National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

First State National Historical Park (Non-Sensitive Version)

Natural Resource Report NPS/FRST/NRR—2021/2306

ON THE COVER
Brandywine Valley Unit, First State National Historical Park, Delaware
Photo by Dave Jones, Colorado State University

Natural Resource Condition Assessment

First State National Historical Park (Non-Sensitive Version)

Natural Resource Report NPS/FRST/NRR—2021/2306

David S. Jones[1], Roy Cook[1], John Sovell[2], Matt Ley[1], Hannah Pilkington[1] and Carlos Linares[3]

[1] Colorado State University
CEMML – Department 1490
Warner College of Natural Resources
Fort Collins, CO 80523-1490

[2] Colorado State University
Colorado Natural Heritage Program
Department of Fish, Wildlife and Conservation Biology
Warner College of Natural Resources
Fort Collins, CO 80523

[3] Colorado State University
Department of Human Dimensions of Natural Resources
Warner College of Natural Resources
Fort Collins, CO 80523

September 2021

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

This report is available in digital format from the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Jones, D. S., R. Cook, J. Sovell, M. Ley, H. Pilkington, and C. Linares. 2021. Natural resource condition assessment: First State National Historical Park (non-sensitive version). Natural Resource Report NPS/FRST/NRR—2021/2306. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2287452.

NPS 207/177418, September 2021

Contents

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Contents (continued)

Page

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

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 First State National Monument on March 25, 2013, and it was designated as First State National Historical Park (FRST) in late 2014. The park is made up of seven sites spread throughout the state of Delaware, with part of one site in Pennsylvania. The seven sites include: Brandywine Valley (previously known as Beaver Valley); the New Castle Court House, Sheriff's House, and Green; Holy Trinity (Old Swedes) Church; Fort Christina; The Green, Dover; John Dickinson Plantation; and the Ryves Holt House. Brandywine Valley and the Sheriff's House are owned and managed by the National Park Service, while the remaining sites are owned and managed by state and local partners who provide tours and programs to the public. The Brandywine Valley site (which straddles the Delaware/Pennsylvania boundary) and the John Dickinson Plantation have substantial natural resources and are the focus of this document. The park's purpose is to "work in partnership to preserve and interpret the nationally significant cultural and historic resources associated with early settlement of the Delaware Valley by the Dutch, Swedish, Finnish, and English, Delaware's role in the establishment of the nation, and the first state to ratify the Constitution. First State National Historical Park works in partnership to conserve and interpret the natural and cultural landscape of the Brandywine Valley consistent with William Poole Bancroft's vision of an open space accessible to the public for their health and well-being."

The NRCA for FRST employed a scoping process involving Colorado State University and NPS staff discussing the NRCA framework, identifying important park resources, and gathering 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 12 focal resources were examined: five addressing system and human dimensions, two addressing chemical and physical attributes, and five addressing biological attributes or integrated biological/environmental systems.

The five system and human dimension attributes examined in this NRCA include land cover and land use, climate change, night sky, soundscape, and visual resource. 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 FRST 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 FRST to also include natural night skies, natural sounds and scenery. Climate change is happening and is affecting resources, but is not considered good or bad per se. The information synthesized in that section is useful in examining potential trends in the vulnerability of several sensitive biological resources below.

The supporting chemical and physical environment at the park includes its air quality and water quality. The condition of these resources can affect human dimensions of the park such as visibility and scenery as well as biological components such as vegetation health and stream biota. Air quality warrants significant concern, while water quality warrants moderate concern. Air quality and water quality at FRST are significantly impacted by historical and current land uses outside the park boundary. Management options are limited for the park and require the establishment of working relationships with other governmental and private entities.

The sole floral biological component examined was forests. Forest resources at FRST have been influenced by historical land uses that have changed the species composition and age structure of the forest. Brandywine Valley contains some of the largest remaining forest tracts in the region, helping to support biodiversity as well as provide corridors for migratory wildlife species. The majority of the forested areas are fragmented, and some areas within Brandywine Valley exhibit late-successional or old-growth characteristics, existing mostly on steeply sloped stream valleys that were spared from development and agriculture. Condition metrics included extent of native vegetation cover, invasive nonnative plants, forest pests and diseases, white-tailed deer population, and climate change. Forest communities at FRST have a long history of being impacted by a variety of stressors and threats including noxious and invasive weeds, diseases and insect pests, compounding effects of climate change, air pollution, acid rain/atmospheric chemistry, past land uses, and impacts associated with white-tailed deer populations. These stressors and threats have collectively shaped and continue to impact forest community condition and ecological succession. Overall condition of forest communities warrants significant concern.

The faunal biological components examined included bats, birds, reptiles, and amphibians. Birds, reptiles, and amphibians warrant moderate concern, while bat populations warrant significant concern and are in decline. The fragmentation of habitat and conversion of native vegetation to urban landscapes outside the park can negatively impact populations of some bats and birds at FRST. The park contains some relatively unfragmented patches of habitat that provide refugia within an altered and urbanized regional landscape. Increased protection and restoration of caves, riparian forests, and wetlands increase community abundance and diversity for bats and birds over time.

The identification of data gaps during an 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 quality monitoring data in the vicinity of the park; availability of consistent, long-term data; and incomplete understanding of the ecology of rare resources.

First State 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. Impacts associated with development outside the park will continue to stress some resources, and while the direct and indirect effects of climate change are likely, 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 develop near-term management priorities, engage in watershed or landscape-scale collaboration and education efforts, conduct park planning, and report program performance.

Acknowledgments

We would like to acknowledge assistance, support and guidance provided by Ethan McKinley, Cinda Waldbuesser and Daniel Hodgson in their roles as Park Superintendent, local knowledge by Alan Mcloughlin, project facilitation and guidance by Christine Arnott and William Thompson, and reviews and expertise provided by FRST park staff (especially Sonja Werth), NPS Region 1 (Sheila Colwell, Holly Salazer and others), and Natural Resource Stewardship and Science Directorate staff members.

Chapter 1. NRCA Background Information

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

NRCAs Strive to Provide…

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

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

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

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

---

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

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

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

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

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

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

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

Important NRCA Success Factors

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

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

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

NRCA Reporting Products…

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

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

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

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

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

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

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Presidential Proclamation[1]

The park was established as First State National Monument by Presidential Proclamation 8944 signed by President Barack Obama on March 25, 2013, and redesignated as First State National Historical Park on December 19, 2014, by Public Law 113-291.

2.1.2. Park History

Famous as the First State to ratify the U.S. Constitution, Delaware was born out of a conflict among three world powers (Sweden, the Netherlands, and Great Britain) for dominance of the Delaware Valley. From this beginning, the region developed a distinct character that tolerated diversity in religion and national origin and valued independence. In June 1776, the three lower counties of Pennsylvania separated from Great Britain and Pennsylvania to form the state of Delaware. In 1787, Delaware became the first state to ratify the U.S. Constitution and in 2013, it became the last state to have a national park unit.

First State National Historical Park (FRST) is made up of seven sites spread throughout the state of Delaware. The seven sites include: Brandywine Valley; the New Castle Court House, Sheriff's House, and Green; Holy Trinity (Old Swedes) Church; Fort Christina; The Green, Dover; John Dickinson Plantation; and the Ryves Holt House. Brandywine Valley and the Sheriff's House are owned and managed by the National Park Service, while the remaining sites are owned and managed by state and local partners. Some data sources and literature cited in this document will refer to the unit currently known as Brandywine Valley by the name of Beaver Valley.

FRST is in a gateway location between the increasingly urbanized Highway 202 corridor and rural landscapes including public lands and large private holdings in the Brandywine Valley. Although most plans are in the development phase and NPS conducts limited management activities in-house, FRST partners are active in resource surveys/research, management and restoration. Partners have critical knowledge of the local area, the regional context, and networks within and around the park. Park partners include, but are not limited to, the Brandywine Conservancy, the Mount Cuba Center, agricultural leasing contractors, The Nature Conservancy, Stroud Water Research Center, and the State of Delaware.

2.1.3. Geographic Setting

The Brandywine Valley unit is located in New Castle County, Delaware, and Delaware County, Pennsylvania, approximately seven miles north of downtown Wilmington, Delaware (71,000 residents (U.S. Census Bureau 2010)) and 30 miles southwest of Philadelphia, Pennsylvania (1,526,000 residents (U.S. Census Bureau 2010)) (Figure 2.1-1). The John Dickinson Plantation is located in Kent County, Delaware, approximately six miles southeast of Dover, Delaware (36,000

---

[1] Excerpted from NPS (2019a)

residents (U.S. Census Bureau 2010)). The Brandywine Valley and John Dickinson Plantation units of FRST are the only two units that contain substantial natural resources.

The Brandywine Valley landscape is characterized by a series of rugged stream valleys that drain to Brandywine Creek. Agricultural land sits between the relatively undisturbed valleys, interspersed with low density residential land use. The adjacent Interstate Highway 202 corridor is lined with intensive commercial uses (PAQ 2011).

2.1.4. Park Unit Descriptions and Significance

<u>Brief Description of FRST Units</u>[2]

Brandywine Valley. This area consists of 1,105 acres of rolling hills and wooded areas along the Brandywine Creek and the arced border between northern Delaware and southern Pennsylvania. This land was first deeded to William Penn and reflects early Quaker settlement patterns and Native American migration. In 1906, William Poole Bancroft purchased this bucolic property to preserve the beauty of the Brandywine Valley for future generations. Since then, the land served as a privately-owned park until it was donated to the National Park Service by the Brandywine Conservancy in 2013.

The period of significance for Brandywine Valley is 1681 to 1928 (NPS 2017). Native Americans, Dutch settlers, colonial Americans, and William Poole Bancroft were all attracted to the Brandywine Valley for the abundance of natural resources. Its flora, fauna, and vast waterways provide sustenance, transportation, power, recreation, and wildlife habitats. The area's natural resources are inseparable from the cultural landscapes and historic structures present today (NPS 2019b). Existing forests at Brandywine Valley are primarily examples of mature Piedmont Upland and include Northern Piedmont chestnut oak (*Q. montana*), Piedmont Mesic oak beech (*Fagus grandifolia*), and Piedmont Basic Mesic hardwood forest types.

New Castle Court House and Green. The town of New Castle served as the colonial capital and the first state capital of Delaware until 1777. Since its establishment as a market area by the end of the 17th century, the New Castle Green has served as a focal point for religious and public functions. Today, as an interpreted historic site, the New Castle Court House Museum is owned and managed by the Delaware Division of Historical and Cultural Affairs. The New Castle Visitor Center is located in the historic Arsenal building on the New Castle Green. The Arsenal is owned by the Delaware Division of Historical and Cultural Affairs and managed by the New Castle Historical Society. The 1857 Sheriff's House, adjacent to the Court House on the New Castle Green, was constructed over the previous 18th century jail and debtor's prison and is all that remains of Delaware's first prison system. The Sheriff's House is owned by the National Park Service. This unit is a cultural site and there are no substantial natural resources present at this unit.

[2] Adapted from NPS (2019a)

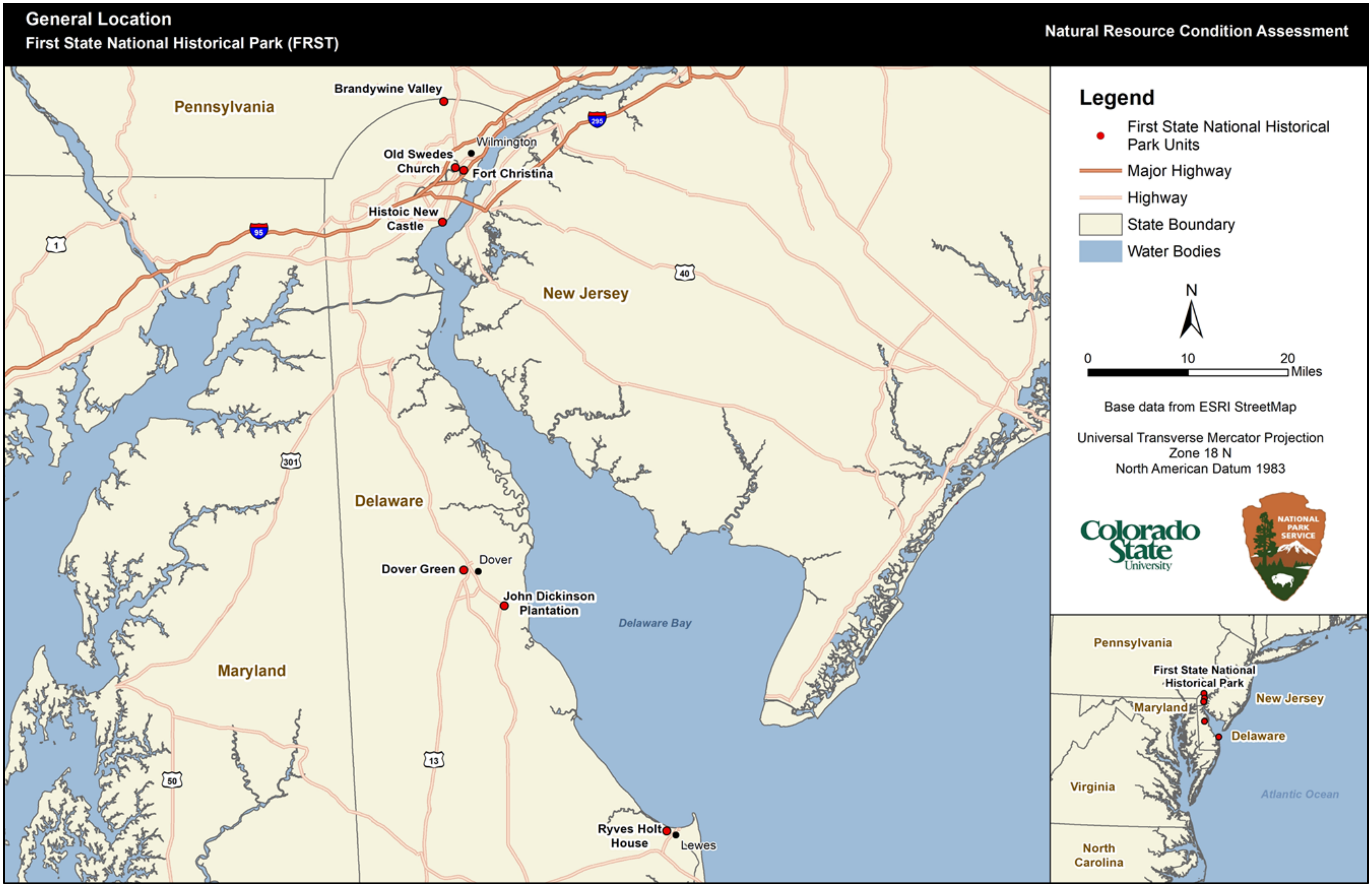


Figure 2.1-1. General location of First State National Historical Park. Data from ESRI Streetmap and NPS.

Old Swedes Church. In 1699, Swedish and Finnish settlers finished building what is now called the Old Swedes Church in Wilmington, Delaware, just a short walk from Fort Christina. The original church still stands today; it is a national historic landmark and is recognized as one of the oldest church buildings in America still used for worship. The church has preserved records of life of early settlers, many of whom are buried at the graveyard on site. Old Swedes Church and burial ground are owned by Trinity Episcopal Church Parish. Interpretive programming and conservation of the historic burial ground is led by the Old Swedes Foundation. There are no substantial natural resources present, although there is concern regarding older trees at the site.

Fort Christina. Here, along the banks of the Christina River more than 375 years ago, Swedish and Finnish settlers aboard the Kalmar Nyckel and the Fogel Grip landed and established the first American Swedish colony, New Sweden. Fort Christina was quickly built and named for the Queen of Sweden at the time. Although the natural wharf of rocks that was the site of the first landing and the entry point for Fort Christina remains, archaeological work has not yet located the fort. A park and monument dedicated in 1938 mark the site. Fort Christina, owned and managed by the Delaware Division of Historical and Cultural Affairs, was designated as a national historic landmark in 1966 and is included in the Underground Railroad Network to Freedom. This unit is a cultural site and there are no substantial natural resources present at this unit.

Dover Green. William Penn established the town of Dover in 1683. As surveyed in 1717, the town featured three public squares including the Green. The Green has a formal design with open lawn and a grid of planted trees. Surrounded by government buildings, shops, homes, and taverns, the Green became the heart of Dover. During the American Revolution, it was the setting for troop reviews, markets, and public gatherings. On December 7, 1787, 30 delegates, 10 from each county, met at the Golden Fleece Tavern facing The Green and ratified the U.S. Constitution, giving Delaware the place of honor as “The First State.” Interpretation and programming are provided in the adjacent Old State House by the Delaware Division of Historical and Cultural Affairs. Interpretation at the John Bell House and The Green are provided by First State Heritage Park, a unit of the Delaware Division of Parks and Recreation. This unit is a cultural site and there are no substantial natural resources present at this unit.

John Dickinson Plantation. The estate, located about 6 miles southeast of The Green in Dover, was the boyhood home of John Dickinson, known as the “Penman of the Revolution.” Dickinson’s “Letters from a Farmer in Pennsylvania” contributed greatly to the American cause by supporting colonial rights. John Dickinson was a member of the Continental Congress, a delegate to the Constitutional Convention, and a signer of the U.S. Constitution. After John Dickinson’s death in 1808, President Thomas Jefferson wrote, “Among the first of the advocates for the rights of his country when assailed by England, [Dickinson] continued to the last the orthodox advocate of the true principles of our new government, and his name will be consecrated in history as one of the great worthies of the revolution.” The John Dickinson Plantation, a national historic landmark, is owned and operated by the Delaware Division of Historical and Cultural Affairs and is included in the Underground Railroad Network to Freedom. Although tidal wetlands are present just outside the unit boundary, John Dickinson Plantation is primarily a cultural site.

Ryves Holt House. This house, built in 1665 in Lewes, Delaware, by early Dutch settlers, is thought to have been built 30 years after the destruction of the nearby ill-fated Zwaanendael colony, one of the first Dutch settlements in America, and the first European settlement in Delaware. The house survived Lord Baltimore's raids that eventually led to the English taking control of the area. The house was purchased in 1723 by its namesake, Ryves Holt, who served as the first Chief Justice of Delaware from 1745 until his death in 1763. The Ryves Holt House is owned and managed by the Lewes Historical Society. This unit is a cultural site and there are no substantial natural resources present at this unit.

Park Significance

Purpose and significance statements highlighted in the park's draft Foundation Document (NPS 2019a) reaffirm the reasons that FRST was added to the NPS and capture the essence of the park's importance to our country's cultural heritage:

> "First State National Historical Park works in partnership to preserve and interpret the nationally significant cultural and historic resources associated with early settlement of the Delaware Valley by the Dutch, Swedish, Finnish, and English, Delaware's role in the establishment of the nation, and the first state to ratify the Constitution. First State National Historical Park works in partnership to conserve and interpret the natural and cultural landscape of the Brandywine Valley consistent with William Poole Bancroft's vision of an open space accessible to the public for their health and well-being."

The following significance statements speak to the different park units:

- Fort Christina, a national historic landmark, preserves the original landing site, known as "The Rocks," of the first Swedish expedition to North America and, together with Holy Trinity (Old Swedes) Church and its burial ground, the sites and resources closely associated with the principal settlement of New Sweden. Built in 1698, almost a half century after the Dutch conquered New Sweden, Holy Trinity illustrates early religious tolerance in Delaware and the continued influence of Swedish settlers in the Delaware Valley.
- Built in 1740, Poplar Hall stands at the center of the boyhood home and country estate of John Dickinson, now known as the John Dickinson Plantation. Known as "the Penman of the Revolution," Dickinson was a delegate to the Continental Congress, the primary author of the Articles of Confederation, and one of the drafters and signers of the U.S. Constitution. Dickinson, whose words and actions included the manumission of his enslaved individuals, shaped the ideals, institutions, and aspirations of the new nation.
- Bordering the Green established by Dutch colonists in the mid-17th century, the New Castle Court House witnessed seminal events in the establishment of the United States and the forging of our nation's most fundamental ideals. Here, prior to casting Delaware's vote in favor of independence in 1776, Delaware's colonial assembly separated from Great Britain and Pennsylvania in June 1776, making the Court House Delaware's first capitol building. Almost three-quarters of a century later, U.S. Chief Justice Roger Taney presided over the well-publicized prosecution of prominent Quaker abolitionists and Underground Railroad

conductors Thomas Garrett and John Hunn under the Fugitive Slave Law of 1793 in the Court House.

- First plotted as a public space in 1717 in accordance with William Penn's orders, The Dover Green occupied a central place in the political and economic affairs of colonial Dover and in the nation's political foundations when, in December 1787, the state convention ratified the U.S. Constitution in the Golden Fleece Tavern at the edge of the Green, earning Delaware the sobriquet of "First State."
- Brandywine Valley is an integral component and legacy of Quaker industrialist William Poole Bancroft's vision for open park lands and the conservation of green space as part of his larger philanthropic community planning experiment in the City of Wilmington that drew upon national and international currents of early 20th century social and industrial reform.

2.1.5. Park Visitation

Visitation statistics are not yet available for the FRST park units. Following patterns of other urban parks in the region, visitation at all units is highest in the summer, moderate in spring and fall, and lowest in the winter. Recreational uses are heaviest at the Brandywine Valley unit, including floating/paddling, swimming, fishing, walking/running/hiking, horseback riding, and mountain biking, although other units may be used for walking and other recreation.

2.1.6. Environmental Setting

Climate

The climate of Delaware is humid-temperate, characterized by mild winters and hot summers. Summers tend to be hot and humid; winter temperatures are moderated by easterly winds associated with cyclonic storms to the southeast, and spring and fall are highly variable. The average annual temperature in northern Delaware is 12.8° Celsius (C) (55° Fahrenheit (F)) (NCDC 2019). The coldest month is January, with an average temperature of −0.1° C (31.8° F). The warmest month is July, with an average temperature of 24.6° C (76.2° F) (Figure 2.1-2) (NRCC 2019). The growing season length ranges from 175 to 195 days with a last spring frost occurring around April 10 and a first fall frost occurring around October 31 (NRCC 2019). The snow season near Brandywine Valley spans December to March and averages 45.7 cm (18 in) of snowfall annually (NCDC 2019). The regional climate and projected changes to climate in the vicinity of the park are discussed in Chapter 4. Due to the State of Delaware's north-south orientation and location at the intersection between the cold of the Northeast and the mild weather of the South, the northern end of the state (where Brandywine Valley is located) experiences lower temperatures and more snowfall compared to its southern end (NCDC 2019).

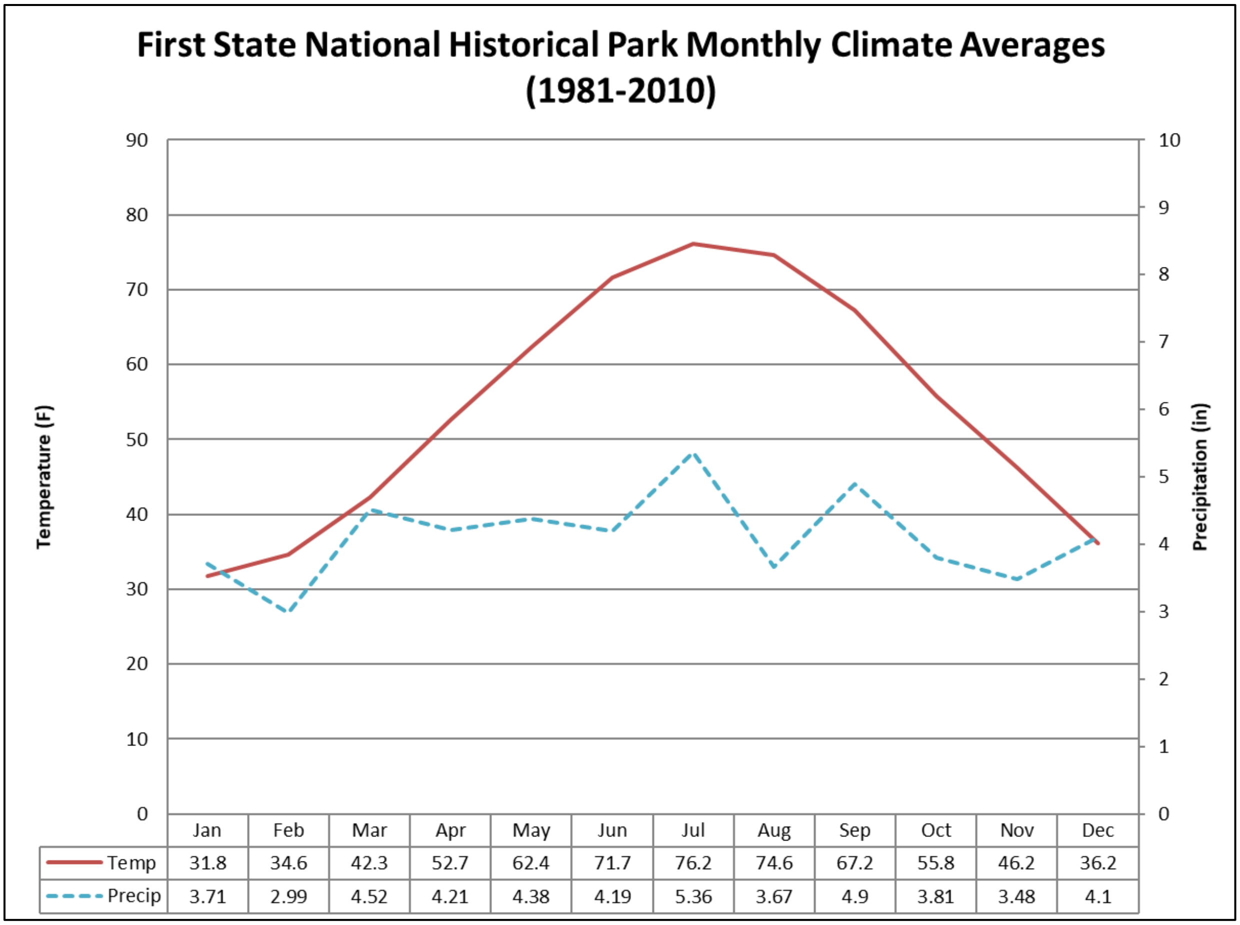


Figure 2.1-2. Walter climate diagram near First State National Historical Park with 30-year temperature and precipitation averages (1981–2010) (data source: NRCC 2019).

Geology and Soils

Delaware is located within two physiographic provinces, the Appalachian Piedmont Plateau and the Atlantic Coastal Plain. Roughly following Route 2 in a southwest diagonal between the cities of Wilmington, Delaware, and Newark, New Jersey, the contact line between these two provinces is known as the fall line. The Brandywine Valley unit is situated just to the north of this line within the rocky and hilly Piedmont zone, but exhibits features unique to a transitional zone (PAQ 2011). All FRST units lie in the coastal plain.

Soils consist of the Glenelg-Manor-Chester Association formed by the in-place weathering of highly micaceous metamorphic rock of the Wissahickon Formation in the northern two-thirds of the property, and the Neshaminy-Aldino-Watchung Association in the southern third. Both of these soil types are well drained, medium-textured soils (PAQ 2011). Soil types found within the Brandywine Valley unit include: Glenelg Loam (490 ac), Gaila Loam (247 ac), Brinklow Channery Loam (167 ac), and Delanco-Codorus-Hatboro Complex (99 ac). Other minor soils include Comus Silt Loam (38 ac), Neshaminy Silt Loam (38 ac), Glenville Silt Loam (36 ac), and Talleyville Silt Loam (34 ac)(Coxe 2014).

Hydrology

Brandywine Valley is within the Brandywine Creek watershed, lying within the larger Christina Basin. Brandywine Creek discharges into the Christina River approximately one mile upstream of its confluence with the tidally influenced Delaware River. Flows in Brandywine Creek are flashy, but generally peak in late-spring and are lowest in early-fall (USGS 2020). Most of the watershed is located in Chester County, Pennsylvania (State of Delaware 2019). Brandywine Creek, White Clay Creek, Red Clay Creek, and the upper Christina River supply drinking water to more than 50% of the population of New Castle County. Four reservoirs lie within the watershed: Chambers Lake, Marsh Creek, Rock Run, and Hoopes Reservoirs.

Air Quality

FRST is designated as a Class II airshed by the Clean Air Act of 1997 (Taylor 2017). The designation is based on park size, location, and date of origin. As a class II airshed, 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 FRST is not directly measured within the park, but is inferred from instrumentation located within the region.

Air quality parameters estimated for FRST reflect regional air quality characteristics. For example, the wet deposition of nitrogen and sulfur for FRST reflects industrial land use from the north and the agricultural character of the region, while ozone concentrations generally mirror regional ones. These specific resource issues as well as visibility are addressed in Chapter 4. Consequences for the health and condition of natural communities, human health, and the quality of the visitor experience are also described in Chapter 4.

Land Use

Major land uses in the Brandywine Creek watershed include agriculture and urban development (45% and 19%, respectively), with a substantial amount of forest and wetland cover (35%) (State of Delaware 2019). The Delaware portion of the watershed is more developed than that of the Pennsylvania portion, and is becoming even more developed over time. The Delaware portion of the watershed saw decreases in agricultural land (10%) and forest and open spaces (12%) from 1992 to 2007 (State of Delaware 2011).

Wildlife

Bat (Nagel and Gates 2017), bird (White and White 2015, Stoner 2014), and herptile (White and White 2015) surveys have been conducted in Brandywine Valley. White-tailed deer (*Odocoileus virginianus*) surveys are currently underway in the Brandywine Valley unit. Eastern red bats (*Lasiurus borealis*) and big brown bats (*Eptesicus fuscus*) were verified via mist-net surveys, while echolocation surveys identified eastern red bats, hoary bats (*L. cinereus*), and big brown or silver-haired bats (*Lasionycterus noctivagans*) (Nagel and Gates 2017). Indiana bats (*Myotis sodalist*) (federally-listed endangered), little brown bats (*M. lucifugus*), northern long-eared bats (*M. septentrionalis*) (federally-listed threatened), Seminole bats (*Lasiurus seminolus*), tricolored bats (*Perimyotis subflavus*), and eastern small-footed bats (*M. leibii*) are all known to inhabit the region but were not found during surveys.

Nearly 200 bird species were identified by White and White (2015). Nineteen are listed as species of concern (NPS 2019b) including three listed as threatened by the State of Delaware including the American kestrel (*Falco sparverius*), broad-winged hawk *(Buteo platypterus*) and northern harrier (*Circus cyaneus*). Thirty-three herptiles were also found at Brandywine Valley during this survey, with two (ring-necked snake (*Diadophis punctatus*) and queensnake (*Regina septemvittata*)) listed as species of concern (NPS 2019b).

Federally listed threatened, endangered, or candidate animal species

The northern long-eared bat (federally threatened) is the only federally listed animal species documented in surveys in the park.

Vegetation[3]

At the time of European settlement, Brandywine Valley was primarily wooded, except where native populations grew subsistence crops in small fields. By the late eighteenth century, much of Brandywine Valley was cleared for agriculture and industry. During the late eighteenth and early nineteenth centuries, even riparian vegetation along Beaver Creek was cleared to allow for industrial development, though marshy wetlands remained. Fields were grazed by livestock or planted in crops, primarily grain and corn for animal fodder. As the nineteenth century progressed, grain production decreased and dairying gained prominence. So too did market crops, such as apples and other orchard fruits. In the late nineteenth and early twentieth centuries, agriculture and industry gave way to residential use and some farm fields reverted to woodland, increasing invasive vegetation. As residents became established, ornamental and vegetable gardens were planted around farmhouses. This practice continues today.

Existing forests at Brandywine Valley are primarily examples of mature Piedmont Upland and include Northern Piedmont chestnut oak, Piedmont Mesic oak-beech, and Piedmont Basic Mesic hardwood. In areas where former fields are no longer used for agriculture, growth of invasive plants such as buckthorn and bittersweet are increasing. More than one hundred acres of the Brandywine Valley site contain small and isolated areas of wetlands (approximately 200 per the National Wetland Inventory), including herbaceous wetlands known as wet meadows. Though orchards were historically located within Brandywine Valley, no remnant historic orchards have been found to date. Ornamental vegetation is located on all of the farms in the Brandywine Valley unit, but further research is necessary to determine the origin of this cultivated vegetation. In addition, certain historic tree specimens within farm fields and within rows near residences contribute to the picturesque nature of the agricultural landscape, which contributed to William Poole Bancroft's decision to purchase and preserve the Brandywine Valley site in 1906.

Thirteen vegetation communities are described for the Woodlawn Tract, of which Brandywine Valley is a portion (National Vegetation Classification Number in parentheses): Box-elder Floodplain Forest (CEGL005033), Cultivated Lawn (CEGL006486), Japanese Stiltgrass Meadow (no NVC classification), Northeastern Coastal Plain/Piedmont Oak-Beech/Heath Forest (CEGL006919),

[3] Adapted from NPS (2017).

Northeastern Modified Successional Forest (CEGL006599), Northeastern Old Field (CEGL006107), Northeastern Successional Shrubland (CEGL006451), Northern Piedmont Mesic Oak-Beech Forest (CEGL006921), Rice Cutgrass-Fowl Mannagrass Wet Meadow (CEGL005106), Skunk Cabbage-Orange Jewelweed Seep (CEGL006567), Southern New England Red Maple Seepage Swamp (CEGL006406), Successional Tuliptree Forest (CEGL007220), and White Pine Plantation (CEGL007178) (Coxe 2014). All or a portion of these vegetation communities may be present within the park.

Federally listed threatened, endangered, or candidate plant species:
No federally listed plant species occur in the park.

2.2. Resource Stewardship

2.2.1. Management Directives and Planning Guidance

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

As a relatively new park within the NPS, documents guiding the management of natural resources in the park are few. The *First State National Historical Park Foundation Document* (NPS 2019a) is currently the primary planning document for FRST. This plan provides a broad direction for FRST management and describes the fundamental resource values of the park. Other important documents guiding stewardship at FRST include a preliminary ecological assessment of the Brandywine Valley unit (PAQ 2011), cultural landscape inventories, and various vertebrate and vascular plant inventories. These broad and park-specific documents and management directives provide important information for identifying and characterizing focal resources and articulating resource reference conditions in this Natural Resource Condition Assessment, which is the first attempt to bring together all elements of the ecological resources of FRST into a single document.

2.2.2. Overview of Resource Management Concerns

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

Natural resources management concerns highlighted in the *FRST Foundation Document* (NPS 2019a) and by park staff during the scoping process consist of natural and cultural resource-related issues as well as stressors from outside the park. Management concerns include resources related to human dimensions/visitor experience (Table 2.2-1) and are included based on concerns in the Draft Foundation Document (NPS 2019a) and discussions with NPS staff and FRST partners.

Brandywine Valley

Management concerns at Brandywine Valley include the spread of invasive exotic plants, forest fragmentation from agriculture and past land uses; development, especially along the Highway 202 Corridor; potential ecological impacts from deer; water quality degradation from multiple sources; and visitation impacts associated mainly with river access (e.g., Smith Bridge picnic and parking areas) and recreational trail use. There are numerous projects with other collaborators at Brandywine Valley, including water quality and watershed monitoring, agricultural land management, and GIS data management (see below). FRST also works with partners; local, state and federal agencies; and adjacent landowners to minimize conflicts between park missions/visitor experience and incompatible land uses. Impacts of climate change on hydrology, flora, and fauna is a concern. A project to estimate deer abundance and evaluate the ecological impacts of deer browsing at Brandywine Valley is underway.

Water quality is a historic and ongoing concern. There are multiple point and non-point pollution sources including agriculture, water treatment, groundwater contamination, stormwater, and road runoff (chloride, other contaminants) sources. Some reaches of the six major tributaries/sub-watersheds in Brandywine Valley (Beaver Creek, Talley Run, Ramsey Run, Palmer Run, Thompson Creek, and Hurricane/Rocky Run) are impaired by runoff. Palmer and Talley Run have the best water quality but very low flows. Ramsey is somewhat impacted by agriculture but may have good potential for restoration. There is PCB contamination and mercury advisories for Brandywine Creek.

John Dickinson Plantation

Noise from traffic on Highway 1 and aircraft noise associated with Dover Air Force Base and seasonal cropdusting on adjacent agricultural lands impact the visitor experience and interrupt interpretive programs. Climate change impact to storm surge and flooding potential in the area surrounding JDP is unknown, but partners have expressed concerns on this topic.

The unit is within Delaware's Saint Jones Estuarine Research Reserve (JERR), which totals over 400 acres. The JERR is bordered by Kitts Hummock Road on the north, Bay Road on the west, the St. Jones River on the south, and the Atlantic Ocean on the east. The unit is less than 20 acres in size. Farming leases exist within the boundary. Management falls under policies and guidance of the JERR and is also approved through the Delaware SHPO. In conjunction with the Friends group, the JDP staff is working on a land management plan for the entire JERR, including JDP.

Fort Christina

Management concerns/issues include noise and visual resource impacts from commercial activities, urban infrastructure, traffic/roads, and nearby industrial activities.

Old Swedes Church

Primary resource management concerns are actual or potential damage to the burial grounds from tree roots; damage associated with underground streams and burrowing animals; noise, mainly from the adjacent railway and commercial and industrial uses; and sustainable planning, maintenance and management of trees on the grounds. Old Swedes Foundation is partnering with University of Delaware Plant and Soil Sciences Department to develop an urban landscape design for the church grounds/cemetery. It will include an inventory and report for all trees present, and a report including a tree succession plan.

New Castle Courthouse, Sherrif's House, and Green

There is concern regarding current flooding of low-lying areas that prevents access to historic New Castle and can damage historic structures. Storm surge and extreme weather is expected to become more severe.

