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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Hopewell Culture National Historical Park

Natural Resource Report NPS/HOCU/NRR—2020/2179

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ON THE COVER
Seip Earthworks, Hopewell Culture National Historical Park
Photograph by Dave Jones, Colorado State University; inset map courtesy NPS

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Contents

Contents (continued)

Page

Contents (continued)

Contents (continued)

Figures

Figures (continued)

Page

Figures (continued)

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

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.

Congress established Hopewell Culture National Historical Park (HOCU) in 1992, renaming the Mound City Group National Monument. HOCU is located in Ross County, Ohio, at six separate sites: Mound City Group, Hopewell Mound Group, Seip Earthworks, Hopeton Earthworks, High Bank Works, and Spruce Hill Works. Each site preserves the remains of mounds and earthworks in the Scioto River watershed that were constructed between approximately 1,600 and 2,000 years ago by the people of the American Indian culture today known as Hopewell. The park's purpose is to preserve, interpret, and research the archeological record of the Hopewell, including earthworks, artifacts, the archeological context, the cultural landscape, and ethnographic information. The legislated boundary includes approximately 1,828 acres, of which approximately 1,188 acres are in NPS ownership.

The NRCA for HOCU employed a scoping process involving Colorado State University, Park and NPS staffs to discuss 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 seven focal resources were examined and are included here: four addressing system and human dimensions, one addressing chemical and physical attributes, and two addressing biological attributes.

Landscape context—both system and human dimensions—included land cover and land use, night sky, natural sounds, and climate change. Climate change and land cover/land use were not assigned a condition or trend, but they provide important context to natural resource condition and management, and can be stressors. Some of the land cover and land use-related stressors at HOCU 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 at HOCU and in the region. The condition of night skies warranted significant concern and the condition of natural sounds warranted moderate concern. Both resources were affected by development and automobile traffic, and had a deteriorating trend. 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 biological resources.

Air quality was the only chemical and physical environment resource examined for HOCU. Air quality conditions can affect human dimensions of the park such as visibility and scenery as well as biological components such as vegetation health. Air quality warranted significant concern with no discernable trend. Air quality in the region is significantly impacted by land uses outside the park boundary, and often from distant sources that degrade regional air quality. Water quality was briefly discussed but surface waters were not considered a focal resource.

The floral biological component looked at forest and grassland communities at each of HOCU's six units. Vegetation communities at HOCU have been influenced by historical land uses that have changed the species composition and age structure of the forest as well as converted natural communities to agriculture. Although some large tracts of forests are found within the park, the majority of the forested areas are fragmented, and few areas within HOCU exhibit late-successional or old-growth characteristics. Condition metrics included invasive nonnative plants, forest pests and diseases, and native plant species composition. Forest communities at HOCU 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. These stressors and threats have collectively shaped and continue to impact vegetation community condition and ecological succession. The condition of vegetation communities at the park warrants moderate concern with an unchanging trend. Grassland restoration and management projects that have been implemented or are planned for the near future will increase the quality and extent of native prairie communities, while reducing noise and pesticide use associated with historical grassland management.

The sole faunal component examined was birds. This resource was found to be in good condition with an unchanging trend. Relative to the surrounding developed and agricultural landscape, HOCU is especially valuable because it provides some unfragmented patches of grassland and forest that serve as a refuge within a highly altered landscape. Habitat fragmentation and conversion of native habitats negatively impacts populations of some breeding and resident birds at HOCU. Threats to the HOCU bird community include the conversion of habitats to agricultural and urban uses including cultivation and livestock grazing and residential, commercial, and industrial development. These threats exist locally, regionally and within the extent of the avian migratory patterns of birds inhabiting HOCU.

The identification of data gaps during the course of the assessment is an important outcome of the NRCA. In some cases significant data gaps contributed to low confidence in the condition or trend assigned to a resource. Primary data gaps and uncertainties encountered were lack of recent survey data; lack of air and water quality monitoring data in the vicinity of the park; availability of consistent, long-term data; and incomplete understanding of the ecology of rare resources.

Hopewell Culture National Historical Park is a relatively young park with a long history of human settlement and environmental impacts associated with agriculture, industrialization, environmental pollution and ecological disturbance. The challenges associated with managing resources within a park that is heavily influenced by competing land uses in close proximity are manifold. The division of the park into several, distinct units also creates its own challenges in terms of staffing, law enforcement, and maintenance, among others. 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. 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. Findings from the NRCA will help park managers to develop near-term management priorities, engage in watershed or landscape-scale collaboration and education efforts, conduct park planning, and report program performance.

Chapter 1. NRCA Background Information

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

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

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

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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

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

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

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

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

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

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

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

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

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

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

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

NRCA Reporting Products…

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

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

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

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

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

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

Chapter 2. Introduction and Resource Setting

2.1. Introduction

Visible remnants of Hopewell culture are concentrated in the Scioto River valley near the present-day city of Chillicothe, Ohio. The most striking Hopewell sites contain earthworks in the form of circles, squares, and other geometric shapes. Many of these sites were built to a monumental scale, with earthen walls up to 12 feet high outlining geometric figures more than 1,000 feet across. Conical and loaf-shaped earthen mounds up to 30 feet high are often found in association with the geometric earthworks (NPS 2018a). Hopewell Culture National Historical Park (HOCU) preserves six earthwork complexes: High Bank Works, Hopeton Earthworks, Hopewell Mound Group, Mound City Group, Seip Earthworks and Spruce Hill Earthworks.

2.1.1. Enabling Legislation

The present HOCU evolved from the former Mound City Group National Monument. The national monument was established by a proclamation signed by President Warren G. Harding in 1923 to preserve prehistoric mounds of great historic and scientific interest near Chillicothe, Ohio, from "all depredations and from all changes that would to any extent mar or jeopardize their historic value". In 1980 Congress expanded the monument by including a portion (150 acres) of the nearby Hopeton Earthworks and directed the National Park Service to investigate other regional archeological sites for their suitability for preservation. Of the nearly 20 sites considered, the National Park Service recommended the addition of four sites (the High Bank Works, the Hopewell Mound Group, the Seip Earthworks, and the remainder of Hopeton Earthworks). These sites were thought to represent some of the best examples of the monumental Hopewellian mound and earthwork complexes.

Hopewell Culture National Historical Park was established on May 27, 1992, when President George H.W. Bush signed Public Law 102-294 renaming the Mound City Group National Monument, expanding the Hopeton Earthworks Unit, and authorizing the acquisition of three additional Hopewell sites in Ross County (High Bank Works, Hopewell Mound Group and Seip Earthworks). The new name recognizes the larger size and greater complexity of the park resulting from the addition of these areas. In 2015 Spruce Hill Works was added as the sixth unit of the park within the legislative boundary.

2.1.2. Geographic Setting

Hopewell Culture National Historical Park is located in six different sites spread across Ross County, Ohio (78,064 residents as of 2010 Census) in the vicinity of Chillicothe, Ohio (21,901, Census 2010) and 45 miles south of Columbus, Ohio's most populous city (787,033, 2010 Census) (Figure 2.1-1). Hopewell Culture National Historical Park lies at the junction of the Western Allegheny Plateau and the Eastern Corn Belt Plains Level III Ecoregions at the southern terminus of the Wisconsin glaciations in southcentral Ohio (Omernik 1987).

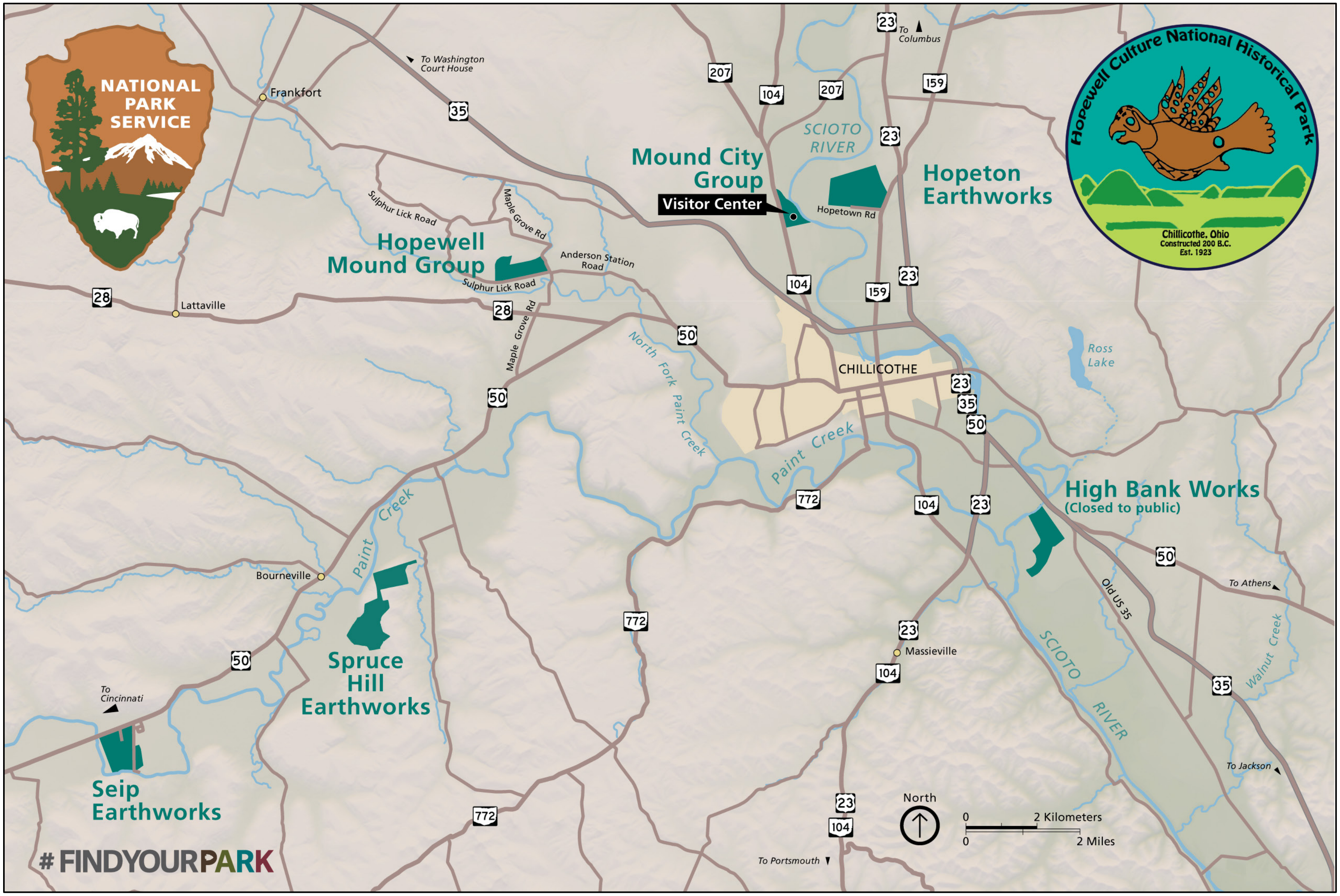

Figure 2.1-1. Location of Hopewell Culture National Historical Park units in the vicinity of Chillicothe, Ohio (map source: NPS 2020).

2.1.3. Park Significance and Purpose[1]

The purpose of HOCU is to preserve, interpret, and research the archeological record of a distinctive and influential American Indian culture known today as Hopewell, including earthworks, artifacts, the archeological context, the cultural landscape, and ethnographic information. The significance statements identified for HOCU are described below. The sequence of the statements do not reflect the level of significance:

- The extensive archeological record preserved in the park includes mounds and earthworks as well as non-mound resources related to Hopewell daily life and work. This provides great potential for new research to better understand how Hopewell peoples related to their environment, the changing climate, and other people around them.
- The artifacts placed in the mounds, including funerary items, made from an unprecedented variety and quality of exotic materials such as copper, obsidian, and mica, reflect a knowledge of and connections to distant places in North America.
- The Scioto River valley holds the world's greatest concentration of monumental earthworks. The park sites are representative of the variety and complexity of Hopewell earthen architecture. The park preserves the biggest conjoined mound (Hopewell Mound Group), the largest concentration of funerary mounds within an enclosure (Mound City Group), a complex geometric enclosure apparently devoted to non-funerary ritual (Hopeton Earthworks), one of two known extant octagonal earthworks (High Bank Works), the largest stone-walled hilltop enclosure (Spruce Hill), and a large tripartite enclosure representative of a type unique to the Scioto River valley (Seip Earthworks).
- Sites that make up the park are closely associated with the development of scientific archeology in North America during the 1800s and early 1900s, and continues to lead to new insights into precontact North America.
- The park fosters an understanding of American Indians' relationship to the natural landscape where these unique earthworks reflected their worldview.

2.1.4. Visitation

Currently, visitors have access to Mound City Group, Hopewell Mound Group, Seip Earthworks, Hopeton Earthworks, and limited access to Spruce Hill Earthworks. Visitors can obtain a pass to enter the gated Spruce Hill parking lot and hike to the top of the hill. Public visitation is not yet allowed at High Bank Works. A visitor center is located at Mound City Group, which is open seven days a week, excluding holidays. The grounds at the park units are open from dawn to dusk. Trails, interpretive displays and other facilities vary by unit.

Annual park recreation visitation decreased steadily through the early 1980s to the early 2000s, with a large spike in visitation in 2003, and a steady rise since 2013. (Figure 2.1-2). Mean annual visitation for the five-year period ending 2017 was 46,539 recreation visitors. Visitation occurs

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[1] Adapted from NPS (2015)

primarily between March and October, and is highest from June to August (Figure 2.1-3) (NPS 2018b). Park visitors are a mixture of recreation and non-recreation travelers and local residents. The NPS estimates that 80% of park users are local and regional visitors, while 20% of the visitors are from outside Ohio (NPS 1997b).

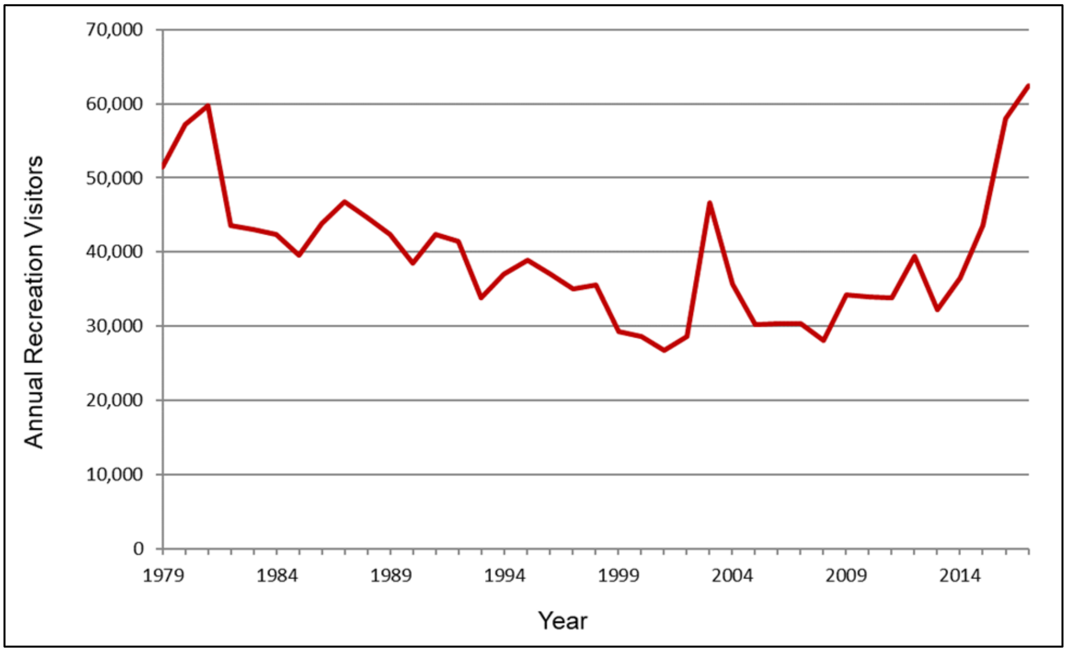

Figure 2.1-2. Annual HOCU visitation for 1979–2017 (Data from NPS 2018b).

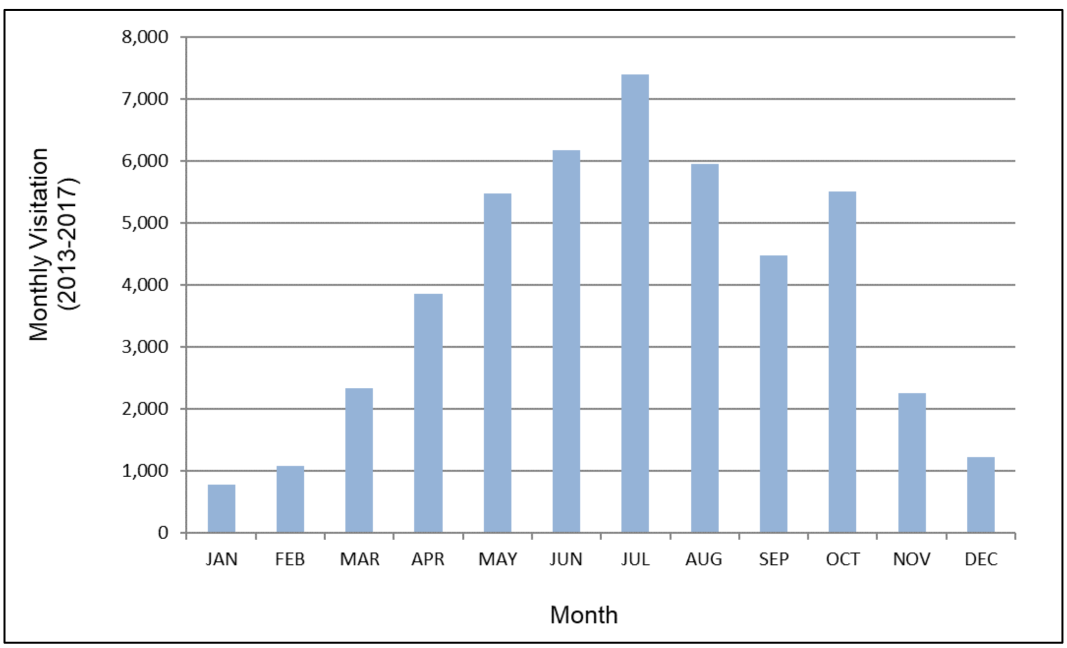

Figure 2.1-3. Mean monthly recreation visitation for HOCU for 2013–2017 (Data from NPS 2018b).

2.1.5. Description of Park Units

The park preserves six earthwork complexes: Mound City Group, Hopewell Mound Group, Seip Earthworks, Hopeton Earthworks, High Bank Works, and Spruce Hill Earthworks (Figure 2.1-1). Mounds are most often located on high river terraces above the current flood plain. The vast majority of earthworks are above the 100-year floodplain, with the exception of the Large Square at Seip Earthworks (NPS 2016). Unfortunately, the earthworks preserved at HOCU fell victim to the same fate that claimed nearly all of the many renowned earthwork complexes of southern Ohio. Two centuries of plowing gradually leveled the sloping earthen embankment walls until they are barely visible today. The mounds that were too large to plow were excavated to below ground level by archeologists in the early 1900s and never reconstructed. Due to these disturbances, some of the earthen monuments of this sacred site are now nearly invisible to the casual visitor's eye (NPS 2018a).

The Mound City Group covers approximately 120 acres adjacent to the Scioto River. It includes at least 25 prehistoric burial or ceremonial mounds surrounded by a low earthen wall enclosing almost 16 acres. In the 1800s, the Ohio and Erie Canal ran along what is now the west border of the unit. During World War I, the Mound City Group was covered by part of the Camp Sherman Army camp, and many of the mounds were disturbed. In 1920 and 1921, the Ohio Archeological and Historical Society excavated and restored many of the mounds. The park's visitor center and museum are located at the Mound City Group. The museum contains objects recovered from the mounds during two major archeological digs at the site, including objects made of copper, flint, mica, and pipestone (NPS 2017). Facilities at the site in addition to the visitor center and museum include administrative buildings, a picnic area, a nature trail, and maintenance facilities (NPS 2016).

The Hopewell Mound Group site is located five miles southwest of the Mound City Group. The Hopewell Mound Group is one of the largest and most complex of all the Hopewell centers. The site includes about three miles of earthen embankments enclosing more than 100 acres; at least 30 mounds, including the largest known Hopewell mound (Mound 25); and two smaller interior earthworks (NPS 2016). The quantity, quality, and diversity of Hopewell artifacts deposited here are unparalleled at any other site. In the 19th and early 20th century archeologists named the culture they were investigating after the site's owner, Mordecai Cloud Hopewell. The Tri-County Triangle Trail crosses this park unit (NPS 2017).

The Seip Earthworks site is located 15 miles southwest of the Mound City Group on the banks of Paint Creek. Seip Earthworks is one of five distinctive tripartite Hopewell earthwork complexes. More than two miles of earthen walls form a large circle connected to a smaller circle and a square; the total area enclosed is more than 100 acres. At least 18 mounds are found within and around the earthworks with as many as 19 interspersed borrow pits. The huge loaf-shaped central mound is one of the three largest Hopewell mounds ever built and the only one to have been fully restored. It stands 250 feet long, 150 feet wide, and 32 feet high. (NPS 2017).

The Hopeton Earthworks site is located about a mile east of the Mound City Group on the east side of the Scioto River. At 308 total acres, the site includes two gigantic joined earthen enclosures in the shape of a large circle and square enclosing almost 40 acres (NPS 2017, NPS 2016). An avenue formed by low parallel embankments of earth nearly 2,500 feet long leads up to the earthwork complex from the floodplain below. Four mounds and several borrow pits are found along the southern and eastern edges. Two small circular embankments open into the area enclosed by the square. Evidence reveals that this earthwork complex was built and used at the same time as the Mound City Group, suggesting that these two earthwork centers served specialized roles within a complex social and ceremonial system (NPS 2017).

The High Bank Works site is located about 7 miles southeast of the Mound City Group on a high bank overlooking the Scioto River. The site consists of a 20-acre circular enclosure connected by a narrow neck to an octagonal enclosure of similar size. The major axis of the High Bank Works is rotated precisely 90 degrees west of the major axis of the only other known circle-octagon enclosure, the Octagon Earthworks at Newark, Ohio, located nearly 70 miles to the northeast. Large borrow pits line the edges of the octagon and low, elaborate embankments extend to another enclosure complex to the south. The earthen architecture at High Bank Works incorporates sophisticated alignments to the paths of the rising and setting of the sun and moon. Access to this site is by permit or for special events (NPS 2017). A largely intact native hardwood forest provides valuable habitat along the Scioto River bank (NPS 2016).

The Spruce Hill Works site is located about 10 miles southwest of the Mound City Group, on a prominent flat-topped hill overlooking the Paint Creek Valley. The Spruce Hill Works represent one of the largest Hopewell hilltop enclosures. In contrast to the regular geometry of the lowland Hopewell enclosures, the earth and stone walls of the Spruce Hill Works ring the brow of the hill following the natural topography. The site is within the park administrative boundary but is owned by the non-profit Arc of Appalachia and co-managed by the Ross County Park District, HOCU and the Arc of Appalachia Preserve System (NPS 2017, NPS 2016).

2.2. Natural Resources

2.2.1. Ecological Units

Hopewell Culture National Historical Park lies at the junction of the Western Allegheny Plateau and the Eastern Corn Belt Plains Level III Ecoregions along the southern terminus of the Wisconsin glaciations in south central Ohio (Omernik 1987).

Level IV ecoregions include the Lower Scioto Dissected Plateau (Ecoregion 70d; units include Hopeton, Mound City, and Hopewell) and the Loamy, High Lime Till Plains (Ecoregion 55b; units include Seip, Spruce Hill, and High Bank) (Woods et al. 2003). The Lower Scioto Dissected Plateau is characterized by a rugged and dissected landscape with steep ridges and high relief. Mixed oak and mesophytic forests were once widespread in this region. Today, steep areas remain mostly wooded, while livestock and agriculture dominate in the flatter areas and valleys. The Loamy, High Lime Till Plains ecoregion is characterized by highly fertile soils developed from glacial deposits from the Wisconsinan age. (Woods et al. 2003).

2.2.2. Resource Descriptions

Climate

The climate at HOCU is continental. Summers tend to be hot and humid; winters are cold, windy, and snowy; and spring and fall are mild with moderate temperatures (NCDC 2018) (Figure 2.2-1). The average annual temperature at HOCU is 11.1 °C (52.0 °F). The coldest month is January, with an average temperature of −1.9 °C (28.5 °F). The warmest month is July, with an average temperature of 23.0 °C (73.5 °F) (MRCC 2018). The median growing season length at HOCU is 201 days with a last spring frost occurring around April 14 and a first fall frost occurring around October 31 (MRCC 2018. The snow season at HOCU spans October to April and averages 44.7 cm (17.6 in) of snowfall annually (MRCC 2018).

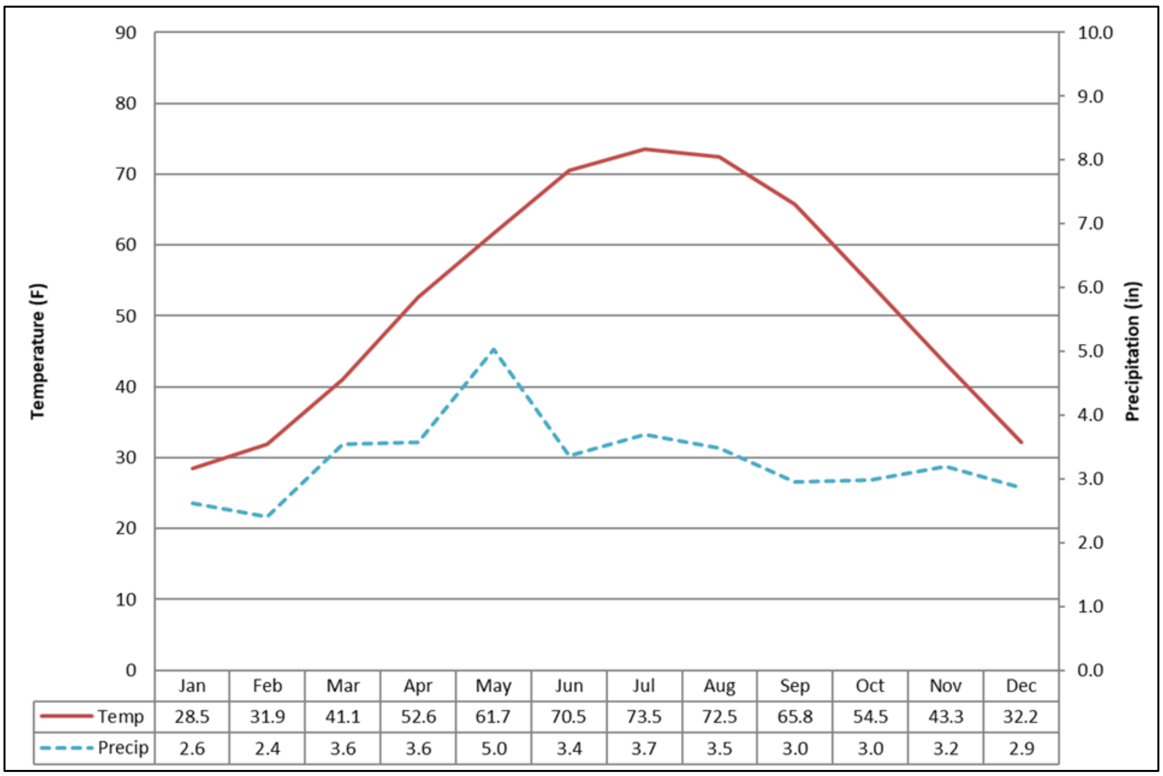

Figure 2.2-1. Walter climate diagram of Hopewell Culture National Historical Park – 30-year temperature and precipitation averages (1981–2010) (Data source: NCDC 2018).

Geology and Soils[2]

Hopewell Culture National Historical Park lies at the boundary of two physiographic provinces, the Central Lowlands to the west and the Allegheny Plateaus to the east. Geologic sections within these provinces include the Allegheny Plateaus, Glaciated Allegheny Plateaus, and the Till Plains sections. The convergence of these three physiographic sections within a narrow area around the park is due to

[2] Adapted from Thornberry-Ehrlich (2013)

its location near the maximum extent of two major Pleistocene glacial advances in Ohio: the Illinoian and more recent Wisconsinan.

The bedrock formations exposed in Ross County are primarily sedimentary rocks of Silurian to Devonian age (444 to 359 million years ago). Silurian shale, dolomite, and evaporite (salt) crop out in the most eroded, northern reaches of the county. The advance and retreat of glaciers during the Pleistocene (2.6 million to 11,700 years ago) left an incredibly complex record of ice-contact and glacial-fluvial deposits on the landscape. The Pleistocene glacial deposits cover much of the local bedrock and are responsible for the relatively muted local topographic expression. Notably, HOCU is located at the maximum extent of the Wisconsinan (most recent) glacial advance and at least one earlier advance, the Illinoian. The peoples of the Hopewell culture built mounds on a variety of named outwash terraces (i.e., prehistoric alluvial terraces) associated with the Wisconsinan advance. Holocene-aged (the past 11,700 years) river alluvium and alluvial terraces are the youngest units on the geologic map for the park and surrounding area. Alluvium associated with the Scioto River or Paint Creek has been mapped within each area of the park.

Bedrock units in the vicinity of HOCU are inclined gently (1° to 2°) eastward. Pre-glacial weathering of these units likely created a dissected plateau wherein resistant units capped hills and ridges and less-resistant units were worn away into valleys. This type of topography is reflected in the hillier, unglaciated southern portion of Ross County. The glaciers scoured the bedrock and left a thick mantle of unconsolidated deposits over the northern and central areas of the county. These events are responsible for the more subdued, gently rolling hills of northern Ross County. The park is located at the transition—the maximum extent of Pleistocene glaciation.

The Scioto River and its tributaries are now eroding through the thick glacial deposits, reworking the sediments, and meandering across their floodplains. The landscape within the park comprises gently sloped areas to relatively flat floodplains adjacent to the Scioto River and Paint Creek.

Hydrology and Watersheds

The park is located in the Scioto River watershed, and all six units are adjacent to or very near segments of the Scioto River and its tributaries. Portions of the Scioto River, including all segments adjacent to the park, are listed as Clean Water Act §303(d), impaired waters, due to agricultural run-off and other non-point pollution sources. Flood control and power dams have altered natural flow regimes of the Scioto River. Good water quality in the Paint Creek tributary at the Seip Earthworks led to its listing as an Outstanding Natural Resource Water (Middlemis-Brown and Young 2012). Paint Creek flows are heavily regulated by two upstream impoundments managed by The U.S. Army Corps of Engineers (Paint Creek Lake) and the Ohio Department of Natural Resources (Rocky Fork Lake).

Air Quality

Hopewell Culture National Historical Park, like all the other parks within the Heartland Inventory & Monitoring Network (HTLN), is designated as a Class II airshed by the Clean Air Act of 1997 (Middlemis-Brown and Young 2012). As such, air quality within the park is protected to a less stringent degree than in some other parks and protected areas around the country. Air quality at

HOCU is not directly measured within the park but instead is inferred from instrumentation located in the region.

The air quality parameters estimated for HOCU reflect regional air quality characteristics. For example, the wet and dry deposition of nitrogen and sulfur for HOCU reflects industrial land use from the North and the agricultural character of Western Ohio, while ozone concentrations generally mirror regional conditions and do not indicate significant ozone concerns. These specific resource issues as well as visibility are addressed later in the document, and all have consequences for the health and condition of natural communities, human health and the quality of the visitor experience.

Land Use

The lands adjacent to HOCU range from the town of Chillicothe and its 21,901 residents (lying between the Mound City Group and Hopeton Earthworks in the north and High Bank Earthworks in the south), to the cultivated farmlands, deciduous forests, and grasslands surrounding the sites. The monument protects small patches of restored prairie and woodland areas along creek bottoms in the face of a changing landscape. The area around HOCU still maintains a semi-rural character. The area surrounding Chillicothe was used for military training and operations in the War of 1812 as well as World War I.

Wildlife[3]

A number of animal inventories have been completed at HOCU, and park staff, HTLN staff, and citizen scientists continue to monitor populations. Ninety-six species of birds have been recorded for the park with 89 permanent or summer residents (Peitz 2012). Fifteen species of continental importance have been recorded during breeding bird monitoring. Eleven mammal species have been documented, all of which are common to the region. Several reptiles are common locally and are likely to occur in the park, including eastern box turtle (*Terrapene carolina carolina*) and midland painted turtle (*Chrysemys picta marginata*). The wildlife populations present at the park include those species generally found throughout the region. At present, wildlife management in the park consists primarily of monitoring and, if necessary, removing pest species such as groundhogs (*Marmota monax*) that threaten the integrity of archeology sites (Middlemis-Brown and Young 2012).

Federally listed threatened, endangered, or candidate animal species

No federally listed species are documented for the park, but the park lies within habitat range of the federally protected bald eagle and Indiana bat. The United States Fish and Wildlife Service (USFWS) has initiated a Conservation Action Plan for the timber rattlesnake, which is known or believed to occur in Ross County, Ohio (USFWS 2019). None of these species is documented within the park units. A herpetological survey conducted in 2002–2003 did not find habitat for the timber rattlesnake within park boundaries.

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

Ohio state-listed animal species

Park staff documented 34 bird species with some level of concern, but only six resident bird species are listed as state threatened or of concern.

Vegetation

Prior to Euro-American settlement, the HOCU area was dominated by oak (*Quercus* spp.) – hickory (*Carya* spp.) upland forests and mixed bottomland forests. Agriculture was practiced by the Native Americans, and a portion of the area prior to Euro-American settlement would have been under cultivation or succeeding from previous disturbance. It is unknown what the character or composition of the vegetation was during the period of significance. Drawings dating from the mid-1800s indicate that portions of some earthworks were cleared of trees, and other portions were forested (NPS 2016). A long history of anthropogenic disturbances, including forest clearing and intensive agricultural use, have severely impacted cultural and natural resources at HOCU. Additionally, cultural resource protection at HOCU necessitates the maintenance of grassland communities around many cultural sites. Native grass cover is utilized around the earthworks whenever possible, but there are situations where the protection of the archeological resource has favored the use of non-native grasses. All six park units contain upland forests, riparian forests, lawns, and farm fields with native, exotic, and invasive species present. The vegetation of all units except Spruce Hill have been mapped (Diamond et al. 2014). The park has initiated a grassland conversion and prairie restoration program that aims to convert former agricultural fields to native prairie grasslands within earthworks buffer zones at Hopeton Earthworks, Seip Earthworks and Mound City Group units. Over 240 acres of grasslands have been planted over the past several years and additional efforts are planned.

