 1989). Subsequent reforestation efforts were also completed in the early-1990s in an attempt to restore LIBO to pre-settlement condition (Pavlovic 1990; Adams 1996).

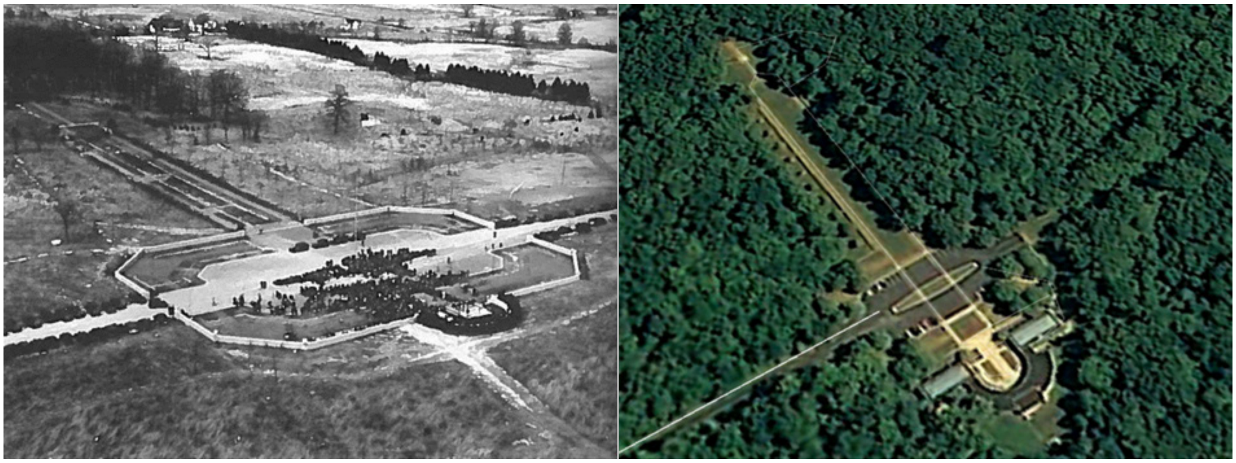


Figure 30. Forest cover in 1931 (left) and in 2010 (right), showing extensive and rapid forest growth. Both views are from the southwest showing the memorial and walled plaza to the south, and the formal allée extending north toward the Nancy Lincoln Gravesite at upper left. (Left photo courtesy of Lincoln Boyhood National Memorial Historic Photograph Collection, reproduced with permission from Capps and Ammeson 2008, right photo via CSU license of Google Earth Pro 2018)

The mature forest now contains a canopy of red oak (*Q. rubra*), black oak (*Q. velutina*), and white oak, as well as pignut hickory (*C. glabra*) and shagbark hickory (C. ovata) (Middlemis-Brown and Young 2013). Other successional uplands, which were not planted, have succeeded to a tulip poplar, red maple, sweetgum, and sassafras (*Sassafras albidum*) forest (Middlemis-Brown and Young 2013). Additionally, a mixed maple-tulip poplar forest, planted during the 1920s and 1930s, covers much of the southeastern corner of LIBO. Forests at LIBO are dominated by successional mesic species such as tulip poplar, sweetgum, and maples with pin oak (*Q. palustris*) also occurring in remnant mature forests (Middlemis-Brown and Young 2013). Given the land use history, a variety of exotic and invasive species are present within the park (Young et al. 2016). No federal or state listed plant species occur in the park (Middlemis-Brown and Young 2013). As outlined in Diamond et al. (2014), five vegetation community types were classified and mapped at LIBO, including three types specific to the park (park specials) and two types that fit well with communities already described within the U.S. National Vegetation Classification system (USNVC) (Table 22, Figure 31). Both USNVC types were mapped at the association level. Among the five community types, Diamond et al. (2014) found the mature Black Oak-White Oak-(Pignut, Shagbark) Hickory Forest association to be in the best condition, occupying 10.2 acres of LIBO around the gravesite of Nancy Hank Lincoln (Figure 32). Diamond et al. (2014) also found a restored deciduous forest containing large sugar maples (*A. saccharum*) and tulip poplars partially surrounded the mature forest, covering 49.4 acres at LIBO. Of the five mapped types, Diamond et al. (2014) found the ruderal red maple forest was the most dominant type in the park, occupying 93.0 acres or 56.5% of the non-developed land within the park. Invasive species were abundant to dominant within this type and no native canopy trees were recorded to be dominant within the plots, indicating that without active management this type may persist as a ruderal forest for decades to come.

Table 22. Extent of mapped vegetation community associations by map classes at LIBO (Diamond et al. 2014).

Vegetation Physiognomy	USNVC Identifier	Mapped Class Name	Ecological Association	Acres	Hectares
Forests and Woodlands	CEGL002076	Black Oak-White Oak-(Pignut, Shagbark) Hickory Forest	*Quercus velutina* – *Quercus alba* – *Carya* (*glabra*, *ovata*) Forest	10.2	4.1
	CEGL006313	Ruderal White Pine Woodland	*Pinus strobus* Woodland	10.3	4.1
	None Assigned	Restored Deciduous Forest	*Acer saccharum* – *Liriodendron tulipifera* – *Liquidambar styraciflua* Forest	49.4	20
	None Assigned	Ruderal Forest	*Acer rubrum* – *Liquidambar styraciflua* Forest	93.0	37.6
	TOTAL FORESTS AND WOODLANDS	**–**	**–**	**162.9**	**65.8**
Herbaceous Vegetation	None Assigned	Ruderal Grassland	*Schedonorus pratensis* – *Trifolium* spp. Herbaceous Vegetation	10.3	4.2
	TOTAL HERBACEOUS VEGETATION	**–**	**–**	**10.3**	**4.2**

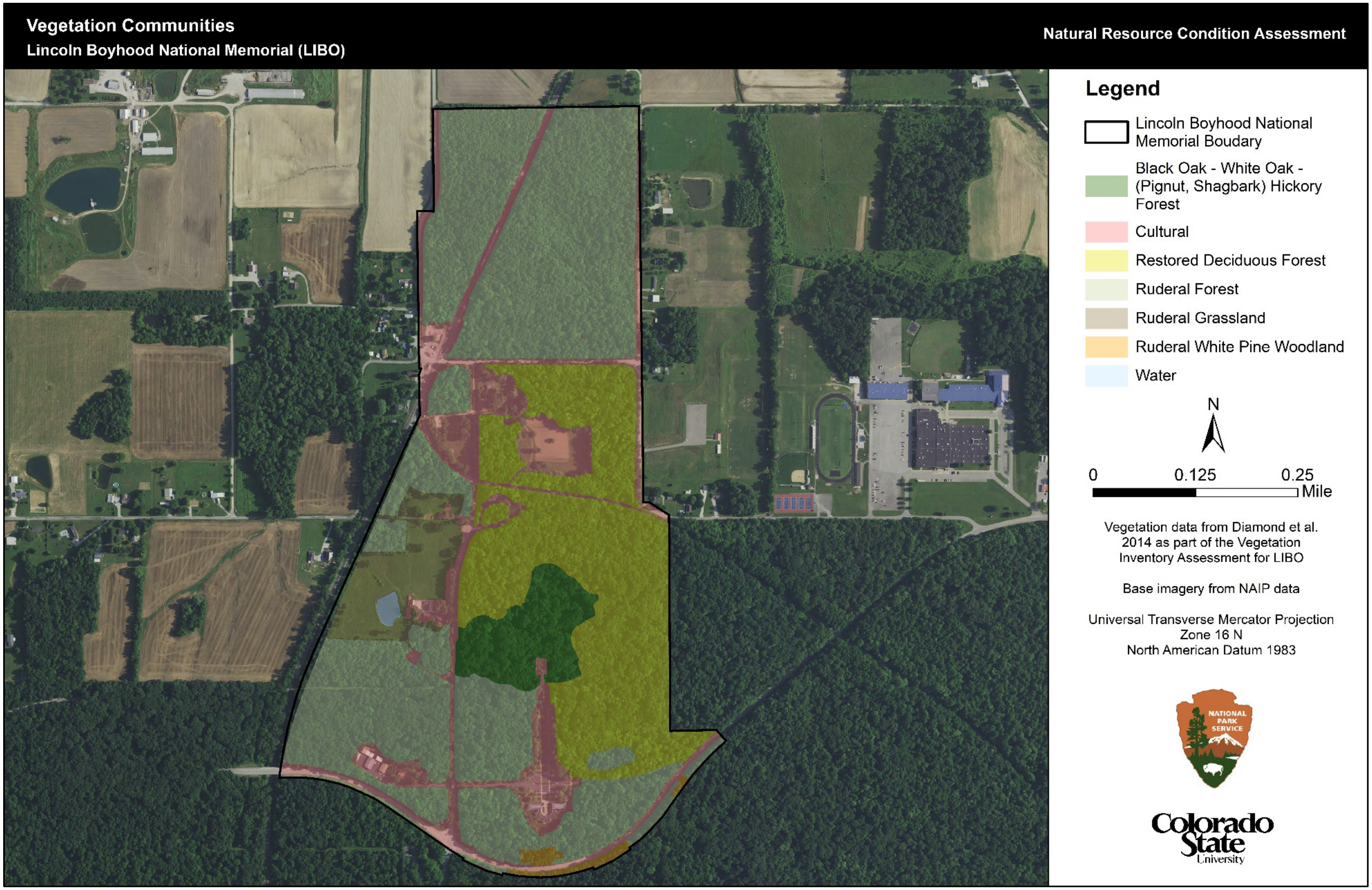


Figure 31. Vegetation community map for LIBO. Ruderal forest includes ruderal white pine woodland. (Data source: Diamond et al. 2014.)

Figure 32. View looking south down the allée toward the memorial (CSU photo).

One of the biggest threats to vegetation communities at LIBO is the impact of invasive, noxious weeds. Beginning in 2006, the NPS began a formal program of monitoring and controlling invasive species at LIBO (Cribbs et al. 2007). Major invasive species targeted include Japanese honeysuckle (*Lonicera japonica*), common periwinkle (*Vinca minor*), European privet (*Ligustrum vulgare*), multiflora rose (*Rosa multiflora*), crownvetch (*Securigera varia*), and autumn olive (*Elaeagnus umbellata*). Monitoring in 2011 and 2015 provided trend data pertaining to invasive weed frequency and abundance across the park and feedback with respect to management effectiveness (Young et al. 2012, 2016).

Forest pests and diseases are natural and important parts of a forest ecosystem. Native insects and pathogens remove old/weakened trees from the canopy, allowing new forest growth and nutrient cycling to occur. This process of forest regeneration and recycling of nutrients has occurred for millennia and is essential for healthy, stable forest ecosystems (Stolte 1997). Historically, native forest pests and diseases were regulated by a number of biotic and abiotic factors including host abundance, host condition, soil, climate, and disturbance history (Berryman 1986). Currently, changes in forest management, climate, and the introduction of exotic insects and diseases have altered the pathogen–host interaction in many forest ecosystems, leading to decreases in forest health (Vitousek et al. 1996). Forest pests and pathogens can influence forest dynamics (i.e., forest patterns and processes) by causing defoliation and mortality. These effects may occur at small scales (individual tree or gap phase) or at broad scales (landscape level, influencing forest development) and can occur at any seral stage (Castello et al. 1995).

The NPS manages over 3,400 square miles of forested area within the eastern U.S., so understanding impacts related to climate change is paramount for future management (Fisichelli et al. 2014). Changes in climate are expected to alter forest structure, function, composition, and regeneration with not all species or communities being impacted equally. For instance, there is expected to be a number of "winners" and "losers" at the species and/or community level in the face of a changing climate with some species' ranges being reduced, other ranges expanding, and still others being relatively unchanged.

Vegetation communities at LIBO have a long history of being impacted by a variety of stressors and threats including noxious and invasive weeds, diseases and insect pests, and the compounding effects of climate change, air pollution, acid rain/atmospheric chemistry and past land uses. These stressors and threats have collectively shaped and continue to impact vegetation community condition and ecological succession. This assessment will evaluate a suite of vegetation community condition indicators and assign an overall condition and trend to vegetation communities at LIBO.

Threats and Stressors

Primary threats to vegetation communities at LIBO include: 1) historical land uses that have impacted the vegetation community structure; 2) fragmentation from development that have reduced the continuity of the large tracts of native vegetation; 3) non-native exotic weeds, pathogens, and insects that influence vegetation community composition (Fisichelli et al. 2014; Fisichelli 2015). Compounding the effects of these stressors and threats are impacts from climate change, air pollution, acid rain, and changes in atmospheric chemistry (NPS 2016b).

Indicators and Measures

- Species composition and diversity
- Mean Coefficient of Conservatism ($\overline{C}$ and $\overline{C}_{\text{(Native)}}$)
- Floristic Quality Assessment Index (*FQAI*)
- Invasive exotic plants (% IEP cover)
- Forest pests and diseases
- Forest vulnerability to climate change

Data and Methods

Species Composition and Diversity

The structure, composition, condition, and diversity of the vegetation communities were evaluated primarily with data collected by Diamond et al. (2014) during a vegetation inventory project at LIBO. The project used vegetation plot data and aerial imagery to describe and map vegetation communities across LIBO using the USNVC. A total of 30 vegetation plots were used to help classify and describe LIBO vegetation communities. Information collected at each plot included the structure and cover, by stratum (herbaceous, shrub, or tree canopy), for all plant species within the plot. For this condition assessment, these data were used to evaluate the community composition, diversity, and richness, and to calculate an index of floristic quality that was used to evaluate community condition as well as provide comparison information for reference conditions. Diamond et al. (2014) contains more specific information on data collection and how the accuracy of the data was determined. Native species composition was determined by calculating the average percentage of plant species that are native in each plot within vegetation communities at LIBO. Monitoring of four vegetation monitoring sites representing a mix of successional hardwood forest and an old homesite restoration area within the southern portion of LIBO took place in 2011, 2015, and 2019 (Leis 2021).

Floristic Quality Assessment Index and Coefficient of Conservatism

Floristic quality was examined using *FQAI* tools. The *FQAI* approach to assessing ecological communities is based on the concept of species conservatism. The basis of the *FQAI* method is the use of "coefficients of conservatism" (*C* values), which are assigned to each floral taxon in a state or region by a panel of regional experts, following methods described by Swink and Wilhelm (1994) and Wilhelm and Masters (1995). *C* values range from 0 to 10 and represent the estimated probability that a plant is likely to occur in a landscape relatively unaltered from pre-Euro-American settlement conditions. High *C* values are assigned to species that are obligate to high-quality natural areas and cannot tolerate habitat degradation. Generally, *C* values of 0 are represented by non-native species (or those always found in disturbed settings); values between 0 and 10 reflect the range of disturbances tolerated by species (Andreas et al. 2004; Rothrock 2004; Lemly and Gilligan 2015). The proportion of conservative plants in a plant community provides a powerful and relatively easy assessment of the integrity of both biotic and abiotic processes and is indicative of the ecological integrity of a site (Wilhelm and Ladd 1988). *C* values from Indiana, (Table 23) were used for this assessment (Rothrock 2004).

Table 23. Coefficients of conservatism (*C* values) descriptions used in the *FQA* for vascular plants (Rothrock 2004; Andreas et al. 2004; Lemly and Gilligan 2015).

C	Description
0	Wide range of ecological tolerances, non-native opportunistic invaders or native taxa that are often part of ruderal communities.
1–2	Widespread taxa that are not typical of a particular community.
3–5	Intermediate range of ecological tolerances that typify a stable phase of a native community and persist under some disturbance.
6–8	Narrow range of ecological tolerances that typify a stable or near "climax" community. Obligate to more natural areas and can sustain some habitat degradation.
9–10	Obligate to high quality or relatively unaltered natural systems with a narrow range of ecological tolerances that exhibit a high degree of fidelity.

An *FQAI* was calculated for the vegetation communities at LIBO. The most basic *FQAI* is a simple average of the *C* values for a given site, generally called the "Mean *C*" or "$\overline{C}$," which can be used as a stand-alone indicator of habitat quality. The *FQAI* can be conceptualized as the weighted averaging of species richness, with the *C* value assigned to each species providing the weighting function. *FQAI* is calculated using the following equation (Andreas et al. 2004):

$$I = \sum((cc_i)/\sqrt{N})$$

Where I = the *FQAI* score, cc_i = the *C* value of plant *i*, and N = the total number of species in the site being evaluated. These values can then be compared to other vegetation communities that have been evaluated using a floristic quality assessment. Additionally, these indices can be calculated using only native species within each plot (e.g., $\overline{C}_{\text{(Native)}}$, $FQAI_{\text{(Native)}}$).

Invasive Exotic Plants

Non-native plant species are those considered to have been introduced by humans after the arrival of Euro-americans in the region. While non-native plant species are typically indicative of some level of disturbance, these species vary widely in their potential to cause ecosystem harm. Most non-native plant species are not considered invasive. Invasive species are non-native species that are considered to invade natural habitats and cause some level of environmental or economic harm. Executive Order (EO) 13751 defines an invasive species as "… a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health."