There are no notable natural resource management concerns at the Dover Green or Ryves Holt House.

2.2.3. Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. Much of the supporting baseline survey and monitoring data were collected by private consultants and local and state non-profits. Region 1 of the NPS also supported requests for geospatial data. Landscape context information and aspects of human dimensions were greatly supported by national program staff such as the Natural Sounds and Night Skies Division (NSNSD), the national NPS Air Quality program, and the NPScape Project (no longer active) 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.

2.3. Literature Cited

Coxe, R. 2014. Historical analysis and map of vegetation communities, land covers, and habitats of the Woodlawn Tract, New Castle County, Delaware. Brandywine Creek Watershed. Unpublished Report, Delaware Department of Natural Resources and Environmental Control, Smyrna, Delaware. Submitted to: Mid-Atlantic Network, Inventory and Monitoring Program, National Park Service, Fredericksburg, Virginia.

Nagel, J., and J. E. Gates. 2017. Bat community composition and monitoring for white-nose syndrome at First State National Historical Park, Delaware and Pennsylvania. Natural Resource Report NPS/FRST/NRR—2017/1482. National Park Service, Fort Collins, Colorado.

National Climatic Data Center (NCDC). 2019. Climate of Delaware. Available at: https://www.ncdc.noaa.gov/climatenormals/clim60/states/Clim_DE_01.pdf (accessed 9 September 2019).

National Park Service (NPS). 2006. Management policies 2006: the guide to managing the National Park System. National Park Service, Washington, D.C.

NPS. 2017. Cultural Landscapes Inventory: Beaver Valley, First State National Historical Park.

NPS. 2019a. Draft First State National Historical Park Foundation Document, February 2019. National Park Service.

NPS. 2019b. NPSpecies Database. Available at: https://irma.nps.gov/NPSpecies/ (accessed 9 September 2019).

Northeast Regional Climate Center (NRCC). 2019. Climate Summaries. Available at: http://climod2.nrcc.cornell.edu/ (accessed 10 September 2019).

PAQ. 2011. Preliminary ecological research and assessment in support of the Woodlawn Trustees Vision Plan. Unpublished Report prepared for D.R. Horne and Co.

State of Delaware. 2011. Christina Basin pollution control strategy. Unpublished Report, Delaware Tributary Action Teams, University of Delaware, and Delaware Department of Natural Resources and Environmental Control.

State of Delaware. 2019. Delaware Watersheds. Brandywine Creek. Available at: http://delawarewatersheds.org/piedmont/brandywine-creek/ (accessed 9 September 2019).

Stoner, D. 2014. First State National Monument: Woodlawn Tract bird survey. Unpublished Report.

Taylor, K. A. 2017. National Park Service air quality analysis methods: August 2017. Natural Resource Report NPS/NRSS/ARD/NRR—2017/1490. National Park Service, Fort Collins, Colorado.

U.S. Census Bureau. 2010. American fact finder web site – 2010 Census Total Populations. Available at: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (accessed 10 April 2019).

U.S. Geological Survey. 2020. Streamflow statistics – Brandywine Creek at Wilmington, DE (01481500). https://md.water.usgs.gov/surfacewater/streamflow/brandywine.html (accessed 9 June 2020).

White, J., and A. White. 2015. Amphibian and reptile survey; breeding birds. First State National Historical Park at Beaver Valley Unit, New Castle County, DE and Delaware County, PA. Unpublished Report, Hyla Associates, Hockessin, Delaware.

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 Region 1 Office, First State National Historical Park (FRST), Water Resources Division (NRCA proponent), and National Inventory and Monitoring programs. A site visit and initial meetings took place December 13–15, 2017, at the Pilot School in Wilmington, Delaware. 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:
    - traditional natural resources (e.g., water quality, rare plants),
    - ecological processes or patterns (e.g., fire regime),
    - specific natural or cultural/ethnographic features inextricably linked to natural resources, or
    - values linked to biophysical resources and landscape context (e.g., natural night skies, natural sounds, visual resources);
- 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;
- define project expectations, constraints, and the need to balance depth vs. breadth; and
- review the assessment timeline.

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

- the assessment will provide a snapshot of a subset of park resources, as determined through the scoping process;
- some lower priority resources or those having little supporting data may not be fully examined to allow a more comprehensive analysis of higher-priority resources;
- the assessment will use existing information/data and not modeled or projected data, although limited analysis and data development may be undertaken where feasible (e.g., data to

support views/scenery analysis) – future modeled data are 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 uses a framework adapted from The Heinz Center (2008) to examine condition and trends in key natural resources at the park (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 agents of change. Although threats and stressors are described for each focal resource, the *Land Cover and Land Use* and *Climate Change* sections were added to address broad ecosystem-level processes and stressors affecting multiple resources. A small subset of the resources identified as important to the park and desirable to include in the NRCA during the scoping phase were not included as focal resources 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 12 resources were examined and included here: five addressing system and human dimensions, two addressing chemical and physical attributes, four addressing biological attributes and one addressing integrated resources (wetlands).

The following resources were discussed during the scoping phase but subsequently eliminated from inclusion in the NRCA for reasons described above:

<u>Agricultural Lands – Brandywine Valley Unit</u>

The significance of agricultural fields is discussed in the 2017 *Cultural Landscapes Inventory* for Brandywine Valley (NPS 2017). According to the report, "The agricultural use, the preservation of historic buildings, structures and ruins, and the contrast between the open and wooded areas of the landscape all contribute its Brandywine Valley watershed character." Agriculture operations exist within the Brandywine Valley boundary either as inholdings or under lease. The most high-profile commercial operation is Hypoint Dairy. There are approximately 12 agricultural leases on Brandywine Valley held by individuals and commercial agricultural companies. Agricultural operations managed by the park within Brandywine Valley include permanent hay fields (the majority of the agricultural acreage), row crops such as beans and corn, and horse operations. Park management of agricultural operations, which occurs largely through Team Ag support, focuses on developing and using best management practices, soil conservation plans, and establishing management targets and guidelines for operators/lessees. Primary areas of interest and issues of concern are protecting water quality, maintaining ecological buffers to help contain/filter nutrients and sediments, manure handling and storage, and maintaining soil quality. No significant changes are anticipated to the agriculture leasing and management in the near future. This is an interesting aspect of the Brandywine Valley unit but it was decided that this is not a focal resource for the park.

Table 3.2-1. First State National Historical Park natural resource condition assessment framework.

Ecosystem Attributes	Focal resources	Indicators and Measures of Condition
Landscape Context – System and Human Dimensions	Land Cover and Land Use	Land cover/land use
	Land Cover and Land Use	Population and housing
	Land Cover and Land Use	Conservation/protection status
	Climate Change	Temperature and precipitation changes
	Climate Change	Aridity
	Climate Change	Frost-free period
	Night Sky	Sources of light pollution
	Night Sky	All-sky Light Pollution Ratio (ALR)
	Natural Sounds	Anthropogenic sources of noise
	Natural Sounds	Modeled ambient noise levels above natural levels
	Natural Sounds	Traffic volumes on nearby and park roads
	Visual Resources	Integrity of landscape views from key view points
Chemical and Physical	Air Quality	Level of ozone (human, plant impacts)
	Air Quality	Atmospheric wet deposition of total N and total S
	Air Quality	Visibility haze index
	Water Quality	–
Biological – Plants	Forest Communities	Extent of natural vegetation cover
	Forest Communities	Non-native vegetation
	Forest Communities	White-tailed deer population
	Forest Communities	Forest pests and diseases
	Forest Communities	Forest vulnerability to climate change
Biological – Animals	Birds	Bird index of biotic integrity (IBI)
	Bats	Proportion of expected species present
	Reptiles and Amphibians	Proportion of expected species present
Integrated	Wetlands	Extent
	Wetlands	Surrounding land use index
	Wetlands	Landscape connectivity
	Wetlands	Buffer index

Rare Plants and Plant Communities – Brandywine Valley Unit

The primary sources of information for rare plants are surveys conducted by Janet Ebert, including the initial survey of the 2,000-acre Woodlawn Tract property in 1995 (Ebert 1995) and a resurvey of the 1,105-acre NPS Brandywine Valley Unit during 2014 and 2015 (Ebert undated). For the surveys, the area was divided into 69 survey sections and separate plant lists were kept for each section. The sections were determined by habitat type and land use, using roads, trails, or obvious changes in habitat as much as possible, although many sections contained more than one habitat type. Dividing the area into sections helped to efficiently survey the flora and provides a rough picture of species distribution. Given the differences in effort and sections visited in 1995 vs. 2014/2015, the results for the two years are not directly comparable, but still provide valuable information on species composition, rare species presence, and non-native species frequency and abundance. Approximately 100 species found in 1995 were not documented in 2014/2015, and approximately the same number of species were documented in 2014/2015 but not found in 1995.

In the Delaware portion of Brandywine Valley, 45 rare species were documented (Ebert undated, Ebert 1995). Thirteen species ranked S1 (1 to 5 known statewide populations) and 32 ranked S2 (6 to 20 known statewide populations). The large number of Delaware rarities reflects the limited amount of the Piedmont region in the state and the significance of Brandywine Valley as one of the largest tracts in the Brandywine watershed that has so far escaped development (Ebert undated). Only two species found at Brandywine Valley were ranked as rare in both Pennsylvania and Delaware, nodding trillium (*Trillium cernuum*, S2 in both states) and tawny ironweed (*Vernonia glauca*, S1 in PA, S3 in DE). In 2014/2015, two S1 species and four S2 species found in 1995 were searched for but not found. Habitats supporting rare plants included aquatic and stream edges, floodplain woodlands, floodplain edges, open to partly shaded wetlands, wooded wetlands, disturbed edges, meadows, upland woodlands, Rocky Run forests, dry or rocky forests, mesic rich forests. See Ebert (undated) for a full description of all rare species and their habitats.

These topics may also be mentioned in Chapter 2 or in focal resource sections in Chapter 4.

3.2.2. Reporting Areas

The reporting area varies among focal resources. It is generally the entire area within the park unit boundary. The Brandywine Valley unit is the largest unit, containing the most significant natural resources, and is located in a somewhat rural setting. Likewise, John Dickinson Plantation is located in a rural setting. The remaining units – Fort Christina, Old Swedes Church, New Castle Green, Dover Green, and Ryves Holt house have significance primarily related to cultural and historical values. In some cases (e.g., water quality) indicators were analyzed using subsets based on geographic, hydrologic or ecological strata within the unit. The results for those subsets were then combined into single park-wide condition and trend ratings for the resource. For several resources, such as those capturing landscape context (e.g., land cover and land use, natural night skies, natural sounds and visual resources), the extent of the analysis for some indicators often extends outside park boundaries.

3.2.3. General Approach and Methods

General Approach

This study employed a scoping process involving Colorado State University, FRST and other NPS staff to discuss the NRCA framework, identify important park resources, and gather existing literature and data for each of the focal resources. Indicators and measures to be used for each resource were then identified and evaluated. All available data and information were analyzed and synthesized to provide summaries and address condition, trend, and confidence. Condition ratings compared the current condition(s) at the park to the reference condition(s) when possible. In some cases, due to interrelationships, a focal resource was used to help determine condition and/or trend for another focal resource. For example, changes in fire disturbance regime in the area were used to support trend determination for forest/woodland communities.

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, various plant and animal surveys completed by outside entities, and the public access side of the Integrated Resource Management Applications (IRMA) web portal, which is intended as a "one-stop shop" for data and information on park-related resources. Park and Region 1 staff were also an invaluable source of knowledge regarding resources, stressors, management history, and activities. Spatial data were provided by the park, the NPS Region 1 Office and other sources. GIS data developed to support analyses or maps were documented using NPS metadata standards. The NPS Night Skies and Natural Sounds Division (NSNSD) provided valuable data to support the assessment. Primary data sources are described in each focal resource section. In some cases, existing data were reworked or raw data were summarized in order to make them more useful for analysis.

Subject Matter Experts

Several 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 were 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, to collaborate on an analysis framework/ 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 was established and a condition rating framework presented. The condition rating framework formed the basis for assigning a current condition to each indicator. In some cases, current condition and trend was based on qualitative, semi-quantitative, or quantitative data/ information that was several or more years old. Trend was assigned where data existed for at least two time periods separated by an ecologically significant span or was based on qualitative assessments using historical information, photographs, anecdotal evidence, or professional opinion. There was sometimes a degree of correlation among indicators for a focal resource. In a few cases, the trend assigned to an indicator was influenced by the data for a correlated indicator. For example, traffic trend data influenced the trend rating for anthropogenic noise levels.

The level of confidence assigned to each indicator integrated the comfort level associated with the condition and/or trend rating assigned. A lower confidence (i.e., higher uncertainty) could have been assigned where modeled data had considerable uncertainty or numerous assumptions, where changes were small and no quantitative data were available, where statistical inference was poor (e.g., as is often the case where sample sizes were inadequate), where interannual or seasonal variability was very high or unknown, where detectability was difficult when monitoring (e.g., some plants and birds), where only several closely spaced data points were available for trend determination (e.g., invasive exotic plant sampling only several years apart and only 2 periods available), or where a very small proportion of the reference frame or population of interest was 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 have resulted in an unknown condition rating, which was often associated with unknown trend and low confidence.

The climate change indicators were not assigned a status or trend, but were included for context and as a possible resource stressor. For some resources, the estimated vulnerability was used as a trend indicator along with other indicators. We used climate change vulnerability only as an indicator of trend for focal species and communities of interest.

3.2.5. Symbology and Scoring[4]

This NRCA used 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 provided some consistency with other NPS initiatives such as State of the Parks and Resource Stewardship Strategies.

The overall assessment of the condition for a focal resource was 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 were assigned for two or more indicators or measures of condition. To determine the combined condition, each red symbol was assigned zero points, each yellow symbol was assigned 50 points, and each green symbol was assigned 100 points. Open (uncolored) circles were omitted from the calculation. Average scores of 0 to 33 warranted significant concern, average scores of 34 to 66 warranted moderate concern and average scores of 67 to 100 indicated the resource is in good condition. In some cases, certain indicators were assigned larger weights than others when combining multiple metrics into a condition score. In these cases, the authors provided an explanation for the weights applied.

[4] Adapted from NPS-NRCA Guidance Update dated January 14, 2014.

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 was 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. In somes cases the trend for certain indicators was weighted more heavily.

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 2014). 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 historic conditions and anticipated future conditions (Figure 3.2-1).

For example, substantial overlap may exist for prairie vegetation, moderate overlap may exist for birds and little or no overlap may exist for nonnative invasive plants. Reference conditions can be particularly difficult to define where presettlement conditions or range of variability are unknown, and/or where little inventory and monitoring data exist.

Condition and Trend

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 consolidated for each resource using the condition rating scoring framework described earlier in this chapter.

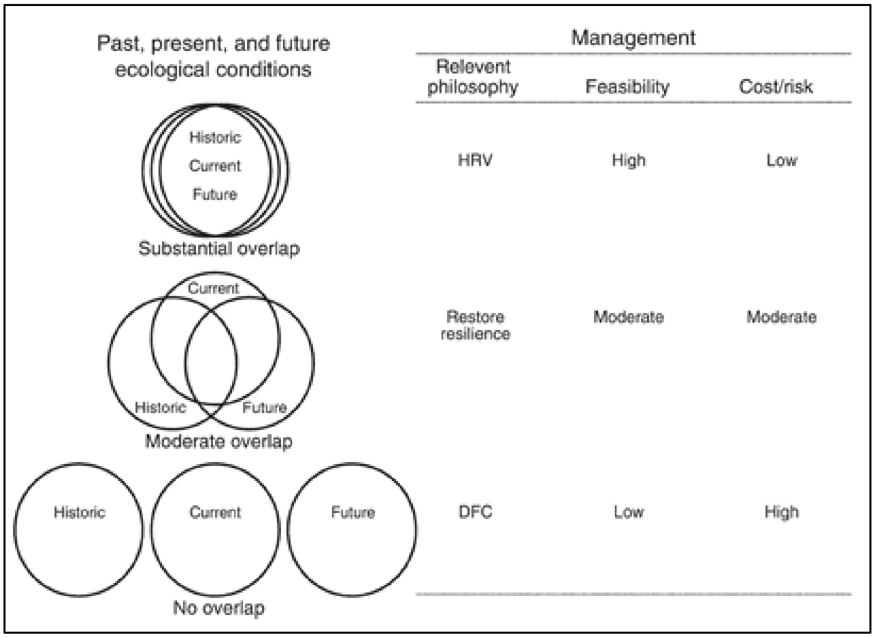


Figure 3.2-1. Illustration of three possible cases of the extent to which current ecosystem conditions in a place differ from historic conditions and from projected future conditions. Circles denote the range of variability for each time period. Also shown are the expected management criteria for each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

Uncertainty and Data Gaps

This section briefly highlights information and data gaps and uncertainties related to assessment of the resource. Low confidence can be associated with a combination of data that are not current, insufficient data, unrepresentative data, poorly documented data, or data having poor precision or accuracy.

Sources of Expertise

Individuals who were consulted or provided preliminary reviews for the focal resource are listed in this section.

Literature Cited

This section lists all the referenced sources in this section.

3.3. Literature Cited

Ebert, J. Undated. First State National Historical Park botanical inventory and assessment (following 2014–2015 surveys). Report prepared for the Brandywine Conservancy.

Ebert, J. 1995. Botanical Survey of Lands of Woodlawn Trustees, Inc. Unpublished.

Hansen, A. J., N. Piekielek, C. Davis, J. Hass, D. M. Theobald, J. E. Gross, W. B. Monahan, T. Olliff, and S. W. Running. 2014. Exposure of U.S. National Parks to land use and climate change 1900–2100. Ecological Applications 24(3):484–502.

National Park Service (NPS). 2014. Natural resource condition assessment guidance documents and useful resources. NPS Water Resources Division. Available at: Natural Resource Condition Assessment Program - Water Resources Division (U.S. National Park Service) (nps.gov)

NPS. 2017. Cultural Landscapes Inventory: Beaver Valley, First State National Historical Park.

The H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center). 2008. The state of the nation's ecosystems 2008: measuring the lands, waters, and living resources of the United States. Washington, D.C.

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 regional conservation value of the park. 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.

Although FRST is comprised of numerous units, only Brandywine Valley and John Dickinson Plantation are analyzed in this section as they are the only units with substantial natural resources that would be affected by these land use metrics. Land use dynamics can also impact resources such as natural night skies and natural sounds, which are addressed in their own chapters.

<u>Threats and Stressors</u>

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 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 natural night skies, natural soundscapes, and viewscapes/scenery.

Indicators and Measures

- Land cover and use
  - Extent of Anderson Level II classes
  - Extent of natural vs. converted land cover
  - Extent of current and projected development intensity
  - Extent of impervious surface area
- Human population and housing
  - Population total and density by census block group
  - Historic population totals by county
  - Historic and projected housing density
- Conservation status
  - Protected area (ownership) extent
  - Biodiversity conservation status (level of protection)
- Ecological Integrity and Resilience
  - Index of Ecological Integrity

4.1.2. Data and Methods

Spatial data for land cover were obtained from the Multi-Resolution Land Characteristics (MRLC) consortium National Land Cover Database (NLCD) for 2011 and 2016. Population and housing data were provided by the NPS NPScape Program. Both the NLCD and data supplied by NPScape were summarized by following 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. Acreages for all metrics include open water unless otherwise noted.

Table 4.1-1. Areas of analysis used for landscape context measures.

Data Type	Indicators and Measures	3 km buffer around park	Park + 30 km buffer	Contributing (upstream) watershed	Counties overlapping with park
Land cover and use	Anderson Level II	X	X	–	–
	Natural vs. converted land cover	X	X	–	–
	Current and projected development intensity	–	X	–	–
	Impervious surfaces	–	X	X	–
Human Population and Housing	Population total and density by census block group	–	X	–	–
	Historic population totals by county	–	–	–	X
	Historic and projected housing density 1970–2010	–	X	–	–
Conservation status	Protected areas (ownership) and biodiversity conservation status	–	X	–	–
Ecological Integrity and Resilience	Index of ecological integrity	X	X	–	–

Land Cover and Use

NLCD data 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 change detection is a very powerful tool because it follows a well-documented, consistent procedure that is highly repeatable over time. 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 Table 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

Current and Projected Development Intensity

The Delaware River Basin Project (DRBP) is a collaboration between the Center for Land Use and Sustainability at Shippensburg University, the University of Vermont Spatial Analysis Lab, USGS and the William Penn Foundation to map, model, and monitor the relationship between water resources and land use dynamics in the Delaware River Basin. The DRBP used NLCD data and the SLEUTH urban growth model to map current (as of 2011) and model future (2030 and 2070) development in the basin. Three scenarios were used to model future changes, with the baseline or "business as usual" option used for the analysis in this section.

Impervious Surface Area

Impervious ground surface percentage was measured using the 2011 NLCD and Open Street Map by the University of Massachusetts Landscape Ecology Lab (McGarigal et al. 2017a) and analyzed using the areas of analysis listed in Table 4.1-1. This analysis was not completed for John Dickinson Plantation due to the difficulty in assessing hydrological contributions to this unit, which are complicated by the tidal nature of the Delaware River in the area as well as the John Dickinson Plantation property being located at the top of its catchment.

Human Population and Housing

Housing Density

Change from 1970 to 2010 and projected changes to 2050 were examined. The NPScape housing density metrics used here are based on the Spatially Explicit Regional Growth Model (SERGoM v3) (Theobald 2005). Housing density data are categorized into 11 non-uniform development classes 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 Brandywine Valley and John Dickenson Plantation Units, and U.S Census Bureau block data from 1990, 2000 and 2010 for population density. Population density (number of people per square kilometer) classes follow NPScape guidance (NPS 2014b).

Conservation Status

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

Ownership

Land ownership greatly influences the level of conservation protection. The PAD-US (CBI Edition) Version 2 is a national database of protected fee lands in the United States. It portrays the United States protected fee lands with a standardized spatial geometry with valuable attribution on land ownership, management designations, and conservation status (using national GAP coding systems). The National Conservation Easement Database (NCED) Version III (July 2013) is a voluntary national geospatial database of conservation easement information that compiles records from land trusts and public agencies throughout the United States. It is a collaborative partnership by the Conservation Biology Institute, Defenders of Wildlife, Ducks Unlimited, NatureServe, and the Trust for Public Land (NCED 2019). As of November 2019, the acreage of publicly-held easements is considered to be 19% complete for Delaware; the accounting of the acreage of NGO-held easements in Delaware is currently estimated at approximately 90% complete. The low percentage of completeness for publicly-held easements is because: 1) they have not been digitized, 2) they were withheld from NCED, or 3) the NCED team is still working with the easement holders to collect the information (NCED 2019; see http://www.conservationeasement.us/about/completeness).

Level of Protection

The United States Geological Survey 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 (CBI Version 2) database includes the coded GAP biodiversity protection status of each parcel. The NCED database is designed to accommodate the GAP protection status field but most parcels have not been assigned a GAP conservation value. The four status categories are described below.

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

- **Status II:** These areas have permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but may receive use or management practices that degrade the quality of existing natural communities. Some national parks, most wilderness areas, USFWS Refuges managed for recreational uses, and BLM Areas of Critical Environmental Concern are included in this class.
- **Status III:** These areas have permanent protection from conversion of natural land cover for the majority of the area, but may be subject to extractive uses of either a broad, low-intensity type or localized intense type. This class also confers protection to federally-listed endangered and threatened species throughout the area. Most non-designated public lands, including USFS, BLM and state park land are included in this class.
- **Status IV:** These areas lack irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types. This class allows for intensive use throughout the tract, and includes those tracts for which the existence of such restrictions or sufficient information to establish a higher status is unknown. Most private lands fall into this category by default.

Protected areas data from the two databases 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.

Ecological Integrity and Resilience

Index of Ecological Integrity

The Index of Ecological Integrity (IEI) is an index of intactness and resiliency to change driven by land use, climate change, or other human or environmentally driven factors (McGarigal et al. 2017b). The IEI is a composite index made up of 21 discrete landscape metrics. It is presented on a 0 to 1 scale with areas having a value of 0 being of low integrity or resilience (representing highly fragmented and developed areas), and 1 being of high integrity or resilience (surrounded by large mostly undisturbed natural areas). The index is scaled by both ecological system and geographic area. Ecological systems are compared to like ecological systems (e.g., a high quality forest may not have the same attributes as a high quality wetland). Scaling by geographical area refers to the index's scaling within a specified extent (e.g., the state-level scaled index will compare like ecological systems within the same state, and not with those outside that state's border). For this analysis, the scale for the 30 km area will use the regional-level scale, while the 3 km area will show the HUC6-level scaled data product. The index is relative, meaning the index for one area is based on areas it is compared to and a score of 1 does not necessarily mean "perfect condition." Documentation for this data product is provided by the University of Massachusetts Landscape Ecology Lab (McGarigal et al. 2017b).

4.1.3. Condition and Trend

Land Cover and Use

Extent of Anderson Level II Classes 2016

In the immediate vicinity of the Brandywine Valley unit, (3 km buffer) nearly 38% of land acreage is forested, and almost 35% is low density development (either low intensity or developed open space) (Table 4.1-3a, Figure 4.1-1). Approximately 20% of the land area within 3 km of Brandywine Valley is non-open space development. Within the 30 km buffer, 22% of the acreage is forested and over 20% is non-open space development. The forest areas are very fragmented, and likely have lost much of their ecological function (Figure 4.1-1). The total amount of agricultural land is fairly low at 17.5% and 22.3% (for the 3 km and 30 km buffers, respectively).

For John Dickinson Plantation, cultivated crops are the largest non-water land cover class for both the 3 km and 30 km buffers (36.1% and 29.7%, respectively; open water accounts for over 36% of the 30 km buffer's area) (Table 4.1-3b).

Table 4.1-3a. Anderson Level II land cover classes within 3 km and 30 km of the park boundary for Brandywine Valley.

	3 km Buffer		Park + 30 km Buffer	
Anderson Level II Classes	**Acres**	**% of Area**	**Acres**	**% of Area**
Barren Land	<3	0.02%	1,572	0.20%
Cultivated Crops	258	1.68%	90,426	11.61%
Deciduous Forest	3,764	24.44%	109,475	14.06%
Developed, High Intensity	313	2.03%	24,231	3.11%
Developed, Low Intensity	2,019	13.11%	84,882	10.90%
Developed, Medium Intensity	755	4.90%	50,015	6.42%
Developed, Open Space	3,321	21.56%	151,579	19.47%
Emergent Herbaceous Wetlands	20	0.13%	21,484	2.76%
Evergreen Forest	160	1.04%	2,648	0.34%
Hay/Pasture	2,442	15.86%	83,354	10.71%
Herbaceous	17	0.11%	3,650	0.47%
Mixed Forest	1,920	12.47%	61,483	7.90%
Open Water	79	0.52%	43,948	5.64%
Perennial Snow/Ice	0	0.00%	0	0.00%
Shrub/Scrub	105	0.68%	6,005	0.77%
Unclassified	0	0.00%	0	0.00%
Woody Wetlands	224	1.45%	43,877	5.64%
Total	**15,399**	**–**	**778,630**	**–**

Table 4.1-3b. Anderson Level II land cover classes within 3 km and 30 km of the park boundary for John Dickinson Plantation (data provided by NPS NPScape Program).

	3 km Buffer		Park + 30 km Buffer	
Anderson Level II Classes	**Acres**	**% of Area**	**Acres**	**% of Area**
Barren Land	87	1.12%	709	0.10%
Cultivated Crops	2,821	36.13%	209,517	29.66%
Deciduous Forest	60	0.77%	21,995	3.11%
Developed, High Intensity	157	2.02%	3,156	0.45%
Developed, Low Intensity	285	3.65%	16,578	2.35%
Developed, Medium Intensity	269	3.44%	7,294	1.03%
Developed, Open Space	1,194	15.29%	30,746	4.35%
Emergent Herbaceous Wetlands	1,523	19.52%	60,345	8.54%
Evergreen Forest	0	0.00%	2,151	0.30%
Hay/Pasture	24	0.31%	1,626	0.23%
Herbaceous	5	0.07%	250	0.04%
Mixed Forest	10	0.13%	8,027	1.14%
Open Water	343	4.39%	256,131	36.26%
Perennial Snow/Ice	0	0.00%	0	0.00%
Shrub/Scrub	0	0.00%	967	0.14%
Unclassified	0	0.00%	0	0.00%
Woody Wetlands	1,027	13.15%	86,934	12.31%
Total	**7,805**	**–**	**706,425**	**–**

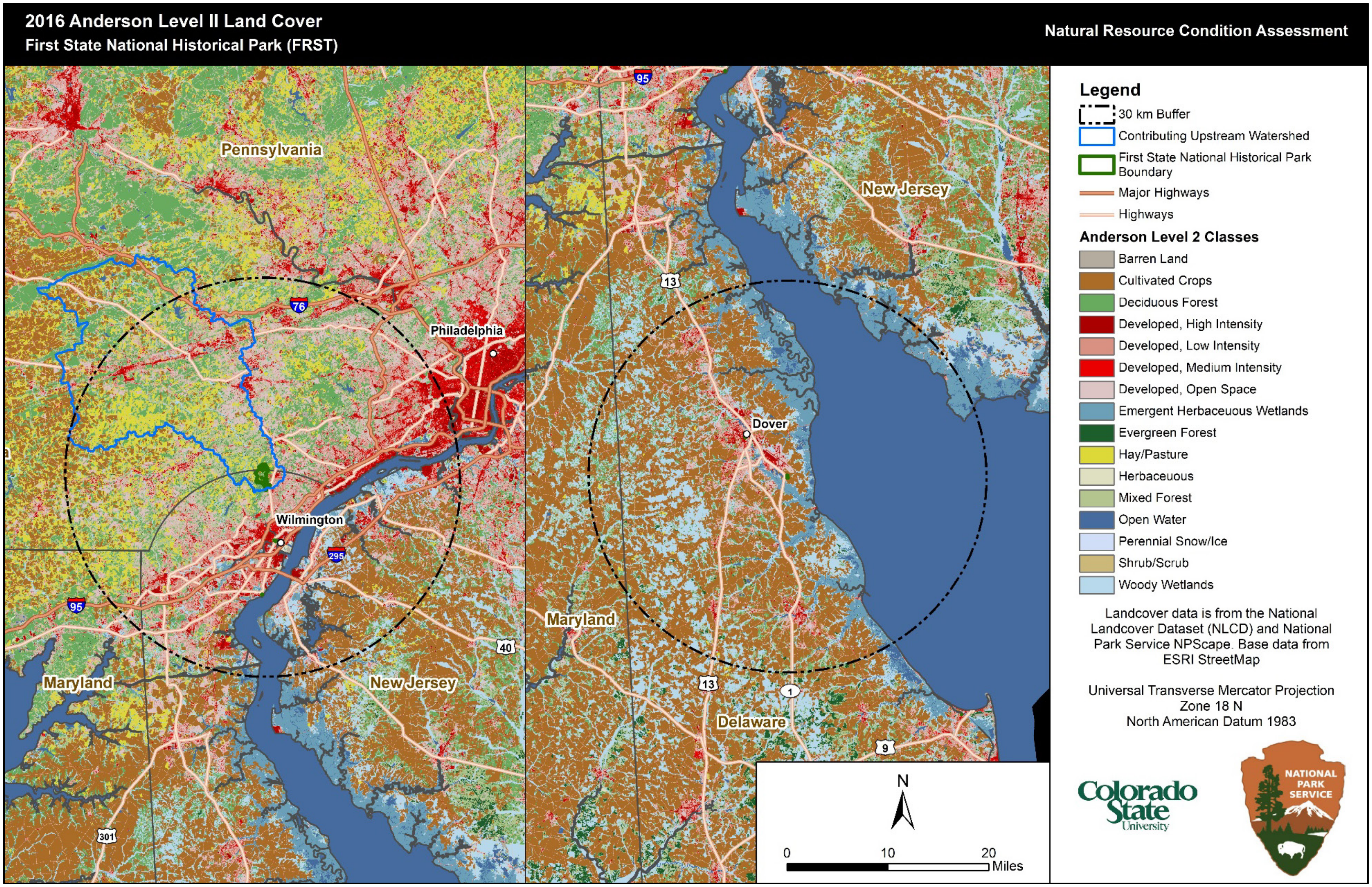


Figure 4.1-1. Anderson Level II land cover classes within 3 km and 30 km of the boundary of Brandywine Valley (left) and John Dickinson Plantation (right). Data from National Land Cover Dataset (MRLC 2016).

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.

Within 30 km of Brandywine Valley, over 62% of the area is classified as converted and just 38% of the 30 km buffer for John Dickinson Plantation is classified as converted, though this is partially due to the presence of open water; Table 4.1-4a, Table 4.1-4b, Figure 4.1-2. Land within the 3 km buffers for both properties is approximately 60% converted.

Table 4.1-4a. Natural vs. converted acreage within 3 km and 30 km of the park boundary for Brandywine Valley (data provided by the NPS NPScape Program).

	Natural		Converted	
AOA	**Acres**	**% of Area**	**Acres**	**% of Area**
3 km	6,291	40.85%	9,108	59.15%
Park + 30 km Buffer	294,142	37.78%	484,488	62.22%

Table 4.1-4b. Natural vs. converted acreage within 3 km and 30 km of the park boundary for John Dickinson Plantation (data provided by the NPS NPScape Program).

	Natural		Converted	
AOA	**Acres**	**% of Area**	**Acres**	**% of Area**
3 km	3,056	39.16	4,748	60.84
Park + 30 km Buffer	437,508	61.93	268,917	38.07

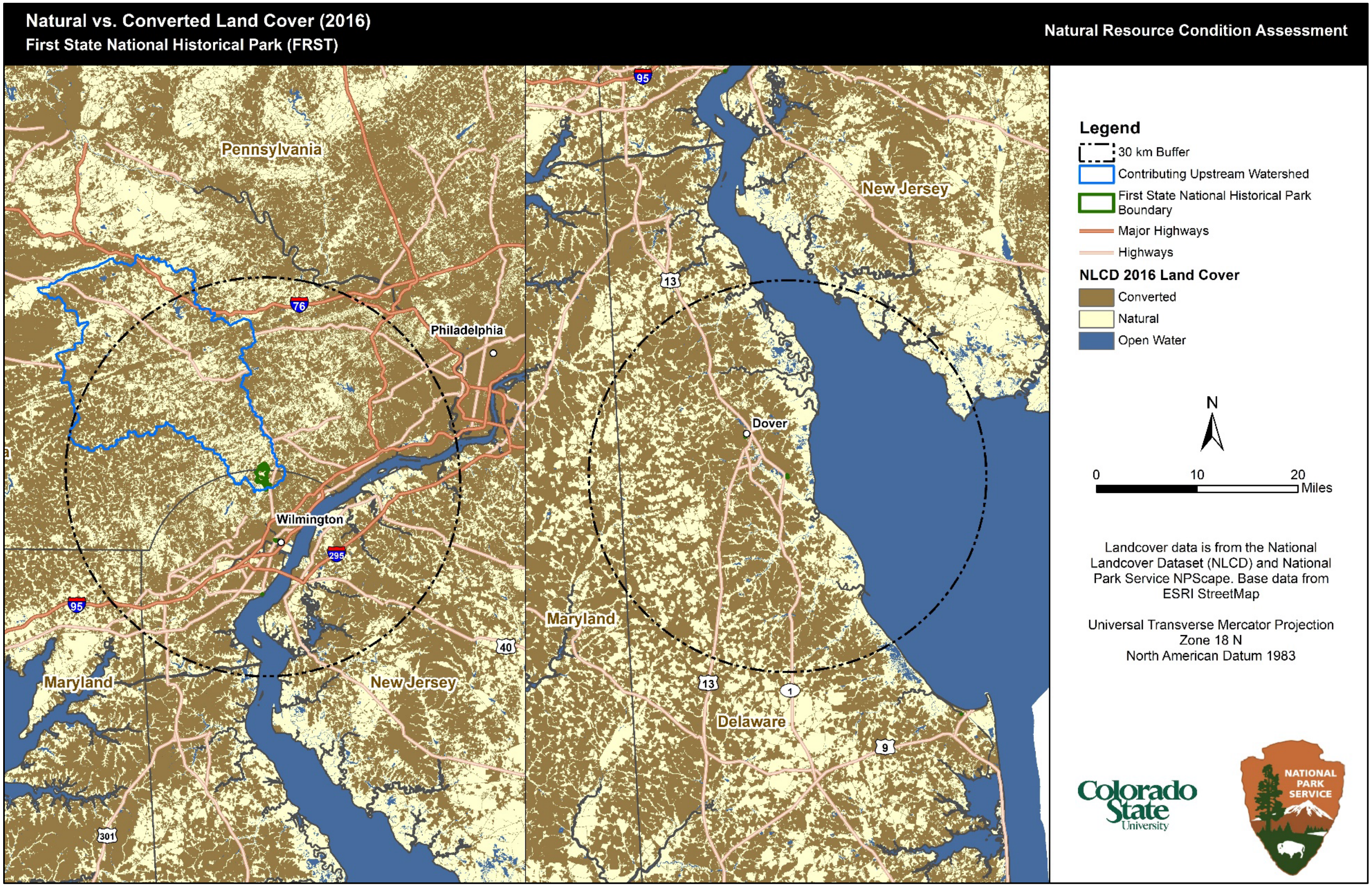


Figure 4.1-2. Natural vs. converted land cover classes within 3 km and 30 km of the boundary of Brandywine Valley (left) and John Dickinson Plantation (right). Data from National Land Cover Dataset (MRLC 2016).