Federally listed threatened, endangered, or candidate plant species

No federally-listed species are documented within HOCU. The USFWS indicates running buffalo clover (*Trifolium stoloniferum*) could occur in the area, but it is not documented in the park.

Ohio state-listed plant species found at HOCU

One state endangered species and three potentially threatened species have been documented, including October lady's tresses (*Spiranthes ovalis* var. *erostellata*) found at the Mound City Group.

2.2.3. 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, development and urbanization, spread of invasive exotic plants and animal species that threaten regional biological diversity, loss of native pollinators, excess deer browsing, and altered hydrology and channel degradation of streams. Management concerns highlighted by park staff during the scoping process and described in the *Draft Foundation Document* (NPS 2017) consist of natural and cultural resource-related issues as well as stressors from outside the park. Primary resource management concerns at HOCU are briefly described below.

Condition and integrity of mounds and earthworks

Earthen architecture, including ditches, borrow pits, postholes, and other associated features at the each of the park's sites are sensitive to disturbance and soil erosion. Some of these exist only as subsurface traces invisible to the visitor. Threats to the features include soil erosion, disturbance from animals and undesirable vegetation development, and damage from extreme flood events, especially with more extreme storms forecast under climate change.

<u>The natural landscape within which the earthworks are situated</u>
The natural landscape is an important resource to consider in planning, management, and interpretation. It is recognized that nature shaped the lives of the Hopewell people, and Hopewell people shaped the natural world around them. The conservation and interpretation of nature in the park is integral to the mission of the National Park Service, fosters an understanding of the environment in which the Hopewell lived, and serves as a refuge for plants and wildlife.

<u>Endangered species, threatened species, candidate species, and species of concern</u>
The park is home to a number of rare species. A variety of vegetation types provides habitats and corridors for these species in and around the park units. The integrity of habitats and management of stressors such as invasive exotic plants are key to supporting these species of concern.

<u>Impacts of land uses on visitor/cultural experience</u>
The sights, sounds and landscape associated with the park environs have changed over time as land uses have changed and development and human populations have increased. The visitor experience is affected by historic uses and newer developments such as communications towers (e.g., Seip Earthworks), noise and light pollution (e.g., Hopewell Mound Group and Hopeton Earthworks), visual resources (especially units near Chillicothe), and solitude. The juxtaposition of development inside and outside the park with HOCU cultural features and landscapes can degrade the visitor experience.

2.3. Resource Stewardship

2.3.1. Management Directive 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. Management Policies 2006 (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.

The management of HOCU is heavily influenced by the interplay between natural and cultural resources. Management is primarily guided by the *Foundation Document* (NPS 2017), the *General*

Management Plan (GMP) (NPS 1997a); the *Long Range Interpretive Plan* (NPS 1997b), cultural landscape inventories (Mound City Group, Hopeton Earthworks, and Hopewell Mound Group), numerous archeological surveys and investigations, and the *Cultural Landscapes Report* (NPS 2016).

2.3.2. 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 by the HTLN beginning in the early 2000s. The HTLN 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 NPS Air Quality program, and the NPScape Project within the Inventory and Monitoring 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.

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Chapter 3. Study Scoping and Design

3.1. 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 NPS Midwest Regional Office, the Heartland Inventory and Monitoring Network (HTLN), HOCU 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), the HOCU Foundation Document (NPS 2015), and other documents in order 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 meetings took place August 25–26, 2015, at HOCU Headquarters. In attendance were Dave Jones and Roy Cook from Colorado State University and Bret Ruby and Bruce Lombardo from HOCU. 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 is only used in the climate change section; and

- assignment of condition ratings may be constrained by insufficient information or inadequately defined reference conditions.

3.2. Study Design

3.2.1. Indicator Framework, Focal Resources and Indicators

The NRCA framework used for HOCU is adapted from The Heinz Center (2008) (Table 3.2-1). 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.

Some resources identified as important to the park and desirable to include in the NRCA during the scoping phase were either not included as focal resources or were addressed briefly due to lack of information or data, poor understanding of their ecological role and significance in the landscape, their absence at the park, or lack of justification to include them as a focal resource. 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. A total of seven focal resources were examined and are included here: four addressing system and human dimensions, one addressing chemical and physical attributes, and two addressing biological attributes.

The following resources were discussed and eliminated from full or partial treatment:

- <u>Scenery</u> – Visual resources have not been assessed for the park. Some important park views are impacted by inconsistent elements. Viewpoints are limited in number at some units due to relatively flat topography, but interesting views are found at all units.

- <u>Water Quality</u> – The Scioto River is listed as an Impaired Water. Some HOCU units are partially bordered by streams, but the park has no management of flows or upstream watersheds and does not actively manage or monitor fauna or other resources within those streams. The vast majority of park acreage is above the 100-year floodplain. The park has little ownership of rivers and stream acreage within its boundaries, with the following exceptions: part of the NPS boundaries of Mound City Group and High Bank Works extends to the center of the Scioto River; a portion of Seip Earthworks boundary extends into Paint Creek; and a very small portion of the Hopewell Mound Group boundary extends into North Fork Paint Creek. For past water quality data in the area, see NPS (2001).

- Herptiles – Reptiles and amphibians were considered a low priority; there is limited information and few sensitive species are present or documented.

Some of these topics are mentioned briefly in Chapter 2 and may also be discussed in focal resource sections in Chapter 4.

Table 3.2-1. Hopewell Culture National Historical Park 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
	Night Skies	• All-sky light pollution ratio (ALR)
	Natural Sounds	• Anthropogenic sources of noise • Traffic volumes on nearby and park 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) • Forest pests and diseases • Forest vulnerability to climate change • Prairie restoration and grassland conversion
Biological – Animals	Birds	• Native species richness (S) • Bird index of biotic integrity (IBI) • Occurrence and status of bird species of conservation concern

3.2.2. Reporting Areas

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

3.2.3. General Approach and Methods

General Approach

This study employed a scoping process involving Colorado State University, HOCU and NPS staffs to discuss the NRCA framework, identify important park resources, and gather existing literature and data for each of the focal resources. Indicators and measures 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 park to the reference condition when possible. In some cases, due to interrelationships, a 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 park were obtained from myriad sources. The primary sources for park-specific resource data were park staff, 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 park-related resources. Park 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 web or obtained from the park or other agency staff. Spatial data were provided by the park, HTLN, the NPS Midwest Regional Office and other sources. The NPS Inventory and Monitoring (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 Chapter 4.

Data Analyses and NRCA Development

Data analysis 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 Chapter 4. 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, park and other NPS staff and subject matter experts took place as needed to obtain additional data and information or to 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 park staff and other reviewers. Reviewer comments were incorporated and addressed to improve the analysis within the limits of the NRCA scope, schedule and budget.

3.2.4. 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 assessed 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 has 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 detection 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 two 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.

3.2.5. Symbology and Scoring[4]

This NRCA uses a standardized set of symbols to represent condition status, trend and confidence in the status and trend assessment (Table 3.2-2, Table 3.2-3). This standardized symbology provides some consistency with other NPS initiatives and reporting programs.

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.

[4] Adapted from NPS-NRCA Guidance Update dated January 18, 2018.

Table 3.2-2. Standardized condition status, trend and confidence symbology used in this NRCA.

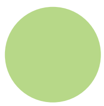
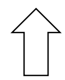
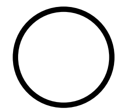
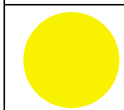
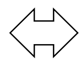
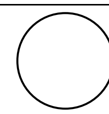
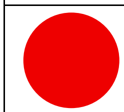
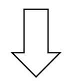
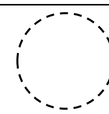
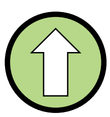
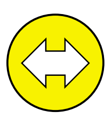
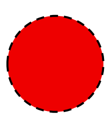
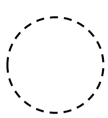
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition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

Table 3.2-3. 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.

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.

3.2.6. Organization of Focal Resource Assessments

Background and Importance

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

Data and Methods

This 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 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 Chapter 1. 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 2018). 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 3.2-1).

For example, moderate overlap may exist for forest vegetation or 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.

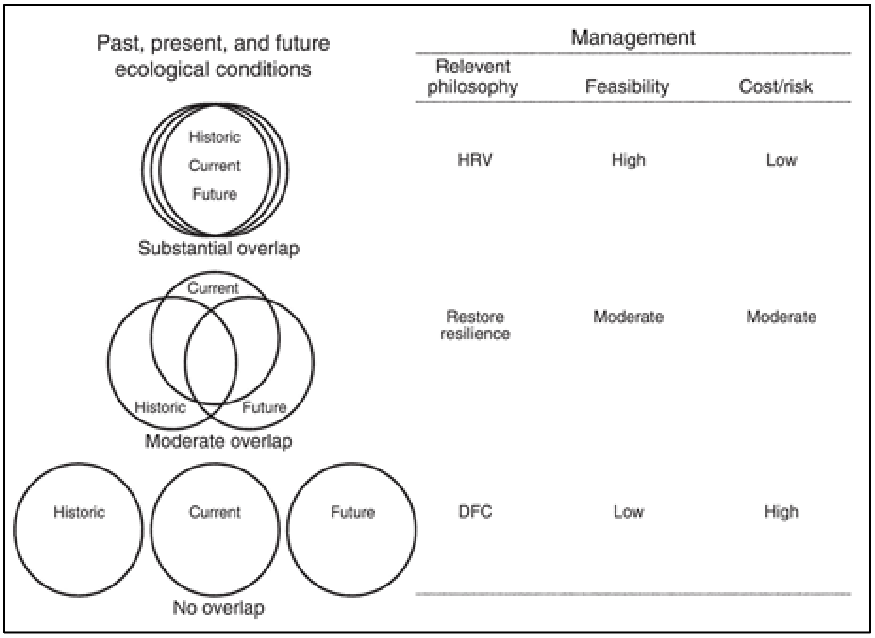


Figure 3.2-1. Illustration of three possible cases of the extent to which current ecosystem conditions in a place differ from historical conditions and from projected future conditions. Circles denote the range of variability for each time period. Also shown are the expected management criteria for each case. Abbreviations are HRV, historical range of variability and DFC, desired future conditions (Hansen et al. 2014).

<u>Condition and Trend</u>
This 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 calculated for each resource using the condition rating scoring framework described earlier in this chapter.

<u>Uncertainty and Data Gaps</u>
This section briefly highlights information and data gaps and uncertainties related to assessment of the focal resources.

<u>Sources of Expertise</u>
Individuals who were consulted or provided preliminary reviews for the focal resource are listed in this section.

<u>Literature Cited</u>
This section lists all of the referenced sources in this section.

3.3. Literature Cited

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Chapter 4. Natural Resource Conditions

4.1. Land Cover and Land Use

4.1.1. Background and Importance

This section places park 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 park resources, and underscores the conservation value of the park to the surrounding region. The synthesis of national data uses a series of straightforward spatial analyses for areas within and surrounding the park. 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 the park has little influence over activities occurring outside park 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 the park, 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.

Threats and Stressors

Land use is intensifying around many protected areas including national park units (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). 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 United States 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 night skies, natural soundscapes and visual resources/scenery.

Indicators and Measures

Indicators of landscape context applied here include a variety of metrics for land cover and land use, population and housing, and land conservation status.

- Land cover and use
  - Extent of Anderson Level II classes
  - Extent of natural vs. converted land cover

- Human population and housing
    - Housing density
    - Total Population and Population Density: historical and projected
- Conservation status
    - Protected area (ownership) extent
    - Biodiversity conservation status (level of protection)

4.1.2. Data and Methods

Spatial data for land cover, 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.

Defining Areas of Interest

Landscape context elements within and adjacent to the park were compared to resource conditions in the broader region surrounding the park. 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 (e.g., 3 km buffer), the local area surrounding a park (e.g., 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 4.1-1), and serve to capture a variety of scales to facilitate examination of the integrated effects of human activities. The park is relatively small, regional topography is very gentle, and climate is fairly uniform throughout the areas of interest.

Table 4.1-1. Areas of analysis used for land cover and land use measures (Monahan et al. 2012).

Landscape Context	Indicators and Measures	3 km buffer around park	Park + 30 km buffer	Counties overlapping with park + 30 km buffer
Land Cover and Use	Anderson Level II	X	X	–
	Natural vs. converted land cover	X	X	–
Human Population and Housing	Population total and density by census block group (historical and projected)	–	X	–
	Historical population totals by county	–	–	X
	Housing density 1970–2010	–	X	–
Conservation Status	Protected areas (ownership) and biodiversity conservation status	X	X	–

Land Cover

Data from the United States Geological Survey (USGS) National Land Cover Dataset (NLCD) 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 4.1-2) for the areas of analysis listed in Table 4.1-1.

Acreage of natural vs. converted land cover

The NLCD Anderson Level I "developed" and "agriculture" classes were reclassified as "converted" (Table 4.1-2) and analyzed using the areas of analysis listed in 4.1-1. Other classes were classified as "natural."

Table 4.1-2. 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

Changes 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 density data 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

The two primary sources of protected areas data were the Protected Areas Database-US (PAD-US) Version 2 (CBI 2013) and the National Conservation Easement Database Version III (NCED 2013a). 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 Version 2 (CBI 2013) 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 their associated land ownership, management designations, and conservation status (using national GAP coding systems). The NCED Version III (2013a) is a voluntary national geospatial database of conservation easement information that compiles records from land trusts and public agencies throughout the United States. It allows for the identification of all lands under conservation easements regardless of ownership. It is a collaborative partnership by the Conservation Biology Institute, Defenders of Wildlife, Ducks Unlimited, NatureServe, and the Trust for Public Land (NCED 2013a). As of September 2018, the acreage of publicly-held easements is considered to be 24% complete for Ohio; the accounting of the acreage of NGO-held easements in Ohio is currently estimated at approximately 90% complete. Some areas are not included because they have not been digitized, they were withheld from NCED or the NCED team is still working with the easement holders to collect the information (NCED 2013b).

Level of Protection

The USGS Gap Analysis Program (GAP) uses a scale of 1 to 4 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 Version 2 (CBI 2013) 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 National Wildlife 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 were 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.

4.1.3. Condition and Trend

<u>Land Cover and Use</u>

Extent of Anderson Level II Classes 2011

Within the 3 km buffer surrounding the Hopewell Culture National Historical Park (HOCU) boundary, over 35% of the land acreage is deciduous forest, and 30% is cultivated crops (Table 4.1-3, Figure 4.1-1). Approximately 12.5% of the area within 3 km of HOCU is developed. Within the 30 km buffer, over 43% of the acreage is deciduous forest and 30% is cultivated crops. The interaction between agricultural acreage and housing development, which is an important aspect of land cover and land use surrounding HOCU, is discussed in the Population and Housing section. These forest areas are fragmented, and likely have lost much of their ecological function (Figure 4.1-1).

Table 4.1-3. Anderson Level II land cover classes within 3 km and 30 km of the park boundary (from National Land Cover dataset data provided by NPS NPScape Program).

Anderson Level II Classes	3 km Buffer		Park + 30km Buffer	
	Acres	**% of Area**	**Acres**	**% of Area**
Barren Land	78	0.14%	1,312	0.10%
Cultivated Crops	17,315	30.06%	375,503	29.60%
Deciduous Forest	20,660	35.87%	555,471	43.79%
Developed, High Intensity	350	0.61%	1,934	0.15%
Developed, Low Intensity	2,269	3.94%	18,012	1.42%
Developed, Medium Intensity	1,274	2.21%	7,290	0.57%
Developed, Open Space	3,283	5.70%	53,649	4.23%
Emergent Herbaceous Wetlands	29	0.05%	441	0.03%
Evergreen Forest	182	0.32%	13,386	1.06%
Hay/Pasture	8,443	14.66%	170,068	13.41%
Herbaceous	1,867	3.24%	38,522	3.04%
Mixed Forest	11	0.02%	2,194	0.17%
Open Water	874	1.52%	10,422	0.82%
Perennial Snow/Ice	0	0.00%	0	0.00%
Shrub/Scrub	940	1.63%	19,802	1.56%
Unclassified	0	0.00%	0	0.00%
Woody Wetlands	29	0.05%	468	0.04%
Total	**57,603**	**–**	**1,268,474**	**–**

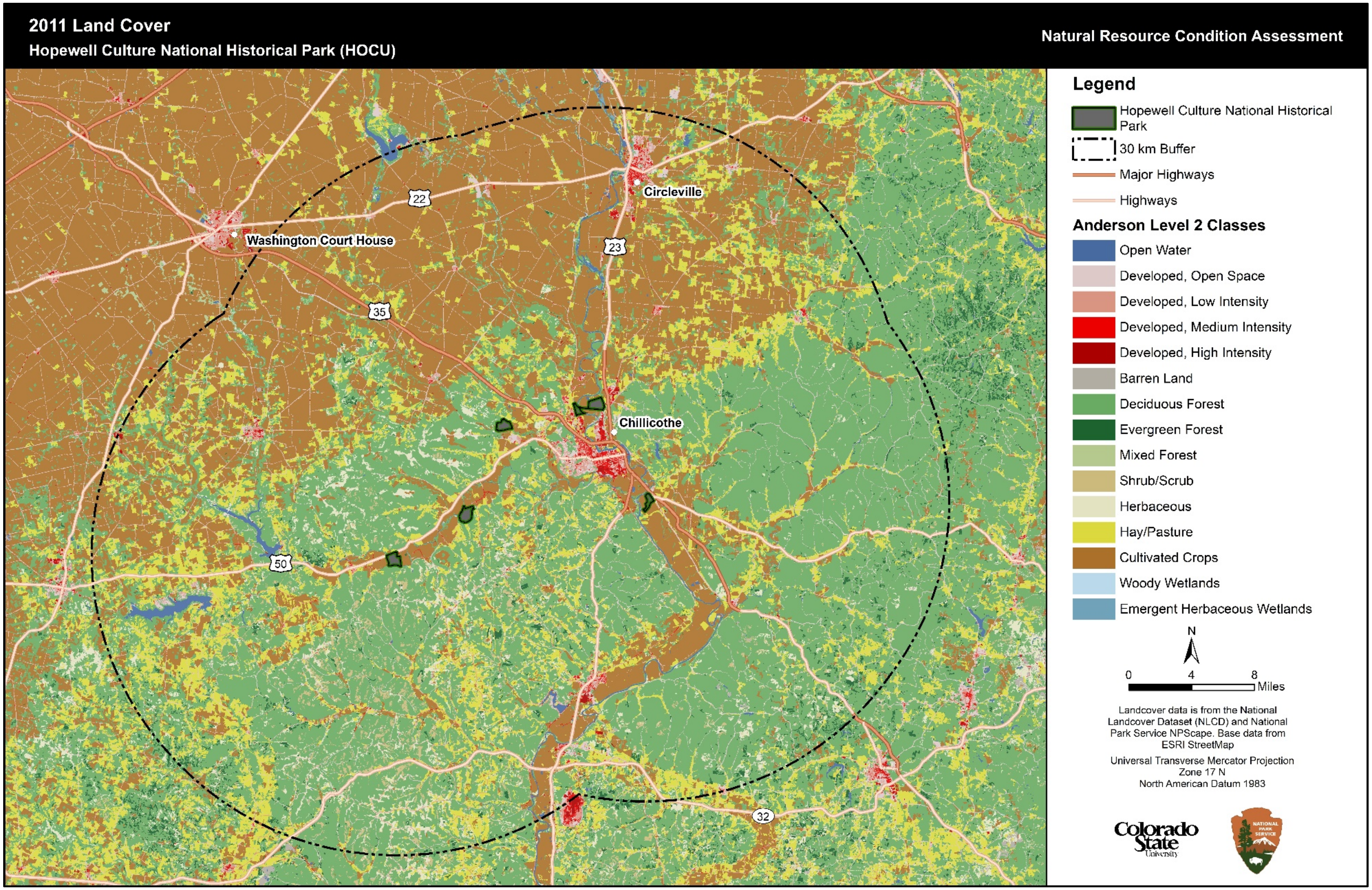

Figure 4.1-1. Anderson Level II land cover classes within 3 km and 30 km of the park boundary. National Land Cover Dataset data provided by NPS NPScape Program. Three kilometer buffer is not shown due to map scale.

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 proportion of natural land cover 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 HOCU is moderate in relation to the region as a whole (Table 4.1-4). Within 30 km of the park boundary, nearly 50% of the area is classified as converted (Figure 4.1-2). The proportion of natural acreage is largely attributed to the heavy agricultural use of the surrounding area.

Table 4.1-4. Natural vs. converted acreage within 3 km and 30 km of the park boundary (from National Land Cover Dataset data provided by NPS NPScape Program).

	Natural		**Converted**	
AOA	**Acres**	**% of Area**	**Acres**	**% of Area**
3 km	24,668	42.83%	32,933	57.17%
Park + 30 km Buffer	642,003	50.61%	626,467	49.39%

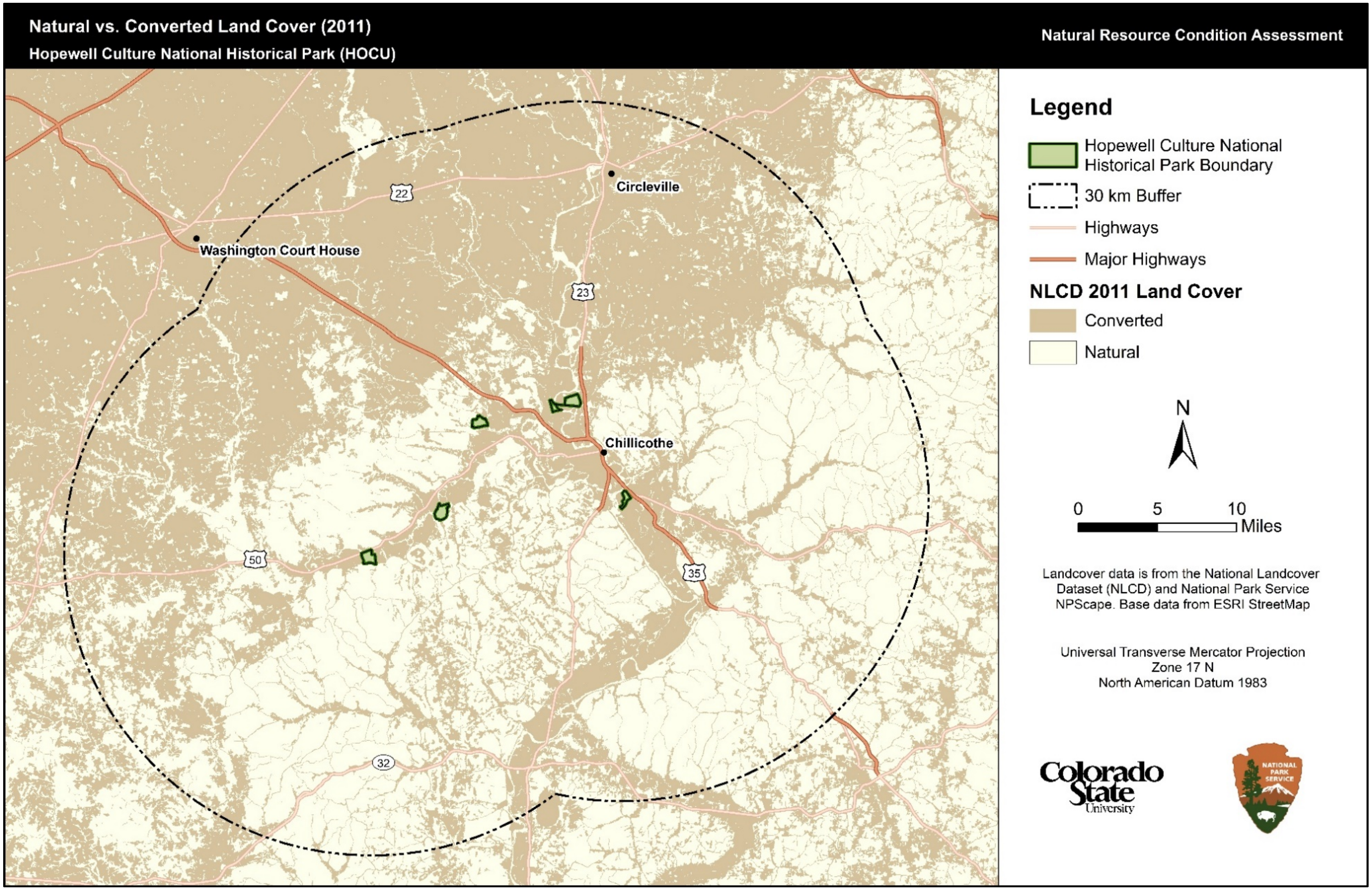

Figure 4.1-2. Natural vs. converted land cover classes within 3 km and 30 km of the park boundary. 2011 National Land Cover Dataset data provided by NPS NPScape Program. Three kilometer buffer is not shown due to map scale.

Human Population and Housing

Total Population and Population Density

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 the park's boundary is low, with most of the analysis area having a density of 1–20 people/km^2 (Table 4.1-5, Figure 4.1-3). Historically, population has been steadily rising since the mid-19th century (Figure 4.1-4).

Table 4.1-5. 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 block data provided by NPS NPScape Program).

	1990		2000		2010	
Population Density (#/km^2)	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
1–20	0	0.00%	0	0.00%	0	0.00%
21–75	908,244	71.93%	818,640	64.84%	792,049	62.73%
76–150	298,810	23.67%	399,565	31.65%	424,826	33.65%
151–300	34,564	2.74%	19,973	1.58%	22,277	1.76%
301–750	13,709	1.09%	14,857	1.18%	12,751	1.01%
751–1200	2,028	0.16%	4,414	0.35%	4,327	0.34%
1201–1500	2,500	0.20%	2,668	0.21%	3,349	0.27%
1501–2000	620	0.05%	624	0.05%	1,159	0.09%
2001–3000	965	0.08%	690	0.05%	1,069	0.08%
>3000	1,136	0.09%	1,146	0.09%	766	0.06%

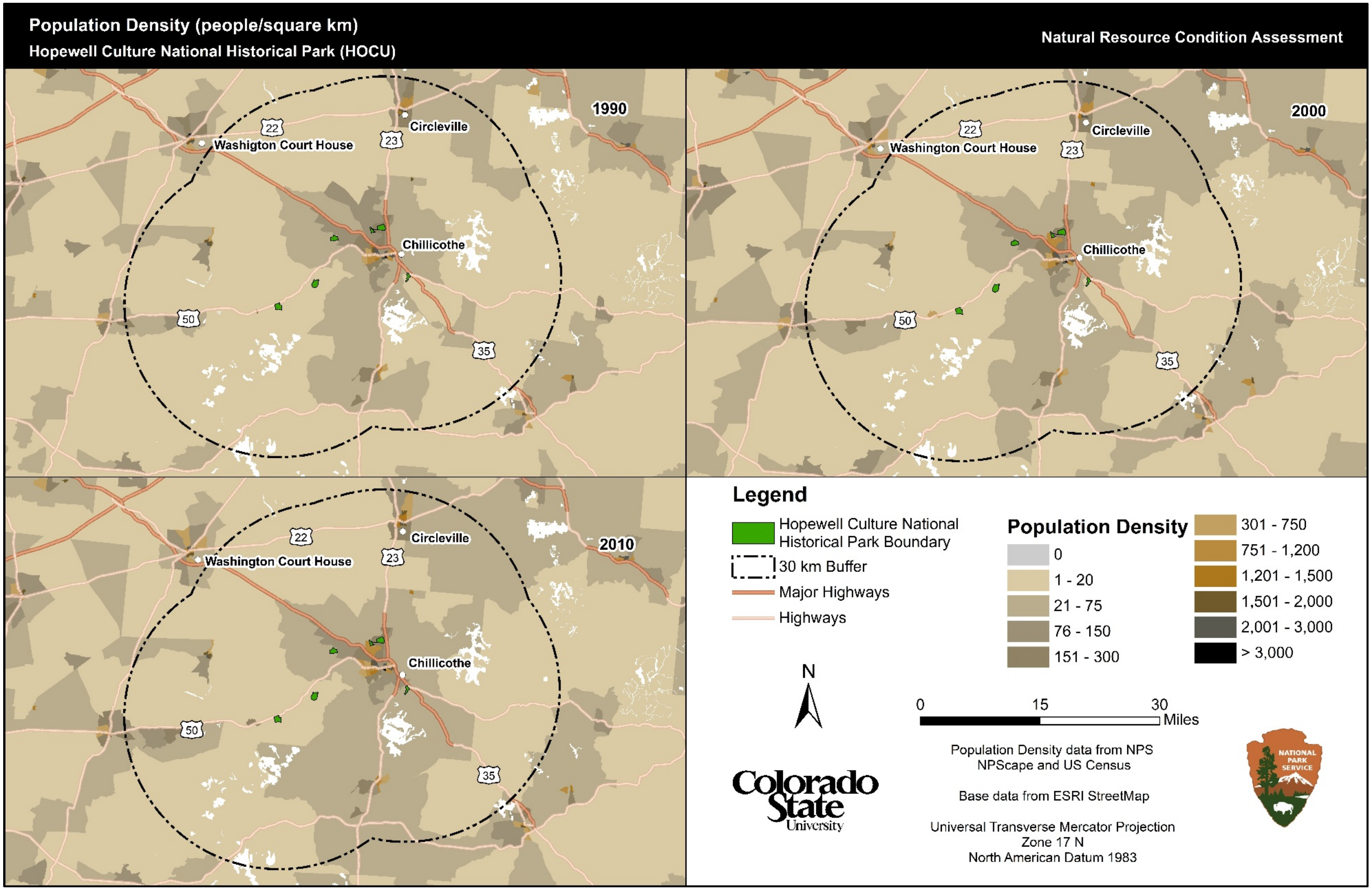

Figure 4.1-3. Population density for 1990, 2000, and 2010 by census block group for the park and surrounding 30 km buffer. U.S. Census data provided by NPS NPScape Program.

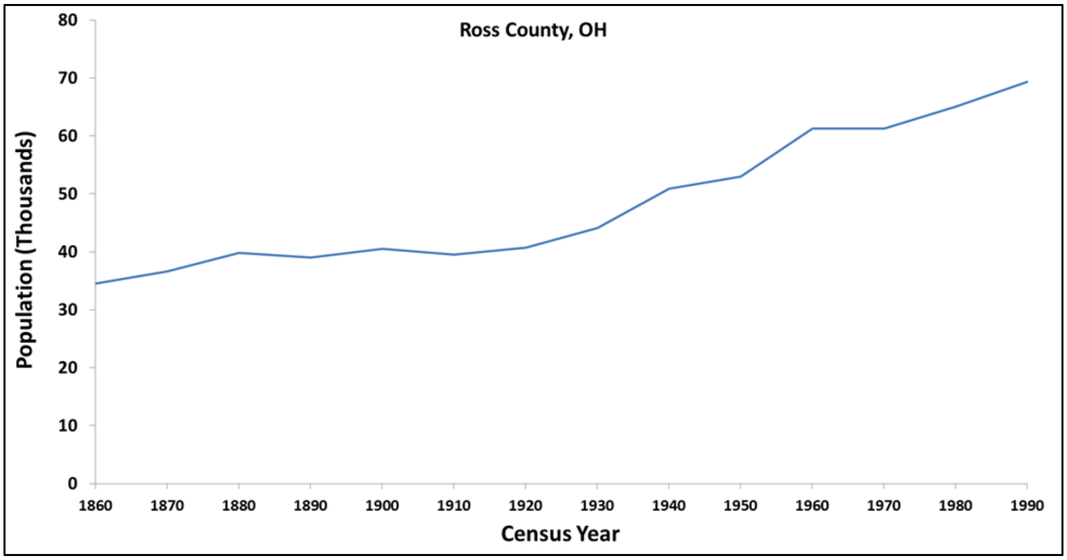

Figure 4.1-4. Historical population by decade of Ross County, Ohio, which is the only county within 30 km of HOCU (U.S. Census Bureau 2010).

Housing Density

Housing density in the region surrounding the park shows marked patterns of change between 1970 and 2010 (Table 4.1-6, Figure 4.1-5). Areas shown in white in Figure 4.1-5 are primarily state parks. Within a 30 km radius of the park, the most notable trend is an increase in suburban areas and a corresponding decrease in rural acreage. Acreage for urban, commercial/industrial, and urban regional park classes for 2010 were 351 (0.03%), 6,949 (0.58%), and 17,228 (1.43%), respectively. These acreages are not forecast to significantly change by 2050. Spruce Hill Earthworks and Seip Earthworks units are distinctly more rural than the other four units of HOCU.

Table 4.1-6. Historical and projected housing density by decade for 1970–2050 for the park and surrounding 30 km buffer (U.S. Census Bureau 2010).