There are 104 invasive plants on the memorial's three "watch lists," including 74 species on the Early Detection Watch List (Table 24), 25 species occurring on the Park-established Watch List (Table 25), and 5 species on the Park-based Watch List (Table 26) (Young et al. 2016). The Early Detection Watch List includes plants designated as high priority invasive species (Young et al. 2016) that are not known to occur in LIBO. The Park-established Watch List includes designated invasive plants known to occur in LIBO. The Park-based Watch List includes species not formally designated as invasive plants but exhibiting invasive characteristics at LIBO. All plants on the lists are non-native with the exception of black locust (*Robinia pseudoacaia*), which, even though it is native to parts of Indiana, has a tendency to exhibit a variety of invasive traits (Young et al. 2016). While aquatic species are listed on the watch lists, only terrestrial plants were the focus of this assessment. These 104 plant species were considered invasive exotic plants (IEP). For each vegetation classification plot, percent IEP cover was calculated by summing the cover values for all IEP species, dividing by the sum of cover values for all species, and converting to a percentage. Additionally, data from Cribbs et al. (2007) and Young et al. (2012, 2016) were used to examine trends in the frequency and abundance of invasive species at LIBO over time. Invasive and nonnative plant data from the vegetation inventory project also were integrated into the Floristic Quality Assessment Index summaries.

Table 24. The 74 invasive exotic plant species on the Early Detection Watch List for LIBO (Young et al. 2016). These taxa have been designated as high priority invasive species and are not known to occur in LIBO.

Scientific Name	Common Name
Acer platanoides	Norway maple
Alliaria petiolata	Garlic mustard
Alnus glutinosa	European alder
Arctium minus	Lesser burdock
Bromus inermis	Smooth brome
Bromus sterilis	Poverty brome
Bromus tectorum	Cheatgrass

Table 24 (continued). The 74 invasive exotic plant species on the Early Detection Watch List for LIBO (Young et al. 2016). These taxa have been designated as high priority invasive species and are not known to occur in LIBO.

Scientific Name	Common Name
Butomus umbellatus	Flowering rush
Carduus nutans	Nodding plumeless thistle
Celastrus orbiculatus	Oriental bittersweet
Centaurea solstitialis	Yellow star-thistle
Centaurea stoebe ssp. *micranthos*	Spotted knapweed
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Cynanchum louiseae	Louise's swallow-wort
Cynanchum rossicum	European swallow-wort
Dipsacus fullonum	Fuller's teasel
Dipsacus laciniatus	Cutleaf teasel
Egeria densa	Brazilian waterweed
Elaeagnus umbellata	Autumn olive
Elymus repens	Quackgrass
Euonymus alata	Burningbush
Euphorbia cyparissias	Cypress spurge
Euphorbia esula	Leafy Spurge
Frangula alnus	Glossy buckthorn
Hesperis matronalis	Dames rocket
Holcus lanatus	Common velvetgrass
Humulus japonicus	Japanese hop
Hypericum perforatum	Common St. Johnswort
Iris pseudacorus	Paleyellow iris
Leonurus cardiaca	Common motherwort
Lepidium latifolium	Broadleaved pepperweed
Lespedeza bicolor	Shrub lesepedza
Linaria vulgaris	Butter and eggs
Lolium arundinaceum	Tall fescue
Lolium pratense	Meadow fescue
Lonicera maackii	Amur honeysuckle
Lonicera tatarica	Tatarian honeysuckle
Lonicera X *bella*	Bell's honeysuckle (hybrid)
Lotus corniculatus	Bird's-foot trefoil
Lysimachia nummularia	Creeping jenny

Table 24 (continued). The 74 invasive exotic plant species on the Early Detection Watch List for LIBO (Young et al. 2016). These taxa have been designated as high priority invasive species and are not known to occur in LIBO.

Scientific Name	**Common Name**
Lythrum salicaria	Purple loosestrife
Microstegium vimineum	Nepalese browntop
Miscanthus sinensis	Chinese silvergrass
Myosotis scorpioides	True forget-me-not
Myriophyllum spicatum	Eurasian watermilfoil
Najas minor	Brittle waternymph
Onopordum acanthium	Scotch cottonthistle
Ornithogalum umbellatum	Sleepydick
Pastinaca sativa	Wild parsnip
Paulownia tomentosa	Princesstree
Phalaris arundinacea	Reed canarygrass
Phragmites australis	Common reed
Populus alba	White poplar
Potamogeton crispus	Curly pondweed
Potentilla recta	Sulphur cinquefoil
Prunus mahaleb	Mahaleb's cherry
Pueraria montana var. *lobata*	Kudzu
Pyrus calleryana	Callery pear
Rhamnus cathartica	Common buckthorn
Rorippa nasturtium-aquaticum	Watercress
Rumex crispus	Curly dock
Saponaria officinalis	Bouncingbet
Sonchus arvensis	Field sowthistle
Securigera varia	Crownvetch
Sorghum halepense	Johnsongrass
Spiraea japonica	Japanese meadowsweet
Tanacetum vulgare	Common tansy
Torilis arvensis	Spreading hedgeparsley
Torilis japonica	Ercet hedgeparsley
Typha angustifolia	Narrowleaf cattail
Typha X *glauca*	Hybrid cattail
Ulmus pumila	Siberian elm
Viburnum opulus	European cranberrybush

Table 25. The 25 invasive plant species on the Park-established Watch List for LIBO as determined by Young et al. (2016). These species are designated invasive plants and are known to occur within the memorial.

Scientific Name	**Common Name**
Ailanthus altissima	Tree of heaven
Albizia julibrissin	Silktree
Berberis thunbergii	Japanese barberry
Bromus racemosus	Bald brome
Daucus carota	Queen Anne's lace
Dioscorea oppositifolia	Chinese yam
Euonymus fortune	Winter creeper
Glechoma hederacea	Ground ivy
Hedera helix	English ivy
Hemerocallis fulva	Orange daylily
Lespedeza cuneata	Sericea lespedeza
Ligustrum obtusifolium	Border privet
Ligustrum vulgare	European privet
Lonicera japonica	Japanese honeysuckle
Lonicera morrowii	Morrow's honeysuckle
Melilotus officinalis	Sweetclover
Morus alba	White mulberry
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Polygonum cuspidatum	Japanese knotweed
Robinia pseudoacacia	Black locust
Rosa multiflora	Multiflora rose
Rumex acetosella	Common sheep sorrel
Verbascum thapsus	Common mullein
Vinca minor	Common periwinkle

Table 26. The five species on the Park-based Watch List, which are not designated invasive species but were include on the IEP list based on park managers' recommendations (Young et al. 2016).

Scientific Name	**Common Name**
Dactylis glomerata	Bermudagrass
Forsythia suspensa	Weeping forsythia
Ligustrum sinense	Chinese privet
Lolium perenne	Perennial ryegrass
Wisteria sinensis	Chinese wisteria

Forest Pests and Diseases

Impacts associated with forest disease and pest issues at LIBO were evaluated using data from Fisichelli et al. (2014) as well as data from the vegetation inventory project for LIBO (Diamond et al. 2014). In addition, information from the 2013–2027 National Insect and Disease Risk Map (NIDRM; Krist et al. 2014) was used to identify potential looming disease and pest threats to LIBO forests. The NIDRM is a nationwide, science-based, administrative planning tool that, through a highly collaborative process with experts within the forest health community, determines the severity and extent of tree-mortality hazards due to disease and pathogen issues (Krist et al. 2014). The NIDRM represents 186 individual insect and disease hazard models that are integrated within a common GIS-based, multi-criteria framework, to provide a consistent, repeatable, transparent, and peer-reviewed process through which interactive spatial and temporal forest health hazard assessments can be conducted (Krist et al. 2014). The NIDRM has been applied to all 50 states based on the best-available science and data and it has been shown to be effective at accounting for regional variations in forest health (Krist et al. 2014).

Forest Vulnerability to Climate Change

Modeled data from Fisichelli et al. (2014) were used to assess the vulnerability of LIBO forest ecosystems to changes in climate. This analysis evaluated changes in potential habitat suitability for a variety of tree species based on both a "least change" and a "major change" scenario (Table 27). The analysis compared forest condition in 1990 (baseline) to modeled results from the year 2100 based on the two scenarios.

Table 27. Modeled changes in climate from baseline (1961–1990) to future (2070–2099) based on two climate change scenarios. These data were used to predict impacts to individual tree species at LIBO. Data from Fisichelli et al. (2014).

Climate Variable	Baseline (1961–1990)	Least Change (2070–2099)	Major Change (2070–2099)
Mean annual temperature	12.5 °C (54.5 °F)	+2.1 °C (+3.8 °F)	+7.1 °C (+12.8 °F)
Mean January temperature	−0.5 °C (31.2 °F)	+1.3 °C (+2.3 °F)	+5.6 °C (+10.1 °F)
Mean July temperature	24.7 °C (76.4 °F)	+2.1 °C (+3.8 °F)	+8.6 °C (+15.6 °F)
Seasonality (July–January temperature)	25.1 °C (45.2 °F)	+0.8 °C (+1.5 °F)	+3 °C (+5.4 °F)
Mean May–September temperature	21.8 °C (71.2 °F)	+2 °C (+3.7 °F)	+8 °C (+14.4 °F)
Annual precipitation	1164 mm (45.8 in)	+4.2%	+14.5%
May–September precipitation	503 mm (19.8 in)	+7.1%	−0.4%

Reference Conditions

Vegetation Community Condition

Reference conditions for vegetation communities are those that are thought to have existed before vegetation structure and function were altered by Euro-american settlers and include changes that may have occurred due to the use of the landscape by indigenous populations. The ideal condition at LIBO would include intact native forests, wetlands, and grasslands with very low levels of anthropogenic disturbance and low to no cover of non-native species. Because this type of reference condition is not feasible for a unit with the history and extent of LIBO, we instead consider a baseline reference condition as a "best attainable condition" (Stoddard et al. 2006) under which the composition, diversity, and structure of vegetation communities at LIBO is sufficient to maintain the plant community in a stable or improving condition.

Species Composition and Diversity
Reported values for the percentage of non-native plant species in national parks within the eastern U.S. range from 10% to 50% of the flora, with a mean value of 20% (Fisichelli et al. 2014). The reference condition rating framework for vegetation community indicators at LIBO is shown in Table 28.

Table 28. Reference condition rating framework for vegetation community indicators at LIBO.

Indicator	Reference, High Quality or Good Condition	Condition Warrants Moderate Concern	Urban Natural Systems, Degraded, Condition Warrants Significant Concern
Composition (% of species native)	≥75%	74–60%	< 60%
Mean Coefficient of Conservatism ($\overline{C}$)	≥4.5	3.5–4.5	<3.5
Floristic Quality Assessment Index (*FQAI*)	≥45	35–45	<35
Invasive Exotic Plants	<10% IEP Cover	10–25% IEP Cover	>25% IEP Cover
Forest Pests and Diseases	<20% of the forested land is in imminent risk of abnormally high levels of tree mortality	20–40% of the forested land is in imminent risk of abnormally high levels of tree mortality	>40% of the forested land is in imminent risk of abnormally high levels of tree mortality
Forest Vulnerability to Climate Change	No changes in potential habitat under either change scenario.	Minor predicted increases or decreases in habitat for <10 species with no extirpation being predicted under either change scenario.	Major predicted increases or decreases in habitat for >10 species with species extirpation being predicted under either change scenario.

Floristic Quality Assessment Index (FQAI) and Coefficient of Conservatism
The *FQA* metrics (e.g., $\overline{C}$, $\overline{C}_{(Native)}$, *FQAI*, $FQAI_{(Native)}$) reflect the "quality" or "naturalness" of a site (Rothrock 2004; Andreas et al. 2004). Numerous studies have shown the *FQA* approach to be an excellent predictor of plant community condition (Swink and Wilhelm 1994; Taft et al. 1997; Fennessy et al. 1998; Mack et al. 2000; Mack 2001; Lopez and Fennessy 2002; Andreas et al. 2004; Bourdaghs 2004; Bourdaghs et al. 2006; Matthews et al. 2009). Swink and Wilhelm (1994) developed a system that rates sites having a $\overline{C}$ value or of 3.5 or higher as being of natural quality while sites of 4.5 or greater are considered high quality natural sites. Sites receiving *FQAI* values of

35 or higher are considered natural sites and sites with values of 45 or higher are "noteworthy" remnant natural areas (Swink and Wilhelm 1994; Rothrock and Homoya 2005). Site $\overline{C}$ and *FQAI* rankings below 3.5 and 35, respectively, are considered to be somewhat degraded, are dominated by lower *C*-value species, and are typically affected by periodic anthropogenic disturbances. The *FQA* rating system guidance from Swink and Wilhelm (1994) provides a reference benchmark for conditions at LIBO (Table 28).

<u>Invasive Exotic Species</u>
The cover of IEP species is thought to be an indicator of a declining trend (Young et al. 2016). In general, IEP cover in excess of 50% is indicative of a highly disturbed system. Most reclaimed natural areas contain approximately 20% non-native species cover with the range in IEP coverage being determined largely by the type and duration of the disturbance regime. For instance, anthropogenic disturbances influence species composition in natural areas located within or adjacent to dense metropolitan areas, with these sites often containing non-native species cover in excess of 40% (Kowarik 2008; Smith and Kuhn 2015).

To quantify "best attainable condition" in relation to IEP cover, we use guidance from Potyondy and Geier (2011), which states that vegetation communities should contain less than 10% cover of terrestrial invasive species (e.g., IEP) to be rated as "good or functioning properly." The reference condition rating framework as it relates to IEP cover at LIBO is shown in Table 28.

<u>Forest Pests and Diseases</u>
Reference conditions for forests are those that are thought to have existed before forest health, structure, and regeneration were altered by exotic forest pest and disease issues and where native disease and pest issues occurred at background levels. Because this type of reference condition is not feasible for a unit with the history and extent of LIBO, we instead consider a baseline reference condition as a "best attainable condition" (Stoddard et al. 2006) under which the composition, diversity, and structure of forest vegetation at LIBO is sufficient to maintain the plant community in a stable or improving condition. In order to quantify "best attainable condition," we use guidance from Potyondy and Geier (2011), which states that less than 20% of the forested land in an area should be at imminent risk of abnormally high levels of tree mortality due to forest disease and pest issues in order to be rated "good or functioning properly." The reference condition rating framework as it relates to forest disease and pest issues at LIBO is shown in Table 28.

<u>Forest Vulnerability to Climate Change</u>
The baseline condition from 1990 (Table 27) was used to approximate reference conditions for this indicator. The reference condition rating system for forest vulnerability to climate change at LIBO is shown in Table 28. In general, no predicted change in habitat under either climate change scenario is given a rating of High Quality or Good Condition; a minor change in potential habitat for <10 species with no species extirpation being predicted is given a rating of Moderate Concern; and finally, a major change in potential habitat for >10 species with extirpation being predicted for at least some species under either change scenario is given a Degraded or Significant Concern rating.

Condition and Trend

Species Composition and Diversity

Species richness averaged 48.4 species per plot for the 30 vegetation inventory plots at LIBO (Figure 33) (Diamond et al. 2014). Average species richness by association varied from a low of 23.5 species per plot for the *Schedonorus pratensis – Trifolium* spp. Herbaceous Vegetation (2 total plots) to 56.9 species per plot for the *Acer rubrum – Liquidambar styraciflua* Forest (20 total plots; Figure 33).

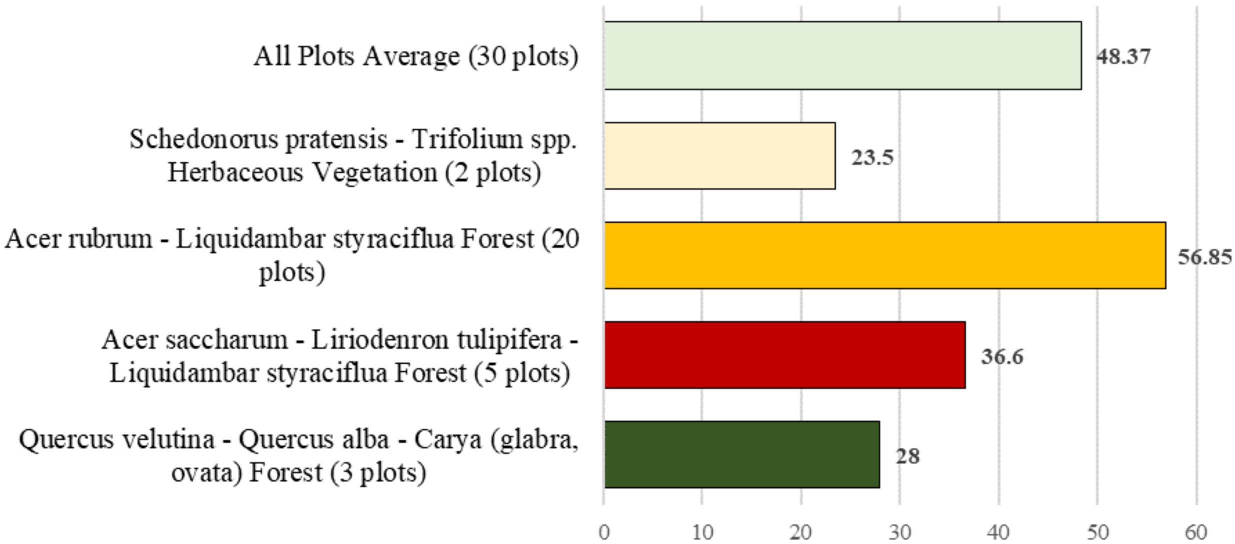


Figure 33. Average species richness for all plots combined and by association for LIBO based on plot data collected by Diamond et al. (2014).