Current and Projected Development Intensity

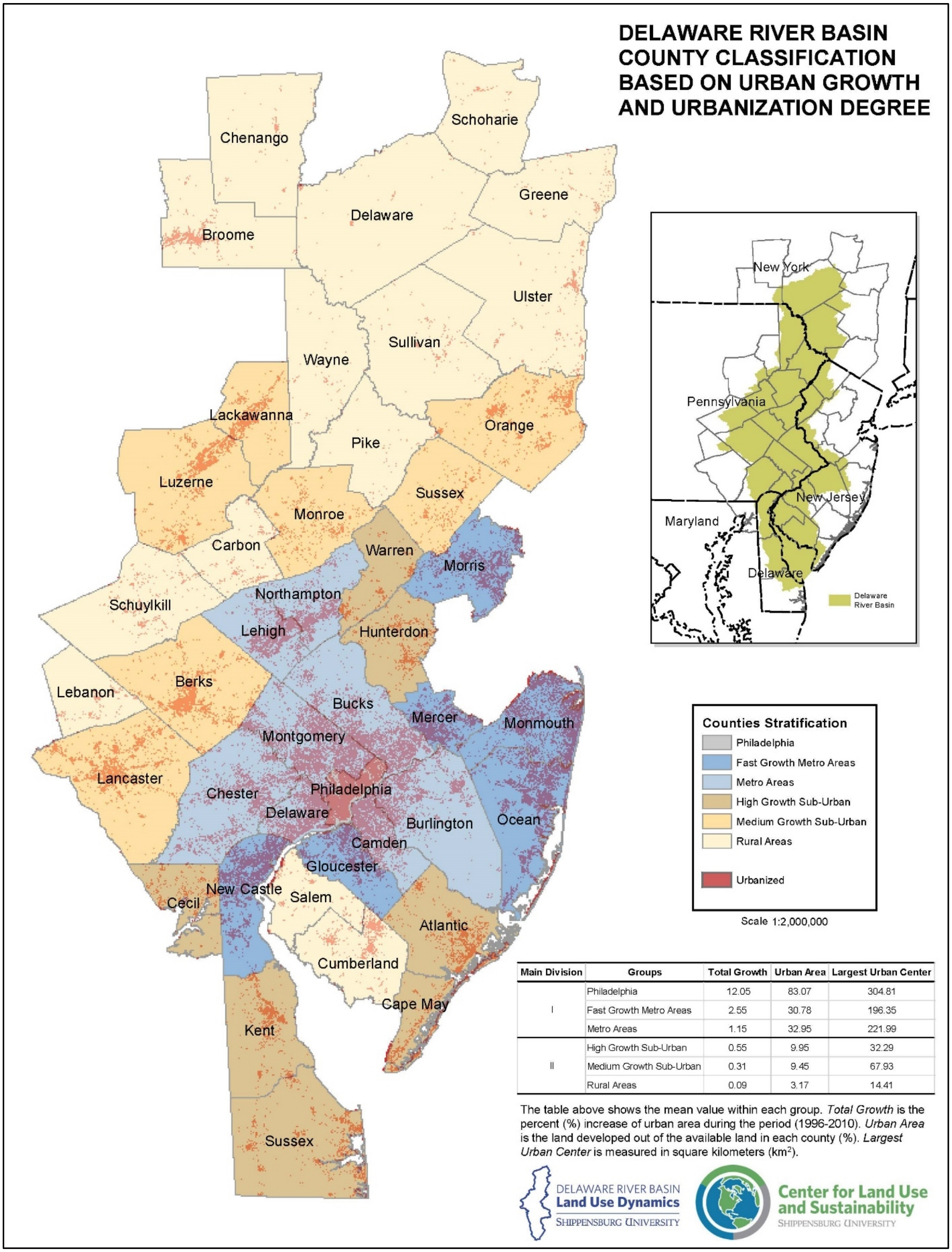
The land cover analysis by the Delaware River Basin Project regarding percent development by watershed shows an increase in development intensity expected between 2011 and 2070 for their baseline or "business as usual" growth scenario (Table 4.1-5, Table 4.1-6) (DRPB 2017). Another county-level land cover analysis by DRBP shows New Castle County (where Brandywine Valley resides) as a "Fast Growth Metro Area" (DRBP 2015) (Figure 4.1-3).

Table 4.1-5. Current (2011) and projected (2030, 2070) percent development categories within 30 km of the park boundary for Brandywine Valley (DRBP 2015).

	2011		2030		2070	
Percent Development	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
33.1–100.0	441,234	54.0%	485,397	59.4%	518,167	63.4%
16.1–33.0	183,118	22.4%	168,669	20.7%	168,563	20.6%
8.1–16.0	113,476	13.9%	107,728	13.2%	90,254	11.1%
≤ 8.0	40,802	9.7%	16,836	6.7%	1,646	4.9%

Table 4.1-6. Current (2011) and projected (2030, 2070) percent development categories within 30 km of the park boundary for John Dickinson Plantation (DRBP 2015). The high acreage for ≤ 8.0% development is primarily due to its proximity to water.

	2011		2030		2070	
Percent Development	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
33.1–100.0	42,506	8.2%	54,384	10.5%	68,574	13.2%
16.1–33.0	55,477	10.7%	62,685	12.0%	59,644	11.5%
8.1–16.0	80,232	15.4%	93,356	17.9%	110,989	21.3%
≤ 8.0	528,210	65.7%	496,000	59.6%	467,218	54.0%



Main Division	Groups	Total Growth	Urban Area	Largest Urban Center
I	Philadelphia	12.05	83.07	304.81
	Fast Growth Metro Areas	2.55	30.78	196.35
	Metro Areas	1.15	32.95	221.99
II	High Growth Sub-Urban	0.55	9.95	32.29
	Medium Growth Sub-Urban	0.31	9.45	67.93
	Rural Areas	0.09	3.17	14.41

The table above shows the mean value within each group. *Total Growth* is the percent (%) increase of urban area during the period (1996-2010). *Urban Area* is the land developed out of the available land in each county (%). *Largest Urban Center* is measured in square kilometers (km^2).

DELAWARE RIVER BASIN Land Use Dynamics SHIPPENSBURG UNIVERSITY

Center for Land Use and Sustainability SHIPPENSBURG UNIVERSITY

Figure 4.1-3. Urbanization by county in the Delaware River Basin (DRBP 2015).

Impervious Surface Area

Impervious surfaces include bare rock, paved roads, and areas covered with concrete/cement. These surfaces prevent infiltration of precipitation into the ground. This reduced infiltration can cause significant hydrological effects including quicker runoff into streams and rivers resulting in flooding, more rapid rising and dropping of streamflow after precipitation events, reduced local evapotranspiration, and reduced recharge of local aquifers. Imperviousness can also increase aquatic pollution as contaminant transport is increased by water flowing directly to a stream or other water body without the opportunity for uptake or decomposition by plants and soil organisms.

Most of Brandywine Valley's contributing (upstream) watershed is in the lowest imperviousness class (0–2% impervious surfaces) (Table 4.1-7). As a benchmark for future analysis, approximately 21.05% of the contributing (upstream) watershed of Brandywine Valley was classified as having >25% impervious surfaces (Table 4.1-7), the majority of which is concentrated near the US-30 highway near Lancaster, Pennsylvania.

Table 4.1-7. Percent impervious surface within the contributing (upstream) watershed of Brandywine Valley (Data provided by the NPS NPScape Program).

Percent Impervious Surface	Acres	% of Area
0%–2%	112,630	69.10%
2%–4%	2,843	1.74%
4%–6%	2,128	1.31%
6%–8%	1,666	1.02%
8%–10%	1,352	0.83%
10%–15%	3,068	1.88%
15%–25%	5,003	3.07%
25%–50%	22,538	13.83%
50%–100%	11,766	7.22%
Total	**162,994**	**–**

Human Population and Housing

Historic Population

High human population density has been shown to adversely affect the persistence of habitats and species (Kerr & 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 Brandywine Valley is low to moderate, with most of the area within this 30 km radius having a density of 21–750 people/km^2 (Table 4.1-8, Figure 4.1-4). The population density of John Dickinson Plantation is lower with more than 60% of the 30 km buffer having a density of 1–75 people/km^2 (Table 4.1-9). Since 1990, population has been steadily rising around both park units from lower (1–150 people/km^2) to moderate (151–1200 people/km^2) densities (Figure 4.1-4, Figure 4.1-5). Historically, the three counties containing Brandywine Valley (New Castle County, Delaware and Delaware County, Pennsylvania) and John Dickinson Plantation (Kent County, Delaware) have all grown in population since the early 1900s, with the counties surrounding Brandywine Valley growing more rapidly since at least 1950 (Figure 4.1-6).

Table 4.1-8. Population density classes and acreage for 1990, 2000, and 2010 by census block group for Brandywine Valley and surrounding 30 km buffer (data provided by the NPS NPScape Program).

	1990		2000		2010	
Population Density (#/km^2)	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
1–20	52,150	7.08%	47,487	6.45%	27,508	3.78%
21–75	146,257	19.86%	126,938	17.24%	118,433	16.25%
76–150	172,919	23.48%	130,690	17.75%	98,114	13.46%
151–300	114,037	15.48%	141,226	19.18%	155,674	21.36%
301–750	121,787	16.54%	143,668	19.51%	180,083	24.71%
751–1200	47,803	6.49%	61,629	8.37%	61,092	8.38%
1201–1500	18,569	2.52%	24,690	3.35%	25,809	3.54%
1501–2000	19,839	2.69%	17,094	2.32%	18,726	2.57%
2001–3000	19,970	2.71%	21,590	2.93%	20,284	2.78%
>3000	23,169	3.15%	21,369	2.90%	22,954	3.15%

Table 4.1-9. Population density classes and acreage for 1990, 2000, and 2010 by census block group for John Dickinson Plantation and surrounding 30 km buffer (data provided by the NPS NPScape Program).

	1990		2000		2010	
Population Density (#/km^2)	**Acres**	**% of Area**	**Acres**	**% of Area**	**Acres**	**% of Area**
1–20	113,597	24.06%	101,774	22.53%	79,905	17.67%
21–75	218,423	46.26%	217,292	48.10%	211,858	46.86%
76–150	75,700	16.03%	76,599	16.96%	80,422	17.79%
151–300	24,015	5.09%	34,712	7.68%	42,706	9.45%
301–750	16,002	3.39%	16,067	3.56%	29,589	6.54%
751–1200	2,701	0.57%	3,895	0.86%	4,807	1.06%
1201–1500	1,190	0.25%	624	0.14%	1,121	0.25%
1501–2000	211	0.04%	742	0.16%	1,474	0.33%
2001–3000	20,284	4.30%	0	0.00%	227	0.05%
>3000	0	0.00%	61	0.01%	0	0.00%

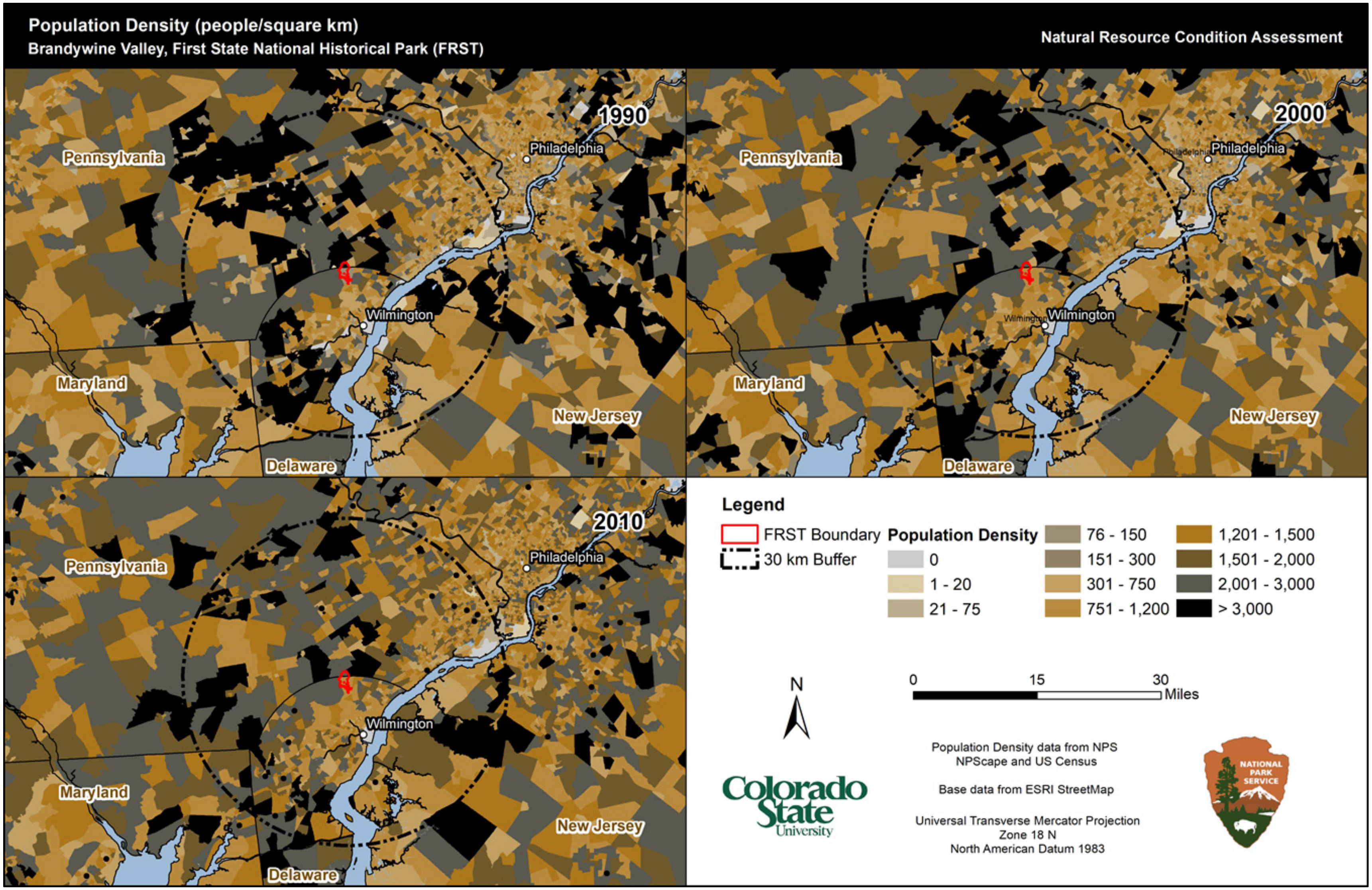


Figure 4.1-4. Population density for 1990, 2000, and 2010 by census block group for Brandywine Valley and surrounding 30 km buffer. U.S. Census data provided by NPScape Program.

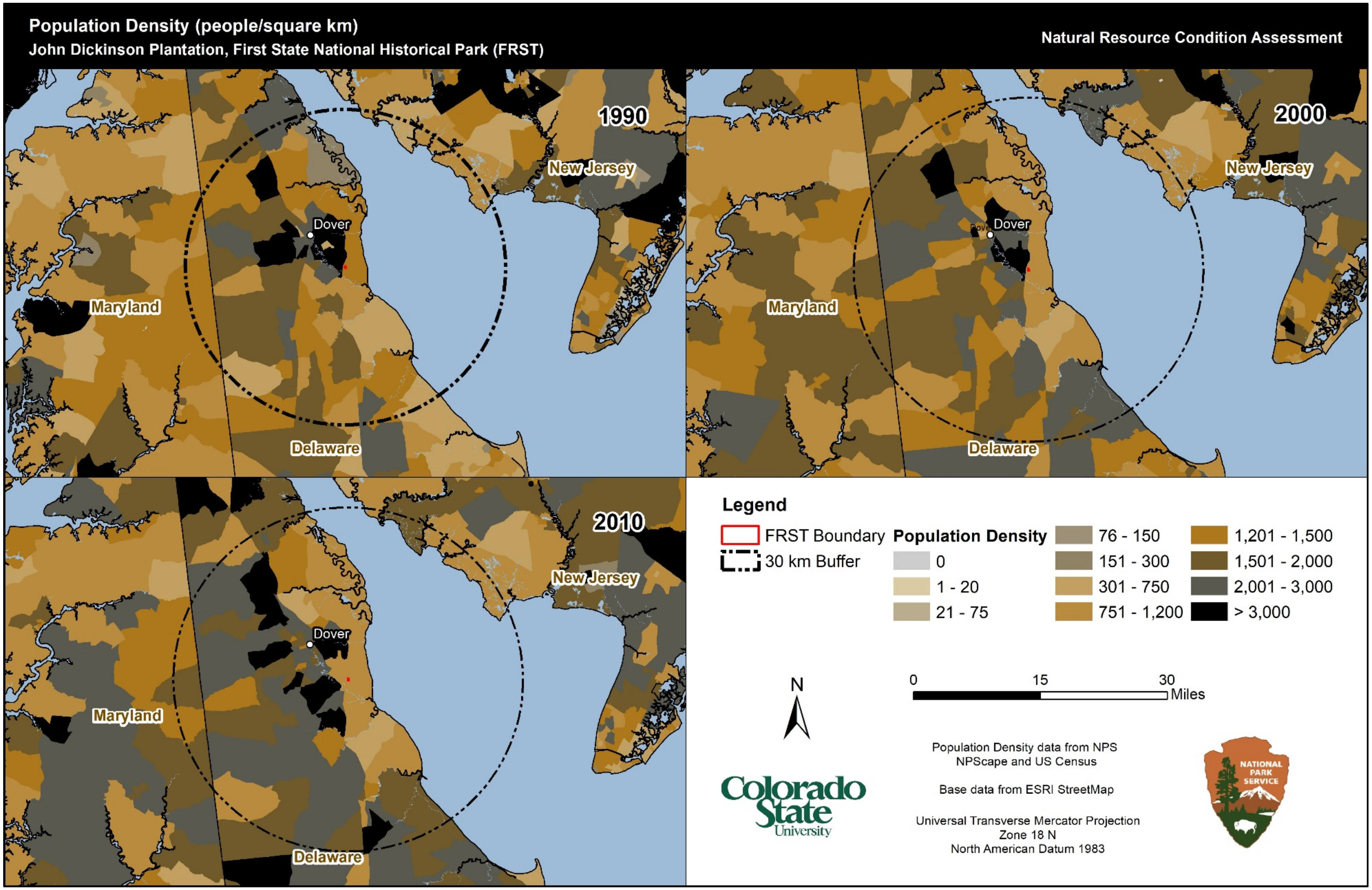


Figure 4.1-5. Population density for 1990, 2000, and 2010 by census block group for John Dickinson Plantation and surrounding 30 km buffer. U.S. Census data provided by NPScape Program.

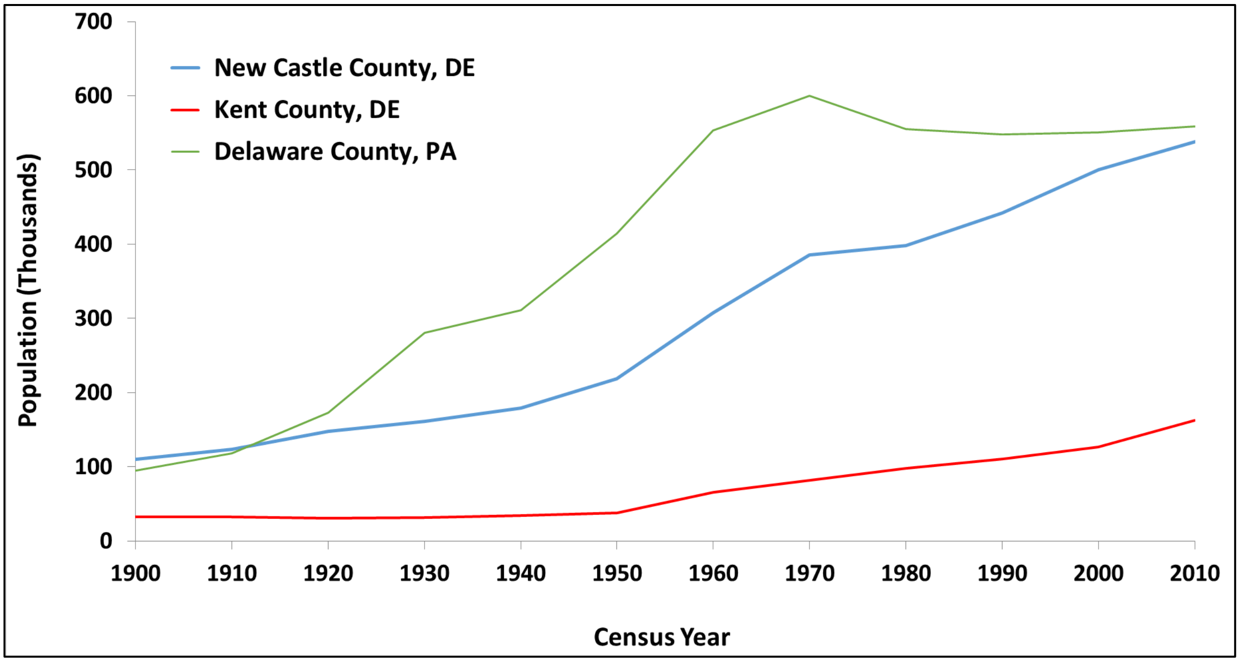


Figure 4.1-6. Historic population by decade for counties overlapping Brandywine Valley and John Dickinson Plantation (U.S. Census 2010).

Historic and Projected Housing Density

Housing density in the region surrounding the park shows marked patterns of change between 1970 and 2010 (Table 4.1-10, Table 4.1-11, Figure 4.1-7, Figure 4.1-8). Within a 30 km radius of Brandywine Valley, the most notable trend is an increase in exurban areas and a corresponding decrease in rural acreage. Acreage for urban, commercial/industrial, and urban regional park classes for 2010 were 16,905 (2.30%), 61,722 (8.40%), and 18,997 (2.59%), respectively. Forecasts of housing density near Brandywine Valley predict a transition from exurban to suburban from 2020 to 2050, although not as drastic as the past changes in rural to exurban acreage (Table 4.1-10).

A similar transition from rural to exurban also occurred within a 30 km radius of John Dickinson Plantation from 1970 to 2010. This trend is predicted to continue through 2050, in contrast to the forecasted exurban to suburban transition surrounding Brandywine Valley (Table 4.1-11). Acreage for urban, commercial/industrial, and urban regional park classes surrounding John Dickinson Plantation for 2010 were 932 (2.30%), 8,271 (1.84%), and 12,355 (2.74%), respectively.

Table 4.1-10. Historic and projected housing density by decade for 1970–2050 for Brandywine Valley and surrounding 30 km buffer, by housing density class (U.S. Census 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	359,559	48.94%	218,816	29.78%	66,555	9.06%
1980	296,186	40.31%	263,155	35.82%	82,802	11.27%
1990	250,121	34.04%	288,609	39.28%	101,190	13.77%
2000	210,018	28.59%	305,711	41.61%	122,211	16.63%
2010	140,226	19.09%	361,011	49.14%	135,824	18.49%
2020	120,321	16.38%	362,706	49.37%	153,311	20.87%
2030	113,101	15.39%	349,271	47.54%	173,458	23.61%
2040	110,267	15.01%	332,416	45.25%	192,579	26.21%
2050	108,933	14.83%	314,735	42.84%	211,119	28.74%

Table 4.1-11. Historic and projected housing density by decade for 1970–2050 for John Dickinson Plantation and surrounding 30 km buffer, by housing density class (U.S. Census 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	380,261	84.45%	43,678	9.70%	5,543	1.23%
1980	349,857	77.70%	70,791	15.72%	8,671	1.93%
1990	319,130	70.87%	98,694	21.92%	11,325	2.51%
2000	284,466	63.17%	130,027	28.88%	14,307	3.18%
2010	210,174	46.67%	202,347	44.94%	16,215	3.60%
2020	182,760	40.59%	228,888	50.83%	17,045	3.79%
2030	166,137	36.90%	244,577	54.32%	17,970	3.99%
2040	154,928	34.41%	254,948	56.62%	128,070	4.17%
2050	145,761	32.37%	263,372	58.49%	195,511	4.33%

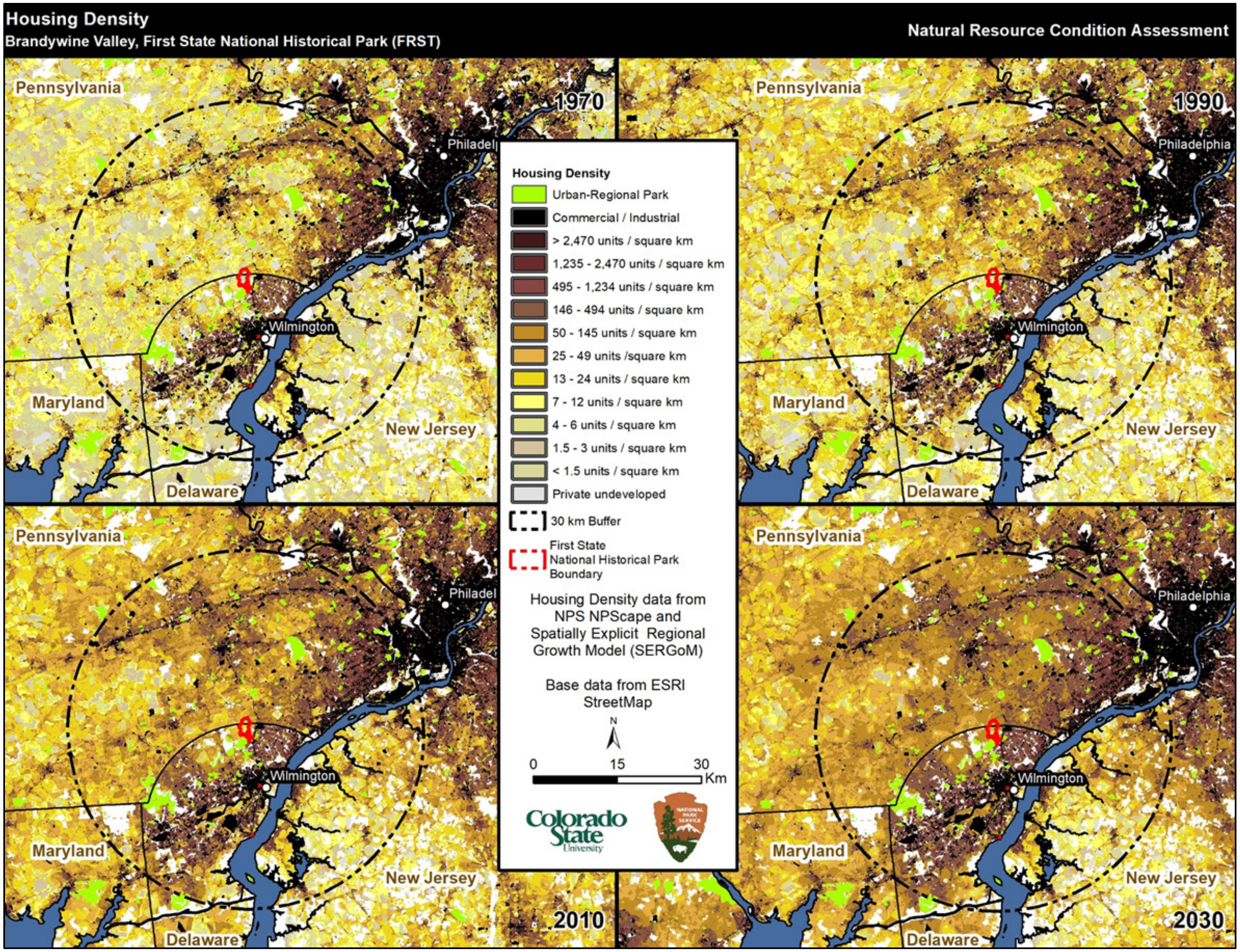


Figure 4.1-7. Historic and projected housing density for 1970, 1990, 2010 and 2030 for Brandywine Valley and surrounding 30 km buffer. SERGOM data provided by NPS NPScape Program.

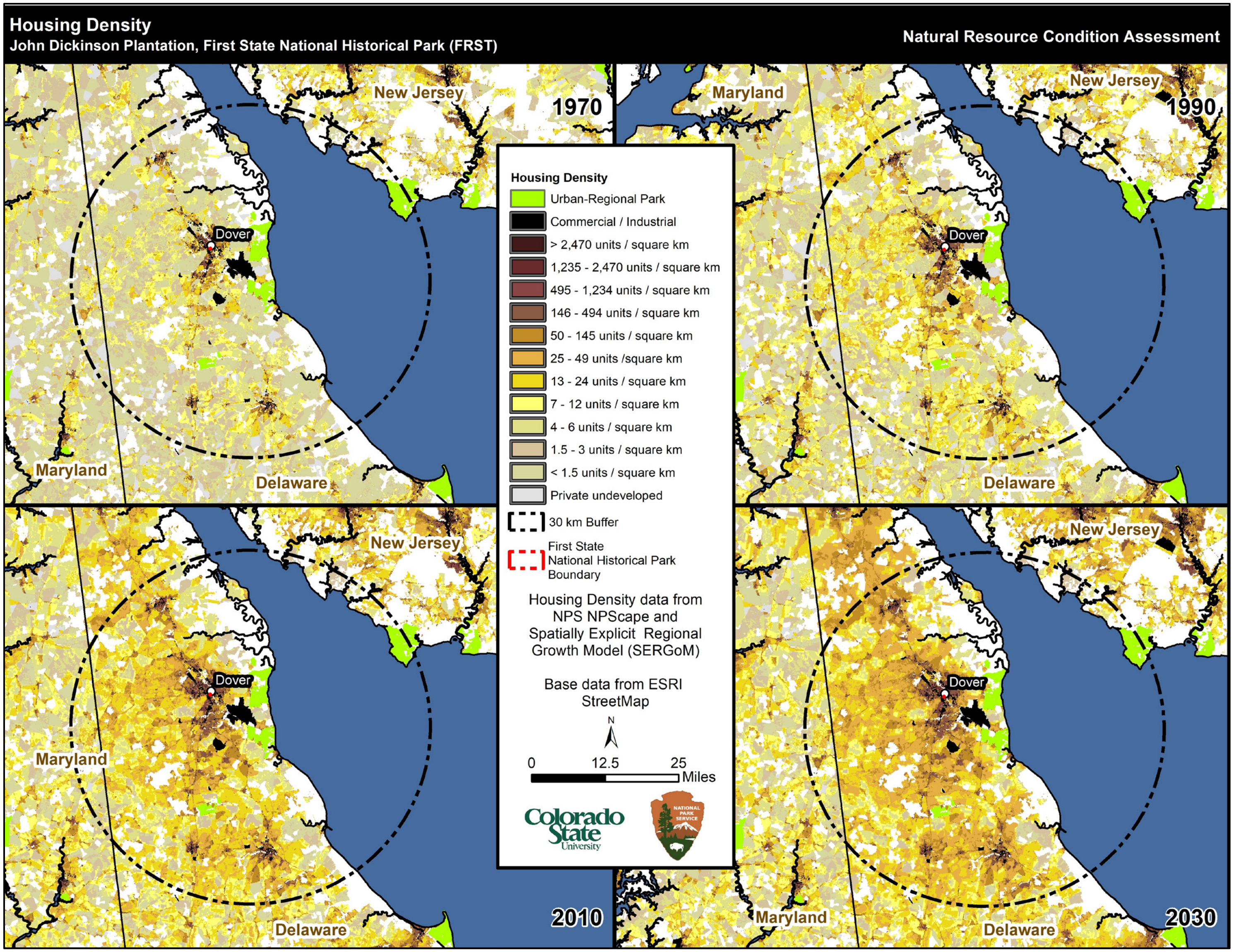


Figure 4.1-8. Historic and projected housing density for 1970, 1990, 2010 and 2030 for John Dickinson Plantation and surrounding 30 km buffer. SERGOM data provided by NPS NPScape Program.

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 4.1-9). The analysis illustrates the fragmented nature of protected areas near the park and in the larger region. The high federal and total percentage of protected area within the John Dickinson Plantation 30 km buffer (and to a lesser extent for Brandywine Valley) is due to the Marine Protected Area (MPA) in Delaware Bay.

Ownership

Within the 30 km park buffer most protected land is owned by the federal government, and to a lesser extent, state and local governments (Table 4.1-12). After subtracting the federally managed (by the National Oceanic and Atmospheric Administration) MPA in Delaware Bay, the federally managed acreage for Brandywine Valley drops to 20,890 acres (2.68% of total land-based acreage) while John Dickinson Plantation drops to 68,360 acres (9.68% of total land-based acreage). The total conserved acreage, with the MPA removed from the analysis, is 134,896 acres within 30 km of Brandywine Valley and 220,794 acres within 30 km of John Dickinson Plantation (17.32 and 31.26% of land area, respectively).

Table 4.1-12. Acreage of conservation areas within 30 km of the boundary of FRST (PAD-US and NCED data). Percentages are the proportion of total area of analysis.

	Brandywine Valley		John Dickinson Plantation	
Ownership	**Acres**	**% of Area**	**Acres**	**% of Area**
Federal	55,776	7.16%	311,410	44.08%
Native American	0	0.00%	0	0.00%
State	30,640	3.94%	118,022	16.71%
Local Government	38,718	4.97%	21,737	3.08%
Private Conservation	3,920	0.50%	123	0.02%
Joint Ownership/Unknown	526	0.07%	0	0.00%
Non-Governmental Organization	40,202	5.16%	12,552	1.78%
Total	**169,782**	**21.80%**	**463,844**	**65.66%**

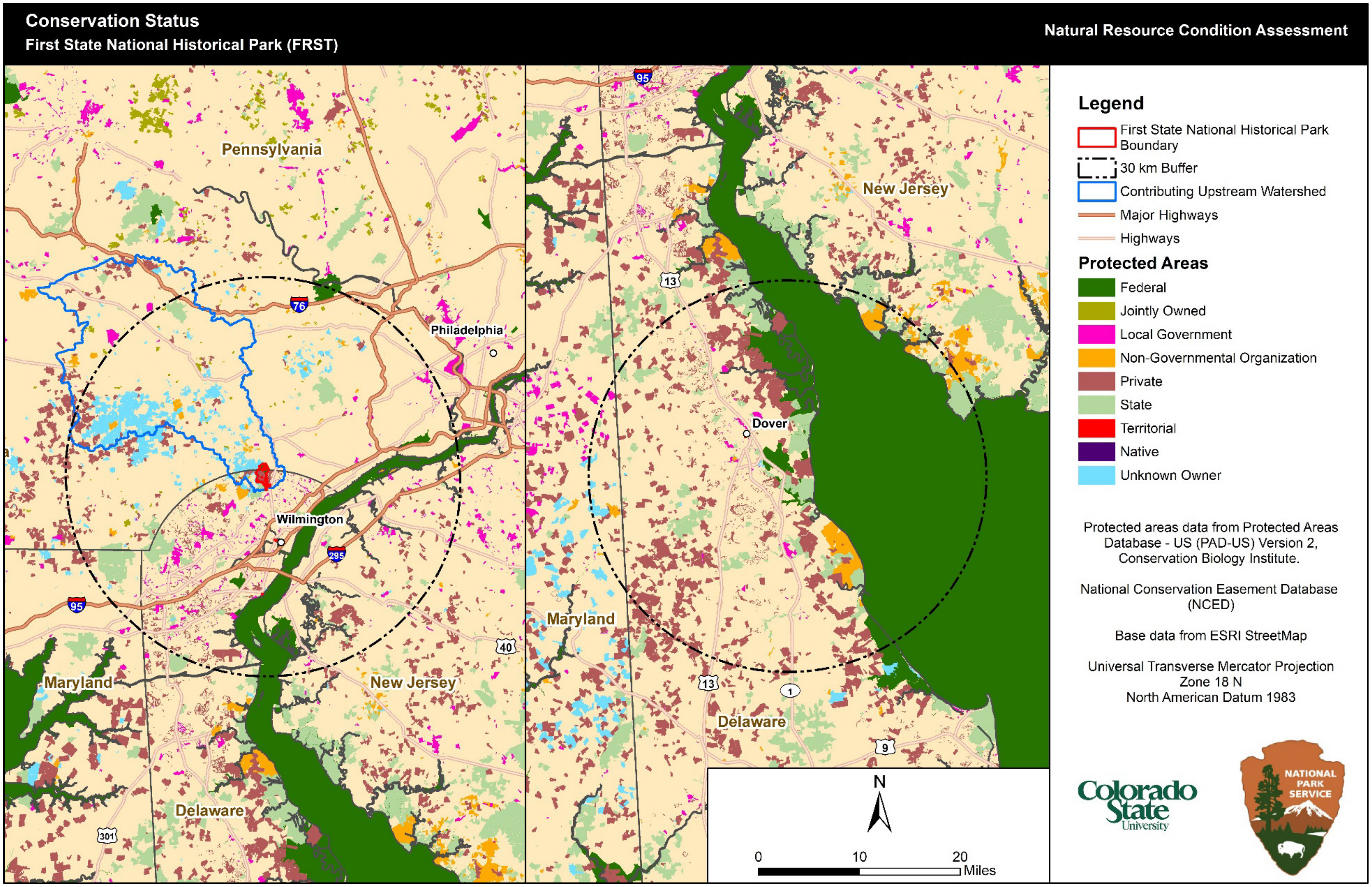


Figure 4.1-9. Conservation status of lands within 30 km of the boundary of Brandywine Valley (left) and John Dickinson Plantation (right). Map classes combine ownership from the NCED database and biodiversity conservation status from the PAD-US protected areas database.