	Rural (0–0.0618 units/ha)		Exurban (0.0618–1.47 units/ha)		Suburban (1.47–10.0 units/ha)	
Census Year	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
1970	1,145,952	95.05%	4,697	0.39%	30,695	2.55%
1980	1,118,911	92.80%	6,220	0.52%	56,155	4.66%
1990	1,094,762	90.80%	7,050	0.58%	79,437	6.59%
2000	1,053,915	87.28%	8,471	0.70%	120,523	9.98%
2010	1,046,593	86.75%	8,584	0.71%	126,795	10.51%
2020	1,045,946	86.69%	8,589	0.71%	127,437	10.56%
2030	1,045,642	86.67%	8,589	0.71%	127,741	10.59%
2040	1,045,311	86.64%	8,592	0.71%	128,070	10.61%
2050	1,045,274	86.64%	8,597	0.71%	128,102	10.62%

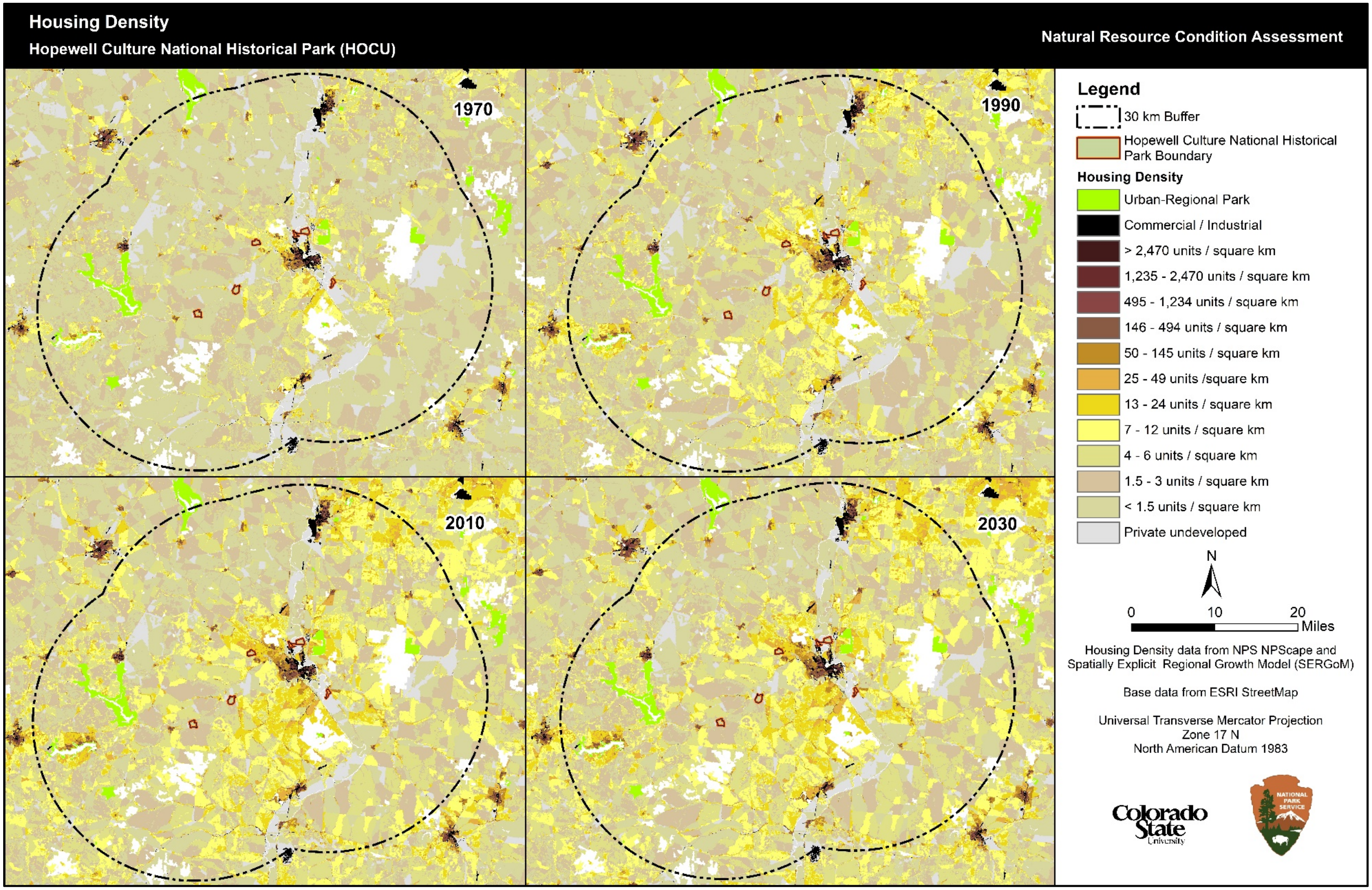

Figure 4.1-5. Historical and projected housing density for 1970, 1990, 2010 and 2030 for the park and surrounding 30 km buffer. SERGOM data provided by NPS NPScape Program.

Conservation Status

Spatial data from the Protected Areas Database-US (PAD-US) Version 2 (CBI 2013) and the National Conservation Easement Database (NCED) were consolidated to show comprehensive protection status for areas of interest while using compatible database attributes such as ownership type and agency (Figure 4.1-6). The analysis illustrates the paucity of protected areas near the park and in the larger region.

Ownership

Within the 30 km park buffer most protected land is owned by the State of Ohio (Table 4.1-7).

Table 4.1-7. Acreage of lands within 30 km of the boundary of HOCU. Percentages are the proportion of total AOA area (CBI 2013, NCED 2013).

	Park + 30 km Buffer	
Ownership	**Acres**	**% of Area**
Federal	2,325	0.18%
Native American	0	0.00%
State	68,257	5.38%
City and County	56	0.00%
Private Conservation	1,590	0.13%
Joint Ownership/Unknown	0	0.00%
Other Conservation Easement	0	0.00%
Total	**72,228**	**5.69%**

Level of Protection

Within 30 km of the park, approximately 5.5% of the land area is classified as having Status II or Status III protection, with small amounts of Status I and IV (Table 4.1-8). More than 90% of land area within the 30 km buffer is not protected, which highlights the importance of HOCU and other occasional parcels that do provide biodiversity protection in the region. Moreover, in protected areas such as HOCU, natural processes and disturbance regimes are more likely to occur and support a greater degree of biodiversity, as well as provide critical linkages to the surrounding natural landscape.

Table 4.1-8. 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)	791	0.06%
II	27,453	2.16%
III	42,024	3.31%
IV (lowest/status unknown)	1,960	0.15%
Total	**72,228**	**5.69%**

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

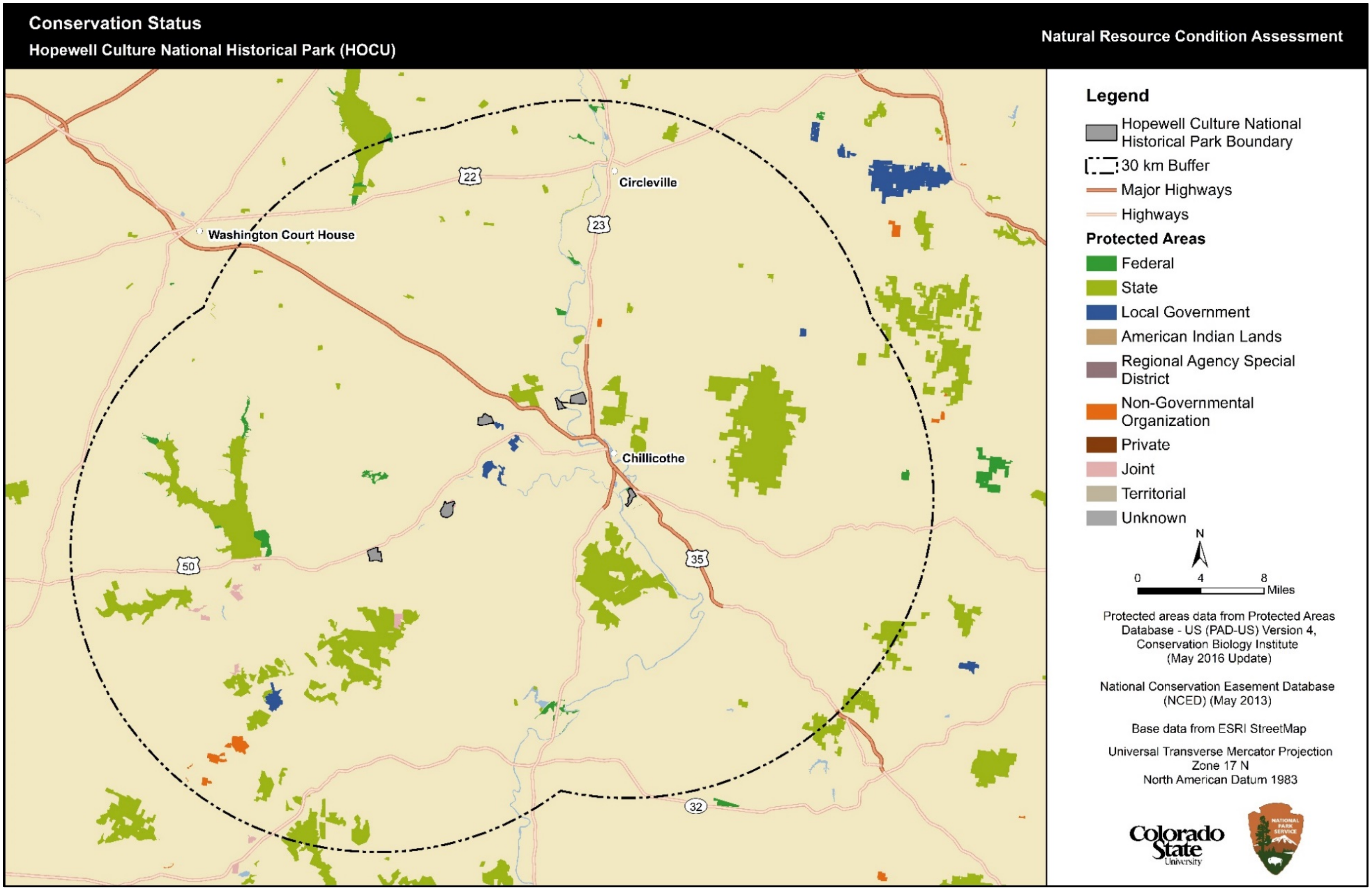

Figure 4.1-6. Conservation status of lands within 30 km of the boundary of Hopewell Culture National Historical Park. Map classes combine ownership from the NCED database and biodiversity conservation status from the PAD-US protected areas database.

4.1.4. Land Cover and Land Use Summary

Overall, the park has similar threats and stressors to other areas in this region. Most of these land cover and land use-related stressors at HOCU and in the larger region are related to the development of rural agricultural land and increases in population/housing over time (Table 4.1-9). Conversion of hay and pasture lands to cropland is also a concern, as the former class has much higher conservation value. This trend in land development, coupled with the lack of significantly-sized and linked protected areas, is of significant concern to the conservation of natural resources of HOCU to also include night skies, natural sounds and scenery. 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 4.1-9. Summary for land cover and land use indicators, Hopewell Culture National Historical Park.

Landscape Context	Indicator	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 HOCU is deciduous forest. The next most prevalent land use is cultivated crops. Most units are located in valleys dominated by agriculture.
	Extent of natural vs. converted land cover	The proportion of converted acreage surrounding HOCU is high with both areas of analysis having greater than 40% converted landcover. This can be attributed to the heavy agricultural use of the surrounding area, which is mostly cropland with some hay/pasture.
Population and Housing	Historical and projected population total and density	Population density within 30 km of the park's boundary is fairly low, with most of the area having a density of 1–20 people/km^2. The low population density is attributable to the prevalence of agriculture surrounding the park. Historically, the population of Ross County has been steadily and gradually increasing since the mid-19th century.
	Housing density	Within a 30 km radius of the park, the most notable trend is an increase in suburban areas and a corresponding decrease in rural acreage. The major change in housing density is associated with existing urban centers such as Chillicothe, Ohio.
Conservation Status	Protected area extent and biodiversity protection status	Only a small portion of the acreage in the region surrounding the park is protected through ownership or conservation easements. The majority of land surrounding HOCU is private agricultural land and private forest, which generally have a low biodiversity protection level and limited conservation value. Agricultural land is also more readily developed than some other types of land. The rarity of protected lands within the region underscores the critical value of the park as a conservation island within a highly altered, predominantly agricultural landscape.

4.1.5. 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).

4.1.6. Source(s) 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.

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4.2. Night Skies

4.2.1. Background and Importance

National Park Service (NPS) units are known for preserving natural resources and ecosystem integrity, but they also function as refuges for the less evident resources like natural darkness and starry night skies. An NPS study found that night skies are rated as “extremely” or “very” important by 57% of visitor groups (Kulesza et al. 2013). The NPS recognizes the significance of natural night skies to humans and wildlife species and is bound to protect the natural night skies just like any other natural resource. For humans, there is cultural, scientific, economic, and recreational value associated with high-quality night skies. *NPS Management Policies* states 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). *NPS Management Policies* also provides 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, using minimal-impact lighting techniques, and providing shielding for artificial lighting (NPS 2006). The night sky in a natural condition regularly cycles between light and dark depending upon many factors including lunar cycle.

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 (Van Doren et al. 2017). Nearly half of all animal species are nocturnal and require naturally dark habitats; the presence of excessive artificial light can cause significant impacts to these species (Rich and Longcore 2005).

Light pollution is the introduction of artificial light either directly or indirectly into the natural environment (Cinzano et al. 2000). Natural night skies unmarred by human light or with moderate semblance to such can contribute to a sense of solitude for visitors. Light pollution can reduce the enjoyment of park visitors by degrading the view of the night sky and reducing the contrast between faint extraterrestrial objects and the background of the luminous atmosphere. Some examples of light pollution are 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, and glare, which is the direct shining of light.

It is important to document excessive artificial light pollution in NPS units by establishing baseline conditions and monitoring changes in conditions over time to support planning and management actions (Moore et al. 2013). Poor air quality, including haze, in combination with light pollution can dim the stars and other celestial objects, reducing the 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 were not present (Kulesza et al. 2013). The NPS has clearly declared its commitment to protecting night skies for the benefit of natural ecosystems and the enjoyment of current and future generations of park visitors (Peel 2000, NPS 2006).

Threats and Stressors

At HOCU, the relatively small size of the park units makes them more vulnerable to anthropogenic light sources on adjacent lands, which are predominantly private. Moreover, HOCU is situated in an agricultural, industrial and residential matrix (NPS 2016) that includes multiple possible sources of artificial light contributing to light pollution. For example some of HOCU units are located in proximity to commercial gravel and asphalt plants and correctional facilities (NPS 2015). Other sources of light pollution include the sky glow from the adjacent city of Chillicothe (population 21,500), and Columbus, Ohio (population 880,000 and growing). Chillicothe likely contributes the most artificial light to the park units. Another possible threat to the night skies of HOCU could be vehicle lights from nearby roads like state road 104, 23, 35 and 50, although there is no precedent of studies or metrics to assess how much traffic lights affect natural night skies.

A comprehensive examination of landscape context related to landcover/landuse, population and housing, all of which are correlated with light pollution, was performed for the area surrounding the park and is presented in *Land Cover and Land Use* (Section 4.1). 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)

4.2.2. Data and Methods

The NPS Natural Sounds and Night Skies Division (NSNSD) recommends ALR as a metric to assess the condition of the night skies at NPS units (Moore et al. 2013). The NSNSD characterizes park unit photic environment by measuring both anthropogenic and natural light. In contrast to nightscapes or natural night skies, photic environments are a broader concept that encompasses the totality of the pattern of light at night at all wavelengths. The ALR is a relatively coarse measure using the ratio of actual/current light to natural light. An ALR value of zero indicates natural light, while an ALR value of one indicates that light levels are 100% brighter than natural light from night skies (Moore et al. 2013). Researchers in collaboration with NPS developed U.S.-wide models that calculate estimated ALR values (Duriscoe et al. 2018). No park-specific night sky measurements or data have been recorded at HOCU.

4.2.3. Reference Conditions

The reference condition for the night sky at HOCU 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 park than anthropogenic sources. During the period of significance associated with the Hopewell culture and subsequent occupation by Native Americans, there were no sources of artificial light beyond relatively small and ephemeral camp and cooking fires. To help the park achieve its cultural mission, it is important that the night sky of the site retain its prehistoric character.

Impact thresholds have been developed for non-urban (Level 1) and urban (Level 2) park night sky resources (Table 4.2-1) (Moore et al. 2013). 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 higher thresholds of impact.

According to the U.S. Census Bureau, HOCU 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. However, the discontinuity of HOCU protected land makes it difficult to assure wildlife and human visitors experience similar natural night skies across all HOCU units.

Table 4.2-1. Reference condition rating framework for night sky indicators at Beaver Valley and John Dickinson Plantation (Moore et al. 2013).

Indicator	Park Class	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Median All-Sky Light Pollution Ratio (ALR)	Non-Urban	ALR < 0.33	ALR = 0.33–2.0	ALR > 2.0
	Urban	ALR < 2.0	ALR = 2.0–18.0	ALR > 18.0

4.2.4. Condition and Trend

The modeled mean ALR value for all HOCU units combined is 3.71 (Figure 4.2-1) (Wood 2015). Median modeled ALR values for each unit, in increasing order, are: Seip Earthworks – 2.29; Spruce Hill – 2.87; High Bank Earthworks – 4.05; Hopewell Mound Group – 4.22; Hopeton Earthworks – 6.69; and Mound City Group – 7.12. Natural night sky degradation is highest for the units closest to Chillicothe. The old prison in Chillicothe is a significant source of anthropogenic light for the Hopeton and Mount City units (pers. comm. Bruce Lombardo, August 2015). The median ALRs for all units exceeds the "significant concern" threshold of 2.0 ALR for non-urban parks (Table 4.2-2). At these light levels, anthropogenic light dominates natural celestial features such as the Milky Way which will appear to have lost most of its detail and may only be visible overhead. Dark adaptation of eye sight is not possible, and substantial glare may be present with visible shadows (Moore et al. 2013).

Based on these results, the condition of night skies at HOCU warrants significant concern with a deteriorating trend due to development and increased housing density within the region and near the park (see section 4.1). Confidence in the assessment is medium.

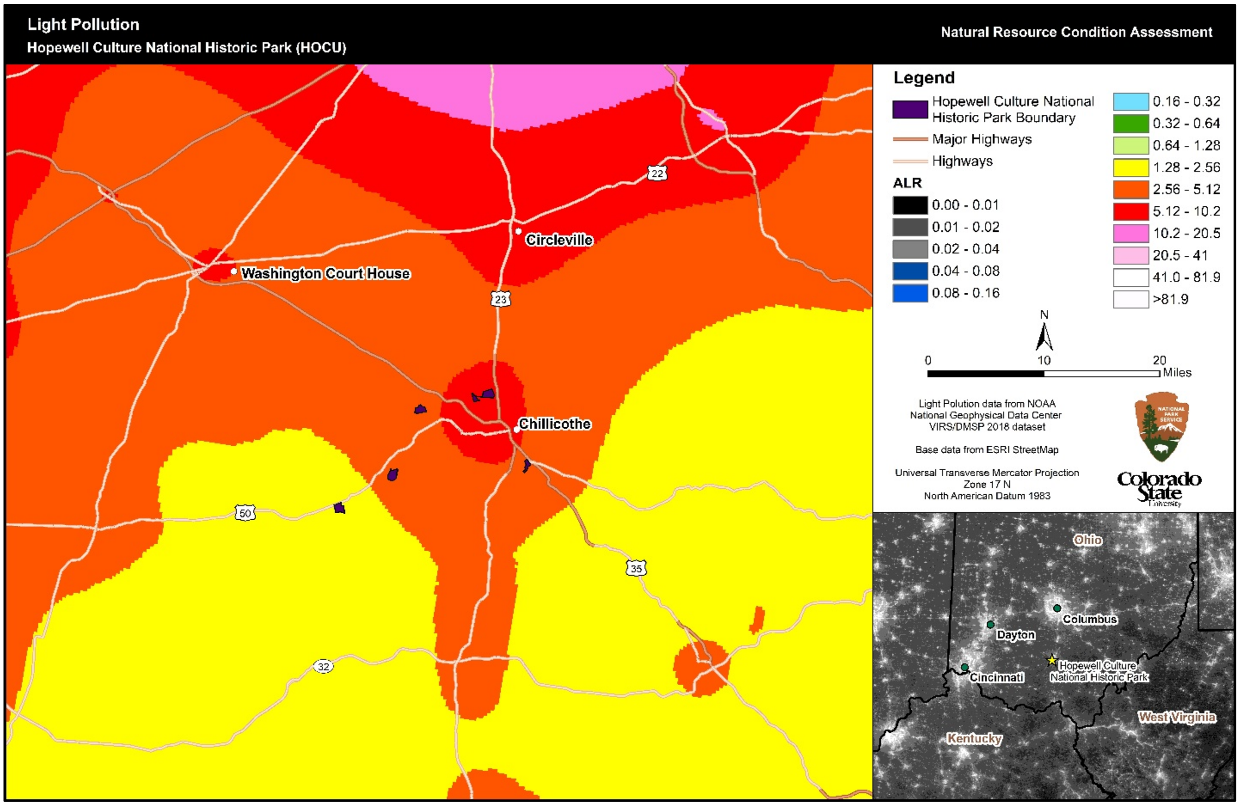
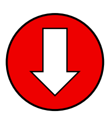
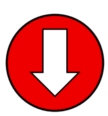


Figure 4.2-1. All-sky Light Pollution Ratio (ALR) calculated by the NSNSD for the six units of Hopewell Culture National Historical Park and its surrounding area (ALR data provided by NPS NSNSD; base data from ESRI Streetmap).

Table 4.2-2. Condition and trend summary for natural night skies at Hopewell Culture National Historical Park.

Indicator	Condition Status/Trend	Rationale
All-sky Light Pollution Ratio (ALR)		ALR values for Hopewell Culture National Historical Park averaged 3.71. Median values for the six units ranged from 2.29 at Seip Earthworks to 7.12 at the Mound City Group, warranting significant concern. Although no ALR trend data are available, the trend is inferred as deteriorating based on recent and anticipated increases in housing development and a trend toward conversion of rural and exurban land to suburban use. In addition, lights from cities like Columbus, Ohio with increasing population growth could also be a concern.
Night Skies overall		**The condition of night skies warrants significant concern with a deteriorating trend. Confidence in the assessment is medium.**

4.2.5. Uncertainty and Data Gaps

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

4.2.6. Sources of Expertise

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

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4.3. Natural Sounds

4.3.1. Background and Importance

All the natural sounds that occur within the boundaries of the National Park System units and the physical capacity for transmitting those natural sounds and their interrelationships with other sounds comprise the natural soundscape of a Park (NPS 2006). Visitors to national parks are often highly motivated to experience natural tranquility, sounds of nature, and solitude (McDonald et al. 1995, Krog et al. 2010, Mace et al. 2013). However, anthropogenic noise increasingly degrades visitor enjoyment (Rapoza et al. 2015). Most visitors prefer to hear sounds intrinsic to the natural and cultural settings of the parks they are visiting. Sounds are important because they can have a strong effect on human perception and enjoyment of a landscape (Benfield et al. 2010). In 2000 the NPS issued the *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" (NPS 2000). The order established guidelines for monitoring and planning to preserve park soundscapes.

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 protect intrinsic soundscapes for the enjoyment of current and future generations of park visitors.

Noise increasingly degrades, disturbs, and reduces visitor enjoyment (Mace et al. 2013, Rapoza et al. 2015, Weinzimmer et al. 2014). Most visitors prefer to hear sounds intrinsic to the natural and cultural settings of the park units they are visiting. Sounds are important because they can have a strong effect on people's perception and enjoyment of a landscape (Benfield et al. 2010). 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. 2009, 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, Shannon et al. 2016).

<u>Threats and Stressors</u>

Common threats to the natural soundscape include noise originating from modern transportation within and beyond the park's boundaries; from motorized park management activities; and from commercial, industrial, urban and exurban development, and resource extraction (Buxton et al. 2017). Aircraft noise is typically one of the most pervasive threats to natural sounds in NPS units, and is a notable source of anthropogenic noise at HOCU. Major nearby airports include Columbus, Dayton and Cincinnati, Ohio. Government reports indicate that air and vehicle traffic are projected to significantly increase at regional and national scales (U.S. Department of Transportation 2010, U.S. Department of Transportation 2013).

Vegetation management at HOCU units adversely impacts the park soundscape (NPS 2016). Much of the area occupied by the earthworks is managed as mowed grasslands, unmowed or hayed pasture, or as agricultural cropland. These cover types require regular periodic mowing, cutting or tilling using various motorized machinery. Some of the activities are NPS and some are by agricultural lessees. The park has initiated a grassland conversion plan that aims to convert a total of over 100 acres of maintained grassland or agricultural acres within earthwork buffer zones to native prairie grassland by 2020 at Hopeton Earthworks, Seip Earthworks and Mound City Group. Most of the noise generated by mowing in these buffer zones coincides with peak visitation months, so this initiative should reduce impacts of park management on the soundscape. While noise associated with park management activities could be minimized over time through the use of best management practices, the transportation and development noise sources are a distinct threat to the natural and historical soundscape of HOCU and the quality of visitor experiences.

Other notable sources of noise include a gravel mine that impacts the natural sound environment at the Hopeton site, and sirens from a correctional institute in Chillicothe (pers. comm. Bruce Lombardo, 2015). The prison is adjacent to Mound City Group, and has been documented as a interment source of noise that that visitors can hear 2 or 3 times a day, especially at Mound City, Hopeton, and Hopewell Mound Group units (NPS 2016). Hopewell Culture National Historical Park is located about 50 miles from potential areas of oil and gas development that could further affect the acoustic environment (Moss 2008).

A comprehensive examination of landscape context related to land cover/land use and population and housing, all of which can degrade natural and historical soundscapes, was performed for the area surrounding the park and is presented in Section 4.1. Changes in these factors can have significant impacts on the soundscape of the park.

<u>Indicators and Measures</u>

- Anthropogenic sources of noise (i.e., noise) – presence/absence and relative noise level
- Road traffic volumes on State Route 104 and U.S. Routes 23, 35, and 50 – vehicle counts to inform trend only
- Noise impacts (modeled) – median and maximum L_{A50} impact in dB

4.3.2. Data and Methods

The condition of the soundscape at HOCU was evaluated using results from nation-wide modeling of ambient sound levels (Mennitt et al. 2013, NPS 2015) provided by the NPS Natural Sounds and Night Skies Division (NSNSD). The sound map reports L_{A50} sound pressure level (in dB). This metric is a median sound level, meaning that sound levels are predicted to be greater than this level 50% of the time, and less than this level 50% of the time. The model predicts conditions during a typical summer day with calm weather conditions. The spatial resolution of the modeled sound is 270 m x 270 m. This analysis permitted estimation of the impact of anthropogenic noise on natural sound levels in the park. Observations and opinions from HOCU staff are also incorporated in this assessment with respect to desired soundscape conditions as well as sources of anthropogenic noise intrinsic and extrinsic to the park units.

Because vehicle traffic is a primary source of noise, vehicle count data for adjacent roads and highways from the Ohio Department of Transportation's (DOT) provide a snapshot of road traffic volumes and trends. Qualitative data from HOCU staff are also presented in this assessment. Staff members were asked to identify natural and human-caused (extrinsic or intrinsic to the park's values) sounds present at HOCU. Staff members were also asked to describe the desired soundscape conditions for HOCU, including anthropogenic cultural sounds that could potentially be considered appropriate for the park's mission and purpose.

A recent publication studied noise pollution in protected areas across the Continental United States (Buxton et al. 2017). Researchers used a metric termed "noise exceedance" to quantify the difference between the predicted A-weighted sound levels and predicted sound levels minimizing the influence of anthropogenic noise. In other words, it is the amount that anthropogenic noise raises sound above natural levels. Data generated for protected areas near HOCU were used to estimate exceedance levels for HOCU, which has similar land cover and land use characteristics as the study area.

<u>Decibel Scale</u>

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. Examples of common sound sources (both within and outside of park environments) and their approximate sound levels are shown in Table 4.3-1 (Lynch 2009).

Table 4.3-1. Sound pressure level examples from NPS and other settings (Lynch 2009).

Park Sound Sources	Common Sound Sources	Sound Level (dB*)
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 AGL (Yukon-Charley Rivers National Preserve)	Train horn at 1m	120

* dB re 20 μPa A-weighted broadband (12.5 Hz—20 kHz) sound level over varied measurement durations and at the distances indicated

4.3.3. Reference Conditions

The reference condition for the soundscape in HOCU is one dominated by silence, as the ceremonial sites are considered sacred by many visitors. Natural quiet, or the absence of sound, was identified by park managers as a desired natural soundscape condition that no longer occurs in the park due to anthropogenic intrusions (pers. comm. B. Lombardo, December 2015). There are no specific natural or cultural sounds that managers would like to be preserved or inventoried to improve the visitor experience and ecological integrity of the area. A condition rating system for the anthropogenic sources of noise and sound level impacts was based on widely-used thresholds and communication with NSNSD (Table 4.3-2).

Table 4.3-2. Reference condition rating framework for soundscape indicators at HOCU. Anthropogenic sound level impact thresholds provided by NPS Natural Sounds and Night Skies Division.

Indicator	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Anthropogenic Sources of Noise	Infrequent, low, or inaudible levels of anthropogenic noise. Annoyance level of visitors perceived as low. Natural sounds heard continuously.	Moderately frequent and audible anthropogenic noise. Annoyance level of visitors perceived as moderate.	Frequent and highly audible anthropogenic noise. Annoyance level of visitors perceived as high.
Anthropogenic L_{A50} 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

4.3.4. Condition and Trend

Anthropogenic Sources of Noise

The following common sources of anthropogenic noise were identified by staff members at HOCU (pers. comm. B. Lombardo, November 9, 2015): sirens from the adjacent correctional prison (activated four to three times each day for roll call), construction noise from a nearby gravel mine/asphalt production facility, and vehicle noise from a heavily-traveled state road that borders two of the five ceremonial sites and a county road that passes through the ceremonial grounds at another site. The majority of anthropogenic noise sources originate outside the park. There is nothing to indicate that these conditions will change in the near future. Noise from park vegetation management was discussed during scoping and is mentioned in the *Cultural Landscapes Report* (NPS 2016). Noise associated with mowing and agricultural management is anticipated to decline at some units in the near future. Based on available information, the condition of this indicator warrants moderate concern, with an unchanging trend and medium confidence.

Traffic Volume: State Route 104, U.S. Routes 23, 35, and 50 (trend only)

According to data obtained from the Ohio Department of Transportation's (DOT) Office of Technical Services Traffic Monitoring Section, most primary roads near park units have increasing traffic levels and as well as an increasing proportion of trucks as a fraction of total traffic. Table 4.3-3 summarizes these annual average traffic volumes near Chillicothe, Ohio for 2010–2017 (Ohio Department of Transportation 2018). There is a general trend towards higher traffic volumes on the heavier-travelled highways close to HOCU units. Total traffic on four out of five arterials increased an average of 11% from 2015 to 2017. The proportion of truck traffic increased more than 50% on 2 roads, was unchanged on two roads, and declined about 8% on one road. Overall traffic volume decreased by 51% on Route 28 near the Hopewell Mound Group. These results indicate a deteriorating trend in traffic volumes and increases in associated noise.

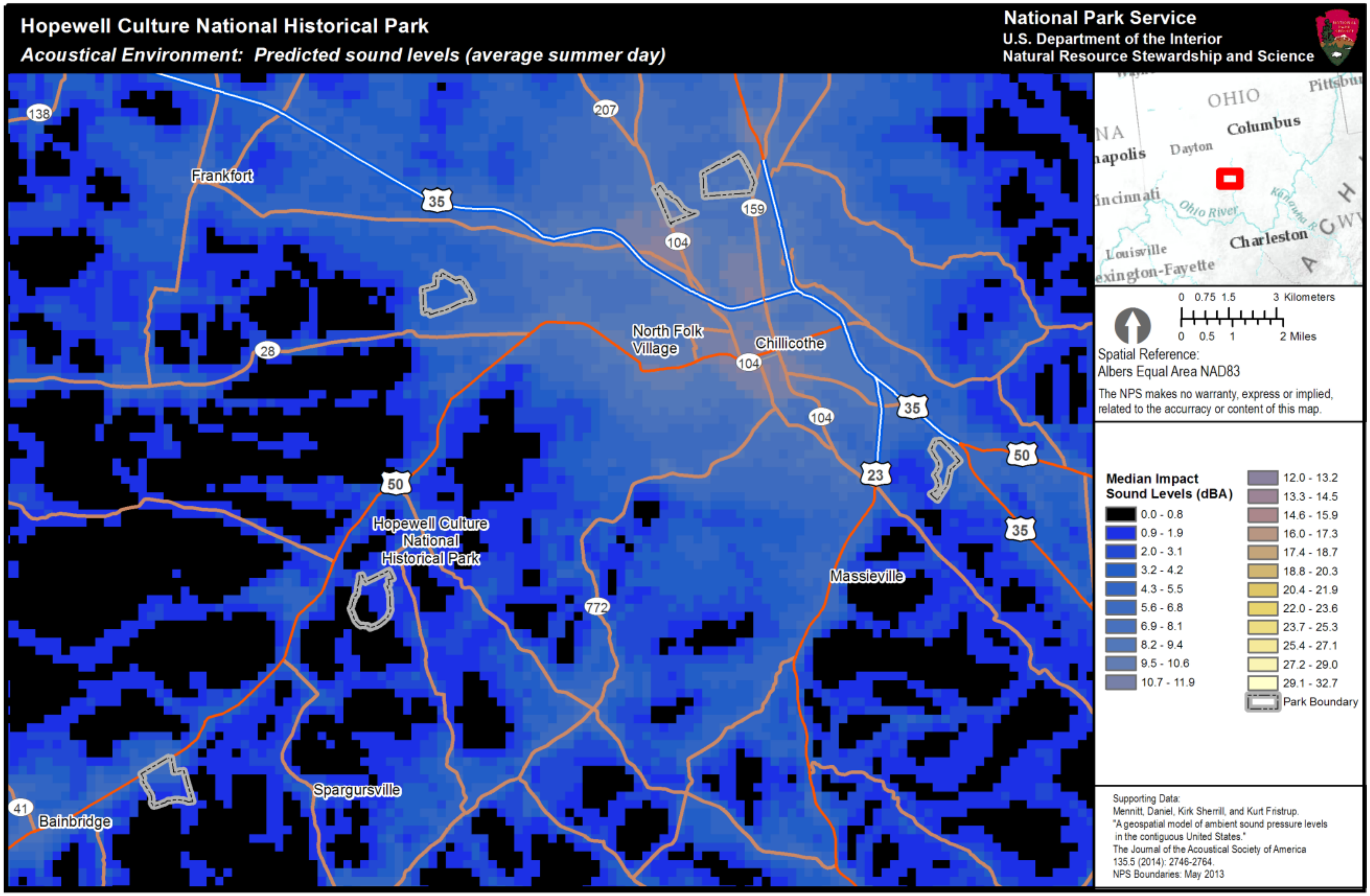
Table 4.3-3. Annual average daily traffic volumes for 2010–2017 near Hopewell Culture National Historical Park, including truck volumes for 2015, 2016, and 2017. (Ohio Department of Transportation 2018).