The average proportion of native plant species within each plot at LIBO averaged 88.26% across all plots and varied from a low of 80.85% native for plots within the *Schedonorus pratensis – Trifolium* spp. Herbaceous Vegetation (2 total plots) to 98.81% native for plots in the *Quercus velutina – Quercus alba – Carya* (*glabra*, *ovata*) Forest (3 plots; Figure 34). No trend data were available. The species composition metric indicates good condition with an unknown trend, and a medium level of confidence in the assessment.

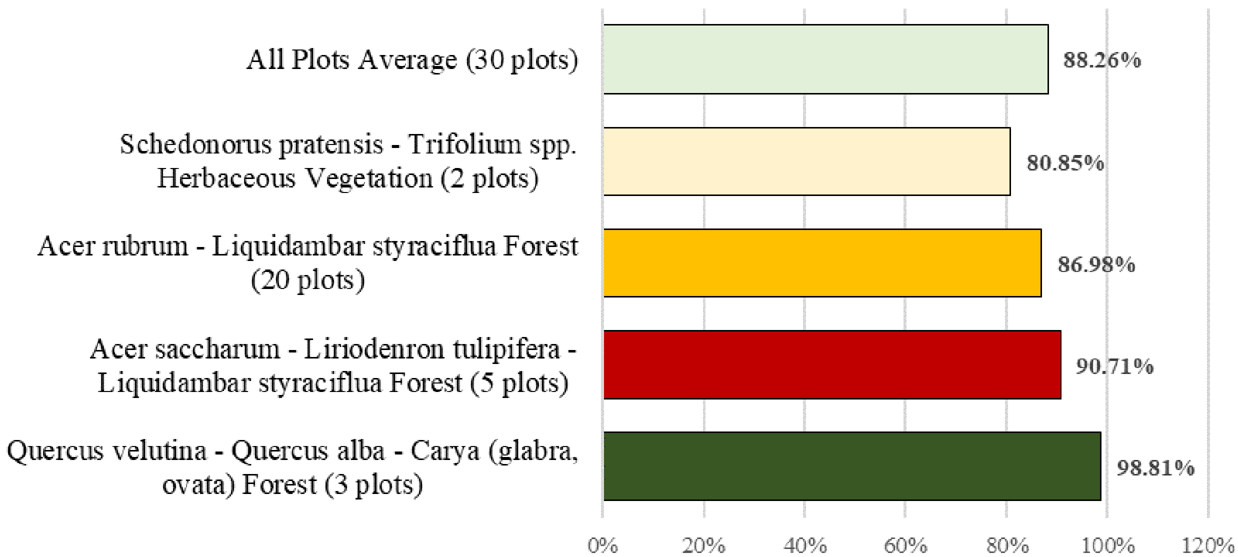


Figure 34. Average percent native species composition for all plots combined and by association for LIBO based on plot data collected by Diamond et al. (2014).

<u>Mean Coefficient of Conservatism ($\overline{C}$)</u>

The average plot $\overline{C}$ and $\overline{C}_{(Native)}$ score was 2.67 and 3.02, respectively, for the 30 vegetation plots sampled during the LIBO vegetation inventory project (Figure 34). Average $\overline{C}$ and $\overline{C}_{(Native)}$ scores by association varied from a low of 1.64 ($\overline{C}$) and 2.16 ($\overline{C}_{(Native)}$) for the *Schedonorus pratensis – Trifolium* spp. Herbaceous Vegetation to a high of 3.10 ($\overline{C}$) and 3.41 ($\overline{C}_{(Native)}$) for the *Acer saccharum – Liriodendron tulipfera – Liquidambar styraciflua* Forest (Figure 35). No trend data were available. When the *FQA* rating system metric from Swink and Wilhelm (1994) is applied, vegetation communities at LIBO are assigned a degraded condition warranting a significant level of concern with an unknown trend and a medium level of confidence.

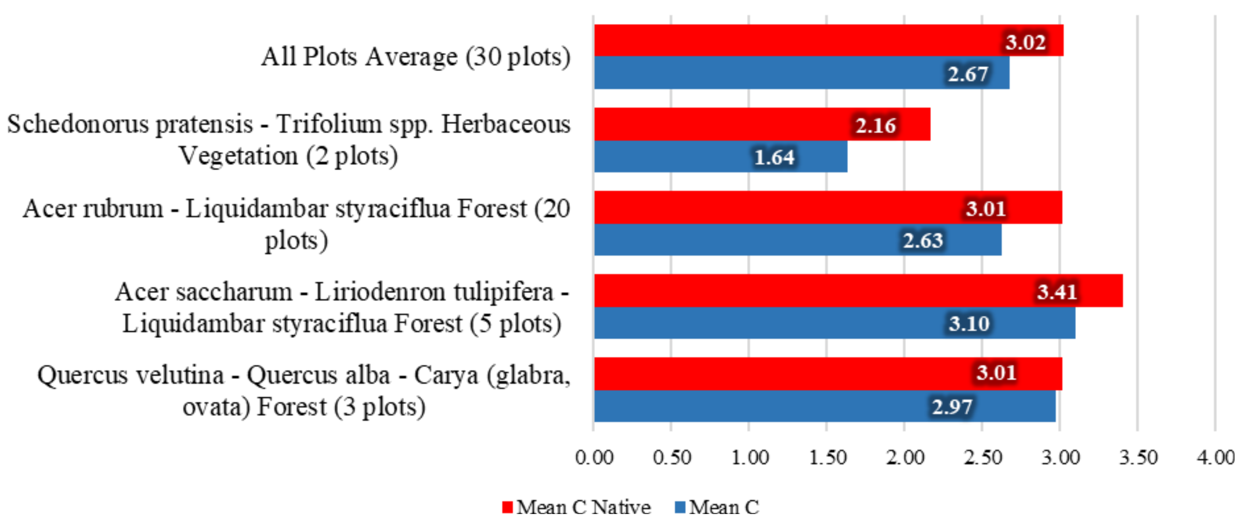


Figure 35. Average plot $\overline{C}$ and $\overline{C}_{(Native)}$ scores for all plots combined and by association for LIBO based on plot data collected by Diamond et al. (2014).

Floristic Quality Assessment Index (*FQAI*)

The current condition of the vegetation communities at LIBO, as reflected by *FQAI*, shows the communities to be in a degraded condition (Table 27). The average plot *FQAI* and $FQAI_{(Native)}$ scores were 18.29 and 19.46, respectively, for the 30 vegetation plots sampled during the LIBO vegetation inventory project (Figure 36) (Diamond et al. 2014). Average *FQAI* and $FQAI_{(Native)}$ scores by association varied from a low of 6.77 (*FQAI*) and 7.71 ($FQAI_{(Native)}$) for the *Schedonorus pratensis – Trifolium* spp. Herbaceous Vegetation to a high of 19.73 (*FQAI*) and 21.14 ($FQAI_{(Native)}$) for the *Acer rubrum –Liquidambar styraciflua* Forest (Figure 36). No trend data were available. When the *FQA* rating system metric from Swink and Wilhelm (1994) is applied, the condition of vegetation communities at LIBO warrants significant concern, with an unknown trend and a medium level of confidence.

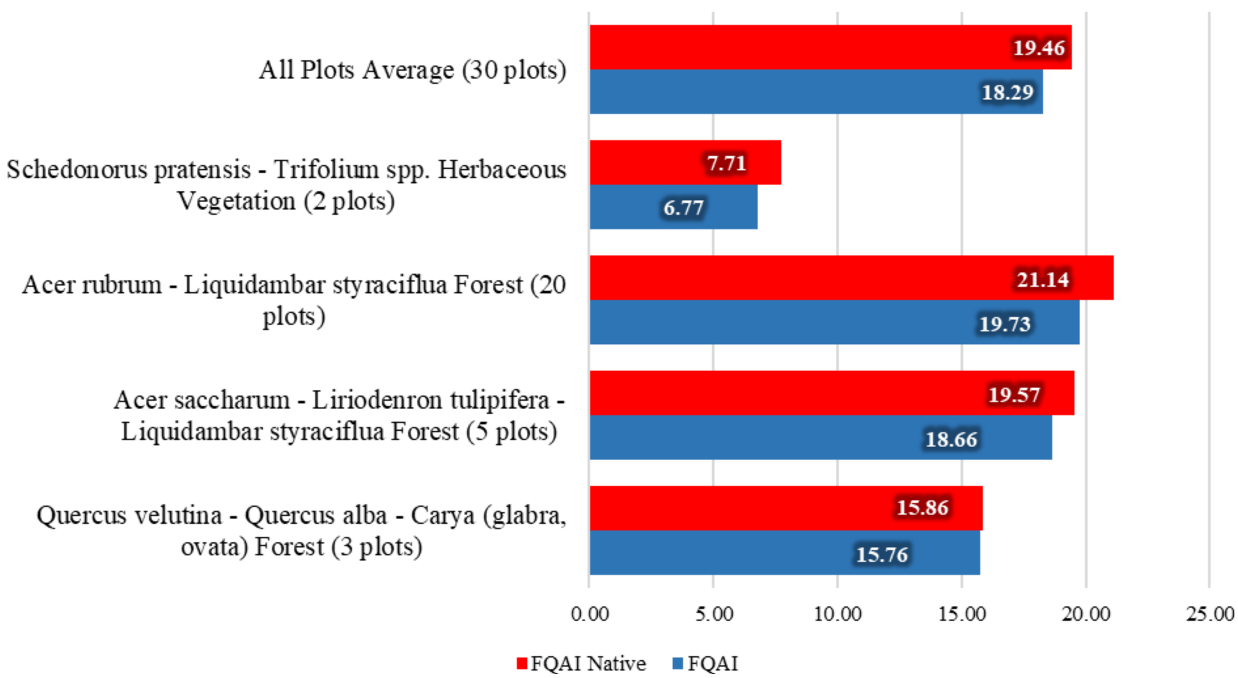


Figure 36. Average plot *FQAI* and *FQAI* $_{(Native)}$ scores for all plots combined and by association for LIBO based on plot data collected by Diamond et al. (2014).

Invasive Exotic Plants (IEP)

Percent IEP cover by plot averaged 27% for all vegetation plots at LIBO using the vegetation inventory plot data from Diamond et al. (2014) (Figure 37). Mean percent IEP cover by association/map class varied from a low of 0.5% for the *Schedonorus pratensis – Trifolium* spp. Herbaceous Vegetation to a high of 34.6% for the *Acer rubrum – Liquidambar styraciflua* Forest (Figure 37). No trend data were available for the memorial. When the rating system from Potyondy and Geier (2011) is applied, vegetation communities at LIBO are assigned a degraded condition warranting a significant level of concern, with an unknown trend, and a medium level of confidence in the assessment.

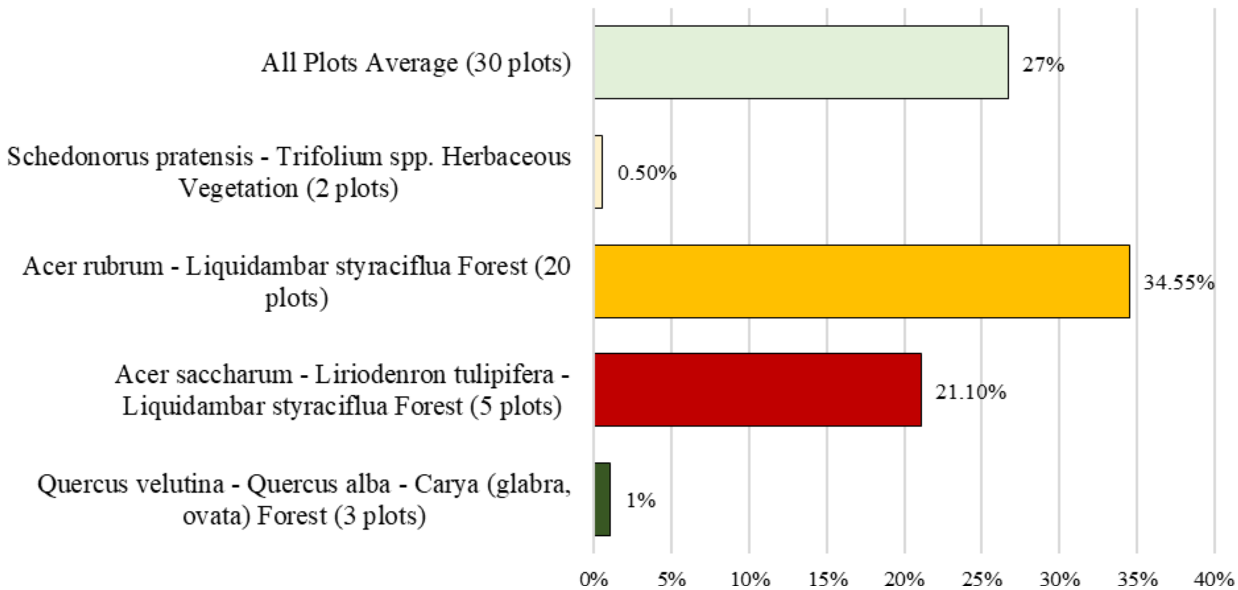


Figure 37. Average plot percent IEP cover for all types combined and by association for LIBO based on plot data collected by Diamond et al. (2014).

Forest Pests and Disease

Fisichelli et al. (2014) identified 41 exotic tree pests and diseases that are or could be at LIBO including 36 that have been detected at the statewide level and 5 that are known to occur at the county level for LIBO (Table 29). In addition, the emerald ash borer (*Agrilus planipennis*; EAB) is documented within the county by the USDA-APHIS (USDA APHIS 2022). Tree species impacted by these diseases and pests include, but are not limited to, ash species (*Fraxinus* spp.), American elm (*Ulmus americana*), pine species (*Pinus* spp.), and red oaks (*Quercus* spp.; USDA-APHIS 2022). Major disease and pest issues that are currently or are predicted to impact forest communities at LIBO include Dutch elm disease, oak decline, oak wilt, Sirex woodwasp (*Sirex noctilio*), southern pine bark beetle (*Dendroctonus frontalis*), and EAB, which is a wood-boring beetle that kills ash trees 3 to 5 years after initial infestation. An infestation only becomes evident once the canopy thins due to branch die back, just as the tree begins to die. EAB has already killed millions of ash trees across the eastern U.S. and is found in every county in Indiana (USDA APHIS 2022).

According to the modeled results from the 2013–2027 National Insect and Disease Risk Map (NIDRM; Krist et al. 2014), 14 acres or 7% of the total LIBO area is thought to be susceptible to high levels of tree mortality in excess of 25% over the 15-year period running from 2013 to 2027 Figure 38). These results also indicate that approximately 7% of all tree biomass at LIBO is at risk to forest pests over this period. Modeled impacts to tree species at LIBO include a 25% decline in American elm due to Dutch elm disease, a 29% decline in ash species due to EAB, a 29% decline in oak species due to oak wilt and oak decline, and a 6% decline in pine species due to the Sirex woodwasp and the southern pine bark beetle (Figure 39; Krist et al. 2014). All modeled results assume no active management over the timeframe (Krist et al. 2014).

Table 29. Non-native tree pests and diseases with infestation areas that include LIBO. Detection scale is the finest spatial scale at which infestation data were available for the park area. Table modified from Fisichelli et al. (2014).

Scientific Name	Common Name	Detection Scale
Adelges abietis	eastern spruce gall adelgid	state
*Agrilus planipennis**	Emerald ash borer	county
Anarsia lineatella	peach twig borer	state
Caliroa cerasi	pear sawfly	state
Carulaspis juniperi	juniper scale	state
Caulocampus acericaulis	maple petiole borer	state
Ceratocystis fagacearum	oak wilt	county
Coleophora laricella	larch casebearer	state
Cronartium ribicola	white pine blister rust	county
Cryphonectria parasitica	chestnut blight	state
Cryptodiaporthe populea	Dothichiza canker of poplar	state
Cryptorhynchus lapathi	poplar-and-willow borer	state
Cyrtepistomus castaneus	Asiatic oak weevil	state
Diaspidiotus perniciosus	San Jose scale	state
Diprion similis	introduced pine sawfly	state
Eulecanium cerasorum	calico scale	state
Fenusa pusilla	birch leafminer	state
Homadaula anisocentra	mimosa webworm	state
Hylastes opacus	European bark beetle	state
Kaliofenusa ulmi	elm leafminer	state
Lepidosaphes ulmi	oystershell scale	state
Neodiprion sertifer	European pine sawfly	state
Ophiostoma novo-ulmi	Dutch elm disease	state
Orchestes alni	European elm flea weevil	state
Otiorhynchus ovatus	strawberry root weevil	state
Otiorhynchus sulcatus	black vine weevil	state
Periphyllus lyropictus	Norway maple aphid	state
Phyllaphis fagi	woolly beech aphid	state
Physokermes piceae	spruce bud scale	state
Phytophthora cinnamomi	littleleaf disease / phytophthora root rot	state
Plagiodera versicolora	imported willow leaf beetle	state
Popillia japonica	Japanese beetle	county
Pristiphora erichsonii	larch sawfly	state
Pristiphora geniculata	mountain-ash sawfly	state

* Emerald ash borer was confirmed in the county in 2014 (USDA-APHIS 2022).