Level of Protection

Within 30 km of FRST, there is conserved area within each biodiversity protection status level (Table 4.1-13). Approximately 42% of the total conservation area within John Dickinson Plantation's 30 km buffer is classified as having Status III protection, mostly due to the Marine Protected Area in Delaware Bay. With the MPA removed from the analysis, 30,375 acres within 30 km of Brandywine Valley and 68,360 acres within 30 km of John Dickinson Plantation (3.90% and 9.68% of total land-based acreage, respectively) are classified as having Status III protection. In protected areas such as Brandywine Valley, 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 4.1-13. Biodiversity protection status of conservation areas within 30 km of the park boundary (PAD-US and NCED data). Percentages are the proportion of total area of analysis.

	Brandywine Valley		John Dickinson Plantation	
Protection Level	**Acres ***	**% of Area ***	**Acres ***	**% of Area ***
I	5,570	0.72%	3,362	0.48%
II	26,584	3.41%	76,589	10.84%
III	65,262	8.38%	294,680	41.71%
IV	72,367	9.29%	89,213	12.63%
Total	**169,782**	**21.80%**	**463,844**	**65.66%**

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

<u>Ecological Integrity and Resilience</u>

Cutoffs for condition status for the IEI have not been established. No numerical data are presented for this index. Instead, the map of IEI within the 3 and 30 km buffers is presented to provide a sense of the level of ecological integrity and resilience to disturbance in these areas. Within Brandywine Valley's 30 km buffer, most natural areas are of moderate to low ecological integrity typical of an urbanized landscape (Figure 4.1-10). Within and near Brandywine Valley's 3 km buffer, pockets of moderately high and high value landscapes exist, especially within the boundary of Brandywine Creek State Park to the south. Within John Dickinson Plantation's 30 km buffer, the area contains mostly moderate to low quality natural area, with the exception of some higher quality tidal and coastal wetlands to the north and south of the plantation (Figure 4.1-10, Figure 4.1-11). The 3 km buffer for John Dickinson Plantation paints a similar picture, with much of the natural area in and near the buffer consisting of moderate to low quality pockets.

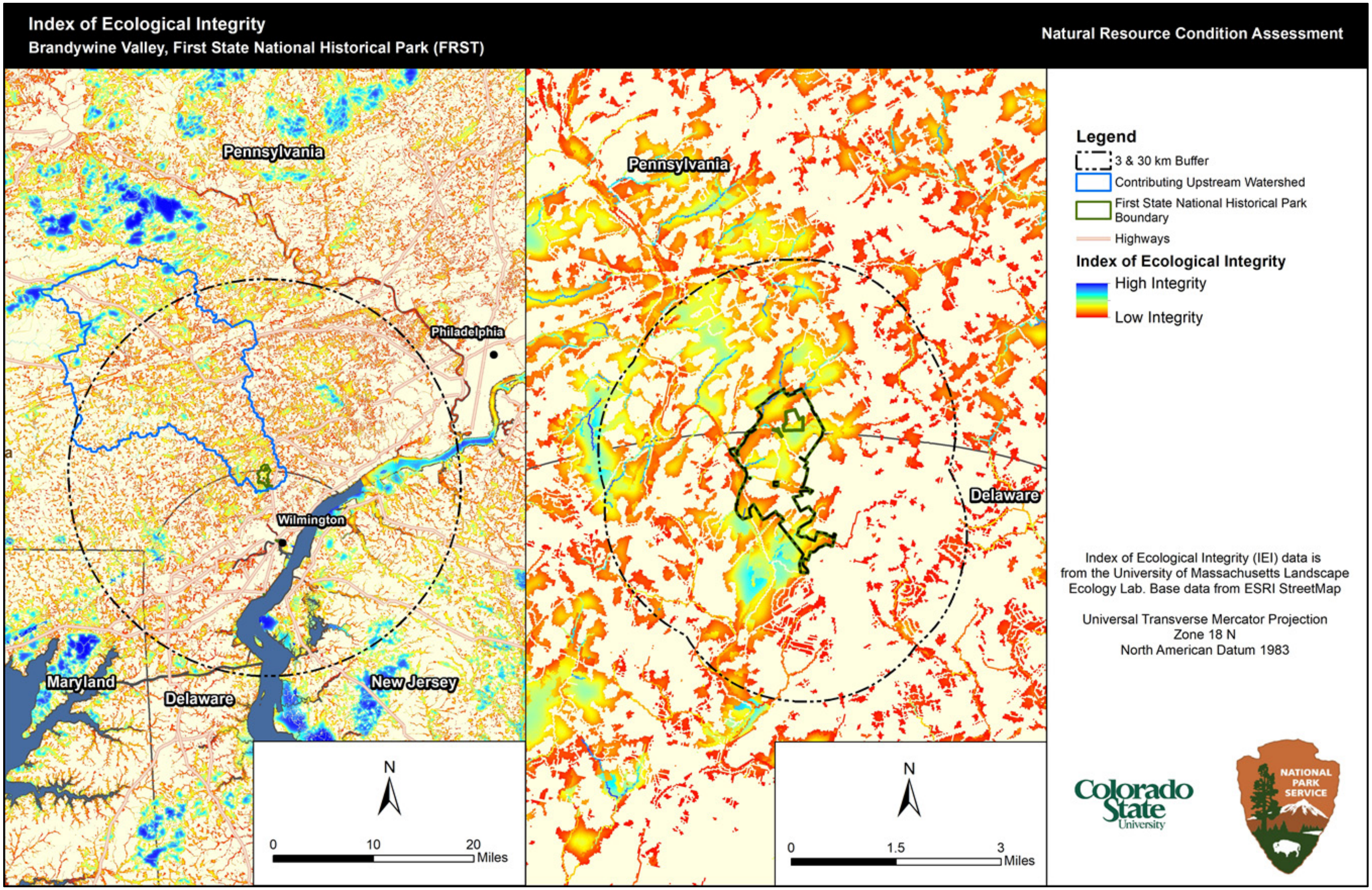


Figure 4.1-10. Index of Ecological ntegrity values within 30 km (left) and 3 km (right) of Brandywine Valley. Data from University of Massachusetts Landscape Ecology Lab.

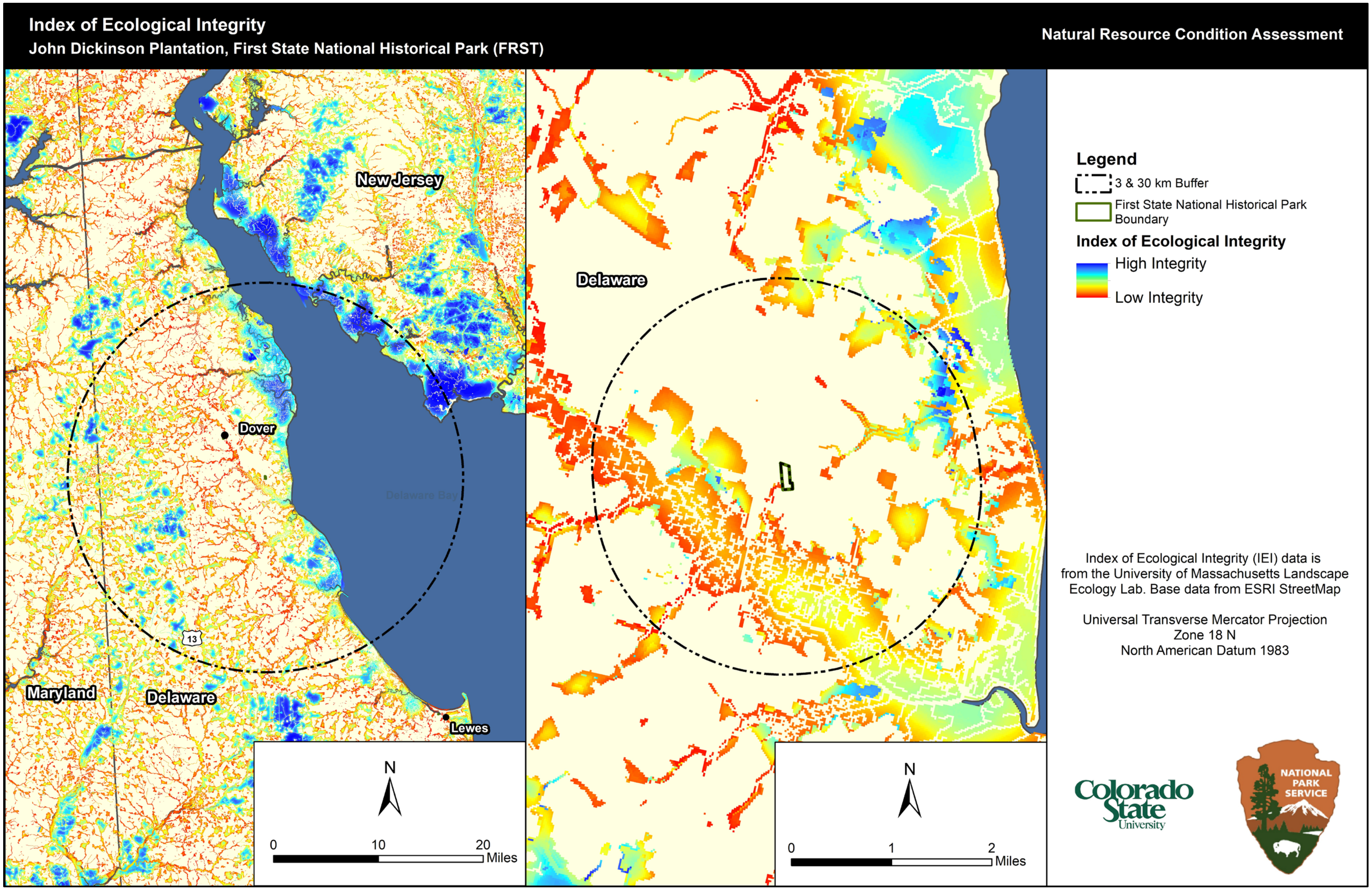


Figure 4.1-11. Index of Ecological Integrity values within 30 km (left) and 3 km (right) of John Dickinson Plantation. Data from University of Massachusetts Landscape Ecology Lab.

Land Cover and Land Use Summary

Overall, the park faces similar threats and stressors to other areas in this region. Most of these land cover and land use-related stressors at FRST and in the larger region are related to the development of rural agricultural land and increases in population/housing over time (Table 4.1-14). This trend in land development, coupled with the lack of significantly sized and linked terrestrial protected areas, is of substantial concern for the conservation of the natural resources of FRST, including natural 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 4.1-14. Summary for landscape context indicators, First State National Historical Park.

Land Cover and Land Use	Indicator	Summary Notes Integrating Results for 3 km, 30 km, and Contributing (Upstream) Watershed Areas of Analysis
Land cover	Extent of Anderson Level II classes	Most of the acreage within 3 km of Brandywine Valley is deciduous forest, followed by developed open space. For John Dickinson Plantation, cultivated crops are the largest non-water land cover class for both the 3 km and 30 km buffers.
	Extent of natural vs. converted land cover	The proportion of converted acreage surrounding FRST is high (approximately 60%) within Brandywine Valley's 3 km and 30 km buffers and John Dickinson Plantation's 3 km buffer. This can be attributed to the heavy agricultural use of the surrounding area, which is mostly cropland with some hay/pasture.
	Current and projected development intensity	An increase in development intensity is expected within the contributing watershed between 2011 and 2070. In addition, New Castle County (which contains Brandywine Valley) is listed as a "Fast Growth Metro Area."
	Impervious surface area	Most of Brandywine Valley's contributing (upstream) watershed is classified as having 0–2% impervious surface area. As a benchmark for future analysis, approximately 21.05% of the contributing (upstream) watershed of Brandywine Valley was classified as having >25% impervious surfaces, the majority of which is concentrated near the US-30 highway near Lancaster, Pennsylvania.
Population and Housing	Population total and density by census block group	Population density within 30 km of Brandywine Valley is low to moderate, with most of the area within this 30 km radius having a density of 21–750 people/km^2. The population density around John Dickinson Plantation is lower, with more than 60% of the 30 km buffer having a density of 1–75 people/km^2.

Table 4.1-14 (continued). Summary for landscape context indicators, First State National Historical Park.

Land Cover and Land Use	Indicator	Summary Notes Integrating Results for 3 km, 30 km, and Contributing (Upstream) Watershed Areas of Analysis
Population and Housing (continued)	Historic population total by county	Historically, the three counties containing Brandywine Valley (New Castle County, Delaware, and Delaware County, Pennsylvania) and John Dickinson Plantation (Kent County, Delaware) have all grown in population since the early 1900s, with the counties surrounding Brandywine Valley growing more rapidly since at least 1950.
	Historic and projected housing density 1970–2010	Within a 30 km radius of Brandywine Valley, the most notable trend is an increase in exurban areas and a corresponding decrease in rural acreage. Forecasts of housing density near Brandywine Valley predict a transition from exurban to suburban from 2020 to 2050, although not as drastic as the past changes in rural to exurban acreage. A similar transition from rural to exurban also occurred within a 30 km radius of John Dickinson Plantation from 1970 to 2010. This trend is predicted to continue through 2050, in contrast to the forecasted exurban to suburban transition surrounding Brandywine Valley.
Conservation Status	Protected area extent and biodiversity protection status	Only a small portion of the land-based acreage in the region surrounding the park is protected through ownership or conservation easements. The majority of land surrounding FRST units is private agricultural land (which generally have a low biodiversity protection level and limited conservation value) and various types of development. Agricultural land is also more readily developed than some other types of land. The paucity of linked and adequately sized protected lands within the region underscores the critical value of the park (especially Brandywine Valley) as a conservation island within a highly altered landscape.
Ecological Integrity and Resilience	Index of ecological integrity	Within Brandywine Valley's 30 km buffer, most natural areas have moderate to low ecological integrity typical of an urbanized landscape. Within and near Brandywine Valley's 3 km buffer, pockets of moderately high and high value landscapes exist, especially within the boundary of Brandywine Creek State Park to the south. For John Dickinson Plantation's 30 km buffer, the area still contains mostly moderate to low quality natural area, except for some higher quality tidal and coastal wetlands to the north and south of the plantation.

4.1.4. 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).

4.1.5. Sources of Expertise

- Bill Monahan, Ph.D., NPS Inventory and Monitoring Division, Fort Collins, Colorado. Dr. Monahan provided NPScape data summaries and consulted on the selection and use of various metrics.
- Additional data came from the Delaware River Basin Project and the University of Massachusetts Landscape Ecology Lab.

4.1.6. Literature Cited

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964. A revision of the land use classification system as presented in U.S. Geological Survey Circular 671. U.S. Geological Survey, Washington, D.C.

Conservation Biology Institute (CBI). 2013. Conservation Biology Institute protected areas database – US (PAD-US) Version 2 download website. Available at: http://consbio.org/products/projects/pad-us-cbi-edition (accessed 23 September 2013).

Chape, S., J. Harrison, M. Spalding, and I. Lysenko. 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of the Royal Society Biological Sciences 360:443–455.

Davis, C. R., and A. J. Hansen. 2011. Trajectories in land-use change around U.S. National Parks and their challenges and opportunities for management. Ecological Applications 21:3299–3316.

Delaware River Basin Project (DRBP). 2015. Delaware River Basin county classification based on urban growth and urbanization degree. Available at: http://drbproject.org/wp-content/uploads/sites/101/2015/10/Counties-Classification_101215.pdf (accessed 11 November 2019).

DRBP. 2017. DRB2070 version 2 baseline and alternative scenarios. Available at: https://2rf7dh2s2l1w1eqeab2caqmi-wpengine.netdna-ssl.com/wp-content/uploads/2017/07/DRB2070_v2.pdf (accessed 11 November 2019).

Hansen, A. J., and D. Gryskiewicz. 2003. Interactions between Heartland National Parks and surrounding land use change: development of conceptual models and indicators for monitoring. Prepared for the National Park Service Heartland Network by Montana State University.

Hansen, A. J., N. Piekielek, C. Davis, J. Hass, D. M. Theobald, J. E. Gross, W. B. Monahan, T. Olliff, and S. W. Running. 2014. Exposure of U.S. National Parks to land use and climate change 1900–2100. Ecological Applications 24(3):484–502.

Kerr, J. T., and D. J. Currie. 1995. Effects of human activity on global extinction risk. Conservation Biology 9:1528–1538.

Luck, G. W. 2007. A review of the relationships between human population density and biodiversity. Biological Reviews 82:607–645.

Multi-Resolution Land Characteristics Consortium (MRLC). 2016. MRLC website. Available at: https://www.mrlc.gov/ (accessed November 2016).

McGarigal, K., B. W. Compton, E. B. Plunkett, W. V. DeLuca, and J. Grand. 2017a. Designing sustainable landscapes: imperviousness settings variable. Report to the North Atlantic Conservation Cooperative, U.S. Fish and Wildlife Service, Northeast Region.

McGarigal, K., B. W. Compton, E. B. Plunkett, W. V. DeLuca, and J. Grand. 2017b. Designing sustainable landscapes: index of ecological integrity. Report to the North Atlantic Conservation Cooperative, U.S. Fish and Wildlife Service, Northeast Region.

Monahan, W. B., J. E. Gross, L. K. Svancara, and T. Philippi. 2012. A guide to interpreting NPScape data and analyses. Natural Resource Technical Report NPS/NRSS/NRTR—2012/578. National Park Service, Fort Collins, Colorado.

National Conservation Easement Database (NCED). 2019. National Conservation Easement Database website. Available at: https://www.conservationeasement.us/ (accessed 02 December 2019).

National Park Service (NPS). 2014a. NPScape standard operating procedure: land cover measure – area per category, impervious surface, change index, and natural vs. converted. Version [2014-05-01]. National Park Service, Natural Resource Stewardship and Science, Fort Collins, Colorado.

NPS. 2014b. NPScape standard operating procedure: population measure – current density and total. Version [2014-05-01]. National Park Service, Natural Resource Stewardship and Science, Fort Collins, Colorado.

O'Neill, R. V., C. T. Hunsaker, K. B. Jones, K. H. Riitters, J. D. Wickham, P. M. Schwartz, I. A. Goodman, B. L. Jackson, and W. S. Baillargeon. 1997. Monitoring environmental quality at the landscape scale. BioScience 47:513–519.

Parks, S. A., and A. H. Harcourt. 2002. Reserve size, local human density, and mammalian extinctions in US protected areas. Conservation Biology 16:800–808.

Pressey, R. L., G. L. Whish, T. W. Barrett, and M. E. Watts. 2002. Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. Biological Conservation 106:57–69.

Radeloff, V. C., S. I. Stewart, T. J. Hawbaker, U. Gimmi, A. M. Pidgeon, C. H. Flather, R. B. Hammer, and D. P. Helmers. 2010. Housing growth in and near United States protected areas limits their conservation value. Proceedings of the National Academy of Sciences of the United States of America 107:940–945.

Scott, J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, Jr., J. Ulliman, and R. G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123:3–41.

Theobald, D. M. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecology and Society 10(32).

Wade, A., and D. Theobald. 2010. Residential development encroachment on U.S. protected areas. Conservation Biology 24:151–161.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience 48:607–615.

Wittemyer, G., P. Elsen, W. T. Bean, A. Coleman, O. Burton, and J. S. Brashares. 2008. Accelerated human population growth at protected area edges. Science 321:123–126.

Woodroffe, R. 2000. Predators and people: using human densities to interpret declines of large carnivores. Animal Conservation 3:165–173.

4.2. Climate Change

4.2.1. 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" for developing new management and adaptation strategies (NPS 2012) and is a significant scientific component of the NPS *Climate Change Response Strategy* (NPS 2010).

An NPS Climate Change Resource Brief (NPS 2014) based upon research from Monahan and Fisichelli (2014) maintains that the local climate near Valley Forge National Historical Park (VAFO; approximately 25 miles north of the Brandywine Valley unit of First State National Historical Park (FRST)) is already getting hotter and wetter. Climate change may also affect visitation patterns at NPS units in the region (NPS 2015). An overall increase in visitation (5–14% annually) as well as increases in both peak season (3–9%, defined as the three busiest contiguous months) and shoulder season (11–20%, defined as the two months prior to and the two months following peak season) may require park management to alter planning schedules. An expansion in the visitation season of 12–24 days could also lead to staffing shortages and altered seasonal worker rotations (NPS 2015).

Overall climate change vulnerability for a particular resource considers 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. We characterize climate 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 evident 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 (NPS 2012).

Threats and Stressors

Increases in atmospheric greenhouse gases are resulting in changes in global, regional, and local climates. Changes in the amounts and patterns of temperature and precipitation have numerous direct and indirect effects on environmental conditions and biota. For instance, as the climate changes, an increase in the frequency of extreme weather is likely.

The frost-free season, 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 lengthening since the 1980s (EPA 2012). The length of the frost-free period, which corresponds to an area's growing season, is an important determinant of which plants will grow and flourish in a region (Walsh 2014a). Increases in temperature are responsible for plants flowering earlier in the spring and the delayed onset of dormancy in autumn (Monahan et al. 2016). 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).

Indicators and Measures

- Temperature changes from baseline – mean annual, seasonal changes
- Precipitation changes from baseline – total annual, very heavy events
- Aridity – Palmer Drought Severity Index (PDSI)
- Frost-free period – changes from baseline

4.2.2. Data and Methods

We apply a variety of data and analysis approaches to characterize the climate during the historical period of record and examine possible changes in climate in the region. A combination of site-specific and regional results is presented. Due to a lack of data at FRST, Valley Forge National Historical Park is used as a proxy for climatic conditions at FRST for the site-specific analyses. Valley Forge National Historical Park is relatively small at 3,500 acres, with minimal local topographic relief. Therefore, climatic variation within VAFO is low. The same is true for FRST, with the largest property (Brandywine Valley) just 1,105 acres in size. Consolidation of future modeled climates and comparisons with historical baseline and graphic representation of results was completed by Monahan and Fisichelli (2014) and Fisichelli (2013). Future modeled climate data are presented in terms of two projected emissions scenarios, A2 (higher emissions of greenhouse gases) and B1 (lower emissions), as in Fisichelli (2013). The A2 and B1 scenarios are from the Intergovernmental Panel on Climate Change's 2007 report (IPCC 2007).

We use the Palmer Drought Severity Index (PDSI) to characterize aridity over the historical period of record. The 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 PDSI is used widely by the U.S. Department of Agriculture and other agencies. PDSI 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." Values below −1.5 are considered drought conditions. The Palmer Index is most effective in determining long-term drought (i.e., lasting at least several months). Monthly PDSI values were obtained from the National Climatic Data Center (NCDC 2019). Assumptions of the PDSI 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 PDSI does appear to corroborate known drought periods and in this assessment the PDSI approach is not used to model future drought.

4.2.3. Reference Conditions

For most indices, the reference condition for this assessment is the period from the early 20th century, when meteorological data were first systematically collected, to approximately the first decade of the

21st century (2013 for Fisichelli (2013) and 2012 for Monahan and Fisichelli (2014)). Although some climatic changes may have occurred 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. For frost-free season length, the baseline period was 1901–1960. For aridity, the period analyzed was 1895–2017, with no future modeled changes available.

4.2.4. Historical Conditions, Range of Variability and Modeled Changes

Temperature

Historical Trends

Monahan and Fisichelli (2014) updated the climate inventories for 289 units of the NPS, including VAFO. The area of analysis included VAFO and a 30-km buffer surrounding the park. To evaluate climate change exposure of the park, Monahan and Fisichelli examined twenty-five biologically relevant climate variables, and highlighted those that have shown extreme values in recent years.

To determine "extreme" values, which indicate the park is significantly exposed to climate change, Monahan and Fisichelli (2014) first calculated 10, 20, and 30-year "moving windows" of averages over the period of record (1901–2012). This moving window approach was used to de-emphasize year-to-year fluctuations. They then compared average temperature metrics, such as mean annual temperature, mean warmest quarter, minimum coldest month, and others, from the most recent 10, 20 and 30-year periods (2003–2012, 1993–2012, and 1983–2012, respectively) to the moving window historical averages. "Extreme" values were defined as those for which the average over the most recent 10, 20 or 30 years was greater than 95% (or less than 5%) of the historical averages.

Annual mean temperature (°C) from 1901 to 2012 is shown in Figure 4.2-1, illustrating the effect of calculating ten-year moving window averages. The results for seven of the most relevant temperature variables at VAFO are shown in Figure 4.2-2. Mean annual, mean warmest quarter and maximum warmest month temperatures were considered extreme. Minimum coldest month and mean coldest quarter had error bars that reached into the extreme zone.

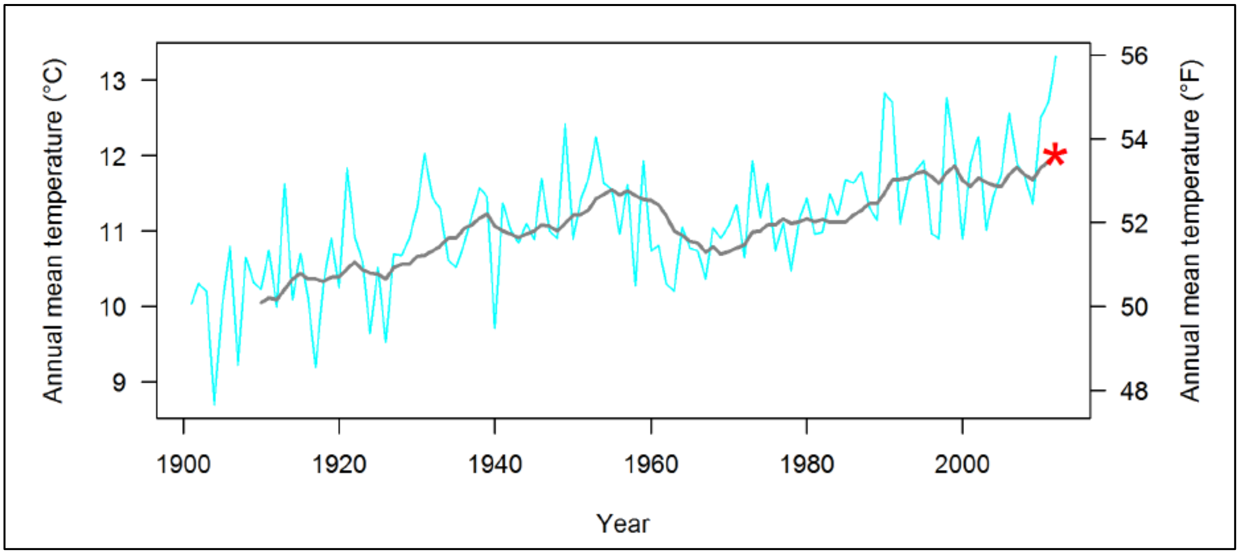


Figure 4.2-1. Annual mean temperature at Valley Forge National Historical Park (including areas within 30 km of the park boundary). The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year moving windows, and the red asterisk is the average temperature of the most recent 10-year moving window as of 2012 (NPS 2014).

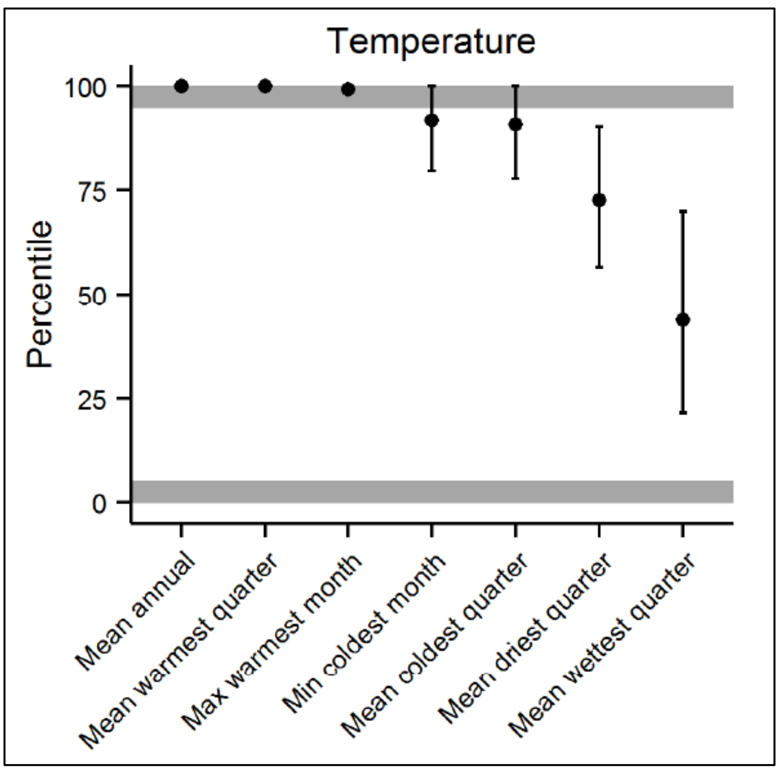


Figure 4.2-2. Results for seven temperature variables (1901–2012) analyzed by Monahan and Fisichelli (2014) at Valley Forge National Historical Park. Results are considered "extreme" if the mean percentiles are <5th percentile or >95th percentile of the historical range of conditions (if the mean is within the upper or lower gray area). Black bars indicate the range of recent percentiles across 10, 20, and 30-year moving windows (larger bars indicate higher sensitivity to moving window size). (NPS 2014).

The climate change summary for VAFO by Fisichelli (2013) shows a statistically significant increase in mean annual temperature from 1893 to 2012 ($p<0.0001$, Figure 4.2-3). This increase in temperature has accelerated since 1960 ($p<0.0001$, Figure 4.2-3).

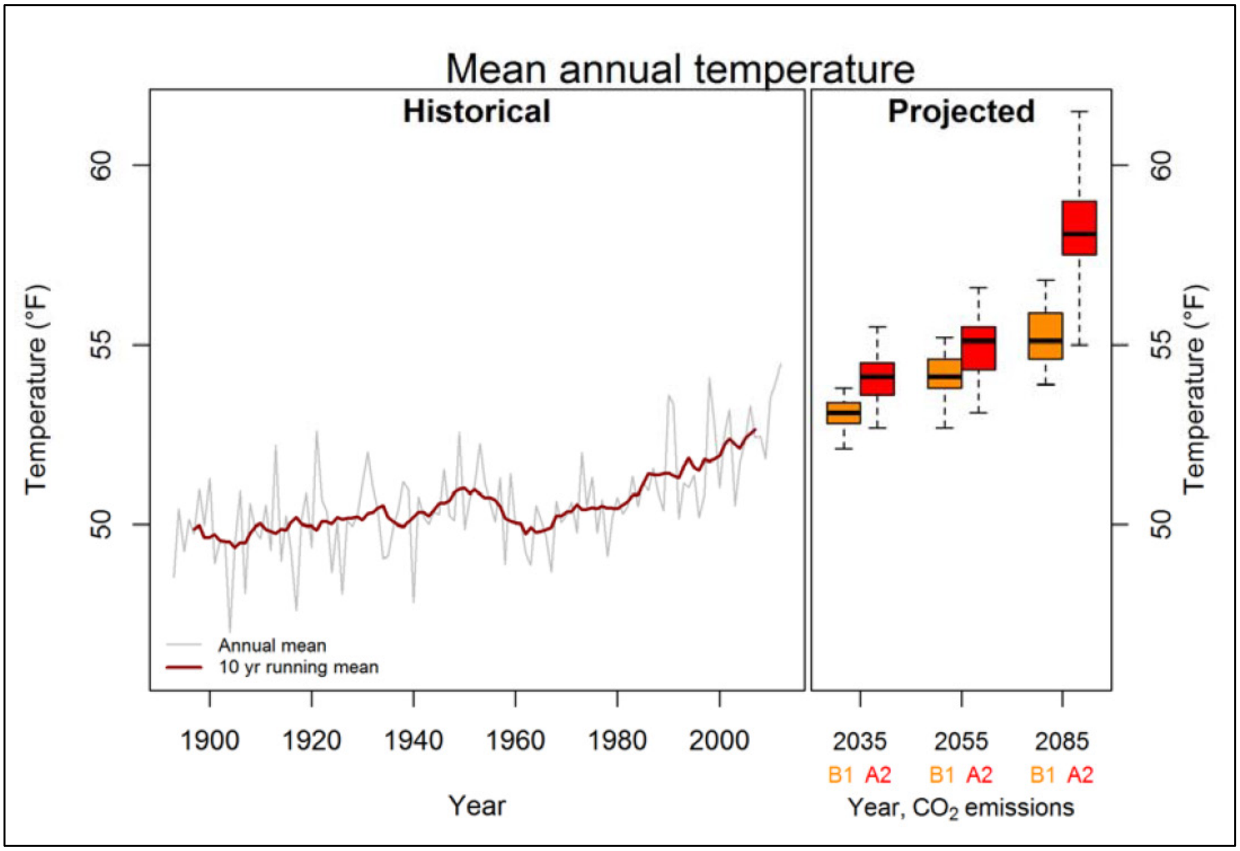


Figure 4.2-3. Historical mean annual temperature for Valley Forge National Historical Park from 1893–2012 and projected temperatures based on two emissions scenarios (Fisichelli 2013).

Modeled Future Changes

Climate models summarized by Fisichelli (2013) indicate that temperatures at VAFO will rise substantially under climate change (Figure 4.2-3). Depending on the emissions scenario, mean annual temperatures are expected to increase by approximately 1.7–2.2°C (3.0–4.0°F) by 2055, and by approximately 2.2–3.9°C (4.0–7.0°F) by 2085.

Seasonally, the greatest increases in temperature will be during the summer, although all seasons are projected to become warmer by mid-century (Figure 4.2-4). In addition, the number of days with maximum temperatures above 95°F is projected to increase by 12–15 days/year by mid-century, and the number of days with minimum temperatures below freezing is projected to decrease by 21 days under the high (A2) emissions scenario (Kunkel et al. 2013). Modeling by Wolfe et al. (2018) also predicts a shortening of the frost-free season by three weeks under the RCP8.5 emissions scenario by the end of the century.

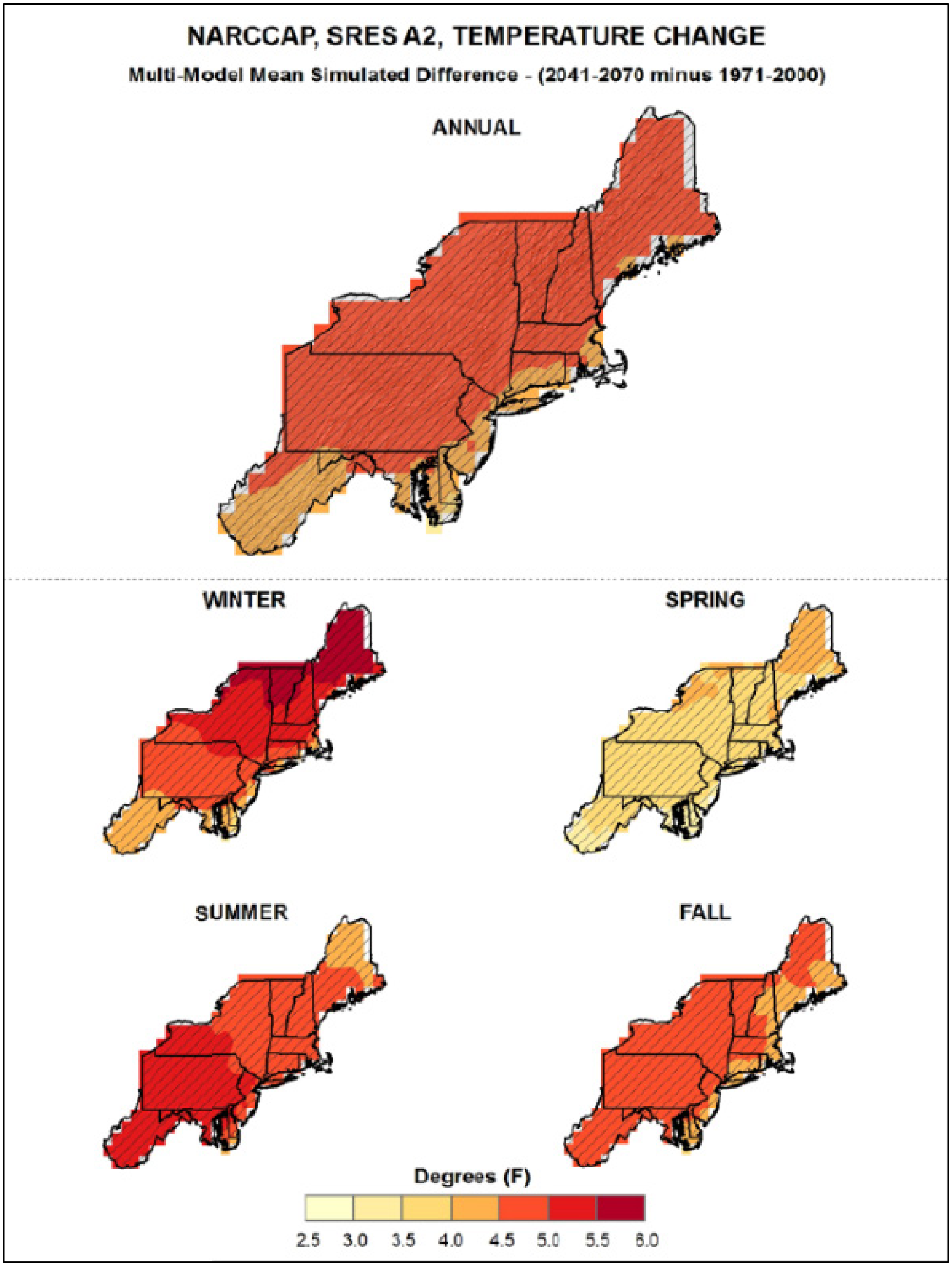


Figure 4.2-4. Projected annual and seasonal temperature change in the northeastern Unites States based on average surface air temperature from 2041–2070 relative to 1971–2000 (Kunkel et al. 2013). Note: patterns for Delaware differ slightly from those of VAFO, located in southeastern Pennsylvania.