Road Segment	Vehicle Type	Annual Average Daily Traffic					% total change 2015–2017	% increase in proportion of truck traffic 2015–2017
		2010	2013	2015	2016	2017		
US-104 (near Mound City Group)	All	10,160	10,930	12,177	12,725	12,819	5.3%	80.0%
	Trucks	–	–	334	433	633	89.5%	–
US-23 (near Hopeton Earthworks)	All	17,880	19,260	20,962	21,987	22,625	7.9%	0.0%
	Trucks	–	–	2,715	2,848	2,931	8.0%	–
US-35 (near High Bank Works)	All	12,670	12,490	22,832	26,212	27,549	20.7%	0.0%
	Trucks	–	–	4,598	5,279	5,548	20.7%	–
Route 28 (near Hopewell Mound Group)	All	–	–	4,014	2,484	2,554	−36.4%	51.3%
	Trucks	–	–	187	175	180	−3.7%	–
US-50 (near Hopewell Mound Group and Seip Earthworks)	All	4,170	3,860	3,993	4,335	4,426	10.8%	−7.7%
	Trucks	–	–	350	351	358	2.3%	–

Anthropogenic Impacts on Ambient Sound Level (Modeled)

In HOCU, the mean sound level impact park-wide was 4.6 dB. Median impact (50% of the park has this impact or less) was 4.5 dB, and maximum impact value inside park boundaries was 11.4 dB. Modeled sound level impacts for HOCU park units and surrounding area are shown in Figure 4.3-1. The area within the park with the lowest anthropogenic sound level impacts is at the Seip Earthworks site southwest of Chillicothe. The area with the highest impacts is at the Mound City Group site just north of Chillicothe. The condition of this indicator warrants significant concern with a medium confidence level (Table 4.3-2). No trend data are available, but the condition is estimated to be deteriorating based on known anthropogenic sources of noise and trends in population and traffic.

Noise exceedance levels calculated by Buxton et al. (2017) indicate levels within HOCU units (Spruce Hill was not included) are relatively high, averaging above 16 dB. (Figure 4.3-2).



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20151007

Figure 4.3-1. Modeled sound level impacts in the area immediately surrounding HOCU. Graphic provided by NSNSD (NPS 2015).

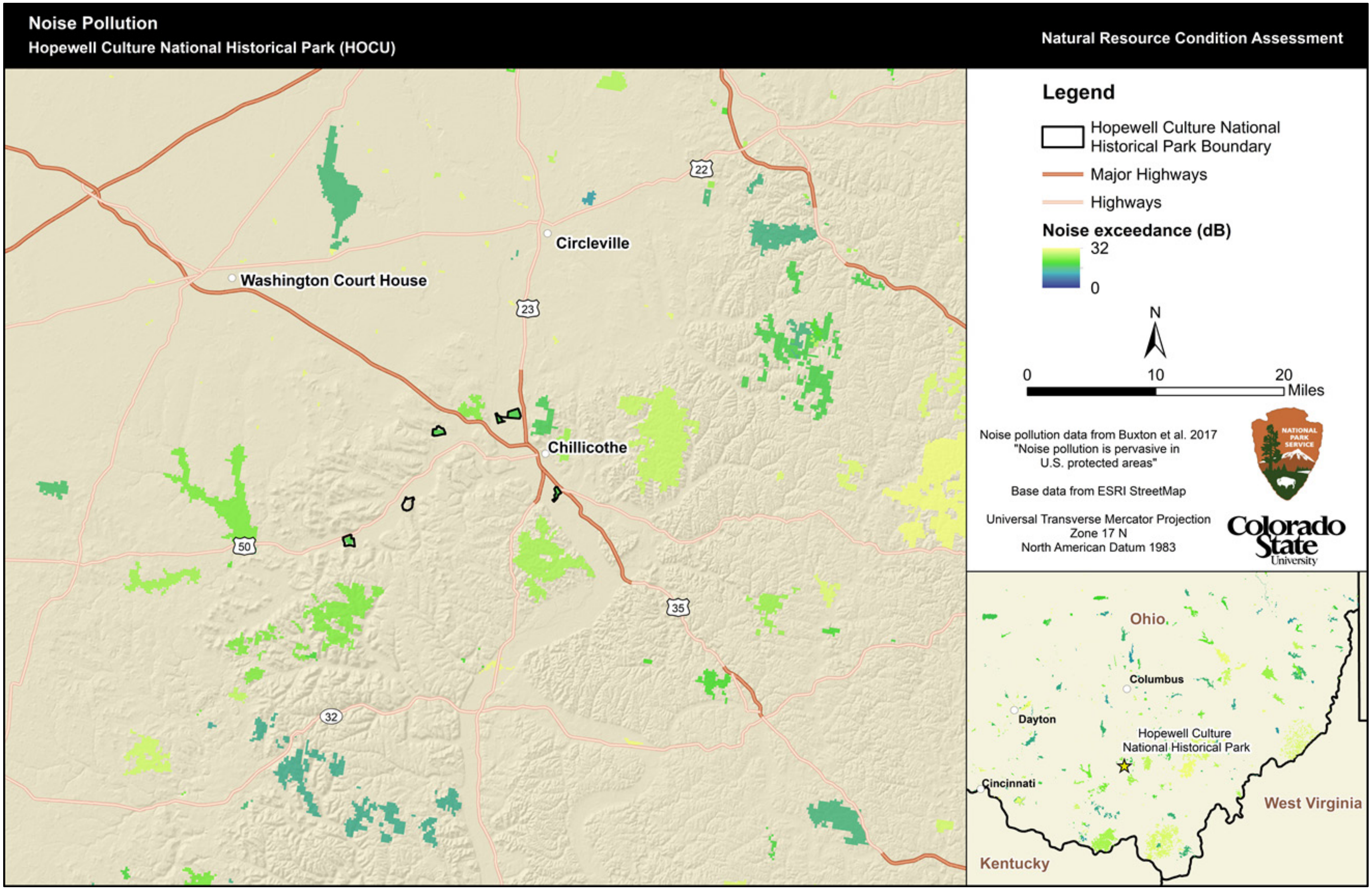
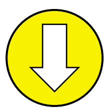
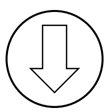
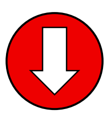
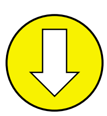


Figure 4.3-2. Noise exceedance levels in and around HOCU from Buxton et al. (2017). Most of the protected areas near HOCU units have levels above 16dB, indicating an important intrusion of anthropogenic noise.

Overall Condition

Available data suggest that the condition of the soundscape at HOCU warrants moderate concern, with a deteriorating trend due to projections for increased ground and air traffic over time (FAA 2017; Ohio Department of Transportation 2018). A summary of acoustic environment indicators is shown in Table 4.3-4. State transportation data indicate that traffic volumes on nearby roads and highways have increased in recent years. 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 (median impact = 4.5 dB; maximum impact = 11.4 dB). Noise exceedance levels around HOCU units average above 16 dB indicating an important intrusion of anthropogenic noise levels into the soundscape. If noise from the adjacent roads and other commercial activities continues to grow, the condition of the soundscape will likely continue to deteriorate. Confidence level associated with the overall rating is medium.

Table 4.3-4. Condition and trend summary for the acoustic environment at Hopewell Culture National Historical Park.

Indicator	Condition Status/Trend	Rationale
Anthropogenic Sources of Noise		Noise from anthropogenic sources is common. Noise from adjacent roads, the state prison, and gravel mine/asphalt production facility particularly threaten the park's natural soundscape. Housing trends contribute to deteriorating trend.
S.R. 104, U.S. 23, U.S. 35, U.S. 50 and S.R. 28 Traffic Volumes		There is a general trend towards higher traffic volumes on the heavier-travelled highways close to HOCU units. If this trend continues, the park's soundscape will be further negatively impacted by noise from increasing traffic and a higher proportion of truck traffic.
Modeled L_{A50} Sound Level Impacts		Anthropogenic noise significantly impacts sound levels above the natural ambient sound level. This affects both the natural environment and the visitor's experience. The median sound level impact varied by unit. For all units combined, the median sound level impact was 4.5 dB and maximum impact was 11.4 dB. Urban, agricultural and industrial noise as well as ground and air traffic are the primary sources of noise at most units. Road and air traffic are generally projected to increase over time.
Natural Sounds overall		**Condition warrants moderate concern with a deteriorating trend. Confidence in the assessment is medium.**

4.3.5. Uncertainty and Data Gaps

Neither acoustical monitoring studies to measure ambient sound levels and audibility of different intrinsic and extrinsic sound sources nor evaluative research to determine the social impacts of existing soundscape conditions on visitor experiences have been collected on-site in HOCU.

4.3.6. 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.

- Bruce Lombardo, Biologist, Hopewell Culture National Historical Park.

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4.4. Climate Change

4.4.1. 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 a significant scientific component of the NPS *Climate Change Response Strategy* (NPS 2010).

Although numerous species at HOCU are vulnerable to climate change, sweet birch (*Betula lenta*), eastern white pine (*Pinus strobus*), bigtooth aspen (*Populus grandidentata*), pin cherry (*Prunus pensylvanica*) and American basswood (*Tilia americana*) may become extirpated from the park even under relatively minor changes in climate (NPS 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 CO_2 tends to increase plant growth and water use efficiency, but may be limited by water and nutrient availability. Transpiration rates usually decline as CO_2 increases, while, in many plants, photosynthesis and growth increase. Growth response to CO_2 is usually highest in rapidly-growing plants and in plants with the C3 photosynthetic pathway (most woody plants and cool-season grasses) versus the C4 pathway (most "warm-season" grasses) which could lead to an increase in the growth rates of tree species prevalent at HOCU (Schramm 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 the park'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 park can do its part to mitigate greenhouse gas emissions and optimize the efficiency of park operations vis a vis greenhouse gases, 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.

<u>Threats and Stressors</u>

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.

<u>Indicators and Measures</u>

- 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

4.4.2. Data and Methods

A variety of data and analysis approaches are used to characterize the climate during the historical period of record and examine possible changes in climate for the park. 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 park boundary. Because the park is small and has relatively little elevation change within its boundaries, climatic variation within the park 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) hosted by Colorado State University. 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. Comparing carbon dioxide concentrations and global temperature change between the 2000 Special Report on Emission Scenarios (SRES) and the 2010 Representative Concentration Pathways (RCP) scenarios, SRES A1 is similar to RCP 8.5, SRES A1B is similar to RCP 6.0 and SRES B1 is similar to RCP 4.5 (Walsh et al. 2014a). Examination of historical climate data used PRISM (4 km) data (PRISM Climate Group 2014). Climate projections for non-spatial graphics use CMIP5 downscaled data downloaded from the Green Data Oasis website (http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html) (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, incorporates soil moisture, and is considered most effective for unirrigated cropland (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). The index uses a value of 0 as "normal". 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 2018). 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 the PSDI approach is not used 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 (USEPA 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 among 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).

4.4.3. 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 roughly 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.

4.4.4. Historical Conditions, Range of Variability and Modeled Changes

Temperature

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 HOCU (Figure 4.4-1). 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. At HOCU, mean minimum monthly temperatures did not increase significantly over time during 1895–1980 ($p=0.13$), but the increase for the 1980–2012 period was significant ($p<0.02$). The model results for mean monthly maximum temperature over time were not statistically significant for either period (p values of 0.46 and 0.55, respectively).

Trends in monthly minimum temperatures over time are further illustrated in a graphical representation of the data for the period of record (Figure 4.4-2, bottom), which normalizes 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. High temperatures associated with severe droughts that occurred in the 1930s, 1950s, and 2010s are clearly shown in Figure 4.4-2 (top). An anomaly plot showing annual mean temperatures over time further illustrates significant changes in this variable during the recent past, with minimum temperatures for most years since 1980 being 0.5–1.5 °C above the long term average (Figure 4.4-3). Monthly data was also grouped by season into model quartiles for minimum temperature (Figure 4.4-4). Seasonal data show a possible increase in minimum temperatures in the winter over the past several decades.

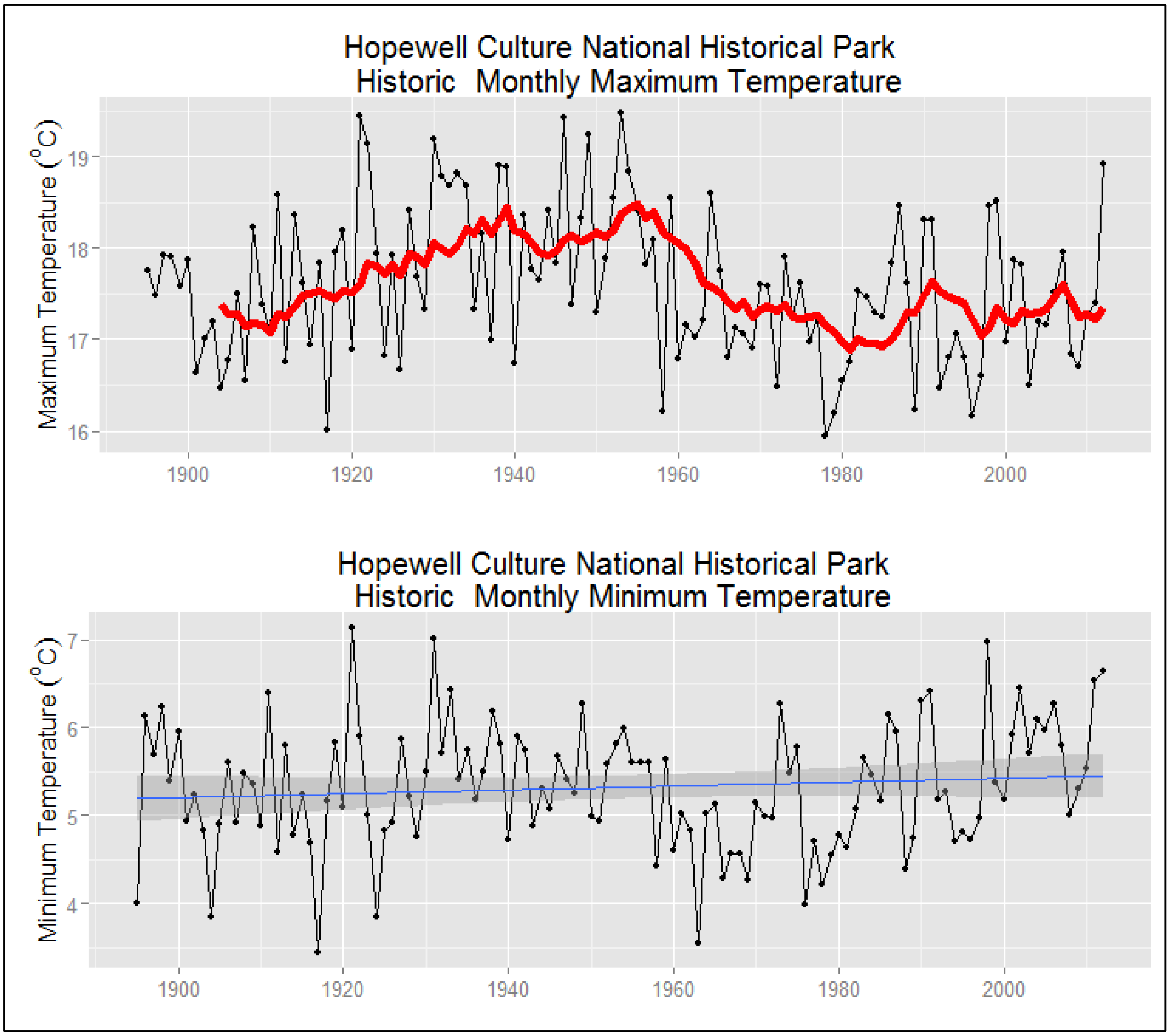

Figure 4.4-1. Historical PRISM data for maximum temperature showing a five year lag running mean (top) and minimum temperature with a significant linear model fit (bottom). (Data and graphic prepared by NCCSC)

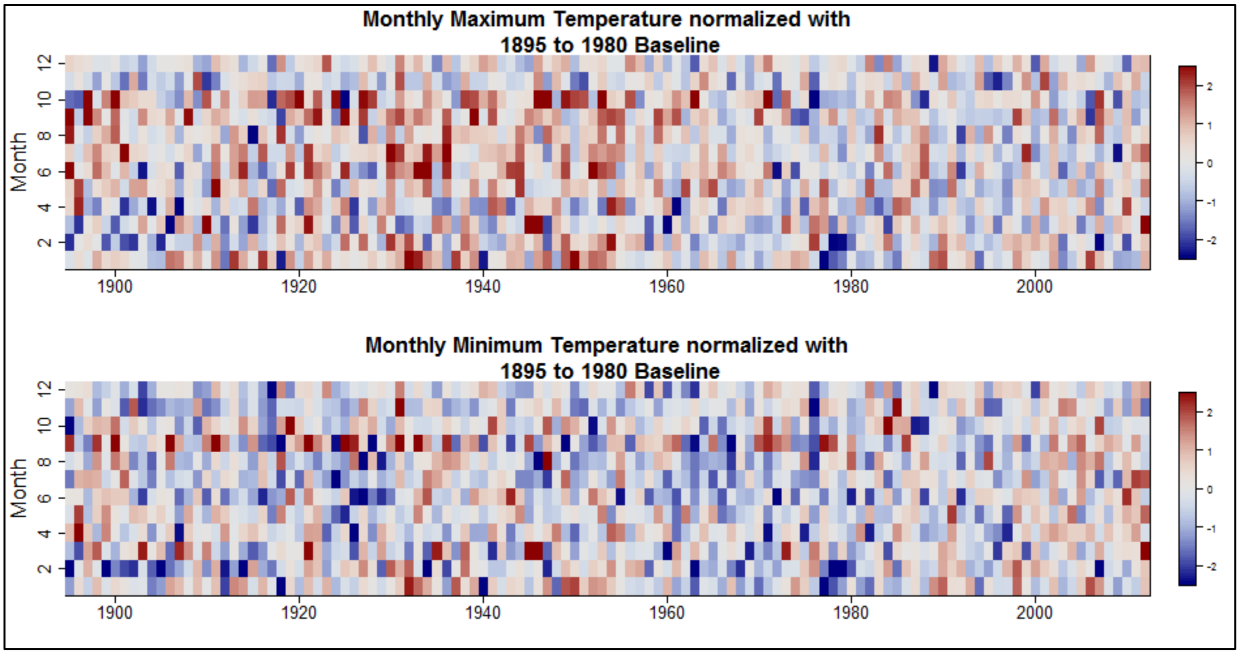

Figure 4.4-2. Mean monthly minimum temperature (top) and monthly maximum temperature (bottom) showing the normalized difference from a baseline (1895–1980) period for each month and year for Hopewell Culture National Historical Park. The baseline is calculated monthly within the specified year range. The pixels are normalized by month and colors range from +/− 2.5 standard deviations from the mean of the baseline period. Red cells are warmer than baseline, while blue cells are cooler than baseline. (Data and graphic prepared by NCCSC)

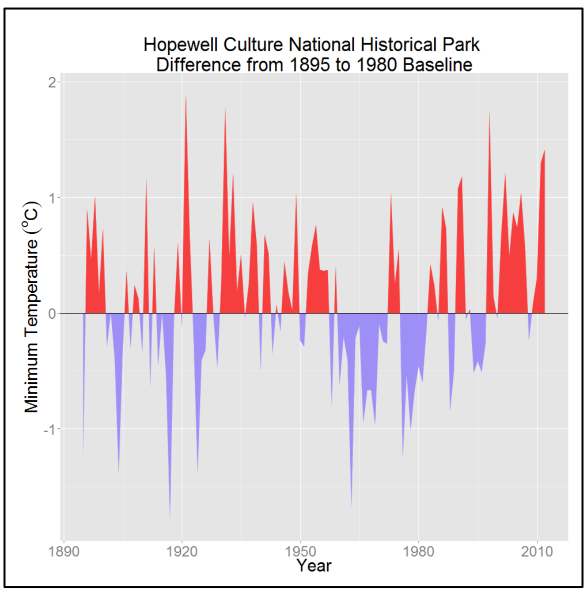

Figure 4.4-3. Anomaly plot for mean minimum temperature showing the difference between individual years from 1895 to 2012 and a baseline (1895 to 1980 average) for Hopewell Culture National Historical Park. (Data and graphic prepared by NCCSC)

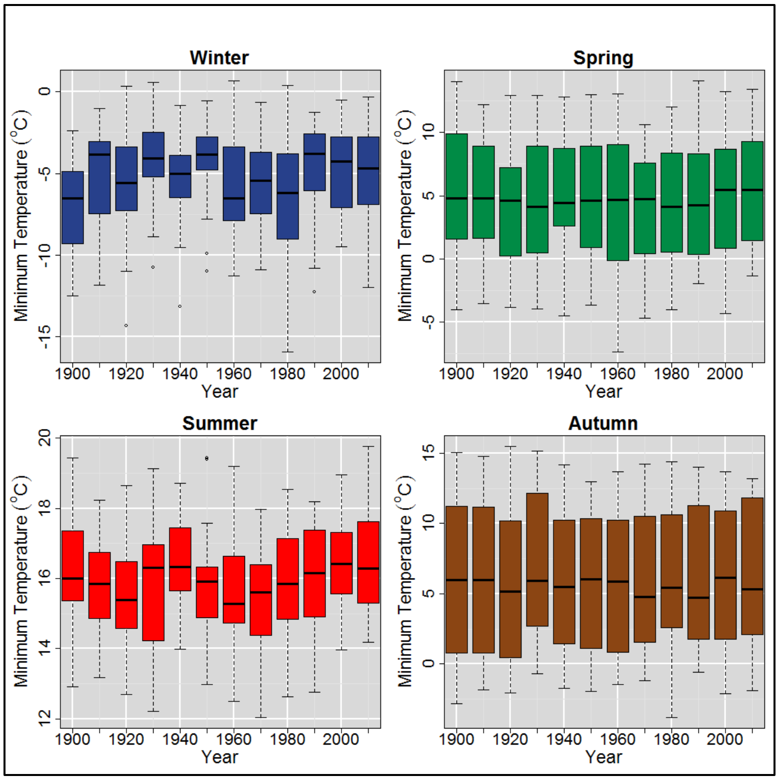

Figure 4.4-4. Seasonal historical mean minimum temperature quartiles using PRISM data at Hopewell Culture National Historical Park. Within a season, darker colors represent higher temperatures. (Data and graphic prepared by NCCSC)

Modeled Future Changes

Models indicate that temperatures at the park will rise significantly under climate change (Figure 4.4-5). According to median ensemble estimates, both minimum and maximum temperature are expected to increase by approximately 1.5–2.0 °C by 2050, and by approximately 2.0–6.5 °C by 2100, depending on the scenario (Figure 4.4-5).

Precipitation

Historical Trends

Historical trends in monthly and annual precipitation for 1895–2010 were examined to understand patterns and variability. Mean monthly precipitation does not show any clear patterns for yearly or seasonal changes (Figure 4.4-6). Linear regression of mean monthly precipitation with time were not significant for the 1895–1980 period (p=0.219) or the 1980–2012 period (p=0.135) (Figure 4.4-7). Variability in seasonal and annual precipitation is relatively high.

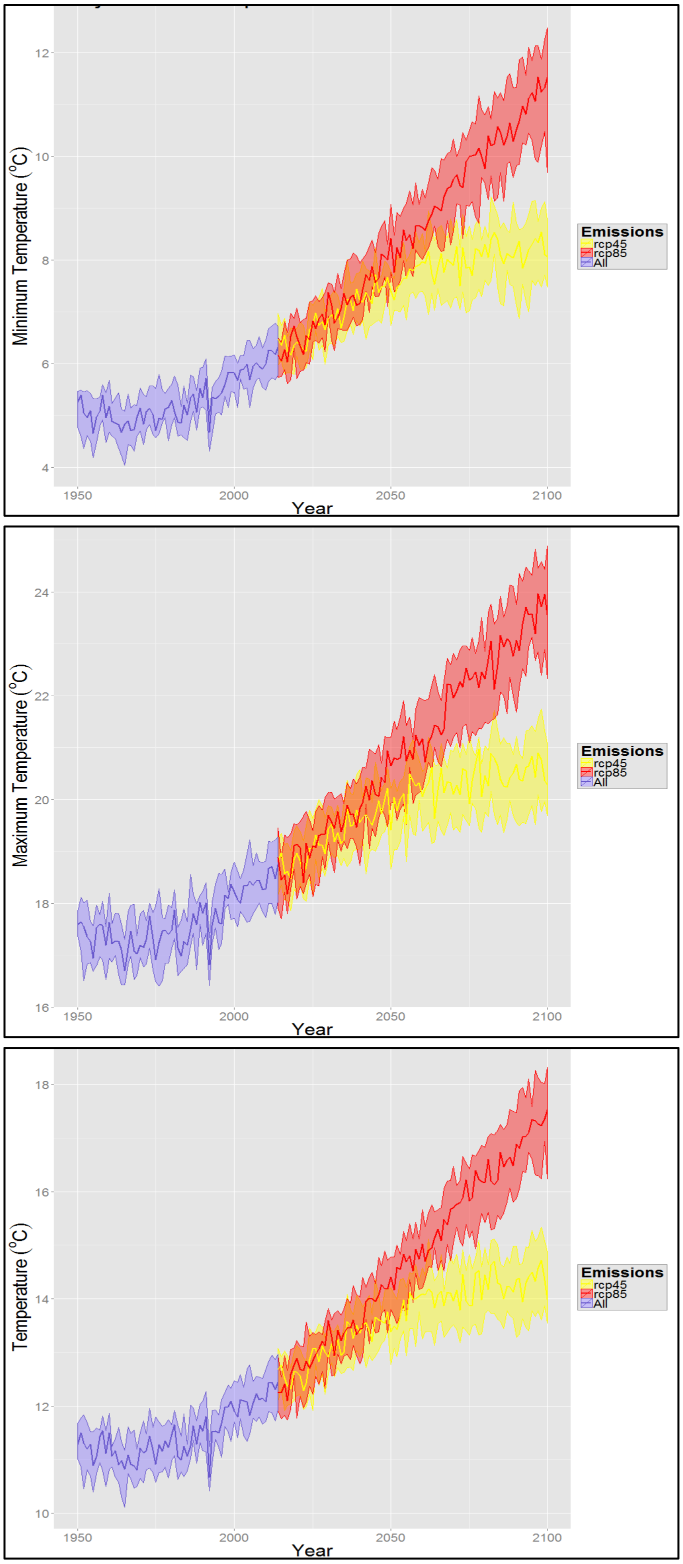

Figure 4.4-5. Projections for annual minimum, maximum and mean temperature with median, 25 and 75% quantiles grouped by emissions scenario for Hopewell Culture National Historical Park. (Data and graphic prepared by NCCSC).

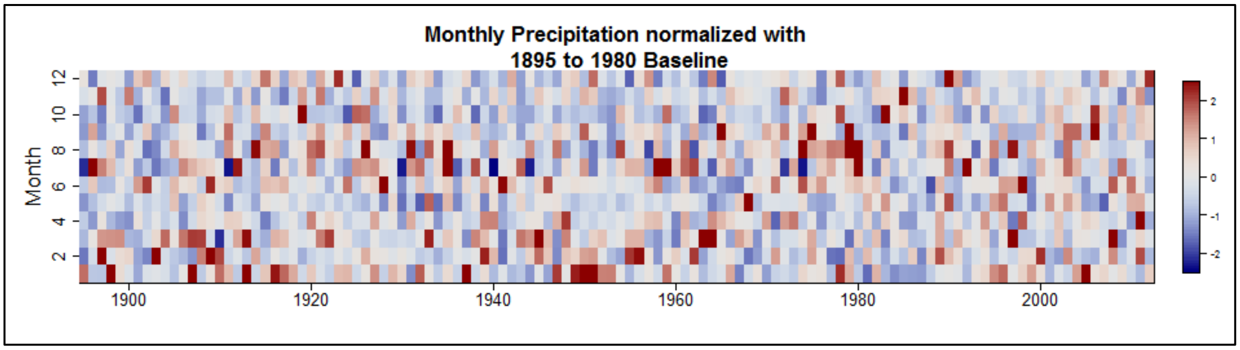

Figure 4.4-6. Mean monthly precipitation showing the normalized difference from a baseline (1895–1980) period for each month and year for Hopewell Culture National Historical Park. The baseline is calculated monthly within the specified year range. The pixels are normalized by month and colors range from +/− 2.5 standard deviations from the mean of the baseline period. (Data and graphic prepared by NCCSC)

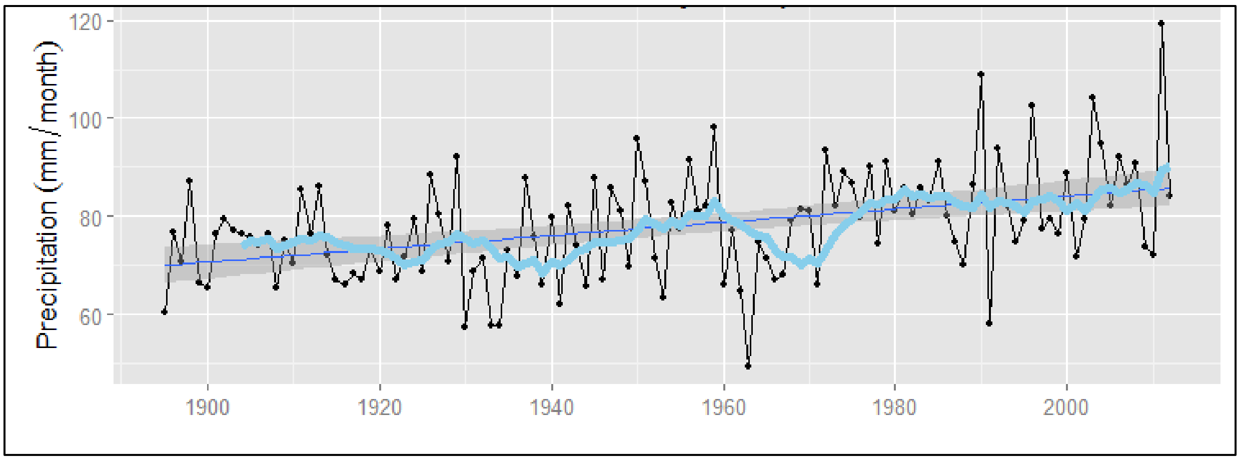

Figure 4.4-7. Historical PRISM data for precipitation at Hopewell Culture National Historical Park showing linear model fit and a five year lag running mean. (Data and graphic prepared by NCCSC)

In recent decades there have been increases nationally in the annual amount of precipitation falling in very heavy events, defined as the heaviest 1% of all daily events from 1901 to 2012. The largest regional increases have been in the Midwest and Northeast when compared to the 1901–1960 average (Walsh et al. 2014b). Regional results for the Midwest region including HOCU 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 4.4-8).

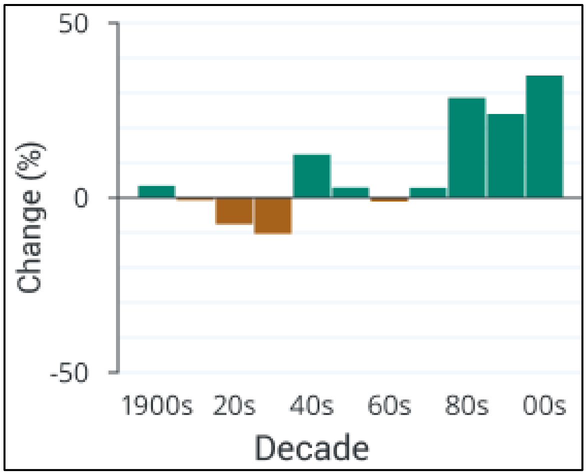

Figure 4.4-8. Percent changes in the annual amount of precipitation falling in very heavy events compared to the 1901–1960 average for the Midwest region. A very heavy event is defined as the heaviest 1% of all daily events from 1901 to 2012. The far right bar is for 2001–2012 (Walsh et al. (2014b)).

Modeled Future Changes

Modeled climate through the year 2100 shows an increase in mean monthly precipitation under both moderate (RCP4.5) and high (RCP8.5) emission scenarios (Figure 4.4-9). Both the medium and high emission scenarios produce higher mean monthly precipitation compared to the baseline period, with increases of approximately 5–6 mm (0.19–0.24 inches) per month or approximately 60–72 mm (2.36–2.83 inches) per year by the 2040s and 5–12 mm (0.19–0.47 inches) per month or approximately 60–144 mm (2.36–5.67 inches) per year by the 2080s.

Aridity

Aridity and moisture availability is examined using the Palmer Drought Severity Index (Palmer 1965) for the historical 1895–2013 period. No modeled future events are 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 4.4-10). The Palmer Index is most effective in determining long term drought (i.e., at least several months). 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. PSDI values range between −4.00 or less (extreme drought) and +4.00 or greater (extreme moisture). The index uses a value of 0 as "normal", and value of −1.5 is considered drought. While drought is sometimes described as cyclic, the frequency and duration of cycles is highly unpredictable. For the period of record, HOCU PDSI data shows periodic moderate drought lasting 2–5 years occurring approximately every 15–20 years since about 1900.