Table 29 (continued). Non-native tree pests and diseases with infestation areas that include LIBO. Detection scale is the finest spatial scale at which infestation data were available for the park area. Table modified from Fisichelli et al. (2014).

Scientific Name	Common Name	Detection Scale
Rhyacionia buoliana	European pine shoot moth	county
Scolytus multistriatus	smaller European elm bark beetle	state
Scolytus schevyrewi	banded elm bark beetle	state
Sirococcus clavigignenti juglandacearum	butternut canker	county
Taeniothrips inconsequens	pear thrips	state
Tomicus piniperda	pine shoot beetle	state
Trichiocampus viminalis	poplar sawfly	state
Xanthogaleruca luteola	elm leafbeetle	state

* Emerald ash borer was confirmed in the county in 2014 (USDA-APHIS 2022).

Figure 38. Emerald ash borer (*Agrilus planipennis*; EAB) is a pest that is impacting ash forest communities at LIBO and across the contiguous U.S. Photo courtesy of NPS.

Based on the best available data, including modeled data from the NIDRM, the forest pest and disease indicator at LIBO appears in good condition. Only 7% of the LIBO area is modeled to be at risk over the 2013 to 2027 timeframe, well below the 20% threshold for moderate condition. Still, modeled impacts to individual tree genera (e.g., a 25% decline in American elm due to Dutch elm disease and a 29% decline in oak species due to oak wilt and oak decline) may justify moderate concern due to significant potential impacts to certain forest communities.

Overall, these results warrant a moderate level of concern. A deteriorating trend is assigned due to the current acute impacts of pests such as EAB and the high potential for future impacts as pests and diseases become more established in the LIBO area. Due to the modeled nature of this data, we assign a medium level of confidence to this assessment.

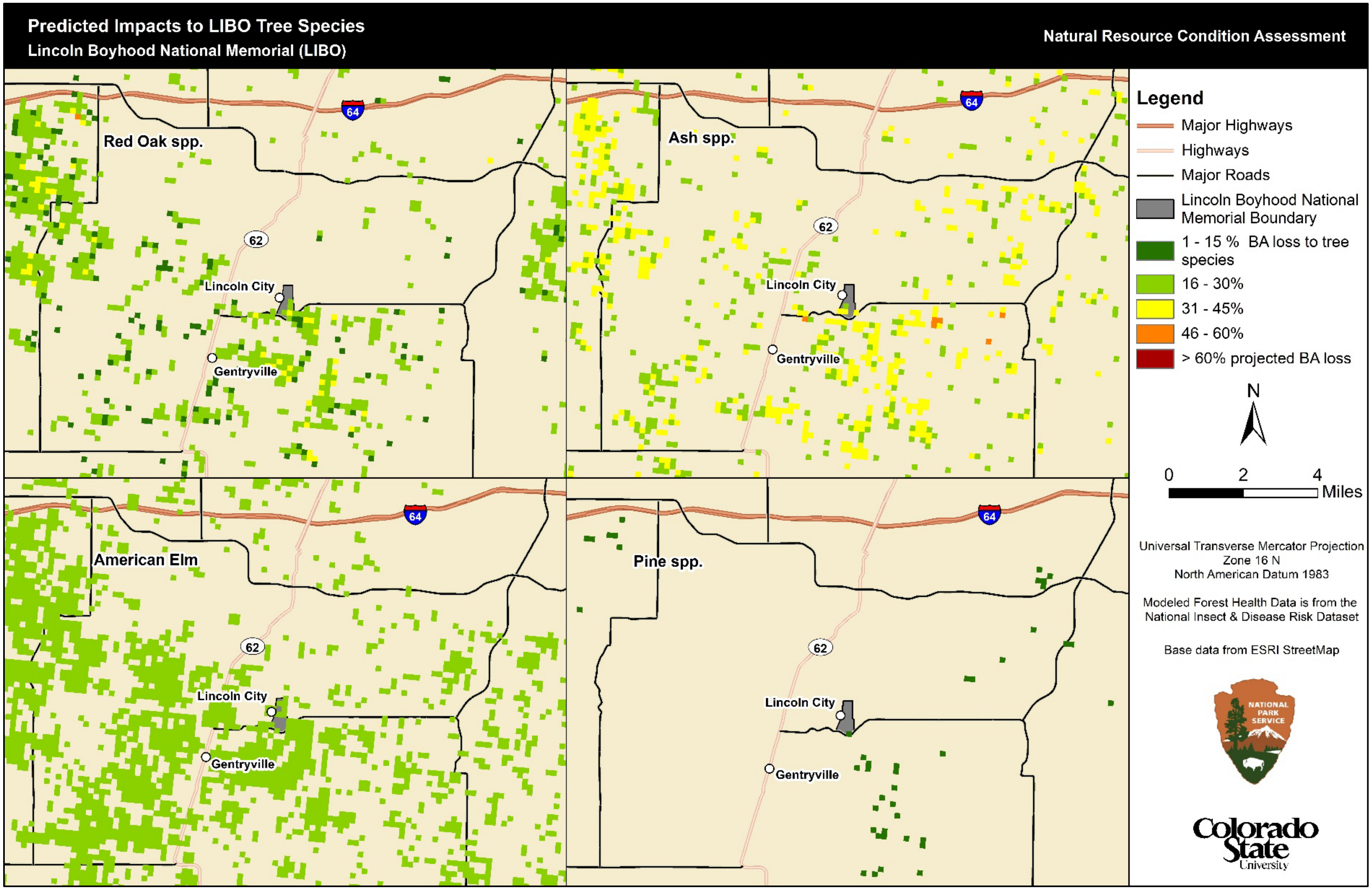


Figure 39. Modeled predicted impacts to four tree species groups (red oak spp., ash spp., American elm, and pine spp.) from 2013 to 2027 at LIBO based on the results of the NIDRM (Krist et al. 2014). Data indicate predicated loss in basal area (BA) due to a variety of forest disease and pest issues. (Data sources: National Insect & Disease Risk Dataset, ESRI StreetMap.)

Forest Vulnerability to Climate Change

Models of changes in LIBO's climate were generated for two scenarios (Table 27). Predicted impacts to LIBO forest based on modeled data from Fisichelli et al. (2014) is substantial (Table 30). The "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes and the "major change" scenario represents continued increasing greenhouse gas emissions and rapid warming. Change class designations are based on the ratio of future (2100) to baseline (1990) habitat suitability and baseline habitat values (e.g., for common species, large decrease is ≤0.5, small decrease is >0.5 and ≤0.8, no change is >0.8 and ≤1.2; small increase is >1.2 and ≤2.0, and large increase is >2.0). Modeled results indicate that 24 species will face small to large decreases in potential habitat based on either of the two climate change scenarios. Three species (*Catalpa speciosa*, *Pinus strobus*, *Quercus bicolor*) are predicted to face extirpation by the year 2100 regardless of scenario (Table 30). In addition, 19 species are predicted to increase in range by 2100 and 3 species are predicted to have no change in their potential habitat under either climate change scenario (Table 30). Predicted impacts from climate change were not always straightforward as 18 species were predicted to have mixed impacts from the two scenarios (Table 30). Finally, Fisichelli et al. (2014) also predicted 4 new species' ranges could expand into LIBO, resulting in new species or communities occurring within the park by the year 2100 (Table 30). While the exact degree of impacts from climate change to individual species is unknown at LIBO, modeled results from Fisichelli et al. (2014) indicate that LIBO forest communities will be dramatically different in the future in the face of a changing climate.

Based on the best available data, the forest vulnerability to climate change indicator at LIBO appears to warrant significant concern. Major increases or decreases in potential habitat range is being predicted for over 50 individual tree species with a number of species facing extirpation under either one or both of the climate change scenarios. A deteriorating trend is applied due to the high potential for future impacts to LIBO forest communities from climate change. A low level of confidence is assigned to this assessment due to the modeled nature of the data.

Table 30. Modeled predicted changes in potential habitat for tree species at LIBO (2100 compared with 1990) based on data from Fisichelli et al. (2014). Species are grouped based on change class designations for two future climate scenarios.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
Decrease	*Acer rubrum*	red maple	small decrease	small decrease
	Acer saccharum	sugar maple	large decrease	extirpated
	Asimina triloba	pawpaw	large decrease	extirpated
	Betula alleghaniensis	yellow birch	large decrease	large decrease
	Carya glabra	pignut hickory	small decrease	large decrease
	Carya ovata	shagbark hickory	small decrease	small decrease
	Catalpa speciosa	northern catalpa	extirpated	extirpated
	Cercis canadensis	eastern redbud	small decrease	large decrease
	Fagus grandifolia	American beech	large decrease	large decrease
	Fraxinus americana	white ash	large decrease	large decrease
	Juglans nigra	black walnut	small decrease	extirpated
	Liriodendron tulipifera	yellow-poplar	large decrease	large decrease
	Pinus strobus	eastern white pine	extirpated	extirpated
	Platanus occidentalis	sycamore	small decrease	small decrease
	Prunus serotina	black cherry	small decrease	small decrease
	Quercus bicolor	swamp white oak	extirpated	extirpated
	Quercus coccinea	scarlet oak	large decrease	extirpated
	Quercus imbricaria	shingle oak	large decrease	small decrease
	Quercus muehlenbergii	chinkapin oak	small decrease	large decrease
	Quercus prinus	chestnut oak	small decrease	small decrease
	Quercus rubra	northern red oak	small decrease	large decrease
	Sassafras albidum	sassafras	small decrease	large decrease
	Taxodium distichum	bald cypress	large decrease	small decrease
	Ulmus rubra	slippery elm	small decrease	small decrease

Table 30 (continued). Modeled predicted changes in potential habitat for tree species at LIBO (2100 compared with 1990) based on data from Fisichelli et al. (2014). Species are grouped based on change class designations for two future climate scenarios.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
No Change	*Carya tomentosa*	mockernut hickory	no change	no change
	Fraxinus pennsylvanica	green ash	no change	no change
	Quercus lyrata	overcup oak	no change	no change
Increase	*Carya cordiformis*	bitternut hickory	small increase	large increase
	Carya illinoinensis	pecan	small increase	large increase
	Carya laciniosa	shellbark hickory	small increase	small increase
	Carya texana	black hickory	large increase	large increase
	Celtis laevigata	sugarberry	large increase	large increase
	Diospyros virginiana	common persimmon	small increase	small increase
	Gleditsia triacanthos	honeylocust	small increase	large increase
	Liquidambar styraciflua	sweetgum	small increase	large increase
	Morus rubra	red mulberry	small increase	large increase
	Pinus echinata	shortleaf pine	large increase	large increase
	Pinus taeda	loblolly pine	large increase	large increase
	Pinus virginiana	Virginia pine	small increase	large increase
	Quercus falcata var. *falcata*	southern red oak	large increase	large increase
	Quercus falcata var. *pagodifolia*	cherrybark oak	large increase	large increase
	Quercus macrocarpa	bur oak	small increase	large increase
	Quercus marilandica	blackjack oak	large increase	large increase
	Quercus phellos	willow oak	large increase	large increase
	Quercus stellata	post oak	large increase	large increase
	Ulmus alata	winged elm	large increase	large increase
Mixed Results	*Acer negundo*	boxelder	no change	small increase
	Acer saccharinum	silver maple	no change	small increase

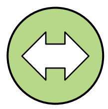
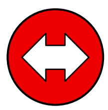
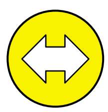
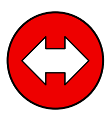
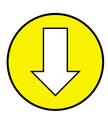
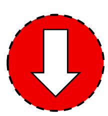
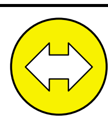
Table 30 (continued). Modeled predicted changes in potential habitat for tree species at LIBO (2100 compared with 1990) based on data from Fisichelli et al. (2014). Species are grouped based on change class designations for two future climate scenarios.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
Mixed Results (continued)	*Betula nigra*	river birch	no change	small increase
	Carpinus caroliniana	American hornbeam	small decrease	small increase
	Celtis occidentalis	hackberry	no change	small decrease
	Cornus florida	flowering dogwood	no change	small decrease
	Juniperus virginiana	eastern redcedar	small increase	no change
	Maclura pomifera	osage-orange	no change	large increase
	Nyssa sylvatica	blackgum	no change	small increase
	Ostrya virginiana	eastern hophornbeam	no change	large increase
	Populus deltoides	eastern cottonwood	no change	large increase
	Quercus alba	white oak	no change	small decrease
	Quercus palustris	pin oak	no change	large decrease
	Quercus velutina	black oak	no change	large decrease
	Robinia pseudoacacia	black locust	no change	large decrease
	Salix nigra	black willow	no change	small increase
	Ulmus americana	American elm	no change	small decrease
	Ulmus thomasii	rock elm	no change	small decrease
New	*Pinus elliottii*	slash pine	–	new entry
	Quercus nigra	water oak	new entry	new entry
	Quercus shumardii	Shumard oak	–	new entry
	Ulmus crassifolia	cedar elm	new entry	new entry

Overall Condition

The data presented above suggest the current condition of vegetation communities at LIBO, which are largely second growth and ruderal communities, warrants moderate concern with an unchanging trend. A summary of all indicators is shown in Table 31.

Table 31. Condition and trend summary for vegetation communities at Lincoln Boyhood National Memorial.

Indicator	Condition Status/Trend	Rationale
Native Species Composition		Native species composition averaged 88.26% across all vegetation plots at LIBO.
Mean Coefficient of Conservatism ($\overline{C}$)		The average plot $\overline{C}$ score was 2.67 for vegetation plots at LIBO and the average plot $\overline{C}_{(Native)}$ was 3.02. Swink and Wilhelm (1994) regarded sites with a $\overline{C}$ <3.5 as "degraded."
Floristic Quality Assessment Index (FQAI)		The average plot *FQAI* and $FQAI_{(Native)}$ scores were 18.29 and 19.46, respectively, for the 30 vegetation plots sampled during the LIBO vegetation inventory project
Invasive Exotic Plants (IEP)		Vegetation plots averaged 27% IEP cover.
Forest Pests and Disease		A variety of forest disease and pest issues currently impact or are predicted to impact LIBO forests. The predicted declines in individual tree species (e.g., 29% decline in ash spp.) warranted the moderate condition. A low medium level is placed on this assessment due to the modeled nature of the data.
Forest Vulnerability to Climate Change		A number of tree species are predicted to be severely impacted by a changing climate at LIBO. A low confidence level is placed on this assessment due to the modeled nature of the data.
Vegetation Communities overall		**The condition of vegetation communities warrants moderate concern with an unchanging trend. Confidence in the assessment is medium.**

Overall trends are difficult to assess but some factors indicate that current forest conditions will change in the near future. For instance, as invasive plants are treated and managed by the park, percent IEP cover should decline and community quality indices such as composition and *FQAI* values are likely to rise (Young et al. 2016). Alternatively, modeled data predict LIBO forest will be impacted by a variety of disease and pest issues as well as changes in climate; these impacts have the potential to drastically affect future forest composition and structure (Fisichelli et al. 2014). Based on this, an overall unchanging trend is applied to this assessment.

Uncertainty and Data Gaps

Uncertainty exists when the interactive effects of anthropogenic stressors, forest health, and climate change impacts are all considered equally. Additional modeling along with continued vegetation monitoring should be continued to help understand these cumulative impacts and better inform the future makeup of LIBO vegetation communities. Periodic monitoring is recommended to document changes in vegetation and help direct management activities over time.

Sources of Expertise

- David Diamond, Missouri Resource Assessment Partnership (MoRAP). Vegetation inventory and mapping project for LIBO.