Precipitation

Historical Trends

Monahan and Fisichelli (2014) analyzed historical data for seven of the most relevant precipitation variables at VAFO (Figure 4.2-5), using the same “moving window” approach described above in the Temperature section. Wettest month annual, and wettest quarter precipitation totals were considered extreme; driest quarter and driest month were close to the extreme range.

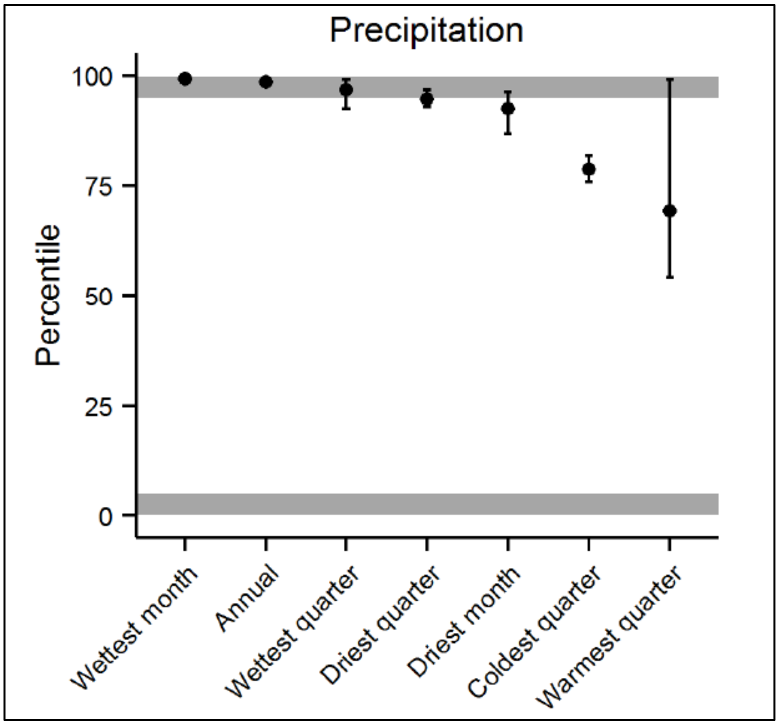


Figure 4.2-5. Results for seven precipitation variables (1901–2012) analyzed by Monahan and Fisichelli (2014) at Valley Forge National Historical Park. Results are considered "extreme" if the mean percentiles are <5th percentile or >95th percentile of the historical range of conditions (if the mean is within the upper or lower gray area).

The climate change summary for VAFO by Fisichelli (2013) shows high historical variability with no significant trend (p=0.40, Figure 4.2-6).

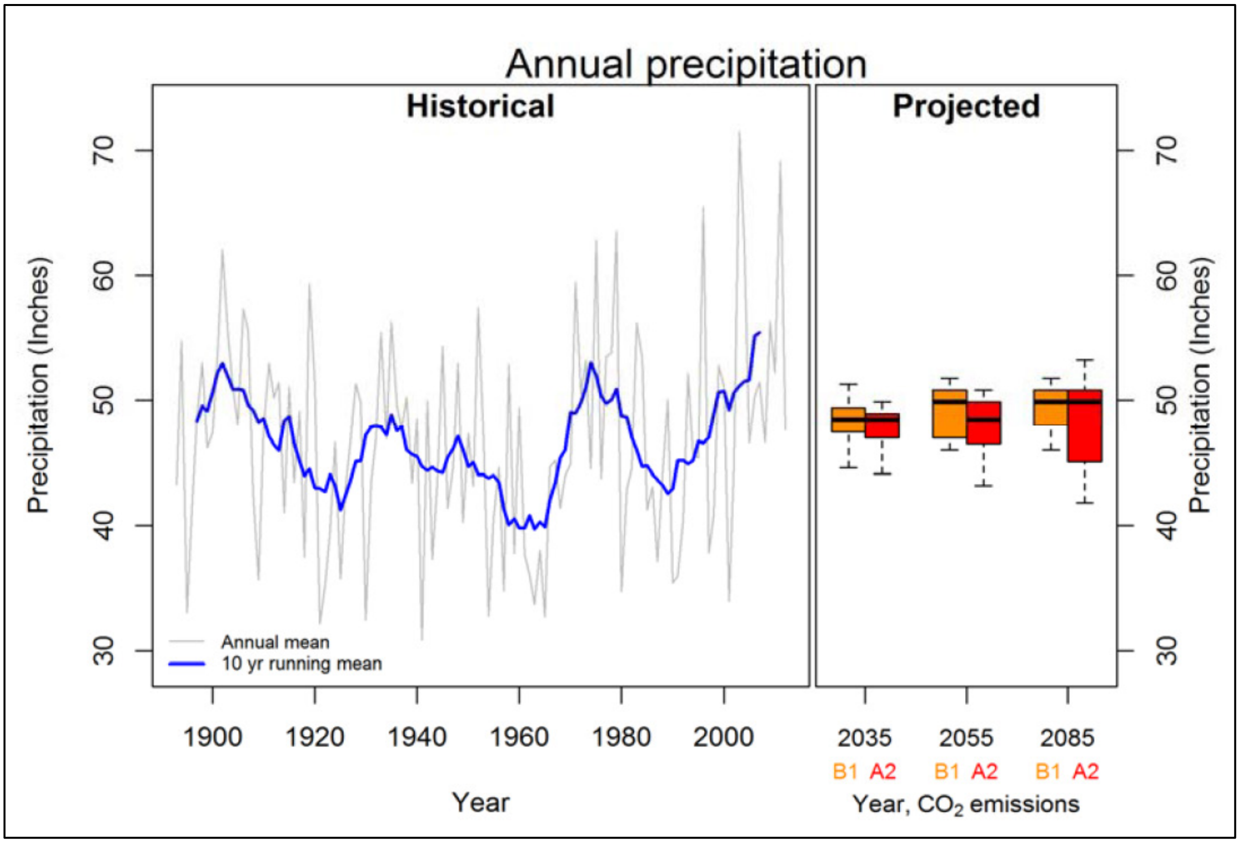


Figure 4.2-6. Historical mean annual precipitation for Valley Forge National Historical Park from 1893–2012 and projected precipitation based on two emissions scenarios (Fisichelli 2013).

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. 2014a). Results for the Northeast region including FRST indicate a substantial increase (71%) in the annual amount of precipitation falling in very heavy events over the past few decades (Figure 4.2-7). This is the largest regional increase in the United States (including Alaska and Hawaii) over this period.

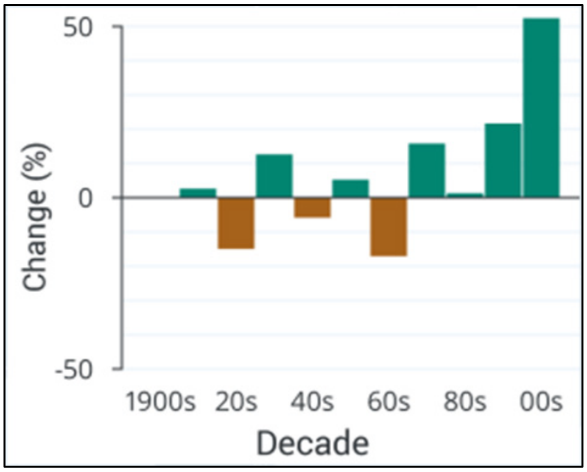


Figure 4.2-7. Percent change in the annual amount of precipitation falling in very heavy events by decade compared to the 1901–1960 average for the Northeast region. A very heavy event is defined as the heaviest 1% of all daily events from 1901 to 2012. The far right bar is for 2001–2012 (Walsh et al. 2014a).

Modeled Future Changes

Models used in Fisichelli (2013) indicate that precipitation at the park may increase slightly by mid-century (Figure 4.2-6); modeling by Kunkel et al. (2013) and Lynch et al. (2016) indicate that most of the increase may come during the winter (Figure 4.2-8). Walsh et al. (2014b) suggest more drastic increases in precipitation in the region, with most of the increase in precipitation coming in the winter and spring. There is greater uncertainty in precipitation than temperature projections; whether the increase is small or moderate, precipitation variability is likely to remain high over the next several decades (Kunkel et al. 2013). The number of days per year with heavy rainfall (>1”) is projected to increase by 10–15%, and the number of days between rain events is likely to increase by several days under the high (A2) emissions scenario (Kunkel et al. 2013).

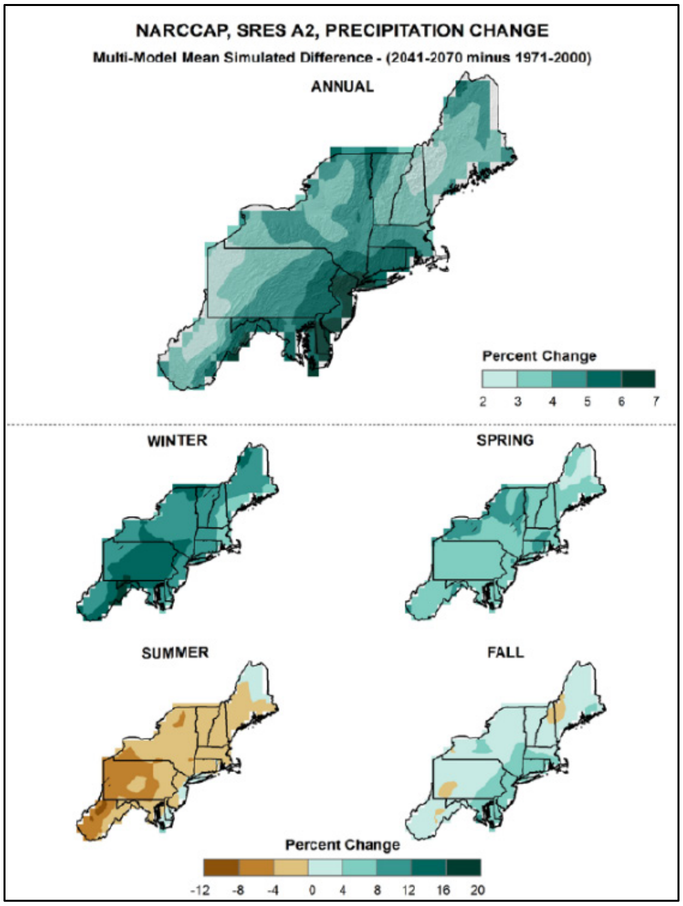


Figure 4.2-8. Projected annual and seasonal precipitation change in the northeastern Unites States from 2041–2070 relative to 1971–2000 (Kunkel et al. 2013). Note: patterns for Delaware differ slightly from those of Valley Forge National Historical Park, located in southeastern Pennsylvania.

<u>Aridity</u>

Aridity and moisture availability are examined using the Palmer Drought Severity Index (Palmer 1965) for the 1895–2018 period. No modeled future changes 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 2018 (Figure 4.2-9). For the period of record, FRST PDSI data show periodic moderate drought lasting 2–5 years occurring approximately every 30–35 years.

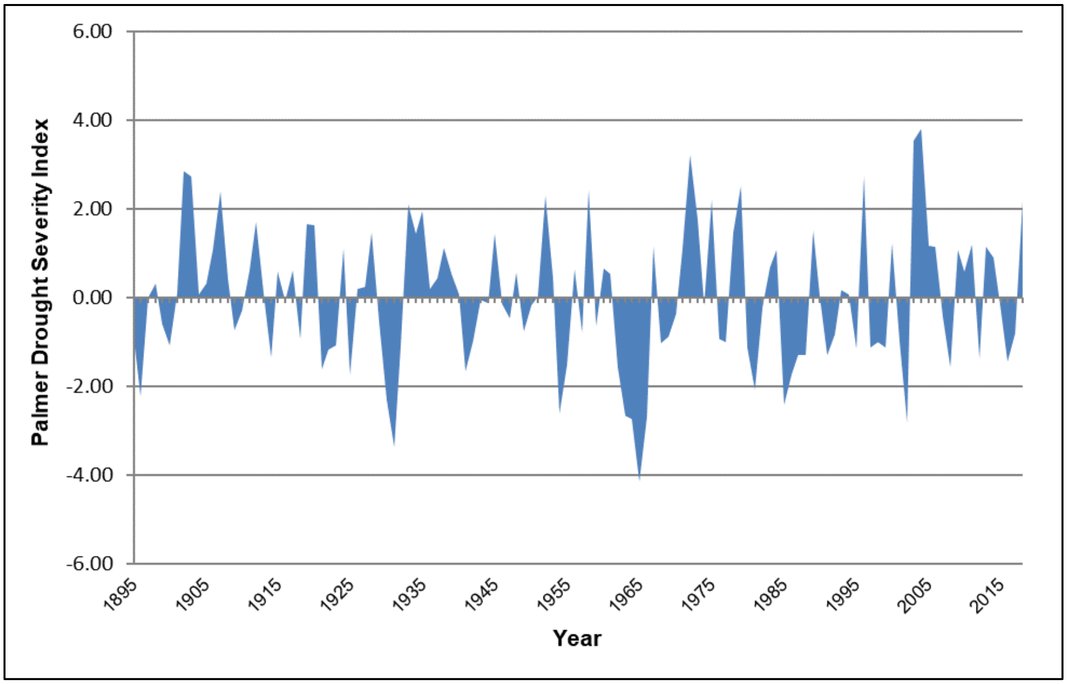


Figure 4.2-9. Palmer Drought Severity Index from 1895 –2018 for First State National Historical Park (Northern Division, Delaware; division code: 0701). Negative values represent dry conditions and positive values represent moist conditions (NCDC 2019).

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 Northeast region, the average frost-free season for 1991–2011 was about 10 days longer than during 1901–1960 (Walsh et al. 2014a). 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 length of frost-free season for the area surrounding FRST is projected to increase substantially as heat-trapping gas emissions continue to grow, increasing by 20–30 days under the lower emissions (B1) scenario and 30–40 days under the higher (A2) emissions scenario compared to the 1971–2000 baseline period (Walsh et al. 2014a).

Overall Assessment

Indications are that the climate in this region is already becoming hotter, possibly wetter, and is potentially more prone to more 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 region.

4.2.5. Management and Ecological Implications

Changing climate is anticipated to impact the mid-Atlantic and northeastern United States in a number of ways, and is likely to compound the effects of existing stressors and increase the vulnerability of forests and wetlands to pests, invasive species, altered fire regimes, and loss of native species (NFWPCAP 2012). Species ranges and ecological dynamics are already responding to recent climate shifts, and current natural areas including NPS units will likely be unable to support all species, communities and ecosystems currently present (Heller and Zavaleta 2009), some of which form the core of their NPS mission. Some of the key anticipated ecological impacts and potential management implications of climate change in the region and at FRST include:

- Increased precipitation intensity and longer time intervals between storms (Fisichelli 2013, Mulholland et al. 1997).
- Wetter winters coupled with warmer temperatures will likely cause increases in winter runoff and decreases in spring runoff as peak runoff shifts to earlier in the year (Loehman and Anderson 2009).
- More frequent droughts, floods, and extension of the frost-free season (Fisichelli 2013).
- Increasing temperatures will cause an increase in evaporation, potentially increasing the vulnerability of organisms in the region to drought and alteration of other ecosystem dynamics (Loehman and Anderson 2009).
- 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 significantly impact wildlife (Parmesan 2006).
- An increase in the transmission of zoonotic diseases to humans including hantavirus pulmonary syndrome, plague, and West Nile virus (Epstein 2001, Confalonieri et al. 2007).
- Increases in invasive exotic plants (NFWPCAP 2012).
- Higher temperatures could affect phenological events such as flowering, fruit set, and seed production (Loehman and Anderson 2009).
- Staffing needs may change as the park is expected to have an increase in annual visitation, with the largest increase coming in shoulder season visitation. This has the potential to divert resources away from the management of species and habitats (NPS 2015).
- Change bird communities by altering habitat quality, food abundance, and availability of microclimates (Schuurman and Wu 2018).
- More frequent extreme events such as heat waves and heavy rains (Karl et al. 2009, Walsh 2014a).

- 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).
- Expansion of and increased susceptibility to non-native tree insects and diseases could lead to changes in forest composition, structure and function (Fisichelli 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.

4.2.6. 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. 2014b). Information gaps needing to be addressed to help manage resources and understand the repercussions of climate change to the park include: 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).

4.2.7. Literature Cited

Bagne, K., P. Ford, and M. Reeves. 2013. Grasslands. USDA Forest Service, Climate Change Resource Center. Available at: https://www.fs.usda.gov/ccrc/topics/grasslands-and-climate-change (accessed 21 October 2013).

Confalonieri, U., B. Menne, R. Akhtar, K. L. Ebi, M. Hauengue, R. S. Kovats, B. Revich, and A. Woodward. 2007. Human health. Pages 391–431 *in* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, editors. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Environmental Protection Agency (EPA). 2012. Climate change indicators in the United States, second edition. U.S. Environmental Protection Agency, Washington, D.C.

Epstein, P. R. 2001. Climate change and emerging infectious diseases. Microbes and Infection 3:747–754.

Fisichelli, N. 2013. Climate change trends for the state of the park report, Valley Forge National Historical Park, Pennsylvania. NPS Climate Change Response Program.

Fisichelli, N. A., S. R. Abella, M. P. Peters, and F. J. Krist Jr. 2014. Climate, trees, pests, and weeds: change, uncertainty, and biotic stressors in eastern U.S. national park forests. Forest Ecology and Management 327:31–39.

Glick, P., B. A. Stein, and N. A. Edelson, editors. 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, D.C.

Heller, N. E., and E. S. Zavaleta. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biological Conservation 142:14–32.

Ibanez, I., R. B. Primack, A. J. Miller-Rushing, E. Ellwood, H. Higuchi, S. D. Lee, H. Kobori, and J. A. Silander. 2010. Forecasting phenology under global warming. Philosophical Transactions of the Royal Society B – Biological Sciences 365:3247–3260.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, UK.

Karl, T. R., J. M. Melillo, and T. C. Peterson, editors. 2009. Global climate change impacts in the United States. United States Global Change Research Program (USGCRP). Cambridge University Press, Cambridge, United Kingdom.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, J. Rennells, A. DeGaetano, and J. G. Dobson. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Part 1. Climate of the Northeast U.S. National Oceanic and Atmospheric Administration Technical Report NESDIS 142-1, Washington, D.C.

Loehman, R., and G. Anderson. 2009. Understanding the science of climate change: talking points – impacts to the Atlantic coast. Natural Resource Report NPS/NRPC/NRR—2009/095. National Park Service, Fort Collins, Colorado.

Lynch, C., A. Seth, and J. Thibeault, 2016: Recent and projected annual cycles of temperature and precipitation in the northeast United States from CMIP5. Journal of Climate, 29 (1), 347–365. http:// dx.doi.org/10.1175/jcli-d-14-00781.1.

Monahan, W. B., and N. A. Fisichelli. 2014. Climate exposure of US national parks in a new era of change. PLoS ONE 9(7): e101302. doi:10.1371/journal.pone.0101302.

Monahan, W. B., A. Rosemartin, K. L. Gerst, N. A. Fisichelli, T. Ault, M. D. Schwartz, J. E. Gross, J. F. Weltzin. 2016. Climate change is advancing spring onset across the U.S. national park system. Ecosphere 7(10):e01465.10.1002/ecs2.1465.

Mulholland, P. J., G. R. Best, C. C. Coutant, G. M. Hornberger, J. L. Meyer, P. J. Robinson, J. R. Stenberg, R. E. Turner, F. Vera-Herrera, and R. G. Wetzel. 1997. Effects of climate change on freshwater ecosystems of the southeastern United States and the Gulf Coast of Mexico. Hydrological Processes 11:949–970.

National Climatic Data Center (NCDC). 2019. Archive of monthly PDSI estimates.

National Fish, Wildlife and Plants Climate Adaptation Partnership (NFWPCAP). 2012. National fish, wildlife and plants climate adaptation strategy. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, D.C.

National Park Service (NPS). 2010. Climate change response strategy. NPS Climate Change Response Program, Fort Collins, Colorado.

NPS. 2012. Applying National Park Service management policies in the context of climate change. US DOI National Park Service Policy Memorandum 12-02. March 6, 2012.

NPS. 2014. Resource Brief: Recent climate change exposure of Valley Forge National Historical Park. NPS Natural Resource Stewardship and Science, Fort Collins, Colorado.

NPS. 2015. Resource Brief: Park visitation and climate change: park-specific brief. Independence National Historical Park: how might future warming alter visitation? National Park Service Climate Change Response Program, Fort Collins, Colorado.

Palmer, W. C. 1965. Meteorological drought. Research Paper No. 45. U.S. Weather Bureau, Washington, D.C.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. The Annual Review of Ecology, Evolution, and Systematics, 637–669.

Peñuelas, J., T. Rutishauser, and I. Filella. 2009. Phenology feedbacks on climate change. Science 324:887–888.

Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, and C. Mason. 2002. Climate change impacts on US coastal and marine ecosystems. Estuaries and Coasts 25:149–164.

Schuurman, G., and J. Wu. 2018. Resource Brief: Birds and climate change: Valley Forge National Historical Park.

Shaeffer, M., D. Ojima, J. M. Antle, D. Kluck, R. A. McPherson, S. Petersen, B. Scanlon, and K. Sherman. 2014. Chapter 19: Great Plains. Pages 441–461 *in* J. M. Melillo, Terese (T.C.)

Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: the third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Sheffield, J., E. F. Wood, and M. L. Roderick. 2012. Little change in global drought over the past 60 years. Nature 491:435–438.

Stein, B. A., A. Staudt, M. S. Cross, N. S. Dobson, C. Enquist, R. Griffis, L. J. Hansen, J. J. Hellman, J. J. Lawler, E. J. Nelson, and A. Pairis. 2013. Preparing for and managing change: climate adaptation for biodiversity and ecosystems. Frontiers in Ecology and the Environment 11(9):502–510.

Stein, B. A., P. Glick, N. Edelson, and A. Staudt, editors. 2014. Climate-smart conservation: putting adaptation principles into practice. National Wildlife Federation, Washington, D.C.

U.S. Department of Agriculture (USDA). 2001. Forests: the potential consequences of climate variability and change. A report of the National Forest Assessment Group for the U.S. Global Change Research Program, Washington, D.C.

USDA. 2014. U.S. Drought Portal, National Integrated Drought Information System. Available at: http://www.drought.gov (accessed 15 March 2014).

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. 2014a. Chapter 2: Our changing climate. Pages 19–67 *in* J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: The third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. 2014b. Appendix 3: Climate science supplement. Pages 790–820 *in* J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: The third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Wolfe, D. W., A. T. DeGaetano, G. M. Peck, M. Carey, L. H. Ziska, J. Lea-Cox, A. R. Kemanian, M. P. Hoffmann, and D. Y. Hollinger. 2018. Unique challenges and opportunities for northeastern US crop production in a changing climate. Climatic Change, 146 (1–2), 231–245. http://dx.doi.org/10.1007/s10584-017-2109-7.

4.3. Night Skies

4.3.1. 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).

The units comprising First State National Historical Park are located in a rural/agricultural, urban, industrial and residential matrix that includes multiple possible sources of artificial light contributing to light pollution. Old Swedes Church, Fort Christina, New Castle Courthouse and Green, and Dover Green are located within urban environments where local light pollution, skyglow from more distant urban centers, and other sources heavily degrade natural night skies. Old Swedes Church and Fort Christina are affected by light from railway, commercial and industrial sources adjacent to the properties. Of the units located in towns and cities, Ryves Holt House in Lewes is perhaps the least affected, although local light pollution may be significant. The two FRST units located in non-urban areas, Brandywine Valley and John Dickinson Plantation, are the focus of this section. John Dickinson Plantation conducts occasional evening programs but generally is closed to the public at night.

Threats and Stressors

At FRST, the relatively small size of the park units makes them more vulnerable to anthropogenic light sources on adjacent lands, which are predominantly private. Primary sources of light pollution include local residential and commercial sources, and sky glow from communities in and around the greater Wilmington and Philadelphia metropolitan areas. John Dickinson Plantation offers a few programs associated with night skies, and is otherwise closed at night.

Anthropogenic light can be perceived many miles away from its source (Falchi et al. 2016). 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). Changes in these factors can have significant impacts on the night sky of the non-urban park units.

Indicators and Measures

- All-Sky Light Pollution Ratio (ALR)

4.3.2. 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 for FRST.

4.3.3. Reference Conditions

The reference condition for the night sky in rural FRST units is one in which the intrusion of artificial light into the night scene is minimized. Under this condition, natural sources of light (such as moonlight, starlight, and the Milky Way) will be more visible from the park than anthropogenic sources, consistent with the pre-industrial-era and character of these units. As little outdoor lighting as is necessary to maintain a safe environment for park visitors and employees is prescribed.

Impact thresholds have been developed for non-urban (Level 1) and urban (Level 2) park night sky resources (Table 4.3-1) (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 (2010), Brandywine Valley is categorized as a mixture of urban and non-urban (described as urban here); John Dickinson Plantation is classified as non-urban (U.S. Census Bureau 2010).

Table 4.3-1. Reference condition rating framework for night sky indicators at Brandywine 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

4.3.4. Condition and Trend

The modeled ALR values for Brandywine Valley range from 20.5 to 40.0, averaging 24.2. This indicates significant management concern for an urban park (Table 4.3-1, Figure 4.3-1). 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 directly overhead. Dark adaptation of eyesight is not possible, and substantial glare may be present with visible shadows (Moore et al. 2013). Although the Brandywine Valley night sky is degraded due to high levels of light pollution from Philadelphia and relatively high levels along the Interstate 95 corridor including Wilmington, Delaware, the conditions at Brandywine Valley are better than surrounding residential areas and commercial corridors, providing an important yet threatened resource for the park locale. The night sky quality improves to the northwest to west into Pennsylvania and predominantly rural areas.

The modeled ALR values for John Dickinson Plantation range from 5.1 to 10.2 and average 7.4, which warrants significant concern for a non-urban park (Table 4.3-1, Figure 4.3-1). John Dickinson Plantation is near the boundary of moderate light pollution from the Dover, Delaware, metropolitan area, and is affected by light from Dover Air Force Base and associated housing areas, as well as numerous suburban developments to the west and toward Dover.

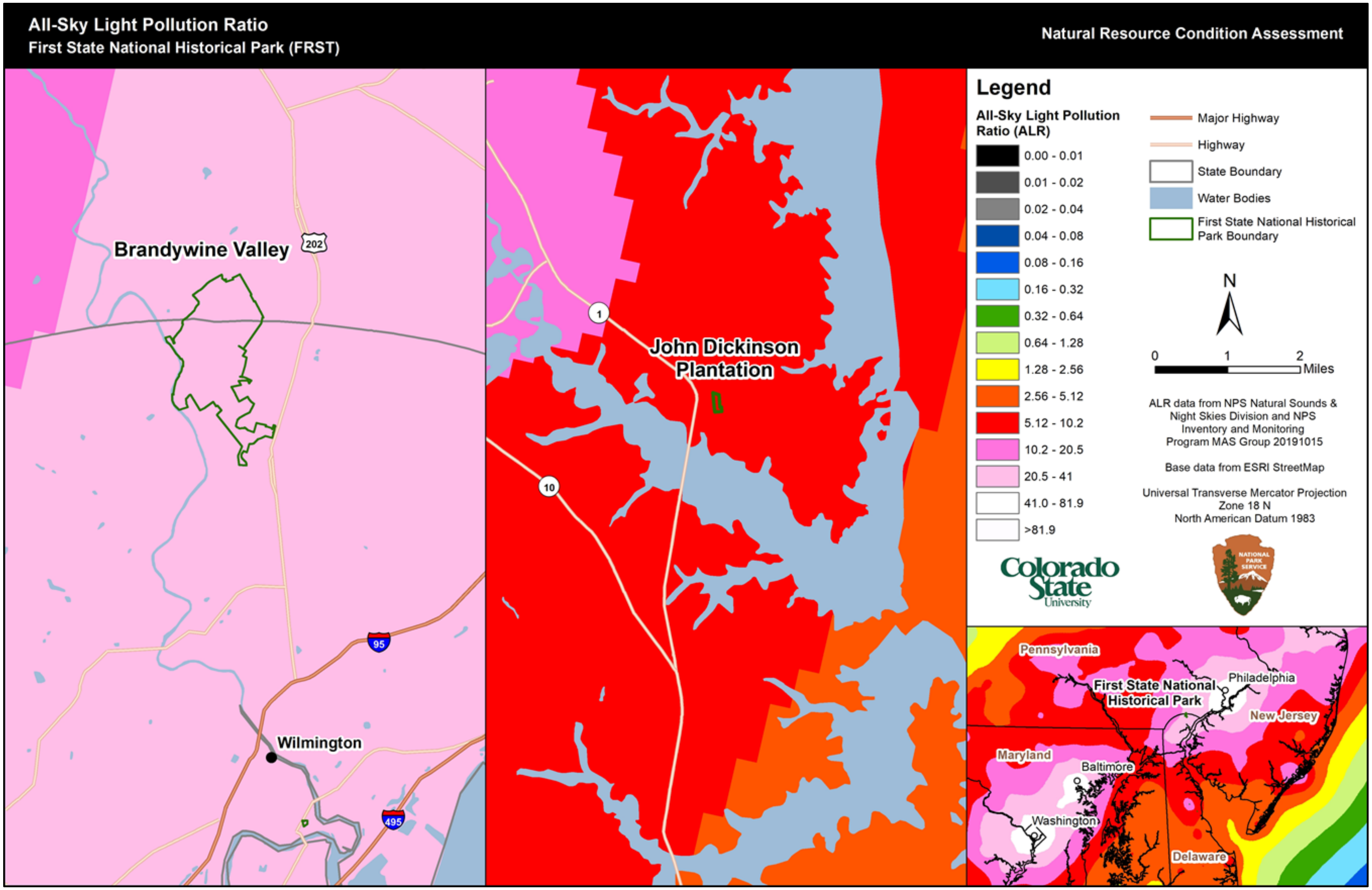
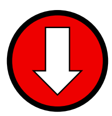
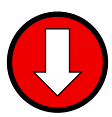
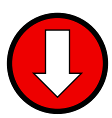


Figure 4.3-1. All-Sky Light Pollution Ratio (ALR) values for Brandywine Valley, John Dickinson Plantation and surrounding areas (Duriscoe et al. 2018).

Housing densities in the region have increased over the past several decades. Recent and projected trends in housing development within the region and near Brandywine Valley and John Dickinson Plantation indicate that housing densities will continue to increase within 30 km of both park units (See Section 4.1, *Land Cover and Land Use*). Within 30 km of Brandywine Valley, between 2020 and 2050 the percentage of acreage classified as either rural or exurban is projected to decline by approximately 8% while the acreage classified as suburban is projected to increase by approximately 8%. In the 30 km area surrounding John Dickinson Plantation, between 2020 and 2050 the percentage of acreage classified as rural is projected to decline by approximately 8% while the acreage classified as exurban is projected to increase by approximately 8% (U.S. Census Bureau 2010). These changes, with concomitant increases in population and associated development, will further degrade the night skies at these units.

Based on these results, the condition of natural night skies at FRST warrants significant concern with a deteriorating trend due to development and increased housing density within the region and near the park (Table 4.3-2). Confidence in the assessment is high.

Table 4.3-2. Condition and trend summary for night skies at the Brandywine Valley and John Dickinson Plantation units, First State National Historical Park.

Indicator	Condition Status/Trend	Rationale
Brandywine Valley – All-Sky Light Pollution Ratio (ALR)		ALR for this unit had a median value between 20.5 and 40.0, which warrants significant concern for an urban park. Housing and population densities have been increasing and are projected to continue to increase between 2020 and 2050.
John Dickinson Plantation – All-Sky Light Pollution Ratio (ALR)		ALR for this unit had a median value between 5.1 and 10.2, which warrants significant concern for a non-urban park. Housing and population densities have been increasing and are projected to continue to increase between 2020 and 2050.
Overall		**Night skies warrant significant concern with a deteriorating trend. Confidence in the assessment is high.**

4.3.5. Uncertainty and Data Gaps

There is a high level of certainty in the assessment due to the site-specific concerns voiced by park staff and the regional impacts documented by modeled data. No on-site night sky monitoring studies have been conducted by the NPS at FRST. Additional measures for night skies could include Bortle Dark Sky Scale assessments, assessment of sky brightness using a charged couple device (CCD), and Unihedron Sky Quality Meter (SQM).

4.3.6. Sources of Expertise

- Sharolyn Anderson, NPS Natural Sounds and Night Skies Division, provided data.

- Emma Brown, NPS Natural Sounds and Night Skies Division, reviewed the draft manuscript and provided helpful comments.

4.3.7. Literature Cited

Cinzano, P., F. Falchi, C. D. Elvidge, and K. E. Baugh. 2000. The artificial night sky brightness mapped from DMSP satellite Operational Linescan System measurements. Monthly Notices of the Royal Astronomical Society 318:641–657.

Duriscoe, D. M., S. J. Anderson, C. B. Luginbuhl, and K. E. Baugh. 2018. A simplified model of all-sky artificial sky glow derived from VIIRS Day/Night band data. Journal of Quantitative Spectroscopy and Radiative Transfer 214:133–145.

Falchi, F., P. Cinzano, D. Duriscoe, C. Kyba, C. Elvidge, K. Baugh, B. A. Portnov, N. A. Rybnikova, and R. Furgoni. 2016. The new world atlas of artificial night sky brightness. Science Advances 2:e1600377.

Kulesza, C., Y. Le, M. Littlejohn, and S. J. Hollenhorst. 2013. National Park Service visitor values and perceptions of clean air, scenic views & dark night skies; 1988–2011. Page 70. Natural Resource Report NPS/NRSS/ARD/NRR–2013/632. National Park Service, Fort Collins, Colorado.

Moore, C., F. Turina, and J. White. 2013. Recommended indicators and thresholds of night sky quality for NPS State of the Park reports. NPS Natural Sounds and Night Skies Division. Available from https://irma.nps.gov/DataStore/Reference/Profile/2198592 (accessed 30 July 2018).

National Park Service (NPS). 2006. Management policies 2006: the guide to managing the National Park System. National Park Service, Washington, D.C.

Peel, K. A. 2000, May 23. Director's Order #47: Soundscape Preservation and Noise Management. Available at: https://www.nps.gov/policy/DOrders/DOrder47.html (accessed 25 June 2018).

Rich, C., and T. Longcore. 2005. Ecological consequences of artificial night lighting. Island Press, Washington, D.C.

U.S. Census Bureau. 2010. 2010 Census – Urban and Rural Classification. Available at: https://www2.census.gov/geo/tiger/TIGER2010/UA/2010/ (accessed 21 June 2018).

Van Doren, B. M., K. G. Horton, A.M. Dokter, H. Klinck, S. B. Elbin, and A. Farnsworth. 2017. High-intensity urban light installation dramatically alters nocturnal bird migration. Proceedings of the National Academy of Sciences 114:11175–11180.

4.4. Natural Sounds

4.4.1. Background and Importance

The acoustic environment includes all sounds present in the environment, and not just those audible to humans. All the natural sounds that occur within the boundaries of the National Park System units, the physical capacity for transmitting those natural sounds, and their interrelationships with other sounds comprise the natural acoustic environment 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). National Park Service management policies include 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 the acoustic environment from unacceptable impacts" (NPS 2006). Excessive noise in NPS units threatens to adversely impact natural and cultural resources and the quality of visitor experiences. FRST units have their own cultural soundscape that is both unique and appropriate to their particular place and period. Loud or inappropriate sound levels from sources such as aircraft, vehicles, and the modern era can detract from the visitor experience (NPS 2019a). The NPS has clearly declared its commitment to protect intrinsic soundscapes for the enjoyment of current and future generations of park visitors.

Anthropogenic 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). 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.

The NPS Natural Sounds and Night Skies Division (NSNSD) has used acoustic modeling to estimate the anthropogenic impact to the ambient sound level in FRST units, which is the existing sound level minus the estimated natural sound level (Mennitt et al. 2013). Mean impact thus provides a measure of how much anthropogenic noise is increasing the existing sound level above the natural sound level, on average, in the park. For reference, for human visitors and resident wildlife, an increase in background sound level of 3 dB produces an approximate decrease in listening area of 50%. In other words, raising the sound level by 3 dB reduces the ability of listeners to hear the sounds around them by half. Furthermore, an increase of 7 dB leads to an approximate decrease in listening area of 80%, and an increase of 10 dB decreases listening area by approximately 90%.

Threats and Stressors

Primary threats to the acoustic environment include noise originating from modern transportation (automobiles and aircraft), development, and commercial or industrial activities. Aircraft and road transportation noise are typically the most pervasive threats to natural sounds in NPS units (Buxton et al. 2017, 2019). At Brandywine Valley, there is relatively little noise associated with park management activities outside of agricultural and residential leases and maintenance of picnic and parking areas near Brandywine Creek. Agricultural noise is primarily from seasonal tilling, planting and harvesting activities. The sound of gunshots from hunting on adjacent lands can also be heard. At John Dickinson Plantation, noise generated by the park is limited to landscaping and maintenance activities. General and specific sources of noise for FRST units are listed below.

Rural Units

Brandywine Valley:

- Road noise from primary routes bisecting and adjacent to the unit.
- Noise from commercial activities along the Concord Pike corridor east of the unit.
- Aircraft noise from travel associated with numerous regional air hubs along the eastern seaboard.