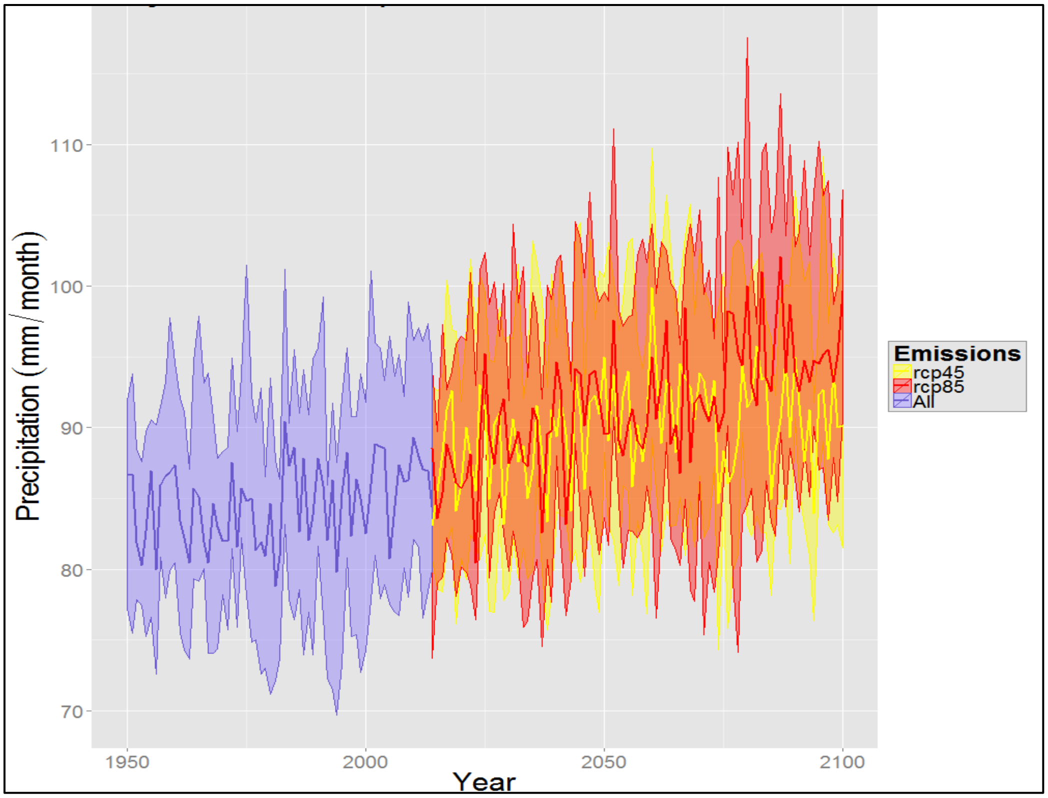

Figure 4.4-9. Projections for precipitation/month with mean, 25% and 75% quantiles grouped by emissions scenario for Hopewell Culture National Historical Park. (Data and graphic prepared by NCCSC)

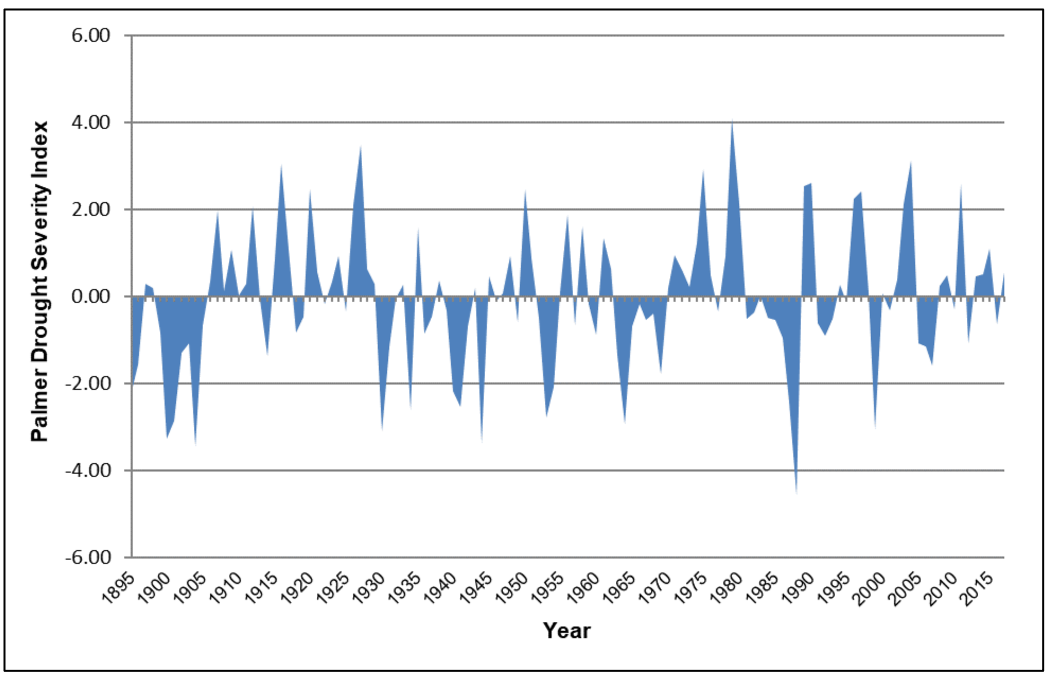

Figure 4.4-10. Palmer Drought Severity Index from 1895 –2017 for Hopewell Culture National Historical Park. Negative values represent dry conditions and positive values represent moist conditions (NCDC 2018).

Frost-Free Period

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). A longer growing season can increase carbon sequestration in plants (Peñuelas et al. 2009) and increase the growth of both desirable and undesirable plants.

Modeled Future Changes

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

Overall Assessment

Indications are that the climate in this park region is already becoming warmer and is 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 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 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 interaction with other ecological processes can be informed by this broad overview of the magnitude of climate change in the park region.

4.4.5. Management and Ecological Implications

Changing climate is anticipated to impact Midwestern ecosystems 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 missions. Some of the key anticipated ecological impacts and potential management implications of climate change in the eastern deciduous forest region and at HOCU include:

- Extreme streamflow events are expected to increase, with a shift toward higher flows in the winter and spring, and lower flows in summer and fall (Schramm 2011).

- 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 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 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 2011).

- Increases in invasive exotic plants (NFWPCAP 2012);

- More frequent extreme events such as heat waves and heavy rains (Karl et al. 2009), and increasing likelihood of flooding in the wetter, northern portions of the Midwest (Walsh 2014b);

- Limited ability for species and communities to adapt; the relatively flat terrain characterizing these forests increases vulnerability to climate change because species and habitats may be obliged to migrate long distances to compensate for temperature shifts. This challenge is exacerbated by the highly fragmented and altered landscape in the region (Schramm 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 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 park, 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 data sets developed by this NRCA will be useful for subsequent park-level climate change studies and planning efforts.

4.4.6. 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 gaps to help manage resources and understand the repercussions of climate change to the park include the need for: 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).

4.4.7. 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.

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4.5. Air Quality

4.5.1. 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 which 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 NPS visitors and employees. 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 the following areas in existence as of August 7, 1977: 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 (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 compared to Class I areas, except in specified cases (NPS ARD 2013). Hopewell Culture National Historical Park is classified as a Class II airshed.

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. While there are no data documenting adverse environmental effects of air pollution at HOCU (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.

As of June 2018, the HOCU area was not listed by EPA as a non-attainment or maintenance area for ozone levels (EPA 2018). Hopewell Culture National Historical Park 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). HOCU 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).

<u>Threats/ Stressors</u>

The Ohio Environmental Protection Agency (OEPA) has not listed Ross County (which HOCU lies within) as being in violation of any air quality standards (OEPA 2016), although none of the OEPA sampling locations are within the county. Hopewell Culture National Historical Park is located in the southern part of Ohio 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

4.5.2. Data and Methods

The condition of air quality within HOCU 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 HOCU to assess 10-year trends. Available monitoring data for the park is interpolated from regional monitoring stations. Ozone is monitored at three stations near the park in Wilmington, Ohio (45 miles west of the park) and two located in Columbus, Ohio 40 miles north of HOCU. Wet deposition is monitored Deer Creek State Park, Ohio 20 miles northwest of the park (NPS ARD 2001). There are no Interagency Monitoring of Protected Visual Environments (IMPROVE) visibility monitoring station within 100 miles of the park (CIRA 2018). Condition and trend data were retrieved from the NPS Air Quality Conditions and Trends by Park database (NPS ARD 2017a).

4.5.3. 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 4.5-1. Condition assessments for contiguous U.S. parks 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 4.5-1. Reference condition framework for air quality indicators (Taylor 2017).

Air Quality Indicator	Specific Measure	Good Condition	Moderate Condition	Poor Condition
Ozone	Human Health: Annual 4th-highest 8hr concentration	≤ 54 ppb	55–70 ppb	≥ 71 ppb
	Vegetation Health: 3-month maximum 12hr W126	< 7 ppm-hrs	7–13 ppm-hrs	> 13 ppm-hrs
Visibility	Haze Index	< 2 dv*	2–8 dv*	> 8 dv*
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

* Above estimated natural conditions.

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 ppb in October, 2015, which strengthened the standard of 75 parts per billion (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 are assigned a Warrants Significant Concern category. Ozone concentrations from 55–70 ppb are assigned Warrants Moderate Concern category. A resource in the Good Condition category is identified when ozone concentrations are less than or equal to 54 ppb (Table 4.5-1) (Taylor 2017).

Ozone: Vegetation Health Risk

The W126 metric is a biologically relevant measure that focuses on plant response to ozone exposure. The W126 metric equation 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 value greater than 13 ppm-hrs warrants significant concern, a value from 7–13 ppm-hrs warrants moderate concern, and a W126 value less than 7 ppm-hrs indicates good condition (Table 4.5-1) (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 4.5-1) (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 4.5-1) (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 HOCU), 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 US. 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 4.5-1)(Taylor 2017).

4.5.4. Condition and Trend

Ozone: Human Health Risk

Ozone causes problems for human health, including difficulty breathing, chest pain, coughing, inflamed airways, and making lungs more susceptible to infection (EPA 2012). From 2011–2015, HOCU experienced a 4th highest 8-hr ozone average concentration of 71.5 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 poor condition for ozone levels with an unknown trend and medium confidence due to on the use of interpolated data from more distant ozone monitors (NPS ARD 2017a).

Ozone: Vegetation Health Risk

In addition to being a concern to the health of park staff and visitors, long-term exposures to ground-level ozone can cause injury to ozone-sensitive plants (Bell et al. 2020). There are 26 plant species identified within HOCU that are sensitive to ozone (NPS ARD 2017b). Ozone is able to enter leaves through stomata and causes chlorosis and necrosis of leaves (Figure 4.5-1), 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 HOCU were at high risk for ozone damage (Kohut 2007).

The 2011–2015 estimated W126 metric is 10.3 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 being based on interpolated data from more distant ozone monitors (NPS ARD 2017a).

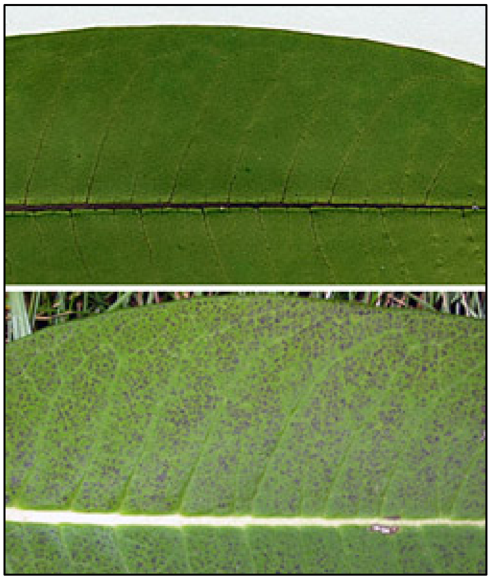

Figure 4.5-1. *Asclepias syriaca* normal leaf (top) and ozone-injured leaf (bottom). Photo: NPS ARD.

Wet Nitrogen Deposition

Based on the 2011–2015 estimated wet nitrogen deposition of 4.6 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 3.2 kg/ha/yr, wet sulfur deposition is in the poor condition category (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).

Visibility

Based on the 2011–2015 estimated visibility on mid-range days of 8.9 dv, the visibility condition falls in the poor condition category with medium confidence due to regional and modeled nature of 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 an unknown trend (Table 4.5-2). Confidence in the assessment is medium because estimates are based on interpolated data from more distant monitoring stations. Impacts to air quality appear to be largely from distant sources that are affecting regional air quality.

Table 4.5-2. Condition and trend summary for air quality at Hopewell Culture National Historical Park.

Indicator	Measure	Condition Status/Trend	Rationale
Ozone	Human Health: Annual 4th-highest 8hr concentration		Human health risk from ground-level ozone warrants significant concern at HOCU. Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated ozone of 71.5 ppb.
	Vegetation Health: 3-month maximum 12hr W126		Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated W126 metric of 10.3 parts per million-hours (ppm-hrs) and warrants moderate concern. The W126 metric relates plant response to ozone exposure. A risk assessment concluded that plants at HOCU were at high risk for ozone damage (Kohut 2007).
Visibility	Haze Index		Visibility warrants significant concern at HOCU. Condition is based on NPS Air Resources Division benchmarks and the 2011–2015 estimated visibility on mid-range days of 8.9 deciviews (dv) above estimated natural conditions.
Nitrogen	Wet Deposition		Wet n0 itrogen deposition warrants significant concern based on NPS Air Resources Division benchmarks and the 2011–2015 estimated wet nitrogen deposition of 4.6 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 3.2 kg/ha/yr.
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.**

4.5.5. Uncertainty and Data Gaps

Monitoring stations within Ross County would better capture air quality conditions at HOCU. Estimated values based on geospatial interpolations are adequate, but can misrepresent park conditions due to modeling errors. Monitoring of air quality conditions within HOCU or nearby would reduce uncertainty from the interpolations for all indicators.

4.5.6. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units, and provide air quality analysis and expertise related to all air quality topics. For current air quality data and information for this park, please visit the NPS Air Resources Division website at www.nps.gov/subjects/air/index.htm.

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4.6. Vegetation Communities

4.6.1. 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 all of Ohio, this ecoregion exhibited vast stretches of unbroken forest which persisted for thousands of years (NPS 2016a). The State of Ohio is split into two physiographic sections including the Central Lowlands to the west and the Allegheny Plateau to the east. The Allegheny Plateau physiographic section is further subdivided into glaciated region to the north and unglaciated region to the south. Hopewell Culture National Historical Park lies at the boundary of these two physiographic sections at the junction of the Western Allegheny Plateau and the Eastern Corn Belt Plains Level III Ecoregions along the southern terminus of the Wisconsin glaciations in southcentral Ohio (Figure 4.6-1) (Omernik 1987).

HOCU earthwork site surrounded by secondary successional forest (CSU Photo).

Prior to Euro-American settlement, the HOCU area was dominated by oak (*Quercus* spp.) – hickory (*Carya* spp.) upland forests and mixed bottomland forests. Agriculture was practiced by the Native Americans, and a portion of the area prior to Euro-American settlement would have been under cultivation or succeeding from previous disturbance. It is unknown what the character or composition of the vegetation was during the period of significance. Drawings dating from the mid-1800s indicate that portions of some earthworks were cleared of trees, and other portions were forested (NPS 2016a). A long history of anthropogenic disturbances, including forest clearing and intensive agricultural use, have severely impacted cultural and natural resources at HOCU. Additionally, cultural resource protection at HOCU necessitates the maintenance of grassland communities, rather than forest, around many cultural sites. Native grass cover is utilized around the earthworks whenever possible, but there are situations where the protection of the archeological resource necessitates the use of non-native grasses. All six park units contain upland forests, riparian forests, lawns, and farm fields with both native, exotic, and invasive species being present. The vegetation of all units except Spruce Hill have been mapped (Diamond 2014) (Figure 4.6-2). Brief descriptions of five of the units follow (NPS 2013).

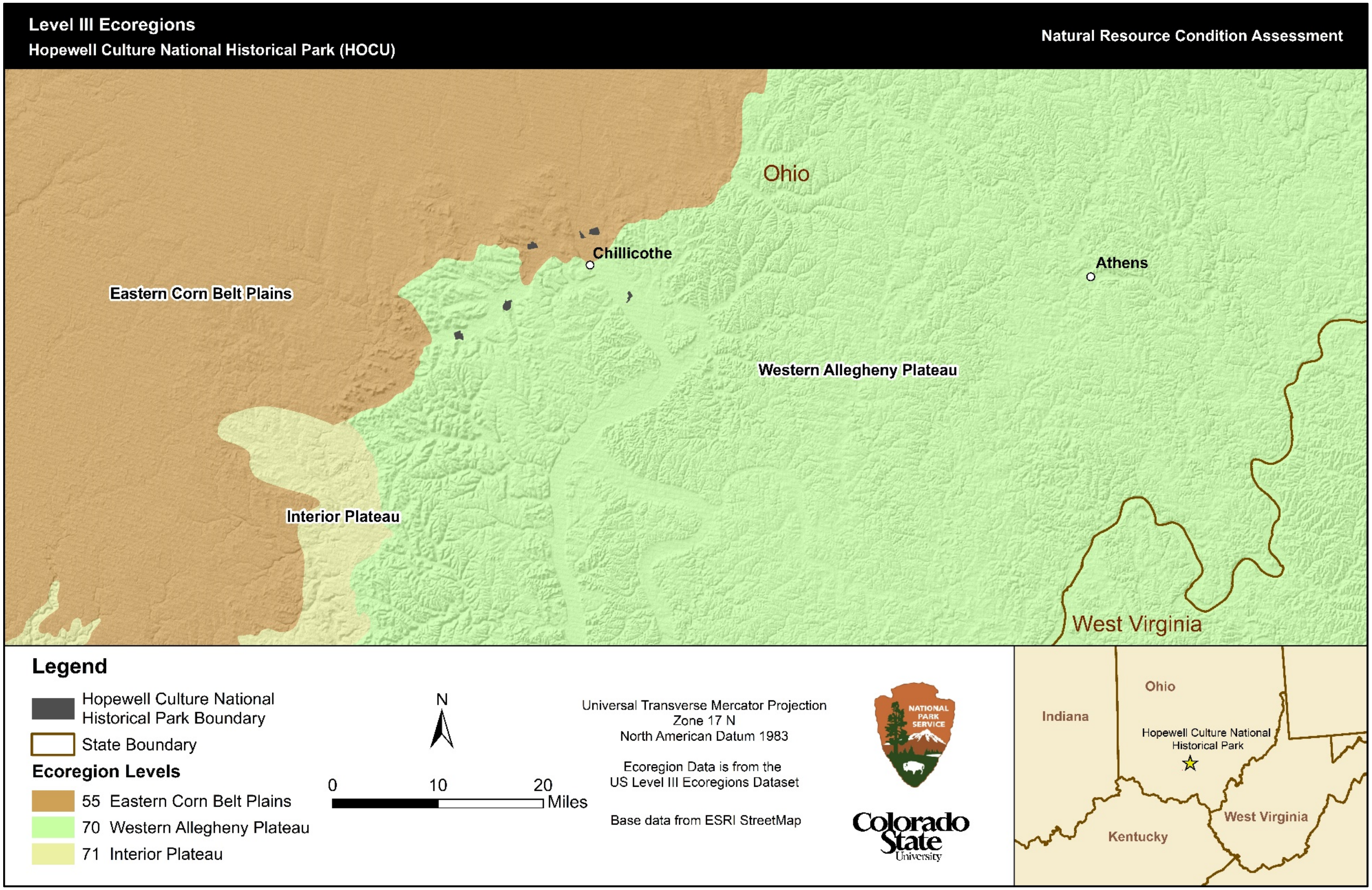


Figure 4.6-1. Hopewell Culture National Historical Park lies at the junction of the Western Allegheny Plateau and the Eastern Corn Belt Plains Level III Ecoregions at the southern terminus of the Wisconsin glaciations in southcentral Ohio (Omernik 1987).

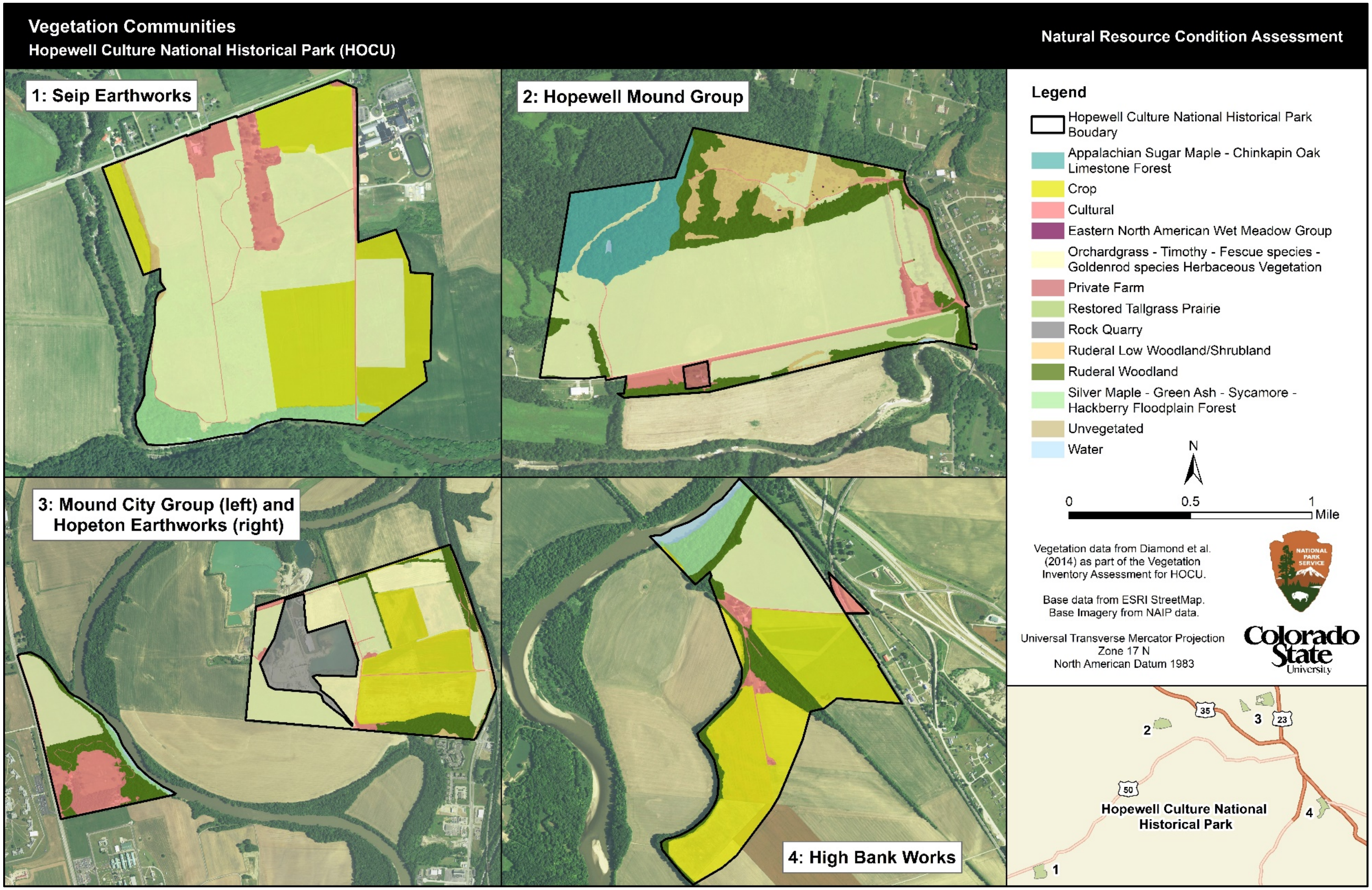


Figure 4.6-2. Vegetation communities at HOCU derived from Diamond et al. (2014) data. Spruce Hill Earthworks has not been formally mapped. Some areas mapped as cropland have recently been converted to native grasslands.

Mound City Group: a total of 120 acres of which 40 acres are in agricultural hay production, 40 acres are early-successional mixed mesophytic forests, and the remaining acreage is represented by developed land uses including restored earthworks and mounds, parking lots, park offices, visitor facilities, and the visitor center.

Hopeton Earthworks: approximately 380 acres of which 14 acres are a seasonal stream surrounded by forest, 4 acres are black walnut (*Juglans nigra*) grove, 110 acres are active soybean cultivation, and remaining acreage is a mix of fallow hay fields and restored grasslands.

Hopewell Mound Group: approximately 310 acres of which 36 acres are a semi-mature mixed mesophytic forest, 6 acres are restored prairie, 140 acres are hay fields, and the remaining acreage is upland escarpment with mixed grasses and forbs. Visitor facilities at this site include a hiking trail, picnic area, and parking lot.

Seip Earthworks: approximately 126 acres of main tract, consisting of 14 acres of a Paint Creek riparian corridor and remaining acreage in fallow field. The Dill Road tract is 26 acres of fallow field.

High Bank Works: approximately 152 acres with 31 acres of riparian woodland, 70 acres of fallow hay field, and the remaining acreage in soybean cultivation to be planted with native prairie species in 2012. The central third of the unit is owned and managed by the Ohio Historical Society.

As outlined in Diamond et al. (2014), seven vegetation community types were classified and mapped at HOCU, including four types specific to the park (park specials) and three types that fit well with communities already described within the U.S. National Vegetation Classification system (USNVC) (Table 4.6-1). Of these three USNVC types, two were mapped at the association level and one was mapped at the group level (Table 4.6-1). Among the seven community types, Diamond et al. (2014) found the Appalachian Sugar Maple (*Acer saccharum*) – Chinkapin Oak (*Q. muehlenbergii*) / Eastern Redbud (*Cercis canadensis*) Limestone Forest was in the best condition, occupying 34.1 acres on the northeastern side of the Hopewell Mound Group unit. Diamond et al. (2014) also found three units supporting narrow, linear stripes of Silver Maple (*A. saccharinum*) – Green Ash (*Fraxinus pennsylvanica*) – Sycamore (*Platanus occidentalis*) Floodplain Forest, with these patches comprising 38.9 acres of HOCU. Of the seven mapped types, Diamond et al. (2014) found the ruderal Orchardgrass (*Dactylis glomerata*) – Timothy (*Phleum pretense*) – Fescue species (*Festuca* spp.) – Goldenrod species (*Solidago* spp.) Herbaceous Vegetation community type to be the most dominant community in the park. This type occupied former croplands across most units accounting for 70.3% (587.8 acres) of the total non-developed park area at HOCU (Figure 4.6-3).

Table 4.6-1. Extent of mapped vegetation community associations by map classes for the Mound City Group, Hopeton, Seip and High Bank earthworks (combined) at HOCU (Diamond et al. 2014).

Vegetation Community	USNVC Identifier	Mapped Class Name	Ecological Associations	Acres	Hectares
Forests and Woodlands	CEGL006017	Appalachian Sugar Maple-Chinkapin Oak/Eastern Redbud Limestone Forest	*Acer saccharum – Quercus muehlenbergii / Cercis canadensis* Limestone Forest	34.1	13.8
	CEGL004693	Ruderal Woodland	*Juglans nigra-Celtis occidentalis* Forest	135.8	55
	None Assigned	Silver Maple-Green Ash-Sycamore Floodplain Forest Group	*Acer saccharinum – Fraxinus pennsylvanica – Platanus occidentalis-Celtis* spp. Forest	38.9	15.7
	None Assigned	Ruderal Low Woodland/ Shrubland	*Elaeagnus umbellata – Gleditsia triacanthos / Rubus pensilvanicus* Woodland or Shrubland	35.6	14.4
	Total Forests and Woodlands	**–**	**–**	**244.4**	**98.9**
Herbaceous Vegetation	CEGL006107	Orchardgrass-Timothy-Fescue species-Goldenrod species Herbaceous Vegetation	*Dactylis glomerata – Phleum pretense – Festuca* spp. – *Solidago* spp. Herbaceous Vegetation	587.8	237.9
	G112	Eastern North American Wet Meadow Group	*Eleocharis* spp. – *Carex* spp. – *Polygonum* spp. Herbaceous Wetland	0.05	0.02
	None Assigned	Restored Tallgrass Prairie	*Andropogon gerardii* Herbaceous Vegetation	4.0	1.6
	Total Herbaceous Vegetation	**–**	**–**	**591.85**	**239.52**

Figure 4.6-3. Panoramic view of a maintained grassland at one of the HOCU earthwork sites. Protection of the cultural resources necessitates the maintenance of grassland communities rather than forest across much of HOCU (CSU Photo).

One of the biggest threats to vegetation communities at HOCU is the impact of invasive, noxious weeds. While no federal noxious weeds are known from the park, six state noxious weeds are present: Canada thistle (*Cirsium arvense*), Johnsongrass (*Sorghum halepense*), nodding plumeless thistle (*Carduus nutans*), poison hemlock (*Conium maculatum*), Queen Anne's lace (*Daucus carota*), and wild parsnip (*Pastinaca sativa*). Also, 16 of the 26 species identified on the Ohio Invasive Plants Council list occur in the park. Clearly, invasive plants are a resource management issue for the park (Young et al. 2012). Beginning in 2008, the NPS began a formal program of monitoring and controlling invasive species at HOCU, focusing on restored successional grasslands and wooded areas. Major invasive species targeted include Canada thistle (*Cirsium arvense*), bull thistle (*C. vulgare*), musk thistle (*Carduus nutans*), Johnsongrass (*Sorghum halepense*), garlic mustard (*Alliaria pettiolata*), bush honeysuckles (*Lonicera* spp.), and exotic olives (*Elaeagnus* spp.). Monitoring of the 2008 survey areas in 2011 and 2015 provide trend data pertaining to invasive weed frequency and abundance across the park and feedback with respect to management effectiveness (Young et al. 2016).

Restored warm-season grassland in foreground at the Hopewell Mound Group between Sulphur Lick Road and Paint Creek (CSU photo by Dave Jones).

Prairie Restoration and Grassland/Cropland Management

Prior to European settlement, most prairie grasslands occurred in the western half of the state in areas of well drained soils, often as part of wooded oak savannahs, or in wetter depressions. Originally occupying approximately five percent of Ohio's vegetation, less than one percent of the state's indigenous tall grass prairie acreage exists today. Use of fire by Native Americans helped to control woody plant invasion and maintain native prairie openings (ODNR 2018). The precise distribution of pre-settlement prairies is unknown. The target vegetation may be managed as a mosaic of bluestem prairie and oak-hickory forest types described by Kuchler, part of which may be managed by prescribed fire (NPS 2004). Kuchler's Bluestem Prairie (Type No. 74) is characterized by dense vegetation of tall grasses and many forbs. The dominants include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*) (Kuchler 1964, Stubbendieck and Willson 1986).

The primary consideration for vegetation management practices in the park is the protection of the archeological resource. As new sites have been added to the park, the earthworks have been stabilized with a grass cover. Native grasses have been used to some degree, but there are situations where protection of the archeological resource or financial considerations necessitate using nonnative grasses (NPS 2016a). In visitor use areas the grasses are kept closely cut to allow visitor access and to facilitate viewing of the earthworks. In areas that do not receive regular visitation grass is allowed to grow and cut two or three times a year as a hay crop. The park does not allow deep-rooted trees to grown on the earthworks due to the potentially damaging effects of roots on archaeological resources (NPS 2004). To prevent encroachment of woody species on the grassland areas containing the earthworks, woody plants can be controlled using prescribed fire, herbicides, and mechanical methods. An example of the historical vegetation patchwork on HOCU units is shown in Figure 4.6-4. Much of the Hopeton acreage is being converted to native grassland.

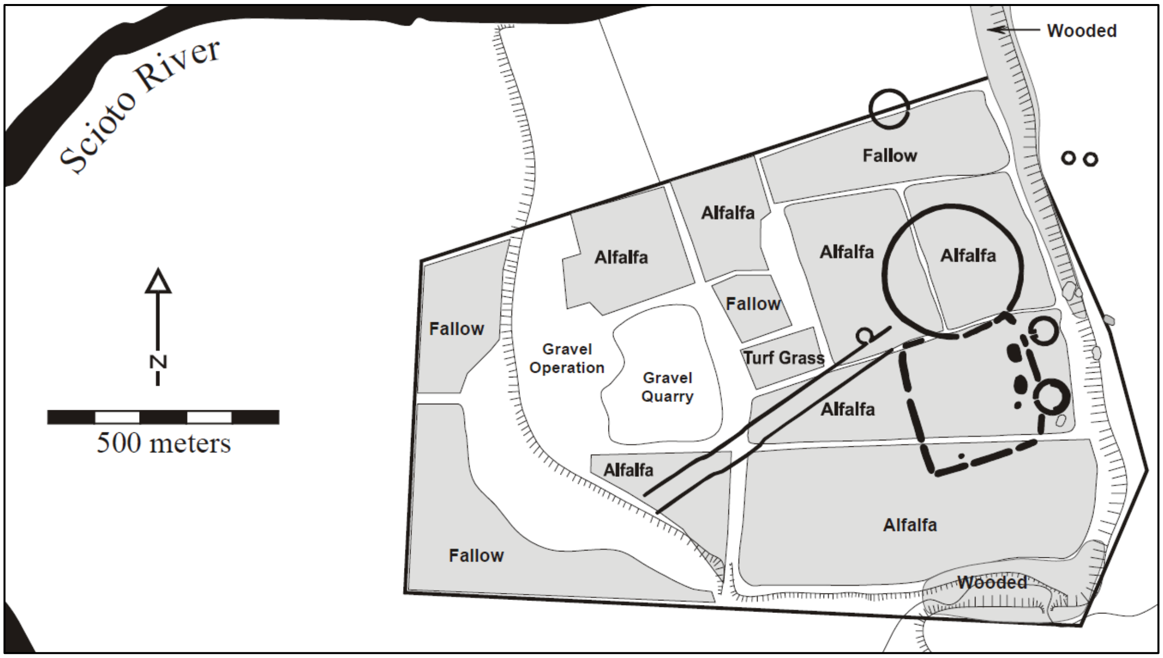


Figure 4.6-4. Mosaic of vegetation types at Hopeton Earthworks Unit as of 2004 (NPS 2004).

Other considerations for vegetation management on and around the earthworks are visitor use patterns and past land use history (NPS 1997), ecological value of different vegetation types (NPS 2015), opportunities to expand public outreach and interpretation programs related to natural history (NPS 2015) and a desire to reduce usage of pesticides and fertilizers through conversion of agricultural areas to native grasslands (NPS 2017).