Birds

Background and Importance

Birds are conspicuous components of those parks residing within hardwood forest ecotones and compose an important natural resource within parks of the Heartland Inventory and Monitoring Network (HTLN). The hardwood forests of the area surrounding LIBO were historically dominated by white oak and maples, but they have undergone significant land use changes from logging to restoration since the time of Lincoln (Leis 2016). The current forest structure generally reflects the historical overstory composition, but white oak was more dominant historically and maples less dominant than in the current forest (Leis 2016; Pavlovic and White 1989). These changes in the hardwood forest at LIBO and the surrounding area have resulted in declines in the avian fauna of the region since the 1970s (Pardieck et al. 2018). The decline in bird populations in general has been caused by multiple factors including the conversion of hardwood forest to other land cover types, habitat fragmentation, and increasing human population growth (Hansen and Gryskiewicz 2003). The NPS formally recognizes this decline and the need to understand the long-term trends in community composition and abundance of breeding bird populations, and how understanding these trends offers one measure of a park's ecosystem integrity (Peitz 2011). "Ecosystem integrity" refers to the system's ability to maintain a balanced, integrated, adaptive community of species having a composition, diversity, and functional organization comparable to that of the natural habitats of the region (Karr and Dudley 1981).

Birds, including forest-dwelling birds, are good indicators of changes in ecosystems (Stolen et al. 2007; Butler et al. 2012) and environmental condition because they occur across a continuum of anthropogenic disturbances, species assemblages are predictive of these disturbance levels, birds are easily detected, and they are well researched through the use of numerous standardized methods, providing a baseline against which change can be assessed (Bibby et al. 2000, Browder et al. 2002, Bryce et al. 2002, NABCI 2009). In addition, birds are well liked by the public, the public can relate to concerns about bird communities, birding is a popular activity at most parks, and bird songs contribute to the natural soundscape.

The hardwood forests in LIBO support wintering, feeding, and breeding populations of both resident and migrating avian species. Because of the lack of agricultural activities within LIBO relative to the surrounding landscape, LIBO is especially valuable by providing relatively unfragmented patches of forest that serve as a refuge within a highly altered landscape. Even so, the habitat fragmentation and the conversion of native vegetation to urban and agrarian landscapes that has occurred outside the memorial can negatively impact populations of some breeding and resident birds at LIBO, particularly specialist species that have evolved within stable environments (Keinath et al. 2017, Matthews et al. 2014, Devictor et al. 2008, La Sorte 2006). Monitoring the change in avian community composition and bird abundance in the memorial is important for detecting ecosystem change caused by these outside activities and could help direct management actions to restore and maintain the landscape at LIBO. The community composition and diversity of woodland species should improve with the restoration of the native hardwood forest communities both within LIBO and within the surrounding landscape (Johnson 2006, Boren et al. 1999).

Threats

The threats at LIBO to the bird community include the conversion of habitats to agricultural and urban uses including cultivation and livestock grazing and residential, commercial, and industrial development locally, regionally and within the extent of the avian migratory patterns of birds inhabiting LIBO (Hansen and Gryskiewicz 2003). The aforementioned activities result in habitat loss and fragmentation, water pollution and the disruption of hydrologic flow regimes. In turn, these modifications disrupt ecological functions important to ecosystem integrity and important to maintaining the community and composition of avian species at LIBO comparable to that found in the natural habitat of the region (Jørgensen and Müller 2000).

Changes in land use outside the park are linked to ecological function within LIBO by five mechanisms (Hansen and Gryskiewicz 2003):

1) land use activities reduce the functional size of a reserve, eliminating important ecosystem components lying outside the park boundary;
2) land use activities alter the flow of energy or materials across the landscape irrespective of the park's political boundary, disrupting the ecological processes dependent upon those flows both outside and inside the park and across its boundaries;
3) habitat conversion outside the park may eliminate unique habitats, such as seasonal habitats and migration corridors;
4) the negative influences of land use activities may extend into the park and create edge effects; and
5) increased human population density may directly impact the park through increased recreation and human disturbance.

Consequently, the ecological functioning of LIBO depends upon maintaining the natural systems within and outside LIBO's boundaries.

Climate change has implications for the bird community at LIBO. Using projections for avifaunal responses to climate change across the U.S. National Park System by Wu (2018), Schuurmann and Wu (2018) synthesized the potential net impacts of climate change to the LIBO bird community. They concluded that climate change is expected to alter the bird community at the Memorial, with greater impacts under the high-emissions pathway than under the low-emissions pathway. They found that among the species likely to be found at the Memorial today, climate suitability in summer under the high-emissions pathway is projected to improve for 11, remain stable for 35, and worsen for 14 species. Suitable climate ceases to occur for 19 species in summer, potentially resulting in extirpation of those species from the Memorial. They made additional projections for climate suitability in winter. Their study focused exclusively on changing climatic conditions for birds over time but emphasize that projected changes in climate suitability are not definitive predictions of future species ranges or abundances and can be affected by numerous other factors. With respect to management implications for the memorial, they state: "Under the high-emissions pathway, Lincoln Boyhood National Memorial falls within the intermediate change group. Parks anticipating intermediate change can best support landscape-scale bird conservation by emphasizing habitat restoration, maintaining natural disturbance regimes, and reducing other stressors."

Indicators and Measures

- Native bird species richness
- Bird index of biotic integrity (IBI)
- Occurrence of bird species of conservation concern (evaluated but not used as a metric)

Data and Methods

The HTLN has implemented long-term monitoring of birds at parks within the HTLN network. The purpose of this monitoring is to track changes in bird community composition and abundance, and to monitor bird response to changes in habitat structure and other habitat variables related to management activities (Peitz 2011). Data from HTLN systematic surveys of breeding birds and their habitat at LIBO, begun in 2007, were used to determine the condition of the bird community (unpublished data provided by NPS Heartland Inventory and Monitoring Program). Monitoring was conducted in 2007 and every year from 2011 through 2018. Thirty-five permanent sites (Figure 40) (Peitz 2011) arranged in a systematic grid of 100 m x 100m cells originating from a random start point were sampled in 2007, 2011 and 2015. In 2012, only one of the 35 sample plots was surveyed so data from 2012 were not used in this assessment. Eight sites were sampled in 2013, 2014, and 2017 and seven sites were sampled in 2016 and 2018. The sampling protocol was based on variable circular plot methodology, wherein all birds seen or heard at plots during 3 to 5-min sampling periods were recorded along with each bird's distance from the observer (Peitz et al. 2008).

To evaluate trends over time for each of the three indicators, we calculated the significance of linear regressions over time, and looked at the overlap of 90% confidence intervals.

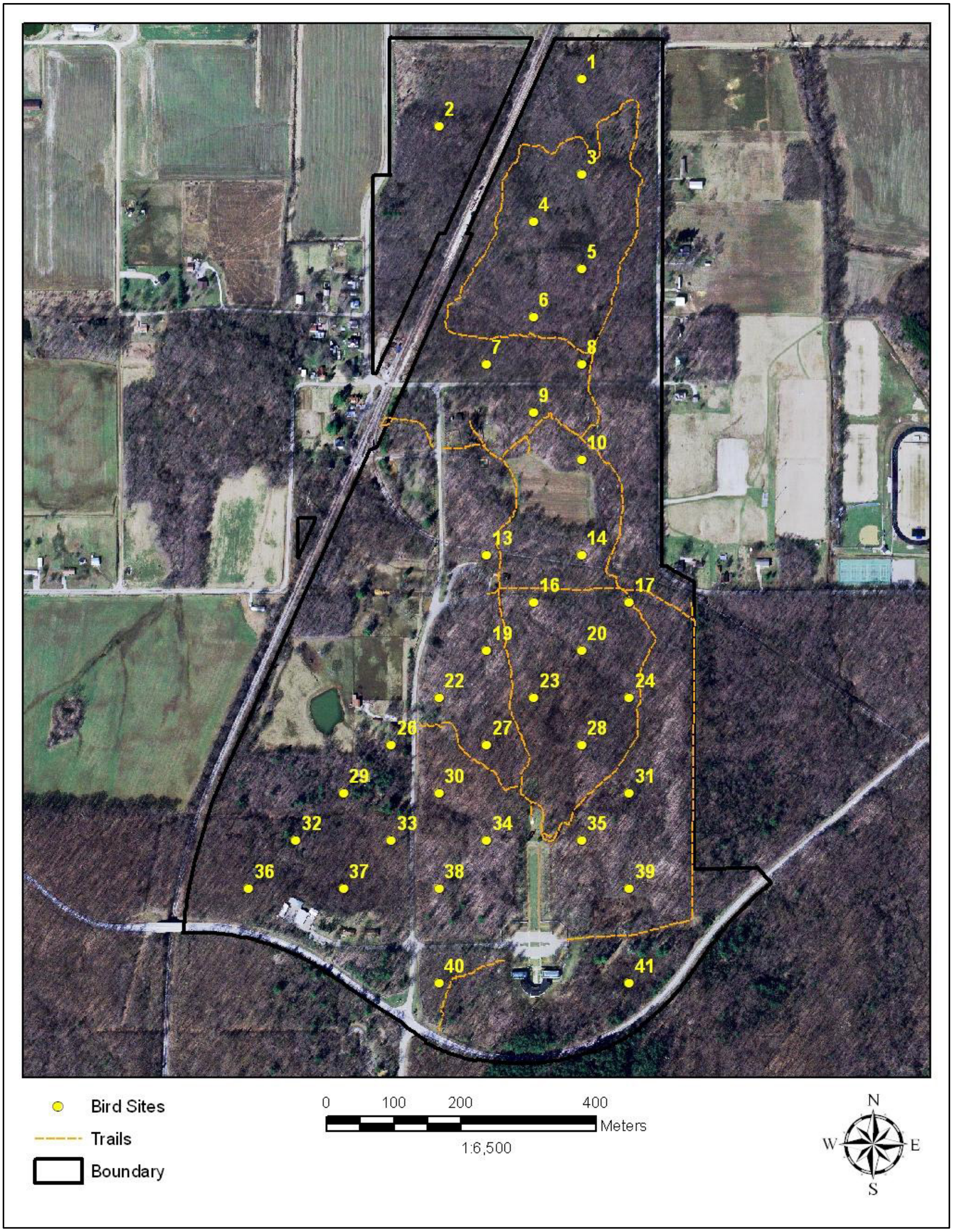


Figure 40. Bird sample sites in Lincoln Boyhood National Memorial, Indiana (Peitz 2011).

Native Bird Species Richness

Data to examine bird species richness was provided by the Heartland I&M Network. Additional data collected in 2019 on 35 bird plots at LIBO was not included in our data analysis because it was published too late to fully incorporate (Peitz and Kull 2020). However, the Peitz and Kull analysis corroborate our findings regarding trends in the bird community.

Bird Index of Biotic Integrity

The bird index of biotic integrity (IBI) is based on methodology developed for bird communities of the mid-Atlantic Highlands (O'Connell et al. 1998a), modified to reflect the land use and land cover types of LIBO (e.g., hardwood forest). Specialist guilds included in the IBI tend to be associated with extensive hardwood forest. Therefore, higher IBI scores reflect bird communities associated with aspects of mature hardwood forest structure, function, and composition. For example, sites with higher bird IBI scores host a bird community with more interior forest-dependent species, invertebrate foragers, and single-brooded species (i.e., specialists) but with fewer omnivores, exotic/non-natives, nest predators/brood parasites, residents, and forest generalists (i.e., generalists). An extensive discussion of why these guilds are chosen over others can be found in O'Connell et al. (1998a).

To calculate the IBI score, species are first assigned to guilds (some species may be assigned to more than one guild, depending on their life history traits). The proportional species richness of each guild is then calculated by dividing the number of species detected within a specific guild by the total number of species detected. The next step in the bird IBI is to rank each category of proportional species richness for each guild on a scale of 5 (high integrity) to 0 (low integrity) (O'Connell et al. 1998a, 1998b, 2000). For specialist guilds, the highest-occurrence category is ranked a "5," the next highest a "4," etc. For generalist guilds, the ranking is reversed: a "5" is assigned to the lowest-occurrence category. Therefore, a site can receive a rank of "5" for a guild if the site supports the highest category of proportional species richness for a specialist guild or the lowest category of proportional species richness for a generalist guild. The final bird IBI score is then calculated by summing the rank for each guild's proportional species richness, across all guilds.

A community at the theoretical maximum high IBI score, or highest integrity, consists of a bird community with only specialist guilds and without any generalist guilds. The integrity represented by a particular IBI score is based upon a theoretical maximum community at LIBO receiving a hardwood forest bird IBI score of 77 (if only specialist guilds are detected) and the theoretical minimum community, a score of 21 (if only generalist guilds are detected).

The biotic or ecological condition described by the bird IBI ranges along a disturbance gradient from relatively intact, extensive, hardwood forest with high IBI scores to more disturbed, developed or urban hardwood forest with low IBI scores. The response guilds used to calculate the bird IBI are listed in Table 32.

Table 32. Bird species guilds used to calculate IBI scores.

Biotic Integrity Element	Guild Category	Response Guild	Number of Species in Guild	Guild Classification
Functional	Trophic	omnivore	23	generalist
	Insectivore Foraging Behavior	bark prober	6	specialist
	Insectivore Foraging Behavior	upper canopy forager	6	specialist
	Insectivore Foraging Behavior	lower canopy forager	13	specialist
	Insectivore Foraging Behavior	ground gleaner	3	specialist
	Insectivore Foraging Behavior	aerial screener	3	specialist
Compositional	Origin	exotic/non-native	1	generalist
	Migration Status	resident	24	generalist
	Migration Status	temperate migrant	13	generalist
	Number of Broods	single-brooded	35	specialist
	Population Limiting	nest predator/brood parasite	4	generalist
Structural	Nest Placement	forest ground nester	5	specialist
	Nest Placement	open ground nester	5	specialist
	Nest Placement	canopy nester	18	specialist
	Nest Placement	shrub nester	11	generalist
	Primary Habitat	forest generalist	25	generalist
	Primary Habitat	interior forest obligate	12	specialist
	Primary Habitat	riparian obligate	2	specialist

Occurrence of Bird Species of Conservation Concern

The analysis of species of conservation concern was limited to bird species that were either breeding at the memorial or that were residents. Species occurring during migration only and incidental occurrences of species outside of their normal ranges were excluded.

To identify bird species of conservation concern we used lists developed by Partners in Flight (PIF), a cooperative effort among federal, state and local government agencies in the United States and Canada that identifies and assesses bird species of conservation concern based on biological criteria including population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend (Rosenberg et al. 2016). PIF assessments are conducted at both the continental and regional scales.

At the continental scale, the PIF North American Landbird Conservation Plan identifies “Red Watch List Species” and “Yellow Watch List Species” (Rosenberg et al. 2016). Red Watch List Species are considered by PIF to have the greatest need for conservation due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Rosenberg et al. 2016). Yellow Watch List Species are defined as those species that are not declining but are vulnerable due to small ranges and populations with moderate threats, or species with population declines and moderate to high threats.

PIF has also adopted Bird Conservation Regions (BCRs), after the North American Bird Conservation Initiative. BCRs are ecologically distinct regions in North America with similar bird communities, habitats and resource management issues. Regional bird conservation plans are developed by PIF using the BCRs as the unit of planning and the same principles of concern (Red Watch List and Yellow Watch List species) are applied at the scale of the BCR. This approach recognizes that some species may be declining dramatically at the regional scale, even though they are not of high concern at the continental scale. LIBO is within the Central Hardwoods BCR and also near the border with the Eastern Tallgrass Prairie BCR; the species of conservation concern identified by PIF within these two BCRs were included on the list of species of conservation concern used in this analysis. Data supporting this indicator were examined and did not support meaningful summary and analysis due to the rarity of species presence and the variability among years. Therefore, this metric was not included in the results.

Reference Conditions

Little historical survey data exist for LIBO prior to 2007, when the HTLN began its monitoring program there. Therefore, 2007 is used as a reference for comparison to current conditions, as determined by the 2018 surveys. Good condition for biodiversity is defined as maintaining 85% or more of the native species richness observed in 2007. Good condition for occurrence of bird species of conservation concern is defined as maintaining 85% or more of the number of species reported in 2007. The condition of the resource is considered higher if more species of concern are observed. This implies that the populations of those species are increasing and/or they are using the memorial more. A resource condition rating framework for birds is shown in Table 33.

Threshold levels for bird IBI scores have not been rigorously defined, but O'Connell et al. (2000) established thresholds for four categories of condition relevant to LIBO: excellent (highest integrity) = score of 68.1–77; good (high integrity) = score of 53.1–68.0; fair (medium integrity) = score of 32.8–53.0; and poor (low-integrity rural and low-integrity urban) = score of 21.0–32.7. For this analysis, the excellent and good categories were combined to produce the three-tiered rating framework shown in Table 33.

Table 33. Resource condition rating framework for birds at Lincoln Boyhood National Memorial.

Indicator	Condition Status		
	Resource is in Good Condition	**Condition Warrants Moderate Concern**	**Condition Warrants Significant Concern**
Native Bird Species Richness (S)	2018 value is >85–100+% of 2007 value	2018 value is 70–85% of 2007 value	2018 value is <70% of 2007 value
Bird Index of Biotic Integrity (IBI)	53.1–77.0	32.8–53.0	21.0–32.7

Condition and Trend

Native Bird Species Richness

A mean of 5.1 native species per sample site was recorded in 2018. This mean was greater than the 3.9 native species recorded per sample site during the initial 2007 bird survey at LIBO (Table 34). The mean native species richness per site recorded in 2018, when compared to the 2007 value, indicates the resource is in good condition (Table 33).