John Dickinson Plantation

- Loud, low-flying crop dusters used by leaseholders impact interpretive programming, especially during July and August (NPS 2019b).
- Although planes are prohibited from flying over the house, noise and vibration from Dover Air Force Base aircraft and the nearby firing range can impact the visitor experience (NPS 2019b; pers. comm., Gloria Henry, January 2018).
- Road noise, especially from State Highway Hwy 1 (Bay Road) to the east.

Urban Units

Old Swedes Church and Fort Christina

- Noise and vibration from nearby passenger rail corridor (NPS 2019b; pers. comm., Rebecca Wilson, December 2017).
- Urban background noise from transportation, commercial activities, and numerous heating/cooling units on site and on adjacent properties.
- Industrial noise associated with adjacent Noramco factory, including rooftop and heating/cooling machinery.

New Castle Courthouse and Green, Dover Green and Ryves Holt House

- Urban background noise from transportation and commercial activities.

A comprehensive examination of landscape context related to land cover/land use and population and housing, all of which can degrade natural and historic 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.

Indicators and Measures

- Anthropogenic sources of noise (i.e., noise) – presence/absence and relative noise level
- Road traffic volumes (Brandywine Valley and John Dickinson Plantation) to inform trend
- Noise impacts (modeled) – median and maximum L_{A50} impact in dB

All three indicators were examined at the FRST units having the most rural and natural/semi-natural settings, i.e., Brandywine Valley and John Dickinson Plantation. The remaining units are located in small towns (e.g., Ryves Holt House in Lewes) to large urban areas (e.g., Fort Christina in Wilmington), with some having notable commercial or industrial elements. For Old Swedes Church, Fort Christina, New Castle Green, Dover Green and Ryves Holt House, we evaluate only the sources and relative magnitudes of anthropogenic noise observed by the authors or noted by NPS or park unit staff or volunteers as a simple qualitative index of the sounds present relative to the historic soundscape.

4.4.2. Data and Methods

The condition of the soundscape at FRST was evaluated using input from park documents and staff, and 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. Sound levels are often lower at night and during the winter (NPS 2018). 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 FRST 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 from the Delaware Department of Transportation provides a snapshot of road traffic volumes and trends for the past 5 years (DelDOT 2019). The breakdown of car vs. truck traffic and projections for future traffic volumes were not available. The primary transportation routes in or adjacent to Brandywine Valley include Brandywine Valley Road, Ramsey Road, Woodlawn Road, Smith Bridge Road, Thompson Bridge Road, and US Highway 202 (Concord Pike). At John Dickinson Plantation, State Road 1/Bay Road is the busiest nearby transportation route in addition to Kitts Hummock Road and Bayside Drive.

Decibel Scale

Sound pressure levels are often represented in the logarithmic decibel (dB) scale. In this scale, 0 dB is equivalent to the lower threshold of human hearing at a frequency of 1 kHz. This scale can be adjusted to account for human sensitivity to different frequencies of sound, a correction known as A-weighting. Examples of common sound sources (both within and outside of park unit environments) and their approximate sound levels are shown in Table 4.4-1 (Lynch 2009).

Table 4.4-1. 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

4.4.3. Reference Conditions

Park managers have not yet identified specific reference conditions for the soundscape for FRST units. The reference condition for the soundscape in FRST is dominated by natural and cultural sounds that are intrinsic to the park period of significance. Natural sounds could include birds, wind, rain, running water, and insects. Cultural sounds might include those related to agricultural, rural and small town and urban transportation, commercial or industrial activities. 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 4.4-2).

Table 4.4-2. Reference condition rating framework for soundscape indicators at FRST. 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	3 dB < Median impact < 5 dB	Median impact ≥ 5 dB
	Maximum impact ≤ 7.5 dB	7.5 dB < Maximum impact < 10 dB	Maximum impact ≥ 10 dB

4.4.4. Condition and Trend

Anthropogenic Sources of Noise

For the rural units examined, the most prominent noise sources are roads/traffic, commercial activity and aircraft noise (pers. comm., Alan Mcloughlin, July 2019). Most anthropogenic noise originates outside the park. There is some noise within Brandywine Valley and John Dickinson Plantation from agricultural operations and park maintenance. Fort Christina and Old Swedes Church are highly impacted by commercial, industrial, train, and traffic noise. Based on input from park staff and observations by the authors, the condition of this indicator warrants moderate to significant concern for the rural units and significant concern for the urban units, with an unknown trend and a medium level of confidence due to lack of visitor survey data.

Anthropogenic Impacts on Ambient Sound Level (Modeled)

At Brandywine Valley, the median modeled L_{A50} sound level impact was 11.2 dB and the maximum impact value was 13.9 dB (NPS 2015). The areas within Brandywine Valley with the lowest anthropogenic sound level impacts are on the western and northern sides closer to rural areas; areas with higher sound impacts are on the eastern side closer to the Concord Pike corridor (Figure 4.4-1). At John Dickinson Plantation, the median modeled impact was 9.7 dB and the maximum impact value was 10.5 dB (Figure 4.4-1). A single modeled pixel represents each of the urban/historical units: Fort Christina (13.6 dB), Old Swedes Church (14.3 dB); New Castle Courthouse and Green (11.6 dB); Dover Green (18.2 dB); and Ryves Holt House (13.0 dB). Based on these modeled results, all rural and urban units have median anthropogenic sound impacts exceeding 5.0 dB and maximum sound impact levels exceeding 10 dB, and therefore warrant significant concern. Confidence is high since the impact levels for all units are more than double the threshold developed by NSNSD. No trend data are available.

Traffic Volume

We examined average annual daily traffic volumes for 2014–2018 for transportation routes in and/or near Brandywine Valley and John Dickinson Plantation (DelDOT 2019) (Table 4.4-3). The slope of the regression line is positive and statistically significant for roads with the highest volumes in or near the units. With respect to changes in traffic volumes affecting park noise levels, Thompson Bridge Road and Concord Pike had increases of 25% and 50.8%, respectively at Brandywine Valley between 2014 and 2018. At John Dickinson Plantation, State Road 1 daily traffic increased by 10% between 2014 and 2018.

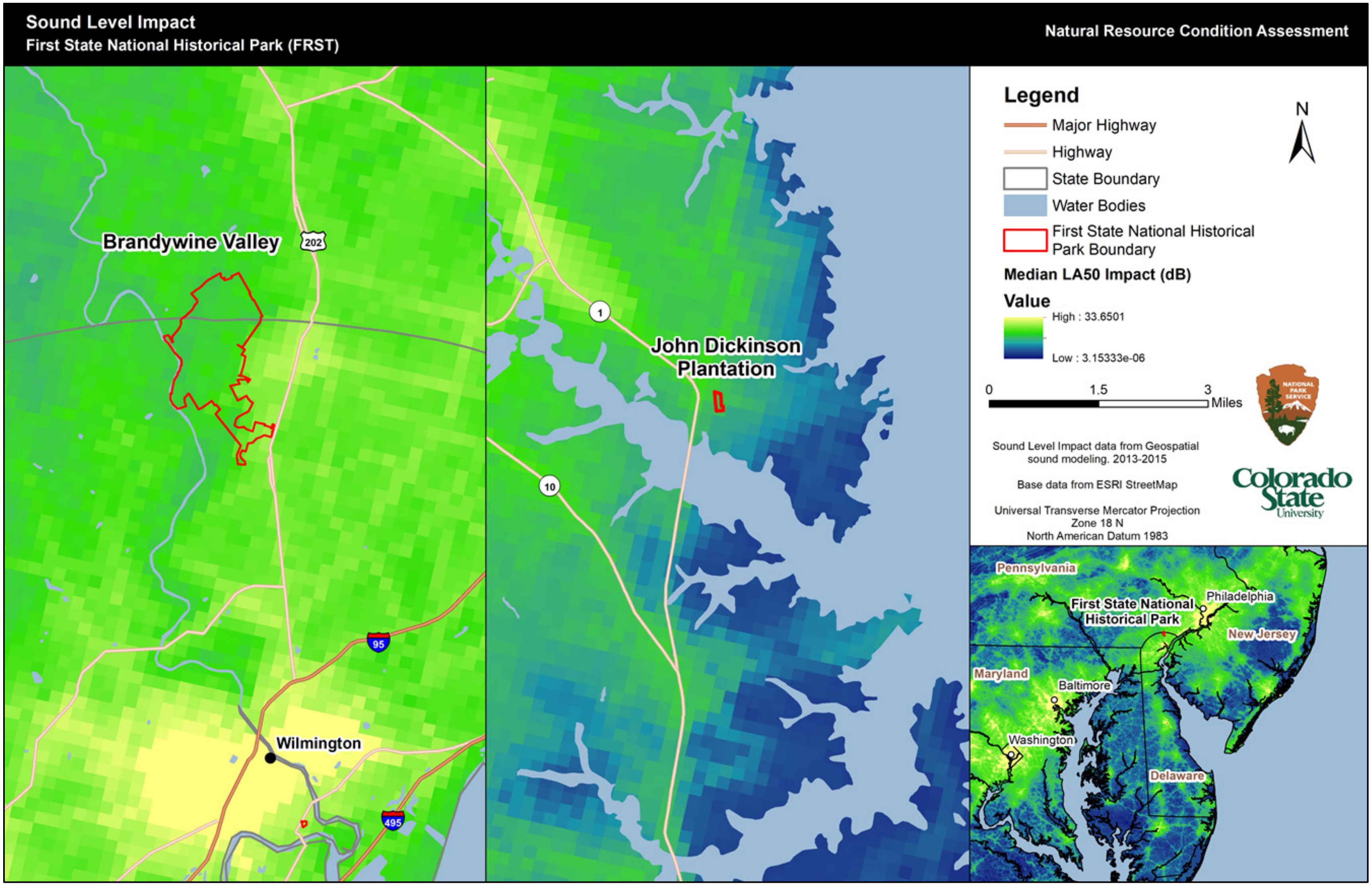


Figure 4.4-1. Modeled sound level impacts for Brandywine Valley, John Dickinson Plantation and surrounding areas (NPS 2015).

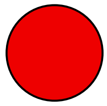
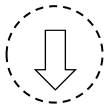
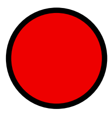
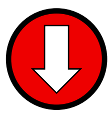
Table 4.4-3. Annual average daily traffic volume, measured as vehicle counts, percent daily volume change (2014–2018) and regression p values for selected road segments in or adjacent to the Brandywine Valley and John Dickinson (J.D.) Plantation units (DelDOT 2019).

Park Unit	Road Name	2014	2015	2016	2017	2018	% change 2014–2018	Regression p value
Brandywine Valley	Beaver Valley Road	2473	2701	2633	2255	2265	−8.4	0.220
Brandywine Valley	Woodlawn Road	1170	1170	1170	1178	1434	22.6	0.170
Brandywine Valley	Thompson Bridge Road	8423	9198	8967	9369	10528	25.0	0.041
Brandywine Valley	Smith Bridge Road	2592	2851	3008	3259	3275	26.4	0.005
Brandywine Valley	US Highway 202 Concord Pike	29641	30162	30394	41129	44686	50.8	0.033
J.D. Plantation	SR1 Bay Road	33953	35854	36481	37094	37327	9.9	0.020
J.D. Plantation	Kitts Hummock Road	1283	1410	1488	1491	1498	16.8	0.048
J.D. Plantation	Bayside Drive	2477	3473	3386	3403	2579	4.1	0.950

Overall Condition

The condition of the soundscape at FRST varies among park units. Not surprisingly, those units located in urbanized or commercial areas have less natural soundscapes relative to more rural units. Median L_{A50} sound level impacts are more than 10 dB for all units. Overall, condition of the units warrants significant concern (Table 4.4-4). The trend in the natural sounds environment is estimated to be deteriorating based on trends in traffic volumes in and near the units and projected population/housing trends for the area (see section 4.1, *Land Cover and Land Use*). Noise from aircraft is prevalent in the region and a NPS management concern, especially at John Dickinson Plantation, but no data have been collected at FRST units. Overall confidence associated with the assessment is medium.

Table 4.4-4. Condition and trend summary for natural sounds at First State National Historical Park.

Indicator	Condition Status/Trend	Rationale
Noise		Vehicles, aircraft traffic and noise from commercial and industrial plants impact FRST units to varying degrees. Condition warrants significant concern.
Road traffic volumes – Brandywine Valley and John Dickinson Plantation.		Traffic volumes on primary transportation routes near Brandywine Valley and John Dickinson Plantation have increased over the past five years, and are major sources of noise.
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. Both rural and urban units have median sound level impacts above 10 dB, more than double the threshold used for significant impacts. Ground and air traffic are the primary sources of noise at most units.
Overall		**Condition warrants significant concern with an anticipated deteriorating trend. Confidence in the assessment is high.**

4.4.5. Uncertainty and Data Gaps

No evaluative data to determine the impacts of existing soundscape conditions on visitor experiences have been collected on-site at FRST.

4.4.6. Sources of Expertise

- Emma Brown, Acoustical Resource Specialist, NPS Night Skies and Natural Sounds Division, provided data and helpful reviews for the section template.

4.4.7. Literature Cited

Barber, J. R., K. M. Fristrup, C. L. Brown, A. R. Hardy, L. M. Angeloni, and K. R. Crooks. 2009. Conserving the wild life therein--Protecting park fauna from anthropogenic noise. ParkScience 26(3):26–31.

Benfield, J. A., P. A. Bell, L. J. Troup, and N. C. Soderstrom. 2010. Aesthetic and affective effects of vocal and traffic noise on natural landscape assessment. Journal of Environmental Psychology 30:103–111.

Buxton, R. T., M. F. McKenna, D. Mennitt, K. Fristrup, K. Crooks, L. Angeloni, and G. Wittemyer. 2017. Noise pollution is pervasive in U.S. protected areas. Science 356:531–533.

Buxton, R., M. McKenna, D. Mennitt, E. Brown, K. Fristrup, K. Crooks, L. Angeloni, and G. Wittemyer. 2019. Anthropogenic noise in US national parks – sources and spatial extent. Frontiers in Ecology and the Environment doi:10.1002/fee.2112.

Delaware Department of Transportation (DelDOT). 2019. DELDOT website: Delaware vehicle volume summary 2018. Available at: https://deldot.gov/Publications/manuals/traffic_counts/index.shtml (accessed 11 December 2019).

Habib, L., E. M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. Journal of Applied Ecology 44:176–184.

Krog, N. H., B. Engdahl, and K. Tambs. 2010. Effects of changed aircraft noise exposure on the use of outdoor recreational areas. International Journal of Environmental Research and Public Health 7:3890–3915.

Lynch, E. 2009. San Antonio Missions National Historical Park acoustical monitoring report 2009. Natural Resource Report NPS/NRPC/NRTR 2009/001. National Park Service, Fort Collins, Colorado.

Mace, B. L., G. C. Corser, L. Zitting, and J. Denison. 2013. Effects of overflights on the national park experience. Journal of Environmental Psychology 35:30–39.

McDonald, C. D., R. M. Baumgartner, and R. Iachan. 1995. National Park Service aircraft management studies: visitor survey. NPOA Report No. 94-2. Available at: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB95196002.xhtml (accessed 30 June 2018).

Mennitt, D., K. Fristrup, K. Sherrill, and L. Nelson. 2013. Mapping sound pressure levels on continental scales using a geospatial sound model. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, Innsbruck, Austria.

National Park Service (NPS). 2000, May 23. Director's Order #47: Soundscape Preservation and Noise Management. Available at: https://www.nps.gov/policy/DOrders/DOrder47.html (accessed 25 June 2018).

NPS. 2006. Management policies 2006: the guide to managing the National Park System. National Park Service, Washington, D.C.

NPS. 2015. Geospatial sound modeling. 2013–2015: modeled sound impacts for L50 dBA. NPS Natural Sounds and Night Skies Division.

NPS. 2018. NPS natural sounds website – mapping sound. Available at: https://www.nps.gov/subjects/sound/soundmap.htm.

NPS. 2019a. NPS natural sounds website – sound impacts on cultural resources. https://www.nps.gov/subjects/sound/effects_cultural.htm (accessed 13 December 2019).

NPS. 2019b. Draft First State National Historical Park Foundation Document, February 2019. National Park Service.

Rabin, L. A., R. G. Coss, and D. H. Owings. 2006. The effects of wind turbines on antipredator behavior in California ground squirrels (*Spermophilus beecheyi*). Biological Conservation 131:410–420.

Rapoza, A., E. Sudderth, and K. Lewis. 2015. The relationship between aircraft noise exposure and day-use visitor survey responses in backcountry areas of national parks. The Journal of the Acoustical Society of America 138:2090–2105.

Shannon, G., M. F. McKenna, L. M. Angeloni, K. R. Crooks, K. M. Fristrup, E. Brown, K. A. Warner, M. D. Nelson, C. White, J. Briggs, S. McFarland, and G. Wittemyer. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews 91:982–1005.

Weinzimmer, D., P. Newman, D. Taff, J. Benfield, E. Lynch, and P. Bell. 2014. Human responses to simulated motorized noise in national parks. Leisure Sciences, 36(3), 251–267.

4.5. Visual Resources

4.5.1. Background and Importance

Visual resources have important value in terms of historic and cultural context, aesthetics, tourism, and health. Scenery encompasses the visible physical features on a landscape including the land, water, vegetation, structures, animals, and other features, and is linked to air quality-related values such as haze and natural night skies. The National Park Service Organic Act of 1916 specifies that the NPS shall "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Protection and conservation of scenic resources is also required under other legislation and policies such as the National Environmental Policy Act, Federal Land Policy and Management Act, National Historic Preservation Act, the Clean Air Act, and NPS guidance. In surveys conducted throughout the national park system, 94% of NPS visitors responded that scenic views are extremely important or very important (Kulesza et al. 2013). Current NPS management policies (NPS 2006) do not provide guidance regarding service-wide policies or practices for scenery conservation.

First State National Historical Park (FRST) consists of seven natural, cultural or historical sites throughout Delaware. These include Brandywine Valley, Old Swedes Church, Fort Christina, Historic New Castle, Dover Green, John Dickinson Plantation, and Ryves Holt House. FRST was originally established as a National Monument in 2013 and became a National Historical Park in 2014. While Brandywine Valley is owned by the NPS, with the exception of the Sheriff's House in New Castle, the other six units are owned and operated by other state, local or nonprofit organizations in partnership with the NPS.

Threats and Stressors

- Increased visitation at each site has the potential to negatively impact visual resources (NPS 2017a). Increased visitation at Brandywine Valley can diminish natural resources and strain park staff as they try to manage and clean up after users on trails and picnic areas. At the six historical sites, increased visitation has the potential to damage the sites' historical character.
- Increased development and traffic surrounding the sites (NPS 2017b) has the potential to impact resources. Commercial and residential development on the edges and on private and leased land within Brandywine Valley impacts views within the park. The park's historic units are within urban environments; several are adjacent to commercial and industrial development.
- Historic sites need constant upkeep to maintain their aesthetic and structural integrity. Limited funding could prevent or defer maintenance on historic structures (NPS 2017a).
- Degraded air quality. The visibility haze index in the FRST area on mid-range days was 6.9 deciviews above the estimated natural condition of 7.7 deciviews (see Section 4.6 *Air Quality* for details). Haze reduces the distance and clarity experienced by the viewer and changes the color, contrast, and vividness associated with a view.

Indicators and Measures

- Scenic quality rating for assessed views

4.5.2. Data and Methods

No previous inventory of visual resources has been completed at FRST. Scenery evaluation and incorporation of results in the NRCA follows unpublished guidance provided by the NPS Air Resources Division (Meyer et al. 2018, National Park Service Air Resources Division [ARD] 2018). Important views were identified based on the FRST website, the FRST Brandywine Valley park map, and park staff input. In collaboration with park staff, 14 views representing a cross-section of visitor experiences were selected for the inventory (Figure 4.5-1). These 14 views are distributed across the seven sites that make up FRST and exemplify a variety of landscapes that may include natural, cultural, or historical significance.

Most viewpoints are accessible by car or are on a hiking trail. Field data were collected for both the viewpoint (where the observer is located) and the viewed landscape seen by the observer. Key characteristics for each viewpoint and viewed landscape included the GPS location, right and left limits of the view, the type of view, weather, observer position, photography, associated records, and the landscape description, which included landscape character type, extent of distance zones, landscape elements, and landscape design elements.

A CSU visual resources team conducted the scenic quality inventory in July 2019 using NPS guidance and methods developed specifically for visual resource inventory (Meyer et al. 2018). Fourteen views from 12 viewpoints were inventoried throughout the park (Figure 4.5-1). Each observer rated the scenic quality based on landscape character integrity, vividness, and visual harmony and panoramic photos were taken of each viewed landscape. Five landscape character types occurred within the park: natural/natural appearing, agricultural, rural, urban, and industrial. Each landscape character type is associated with a list of elements that are expected to occur in that type (below). These features are specific to FRST and vary by park location. Observers recorded individual ratings and then the group discussed and assigned a single scenic quality rating to each view on a scale of A (highest scenic quality) to E (lowest scenic quality).

Natural/Natural Appearing Landscape

This landscape character type is dominated by natural features. There may be evidence of human changes to the landscape, but they are minimal and do not detract from the natural landscape character. Typical elements include:

- Streams/Rivers
- Valleys
- Forests
- Grasslands
- Rolling hills
- Wetlands/Marshes
- Rock outcroppings

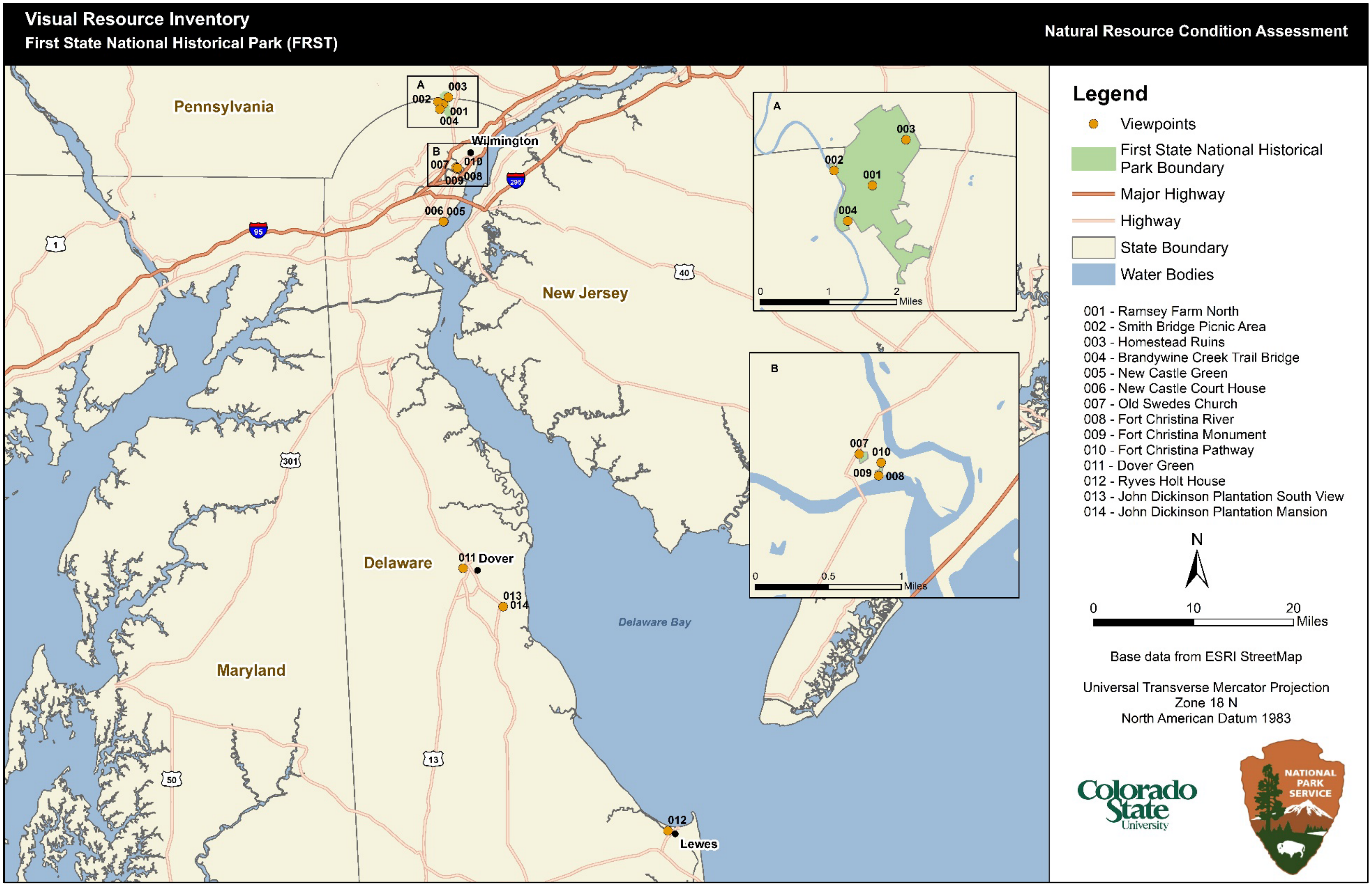


Figure 4.5-1. Locations of viewpoints from which 14 views were assessed during July 2019 at First State National Historical Park.

Agricultural Landscape

This landscape character type can include planted fields of row crops, orchards, and livestock pasture or confined feeding operations. The topography is typically flat to rolling and generally does not occur on steep terrain. These landscapes sometimes have clustered farm buildings and structures. Typical elements include:

- Planted crops and/or fields
- Fencing
- Farm buildings/equipment
- Gravel or paved local roads

Urban

This landscape contains more densely populated and developed areas where infrastructure and circulation patterns dominate the visual setting. Typical elements may include:

- Populated/developed areas dominated by infrastructure and circulation patterns
- Buildings – various sizes used for residential, office, retail/commercial
- Highways, roads, bridges, railroads

Rural

This landscape character type generally consists of isolated non-farmhouses, or small settlements with low populations, often located away from larger cities, suburbs, and towns; recreational areas may be present. Typical elements may include:

- Single family homes
- Gravel or local paved roads
- Forests
- Grasslands/open fields
- Community infrastructure
- Parks/recreation areas
- Local-scale roads and bridges

Industrial

This landscape character type may be integrated into an urban area or found on the edge of town/city centers. Regardless, industrial facilities are considered the dominant feature of this type. Typical elements include:

- Light or heavy industrial buildings or infrastructure, factories, or warehouse-appearing buildings
- Conventional energy generation or transmission facilities/infrastructure
- Shipyards/railyards

View importance, which considers viewpoint importance, viewed landscape importance, and viewer concern, is rated on a scale of 1 (highest) to 5 (lowest). Assessing view importance requires knowledge of the historic or cultural significance and designated status of both the viewpoint and viewed landscape. View importance was not evaluated in the 2019 inventory and hopefully can be completed by park staff at a later date. As per the NPS visual resources guidance (NPS ARD 2018), the overall scenic inventory value (SIV) for a view is based on a combination of the scenic quality and the view importance scores (Table 4.5-1). The SIV ratings are: very high (VH), high (H), medium (M), low (L), or very low (VL). Final visual resource inventory data are entered into the Enjoy the View (ETV) web-enabled database: https://irma.nps.gov/ETV/ (accessible when connected to a Department of Interior network). This database can produce summary inventory reports on a view-by-view basis, summarizing scenic quality and view importance, location and extent of the view, the overall scenic inventory value, and any additional field notes.

Table 4.5-1. Scenic Inventory Value (SIV) rating matrix for combinations of scenic quality and view importance (NPS ARD 2018). VL = very low, L = low, M = medium, H = high, VH = very high.

	View Importance Rating				
Scenic Quality	**1**	**2**	**3**	**4**	**5**
A	VH	VH	VH	H	M
B	VH	VH	H	M	L
C	H	H	M	L	L
D	H	M	L	VL	VL
E	M	L	VL	VL	VL

4.5.3. Reference Conditions/Values

First State National Historical Park holds significant value for the state of Delaware. Each of the seven sites represents a time in history, spanning from the first European settlers landing in Delaware through the American Revolution and later. Visitors experience the social context, architecture, culture, and historic events as they travel between park units. The Brandywine Valley unit contains the historical and cultural context of the eighteenth-century Quaker settlement. Throughout the valley, old structures, homesteads, mills, and roads demonstrate the original settlements. The park works to maintain these historically and culturally significant resources to conserve and interpret the natural and cultural landscape for the benefit of the public (NPS 2017b). However, elements inconsistent with the cultural and historic context are increasingly present at these sites. For example, modern agricultural buildings and equipment, paved roads, trails, and picnic areas occur within Brandywine Valley on inholdings and leases. Many of the other units are in urban centers surrounded by modern development that can distract or detract from the historic features. The park also has limited resources to keep up with the maintenance of historical structures on NPS-owned lands.

The condition rating framework for visual resources follows guidance from NPS Air Resources Division (ARD) (2018) and is based on scenic inventory values that combine scenic quality and view importance ratings. The ARD guidance of five categories (very good, good, fair, poor, and very poor) was consolidated to fit into three categories to be consistent with the NRCA program guidance (Table 4.5-2).

Table 4.5-2. Condition rating framework for scenic quality ratings (modified from NPS ARD 2018).

Condition Rating	Criteria
Good Condition	75% or more views have a Scenic Quality rating of A or B
Moderate Concern	50% to 74% of views have a Scenic Quality rating of A or B
Significant Concern	51% to 75% or more views have a Scenic Quality rating of C or lower

4.5.4. Condition and Trend

The scenic quality ratings were high. Eleven views received a B rating, two received a C, and one received an A (Table 4.5-3). View importance ratings that require knowledge of historical, cultural, and landscape designations within the park, necessitate the participation of FRST staff, and have not yet been completed. Once the view importance assessment is complete, the scenic inventory value will be determined for each viewpoint. Overall, the scenic quality ratings were in good condition for FRST. This assessment is a baseline inventory.

The level of confidence in this assessment of visual resources is high because almost all of the views identified as important by the park staff were inventoried, the views inventoried represent each unit within the park, and view assessments were done in the field (NPS ARD 2018). The primary threat to visual resources at FRST is the encroachment of new development at each of the sites, as well as limited funding for the maintenance and upkeep of historical structures.

Table 4.5-3. Scenic quality, view importance and scenic inventory values for viewpoints/landscape views assessed at First State National Historical Park.

View/Viewpoint Number	Viewpoint/View Name	Scenic Quality
001	Brandywine Valley, Ramsey Farm North	C
002	Brandywine Valley, Smith Bridge Picnic Area	B
003	Brandywine Valley, Homestead Ruins	B
004	Brandywine Valley, Brandywine Creek Trail Bridge	B
005	New Castle Green	B
006	New Castle Court House	B
007	Old Swedes Church	B
008	Fort Christina River	C
009	Fort Christina Monument	B
010	Fort Christina Pathway	B
011	Dover Green	B
012	Ryves Holt House	B

Table 4.5-3 (continued). Scenic quality, view importance and scenic inventory values for viewpoints/landscape views assessed at First State National Historical Park.

View/Viewpoint Number	Viewpoint/View Name	Scenic Quality
013	John Dickinson Plantation, South View	B
014	John Dickinson Plantation, Mansion	A

Brandywine Valley

Landscape characteristics identified within Brandywine Valley include natural systems and features, land uses, spatial organization, topography, vegetation, buildings and structures, views and vistas, and small-scale features. Many characteristics have associated features that contribute to the site's overall significance and integrity, as well as features that do not contribute. The features that contribute were present during the period of significance, 1681 to 1928. Considered as a whole, the contributing characteristics and features convey the cultural landscape that was identified and preserved by William Bancroft in his progressive community planning efforts for Wilmington at the turn of the twentieth century.

Brandywine Valley retains historic landscape characteristics that evoke the feeling of the early twentieth-century Brandywine Valley, with limited contemporary intrusion. The historic feeling is generated by the pastoral agricultural hilltops and beautiful views of creek valleys that inspired William Bancroft to initially consider Brandywine Valley as park land. The feeling of an industrial landscape within the Beaver Creek corridor has been substantially lost, although ruins of this past use remain through stone foundations and traces of waterways and quarries.

Adjacent lands beyond the cultural landscape boundary, either inside or outside of the park boundaries, contribute to the integrity and significance of the Brandywine Valley cultural landscape. The Brandywine Valley unit is set within a landscape characteristic of the Brandywine Creek watershed. Views from within the park encompass the early twentieth-century Granogue Estate, representative of the "Chateau Country" era. To the south, the cultural landscape of Brandywine Creek State Park, once agricultural lands of the du Pont family, is similar to that of Brandywine Valley. The landscape north and east of Brandywine Valley also reflects eighteenth and nineteenth-century Brandywine Valley history.

Bancroft believed strongly in the importance of protecting parkland as part of his more broadly based community improvement efforts, specifically in conserving the beauty of the Brandywine Creek valley for public enjoyment. According to the records of the Woodlawn Trustees, Bancroft would take guests to a rock high above the east side of a bend in the Brandywine, likely Peter's Rock, where he would show them the view both upstream and down. His concern was the protection of the pastoral beauty of the river valley and its protection from the abuse of over-use. Indeed Bancroft "felt rather a special debt or obligation to the people of Wilmington and vicinity, all of whom he considered his neighbors. This feeling was partly due to his love of the Brandywine Creek Valley which had been despoiled in the Kentmere Rockford area, south of Brandywine Valley, by the Bancroft Mills" (letter from Ayers to Bancroft, 1920 (cited in NPS 2019).

View descriptions

All view photos were taken by CSU as described in section 4.5.2.

Viewpoint 1, Ramsey Farm, North: Ramsey Farm is located at 405 Ramsey Road. The view is looking southwest from the dirt road behind the farmhouse, on the top of the hill. The Granogue Estate is seen on the ridge across the Brandywine Valley to the west. This viewpoint scored 29.5 or a C. Evidence of modern development, including hoop houses/structures, cell phone towers and transmission lines, detracted from the view. The Ramsey House, although largely obscured by foliage in summer from this viewpoint, appears to need maintenance and repairs (Figure 4.5-2).

Viewpoint 2, Smith Bridge Picnic Area: Smith Bridge Picnic Area is located on the western side of Brandywine Valley along Brandywine Creek Road. The view was assessed standing on the eastern bank with a 180-degree view of the river. This view scored 34.5, a B. There were no inconsistent elements visible and the view had strong visual interest with the moving water and the forest on the opposite bank (Figure 4.5-3).

Viewpoint 3, Homestead Ruins: Homestead ruins are located east of 601 Beaver Valley Road, approximately 1,000 feet south of the property at 140 Beaver Valley Road. The inventoried view consisted of the remains of a structure, most likely used as either a home or a mill, surrounded by hilly terrain and forests. The view scored 38, a B, due to a few elements missing for a Natural/Natural Appearing landscape (Figure 4.5-4).

Viewpoint 4, Brandywine Creek Trail Bridge: This viewpoint is located along the Brandywine Creek Trail south of the parking lot on Ramsey Road, where Palmer Run crosses the old road, close to the border with Brandywine Creek State Park. The view was assessed standing south of the bridge looking north following the dirt road across the bridge. The Brandywine Creek Bridge scored 34, a B, due to multiple missing elements expected for a natural/natural appearing landscape and a limited range of colors (Figure 4.5-5).

Figure 4.5-2. Viewpoint 1: Brandywine Valley, Ramsey Farm, North.

Figure 4.5-3. Viewpoint 2: Brandywine Valley, Smith Bridge Picnic Area.

Figure 4.5-4. Viewpoint 3: Brandywine Valley, Homestead Ruins.

Figure 4.5-5. Viewpoint 4: Brandywine Valley, Brandywine Creek Trail Bridge.

New Castle Green

The New Castle Court House holds significant value for the history of the state of Delaware. New Castle was the original capitol of Delaware until the capitol was moved farther inland to Dover during the American Revolution (NPS 2019). In 1776, the Delaware Assembly met at the Court House and voted to separate Delaware from England and Pennsylvania (NPS 2019). The Court House continued to hold legislative meetings late into the 1800s and was an important part of life in New Castle. Behind the Court House, The Green was used as a community gathering area for the town. Next to the Court House stands the NPS-owned Sheriff's House, which was Delaware's first prison (NPS 2019). The Sheriff's House will serve as the park's welcome center and headquarters.

View descriptions

Viewpoint 5, New Castle Green: New Castle Green consists of a block of green space containing the historic Court House, Sheriff's House, and Arsenal. Several brick paths cross the Green. Numerous large trees line the border of the Green and some of the interior. Tree species include American elm (*Ulmus Americana*), red oak *Quercus rubra*), European beech (*Fagus sylvatica*), American holly (*Ilex opaca*) and paulownia (*Paulownia tomentosa*). The view was from near the northeastern corner of the Sheriff's House looking north across the lawn. The view earned a 34.5, a B. The view lost points for the lack of focal points and disproportionate spatial relationship between the buildings and trees (Figure 4.5-6).

Viewpoint 6, New Castle Court House: The view of the New Castle Court House is from across the street on the eastern corner, looking toward the Court House at an angle so that both the Green and the Court House are visible. The view scored 36.5, a B. The view scored very highly in all categories except visual harmony, due to the many cars and signs taking attention away from the building (Figure 4.5-7).

Old Swedes Church

Old Swedes Church, located in Wilmington, Delaware, was originally settled in 1638 by the Swedish. The area was first used as a burial area for Fort Christina and the church was built on the site years later. The church is one of the oldest active congregations in the United States (Old Swedes Historic Site 2019).