Restoration Activities

Prairie restoration initiatives at HOCU have been in the planning stage for some years. Native prairie vegetation is recognized as a diverse component of the landscape that provides habitat for declining grassland birds, bees, and other species, and allows for reduced management effort, fertilizers and pesticides compared to traditional agricultural or landscaping approaches (NPS 2015, NPS 2017). One stand of approximately four acres of restored tallgrass prairie is located on the southeast corner of the Hopewell Mound Group, on the north side of Paint Creek. The prairie restoration is surrounded by the Orchardgrass – Timothy – Fescue spp. – Goldenrod spp. Herbaceous Vegetation, and is clearly distinguishable when the flowering culms of big bluestem (*Andropogon gerardii*) and other native grasses are visible in the fall. Big bluestem and Canada goldenrod (*Solidago canadensis*) are the dominant species. Other important species include sideoats grama (*Bouteloua curtipendula*), blackeyed and browneyed Susan (*Rudbeckia hirta and R. triloba*), wild bergamot *(Monarda fistulosa*), and stiff goldenrod (*Oligoneuron rigidum*). Shrubs and small trees include Pennsylvania blackberry (*Rubus pensilvanicus*), American elm (*Ulmus americana*), multiflora rose (*Rosa multiflora*), and slippery elm (*Ulmus rubra*).

According to the *Grassland Conversion Plan* for HOCU, completed for the park in 2017, restored grasslands will help visitors appreciate the scope and extent of the earthwork complexes, restore the cultural landscape, control soil erosion (associated with row cropping), protect sensitive archeological resources, control exotic invasive plants, control woody plant encroachment, and provide grassland habitat for native flora and fauna (NPS 2017). The plan describes the eventual conversion of over 200 acres at the Hopeton, Seip and Mound City Group units from agricultural or non-native ruderal grasslands to native prairie (Table 4.6-2). Species included in the grassland restoration mix include a variety of native grasses and forbs: Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switch grass (*Panicum virgatum*), side-oats grama (*Bouteloua curtipendula*), Virginia wildrye (*Elymus virginicus*), Canada wildrye (*Elymus canadensis*), Rudbeckia sp., partridge pea (*Chamaecrista fasciculate*), Illinois bundleflower (*Desmanthus illinoensis*), coneflowers (*Echinaceae* sp.), ironweed (*Vernonia* sp.) and goldenrods (*Solidago* sp.). To date, the conversion goals established in the 2017 Plan have been exceeded. A total of 240 acres were planted to native grassland. Field sampling of 100 randomized 1 square foot (sf) plots at Hopeton Grassland in 2018 found the most abundant planted species to be Indian grass (51 plants/100 sf), *Rudbeckia* spp. (38 plants/100 sf), big bluestem (36 plants/100 sf) and switchgrass (18 plants/ 100 sf) (unpublished data provided by Jason Snider). Planted native forbs combined averaged about 7 plants per 100 sf. Another 120 acres of restoration plantings were planned for winter 2019. As of 2020, it is anticipated that there will be no production agriculture in HOCU. Haying will continue at High Bank Earthworks to maintain low vegetation. There is discussion of establishing a grazing program at HOCU to promote native vegetation and control nonnative vegetation (pers. comm. Jason Snider, March 2019).

Table 4.6-2. Summary of planned conversion of approximately 107 acres from agricultural use to native grasslands and other native grassland restoration (NPS 2017).

Park Unit	Area Type	Area Size (acres)	Management Target
Hopeton Earthworks	Buffer zone around earthworks	37	Plant to soybeans in 2017 for 2 years, and establish native prairie in 2019.
	Ruderal mixed grassland on former cropland, west and south of earthworks	69	Conversion to native grassland in 2017.
Seip Earthworks	Buffer zone around earthworks	39	Plant to soybeans in 2017 for 2 years, and establish native prairie in 2019.
	Ruderal mixed grasslands on former croplands, 2 fields on northern border.	35	Conversion to native grassland in 2019.
Mound City Group	Cropland on northern half of unit between riparian forest and Highway 104.	36	Plant to soybeans for 2–3 years, and establish native prairie in 2020.

Prescribed Fire at HOCU

The National Park Service's Director's Order 18 requires that all parks with vegetation capable of sustaining fire develop a Fire Management Plan. There are over 1,170 acres of land within HOCU that are burnable. The burnable land that can sustain fire is covered with grassland, deciduous forest, agricultural wetland vegetation that could potentially benefit from periodic, prescribed fires. Prehistoric Native Americans undoubtedly used fire for a variety of reasons: known examples of fire use by historical Native Americans include hunting, crop management, forage improvement to attract game, fireproofing areas, collecting insects, managing pests, warfare and signaling, economic extortion, and clearing areas for travel (Williams 2002). Active fire suppression starting in the early 1920s in Ohio has resulted in the reduction of oak savanna and a return of woody species to lands that are not used for agriculture (NPS 2004). Fire is not known to have been a factor in this area in historical times (NPS 1997). The time since the last wildfire on park lands is unknown, and would have occurred prior to the 1970s (NPS 2004).

The use of prescribed fire as a resource management tool is expected to play an important role in meeting vegetation management objectives as well as a tool for controlling or eradicating invasive exotic species (NPS 2002). Developed in 2004, the park's *Draft Wildland Fire Management Plan* (FMP) supports the park's overriding goal of restoration or maintenance of the historic scene and the associated cultural resources, while providing for firefighter and public safety, protection of natural and cultural resources and human developments from unwanted wildland fire or damage associated with fire management or suppression (NPS 2004). The plan governs wildland fire suppression and prescribed fire activities, and will help facilitate the use of prescribed fire to help manage native grass and prairie restoration efforts within the park. Management of wildland fires to achieve park objectives is infeasible due to the size of the park, the significant degree of wildland urban interface along the park boundary, and the lack of adequate numbers of available qualified personnel required to manage wildland fires (NPS 2004).

In November, 2009, NPS planned and implemented a six acre prescribed fire within a restored tallgrass prairie patch in the Hopewell Mound Group. The burn represented the first step in reintroducing fire to the landscape. The primary objectives of this prescribed fire were to reduce the accumulation of hazardous fuels, suppress tree and shrub encroachment, reestablish the dominance of native plant species, and help restore the cultural landscape. It is believed that successful planning and implementation of the 2009 burn will facilitate the use of prescribed fires at HOCU in the future (NPS 2018).

It is anticipated that prescribed fire will be used infrequently and that a long-term plan for its use will be developed in the future (NPS 2004). Challenges to using prescribed fire are similar to those for managing wildland fires, and include air quality concerns. Carrying out prescribed burns at smaller parks is especially challenging, partly because they do not have sufficient resources to conduct a burn on their own and are obliged to order or solicit resources from other parks and agencies.

<u>Threats and Stressors</u>

Primary threats to vegetation communities at HOCU include: 1) historical land uses that have impacted the vegetation community structure; 2) fragmentation from development that has reduced connectivity of large tracts of native vegetation; 3) non-native exotic weeds, pathogens, and insects that influence vegetation community composition (Fisichelli et al. 2014, Fisichelli 2015). Lack of regular fire is a stressor on native prairie vegetation. 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

- Community composition (Native Species Composition)
- Invasive exotic plants cover (% IEP cover)
- Floristic Quality Assessment Index (FQAI)
- Mean Coefficient of Conservatism ($\overline{C}$)
- Forest pests and diseases
- Forest vulnerability to climate change
- Prairie restoration and grassland management

4.6.2. Data and Methods

Species Composition and Diversity

The community structure, composition, condition, and diversity of the vegetation communities were evaluated primarily with data collected by Diamond et al. (2014) during the vegetation inventory and mapping project at HOCU. The project used vegetation plot data and aerial imagery to describe and map vegetation communities across HOCU using the USNVC. A total of 33 vegetation plots surveyed and used to classify and describe HOCU vegetation communities park-wide. Information that was collected at each plot included vegetation structure and cover by stratum (herbaceous, shrub, or tree canopy) for all plant species within the $400m^2$ plot. For this condition assessment, this data was used to evaluate the community composition, diversity, 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. Average native species composition was determined by calculating the average number of native plant species documented in each plot within vegetation communities at HOCU.

Floristic Quality Assessment Index (FQAI) 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 all the species in a state following methods described by Swink and Wilhelm (1994) and Wilhelm and Masters (1995). These values are assigned to each floral taxon in a state or region by a panel of experts for the region. *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 which 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) and values in between reflect the range of disturbances tolerated by species (Andreas et al. 2004; Lemly and Gilligan 2015). *C* values that have been assigned to taxa in the Ohio flora are found in Andreas et al. (2004). The proportion of conservative plants in a plant community provide 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). The *C* values ranges and associated interpretation are provided in Table 4.6-3.

Table 4.6-3. Coefficients of conservatism (*C* values) descriptions used in the *FQA* for vascular plants.

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.

* Sources: Andreas et al. 2004; Lemly and Gilligan 2015

The most basic *FQA* index 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. An *FQAI* was also calculated for the vegetation communities at HOCU. 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):

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

Where I = the *FQAI* score, cc_{i} = the *C* value of plant, 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 *FQA* assessment. Additionally, these indices can be calculated using only native species within each plot (e.g., $\overline{C}_{(Native)}$, $FQAI_{(Native)}$).

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.

Garlic mustard (*Alliaria petiolata*) is an invasive species threat to HOCU. (NPS photo)

There are 106 invasive plants on the park's two "watch lists", including 66 species on the Early Detection Watch List (Table 4.6-4) and 40 species occurring on the Park-established Watch List (Table 4.6-5) (Young et al. 2016). These 106 plants were considered invasive exotic plants (IEP). Plants designated as high priority invasive species (Young et al. 2008) and not known to occur on the park constituted the "early detection watch list". Black locust (*Robinia pseudocacaia*) exhibits a variety of invasive traits and was included on the park-established list even though it is native to the U.S., Ohio, and possibly the HOCU area (Young et al. 2016). While aquatic species are listed on the two watch lists, only terrestrial plants were the focus of this assessment.

Primary data sources for examining invasive exotic plants are the vegetation classification and mapping plot data (Diamond et al. 2014) and Heartland Inventory and Monitoring Network (HTLN) invasives survey data (Young et al. 2016). For the Diamond et al. (2014) data, percent IEP cover for each 400m^2 vegetation classification plot 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—i.e., mean relative IEP cover. A total of 33 plots were distributed across all HOCU units except Spruce Hill. Additionally, data from surveys conducted by Young et al. (2008, 2012, 2016) in 2008, 2011, and 2015 were used to examine trends in the frequency and abundance of invasive species at HOCU over time and to guide and evaluate treatment success. The HTLN efforts surveyed restored prairie grasslands and wooded areas. The sampling design consisted of a uniform grid of search units approximately 2 acres in size. Three equidistant passes through each search unit were made along a 3–12m-wide belt transect and survey cells were not fully searched (Young et al. 2016) (Figure 4.6-5). The HTLN data and summaries complemented the Diamond et al. data; frequencies of listed IEPs were used to assign a trend to IEP condition. Invasive and nonnative plant data from the vegetation inventory project are also integrated into the Floristic Quality Assessment Index summaries.

Table 4.6-4. The 66 invasive plant species (IEP) on the Early Detection Watch List for HOCU (Young et al. 2008, 2012, 2016). These taxa have been designated as high priority invasive species and are not known to occur in the park.

Scientific Name	**Common Name**
Acer ginnala	Amur maple
Acer platanoides	Norway maple
Alnus glutinosa	European alder
Ampelopsis brevipedunculata	Amur peppervine
Bromus racemosus	Bald brome
Bromus sterilis	Poverty brome
Butomus umbellatus	Flowering rush
Celastrus orbiculatus	Oriental bittersweet
Centaurea solstitialis	Yellow star-thistle
Centaurea stoebe ssp. *micranthos*	Spotted knapweed
Coronilla varia	Crownvetch
Cynanchum louiseae	Louise's swallow-wort
Dioscorea oppositifolia	Chinese yam
Dipsacus laciniatus	Cutleaf teasel
Egeria densa	Brazilian waterweed
Elaeagnus umbellata	Autumn olive
Elaeagnus umbellate/angustifolia	Russian olive
Elymus repens	Quackgrass
Euonymus alata	Burningbush
Euonymus fortunei	Winter creeper
Euphorbia cyparissias	Cypress spurge
Euphorbia esula	Leafy spurge
Frangula alnus	Glossy buckthorn
Hedera helix	English ivy
Holcus lanatus	Common velvetgrass
Humulus japonicus	Japanese hop
Iris pseudacorus	Paleyellow iris
Lespedeza bicolor	Shrub lespedeza
Lespedeza cuneata	Sericea lespedeza
Ligustrum obtusifolium	Border privet
Linaria vulgaris	Butter and eggs
Lolium arundinaceum	Tall fescue
Lolium pratense	Meadow fescue
Lolium spp.	Ryegrass

Table 4.6-4 (continued). The 66 invasive plant species (IEP) on the Early Detection Watch List for HOCU (Young et al. 2008, 2012, 2016). These taxa have been designated as high priority invasive species and are not known to occur in the park.

Scientific Name	Common Name
Lonicera morrowii	Morrow's honeysuckle
Lonicera X *bella*	Showy fly honeysuckle
Lotus corniculatus	Bird's-foot trefoil
Lotus tenuis	Narrow-leaf bird's trefoil
Lythrum salicaria	Purple loosestrife
Microstegium vimineum	Nepalese browntop
Miscanthus sinensis	Chinese silvergrass
Myosotis scorpioides	True forget-me-not
Myriophyllum aquaticum	Parrot feather watermilfoil
Myriophyllum spicatum	Eurasian watermilfoil
Najas minor	Brittle waternymph
Onopordum acanthium	Scotch cottonthistle
Phalaris arundinacea	Reed canarygrass
Phragmites australis	Common reed
Poa compressa	Canada bluegrass
Polygonum cuspidatum	Japanese knotweed
Polygonum perfoliatum	Asiatic tearthumb
Polygonum sachalinense	Giant knotweed
Populus alba	White poplar
Potamogeton crispus	Curly pondweed
Pueraria montana var. *lobata*	Kudzu
Pyrus calleryana	Callery pear
Rhamnus cathartica	Common buckthorn
Rorippa nasturtium-aquaticum	–
Sonchus arvensis	Field sowthistle
Spiraea japonica	Japanese meadowsweet
Tanacetum vulgare	Common tansy
Torilis japonica	Erect hedgeparsley
Typha angustifolia	Narrowleaf cattail
Typha X *glauca*	–

Table 4.6-4 (continued). The 66 invasive plant species (IEP) on the Early Detection Watch List for HOCU (Young et al. 2008, 2012, 2016). These taxa have been designated as high priority invasive species and are not known to occur in the park.

Scientific Name	Common Name
Viburnum opulus	European cranberrybush
Wisteria floribunda	Japanese wisteria

Table 4.6-5. The 40 invasive plant species (IEP) on the Park-established Watch List for HOCU (Young et al. 2008, 2012, 2016). These species are known to occur within the park and, along with species on the Early Detection Watch List, form the list of invasives for the IEP surveys.

Scientific Name	Common Name
Ailanthus altissima	Tree of heaven
Albizia julibrissin	Silktree
Alliaria petiolata	Garlic mustard
Arctium minus	Lesser burdock
Berberis thunbergii	Japanese barberry
Bromus inermis	Smooth Brome
Bromus tectorum	Cheatgrass
Carduus nutans	Nodding plumeless thistle
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Daucus carota	Queen Anne’s lace
Dipsacus fullonum	Fuller’s teasel
Elaeagnus angustifolia	Russian olive
Glechoma hederacea	Ground ivy
Hemerocallis fulva	Orange daylily
Hesperis matronalis	Dames rocket
Hypericum perforatum	Common St. Johnswort
Leonurus cardiac	Common motherwort
Ligustrum vulgare	European privet
Lonicera japonica	Japanese honeysuckle
Lonicera maackii	Amur honeysuckle
Lonicera tatarica	Tatarian honeysuckle
Lysimachia nummularia	Creeping jenny
Melilotus officinalis	Sweetclover
Morus alba	White mulberry
Pastinaca sativa	Wild parsnip

Table 4.6-5 (continued). The 40 invasive plant species (IEP) on the Park-established Watch List for HOCU (Young et al. 2008, 2012, 2016). These species are known to occur within the park and, along with species on the Early Detection Watch List, form the list of invasives for the IEP surveys.

Scientific Name	Common Name
Paulownia tomentosa	Princesstree
Poa pratensis	Kentucky bluegrass
Potentilla recta	Sulphur cinquefoil
Prunus mahaleb	Mahaleb cherry
Robinia pseudoacacia	Black locust (NATIVE)
Rosa multiflora	Multiflora rose
Rumex acetosella	Common sheep sorrel
Rumex crispus	Rumex crispus
Saponaria officinalis	Bouncingbet
Sorghum halepense	Johnsongrass
Torilis arvensis	Spreading hedgeparsley
Ulmus pumila	Siberian elm
Verbascum thapsus	Common mullein
Vinca minor	Common periwinkle

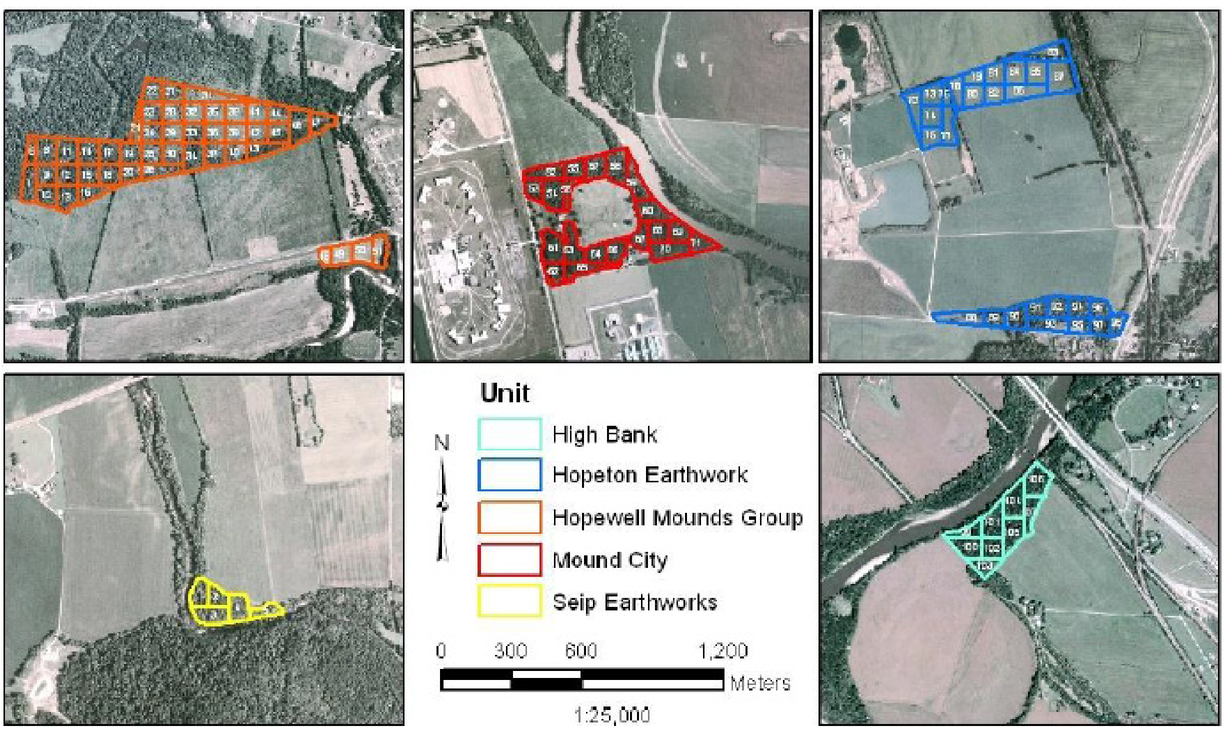


Figure 4.6-5. Invasive plant search units (n=107) on Hopewell Culture National Historical Park. Search units focused on restored prairies and intact forests on the park and did not include Spruce Hill (Young et al. 2012).

Forest Pests and Diseases

Forest pest and diseases are a natural and important part of a forest ecosystem. Native insect and pathogens remove old/weakened trees from the canopy allowing for new forest growth and nutrient cycling to occur. This process of forest regeneration and recycling of nutrients has occurred for a millennia and is essential for healthy, stable forest ecosystems (Stolte 1997). Historically, native forest pest/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 pest 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).

Forest ecosystems in Ohio have a long and varied history of impacts associated with forest pests and pathogens. These issues have been shown to alter species composition and change forest community structure over time. For example, the American chestnut (*Castanea dentata*) was once a dominant canopy species of the Eastern Deciduous Forest until it was wiped out by the chestnut blight (*Cryphonectria parasitica*) in the early to mid-20th century (ODNR 2018). Similarly, the American elm (*Ulmus americana*), another important component of the eastern hardwood forests, has had its numbers significantly reduced by the fungal Dutch elm disease (*Ophiostoma novo-ulmi*). Other forest disease and pest issues across Ohio include the anthracnose fungus, gypsy moth (*Lymantria dispar dispar*) and beech bark disease (*Nectria coccinea*) which have all have increased the mortality of overstory trees. The result of these disturbances is a forest that is very different from the forest that once covered much of the Ohio and the Allegheny Plateau.

Impacts associated with forest disease and pest issues at HOCU were evaluated using data from Fisichelli et al. (2015) as well as data from the vegetation inventory project for HOCU (Diamond et al. 2014). In addition, information from the 2013–2027 National Insect and Disease Risk Map (NIDRM) (Krist et al. 2014) was also used to identify potential looming disease and pest threats to HOCU forest. 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

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 instances, there is expected to be a number of “winners” and “loser” 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. Fisichelli et al. (2014) modeled impacts to forest ecosystems at 121 eastern NPS units spread across the eastern U.S. to understand what the magnitude of potential impacts may be. For this analyses, two climate change scenarios (“least” change and “major” change) were evaluated. Results from this data were used to evaluate the vulnerability of forest communities at HOCU to climate change.

4.6.3. Reference Conditions

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 would include changes that may have occurred due to the use of the landscape by indigenous populations. The ideal condition at HOCU 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 HOCU, 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 HOCU is sufficient to maintain the plant community in a stable or improving condition. The reference condition rating framework applied to HOCU vegetation community indicators is shown in Table 4.6-6.

Table 4.6-6. Reference condition rating framework for vegetation community indicators at HOCU (condition rating cutoffs are based on professional opinion of the authors).

Indicator	Reference, High Quality or Good Condition	Condition Warrants Moderate Concern	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
Invasive Exotic Plants	<10% IEP Cover	10–25% IEP Cover	>25% IEP Cover
Floristic Quality Assessment Index (*FQAI*)	≥45	15–45	<15
Forest Pests and Disease	<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 predicated under either change scenario.	Major predicted increases or decreases in habitat for >10 species with species extirpation being predicated under either change scenario.

Table 4.6-6 (continued). Reference condition rating framework for vegetation community indicators at HOCU (condition rating cutoffs are based on professional opinion of the authors).

Indicator	Reference, High Quality or Good Condition	Condition Warrants Moderate Concern	Condition Warrants Significant Concern
Grassland Restoration and Conversion	Significant progress toward *Grassland Conversion Plan* (2017) goals. Converted areas are being managed in accordance with BMPs.	Some progress toward *Grassland Conversion Plan* (2017) goals. Management of converted and restoration areas needs additional attention.	Little progress toward *Grassland Conversion Plan* (2017) goals. The condition of vegetation/soils in converted and restoration areas is poor.

Species Composition and Diversity

The average percent cover of native species was used to evaluate vegetation community composition, as the presence of non-native species often indicate disturbance. The percentage of non-native plant species for national parks units within the Eastern Deciduous Forest is estimated to be between 10% and 50% of the flora with a mean value of 20% (Fisichelli et al. 2014). The reference condition rating framework for vegetation community indicators at HOCU is shown in Table 4.6-6.

Floristic Quality Assessment Index (FQAI) and Coefficient of Conservatism

The *FQA* metrics (e.g.,$\overline{C}$, $\overline{C}_{(Native)}$, *FQAI*, *FQAI*$_{(Native)}$), reflects the "quality" or "naturalness" of a site (Andreas et al. 2004). Numerous studies have shown the *FQA* approach to be an excellent predictor of plant community condition in both upland and bottomland environments (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 an *FQA* rating 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. Floristic quality values have been calculated for a number of Ohio's highest quality vegetation communities (Fennessy 1998; Andreas et al. 2004; Gara 2013). Representative *FQAI* scores derived from these quantitative, plot-based sampling efforts from these high quality vegetation communities in Ohio tend to conform to the Swink and Wilhelm (1994) *FQA* rating system (Andreas et al. 2004). The *FQA* rating system guidance from Swink and Wilhelm (1994) provides a reference benchmark for conditions at HOCU (Table 4.6-6).

Invasive Exotic Species

The cover of IEP species is thought to be an indicator of condition (Young et al. 2016). In general, IEP cover values above 50% indicate highly disturbed systems, which are typical for most urban areas. 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 instances, anthropogenic disturbances have been directly linked to 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).

The ideal condition for vegetation communities at HOCU would be the complete absence of non-native species, representing conditions during pre-settlement times. Because this type of reference condition is not feasible for a unit with the history and extent of HOCU, 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 HOCU 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 vegetation communities should contain less than 10% cover of terrestrial invasive species in order to be rated as "good or functioning properly". The reference condition rating framework as it relates to IEP cover at HOCU is shown in Table 4.6-6.

Forest Pests and Diseases

Reference conditions for forests are those that are thought to have existed before forest health, structure, and regeneration were altered by exotic forest pest/disease issues and where native disease/pest issues occurred at background levels. Because this type of reference condition is not feasible for a unit with the history and extent of HOCU, 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 HOCU 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 HOCU is shown in Table 4.6-6.

Forest Vulnerability to Climate Change

Modeled data from Fisichelli et al. (2014) was used to assess the vulnerability of HOCU forest ecosystems to changes in climate. This analyses evaluated changes in potential habitat suitability for a variety of tree species based on both a "least change" and a "major change" scenario. The analysis compared forest condition in 1990 (baseline or reference condition) to modeled results from the 2017–2099 based on the two scenarios. The reference condition rating system for forest vulnerability to climate change at HOCU is shown in Table 4.6-6. 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 Significant Concern rating.

Prairie Restoration and Grassland Management

The condition of native grassland is being treated in an administrative, planning and implementation context. In 2017, the park established goals for prairie restoration and conversion of agricultural areas. Progress toward these goals is used to evaluate condition of the resource. The ecological condition of the prairies and success relative to specific vegetation quality or diversity objectives is not considered here due to recent implementation and lack of quantitative data.

4.6.4. Condition and Trend

Species Composition and Diversity

The proportion of native species recorded for each plan community association was examined. Total species richness averaged 30.06 species per plot for the 33 vegetation inventory plots at HOCU (Figure 4.6-6) (Diamond et al. 2014). The highest mean total richness (43.17 species) was found in the *Acer saccharum – Quercus muehlenbergii* / *Cercis canadensis* Limestone Forest (6 total plots). The average proportion of native plant species within each plot at HOCU averaged 75.08% across all plots and varied from a low of 54.76% native for plots within the *Elaeagnus umbellata – Gleditsia triacanthos* / *Rubus pensilvanicus* Woodland / Shrubland to 88.41% native for plots in the *Acer saccharum – Quercus muehlenbergii* / *Cercis canadensis.* Limestone Forest (Figure 4.6-7). Based on the available data, species composition is in good condition for vegetation communities at HOCU, with an unchanging trend, and a medium level of confidence.

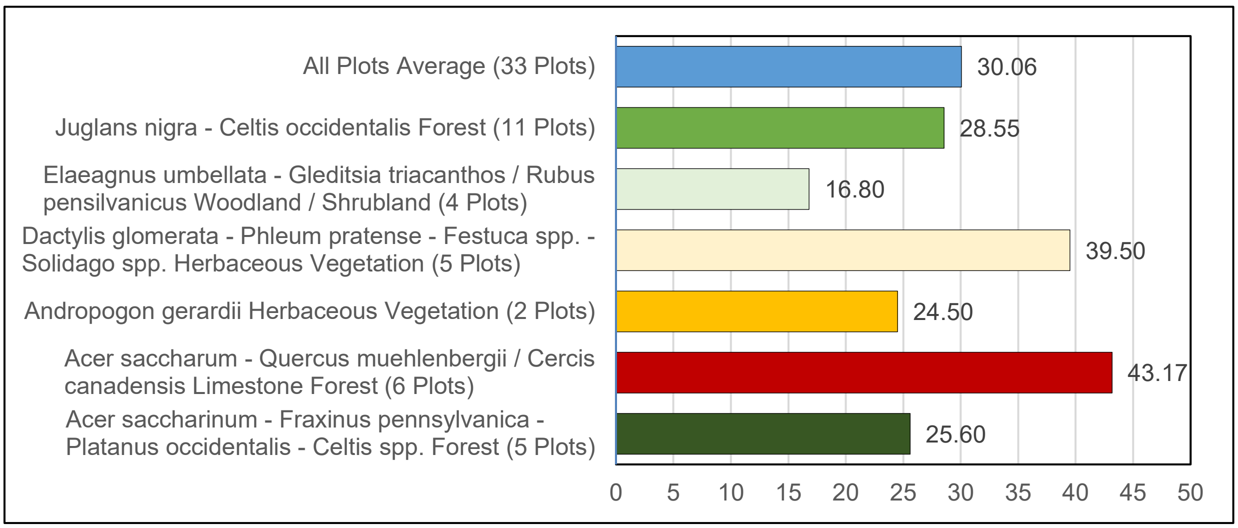


Figure 4.6-6. Average species richness for all plots combined and by association for HOCU based on plot data collected by Diamond et al. (2014).

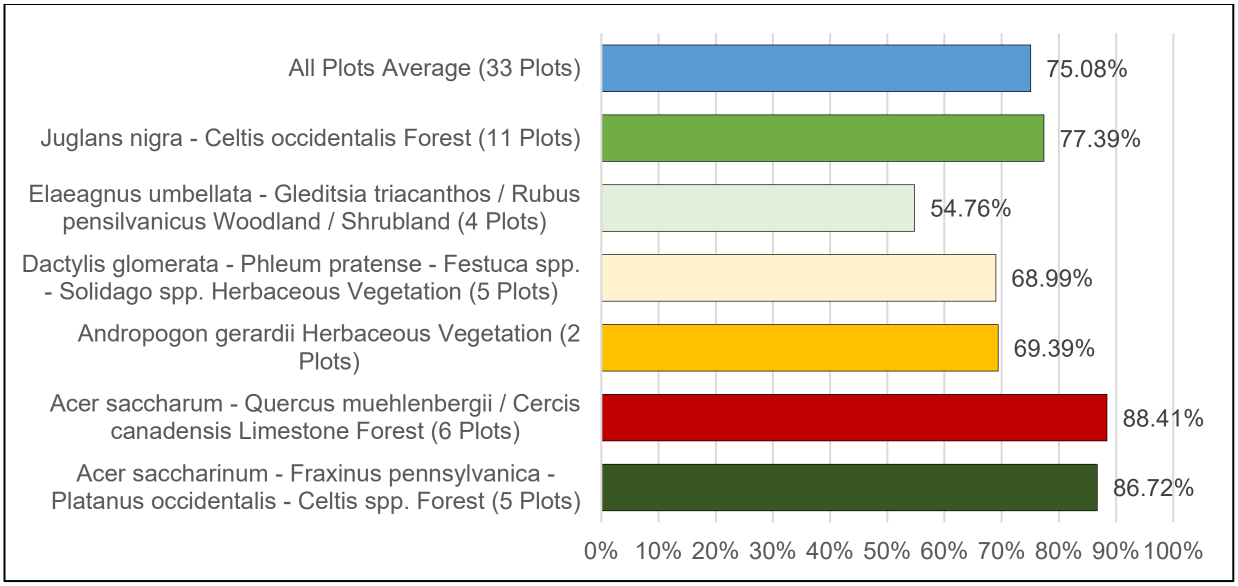


Figure 4.6-7. Average percent native species composition for all plots combined and by association for HOCU based on plot data collected by Diamond et al. (2014).

<u>Invasive Exotic Plants (IEP)</u>

Percent IEP cover by plot averaged 30.5% for all vegetation plots at HOCU using the vegetation inventory plot data from Diamond et al. (2014). Mean percent IEP cover by association/map class varied from a low of 1.5% for the *Andropogon gerardii* Grassland to a high of 57.45% for the *Juglans nigra – Celtis occidentalis* Forest (Figure 4.6-8).

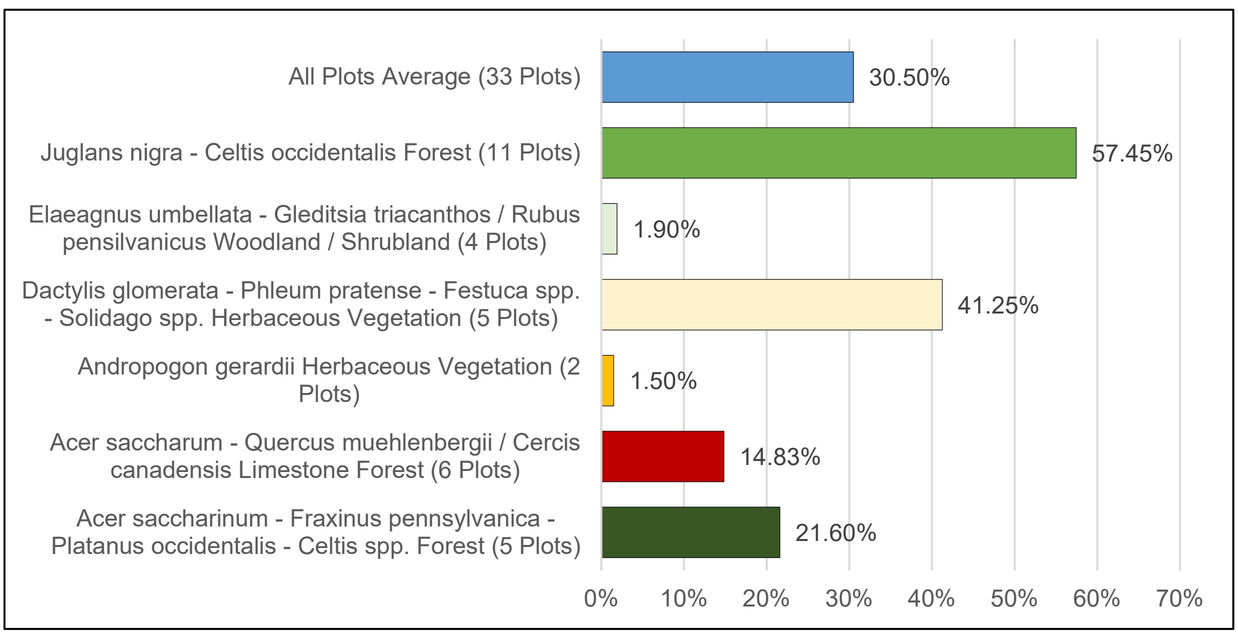


Figure 4.6-8. Average plot % IEP cover for all plots combined and by association for HOCU based on plot data collected by Diamond et al. (2014).