Table 34. Number of sites where bird species were detected in 2018 (out of 7 sites sampled) and 2007 (out of 35 sites sampled) in Lincoln Boyhood National Memorial. (Data source: Heartland I&M Program).

Common name	Species name	Detected 2018	Detected 2007
Acadian Flycatcher	*Empidonax virescens*	–	2
American Crow	*Fulica americana*	2	11
American Robin	*Falco sparverius*	1	2
American Woodcock	*Scolopax minor*	–	1
Black-capped Chickadee	*Poecile atricapillus*	1	–
Blue Jay	*Cyanocitta cristata*	3	3
Blue-gray Gnatcatcher	*Polioptila caerulea*	1	8
Brown-headed Cowbird	*Molothrus ater*	1	–
Carolina Chickadee	*Poecile carolinensis*	–	3
Carolina Wren	*Thryothorus ludovicianus*	2	8
Chipping Sparrow	*Spizella passerina*	–	1
Common Grackle	*Quiscalus quiscula*	–	1
Downy Woodpecker	*Dryobates pubescens*	1	–
Eastern Bluebird	*Sialia sialis*	1	–
Eastern Towhee	*Pipilo erythrophthalmus*	–	1
Eastern Wood-Pewee	*Contopus virens*	–	9
Golden-winged Warbler [1, 2, 3]	***Vermivora chrysoptera***	**1**	**–**
Gray Catbird	*Dumetella carolinensis*	–	2
Great Crested Flycatcher	*Myiarchus crinitus*	–	4
Indigo Bunting	*Passerina cyanea*	–	10
Kentucky Warbler [2]	*Geothlypis formosa*	–	1
Killdeer	*Charadrius vociferus*	2	–
Mourning Dove	*Zenaida macroura*	1	–

[1] Bolded names are on the Partners in Flight continental Red Watch List or Yellow Watch List.

[2] Highlighted names are on the Partners in Flight Red Watch List or Yellow Watch List for the Eastern Tallgrass Prairie BCR or the Central Hardwoods BCR.

[3] Species that are both bolded and highlighted are listed as priorities both continentally and in the Eastern Tallgrass Prairie or Central Hardwoods BCR.)

Table 34 (continued). Number of sites where bird species were detected in 2018 (out of 7 sites sampled) and 2007 (out of 35 sites sampled) in Lincoln Boyhood National Memorial. (Data source: Heartland I&M Program).

Common name	Species name	Detected 2018	Detected 2007
Northern Bobwhite [1]	***Colinus virginianus***	**–**	**1**
Northern Cardinal	*Cardinalis cardinalis*	7	24
Northern Parula	*Setophaga americana*	–	3
Ovenbird	*Seiurus aurocapilla*	–	1
Pileated Woodpecker	*Dryocopus pileatus*	1	3
Prothonotary Warbler	*Protonotaria citrea*	–	1
Red-bellied Woodpecker	*Melanerpes carolinus*	7	7
Red-eyed Vireo	*Vireo olivaceus*	–	4
Red-headed Woodpecker [2]	*Melanerpes erythrocephalus*	–	2
Red-tailed Hawk	*Buteo jamaicensis*	1	–
Red-winged Blackbird	*Agelaius phoeniceus*	1	–
Sharp-shinned Hawk	*Accipiter striatus*	–	1
Summer Tanager	*Piranga rubra*	–	1
Tufted Titmouse	*Baeolophus bicolor*	5	14
Turkey Vulture	*Cathartes aura*	1	–
White-breasted Nuthatch	*Sitta carolinensis*	–	6
Wild Turkey	*Meleagris gallopavo*	–	1
Wood Thrush [2]	*Hylocichla mustelina*	–	4
Yellow Warbler	*Setophaga petechia*	–	1
Yellow-billed Cuckoo [1]	***Coccyzus americanus***	**–**	**9**
Yellow-throated Vireo	*Vireo flavifrons*	–	4
Yellow-throated Warbler	*Setophaga dominica*	–	1

[1] Bolded names are on the Partners in Flight continental Red Watch List or Yellow Watch List.

[2] Highlighted names are on the Partners in Flight Red Watch List or Yellow Watch List for the Eastern Tallgrass Prairie BCR or the Central Hardwoods BCR.

[3] Species that are both bolded and highlighted are listed as priorities both continentally and in the Eastern Tallgrass Prairie or Central Hardwoods BCR.)

The slope of the linear regression line for mean native bird species richness for all sampling periods available was positive and marginally statistically significant ($r^2 = 0.5$, $p = 0.07$), suggesting a possibly increasing trend in the richness of the bird community at LIBO. However, the 90% confidence intervals for native species richness overlap across all but one year, indicating that native bird species richness was sometimes variable and unchanging during the years monitored (Figure 41). Findings by Peitz and Kull (2020) incorporated 2019 data not used in our analysis and concluded that the bird community at LIBO is faring similarly to the bird communities in the Central Hardwoods Bird Conservation Region as a whole. For five of the more common bird species, they concluded that trends for bird diversity, richness, and evenness values are stable, which suggests that the park's habitat continues to meet the needs of many bird species. These results indicate an unchanging trend for native bird richness.

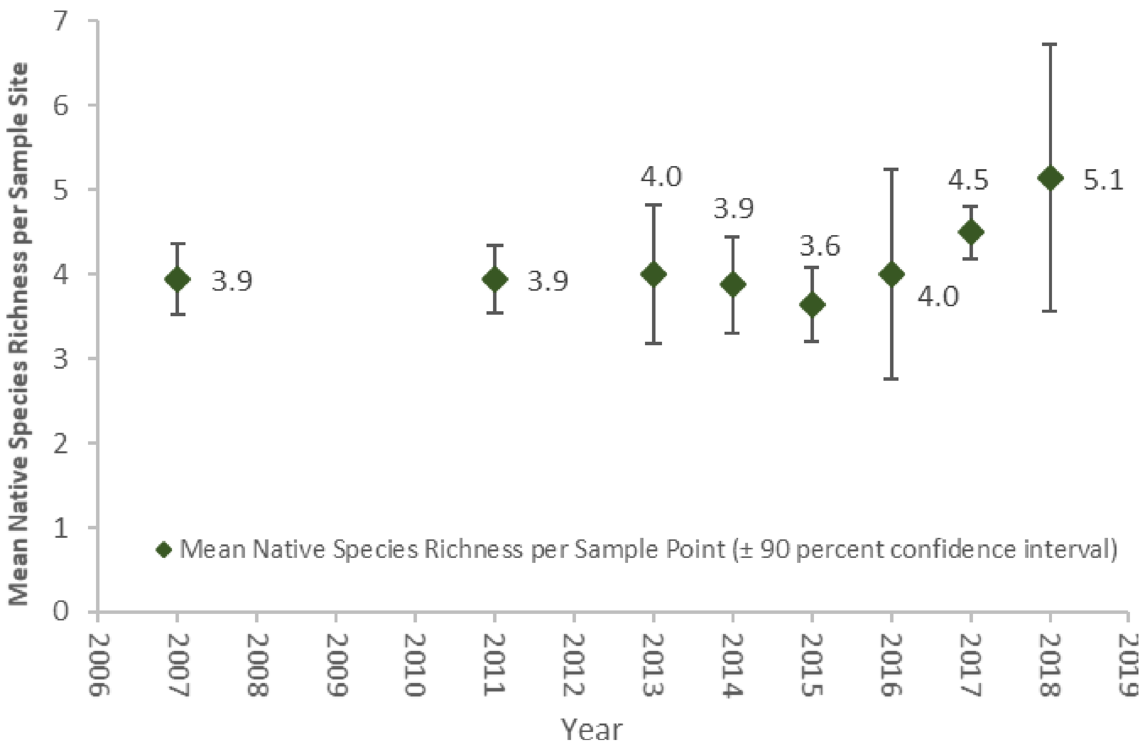


Figure 41. Mean native bird species richness at Lincoln Boyhood National Memorial from 2007 to 2018 with 90 percent confidence intervals shown. (Data source: Heartland I&M Network.)

<u>Bird Index of Biotic Integrity</u>

The 2018 bird IBI score of 37.4 indicates that composition of the bird community at LIBO warrants moderate concern (Table 33). The slope of the linear regression line for the bird IBI scores across all years was not statistically significant (p>.05), suggesting a stable trend in the IBI scores at LIBO. There is a great amount of overlap in the 90% confidence intervals for the scores, also suggesting the scores have remained stable over the sampling period (Figure 42). The IBI score suggests that the bird community is represented by both interior forest dependent species and generalists, which might be expected given the varying age of forest stands and the persistence of forest openings and early-seral communities at LIBO.

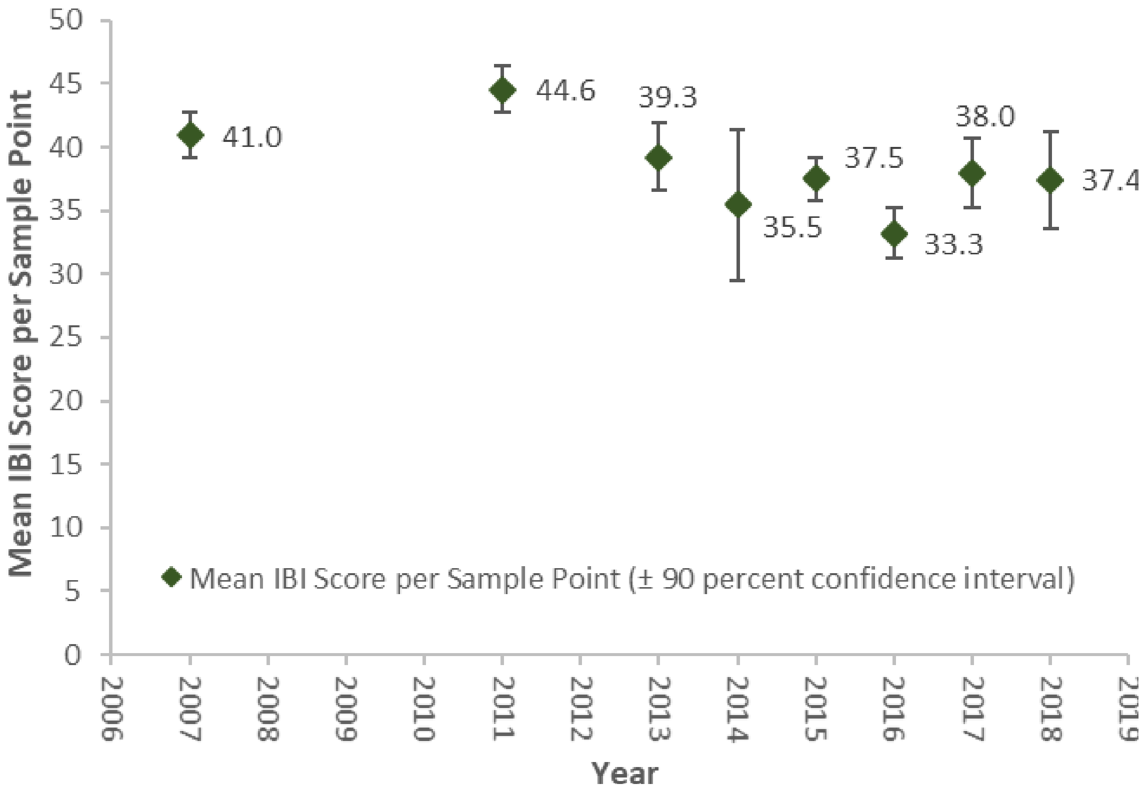
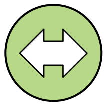
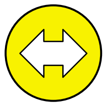
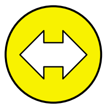


Figure 42. Mean bird IBI scores at Lincoln Boyhood National Memorial from 2007 to 2018 with 90 percent confidence intervals. (Data source: Heartland I&M Network.)

<u>Overall Condition and Trend</u>

The 2018 values for the indicators of native bird species richness and bird IBI indicate that the bird community at LIBO warrants moderate concern, with a number of specialist insectivorous foraging bird species, numerous species within the nest placement specialist guilds, and a community structure that is representative of a moderately disturbed landscape (Table 34). The metrics calculated for the years 2007 to 2018 suggest an unchanging trend in bird community diversity and structure at LIBO. Overall, the bird community at LIBO warrants moderate concern with an unchanging trend; confidence in the assessment is medium (Table 35).

Table 35. Condition and trend summary for birds at Lincoln Boyhood National Memorial.

Indicator	Condition Status/Trend	Rationale
Native Bird Species Richness		Mean native bird species richness per sample site fluctuated between 5.1 and 3.6 species per site between 2007 and 2018. Mean richness was 5.1 in 2018, which was greater than the reference condition of 85% of the 2007 value of 3.9. Analysis of the data indicates an unchanging trend in native bird species richness from 2007 to 2018.
Bird Index of Biotic Integrity		In 2018, the mean bird IBI score per sample site was 37.4. Analysis of the bird IBI scores indicates an unchanging trend in the biotic integrity of the bird community between 2007 and 2018.
Birds overall		**The resource condition warrants moderate concern with an unchanging trend. Confidence in the assessment is medium.**

Uncertainty and Data Gaps

Confidence in this assessment was medium as is the confidence in the trend analyses. The key uncertainty related to the assessment of the bird community at LIBO is in the limited number of sample sites surveyed in six of the sample years and the limited number of sample years (8), covering a period of just over one decade. For example, surveying seven plots in 2018 makes it less likely that rare species, such as species of conservation concern, would have been encountered than in the comparison year of 2007, when 35 plots were surveyed. Assessments using species richness, biotic integrity, and the presence of species of concern should be based on a larger number of sample sites and sample years, over a span of decades. Comprehensive data collected over a number of years and a number of sample sites is needed to assess the natural temporal fluctuation of the condition indicators used in this assessment and to assure the accuracy of the assessment (Denes et al. 2015). However, comprehensive data from additional years are not available for the bird community at LIBO.

Also, this assessment is based upon monitoring data collected over multiple years by multiple trained volunteer observers with varying skills in conducting point counts. This potential variation in the detection probabilities of different observers could introduce measurement error into the data, leading to bias. This bias can reduce the ability to identify statistically significant trends in the indicators (Dornelas et al. 2012).

Sources of Expertise

- David Peitz, a wildlife biologist at the Heartland I&M Network is responsible for collecting the monitoring data at LIBO upon which this assessment is based and also for leading the design of the protocol used to monitor birds at parks of the HTLN (Peitz et al. 2008).

Herptiles

Background and Importance

Forest herpetofauna are important components of terrestrial and aquatic systems in the parks of the Heartland Inventory and Monitoring Network (HTLN). Worldwide, herpetofauna have declined due to combinations of multiple factors including habitat loss, habitat fragmentation, disease, pollution, climatic shifts, and others (Becker et al. 2007; Cushman 2006; Gardner et al. 2007).

Herpetofauna species, especially amphibians, are widely considered to be effective indicators of the quality and condition of terrestrial and aquatic systems (Mifsud 2014; Welsh and Droege 2001). Because they are sensitive to habitat changes that change moisture regimes, including wetland filling or draining, urbanization, and clearcutting (Pechmann et al. 1991; Blaustein et al. 1994; Fontenot et al. 1996), herpetofauna assemblages are indicative of habitat quality.

NPS lands provide some of the least impacted habitat remaining in the Midwest, serving as refugia for some species by providing seasonally wet areas and important older forest structure for native herpetofauna (Miller et al. 2016; Gibbons 2003; Lodato 1997). Because of the rarity of non-agricultural lands in the region, Lincoln Boyhood National Memorial (LIBO) is especially valuable for providing relatively undisturbed patches of habitat critical for sustaining native forest within a highly altered agricultural landscape (Hansen and Gryskiewicz 2003). The habitat fragmentation and conversion of native vegetation to agricultural and urban landscapes occurring outside the memorial will negatively impact populations of some herpetofauna species resident to LIBO, particularly intolerant species that have evolved within stable environments (Palmeirim et al. 2017; Newbold et al. 2016; Devictor et al. 2008). Herpetofauna community composition and diversity should improve with restoration projects such as identifying, maintaining and restoring seasonal wetlands, native forest cover, and downed woody material and forest litter both within LIBO and within the surrounding landscape (Kingsbury and Gibson 2012; Lodato 1997).

<u>Threats</u>

The herpetofauna community at LIBO has been affected by habitat conversion, degradation, modification, and fragmentation (Hansen and Gryskiewicz 2003). Agriculture and development in the surrounding landscape have resulted in the loss of both terrestrial and aquatic habitat (Hansen and Gryskiewicz 2003). The combined and interacting effects of these influences have the potential to cause declines in herpetofauna not only at LIBO, but also in the area surrounding the memorial (Struecker and Milanovich 2017; Casper 2000).