View description

Viewpoint 7, Old Swedes Church: Old Swedes Church is surrounded by a graveyard contained within a small fence surrounding the property. The Hendriksen house stands on the edge of the property and is now used as the visitor's center. The viewpoint is located on the main pathway through the graveyard, between the Hendriksen house and the Church. This view received a 33, a B, primarily due to the presence of an industrial building and other urban infrastructure that is visible beyond the fence (Figure 4.5-8).

Figure 4.5-6. Viewpoint 5: New Castle Green.

Figure 4.5-7. Viewpoint 6: New Castle Court House.

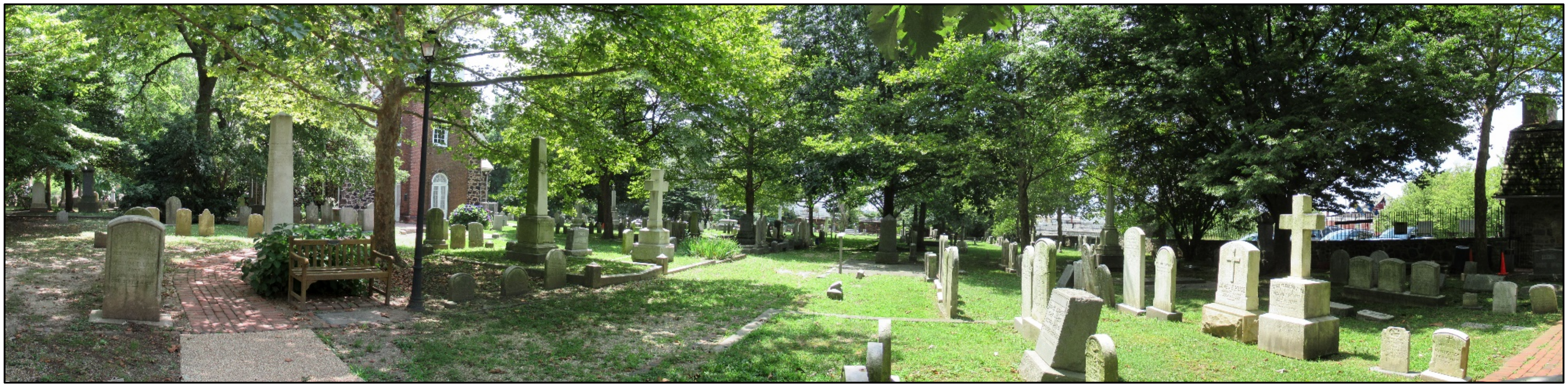


Figure 4.5-8. Viewpoint 7: Old Swedes Church.

Fort Christina

Fort Christina marks where the Swedish and Finnish immigrants on board the Kalmar Nyckel landed and established the first American Swedish colony (NPS 2017a). The monument was given to the United States by Sweden to commemorate the landing and historic settlement (NPS 2019).

View description

Viewpoint 8, Fort Christina River: The Fort Christina Monument stands at the end of a long path leading up to the river. This viewpoint is located near the monument and the Christina River. The view extends up, down, and across the river. The viewed landscape character was considered industrial because rail cars and a warehouse on the opposite side of the river made up most of the view. This view scored a 27, a C. The view felt chaotic with little organization between the river, bridge, trees, and warehouse. The visual harmony and spatial relationship categories rated low (Figure 4.5-9).

Viewpoint 9, Fort Christina Monument: The Fort Christina Monument view was taken from the same viewpoint as the Fort Christina River but facing in the opposite direction, toward the monument. Beyond the brick wall along the western edge of the property, a pharmaceutical plant is visible through the trees along with other commercial buildings. These elements detracted from the landscape integrity of the view, which scored 36.5, a B (Figure 4.5-10).

Viewpoint 10, Fort Christina Pathway: From the entrance gate, a path lined by mature sweet gum (*Liquidambar styraciflua*) trees extends to the Kalmar Nyckel monument. The Fort Christina Pathway viewpoint is located approximately 50 m down the pathway looking toward the monument. The view received a 38, a B. The canopied view is formal and structured, with a limited color palette, consisting only of the green trees and grass and the brick fence surrounding the monument area (Figure 4.5-11).

Dover Green

The Dover Green is an open park-like setting within a historic district in Dover. It is a rectangular park with a variety of large, mature trees (primarily sycamore – *Platanus*, oaks – *Quercus*, and elms – *Ulmus*) with maintained lawn surrounded by homes, community buildings such as the Old State House and Supreme Court buildings, and businesses. The Green is bisected by South State Street. During the American Revolution, the Green was a place for troop reviews, markets, and public gatherings. On the edge of the Green, the Golden Fleece Tavern was the meeting place where thirty delegates ratified the United States Constitution, making Delaware the first state in the union (NPS 2019). Today, the buildings surrounding the Green hold much of their historical character.

View description

Viewpoint 11, Dover Green: The viewpoint is on the Green near the northeast corner. The view extends across the Green to the west and south. The Dover Green sits in the middle of an urban setting, surrounded by colonial-style buildings. The Green is an open grass area with three rows of trees planted along the length of the space. The view received a 37.5, a B, due to the lack of main focal points within the view (Figure 4.5-12).

Figure 4.5-9. Viewpoint 8: Fort Christina River.

Figure 4.5-10. Viewpoint 9: Fort Christina Monument.

Figure 4.5-11. Viewpoint 10: Fort Christina Pathway.

Figure 4.5-12. Viewpoint 11: Dover Green.

Ryves Holt House

The Ryves Holt House was built in 1665 in what is now known as Lewes, Delaware. The house is believed to be one of the oldest homes in the state and was built by Dutch settlers. This area was disputed territory during the early colonial period but eventually came to be controlled by the English (NPS 2019). Ryves Holt served as the first Chief Justice of Delaware and purchased the home in 1723 (NPS 2017a).

View description

Viewpoint 12, Ryves Holt House: The Ryves Holt House is within an urban setting, surrounded by both new and historical homes. The house sits on the southeast corner of Mulberry and Second Streets. The viewpoint is located on the north side of Second Street across from the front of the house. The view received a 35.5, a B. The exterior of the home needs some maintenance and multiple signs in front of the house detracted from the view of the house (Figure 4.5-13).

John Dickinson Plantation

John Dickinson Plantation in Dover, DE, was the home of John Dickinson and his family. He was known as the "Penman of the Revolution" due to his ability to capture the thoughts of the revolution. He wrote to many audiences, including the King of England as well as to colony citizens to encourage the fight for independence (NPS 2019). He is the author of the *Articles of Confederation and Letters from a Farmer in Pennsylvania* and co-author and signatory of the U.S. Constitution (NPS 2017a). John Dickinson was also a member of the Continental Congress and a delegate to the Constitutional Convention (NPS 2017a). The John Dickinson Plantation preserves and interprets the family home of John Dickinson during the American Revolution era.

View description

Viewpoint 13, John Dickinson Plantation, South View: The viewpoint is on the southern side of the colonial revival formal garden just south of the main mansion entrance. The viewed landscape is agricultural, facing south across croplands across the flat, coastal plain, with forested areas in the distance and along the horizon. The view received a scenic quality score of 31.5, a B. The vividness of the view was lacking with few distinguishing forms, lines, and focal points, and a limited color variety (Figure 4.5-14).

Viewpoint 14, John Dickinson Plantation, Mansion: The viewpoint is on the southern side of the colonial revival formal garden just south of the main mansion entrance. The view is north across the garden and toward the front of the mansion. The scenic quality score was 39.5, an A. The high score was due to the balance, strong lines, and structure. Color vividness was moderate because the trees and shrubs covered much of the mansion (Figure 4.5-15).

Figure 4.5-13. Viewpoint 12: Ryves Holt House.

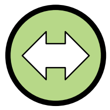
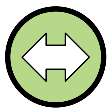
Figure 4.5-14. Viewpoint 13: John Dickinson Plantation, South View.

Figure 4.5-15. Viewpoint 14: John Dickinson Plantation, Mansion.

Condition Summary

Visual resources at FRST are in good condition (Table 4.5-4).

Table 4.5-4. Condition and trend summary for visual resources at First State National Historical Park.

Indicator	Condition Status	Rationale
Scenic Inventory Rating		Scenic quality ratings were very good and mostly consisted of B ratings, with one A, and two C ratings. For some views, information gaps reduced the confidence of the importance rating to low. Trends in the condition of viewed landscapes is unknown, although most lilkely unchanging due to relative constancy in ownership and land uses. Confidence in the assessment is high because nearly all the views considered important were inventoried and there is good representation of the landscape types present.
Overall		**Condition is good with an unchanging trend. Confidence in the assessment is high.**

4.5.5. Uncertainty and Data Gaps

The level of confidence in the assessment is high. However, the assessment team lacked information or local expertise to complete the view importance assessment. Input from park staff regarding cultural, historic, or regulatory importance of the area associated with each viewpoint and viewed landscape was not available but could easily be added to the assessment to improve accuracy and completeness.

4.5.6. Sources of Expertise

- Mark Meyer, Visual Resources Specialist, National Park Service Air Resources Division.

4.5.7. Literature Cited

Kulesza, C., Y. Le, and S. J. Hollenhorst. 2013. National Park Service visitor perceptions & values of clean air, scenic views, & dark night skies, 1988–2011. Natural Resource Report NPS/NRSS/ARD/NRR–2013/632. National Park Service, Fort Collins, Colorado.

Meyer, M., M. Peters, Ksienya Taylor, and R. Sullivan. 2018. Visual Resources Inventory Training Manual – Draft (April 2018). NPS Natural Resource Stewardship and Science and Argonne National Laboratory.

National Park Service (NPS). 2006. Management policies 2006: the guide to managing the National Park System. National Park Service, Washington, D.C.

NPS. 2017a. Draft Foundation Document, First State National Historical Park. National Park Service, New Castle, Delaware.

NPS. 2017b. Cultural Landscapes Inventory: Beaver Valley, First State National Historical Park.

NPS. 2019. First State National Historical Park website. Available at: https://www.nps.gov/frst/index.htm (accessed 15 July 2019).

National Park Service Air Resources Division (NPS ARD). 2018. Guidance for evaluating visual resources in Natural Resource Conditions Assessments (August 2018 Version). Unpublished Report. U.S. National Park Service, Air Resources Division.

Old Swedes Historic Site. 2019. Old Swedes Historic Site website. Available at: http://www.oldswedes.org/ (accessed 15 July 2019).

4.6. Air Quality

4.6.1. 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. Among the purposes of the CAA, one is "to preserve, protect, and enhance the air quality in national parks and other areas of special national or regional natural, recreational, scenic, or historic value." The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in national parks and wilderness areas (Taylor 2017).

The NPS is responsible for protecting air quality and related values and resources that may be impacted by air pollution. Three categories of air quality areas have been established through the authority of the CAA. The air quality classes allow different levels of permissible air pollution increases, with Class I areas receiving the most stringent protection. There are only 48 Class I units in the NPS, with most units falling under Class II. While FRST is designated as a Class II area, the NPS Organic Act and NPS Management policies direct that all units of the National Park System be managed to protect resources unimpaired for the benefit of current and future generations. This includes protecting air resources in all park units, Class I and Class II alike. Direction in the CAA, as well as the mandates under the NPS Organic Act and associated management policies, gives the NPS a responsibility and an opportunity to participate in the decision making processes of regulatory agencies that might affect air quality in these federally protected areas (NPS 2006).

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 the many connections between air quality, resource condition, and visitor experience, poor and/or declining air quality can impact park visitation. A synthesis of 19 visitor studies conducted by the NPS found that clean air was ranked as extremely important or very important by 97% of visitor groups (Kulesza et al. 2013).

Air quality can have a significant impact on the vegetation and ecology of an area. 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. The NPS Air Resources Division (ARD) describes ground-level ozone (along riparian corridors) and atmospheric nitrogen deposition (invasive grass response) as having the largest risk to ecosystem processes (Rao and Allen 2010, Kohut 2017).

Decreased visibility from haze does not affect the ecology of an area so much as it affects the human element through hazards to health and decreased viewing opportunities of the NPS lands, other protected lands and surrounding areas. The NPS ARD has been analyzing particulate matter levels at certain NPS units since the early 2000s (Taylor 2017).

Breathing small particles can cause human health effects including chest pain, respiratory irritation, and reduced lung function. As of 2017, part of the park is in an area designated by the Environmental

Protection Agency (EPA) as nonattainment for the 2012 $PM_{2.5}$ annual average standard (12 $\mu g/m^3$) (NPS ARD 2019a).

Monitoring in the region has found that other units in the network experience either “High” or “Very High” exposure to atmospheric nitrogen (N) enrichment and have been described as being at “High” or “Very High” risk from N enrichment (Sullivan et al. 2011a). The network also has “High” or “Very High” exposure to acidic deposition from sulfur (S) and N emissions and has been described as mostly at “Moderate” risk from acidic deposition (Sullivan et al. 2011b). Twenty-seven plant species within FRST properties have been identified as being sensitive to acidification (NPS ARD 2019b).

Ozone also poses a risk for sensitive vegetation. Ozone can enter leaves through stomata and causes chlorosis and necrosis of leaves (Figure 4.6-1), 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). Therefore, plants in wetter regions (such as the northeastern United States, where FRST is located) may be at greater risk because their uptake of ozone is less likely to be limited by dry soil conditions (Sullivan 2016). Thirty-six plant species within FRST have been identified as being sensitive to ozone (NPS ARD 2017). A risk assessment completed prior to FRST becoming an NPS unit concluded that plants in all NCBN units were at high risk for ozone damage (Kohut 2007). As of May 2019, the FRST area was listed by EPA as a nonattainment area for ozone levels (EPA 2018). EPA nonattainment listing is based on public health-based standards, and damage to vegetation can occur at much lower levels.

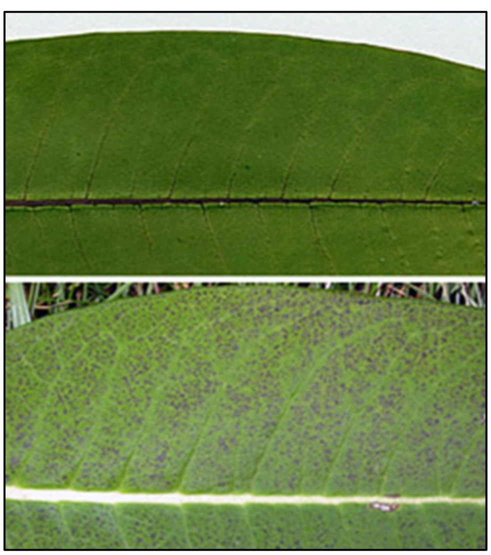


Figure 4.6-1. Example of ozone damage to plant leaf. *Asclepias syriaca* normal leaf (top) and ozone-injured leaf (bottom). Photo: NPS ARD

As measured by the Air Quality Index (AQI, created by the EPA as a measure of overall air quality to ensure national uniformity of daily air quality reports), only a few days each year fall into the moderate or unhealthy categories for sensitive human populations (DDNRECDAQ 2018).

Threats/ Stressors

FRST properties lie in an effectively continuous urban complex that stretches from the Washington, D.C. area to Boston, Massachusetts. Numerous high-density population centers occur within approximately 100 miles of Wilmington, Delaware (Philadelphia, Pennsylvania: 1,526,006; Baltimore, Maryland: 620,961, Washington, D.C.: 601,723) (U.S. Census Bureau 2010). With such a large and dense population comes numerous sources of air quality degradation, from both point sources as well as more distributed sources.

The legacy of coal-fired power plants continues to affect the region, where nitrogen and sulfur deposition rates remain high, even after decreases in recent decades (USEIA 2017, DDNRECDAQ 2018).

Additional sources of air pollution in the region include: nitrogen oxides and volatile organic compounds (both precursors to ozone) from automobiles, power plants and other combustion activities, gasoline vapors, and a variety of large and small commercial and industrial sources that use chemical solvents, paint thinners, and other chemical compounds known as area sources or distributed sources. These area sources, although individually small, can accumulate to large amounts of pollution impacting an urban region’s air quality (DDNRECDAQ 2016, 2019).

Indicators and Measures

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

4.6.2. Data and Methods

The condition of air quality within FRST was assessed using methodology developed by the NPS ARD for use in Natural Resource Condition Assessments (Taylor 2017). For condition assessments, the NPS 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. This method is used to estimate 5-year average values (2013–2017 for all measures except for nitrogen deposition, which was 2012–2016). The exception to this is $PM_{2.5}$, which uses a 3-year average (2015–2017). Data are derived from all available monitors, but data from the closest stations are more heavily weighted.

Trends are computed from data collected over a 10-year period (2008–2017, 2007–2016 for nitrogen deposition) 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. Currently, there are no representative monitoring stations for wet deposition or visibility located near FRST to assess 10-year trends, so monitoring data for wet deposition and visibility are from regional monitoring stations and interpolated values. Ozone and $PM_{2.5}$ are monitored in New Castle, Delaware, which is a representative monitoring station for FRST (AQS Monitor ID: 100031010) (NPS ARD 2019a).

Condition and trends data were retrieved from the NPS *Air Quality Conditions and Trends by Park* database (NPS ARD 2019a).

4.6.3. Reference Conditions

Reference conditions are based on regulatory standards, best available scientific knowledge, or recommendations by NPS ARD (Taylor 2017). A summary of reference conditions and a condition class rating framework for air quality indicators is shown in Table 4.6-1.

Table 4.6-1. Reference condition framework for air quality indicators (Taylor 2017).

Air Quality Indicator	Specific Measure	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Ozone	Human Health: Annual 4th-highest 8hr concentration	≤ 54 ppb	55–70 ppb	≥ 71 ppb
	Vegetation Health: 3-month maximum 12hr W126	< 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
$PM_{2.5}$	Weighted annual mean 24-hour $PM_{2.5}$ concentration	≤ 4 μg/m³	4.1–12.4 μg/m³	≥ 12.5 μg/m³
	98th percentile 24-hour $PM_{2.5}$ concentration	≤ 12 μg/m³	12.1–35.4 μg/m³	≥ 35.5 μg/m³

* ppm-hrs = parts per million-hours; dv = deciviews

<u>Ozone: Human Health Risk</u>

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 2015 ozone standard is an 8-hour average ozone concentration of 70 parts per billion (ppb). The NPS ARD benchmarks for human health risk from ozone are based on the EPA's 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 considered to "warrant significant concern," ozone concentrations from 55–70 ppb are considered to "warrant moderate concern," and ozone concentrations less than or equal to 54 ppb are considered to indicate "good condition" (Table 4.6-1) (Taylor 2017).

Ozone: Vegetation Health Risk

The W126 metric is a biologically relevant measure that focuses on plant response to ozone exposure. The equation for calculating the W126 metric preferentially weights higher ozone concentrations, which are more likely to cause plant damage. It sums all 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, W126 values greater than 13 ppm-hrs are considered to "warrant significant concern," W126 values from 7–13 ppm-hrs are considered to "warrant moderate concern," and W126 values less than 7 ppm-hrs indicate "good condition" (Table 4.6-1) (Taylor 2017).

Atmospheric Wet Deposition of Nitrogen

The NPS ARD (Taylor 2017) considers parks that receive less than 1 kg/ha/yr of nitrogen to be in "good condition." Parks receiving between 1–3 kg/ha/yr are considered to "warrant moderate concern." Parks that receive greater than 3 kg/ha/yr are considered to "warrant significant concern" (Table 4.6-1) (Taylor 2017). Nitrogen deposition data were not released for 2017, thus the park's 5-year condition and 10-year trend values end in 2016.

Atmospheric Wet Deposition of Sulfur

The NPS ARD (Taylor 2017) considers parks that receive less than 1 kg/ha/yr of sulfur to be in "good condition." Parks receiving between 1–3 kg/ha/yr are considered to "warrant moderate concern." Parks that receive greater than 3 kg/ha/yr are considered to "warrant significant concern" (Table 4.6-1) (Taylor 2017).

Visibility Haze Index

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 (7.7 dv at FRST), where the mid-range day natural visibility is the mean between the 40th and 60th percentiles (Taylor 2017). Five-year interpolated averages are used in the contiguous United States. Visibility is considered in "good condition" if visibility is less than 2 dv, "warrant moderate concern" if between 2–8 dv, and "warrant significant concern" if greater than 8 dv (Table 4.6-1) (Taylor 2017).

Particulate Matter ($PM_{2.5}$)

The particulate matter condition is based on the NAAQS for $PM_{2.5}$, which is established by the EPA to protect human health. The $PM_{2.5}$ primary NAAQS standard is 12 micrograms per cubic meter ($\mu g/m^3$) annually (using the 3-year average of weighted annual mean) and 35 $\mu g/m^3$ for 24 hours (using the 3-year average of the 98th percentile of 24-hour concentrations). EPA AQI breakpoints were used to develop benchmarks that inform the NPS ARD condition ratings. The measurement with the most conservative status category determines the overall particulate matter status (Taylor 2017).

4.6.4. Condition and Trend

Ozone: Human Health Risk

From 2013–2017, the estimated 4th highest daily maximum 8-hr ozone average concentration was 71.4 ppb (NPS ARD 2019a). For 2008–2017, the trend in ozone concentration at FRST improved (NPS ARD 2019a). Thus, the available data indicate that FRST warrants significant concern for the human health risk of ozone, with an improving trend and high confidence in the assessment due to a nearby ozone monitor (NPS ARD 2019a).

Ozone: Vegetation Health Risk

The 2013–2017 estimated W126 metric is 9.9 ppm-hrs. This value indicates moderate concern for the impact of ozone on vegetation (NPS ARD 2019a). For 2008–2017, the trend in ozone concentration at FRST remained unchanged (NPS ARD 2019a). Overall, the vegetation health risk from ground-level ozone is in moderate condition with an unchanging trend and high confidence due to an on-site ozone monitor (NPS ARD 2019a).

Visibility Haze Index

Based on the 2013–2017 estimated visibility on mid-range days of 6.9 dv above the estimated natural condition of 7.7 dv, the visibility condition warrants moderate concern with medium confidence due to the regional and modeled nature of the data. The trend is unknown because there are not enough nearby visibility monitoring data to calculate a 10-year trend (NPS ARD 2019a).

Atmospheric Wet Deposition of Nitrogen

Based on the 2012–2016 estimated wet nitrogen deposition of 5.1 kg/ha/yr, wet nitrogen deposition 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 enough on-site or nearby deposition monitoring data (NPS ARD 2019a).

Atmospheric Wet Deposition of Sulfur

Based on the 2013–2017 estimated wet sulfur deposition of 2.2 kg/ha/yr, wet sulfur deposition warrants moderate concern with medium confidence due to the regional and modeled nature of the data. The trend is unknown because there are insufficient on-site or nearby deposition monitoring data (NPS ARD 2019a).

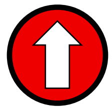
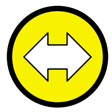
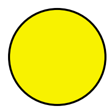
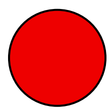
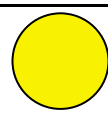
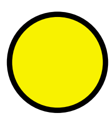
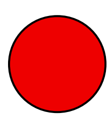
Particulate Matter ($PM_{2.5}$)

Based on the 2015–2017 weighted annual mean $PM_{2.5}$ concentration of 7.2 $\mu g/m^3$ and 98th percentile 24-hour $PM_{2.5}$ concentration of 17.3 $\mu g/m^3$, particulate matter concentrations warrant moderate concern at FRST. Particulate matter trend summaries will not be available until 2020. The degree of confidence at FRST is high because there is an in-park or nearby representative monitoring station (NPS ARD 2019a).

Condition Summary

Based on the evaluation of air quality indicators, air quality condition warrants moderate concern, with no trend determined (Table 4.6-2). Confidence in the assessment is medium. Impacts to air quality appear to be largely from off-site and distant sources that are affecting regional air quality.

Table 4.6-2. Condition and trend summary for air quality at First State 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 FRST. Condition is based on NPS Air Resources Division benchmarks and the 2013–2017 estimated ozone of 71.4 ppb. The degree of confidence at FRST is high because there is an on-site or nearby ozone monitor.
	Vegetation Health: 3-month maximum 12hr W126		Condition is based on NPS Air Resources Division benchmarks and the 2013–2017 estimated W126 metric of 9.9 parts per million-hours (ppm-hrs) and warrants moderate concern. The degree of confidence at FRST is high because there is an on-site or nearby ozone monitor.
Visibility	Haze Index		Visibility warrants moderate concern at FRST. Condition is based on NPS Air Resources Division benchmarks and the 2013–2017 estimated visibility on mid-range days of 6.9 deciviews (dv) above estimated natural conditions.
Nitrogen	Wet Deposition		Wet nitrogen deposition warrants significant concern based on NPS Air Resources Division benchmarks and the 2012–2016 estimated wet nitrogen deposition of 5.1 kg/ha/yr.
Sulfur	Wet Deposition		Wet sulfur deposition warrants moderate concern based on NPS Air Resources Division benchmarks and the 2013–2017 estimated wet sulfur deposition of 2.2 kg/ha/yr.
$PM_{2.5}$	Weighted annual mean 24-hour $PM_{2.5}$ Concentration & 98th percentile 24-hour $PM_{2.5}$ concentration		The results for both $PM_{2.5}$ metrics are combined into a single condition and trend by NPS ARD. The weighted annual mean 24-hour $PM_{2.5}$ concentration of 7.2 µg/m³ at FRST warrants moderate concern. The degree of confidence at First State NHP is high because there is an in-park or nearby representative monitor. The 98th percentile 24-hour $PM_{2.5}$ concentration of 17.3 µg/m³ at FRST warrants moderate concern. The degree of confidence at First State NHP is high because there is an in-park or nearby representative monitor.
Overall			**Overall, air quality condition warrants significant concern with no trend determined. Confidence in the assessment is medium because most estimates are based on interpolated data from more distant monitoring stations.**

4.6.5. Uncertainty and Data Gaps

Monitoring stations for wet deposition and visibility are needed at FRST to better understand these specific air quality conditions at the park. Estimated air quality values determined through interpolation are adequate but can misrepresent park conditions due to modeling errors. Monitoring all air quality parameters within FRST or nearby would eliminate uncertainty from the interpolations.

4.6.6. 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.
- Preliminary drafts of this section were reviewed by Holly Salazer, Air Resources Coordinator, NPS Region 1.

4.6.7. Literature Cited

Delaware Department of Natural Resources and Environmental Control Division of Air Quality (DDNRECDAQ). 2016. Air Quality. Available at: http://www.dnrec.delaware.gov/Air/Pages/Air-Quality.aspx (accessed 25 Apr 2019).

DDNRECDAQ. 2018. Delaware Annual Air Quality Report 2017. Doc. No. 40-04-02/18/10/04. Available at: http://www.dnrec.delaware.gov/Air/Documents/Ann%20Rpt%2017%20Final.pdf (accessed 25 Apr 2019).

DDNRECDAQ. 2019. Smaller sources of air pollution. Available at: https://dnrec.alpha.delaware.gov/air/permitting/area-sources/ (accessed 25 Apr 2019).

Environmental Protection Agency (EPA). 2018. The Green Book nonattainment areas for criteria pollutants. Available at: https://www.epa.gov/green-book (accessed 30 March 2018).

Kohut, R. J. 2007. Ozone risk assessment for Vital Signs Monitoring Networks, Appalachian National Scenic Trail, and Natchez Trace National Scenic Trail. NPS/NRPC/ARD/NRTR—2007/001. National Park Service, Fort Collins, Colorado.

Kohut, R. J. 2017. Field surveys to assess foliar ozone injury on plants in national parks and monuments on the Colorado Plateau. Ithaca, NY.

Kulesza, C., Y. Le, and S. J. Hollenhorst. 2013. National Park Service visitor perceptions & values of clean air, scenic views, & dark night skies: 1988–2011. Natural Resource Report NPS/NRSS/ARD/NRR–2013/632. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2006. Management policies 2006: the guide to managing the National Park System. National Park Service, Washington, D.C.

National Park Service, Air Resources Division (NPS ARD). 2017. Ozone sensitive species. Available at: https://irma.nps.gov/NPSpecies/Reports/Systemwide/Ozone-Sensitive%20Species%20in%20a%20Park (accessed 04 August 2017).

NPS ARD. 2019a Air quality conditions & trends by park. Available at: https://www.nature.nps.gov/air/data/products/parks/index.cfm (accessed 12 November 2019).

NPS ARD. 2019b. Acid sensitive species. Available at: https://irma.nps.gov/NPSpecies/Reports/Systemwide/Acid-sensitive%20Species%20in%20a%20Park (accessed 25 April 2019).

Panek, J. A., and S. L. Ustin. 2004. Ozone uptake in relation to water availability in ponderosa pine forests: measurements, modeling, and remote-sensing. PMIS #76735. King's Canyon and Yosemite National Parks.

Rao, L., and E. Allen. 2010. Combined effects of precipitation and nitrogen deposition on native and invasive winter annual production in California deserts. Oecologia 162:1035–1046.

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Northeast Coastal and Barrier Network (NCBN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/318. National Park Service, Denver, Colorado.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Northeast Coastal and Barrier Network (NCBN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/364. National Park Service, Denver, Colorado.

Sullivan, T. J. 2016. Air quality related values (AQRVs) for Northeast Coastal and Barrier Network (NCBN) parks: Effects from ozone; visibility reducing particles; and atmospheric deposition of acids, nutrients and toxics. Natural Resource Report NPS/NCBN/NRR—2016/1176. National Park Service, Fort Collins, Colorado.

Taylor, K. A. 2017. National Park Service air quality analysis methods: August 2017. Natural Resource Report NPS/NRSS/ARD/NRR—2017/1490. National Park Service, Fort Collins, Colorado.

U.S. Census Bureau. 2010. 2010 Census – Urban and Rural Classification. Available at: https://www2.census.gov/geo/tiger/TIGER2010/UA/2010/ (accessed 21 June 2018).

U.S. Energy Information Administration. 2017. Sulfur dioxide emissions from U.S. power plants have fallen faster than coal generation. Today in Energy. Available at: https://www.eia.gov/todayinenergy/detail.php?id=29812 (accessed 12 Nov 2019).

4.7. Water Quality

4.7.1. Background and Importance

The Brandywine Valley unit of FRST is the only unit containing surface waters within its boundary and is the focus of this section. The Brandywine Creek watershed, located in southeastern Pennsylvania and northern Delaware with an area of 324 mi^2, is home to 250,525 people and is part of the larger Christina River Basin (State of Delaware undated). Surface waters at Brandywine Valley include a variety of perennial and intermittent streams, springs, and ponds. Brandywine Creek and its major tributaries, which all flow in a generally east to west course, make up the primary perennial surface water flowing through or fully contained within the Brandywine Valley unit boundary (Figure 4.7-1). North Fork and South Fork Beaver Creek originate northeast of the park unit and combine to create Beaver Creek, which flows into Brandywine Creek just south of the Pennsylvania/Delaware border. Beaver Creek is one of only five streams in the state that has cold water fishery water temperature standards. From north to south respectively, Talley Run, Ramsey Run and Casia Run (aka Palmer Run) are fully contained within Brandywine Valley, with Ramsey Run more or less bisecting the unit. At the southern end of the unit, Hurricane Run flows into Rocky Run, which has its terminus at Brandywine Creek. The upper reaches of Rocky Run flow through a highly developed mixed-use area near shopping malls and suburban neighborhoods.

The federal Clean Water Act (as amended in 1972) requires states to adopt water quality standards to protect lakes, streams, and wetlands from pollution. The standards define how much of a pollutant can be in the water and still meet designated uses, such as drinking, fishing, and swimming. A water body is “impaired” if it fails to meet one or more water quality standards. To identify and restore impaired waters, Section 303(d) of the Clean Water Act requires states to assess all waters to determine if they meet water quality standards, list waters that do not meet standards (also known as the 303d list), and update the list every even-numbered year, and conduct total maximum daily load (TMDL) studies to establish pollutant-reduction goals needed to restore waters. Federal and state regulations and programs also require implementation of restoration measures to meet TMDLs. Delisting of impaired waters only occurs when new and reliable data indicate that the water body is no longer impaired. Currently, Brandywine Creek is considered impaired under section 303(d) for bacteria and nutrients (EPA 2006a, EPA 2006b, EPA 2006c, DDNREC 2019). TMDLs have been developed for these impairments and were last updated in 2006 (EPA 2006a, EPA 2006b, EPA 2006c). The Brandywine Creek watershed is also on the 303(d) list and has a state fish consumption advisory for PCB’s and dioxins (State of Delaware undated).

Uses listed by the State of Delaware for the section of Brandywine Creek running adjacent to FRST include public water supply source, industrial water supply, primary and secondary contact recreation, fish and aquatic life, and agricultural water supply. This section of Brandywine Creek is also listed as a “water of exceptional recreational or ecological significance” (DDNREC 2017).

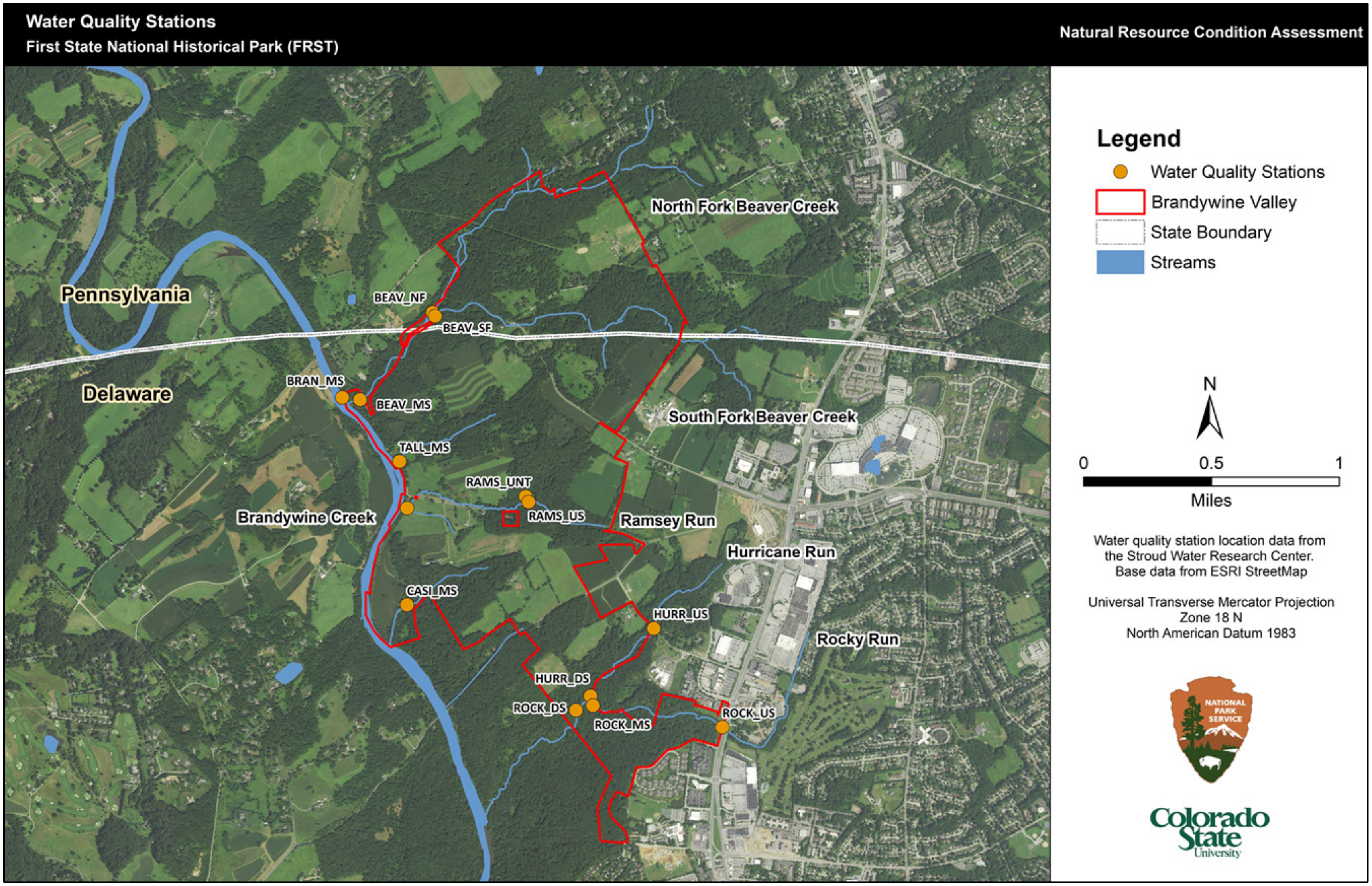


Figure 4.7-1. Streams and water quality stations at Brandywine Valley near Wilmington, Delaware. Base data from ESRI Streetmap, station locations provided by Stroud Water Research Center, Delaware.

Threats and Stressors

Water quality through FRST is mostly affected by agriculture in the upper reaches of the watershed and runoff (which can include pollutants such as volatile organic compounds (VOCs), sediment, salts, nutrients, etc.) from development near Wilmington, Delaware. These two land uses comprise 45% and 19% of the watershed's area, respectively (State of Delaware undated). Water quality, especially for the drinking water supply, is also threatened by the presence of over 500 contaminated sites in the watershed (as of 2011). These sites include but are not limited to hazardous waste generators, landfills, salvage yards, and leaking underground storage tanks (DDNREC 2011).