Heartland Inventory and Monitoring Network surveys conducted in 2008, 2011 and 2015 identified a total of 54 invasive exotic plant species present on park watch lists. Nine species showed non-overlapping abundance ranges with five showing declines in abundance, although of these only *Lonicera maackii* (Amur honeysuckle) and *Pyrus calleryana* (Callery pear) were subjected to any treatment. Based on the relatively high abundance of the woody plant species *Elaeagnus umbellata* (autumn olive) and bush *Lonicera* spp. (*L. maackii, L. morrowii, L. tatarica*) and the relative effectiveness of controls, management of these plants in high priority areas will lead to wide-scale changes in the park's vegetation. Two species which should be considered for control due to possible recent increases are *Ailanthus altissima* (tree-of-heaven) and *Microstegium vimineum* (Japanese stiltgrass). Both species, although already widespread and abundant, may be controlled in high priority areas. Finally, the relatively early stage of colonization by *Phalaris arundinacea* (reed canarygrass), *Polygonum cuspidatum* (Japanese knotweed), *Pyrus calleryana* (Callery pear), and *Securigera varia* (crownvetch) suggests these species should continue to be targeted for rapid response efforts (Young et al. 2016). The distribution of IEP species frequencies over time within the 107 search units was examined to provide an index of trend between 2008 and 2015 (Figure 4.6-9). Park-wide IEP frequencies increased for most frequency classes between 2008 and 2015.

Invasive plants continue to occupy significant area within HOCU; 98 of 107 search units are occupied by at least 1 invasive plant species. This problem likely requires ongoing control efforts of both widely-distributed, well-established species as well as early detection species (Young et al. 2016). When the rating system from Potyondy and Geier (2011) is applied to the vegetation classification data from 2012, the forest and prairie vegetation communities at HOCU are assigned a degraded condition warranting significant concern. Although IEP control efforts may successfully reduce localized populations of target species, park-wide frequency data indicates that the extent of many IEPs is expanding. Therefore, we conclude there is a deteriorating trend in IEP. Confidence in the assessment is high due to the recent quantitative data available and multiple data sources.

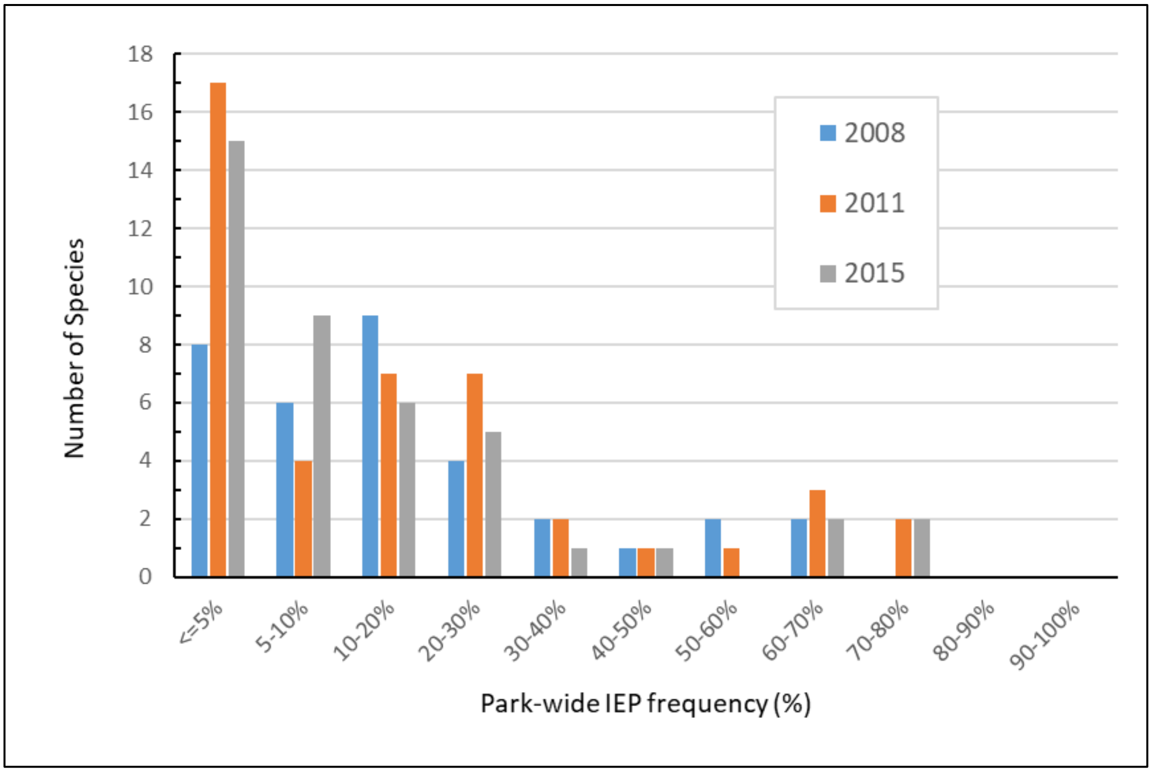


Figure 4.6-9. Frequency histogram of invasive plants found in Hopewell Culture National Historical Park during 2008, 2011, and 2015 surveys (Data from Young et al. 2016).

Floristic Quality Assessment Index (FQAI)

The current condition of the vegetation communities at HOCU, as reflected by *FQAI*, shows the communities to be in a degraded condition. The average plot *FQAI* and *FQAI* $_{\text{(Native)}}$ score was 14.25 and 15.93, respectively, for the 33 vegetation plots sampled during the HOCU vegetation inventory project (Figure 4.6-10). Average *FQAI* and *FQAI* $_{\text{(Native)}}$ scores by association varied from a low of 3.76 (*FQAI*) and 4.99 ($FQAI_{\text{Native}}$) for the *Elaeagnus umbellata* ruderal woodland to a high of 23.50 (*FQAI*) and 25.03 ($FQAI_{\text{Native}}$) for the *Acer saccharum* limestone forest. When the *FQA* rating system metric from Swink and Wilhelm (1994) is applied, the condition of vegetation communities at HOCU warrants a degraded condition warranting a significant level of concern for vegetation communities at HOCU. The indicator is assigned an unchanging trend and there is a medium level of confidence.

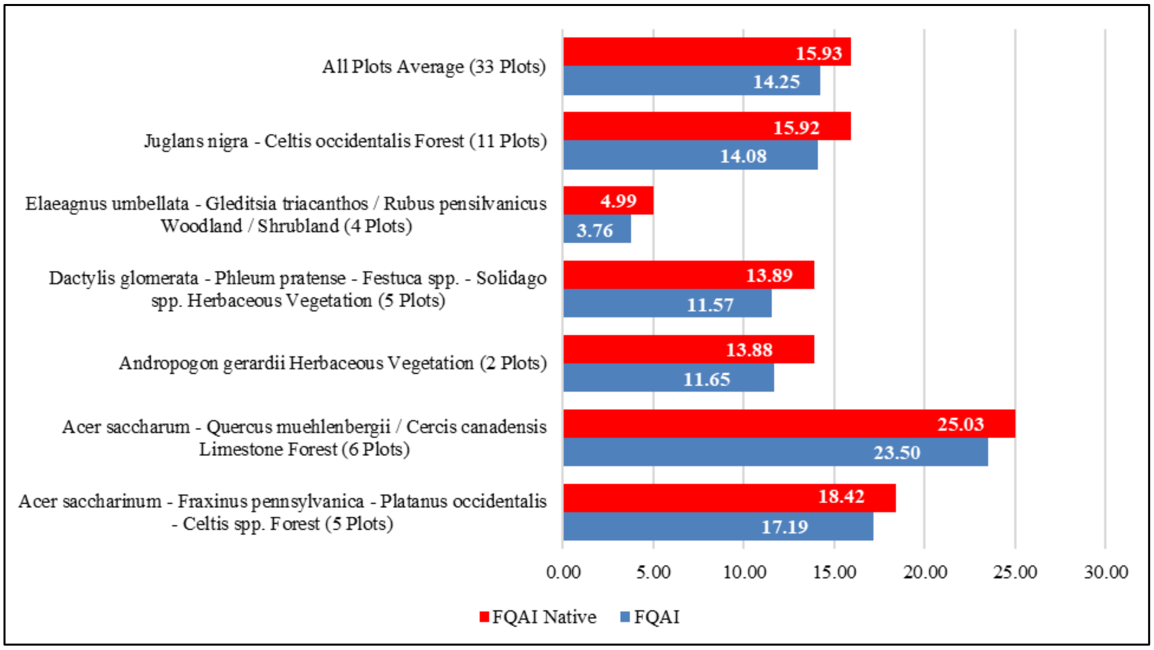


Figure 4.6-10. Average plot FQAI and FQAI (Native) scores for all plots combined and by association for HOCU based on plot data collected by Diamond et al. (2014).

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

The average plot $\overline{C}$ and $\overline{C}_{\text{(Native)}}$ score was 2.57 and 3.25, respectively, for the 33 vegetation plots sampled during the HOCU vegetation inventory project (Figure 4.6-11). Average $\overline{C}$ and $\overline{C}_{\text{(Native)}}$ scores by association varied from a low of 0.87 ($\overline{C}$) and 1.55 ($\overline{C}_{\text{Native}}$) for the *Elaeagnus umbellata* ruderal woodland to a high of 3.57 ($\overline{C}$) and 4.07 ($\overline{C}_{\text{Native}}$) for the *Acer saccharum* limestone forest. When the FQA rating system metric from Swink and Wilhelm (1994) is applied, vegetation communities at HOCU warrant a significant level of concern, with an unchanging trend, and a medium level of confidence.

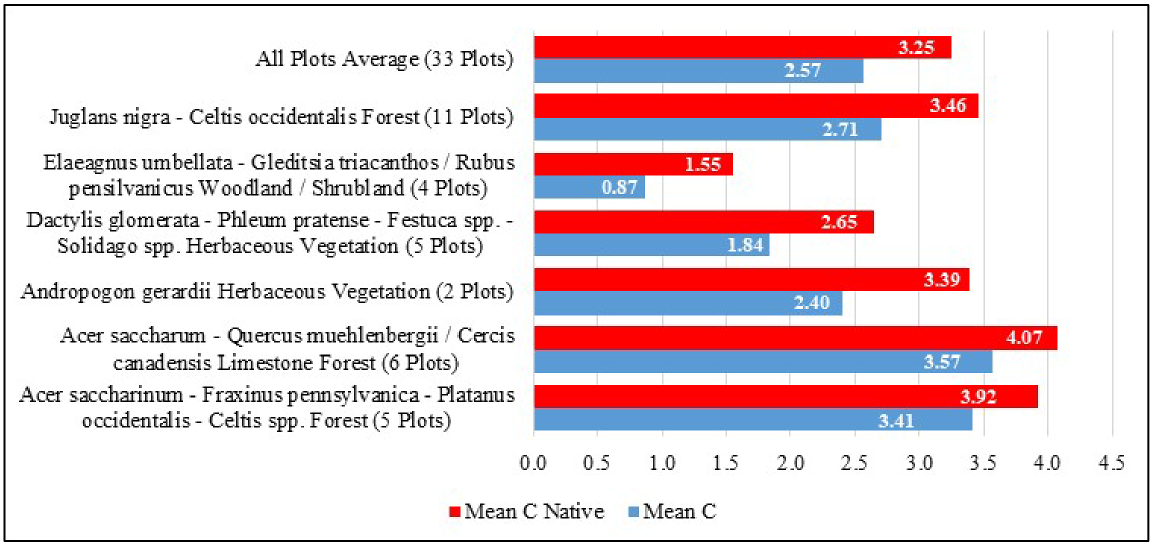


Figure 4.6-11. Average plot $\overline{C}$ and $\overline{C}_{(\text{Native})}$ scores for all plots combined and by association for HOCU based on plot data collected by Diamond et al. (2014).

Forest Pests and Disease

Fisichelli et al. (2015) identified 43 exotic tree pests and diseases that are/could be at HOCU including 32 that have been detected at the statewide level and 11 that are known to occur at the county level for HOCU. Tree species impacted by these diseases and pests include, but are not limited to, ash species (*Fraxinus* spp.), beech (*Fagus grandifolia*), American elm (*Ulmus americana*), sugar maple (*Acer saccharum*), and shingle oak (*Quercus imbricaria*; USDA 2018). Major disease and pest issues which are currently or are predicted to impact forest communities at HOCU include Dutch elm disease, Beech bark disease, and the Emerald Ash Borer (*Agrilus planipennis*), or EAB, which has recently been documented near the park and is found in all counties in Ohio (Figure 4.6-12) (USDA APHIS 2018). EAB 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 Ohio.

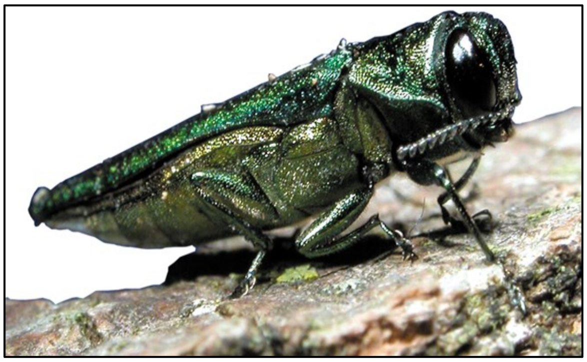


Figure 4.6-12. Emerald Ash Borer (Agrilus planipennis) or EAB is a new pest that is just beginning to impact forest communities at HOCU. Photo courtesy of NPS.

According to the modeled results from the 2013–2027 National Insect and Disease Risk Map (NIDRM; Krist et al. 2014), little or no areas at HOCU are thought to be susceptible to high levels of tree mortality in excess of 25% over the 15-year period running from 2013 to 2027. It is estimated that approximately 11% of all tree biomass at HOCU is at risk to forest pests over this period. Modeled impacts to the basal area (BA) of specific trees species at HOCU include a 30% decline in American elm due to Dutch elm disease, a 21% decline in ash species due to EAB, a 21% decline in sugar maple due to maple decline, a 18% decline in beech due to Beech Bark Disease, and a 17% decline in shingle oak due to oak decline (Figure 4.6-13). All modeled results assume no active management over the timeframe (Krist et al. 2014).

Based on the best available data, including modeled data from the NIDRM, the forest pest and disease indicator at HOCU appears to be in good condition. Only 11% of the tree biomass is modeled to be at risk over the 2013 to 2027 timeframe, well below the 20% threshold for moderate condition. However, modeled impacts to individual species (e.g., 30% decline in elm species, 21% decline in ash) are likely to significantly impact forest structure and dominance in certain areas Based on this, a moderate condition warranting a moderate level of concern is applied to this indicator. A deteriorating trend is applied due to on-going impacts and forecasted impacts as pest species become more established in the HOCU area (e.g., EAB). Due to the modeled nature of this data, a low level of confidence is assigned.

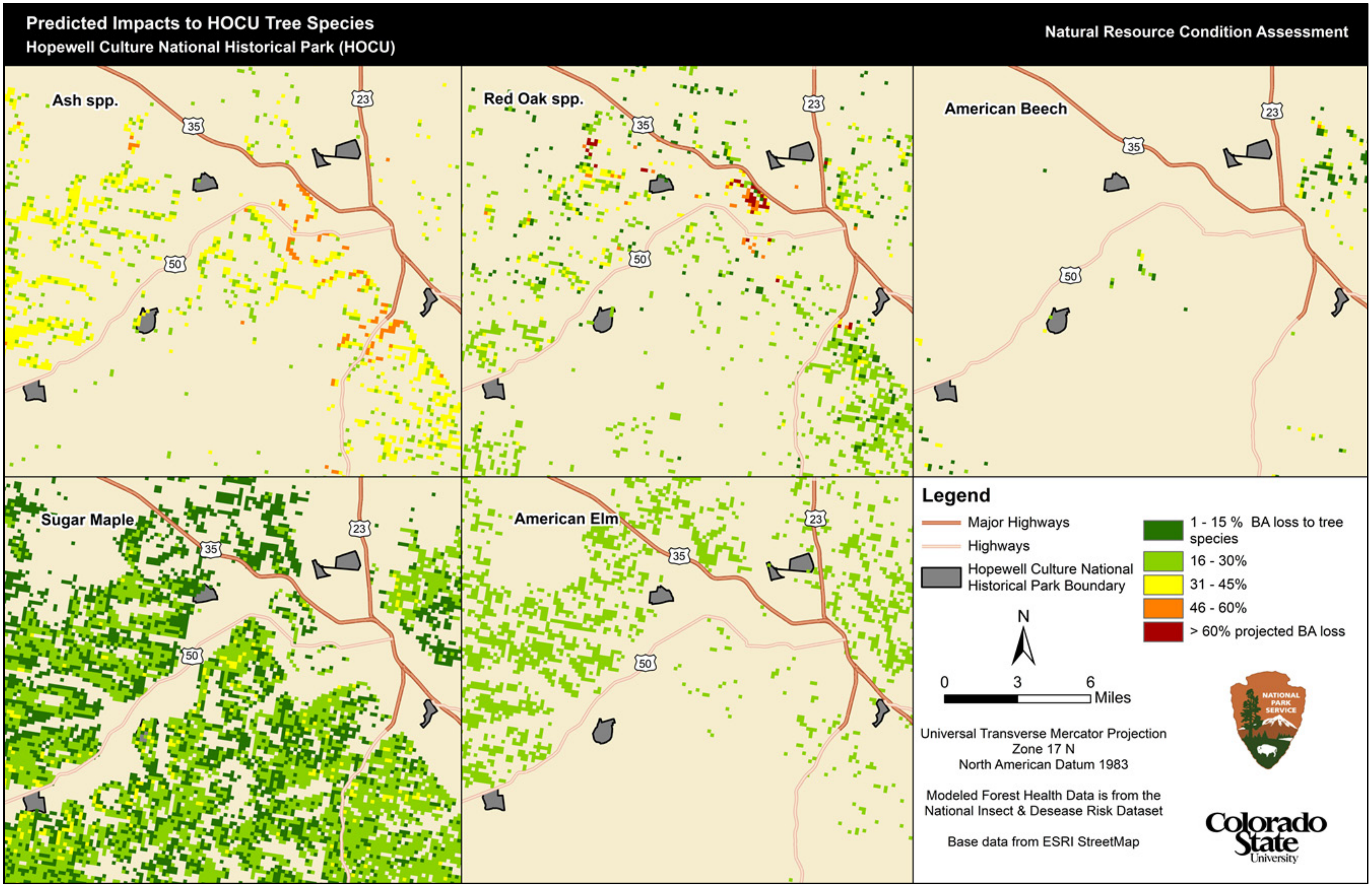


Figure 4.6-13. Modeled predicted impacts to individual tree species from 2013 to 2027 at HOCU based on the results of the NIDRM (Krist et al. 2014). Data indicates predicted loss in basal area (BA) by tree species due to a variety of forest diseases and pests.

Forest Vulnerability to Climate Change

Modeled changes in HOCU's climate were generated for two scenarios (Table 4.6-7). Predicted impacts to HOCU forest based on modeled data from Fisichelli et al. (2015) are substantial (Table 4.6-8). 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 16 species will face small-large decreases in potential habitat based on the two climate change scenarios. Additionally, several of these species are predicted to face extirpation by the year 2100 regardless of scenario (i.e., *Betula lenta*, *Pinus strobus*, *Populus grandidentata*, *Prunus pensylvanica*, *Tilia Americana*). Alternatively, 15 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 4.6-8).

Predicted impacts from climate change were not always straightforward; 24 species were predicted to have mixed impacts from the two scenarios. Fisichelli et al. (2015) also predicted 11 new species ranges could expanded into HOCU resulting in new species or communities occurring within the park by the year 2100 (Table 4.6-8). While the degree of impacts from climate change to individual species is unknown at HOCU, modeled results from Fisichelli et al. (2015) paint a likely picture that HOCU 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 HOCU appears to warrant significant concern. Major increases or decreases in potential habitat range are being predicted for over 50 individual tree species with a number of species facing extirpation under either one or both the two climate change scenarios. A deteriorating trend is assigned due to the high potential for future impacts to HOCU forest communities from climate change. We assign a low level of confidence to this assessment due to the modeled nature of the data.

Table 4.6-7. Modeled changes in climate from baseline (1961–1990) to future (2070–2099) based on two climate change scenarios. This data was used to predict impacts to individual tree species at HOCU. Data from Fisichelli et al. 2015.

Climate Variable	Baseline (1961–1990)	Least Change (2070–2099)	Major Change (2070–2099)
mean annual temperature	10.7 °C (51.2 °F)	+2.1 °C (+3.8 °F)	+7.1 °C (+12.7 °F)
mean January temperature	−2.1 °C (28.1 °F)	+1.6 °C (+2.9 °F)	+5.5 °C (+10 °F)
mean July temperature	22.6 °C (72.6 °F)	+2.1 °C (+3.7 °F)	+8.5 °C (+15.3 °F)
seasonality (July–January temp.)	24.7 °C (44.5 °F)	+0.5 °C (+0.8 °F)	+3 °C (+5.3 °F)
mean May–September temp.	19.7 °C (67.5 °F)	+2.2 °C (+3.9 °F)	+8 °C (+14.5 °F)
annual precipitation	1025 mm (40.4 in)	+9.7%	+12.5%
May–September precipitation	486 mm (19.1 in)	+9.9%	−1.5%

Table 4.6-8. Modeled predicted changes in potential habitat for tree species at HOCU (2100 compared with 1990) based on data from Fisichelli et al. (2014, 2015). Species are grouped based on change class designations for two future climate scenarios.

Predicted Change	Scientific Name	Common Name	Least Change	Major Change
Decreases in Potential Habitat	*Acer rubrum*	red maple	small decrease	large decrease
	Acer saccharum	sugar maple	small decrease	extirpated
	Aesculus glabra	Ohio buckeye	large decrease	extirpated
	Aesculus octandra	yellow buckeye	small decrease	small decrease
	Betula lenta	sweet birch	extirpated	extirpated
	Fagus grandifolia	American beech	small decrease	large decrease
	Fraxinus americana	white ash	small decrease	large decrease
	Pinus rigida	pitch pine	small decrease	small decrease
	Pinus strobus	eastern white pine	extirpated	extirpated
	Pinus virginiana	Virginia pine	small decrease	small decrease
	Populus grandidentata	bigtooth aspen	extirpated	extirpated
	Prunus pensylvanica	pin cherry	extirpated	extirpated
	Prunus serotina	black cherry	large decrease	large decrease
	Quercus prinus	chestnut oak	small decrease	large decrease
	Robinia pseudoacacia	black locust	small decrease	large decrease
	Tilia americana	American basswood	extirpated	extirpated
No Change in Potential Habitat	*Carpinus caroliniana*	American hornbeam	no change	no change
	Carya tomentosa	mockernut hickory	no change	no change
	Oxydendrum arboreum	sourwood	no change	no change
Increases in Potential Habitat	*Acer saccharinum*	silver maple	small increase	large increase
	Carya cordiformis	bitternut hickory	large increase	large increase
	Diospyros virginiana	common persimmon	large increase	large increase
	Fraxinus pennsylvanica	green ash	small increase	large increase
	Gleditsia triacanthos	honeylocust	small increase	small increase
	Juniperus virginiana	eastern redcedar	large increase	large increase
	Liquidambar styraciflua	sweetgum	large increase	large increase
	Morus rubra	red mulberry	large increase	large increase
	Pinus echinata	shortleaf pine	large increase	large increase
	Populus deltoides	eastern cottonwood	small increase	large increase
	Quercus imbricaria	shingle oak	large increase	large increase
	Quercus muehlenbergii	chinkapin oak	large increase	small increase

Table 4.6-8 (continued). Modeled predicted changes in potential habitat for tree species at HOCU (2100 compared with 1990) based on data from Fisichelli et al. (2014, 2015). Species are grouped based on change class designations for two future climate scenarios.

Predicted Change	Scientific Name	Common Name	Least Change	Major Change
Increases in Potential Habitat (continued)	*Quercus stellata*	post oak	large increase	large increase
	Quercus velutina	black oak	small increase	small increase
	Salix nigra	black willow	large increase	small increase
Mixed Results	*Acer negundo*	boxelder	no change	small decrease
	Amelanchier spp.	serviceberry	no change	large decrease
	Asimina triloba	pawpaw	small increase	extirpated
	Betula nigra	river birch	no change	large increase
	Carya glabra	pignut hickory	no change	small decrease
	Carya ovata	shagbark hickory	small increase	no change
	Celtis occidentalis	hackberry	small increase	small decrease
	Cercis canadensis	eastern redbud	no change	small decrease
	Cornus florida	flowering dogwood	no change	small decrease
	Juglans nigra	black walnut	small increase	large decrease
	Liriodendron tulipifera	yellow-poplar	no change	large decrease
	Maclura pomifera	osage-orange	no change	small increase
	Nyssa sylvatica	blackgum	small increase	no change
	Ostrya virginiana	eastern hophornbeam	small decrease	no change
	Platanus occidentalis	sycamore	no change	small decrease
	Quercus alba	white oak	no change	small decrease
	Quercus bicolor	swamp white oak	small increase	large decrease
	Quercus coccinea	scarlet oak	small increase	small decrease
	Quercus macrocarpa	bur oak	no change	large increase
	Quercus palustris	pin oak	small increase	small decrease
	Quercus rubra	northern red oak	no change	large decrease
	Sassafras albidum	sassafras	no change	large decrease
	Ulmus americana	American elm	no change	large decrease
	Ulmus rubra	slippery elm	no change	large decrease
New Potential Habitat	*Carya illinoinensis*	pecan	–	new entry
	Carya texana	black hickory	new entry	new entry
	Celtis laevigata	sugarberry	new entry	new entry
	Pinus taeda	loblolly pine	–	new entry
	Quercus falcata var. *falcata*	southern red oak	new entry	new entry

Table 4.6-8 (continued). Modeled predicted changes in potential habitat for tree species at HOCU (2100 compared with 1990) based on data from Fisichelli et al. (2014, 2015). Species are grouped based on change class designations for two future climate scenarios.

Predicted Change	Scientific Name	Common Name	Least Change	Major Change
New Potential Habitat (continued)	*Quercus marilandica*	blackjack oak	new entry	new entry
	Quercus nigra	water oak	–	new entry
	Quercus phellos	willow oak	–	new entry
	Quercus shumardii	Shumard oak	–	new entry
	Ulmus alata	winged elm	new entry	new entry
	Ulmus crassifolia	cedar elm	–	new entry

<u>Prairie Restoration and Grassland Management</u>

The park has planted over 240 acres of native grassland over the past few years, exceeding its original grassland conversion goals. Additional restoration areas are planned, and the phasing out of nearly all haying and most mowing areas will be achieved within several more years (pers. comm. Jason Snider, 2019). Administratively, these areas are in good condition with an improving trend. Confidence in the assessment is high. Additional management activities, including weed management and possibly grazing and/or fire should improve the floristic quality of the areas over time (pers. comm. Bruce Lombardo, 2016).

<u>Overall Condition</u>

The data presented above suggest the current condition of vegetation communities at HOCU warrants moderate concern and major plant communities are in a degraded condition persisting under a variety of disturbances. A summary of all indicators is shown in Table 4.6-9.

Table 4.6-9. Condition and trend summary for vegetation communities at Hopewell Culture National Historical Park.

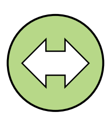
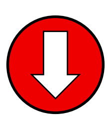
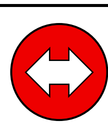
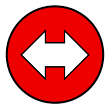
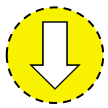
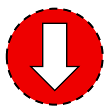
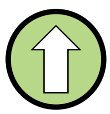
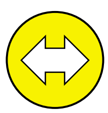
Indicator	Condition Status/Trend	Rationale
Native Species Composition		Native species composition averaged 75.08% across all vegetation plots at HOCU.
Invasive Exotic Plants (IEP)		Vegetation plots averaged 30.5% IEP cover. Some progress controlling localized patches of some species, but overall trend appears to be deteriorating; some species are expanding while others are controlled.
Floristic Quality Assessment Index (*FQAI*)		The average plot *FQAI* and *FQAI* (Native) score was 14.25 and 15.93, respectively, for the 33 vegetation plots sampled during the HOCU vegetation inventory project

Table 4.6-9 (continued). Condition and trend summary for vegetation communities at Hopewell Culture National Historical Park.

Indicator	Condition Status/Trend	Rationale
Mean Coefficient of Conservatism ($\overline{C}$)		The average plot $\overline{C}$ score was 2.57 for vegetation plots at HOCU and the average plot $\overline{C}_{(Native)}$ 3.25. Swink and Wilhelm (1994) regarded sites with a $\overline{C}$ < 3.5 as "degraded".
Forest Pests and Disease		A variety of forest disease and pest issues currently are or are predicted to impact HOCU. The predicted declines in individual tree species (e.g., 21% decline in Ash spp.) warranted the moderate condition. A low confidence 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 HOCU. A low confidence level is placed on this assessment due to the modeled nature of the data.
Prairie Restoration and Grassland Management (Administrative)		The park has planted over 240 acres of native grassland over the past few years, exceeding its original grassland conversion goals. Additional restoration areas are planned, and the phasing out of nearly all haying and most mowing areas will be achieved within several more years. Additional management activities, including weed management and possibly grazing and/or fire should improve the floristic quality of conversion areas over time
Vegetation Communities overall		**The condition of vegetation communities at HOCU warrants moderate concern with an unchanging trend. Confidence in the assessment is medium.**

Overall trends are difficult to assess but several factors indicate current vegetation community conditions will change in the near future. Modeled data predict that HOCU forests 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. 2015). Based on this, an unchanging trend is applied to this assessment. However, this may be balanced somewhat by ongoing and new vegetation management activities and initiatives.

4.6.5. 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 HOCU vegetation communities. Periodic monitoring is recommended to document changes in vegetation and help direct management activities over time.

4.6.6. Sources of Expertise

- David Diamond, MoRAP, Vegetation inventory and mapping project for HOCU.

- Nicholas Fisichelli, NPS Climate Program, Issues related to climate change and forest disease and pests.
- Craig Young, Inventory and Monitoring Heartland Network, invasive exotic plant monitoring.
- Jason Snider, Biological Technician, HOCU.

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4.7. Birds

4.7.1. Background and Importance

Birds are conspicuous components of parks located within grassland and hardwood forest ecotones and an important natural resource within parks of the HTLN. The tallgrass prairie openings that once occupied the region where HOCU is located historically consisted of the tallest and lushest grasslands of the Great Plains, but these areas within the park are now largely dominated by introduced grasses including orchard grass (*Dactylis glomerata*) and timothy (*Pleum pretense*) (Peitz 2015, Diamond et al. 2014). Some grasslands are being restored using native prairie species. The hardwood forests of the area were dominated by oak-hickory and other deciduous trees, but now include ruderal forests that are dominated by exotic species like amur honeysuckle (*Lonicera maakii*) (Peitz 2015, Diamond et al. 2014). This change in the grasslands and forests of the region has resulted in declines in the avian fauna of the region since the 1970s (Pardieck et al. 2018). The decline in bird populations has been caused by multiple factors including the conversion of grassland and forest to other land cover types, habitat fragmentation, and increasing human population growth (Lookingbill 2012; Hansen and Gryskiewicz 2003). The NPS formally recognizes this decline, 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 2015).

Birds, including waterbirds, are good indicators of changes in ecosystems (Stolen et al. 2005 and Butler et al. 2012), partly because they occur across a continuum of anthropogenic disturbances, species assemblages are predictive of these disturbance levels, birds are easily detected using standardized methods, and are well researched, 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.

Grasslands and hardwood forests at HOCU support wintering, feeding, and breeding populations of both resident and migrating avian species. Relative to the surrounding developed and agricultural landscape, HOCU is especially valuable because it provides some unfragmented patches of grassland and forest that serve as a refuge within a highly altered landscape. Habitat fragmentation and conversion of native habitats negatively impacts populations of some breeding and resident birds at HOCU, 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 park may be indicative of ecosystem change due to landuse and other stressors. Avian community composition and diversity should improve with the restoration of the grassland and native hardwood forest communities both within HOCU and within the surrounding landscape (Johnson 2006, Boren et al. 1999).

<u>Threats</u>

Threats to the HOCU bird community include the conversion of habitats to agricultural and urban uses including cultivation and livestock grazing and residential, commercial, and industrial development. These threats exist locally, regionally and within the extent of the avian migratory patterns of birds inhabiting HOCU (Hansen and Gryskiewicz 2003). The aforementioned activities result in habitat loss and fragmentation, water pollution and the disruption of hydrologic flow regimes. These stressors make it difficult to maintaining the bird community at HOCU relative to that of the natural habitat of the region (Jorgensen and Müller 2000). Consequently, the ecological functioning of HOCU depends upon maintaining the natural systems within and outside the parks boundaries. Changes in land use can disrupt ecological function by reducing the functional size of a reserve, disrupting ecological processes and flows across the landscape, damaging or eliminating unique or rare habitats, creating excessive edges, and increasing human populations and associated disturbance (Hansen and Gryskiewicz 2003).

Indicators and Measures

- Native bird species richness (S)
- Bird index of biotic integrity (IBI)
- Occurrence and status of bird species of conservation concern

4.7.2. Data and Methods

The HTLN has implemented long-term monitoring of birds at HOCU in order 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 et al. 2015). In 2005, the HTLN began systematic surveys of breeding birds and their habitats at HOCU. The Spruce Hill Unit has not been sampled. Monitoring was conducted every subsequent year through 2018 at 27 permanent sample sites arranged in a systematic grid of 400 X 400 m cells, originating from a random start point (Figure 4.7-1) (Peitz 2015). The sampling protocol was based on variable circular plot methodology, wherein all birds seen or heard at plots during 3 to 5-minute sampling periods were recorded along with their corresponding distance from the observer (Peitz et al. 2008).