Modifications to the surrounding landscape disrupt ecological functions important to ecosystem integrity and important to maintaining the community and composition of herptile species at LIBO comparable to that found in the natural habitat of the region (Jørgensen and Müller 2000). These changes in land use are linked to ecological function at LIBO by five mechanisms (Hansen and Gryskiewicz 2003):

1) land use activities reduce the functional size of a reserve, eliminating important ecosystem components lying outside the park's boundary;

2) land use activities alter the flow of energy or materials across the landscape irrespective of the park's political boundary, disrupting the ecological processes dependent upon those flows both outside and inside the park and across its boundaries;
3) habitat conversion outside the park may eliminate unique habitats, such as seasonal habitats and migration corridors;
4) the negative influences of land use activities may extend into the park and create edge effects; and
5) increased population density may directly impact the park through increased recreation and human disturbance.

Consequently, the ecological functioning of LIBO depends upon maintaining the natural systems within and outside the park's boundaries.

Indicators and Measures

- Percent of the expected species present

Data and Methods

NPS conducted herpetofauna surveys at LIBO in 1997, from February to September (Lodato 1997). Prior to this survey effort the status of herpetofauna at LIBO was unknown. The information presented in this report is a summary of the survey findings.

Multiple sampling techniques were employed at LIBO in 1997 including random walking surveys using visual encounters, vehicle road surveys, surveys by canoe, and a turtle trap set in the permanent pond found in the memorial's west unit (Lodato 1997). Of these four techniques, the primary method used to survey amphibians and reptiles was the random walk visual encounter survey (Lodato 1997).

The NPSpecies database identifies 33 species of herpetofauna that could occur within LIBO (NPS 2018d), including nine species of frogs and toads, six salamanders, 14 lizards and snakes, and four turtles (Table 36).

Table 36. Native herpetofauna species that could occur at Lincoln Boyhood National Memorial with confirmation of those documented during the 1997 survey (NPS 2018d).

Class	Order	Common Name	Scientific Name	Confirmation Status
Amphibians	Anura	Blanchard's cricket frog	*Acris crepitans blanchardi*	unconfirmed
	Anura	Bullfrog	*Rana catesbeiana*	unconfirmed
	Anura	Cope's gray treefrog	*Hyla chrysoscelis*	confirmed
	Anura	Fowler's toad	*Bufo fowleri*	confirmed
	Anura	Green frog	*Rana clamitans melanota*	confirmed
	Anura	Southern leopard frog	*Rana utricularia*	confirmed
	Anura	Spring peeper	*Pseudacris crucifer*	confirmed
	Anura	Striped chorus frog	*Pseudacris triseriata*	confirmed
	Anura	Wood frog	*Rana sylvatica*	confirmed
	Caudata	Cave salamander	*Eurycea lucifuga*	unconfirmed
	Caudata	Eastern red-backed salamander	*Plethodon cinereus*	confirmed
	Caudata	Marbled salamander	*Ambystoma opacum*	confirmed
	Caudata	Northern slimy salamander	*Plethodon glutinosus*	confirmed
	Caudata	Small-mouthed salamander	*Ambystoma texanum*	confirmed
	Caudata	Spotted salamander	*Ambystoma maculatum*	unconfirmed
Reptiles	Squamata	Black kingsnake	*Lampropeltis getula nigra*	unconfirmed
	Squamata	Black rat snake	*Elaphe obsoleta*	unconfirmed
	Squamata	Common garter snake	*Thamnophis sirtalis*	confirmed
	Squamata	Eastern hog-nosed snake	*Heterodon platirhinos*	unconfirmed
	Squamata	Five-lined skink	*Eumeces fasciatus*	confirmed
	Squamata	Gray ratsnake	*Elaphe spiloides*	unconfirmed
	Squamata	Midland brown snake	*Storeria dekayi wrightorum*	confirmed
	Squamata	Midland water snake	*Nerodia sipedon pleuralis*	confirmed
	Squamata	Midwest worm snake	*Carphophis amoenus helenae*	unconfirmed

Table 36 (continued). Native herpetofauna species that could occur at Lincoln Boyhood National Memorial with confirmation of those documented during the 1997 survey (NPS 2018d).

Class	Order	Common Name	Scientific Name	Confirmation Status
Reptiles (continued)	Squamata	Northern copperhead	*Agkistrodon contortrix mokasen*	unconfirmed
	Squamata	Northern fence lizard	*Sceloporus undulatus hyacinthinus*	confirmed
	Squamata	Rat snake	*Elaphe obsoleta*	confirmed
	Squamata	Rough green snake	*Opheodrys aestivus*	confirmed
	Squamata	Southern black racer	*Coluber constrictor priapus*	confirmed
	Testudines	Common snapping turtle	*Chelydra serpentina*	confirmed
	Testudines	Eastern box turtle	*Terrapene carolina*	confirmed
	Testudines	Midland painted turtle	*Chrysemys picta marginata*	confirmed
	Testudines	Red-eared slider	*Trachemys scripta elegans*	confirmed

Reference Conditions

Reference condition was set to the number of native herptile species with the potential to occur within the memorial (33 species), as identified by the NPSpecies database (NPS 2018d). More quantitative metrics and thresholds describing the population dynamics of specific species or the herptofauna group as a whole could not be determined at this time due to the limited data available. However, the Lodato (1997) study does allow us to make some inference regarding the condition of herptofauna within the memorial and should be used as the basis for future monitoring efforts. A condition rating framework for herpetofauna at LIBO is shown in Table 37.

Table 37. Resource condition rating framework for herpetofauna at Lincoln Boyhood National Memorial, Indiana.

Indicator	Condition Status		
	Resource is in Good Condition	Condition Warrants Moderate Concern	Condition Warrants Significant Concern
Percent of Expected Species Confirmed	>85–100+% of expected species are confirmed	70–85% of expected species are confirmed	<70% of expected species are confirmed

Condition and Trend

Across all herptiles, 23 of the 33 expected species (70%) were confirmed during the 1997 survey (Table 36), which warrants moderate concern (Table 38). The survey found 73% of expected amphibians and 67% of expected reptiles. Ratios of observed-to-expected species were as follows: seven of nine frogs and toads (78%), four of six salamanders (67%), eight of 14 lizards and snakes (57%), and all four turtles species (100%). Because surveys only indicate presence of a species, a species not being observed does not indicate local extirpation. The lack of a species observation may be an artifact of the sampling design or sampling season.

Trend for this indicator cannot be assessed due to the single sample period. Confidence in the assessment is low because the only data available are from a single year more than two decades ago and the data examined are simply presence-absence. Herpetofauna diversity at LIBO could have changed in at the memorial during the intervening period.

Table 38. Condition and trend summary for herpetofauna at Lincoln Boyhood National Memorial.

Indicator	Condition Status/Trend	Rationale
Percent of Expected Species Confirmed		The percent of herpetofauna confirmed in 1997 was 70% (warrants moderate concern), less than the reference condition of 85% of 33 expected species. Analysis of the herpetofauna data for trend was not possible because only one year of sampling data was available.
Herpetofauna overall		**Condition warrants moderate concern with an unknown trend. Confidence in the assessment is low.**

Uncertainty and Data Gaps

Herpetofauna data for LIBO were limited. Survey data were only available for a single time period and no monitoring data were available. The survey documented species present on site; however, the lack of detection of a species does not necessarily indicate a local extirpation. The lack of detection of a species may be an artifact of the sampling design or the seasonal timing of the survey. Trends were not identified for herpetofauna within the memorial because data were available for only a single year.

Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades rather than the one period of survey data available for this assessment (Holmes 2010; Magurran et al. 2010). Continued monitoring could either support or refute the outcome of the current assessment. Comprehensive data collected from numerous sites within LIBO and over an extended time period are needed to assess the natural temporal fluctuation of the condition indicator used in this assessment and to verify the accuracy of the assessment (Dornelas et al. 2012).

If a monitoring program for herpetofauna is implemented at LIBO, then sampling effort should be kept consistent across years. If multiple sites are monitored, then all sites or at least a subset utilizing all of the same sites should be monitored every year. Otherwise, the number of species detected in a given year could be a factor of how many sites were sampled rather than the actual number of species present. This confounding influence would make it difficult to interpret changes over time. Sampling the same sites and the same number of sites every year would help control for this bias.

Sources of Expertise

- Michael Lodato, a herpetologist and private consultant, was responsible for collecting the survey data at LIBO (Lobato 1997). His research interests focus on the biogeography of herpetofauna in Indiana.

Mammals

Background and Importance

Mammals are important components of forest parks of the Heartland Inventory and Monitoring Network (HTLN). The hardwood forests of the area surrounding Lincoln Boyhood National Memorial (LIBO) were historically dominated by oaks and maples, but they have undergone significant changes due to historical land uses such as agriculture, logging, and invasion by nonnative species and restoration since the time of Lincoln (Leis 2016). Most of the memorial currently supports mixed mesic successional forest that reflects forests that developed after agricultural uses (Pavlovic and White 1989). These changes in the hardwood forest at LIBO and the surrounding area have the potential to impact the mammal fauna of the region in complex ways (Degrassi 2018; Degrassi 2016; Kaminski et al. 2007; Mankin and Warner 1997).

Mammal populations, especially small mammals, are excellent indicators of environmental condition because they respond to changes in vegetation structure, respond rapidly to habitat changes, can move about freely and leave disturbed and unsuitable sites, and are ubiquitous and fecund, making them suitable for landscape-level studies (Klenner and Sullivan 2009, Leis et al. 2008). For this reason, mammal community composition offers an indication of environmental health. Understanding the community structure and abundance of mammals within LIBO will be useful for assessing the impacts of management activities at the memorial (Roth and Roth 1997).

NPS lands provide some of the least impacted habitat remaining in the Midwest, serving as refugia for some species and offering potential habitat for native mammals (Miller et al. 2016). Within a highly altered landscape, LIBO provides valuable, relatively undisturbed patches of habitat critical for sustaining native prairie (Hansen and Gryskiewicz 2003). Habitat fragmentation and the conversion of native vegetation to urban and agrarian landscapes outside the memorial can negatively impact populations of some breeding mammals at LIBO, particularly specialist species that have evolved within stable environments (Keinath et al. 2017; Matthews et al. 2014; Devictor et al. 2008; La Sorte 2006).

Mammal community composition and diversity should improve with the restoration of the native hardwood forest communities both within LIBO and within the surrounding landscape (Johnson 2006; Boren et al. 1999). The goal of managers at LIBO is ultimately to restore the forest to the conditions present prior to or at Euro-American settlement during the period of reference (1816–1830). Such late successional forest communities would benefit the mammal community at LIBO (Wagner and Roth 1997).

<u>Threats</u>

The mammal community at LIBO has been affected by habitat conversion, degradation, modification, and fragmentation (Hansen and Gryskiewicz 2003). Agriculture and development in the surrounding landscape have resulted in the loss of both terrestrial and aquatic habitat (Hansen and Gryskiewicz 2003). The combined and interacting effects of these influences have resulted in population declines and range reduction of mammals within the Midwest (Mankin and Warner 1997) and also probably at LIBO and in the area surrounding the memorial.

Modifications to the surrounding landscape disrupt ecological functions important to ecosystem integrity and important to maintaining the community and composition of mammalian species at LIBO comparable to that found in the natural habitat of the region (Jørgensen and Müller 2000). Changes in land use outside the memorial are linked to ecological function within LIBO through five mechanisms (Hansen and Gryskiewicz 2003):

1) land use activities reduce the functional size of a reserve, eliminating important ecosystem components lying outside the memorial's boundary;
2) land use activities alter the flow of energy or materials across the landscape irrespective of the memorial's political boundary, disrupting the ecological processes dependent upon those flows both outside and inside the memorial and across its boundaries;
3) habitat conversion outside the memorial may eliminate unique habitats, such as seasonal habitats and migration corridors;
4) the negative influences of land use activities may extend into the memorial and create edge effects; and
5) increased human population density may directly impact the memorial through increased recreation and human disturbance.

Consequently, the ecological functioning of LIBO depends upon maintaining the natural systems within and outside the memorial's boundaries.

<u>Indicators and Measures</u>

- Percent of expected mammal species present

Data and Methods

This assessment uses data from mammal surveys conducted at LIBO in August and September 1996 by Whitaker and Lindley (1996), in February 1997 by Roth and Roth (1997) and in June 1997 by Wagner and Roth (1997). In 1996, small mammal trapping was conducted on 24 plots and bats were mist-netted at two locations (Whitaker and Lindley 1996). In 1997, small mammals were trapped along nine east-west transects placed 175 meters apart throughout the memorial (Wagner and Roth 1997) and large mammals were surveyed at 31 scent stations placed 175 meters apart along the same east-west transects (Roth and Roth 1997) (Figure 43). Because all surveys were conducted within an eleven-month span, we aggregated all of the data into a single sample.

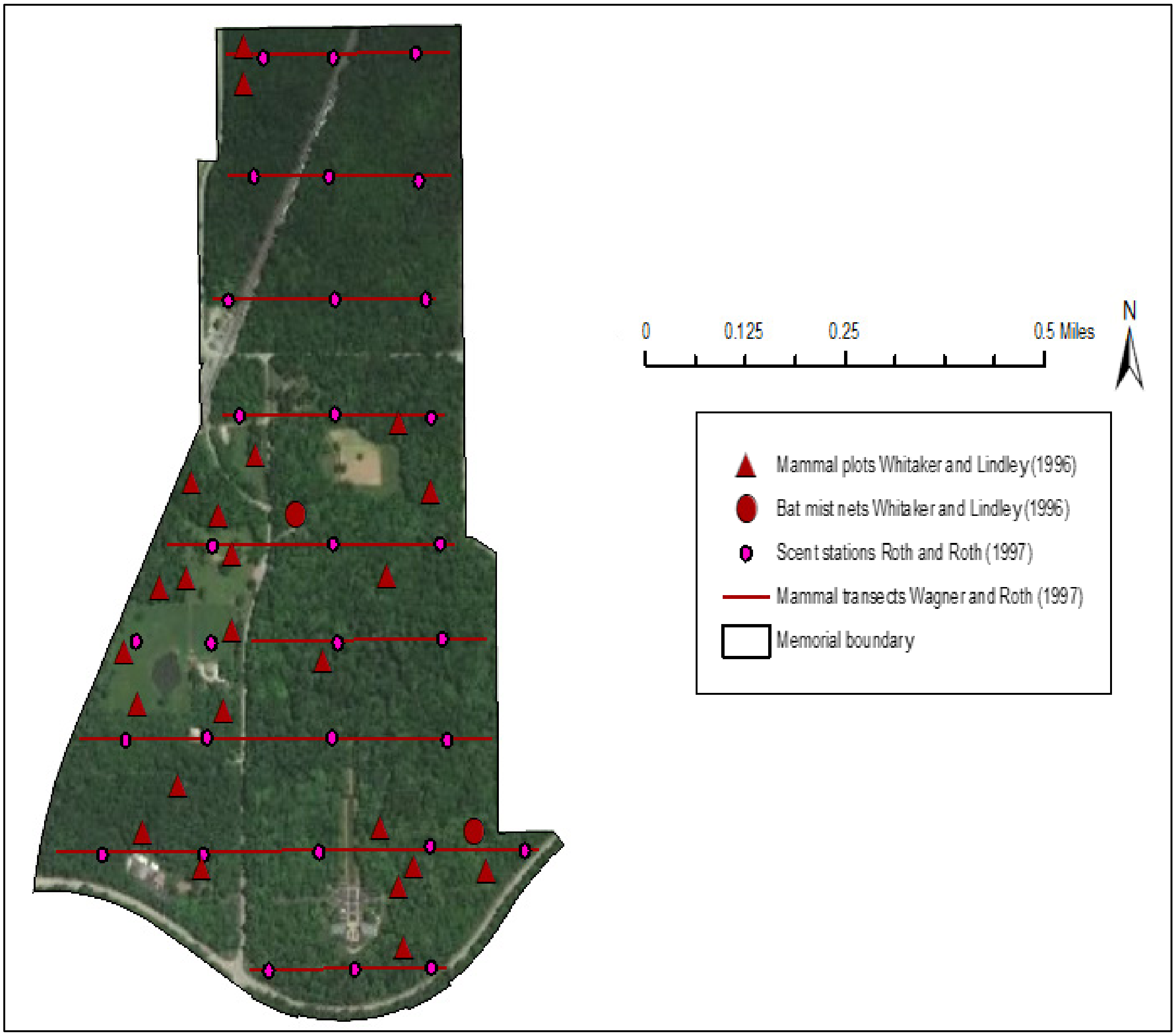


Figure 43. Location of mammal sampling locations at Lincoln Boyhood National Memorial (after Whitaker and Lindley 1996, Roth and Roth 1997, and Wagner and Roth 1997). The "Mammal transects" represent small mammal transects and the "Scent stations" represent large mammal scent stations.

The NPSpecies database identifies 36 species of native mammals that could occur within LIBO (NPS 2018d). These species include one deer, eight carnivores, eight bats, one opossum, one rabbit, 13 rodents, and four shrews or moles (Table 39).

Table 39. Native mammal species that could potentially occur at Lincoln Boyhood National Memorial with indication of which species were confirmed during the 1996 and 1997 surveys.

Order	Common name	Scientific Name	Confirmation Status
Artiodactyla	White-tailed deer	*Odocoileus virginianus*	confirmed
Carnivora	American mink	*Mustela vison*	unconfirmed

Table 39 (continued). Native mammal species that could potentially occur at Lincoln Boyhood National Memorial with indication of which species were confirmed during the 1996 and 1997 surveys.

Order	Common name	Scientific Name	Confirmation Status
Carnivora (continued)	Bobcat	*Lynx rufus*	unconfirmed
	Coyote	*Canis latrans*	confirmed
	Gray fox	*Urocyon cinereoargenteus*	unconfirmed
	Long-tailed weasel	*Mustela frenata*	unconfirmed
	Raccoon	*Procyon lotor*	confirmed
	Red fox	*Vulpes vulpes*	confirmed
	Striped skunk	*Mephitis mephitis*	unconfirmed
Chiroptera	Big brown bat	*Eptesicus fuscus*	unconfirmed
	Eastern pipistrelle	*Pipistrellus subflavus*	unconfirmed
	Eastern red bat	*Lasiurus borealis*	confirmed
	Hoary bat	*Lasiurus cinereus*	unconfirmed
	Indiana bat	*Myotis sodalis*	unconfirmed
	Little brown bat	*Myotis lucifugus*	unconfirmed
	Northern long-eared bat	*Myotis septentrionalis*	unconfirmed
	Silver-haired bat	*Lasionycteris noctivagans*	unconfirmed
Didelphimorphia	Virginia opossum	*Didelphis virginiana*	confirmed
Lagomorpha	Eastern cottontail	*Sylvilagus floridanus*	confirmed
Rodentia	Common muskrat	*Ondatra zibethicus*	unconfirmed
	Eastern chipmunk	*Tamias striatus*	unconfirmed
	Fox squirrel	*Sciurus niger*	unconfirmed
	Gray squirrel	*Sciurus carolinensis*	unconfirmed
	Groundhog	*Marmota monax*	unconfirmed
	Meadow jumping mouse	*Zapus hudsonius*	unconfirmed
	Meadow vole	*Microtus pennsylvanicus*	unconfirmed
	Pine vole	*Microtus pinetorum*	unconfirmed
	Prairie deer mouse	*Peromyscus maniculatus bairdii*	confirmed
	Prairie vole	*Microtus ochrogaster*	unconfirmed
	Southern bog lemming	*Synaptomys cooperi*	unconfirmed
	Southern flying squirrel	*Glaucomys volans*	unconfirmed
	White-footed mouse	*Peromyscus leucopus*	confirmed
Soricomorpha	Eastern mole	*Scalopus aquaticus*	confirmed
	Least shrew	*Cryptotis parva*	unconfirmed
	Northern short-tailed shrew	*Blarina brevicauda*	confirmed
	Southeastern shrew	*Sorex longirostris*	unconfirmed

Reference Conditions

Reference condition was set to the number of native mammalian species with the potential to occur within the memorial, as identified in the NPSpecies database (NPS 2018d). Other quantitative metrics describing the population dynamics of specific species or the mammal group as a whole could not be assessed due to the limited data available. However, the three studies conducted from 1996 to 1997 do allow us to make some inferences regarding the condition of the mammal community within the memorial. A condition rating framework for mammals at LIBO is shown in Table 40.

Table 40. Resource condition rating framework for the mammal community at Lincoln Boyhood National Memorial, Indiana.

Indicator	Condition Status		
	Resource is in Good Condition	**Condition Warrants Moderate Concern**	**Condition Warrants Significant Concern**
Percent of Expected Species Confirmed	>85–100+% of expected species are confirmed	70–85% of expected species are confirmed	<70% of expected species are confirmed

Condition and Trend

Only 11 of the 36 expected species (30.5%) were confirmed during the 1996 and 1997 surveys (Table 39), which warrants significant concern (Table 41). Ratios of observed-to-expected species were as follows: one of one (100%) each for the deer, opossum, and rabbit; three of eight carnivores (37.5%); one of eight bats (12.5%); two of 13 rodents (15%); and two of four shrews and moles (50%). Because surveys only indicate presence of a species, the lack of an observation does not indicate species absence or local extirpation. The lack of a species observation may be an artifact of the sampling design or sampling season.

No trend assessment is currently possible for this metric due to the limited sampling periods. Confidence in the assessment is low because all of the data were collected within an eleven-month period more than two decades ago; changes in the composition and abundance of mammal species and their habitats at LIBO could have occurred since then.

Table 41. Condition and trend summary for mammals at Lincoln Boyhood National Memorial.

Indicator	Condition Status/Trend	Rationale
Percent of Expected Species Confirmed		The percent of expected mammal species confirmed in 1996 and 1997 was 30.5% (warrants significant concern), significantly less than the reference condition of 85% of 36 expected species. Because all data were collected within an 11-month period more than two decades ago, the trend in mammal populations is unknown.
Mammals overall		**Condition warrants significant concern with an unknown trend. Confidence in the assessment is low.**

Uncertainty and Data Gaps

Mammal data were limited for LIBO. All survey data were collected within an eleven-month period, with no subsequent monitoring data available. The surveys documented species detected, but the lack of detection of a species does not necessarily indicate a local extirpation. The absence of a species may be an artifact of the sampling design or the seasonal timing of the survey. For example, the only bat surveys used mist nets, which are often inadequate for sampling forest-dwelling bats when no waterways are present. Acoustical sampling is a much more effective method for surveying forest dwelling bats. However, acoustical sonogram technology was rudimentary at the time the mammal surveys were completed at LIBO. Trends were not identified for mammals within the memorial because results were available for such a short period of time.

Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades rather than the short period of sampling data available for this assessment (Holmes 2010; Magurran et al. 2010). Comprehensive data collected from numerous sites within LIBO and over an extended time period are needed to assess the natural temporal fluctuation of the condition indicator used in this assessment and to enable the use of additional quantitative metrics (Dornelas et al. 2012).

If a monitoring program for mammals is implemented at LIBO, sampling effort should be kept consistent from year to year. If multiple sites are monitored, then all sites or at least a subset of the same sites should be monitored to minimize the effects of sampling effort variability across years.

Sources of Expertise

- John Whitaker, Jr., professor of Ecology and Organismal Biology at Indiana State University, authored the 1996 LIBO mammal inventory report with Felicia Lindley. Dr. Whitaker's research emphasizes small mammal ecology.
- Gia Wagner was the Environmental Protection Specialist at LIBO in 1997 and is now a Natural Resource Branch Chief at the National Park Service, Indiana Dunes National Lakeshore. Gia was the lead author of the 1997 LIBO small mammal report.
- Chuck Roth, a Life Scientist at the USEPA, Region 5 Superfund Division, Chicago, Illinois, was the second author of the 1997 LIBO small mammal report and was a Master of Science Student at Governors State University, Chicago, Illinois, in 1997.
- Lori Roth was a Master of Science Student at Governors State University, Chicago, Illinois, in 1997 and authored the LIBO large mammal report with Chuck Roth.

Chapter 5. Summary and Discussion

This section summarizes condition and trend results by focal resource, highlights management implications and interrelationships among resources, reinforces relationships between resource condition and landscape context elements, and consolidates data gaps.

Condition Summary and Management Implications

A total of nine focal resources were examined: four addressing landscape context – system and human dimensions, one addressing chemical and physical attributes, and four addressing biological or integrated attributes. Status and trend assigned to each focal resource and a synopsis of supporting rationale are presented in Table 42.

Table 42. Summary of focal resource condition and trend for Lincoln Boyhood National Memorial.

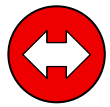
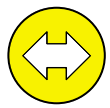
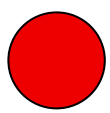
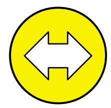
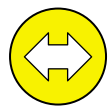
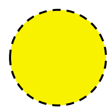
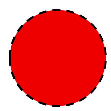
Ecosystem Attribute	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Landscape Context – System and Human Dimensions	Land Cover and Land Use	condition and trend not assigned	LIBO is within a rural/exurban matrix landscape. Most of the stressors to the landscape surrounding LIBO are due to land conversion and a lack of well-connected protected areas. Overall, the status and degree of these threats and stressors on the park are low in comparison to other federal and state parks in the region.
	Natural Night Sky		Median ALR at LIBO ranges between 1.28 and 2.56, indicating moderate to significant management concern, and nearby urban centers produce significant light pollution. The trend is deteriorating based on recent and anticipated increases in development and urbanization, which are typically linked to natural night sky quality.
	Soundscape		Results indicate that the condition of the soundscape at LIBO warrants moderate concern. Nationwide modeling of anthropogenic sound level impacts indicates that modern noise intrusions are substantially increasing the existing ambient sound level above the natural ambient sound level of the memorial.
	Climate Change	condition and trend not assigned	LIBO's climate is already becoming wetter, hotter, and is potentially more prone to more frequent and extreme weather events. Trends are projected to continue or accelerate by the end of the century. Research and monitoring related to climate change, the anticipated vulnerability of specific resources vis-a-vis climate change, and its associated effects on resources and interaction with other ecological processes can be informed by this broad overview of the magnitude of climate change. It also supports ongoing, anticipatory and adaptive management. More specific climate change adaptation tools and techniques appear to be needed at the park scale.
Chemical and Physical Environment	Air Quality		Based on the evaluation of air quality indicators, air quality condition warrants significant concern, with no trend determined due to insufficient on-site or nearby monitoring data. Confidence in the assessment is medium. Impacts to air quality appear to be largely from distant sources that are affecting regional air quality.

Table 42 (continued). Summary of focal resource condition and trend for Lincoln Boyhood National Memorial.

Ecosystem Attribute	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Biological – Plants	Vegetation Communities		Results consolidated across multiple indicators suggest the current condition of vegetation communities at LIBO warrants moderate concern, with an unchanging trend and medium confidence. The current condition of vegetation communities (as assessed by native species composition, Mean Coefficient of Conservation, and FQAI) at the memorial shows mixed results. The potential impact of external factors (IEP, forest pests and disease, and vulnerability to climate change) in the future displays a more concerning valuation.
Biological – Animals	Birds		Data representing native species richness and bird IBI indicate that the condition of the bird community at LIBO warrants moderate concern, with no trend in the data. Confidence in the assessment is medium.
	Herptiles		The condition of herptile communities at LIBO warrants moderate concern, with low confidence due to the length of time since data were collected.
	Mammals		The condition of herptile communities at LIBO warrants moderate concern, with low confidence due to the length of time since data were collected.

Landscape Context –System and Human Dimensions

Landscape context – system and human dimensions included land cover and land use, night sky, soundscape, and climate change (Table 42). Climate change and land cover/land use were not assigned a condition or trend—they provide important context to the memorial and many natural resources and can be stressors. Some of the land cover and land use-related stressors at LIBO and in the larger region are related to the development of rural land and increases in population/housing over time. The trend in land development, coupled with the lack of significantly-sized and linked protected areas, presents significant challenges to the conservation of natural resources of LIBO to also include natural night skies, natural sounds and scenery. Climate change is happening and is affecting resources, but is not considered *good* or *bad* per se. The information synthesized in that section is useful in examining potential trends in the vulnerability of sensitive resources and broad habitat types such as forests. Night skies and soundscapes, significantly altered by disturbance due to traffic, development and urbanization, warrant significant and moderate concern, respectively, and appear to be in further decline.

There are opportunities to mitigate the effects of local landscape context stressors through planning, management and mitigation. Stressors driven by more distant factors such as light pollution generated by urban centers and increase in regional transportation volumes affecting sights and sounds are more difficult to mitigate. The results for these landscape-scale indicators support resource planning and management within the memorial and provides a foundation for collaborative conservation with other landowners in the surrounding area.

Chemical and Physical Environment

Air quality was the sole resource supporting chemical and physical environment at the memorial (Table 42). The condition of air quality can affect human dimensions of the park such as visibility and scenery as well as biological components such as the effect of ozone levels on vegetation health. Air quality warrants significant concern and is largely impacted by historical and current land uses outside the memorial boundary.

Biological Component – Plants

The floral biological component was examined by assessing native species composition, Mean Coefficient of Conservation, FQAI, IEP, forest pests and disease, and forest vulnerability to climate change (Table 42). Vegetation resources at LIBO have been influenced by historical land uses that have changed the species composition and age structure of these communities. Although large tracts of forests can be found surrounding the park, the majority of the forested areas are fragmented, and few areas within and around LIBO exhibit late-successional or old-growth characteristics. Vegetation communities at LIBO have a long history of being impacted by a variety of stressors and threats including noxious and invasive weeds, diseases and insect pests, compounding effects of climate change, air pollution, acid rain/atmospheric chemistry, past land uses, and impacts associated with overabundant white-tail deer populations. These stressors and threats have collectively shaped and continue to impact plant community condition and ecological succession. The sole metric in good condition was native species composition, while all other indicators and metrics warranted either moderate or significant concern.

Biological Component – Animals

The faunal biological components examined included birds, herptiles, and mammals (Table 42). Birds (unchanging trend) and herptiles (no trend determined) warrant moderate concern, while mammal populations warrant significant concern (no trend determined). The confidence of both herptiles and mammals was low due to length of time since data were last collected. Current forest structure within and surrounding LIBO generally reflects the historical overstory composition, but white oak was more dominant historically and maples less dominant than in the current forest. These changes in the hardwood forest at LIBO and the surrounding area have resulted in declines in the avian fauna of the region since the 1970s. The decline in woodland bird populations has been caused by multiple factors including the conversion of hardwood forest to other land cover types, habitat fragmentation, and increasing human population growth.

Habitat fragmentation and conversion of native vegetation to agricultural and urban landscapes occurring outside the memorial has likely negatively impacted populations of some herpetofauna and small mammal species resident to LIBO, particularly intolerant species that have evolved within stable environments. Herpetofauna and mammal community composition and diversity should improve with current and planned restoration projects within LIBO and the surrounding landscape.

Data Gaps and Uncertainties

The identification of data gaps during the course of the assessment is an important NRCA outcome (Table 43). Resource-specific details are presented in each resource section. In some cases, significant data gaps contributed to the resource not being evaluated or low confidence in the condition or trend being assigned to a resource. Primary data gaps and uncertainties encountered were lack of recent survey data, uncertainties regarding reference conditions, availability of consistent long-term data, and more robust sampling designs.

Table 43. Data gaps identified for focal resources examined at Lincoln Boyhood National Memorial.

Ecosystem Attribute	Resource	Data Gaps and Uncertainties
Landscape Context – System and Human Dimensions	Land Cover and Land Use	Condition/status of other protected lands in the region.
	Night Sky	No on-site night sky monitoring studies have been conducted by the NPS in LIBO. Condition and trend are based on modelled data.
	Soundscape	No acoustical monitoring studies have been conducted inside LIBO. Condition and trend are based on modelled data.
	Climate Change	Climate change projections are complex with inherently high uncertainty. More specific guidance for park adaptation is needed with regard to local ecosystems and other resources.
Chemical and Physical Environment	Air Quality	Local air monitoring stations vs. interpolated regional data would improve accuracy.

Table 43 (continued). Data gaps identified for focal resources examined at Lincoln Boyhood National Memorial.

Ecosystem Attribute	Resource	Data Gaps and Uncertainties
Biological – Plants	Vegetation Communities	Uncertainty exists when the interactive effects of anthropogenic stressors, vegetation health, and climate change impacts are all considered equally. Additional modeling along with continued vegetation monitoring should be continued to help understand these cumulative impacts and better inform the future makeup of LIBO vegetation communities. Periodic monitoring is recommended to document changes in vegetation and help direct management activities over time.
Biological – Animals	Birds	The key uncertainty related to the assessment of the bird community at LIBO is in the limited number of sample sites surveyed in six of the sample years and the limited number of sample years (8), covering a period of just over one decade. The assessment is based upon monitoring data collected over multiple years by multiple trained volunteer observers with varying skills in conducting point counts. This potential variation in the detection probabilities of different observers could introduce measurement error into the data, leading to bias.
	Herptiles	Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades rather than the one period of survey data available for this assessment.
	Mammals	All survey data were collected within an eleven-month period, with no subsequent monitoring data available.

Conclusions

The area in and around LIBO has a long history of human settlement and environmental impacts associated with agriculture, natural resource uses and ecological disturbance. The challenges associated with managing resources within a small park that is heavily influenced by its urban and exurban fringes are manifold, especially within a region with extensive agriculture. Impacts associated with development outside the park will continue to stress some resources, and regionally, the direct and indirect effects of climate change are likely but specific outcomes are uncertain. Nonetheless, within the past several decades, some progress has been made toward restoring the quality of natural resources, most notably the forested environments. Regional and park-specific mitigation and adaptation strategies are needed to maintain or improve the condition of some resources over time. Success will require acknowledging a "dynamic change context" that manages widespread and volatile problems while confronting uncertainties, managing natural and cultural resources simultaneously and interdependently, developing broad disciplinary and interdisciplinary knowledge, and establishing connectivity across broad landscapes beyond park borders (National Park Service Advisory Board Science Committee 2012).

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