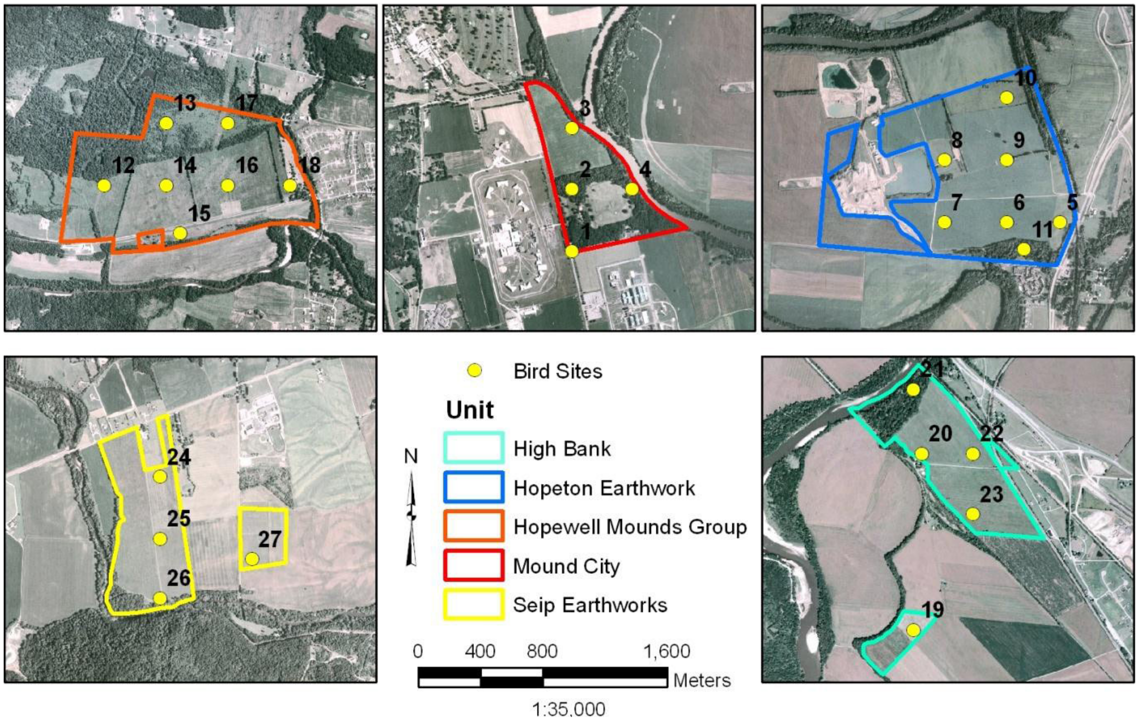


Figure 4.7-1. Bird monitoring plot locations at each unit on Hopewell Culture National Historical Park, Ohio (Peitz 2015).

Due to relatively small sample sizes within each park unit (4–7 samples), the samples aggregated to represent the entire park bird population. To evaluate trends over time, we compared native species richness, the occurrence of species of concern, and the scores calculated for a bird index of biotic integrity between 2005 and 2018.

The Bird Index of Biotic Integrity (IBI) is based on the methodology developed for bird communities of the mid-Atlantic Highlands (O'Connell et al 1998a). It is important to note that the bird IBI was modified from that of O'Connell (1998a) to reflect the land-use and land-cover types of HOCU (e.g., grassland and hardwood forest). Specialist guilds included in the IBI tend to be associated with either extensive marshland or woodland cover. Therefore, higher IBI scores reflect bird communities associated with aspects of mature marshland and riparian woodland structure, function, and composition. For example, sites with higher bird IBI scores consist of a bird community with more marshland or interior forest-dependent species, invertebrate foragers, and single-brooded (i.e., specialists). The high IBI score sites would tend to have fewer omnivores, exotic/non-natives, nest predators/brood parasites, residents, and generalists. Guild selection considerations are discussed in Crewe and Timmermans (2005), and 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 HOCU receiving a grassland and hardwood forest bird IBI score of 77 and the theoretical minimum community, a score of 21, which corresponds to either only species from "specialist guilds" being detected or only species from "generalist guilds" being detected, respectively. The biotic or ecological "condition" described by the bird IBI, then moves along a disturbance gradient from relatively intact, extensive, grassland and hardwood communities with high IBI scores to more disturbed, developed or urban grassland and hardwood communities with low IBI scores. The response guilds incorporated into the bird IBI are listed in Table 4.7-1.

Table 4.7-1. Bird species guilds used to calculate IBI scores (O'Connell et al. 1998a, 1998b, 2000).

Biotic Integrity Element	Guild Category	Response Guild	Number of Species in Guild	Guild Classification
Functional	Trophic	omnivore	33	generalist
	Insectivore Foraging Behavior	bark prober	4	specialist
	Insectivore Foraging Behavior	upper canopy forager	7	specialist
	Insectivore Foraging Behavior	lower canopy forager	17	specialist
	Insectivore Foraging Behavior	ground gleaner	4	specialist
	Insectivore Foraging Behavior	aerial screener	11	specialist
Compositional	Origin	exotic/non-native	5	generalist
	Migration Status	resident	29	generalist
	Migration Status	temperate migrant	24	generalist
	Number Of Broods	single-brooded	51	specialist
	Population Limiting	nest predator/brood parasite	5	generalist
Structural	Nest Placement	forest ground nester	3	specialist
	Nest Placement	wetland nester	6	specialist
	Nest Placement	open ground nester	17	specialist
	Nest Placement	canopy nester	31	specialist
	Nest Placement	shrub nester	17	specialist

Table 4.7-1 (continued). Bird species guilds used to calculate IBI scores (O'Connell et al. 1998a, 1998b, 2000).

Biotic Integrity Element	Guild Category	Response Guild	Number of Species in Guild	Guild Classification
Structural (continued)	Primary Habitat	forest generalist	24	generalist
	Primary Habitat	grassland obligate	2	specialist
	Primary Habitat	interior forest obligate	9	specialist
	Primary Habitat	riparian obligate	8	specialist

For species of conservation concern, our intent was to determine which species that occur at HOCU are considered as species of concern at either a national or local scale, to assess the current status (occurrence) of those species at the park, and to evaluate the potential for the park to play a role in conserving those species. This analysis was restricted to those species that were either breeding at the park or that were residents. Those species occurring during migration only and incidental occurrences of species outside of their normal range were excluded.

To identify priority conservation species we used lists developed by Partners in Flight (PIF), a cooperative effort among federal, state and local government agencies that identifies and assesses 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 national and regional scales. At the national scale, the PIF North American Landbird Conservation Plan identifies what are considered "Red Watch List Species" and "Yellow Watch List Species" (Rosenberg et al. 2016). Red Watch List Species are considered by PIF as those with the greatest need for conservation due to a combination of small and declining populations, limited distributions, and significant threats throughout their ranges (Rosenberg et al. 2016). Yellow Watch List Species are defined as those species that are not declining but that are vulnerable due to small ranges, 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 local scale, even though they are not of high concern from a continental perspective. Hopewell Culture National Historical Park borders the Eastern Tallgrass Prairie and Appalachian Mountains BCRs. The species of conservation concern identified by PIF within these two regions were also added to the birds on the national list of conservation concern used in the analysis.

4.7.3. Reference Conditions

Outside of the HTLN survey data from 2005–2018, little historical survey data exist for HOCU. The 2005 data is used as a baseline reference for comparison with subsequent data. For native species richness and the status of species of conservation concern, maintaining values approaching or exceeding the 2005 baseline values are the basis for the reference conditions. 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 park more.

Threshold levels for bird IBI scores have not been rigorously defined, but O'Connell et al. (2000) established thresholds that include four categories of condition corresponding to the proportional species richness of each specialist guild and generalist guild. For the bird IBI score at HOCU these thresholds include the following categories: 1) excellent (highest integrity) – score of 68.1–77; 2) good (high integrity) – score of 53.1–68.0; 3) fair (medium integrity) – score of 32.8–53.0; and 4) poor (low-integrity rural and low-integrity urban) – score of 21.0–32.7. The condition classes were modified to accommodate the three-tiered system used by the NRCA. A condition rating framework for birds is shown in Table 4.7-2.

Table 4.7-2. Resource condition rating framework for birds at Hopewell Culture National Historical Park (adapted from O'Connell et al. 2000).

	NRCA Condition Rating		
Indicator	**Resource is in Good Condition**	**Condition Warrants Moderate Concern**	**Condition Warrants Significant Concern**
Native Species Richness (S)	>85–100+ % of 2005 value	70–85% of 2005 value	<70% of 2005 value
Index of Biotic Integrity	53.1–77.0	32.8–53.0	21.0–32.7
Bird Species of Conservation Concern	>85–100+ % of 2005 value	70–85% of 2005 value	<70% of 2005 value

4.7.4. Condition and Trend

Species Richness

A mean of 11.4 native species per sample site was recorded in 2018. The most common species were the red-winged blackbird (*Agelaius phoeniceus*) and eastern meadowlark (*Sturnella magna*). This total was greater than the 5.4 native species recorded per sampling station during the initial 2005 bird survey at HOCU (Table 4.7-3). The mean species richness per site recorded in 2018, when compared to the 2005 value, indicates the resource is in good condition.

Table 4.7-3. Bird species recorded in 2018 and 2005 at survey stations on Hopewell Culture National Historical Park (data provided by HTLN).

Common name	**Species name**	**Detected 2018**	**Detected 2005**
Acadian Flycatcher	*Empidonax virescens*	1	–
American Crow	*Fulica americana*	12	2
American Goldfinch	*Spinus tristis*	16	2
American Redstart	*Falco sparverius*	1	–
American Robin	*Falco sparverius*	18	9
Baltimore Oriole	*Icterus galbula*	5	1
Bank Swallow	*Riparia*	3	–
Barn Swallow	*Hirundo rustica*	11	–
Belted Kingfisher	*Megaceryle alcyon*	–	1
Black Vulture	*Coragyps atratus*	1	–
Blue Jay	*Cyanocitta cristata*	6	1
Blue-gray Gnatcatcher	*Polioptila caerulea*	4	1
Bobolink[a]	*Dolichonyx oryzivorus*	2	–
Brown Thrasher[a]	*Toxostoma rufum*	3	1
Brown-headed Cowbird	*Molothrus ater*	8	1
Canada Goose	*Branta canadensis*	1	–
Carolina Chickadee	*Poecile carolinensis*	1	–
Carolina Wren	*Thryothorus ludovicianus*	2	9
Cedar Waxwing	*Bombycilla cedrorum*	3	–
Chipping Sparrow	*Spizella passerina*	2	–
Cliff Swallow	*Petrochelidon pyrrhonota*	1	–
Common Grackle	*Quiscalus quiscula*	11	–
Common Yellowthroat	*Geothlypis trichas*	23	6
Cooper's Hawk	*Accipiter cooperii*	1	–
Dickcissel	*Spiza americana*	26	11
Downy Woodpecker	*Dryobates pubescens*	2	–
Eastern Bluebird	*Sialia sialis*	–	1
Eastern Kingbird	*Tyrannus*	2	–
Eastern Meadowlark[a]	*Sturnella magna*	41	11
Eastern Phoebe	*Sayornis phoebe*	1	1
Eastern Towhee[a]	*Pipilo erythrophthalmus*	3	4
Eastern Wood-Pewee[a]	*Contopus virens*	4	2
European Starling	*Sturnus vulgaris*	9	1

[a] Partners in Flight Priority Species for Physiographic Area 24: The Allegheny Mountains (also highlighted in gray).

Table 4.7-3 (continued). Bird species recorded in 2018 and 2005 at survey stations on Hopewell Culture National Historical Park (data provided by HTLN).

Common name	Species name	Detected 2018	Detected 2005
Field Sparrow[b]	***Spizella pusilla***	**23**	**9**
Grasshopper Sparrow[b]	***Ammodramus savannarum***	**11**	**5**
Gray Catbird	*Dumetella carolinensis*	9	–
Great Blue Heron	*Ardea herodias*	–	2
Hairy Woodpecker	*Dryobates villosus*	1	–
Henslow's Sparrow[a]	*Centronyx henslowii*	22	2
House Finch	*Haemorhous mexicanus*	–	1
House Sparrow	*Passer domesticus*	2	–
House Wren	*Troglodytes aedon*	8	1
Indigo Bunting[a]	*Passerina cyanea*	8	9
Killdeer	*Charadrius vociferus*	2	1
Mourning Dove	*Zenaida macroura*	14	2
Northern Bobwhite[b]	***Colinus virginianus***	**–**	**5**
Northern Cardinal	*Cardinalis*	27	6
Northern Harrier[a]	*Circus hudsonius*	2	–
Northern Parula[a]	*Setophaga americana*	1	–
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	3	–
Orchard Oriole	*Icterus spurius*	4	–
Pileated Woodpecker	*Dryocopus pileatus*	2	–
Prairie Warbler[a]	*Setophaga discolor*	3	–
Red-bellied Woodpecker[a]	*Melanerpes carolinus*	10	1
Red-eyed Vireo	*Vireo olivaceus*	1	1
Red-tailed Hawk	*Buteo jamaicensis*	1	1
Red-winged Blackbird	*Agelaius phoeniceus*	57	69
Ring-necked Pheasant	*Phasianus colchicus*	5	7
Rock Pigeon	*Columba livia*	3	2
Scarlet Tanager[a]	*Piranga olivacea*	1	–
Song Sparrow	*Melospiza melodia*	20	11
Tree Swallow	*Tachycineta bicolor*	8	8
Tufted Titmouse	*Baeolophus bicolor*	8	4
Turkey Vulture	*Cathartes aura*	4	1
White-eyed Vireo	*Vireo griseus*	3	–

[a] Partners in Flight Priority Species for Physiographic Area 24: The Allegheny Mountains (also highlighted in gray).

[b] Partners in Flight species considered of continental importance or common birds in steep decline (also in bold).

Table 4.7-3 (continued). Bird species recorded in 2018 and 2005 at survey stations on Hopewell Culture National Historical Park (data provided by HTLN).

Common name	Species name	Detected 2018	Detected 2005
Willow Flycatcher[a]	*Empidonax traillii*	4	–
Wood Duck	*Aix sponsa*	1	–
Wood Thrush[a]	*Hylocichla mustelina*	5	3
Yellow Warbler	*Setophaga petechia*	7	6
Yellow-billed Cuckoo[b]	***Coccyzus americanus***	**1**	**–**
Yellow-breasted Chat[a]	*Icteria virens*	4	5
Yellow-shafted Flicker	*Colaptes auratus*	3	–

[a] Partners in Flight Priority Species for Physiographic Area 24: The Allegheny Mountains (also highlighted in gray).

[b] Partners in Flight species considered of continental importance or common birds in steep decline (also in bold).

The slope of the linear regression for mean native bird species richness was positive and marginally statistically significant ($r^2 = 0.2$, $p = 0.1$), suggesting an increase in native richness of the bird community over time at HOCU (Figure 4.7-2).

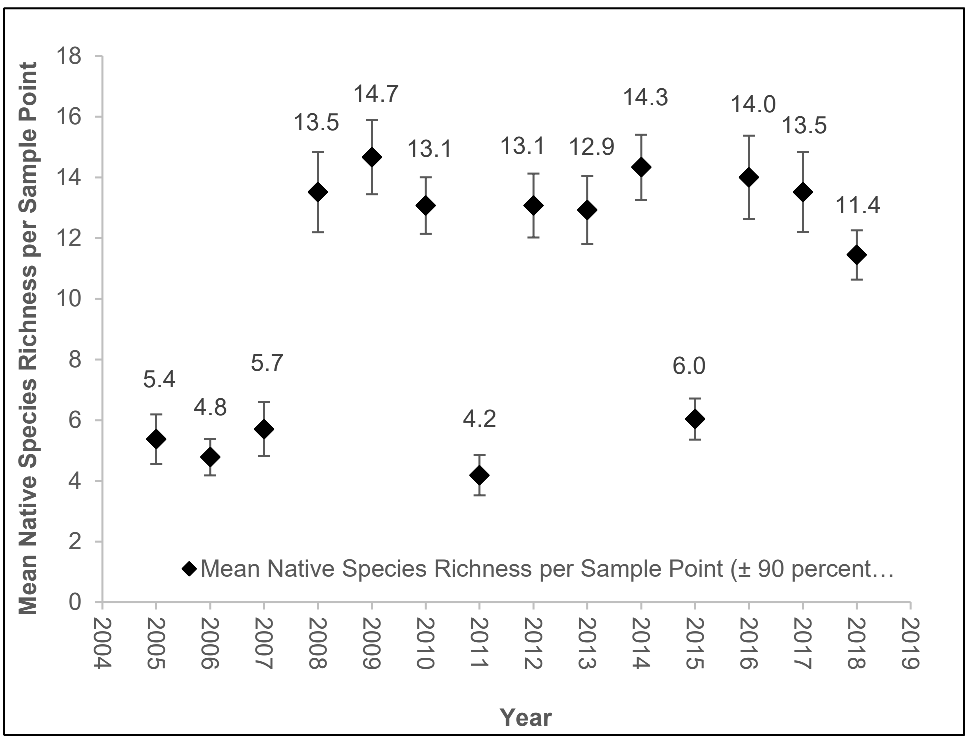


Figure 4.7-2. Means and 90 percent confidence intervals for native bird species richness at Hopewell Culture National Historical Park from 2005 to 2018 (raw data provided by HTLN).

Index of Biotic Integrity
The 2018 bird IBI score of 41.3 indicates that composition of the bird community at HOCU warrants moderate concern (Table 4.7-2). The slope of the linear regression line for the bird IBI scores was negative, but not statistically significant, suggesting an unchanging trend in the richness of the bird community during the monitoring period at HOCU. There is some overlap in the 90 percent confidence intervals for the scores, but the intervals are relatively narrow suggesting similarities among sites (Figure 4.7-3).

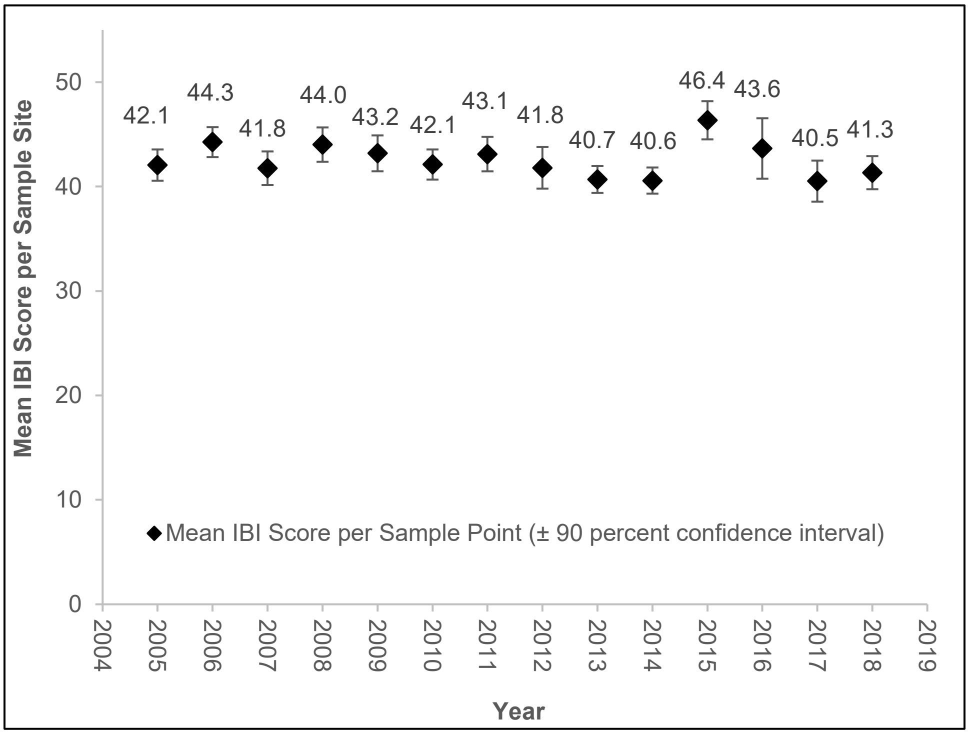


Figure 4.7-3. Means and 90% confidence intervals for bird IBI scores at Hopewell Culture National Historical Park from 2005 to 2018 (raw data provided by HTLN).

Species of Concern
A mean of 2.7 species of concern per sample site was recorded in 2018, which was more than the 1.7 species of conservation concern recorded in 2005 (Table 4.7-3). Seventeen species of conservation concern were recorded at HOCU in 2018 (Table 4.7-3). The most common species of concern recorded at HOCU in 2018 was the eastern meadowlark. Most of the species of concern appeared to increase between the 2005 and 2018 surveys (Table 4.7-3). In 2018, bird species of concern at HOCU averaged 2.7 per sample site, more than the management target of 85% of 1.7, indicating the resource is in good condition (Table 4.7-3).

There was considerable variability around the regression line; the slope of the linear regression for bird species of concern was positive but not statistically significant ($r^2 = 0.18$, $p = 0.13$), suggesting no trend in the number of bird species of concern present at HOCU. The confidence intervals for the number of species of concern for the years 2005 to 2007 tend not to overlap with the years from 2008 to 2018, suggesting that most years after 2007 had higher numbers of bird species of concern compared to the 2005–2007 period (Figure 4.7-4).

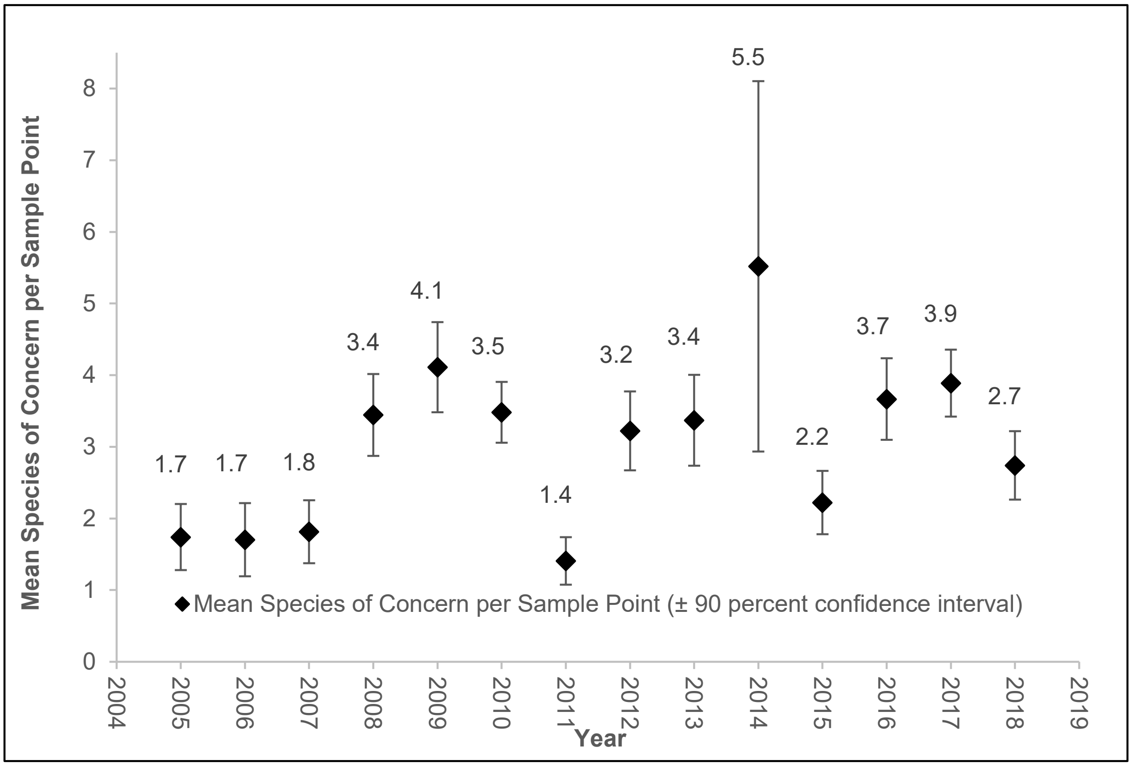
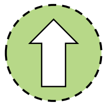
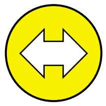
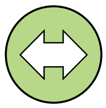
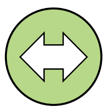


Figure 4.7-4. Mean number of bird species of concern at Hopewell Culture National Historical Park from 2005 to 2018 with 90 percent confidence intervals (raw data provided by HTLN).

Overall Condition and Trend

The values for the metrics of native species richness, the bird IBI, and the number of species of concern present in 2018 indicate the bird community at HOCU is in good condition, 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 4.7-4). Additionally, the values for these metrics calculated for the years 2005 to 2018, suggest an improving trend in bird community diversity and structure at HOCU. Overall, the bird community at HOCU is in good condition with an increasing trend; confidence in the assessment is medium.

Table 4.7-4. Condition and trend summary for birds at Hopewell Culture National Historical Park.

Indicator	Condition Status/Trend	Rationale
Native Species Richness (S)		Mean native bird species richness per sample site has fluctuated between 4.2 and 14.7 species per site from 2005 to 2018 with mean richness equaling 11.4 in 2018 (good condition), greater than the management target of 85 percent of 5.4. Analysis of the bird monitoring data indicates the possibility for an increasing trend in native species richness from 2005 to 2018.
Bird Index of Biotic Integrity		In 2018, the mean bird IBI score per sample site was 41.3 (warrants moderate concern). Analysis of the bird IBI scores indicates an unchanging trend in the biotic integrity of the bird community between 2005 and 2018.
Species of Conservation Concern		The mean number of bird species of concern per sample site fluctuated between 1.4 and 5.5 species from 2005 to 2018 with 3.7 species of concern present in 2018 (good condition), greater than the management target of 85 percent of 1.7. Analysis of the bird monitoring data indicates no trend in the number of species of concern present between 2005 and 2018.
Birds overall		**The resource is in good condition concern with an unchanging trend. Confidence in the assessment is medium.**

4.7.5. Uncertainty and Data Gaps

Confidence in the condition and trend was medium. The key uncertainty related to the assessment of the bird community at HOCU is stratification within vegetation communities or habitat types. Approximately 100 acres of degraded pasture or cropland are being converted to prairie vegetation. Larger sample sizes in forested and restored prairies would improve the sensitivity of the results and likely capture more of the bird diversity present. This assessment is based upon monitoring data collected over multiple years by multiple trained volunteer observers with varying skills in conducting point counts. Non-sampling errors associated with the use of multiple volunteers over long time periods could introduce error, including bias associated with varying detection capabilities of the observers, which can reduce the ability to identify statistically significant trends in the data (Dornelas et al. 2012).

4.7.6. Sources of Expertise

David Peitz, a wildlife biologist at the Heartland I&M Network is responsible for collecting the monitoring data at HOCU 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). David assisted in validating the bird indicators for HTLN parks for use in the NRCA.

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Chapter 5. Summary 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.

5.1. Condition Summary and Management Implications

A total of seven focal resources were examined: four addressing landscape context – system and human dimensions, one addressing chemical and physical attributes, and two addressing biological or integrated attributes. Status and trend assigned to each focal resource and a synopsis of supporting rationale are presented in Table 5.5-1.

5.1.1. 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 5.1-1). Climate change and land cover/land use were not assigned a condition or trend—they provide important context to the park and many natural resources, and can be stressors. Some of the land cover and land use-related stressors at Hopewell Culture National Historical Park (HOCU) 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 HOCU to also include 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 several sensitive biological resources below.

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. Collectively, this context supports resource planning and management within the park, and provides a foundation for collaborative conservation with other landowners in the surrounding area.

5.1.2. Chemical and Physical Environment

The sole resource examined supporting chemical and physical environment at the park was air quality; water quality is briefly discussed in section 3.2.1 (Table 5.1-1). Air quality can affect human dimensions of the park such as visibility and scenery as well as biological components such as vegetation health and chemical/nutrient inputs to soil and water. Air quality warranted significant concern with no trend able to be determined due to insufficient on-site or nearby monitoring data. Air quality in the region is significantly impacted by land uses outside the park boundary.

Table 5.1-1. Summary of focal resource condition and trend for Hopewell Culture National Historical Park.

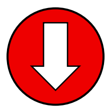
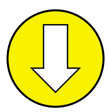
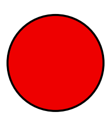
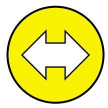
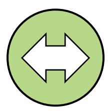
Ecosystem Attributes	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Landscape Context – System and Human Dimensions	Land Cover and Land Use	condition and trend not assigned	Most of the land cover and land use-related stressors at HOCU and in the larger region are related to the development of rural land and increases in population/housing over time. Conversion of hay and pasture lands to cropland is also a concern, as the former class has much higher conservation value. This trend in land development, coupled with the lack of significantly-sized and linked protected areas, is of significant concern to the conservation of natural resources of Hopewell Culture National Historical Park to also include dark night skies, natural sounds and scenery.
	Night Skies		All-sky light pollution ration (ALR) values for HOCU averaged 3.71. Median values for the six units ranged from 2.29 at Seip Earthworks to 7.12 at the Mound City Group, warranting significant concern. Although no ALR trend data are available, the trend is inferred as deteriorating based on recent and anticipated increases in housing development and a trend toward conversion of rural and exurban land to suburban use. In addition, lights from cities like Columbus, Ohio with increasing population growth could also be a concern.
	Natural Sounds		The condition of the soundscape at HOCU warrants moderate concern, with a deteriorating trend due to projections for increased ground and air traffic over time.Noise from anthropogenic sources is common. Noise from adjacent roads, the state prison, and gravel mine/asphalt production facility particularly threaten the park's natural soundscape. Housing trends contribute to deteriorating trend. Noise from anthropogenic sources is common. Noise from adjacent roads, the state prison, and gravel mine/asphalt production facility particularly threaten the park's natural soundscape. Housing trends contribute to deteriorating trend.
	Climate Change	condition and trend not assigned	HOCU's climate is already becoming warmer 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 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 in the park region.
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 5.1-1 (continued). Summary of focal resource condition and trend for Hopewell Culture National Historical Park.

Ecosystem Attributes	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Biological – Plants	Vegetation Communities		The data presented suggest the current condition of most vegetation communities at HOCU warrants moderate concern; they are in a degraded condition persisting under a variety of disturbances. Overall trends are difficult to assess but it is likely that vegetation community 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 metrics should improve. Alternatively, modeled data predicts HOCU forest will be impacted by a variety of disease and pest issues as well as changes in climate with these impacts having the potential to drastically affect future forest composition and structure. Significant strides have been made recently in grassland management and prairie restoration (improving trend in those areas).
Biological – Animals	Birds		Native species richness, the bird Index of Biotic Integrity, and the number of species of concern present in 2018 indicate the bird community at HOCU is in good condition with an unchanging trend. 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 are present.

5.1.3. Biological Component – Plants

The floral biological component looked at forest and grassland communities at each of HOCU's six units (Table 5.1-1). Vegetation communities at HOCU have been influenced by historical land uses that have changed the species composition and age structure of the forest as well as converted grasslands to agriculture. Although some large tracts of forests can be found within some units of the park, the majority of the forested areas are fragmented, and few areas within HOCU exhibit late-successional or old-growth characteristics. Condition metrics included invasive nonnative plants, forest pests and diseases, and native plant species composition. Forest communities at HOCU 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. These stressors and threats have collectively shaped and continue to impact vegetation community condition and ecological succession. The condition of vegetation communities at the park warrants significant concern with an unchanging trend. Grassland restoration and management projects that have been implemented or are planned for the near future will increase the quality and extent of native prairie communities, while reducing noise and pesticide use associated with historical grassland management.

5.1.4. Biological Component – Animals

The sole faunal component examined was birds (Table 5.1-1). This resource was found to be in good condition with an unchanging trend. Relative to the surrounding developed and agricultural landscape, HOCU is especially valuable because it provides some unfragmented patches of grassland and forest that serve as a refuge within a highly altered landscape. Habitat fragmentation and conversion of native habitats negatively impacts populations of some breeding and resident birds at HOCU. Threats to the HOCU bird community include the conversion of habitats to agricultural and urban uses including cultivation and livestock grazing and residential, commercial, and industrial development. These threats exist locally, regionally and within the extent of the avian migratory patterns of birds inhabiting HOCU.

5.2. Data Gaps and Uncertainties

The identification of data gaps during the course of the assessment is an important outcome of the NRCA (Table 5.2-1). In some cases significant data gaps contributed to low confidence in the condition or trend assigned to a resource. Primary data gaps and uncertainties encountered were lack of recent survey data; lack of air and water quality monitoring data in the vicinity of the park; availability of consistent, long-term data; and incomplete understanding of the ecology of rare resources.

Table 5.2-1. Data gaps identified for focal resources examined at Hopewell Culture National Historical Park.

Ecosystem Attributes	Resource	Data Gaps
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 Hopewell Culture National Historical Park. Condition and trend are based on modelled data.
	Soundscape	No acoustical monitoring studies have been conducted inside HOCU. 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 the resources specific to HOCU.
Chemical and Physical Environment	Air Quality	Local air monitoring stations vs. interpolated regional data would improve accuracy.
Biological – Plants	Vegetation Communities	Additional modeling along with continued forest monitoring should be continued to help understand the cumulative impacts of anthropogenic stressors, forest health, and climate change impacts.
Biological – Animals	Birds	Consistency in sampling design and efforts may increase the power of the data.

5.3. Conclusions

Hopewell Culture National Historical Park is a young park with a long history of human settlement and environmental impacts associated with agriculture, industrialization, environmental pollution and ecological disturbance. The challenges associated with managing resources within a park that is heavily influenced by competing land uses in close proximity are manifold. The division of the park into several, distinct units also creates its own challenges in terms of staffing, law enforcement, and maintenance, among others. 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. 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).

5.4. Literature Cited

National Park System Advisory Board Science Committee. 2012. Revisiting Leopold: resource stewardship in the National Parks. Washington D.C.

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