Indicators and Measures

The NPS measures five core parameters with every water quality sample taken: specific conductivity, flow, temperature, pH, and dissolved oxygen (NPS WRD 2006). These parameters (with the exception of flow), in addition to other field and laboratory measurements chosen depending on local water quality concerns, are compared to state water or EPA quality standards to determine whether current concentrations are within these limits and to detect changes over time that may lead to a parameter going beyond its acceptable limit (NPS WRD 2006). In addition to the core parameters, five additional measures (chloride, sulfate, *Escherichia coli*, nitrogen, and phosphorus) were added to this analysis by the CSU project team due to their usefulness in determining potentially degraded conditions with respect to drinking water supply, recreational contact, or the health of aquatic organisms as well as their length of record for the site.

Lastly, five biological indicators selected by the CSU project team were also assessed to determine the condition of aquatic macroinvertebrates at FRST. Aquatic macroinvertebrate assemblages are commonly used to assess water quality conditions that may not manifest themselves through normal water quality indicators.

Flow

Flow rate is the volume of water per unit time. Flow rates are important to aquatic and terrestrial fauna as well as to water quality (EPA 2017). Larger flow rates can ameliorate pollutants in a water body faster than smaller flow rates. Organisms are influenced by flow rates as well; some aquatic fauna require fast flowing waters while others require calm pools or springs (EPA 2017). Due to the difficulty in assessing what constitutes good or poor condition in terms of stream flow, this parameter was not included in the assessment. Flow data will be used to help determine trends for other measures and indicators, as described in *Data and Methods*.

Temperature

Water temperature has a major influence on water chemistry, biological activity, and the species of organisms that can survive in a body of water. Higher temperatures generally increase the rate of chemical reactions, which can lead to more dissolved minerals and metals. More importantly, water temperature is the primary determinant of dissolved oxygen levels in surface waters, with colder water able to hold more dissolved oxygen. Species that are adapted to higher levels of dissolved oxygen may not be able to survive in a body of water with lower levels. Changes in water temperature can be caused by runoff from impervious surfaces, seasonal changes, loss of riparian vegetation, impoundments such as dams, and climate change (USGS 2016). Large dams can change natural seasonal patterns of water temperature, leading to altered timing of biological events for aquatic organisms such as spawning, mating, migration and insect hatches (Caissie 2006).

pH

Measured on a scale of 0 (pure acid) to 14 (pure base), pH is a measure of how acidic or basic a water sample is. Aquatic life forms are adapted to the pH range found in the body of water in which they evolved. Even small to moderate changes can have large effects on fish, amphibians, and aquatic insects. Some of these effects include reduced hatching success and irritation of gills and other membranes. Like temperature, changes in pH can also alter chemical reactions that take place in a water body, making certain compounds more toxic (like ammonia), or leaching metals from surrounding bank and bed materials (like aluminum). Atmospheric deposition of acidic compounds from past and present industrial processes and point source pollution, especially from mining, can alter the pH of surface waters (Mesner and Geiger 2005).

Dissolved Oxygen

Dissolved oxygen (DO) in water bodies is critical for aquatic fauna. Oxygen enters water bodies from the atmosphere as well as via ground water discharge. The amount of DO in a water body is also related to the temperature of the water body; cold water is able to hold more oxygen than warm water. All forms of aquatic life use DO, and therefore, DO is used to measure the "health" of lakes and streams. Depletion of DO from water bodies leads to eutrophication and can have negative effects on the development of larval and juvenile fish (Rounds et al. 2013).

Specific Conductivity

Specific conductivity is a measure of a sample of water's ability to pass electrical current and is largely affected by the presence of inorganic dissolved solids. Conductance in natural bodies of water is primarily due to the geology of the surrounding area. However, certain human-induced impacts can alter conductivity such as a sewage leak (raises conductivity) or an oil spill (lowers conductivity) (EPA 2012c).

Chloride

Chloride forms inorganic salts that may be deposited into surface waters from a variety of sources such as road salting, oil and gas wells, and agricultural runoff (McDaniel 2013). High levels of chloride can be toxic to freshwater fish and macroinvertebrates. The toxicity of chloride is increased when mixed with potassium or magnesium, as it is with certain road salts. When these metals are released from chloride, dissolved oxygen levels are reduced, which causes additional stress to aquatic life (NHDES 2017). Additionally, high chloride levels can facilitate some fast-growing invasive plants, such as Eurasian water milfoil, which can out-compete native fauna (Evans and Frick 2001).

Sulfate

Sulfate is a constituent of total dissolved solids (TDS) and may form salts with sodium, potassium, calcium, magnesium, and other cations. Sulfate can occur naturally in surface waters but anthropogenic sources such as reverse osmosis reject water, waste from pyrite oxidation, and coal preparation wastewater may lead to elevated levels of sulfate. Elevated levels of sulfate may be toxic to some macroinvertebrates while fish are more tolerant of excess sulfate (IDNR 2009).

Escherichia coli

Escherichia coli (*E. coli*) bacteria are measured via a laboratory test examining the number of bacterial colonies that grow on a prepared medium. *E. coli* are coliform bacteria found in the intestinal tract of warm-blooded animals. *E. coli* can cause a variety of illnesses and have been used to establish microbial water quality criteria (USGS 2017).

Nitrogen (as Nitrate and Nitrite)

Nitrate and Nitrite as N is a measure of the inorganic forms of nitrogen. Excessive nitrogen in a water body can lead to increased plant production and toxic conditions for aquatic life and humans (EPA 2019).

Total Phosphorus

Total phosphorus is a measure of all forms of phosphorus found in a water sample. Like nitrogen, phosphorus can be found in a variety of forms. Excessive phosphorus in a water body can also lead to greatly increased plant production which can, in turn, lead to eutrophication of water bodies. Large growths of plants or algae along waterways can lead to fish illness and mortality (EPA 2019).

Aquatic Macroinvertebrates

Aquatic macroinvertebrates live in the water for all or part of their lives and are dependent on water quality. Aquatic macroinvertebrates are an essential part of the food chain in aquatic environments. They are sensitive to chemical, physical, and biological water conditions, and are a good indicator of water quality. Some aquatic macroinvertebrates, such as stonefly nymphs, are more sensitive to water quality than others. For example, stonefly nymphs cannot survive low DO levels and their absence may indicate the impaired "health" of a water body (EPA 2012a). The following aquatic macroinvertebrate metrics and indicators were assessed:

Taxa (Genus) Richness

Genus Richness is calculated as the number of invertebrate genera present in a replicate sample. Lower genus richness may indicate habitat or water quality impairment (Resh and Jackson 1993).

EPT Richness

EPT Richness is calculated as the total number of genera in the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). Lower richness may indicate stream impairment. Most taxa in these three orders are intolerant to pollution (Resh and Jackson 1993).

EPT/C Ratio

EPT/C Ratio is the ratio of Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance to Chironomidae abundance plus EPT abundance (EPT/(EPT + Chironomidae)). As discussed previously, EPT orders are generally intolerant of pollution. The Chironomidae (a family within the order Diptera, or true flies) often are more tolerant of disturbance and an increase in their density relative to EPT abundance may signal impairment (Peitz and Cribbs 2005).

Shannon Index

Shannon Index (or Shannon-Weiner Index) as a measure of taxa diversity assesses how the total number of individuals in a sample are distributed among the total species in the sample. High diversity generally implies better stream condition and normally decreases with declining water quality because of reductions in both richness and evenness (Resh and Jackson 1993). This index is calculated for the genus level.

Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (HBI) was first developed by Hilsenhoff in 1982 and subsequently modified by Hilsenhoff (1988). Each taxon is assigned a pollution tolerance value related to its assumed or known tolerance of water quality degradation. Tolerance values used in this report are adapted from Hilsenhoff (1988). HBI is an indicator of organic water pollution, such as from livestock or sewage. The HBI increases with increasing impairment.

Several commonly used water quality parameters (iron, total dissolved solids, and others) were not used due to a lack of recent data.

4.7.2. Data and Methods

Water quality data were obtained from both the National Water Quality Monitoring Council (NWQMC) Water Quality Data Portal (NWQMC 2019) and from data collected by Stroud Water Research Center in coordination with The Nature Conservancy (TNC). The data from Stroud Water Research Center and TNC were collected on four dates (April 28, 2016; February 11 and May 4, 2017; and June 7, 2018; except where noted) from various locations in the watershed (Table 4.7-1, Figure 4.7-1). These data are not used to assess condition or trend but are included for informational purposes and to help establish a baseline for future analyses of these stations.

Data from the Brandywine Creek Mainstem at Smith Bridge monitoring station (Station ID: 21DELAWQ_WQX-104051; hereafter designated as BRAN_MS) obtained from NWQMC will be used to determine condition and trend as it is the only station with an adequate sampling frequency and history (in operation since 1974). The water quality data stored in and retrieved from the NWQMC database were collected by the Delaware Department of Natural Resources and Environmental Control and the USGS Maryland Water Science Center. The overall period of record was October 1974 to July 2019 with no samples recorded from 1981 to 1998.

For *E. coli*, data were collected in July and August 2017, and August and September 2018 during low-flow conditions by Stroud Water Research Center and TNC. All stations listed in Table 4.7-1 were sampled except for BRAN_MS, with between five and seven total samples taken per site.

For aquatic macroinvertebrates, data were collected by Stroud Water Research Center and TNC in April 2016 and April 2017. Samples were collected on plates and taxa quantities were normalized to density per square meter. Four replicate samples were taken on the same date at each of five locations (BEAV_MS, CASI_MS, RAMS_MS, ROCK_MS and TALL_MS).

Table 4.7-1. Water quality stations at Brandywine Valley. Adapted from Stroud Water Research Center (2017).

Site Code	Stream	Lat.	Long.	Site Description
BRAN_MS *	Brandywine Creek	39.834962	−75.577494	Mainstem of Brandywine Creek at Smith Bridge upstream of Beaver Rn
BEAV_MS	Beaver Creek	39.83485	−75.57619	Creek Rd & Beaver Dam Rd
BEAV_NF	Beaver Creek North Fork	39.839828	−75.570895	North fork above confluence w/ Beaver Creek, Beaver Dam Rd near Creek Rd
BEAV_SF	Beaver Creek South Fork	39.839623	−75.570702	South fork above confluence, Beaver Dam Rd near Creek Rd
CASI_MS	Casia Run (aka Palmer Run)	39.82319	−75.57264	North of Thompson Bridge Rd on Fire Trail
HURR_DS	Hurricane Run	39.818074	−75.55909	Upstream of confluence with Rocky, Rocky Run Trail in park
HURR_US	Hurricane Run	39.821942	−75.554462	Upstream of confluence with Rocky at Woodlawn Rd near Ramsey Rd
RAMS_MS	Ramsey Run	39.828697	−75.57267	Creek Rd & Ramsey Rd
RAMS_UNT	Ramsey Unnamed Trib.	39.829407	−75.563954	Unnamed tributary on Ramsey
RAMS_US	Ramsey Run	39.829094	−75.563739	Upstream of unnamed tributary
ROCK_DS	Rocky Run	39.817539	−75.558907	Upstream of confluence with Hurricane, Rocky Run Trail in park
ROCK_MS	Rocky Run	39.817271	−75.560155	South of Thompson Bridge Rd on Rocky Run Trail in Park
ROCK_US	Rocky Run	39.816355	−75.549369	Upstream of confluence with Hurricane at Rt 202 near Rocky Run Parkway
TALL_MS	Talley Run	39.831342	−75.573249	Creek Rd between Beaver Dam Rd & Ramsey Rd

* BRAN_MS will be used to determine condition and trend for water quality at First State National Historical Park due to its sampling frequency and history. Data from all other stations will be included for informational purposes but will not be used to determine condition and trend.

4.7.3. Reference Conditions

The reference conditions for FRST water quality (with the exception of aquatic macroinvertebrates, explained below) are the State of Delaware (from the Delaware Department of Natural Resources and Environmental Control, DDNREC) water quality standards for surface waters, which provide limits for each parameter depending on the designated use (Table 4.7-2). EPA standards are also listed for reference purposes and are used when state standards for the parameter do not exist.

All stream reaches sampled by Stroud Water Research Center and The Nature Conservancy, as described in the Data and Methods section, occur within the Brandywine Creek Basin as delineated by the DDNREC. The designated uses for this basin include public water supply source (freshwater segments only); industrial water supply; primary and secondary contact recreation; fish, aquatic life and wildlife; cold water fish (from March 15 to June 30); agricultural water supply (for freshwater segments only); and Exceptional Recreational or Ecological Significance (ERES) water (DDNREC 2017). ERES waters are recognized by the State of Delaware as "special natural assets of the State, and must be protected and enhanced for the benefit of present and future generations of Delawareans" (DDNREC 2017).

Table 4.7-2. Delaware and EPA standards for surface-water quality (DDNREC 2017, EPA 2018a, EPA 2018b). Standards are for warmwater aquatic life criteria for rivers and streams unless otherwise noted.

Parameter	Delaware Standard	EPA Standard
Temperature, water	15Mar–30Jun: ≤ 23.9 °C [1] 01Jul–14Mar: ≤ 27.8 °C [1]	Location and species dependent
pH	6.5–8.5	6.5–9.0
Dissolved oxygen	15Mar–30Jun: ≥ 6.5 mg/L [1] 01Jul–14Mar: ≥ 5.5 mg/L [1]	≥ 5.0 mg/L
Specific Conductivity	none	≤ 500 mS/cm[2]
Chloride	none	≤ 860 mg/L[3]
Sulfate	none	≤ 250 mg/L[3]
Coliform bacteria	≤ 100 CFU/100mL [4]	≤ 126 CFU/100mL [4]
Nitrogen	none	≤ 0.71 mg/L [5]
Phosphorous	none	≤ 31.25 µg/L [5]

[1] Cold water fishery standards apply on Beaver Creek (listed as Beaver Run in Delaware water quality standards document (DDNREC 2017)) from March 15 to June 30 due to trout stocking. For all other stream reaches, the July 1 to March 14 standard applies year-round.

[2] Although a numerical standard does not exist, studies have shown that conductivity levels in excess of 500 mS/cm2 are not suitable for numerous freshwater species (EPA 2012c).

[3] Standard for drinking water.

[4] Primary contact recreation standard; CFU = colony-forming units.

[5] Based on aggregate eco-region XIV (eastern coastal plain) nutrient criteria for rivers and streams (EPA 2000).

The standards for aquatic macroinvertebrate metrics follow suggested cutoffs from several entities and studies (Table 4.7-3). Where available, these cutoffs are based on studies conducted in the northeastern United States.

Table 4.7-3. Resource condition indicator rating framework for aquatic macroinvertebrate communities at First State National Historical Park.

Indicator	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Taxa (Genus) Richness [1]	> 43	30–43	< 30
EPT Richness [2]	> 14	8–14	< 8
EPT/C Ratio [3]	> 0.75	0.25–0.75	< 0.25
Shannon Index [4]	>2.5	1–2.5	<1
Hilsenhoff Biotic Index [5]	0.00–4.25	4.26–6.50	6.51–10.00

[1] Based on the descriptions of a medium-size high gradient stream from VDEC (2004)

[2] Bukantis (1998)

[3] VDEC (2008)

[4] Wilhm (1970)

[5] Hilsenhoff (1988)

Condition Rating Methodology

Descriptive statistics for all sites and graphs of each value over time for BRAN-MS were created for each water quality indicator. The condition of each indicator was assessed using the approach described in USGS (2018). This summary used a three-tiered concern level system similar to the NRCA condition rating system described in Chapter 3 of this document. For most water quality parameters, the 85th percentile of the data for the BRAN_MS station was used to determine the concern level. If the 85th percentile was higher than the state or federal standard (whichever is more stringent), the parameter was placed in the "warrants significant concern" or poor condition category for this analysis. Studies suggest that if the 85th percentile of an assessed value exceeds the standard, then there is a high degree of confidence (95%) that the actual concentration is significantly higher than the standard (Appendix B of CDPHE 2017). If the 85th percentile was between 50% and 100% of the more stringent standard, the parameter was placed in the "warrants moderate concern", category. Indicators with an 85th percentile of less than one-half of the state standard were considered in good condition. Data from BRAN_MS that align in time with the earliest sampling by Stroud Water Research Center/TNC (April 2016) and later were used as "current data" and their 85th percentile calculated to determine the condition rating for that parameter and river segment. All parameters apply the above condition rating system except as follows:

Dissolved Oxygen –The 15th percentile for DO are used to determine the condition rating. If the 15th percentile for current data is above the standard, the river segment is considered in good condition. If the 15th percentile for current data are below the standard, the river segment is considered in poor condition or "warrants significant concern."

E. coli – The geometric mean for *E. coli* i used to determine the condition rating. The geometric mean is used in place of an arithmetic mean due to its ability to dampen the effects of very high or low values, which can be helpful given that bacteria concentrations often vary by several degrees of magnitude over a specified sampling period (EPA 2012b). If the geometric mean for current data is below the standard, the river segment is considered in good condition. If the geometric mean for current data is above the standard, the river segment is considered in poor condition or "warrants significant concern." *E. coli* data were collected on six sampling dates from July 2017 to September 2018 by Stroud Water Research Center and TNC at several sites in Brandywine Valley. There are no *E. coli* data available for the area from the NWQMC. To obtain enough samples to adequately assess the condition for this indicator, data for all sites were combined.

pH –The 15^{th} and 85^{th} percentiles for current data are used to determine the condition rating. If either percentile is outside of the pH range of 6.5–8.5, the river segment is considered in poor condition or "warrants significant concern".

Water Temperature –State water temperature standards are based on either the maximum weekly average temperature (MWAT) or the daily mean (DM) standard. Neither of these is calculable from periodic water samples; therefore, the 85^{th} percentile is used in this analysis as a comparison to the DM temperature standard for each river segment (USGS 2018). The 85^{th} percentile for water temperature is used to determine the condition rating. If the 85th percentile for current data is below the standard, the river segment is considered in good condition. If the 85th percentile for current data is above the standard, the river segment is considered in poor condition or "warrants significant concern."

Aquatic Macroinvertebrates – Data from the five locations sampled for macroinvertebrates are combined into a global mean for each metric for the entire study area and compared to the metric cutoffs shown in Table 4.7-3.

Trend and Level of Confidence

Data for March 2016 and earlier were used as historical data to determine trends in the condition of each water quality parameter. Trends were determined using a Seasonal Mann-Kendall non-parametric trend test (with Locally Weighted Scatterplot Smoothing [LOWESS]) run in a DOS-based program developed by the USGS for Mann-Kendall trend tests (Helsel et al. 2006). A nonparametric test was chosen for its higher statistical power in cases of nonnormality, large data gaps, and robustness against outliers. This statistical test accounts for seasonal patterns in data that may lead to inaccurate trend determinations. The Seasonal Mann-Kendall test performs a Mann-Kendall calculation for each season, then combines the results for each season into a single statistic (τ). This trend test is robust and powerful, making it an often-used method for water quality trend determinations (Meals et al. 2011). In addition, differences in parameter concentrations due to the variance in streamflow throughout the year were accounted for by using streamflow as a covariate via a LOWESS algorithm. LOWESS is analogous to regression without requiring a straight line as the output. For more information on seasonality, covariance and LOWESS, see Meals et al. (2011). Parameter samples that did not have a corresponding streamflow measurement on the same day were not used in the trend analysis (the number of samples used is noted in each trend test summary in the following parameter sections; this number will be lower than the sample size stated for the entire period of record due to removing samples that did not have corresponding flow data). A significance level of $\alpha = 0.05$ was used for all tests.

For parameters with at least 25 observations since March 2016, the rating was assigned high confidence in the assessment. For parameters with at least 10 but fewer than 25 observations since March 2016, the rating was assigned medium confidence in the assessment. For parameters with fewer than 10 observations in this time period, low confidence was assigned. One exception to this was the confidence for *E. coli*, which is discussed in that section.

A trend was not determined for aquatic macroinvertebrates due to lack of sampling history. Confidence in the assessment for aquatic macroinvertebrates is medium due to relatively small sample sizes and high variability among samples.

4.7.4. Condition and Trend

Temperature

The DDNREC standard for water temperature in streams is less than or equal to 27.8°C. All stations are substantially below the standard, and there have been no exceedances in any measurement since sampling began in 1974 (Table 4.7-4, Figure 4.7-2). All measurements for Beaver Creek are below the cold-water fishery standard described in Table 4.7-2. The condition of water temperature for Brandywine Valley streams is good with an unchanging trend ($n = 159$, $\tau = -0.25$, $p = 0.23$). Confidence in the assessment is medium.

Table 4.7-4. Water temperature measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
BRAN_MS	10/74–06/19	187	0	<0.1	25.9	13.8(7.7)	23.2
BEAV_MS	04/16–06/18	5	0	11.0	15.4	12.5(2.5)	–
BEAV_NF	04/16–06/18	3	0	11.0	15.2	12.5(2.3)	–
BEAV_SF	04/16–06/18	3	0	11.1	15.3	12.7(2.3)	–
CASI_MS	04/16–06/18	4	0	10.9	13.7	11.9(1.5)	–
HURR_DS	04/16–06/18	4	0	11.6	15.4	13.1(2.0)	–
HURR_US	04/16–06/18	3	0	11.0	16	13.1(2.6)	–
RAMS_MS	04/16–06/18	3	0	11.1	15.1	12.8(2.1)	–
RAMS_UNT	04/16–06/18	3	0	11.2	14.8	12.5(2.0)	–
RAMS_US	04/16–06/18	3	0	11.6	14.9	12.9(1.8)	–
ROCK_DS	04/16–06/18	3	0	12.8	16.6	14.4(2.0)	–
ROCK_MS	04/16–06/18	3	0	12.2	15.9	13.6(2.0)	–
ROCK_US	04/16–06/18	3	0	13.2	18.8	15.4(3.0)	–
TALL_MS	04/16–06/18	3	0	10.5	14.3	11.9(2.1)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

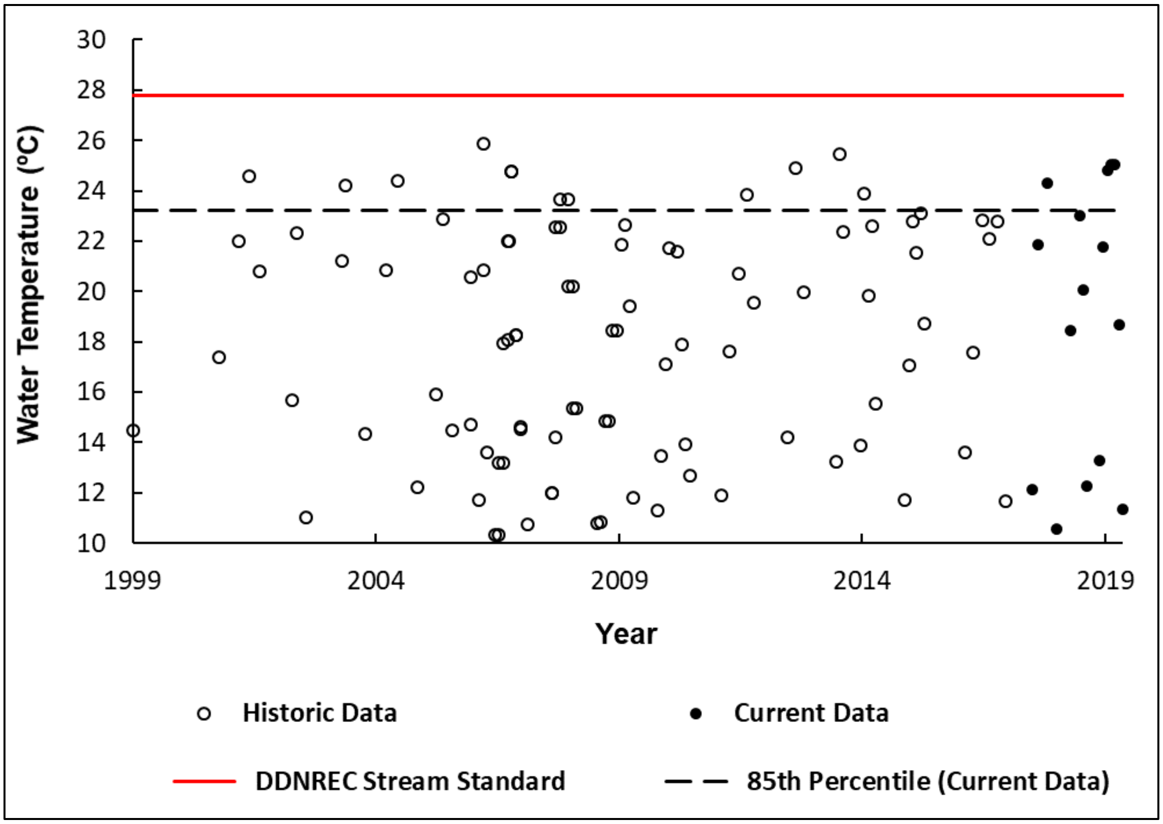


Figure 4.7-2. Water temperature measurements for BRAN_MS from 1999 to 2019. Six samples from 1974 to 1980 were omitted to improve graph scale. All of the six omitted were below the DDNREC standard of 27.8°C (Stroud Water Research Center 2017). DDNREC stream standard threshold is shown as a red line.

pH

The DDNREC standard for pH is from 6.5 to 8.5, slightly more stringent than the EPA standard of 6.5 to 9.0. Brandywine Creek has had six exceedances for pH since 1974, with two samples below 6.5 and four samples above 8.5 (Table 4.7-5, Figure 4.7-3). All other stations are within standards. Both the 15th and 85th percentiles fall within the upper and lower pH standard, indicating that pH is in good condition. The trend for pH in Brandywine Creek is rising (i.e., becoming more basic) ($n = 161$, $\tau = 0.29$, $p<0.01$). Since the trend both starts and ends within the upper and lower standard, it is difficult to assess whether this trend is “improving” or “deteriorating,” therefore no official trend will be given for pH. However, it does seem that the trend suggests deterioration due to a recent increase in pH values toward the upper limit. This information should serve as a notice to begin monitoring pH more closely in Brandywine Creek to ensure it does not exceed the upper standard of 8.5. Confidence in the assessment is medium.

Table 4.7-5. pH measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 15th/85th Percentile
BRAN_MS	10/74–06/19	188	6	6.2	8.8	7.9(0.3)	7.6/8.2
BEAV_MS	04/16–06/18	5	0	7.5	7.7	7.7(0.1)	–
BEAV_NF	04/16–06/18	3	0	7.5	7.7	7.6(0.1)	–
BEAV_SF	04/16–06/18	3	0	7.3	7.7	7.6(0.2)	–
CASI_MS	04/16–06/18	4	0	5.9	8.2	7.0(1.0)	–
HURR_DS	04/16–06/18	4	0	7.1	7.7	7.4(0.3)	–
HURR_US	04/16–06/18	3	0	7.1	7.2	7.2(0.0)	–
RAMS_MS	04/16–06/18	3	0	7.1	7.4	7.3(0.2)	–
RAMS_UNT	04/16–06/18	3	0	6.7	7.1	6.8(0.2)	–
RAMS_US	04/16–06/18	3	0	6.8	7.2	7.0(0.2)	–
ROCK_DS	04/16–06/18	3	0	7.3	7.6	7.4(0.2)	–
ROCK_MS	04/16–06/18	3	0	7.5	7.8	7.6(0.2)	–
ROCK_US	04/16–06/18	3	0	7.0	7.3	7.1(0.2)	–
TALL_MS	04/16–06/18	3	0	6.9	7.0	7.0(0.1)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

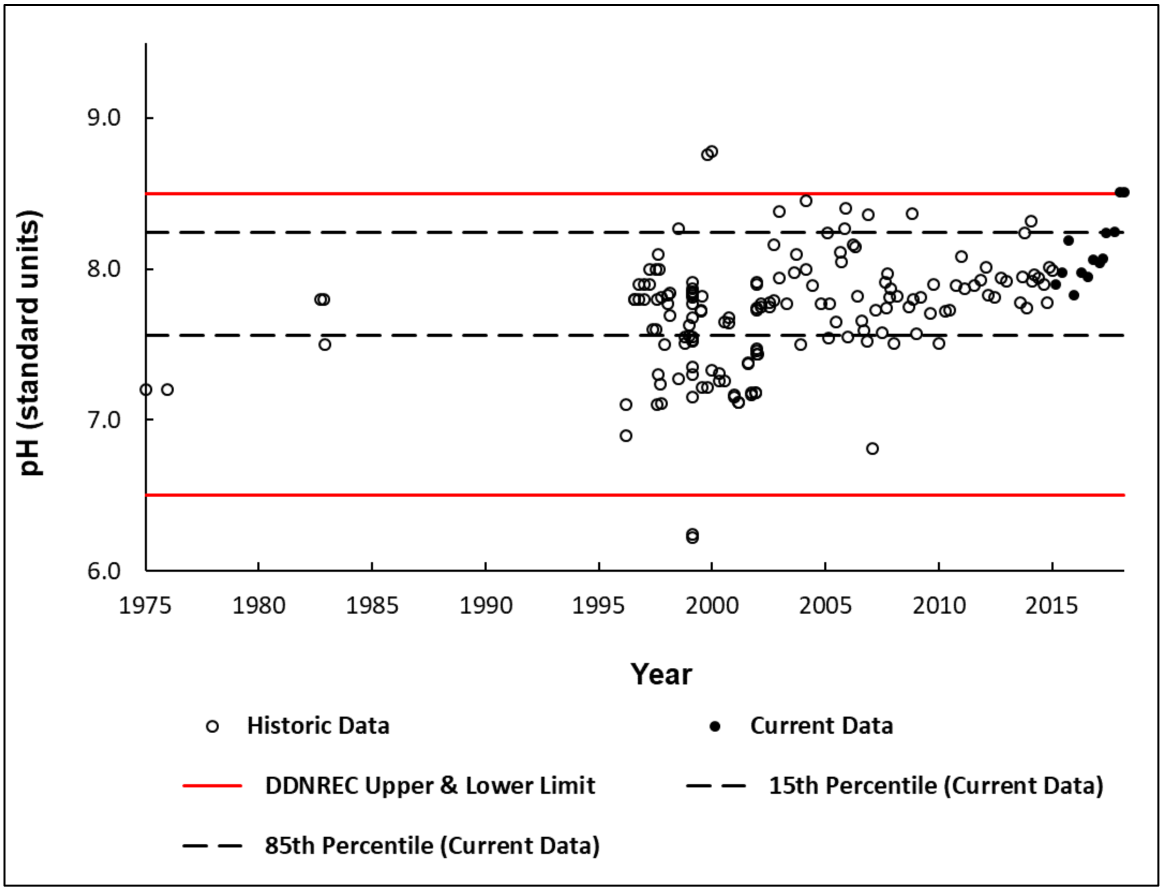


Figure 4.7-3. pH measurements for BRAN_MS from 1974 to 2019 (Stroud Water Research Center 2017). DDNREC upper and lower limits are shown as red lines.

Dissolved Oxygen

The EPA standard for DO is greater than or equal to 5 mg/L while the DDNREC standard for Brandywine Creek is stricter at greater than or equal to 5.5 mg/L. The mean DO concentration for each station over the period of record is greater than the DDNREC standard (Table 4.7-6, Figure 4.7-4). Except for a single reading (5.4 mg/L in June 2006), DO has been consistently above the EPA and DDNREC standards. DO measurements for all tributaries were also well above both standards, with a minimum value of 7.5 mg/L. The trend of DO in Brandywine Creek is unchanging ($n = 154$, $\tau < -0.04$, $p = 0.68$). DO is in good condition with an unchanging trend and high confidence in the assessment.

Table 4.7-6. Dissolved oxygen measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 15th Percentile
BRAN_MS	01/99–06/19	238	1	5.4	16.9	10.5(2.1)	8.2
BEAV_MS	04/16–06/18	5	0	9.3	11.2	10.3(1.0)	–
BEAV_NF	04/16–06/18	3	0	9.1	11.0	10.1(1.0)	–
BEAV_SF	04/16–06/18	3	0	9.2	11.1	10.3(1.0)	–
CASI_MS	04/16–06/18	4	0	9.1	11.1	10.1(1.0)	–
HURR_DS	04/16–06/18	4	0	9.0	10.7	9.9(0.9)	–
HURR_US	04/16–06/18	3	0	8.8	10.7	10.0(1.0)	–
RAMS_MS	04/16–06/18	3	0	9.2	11.1	10.3(1.0)	–
RAMS_UNT	04/16–06/18	3	0	9.1	10.7	9.8(0.8)	–
RAMS_US	04/16–06/18	3	0	9.1	10.6	9.8(0.7)	–
ROCK_DS	04/16–06/18	3	0	8.3	10.3	9.2(1.0)	–
ROCK_MS	04/16–06/18	3	0	8.8	10.8	9.9(1.0)	–
ROCK_US	04/16–06/18	3	0	7.5	9.6	8.3(1.1)	–
TALL_MS	04/16–06/18	3	0	9.3	10.8	10.1(0.8)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

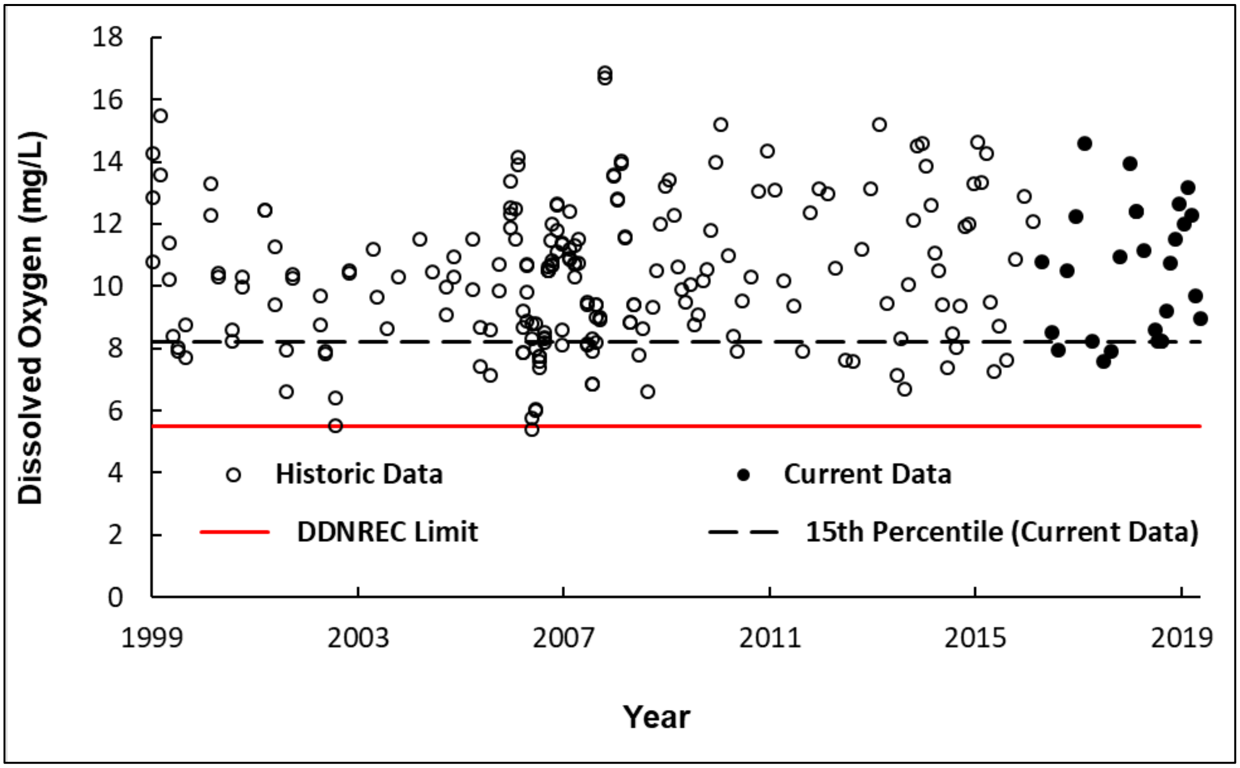


Figure 4.7-4. Dissolved oxygen measurements for BRAN_MS from 1999 to 2019 (Stroud Water Research Center 2017). The DDNREC limit is shown by a red line.

Specific Conductivity

The EPA guideline for specific conductivity for health of freshwater species is less than or equal to 500 mS/cm. Most measurements at Brandywine Valley are lower than this threshold. However, there are several exceedances and the 85th percentile is more than half of the guideline (Table 4.7-7, Figure 4.7-5). Specific conductivity is in moderate condition with a deteriorating trend ($n = 159$, $\tau = 0.58$, $p<0.01$). Confidence in the assessment is medium.

Table 4.7-7. Specific conductivity measurements from 14 monitoring stations including minimum, maximum, and mean values (mS/cm) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
BRAN_MS	01/99–06/19	186	12	143	1,072	365(107)	397
BEAV_MS	04/16–06/18	5	1	375	1,025	579(300)	–
BEAV_NF	04/16–06/18	3	2	288	356	322(34)	–
BEAV_SF	04/16–06/18	3	0	474	605	546(66)	–
CASI_MS	04/16–06/18	4	0	109	143	125(14)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

Table 4.7-7 (continued). Specific conductivity measurements from 14 monitoring stations including minimum, maximum, and mean values (mS/cm) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
HURR_DS	04/16–06/18	4	1	351	938	528(275)	–
HURR_US	04/16–06/18	3	2	426	533	487(55)	–
RAMS_MS	04/16–06/18	3	0	264	285	276(11)	–
RAMS_UNT	04/16–06/18	3	0	151	168	158(9)	–
RAMS_US	04/16–06/18	3	0	297	328	317(17)	–
ROCK_DS	04/16–06/18	3	3	533	682	602(75)	–
ROCK_MS	04/16–06/18	3	1	448	550	492(52)	–
ROCK_US	04/16–06/18	3	3	666	823	751(79)	–
TALL_MS	04/16–06/18	3	0	136	138	137(1)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

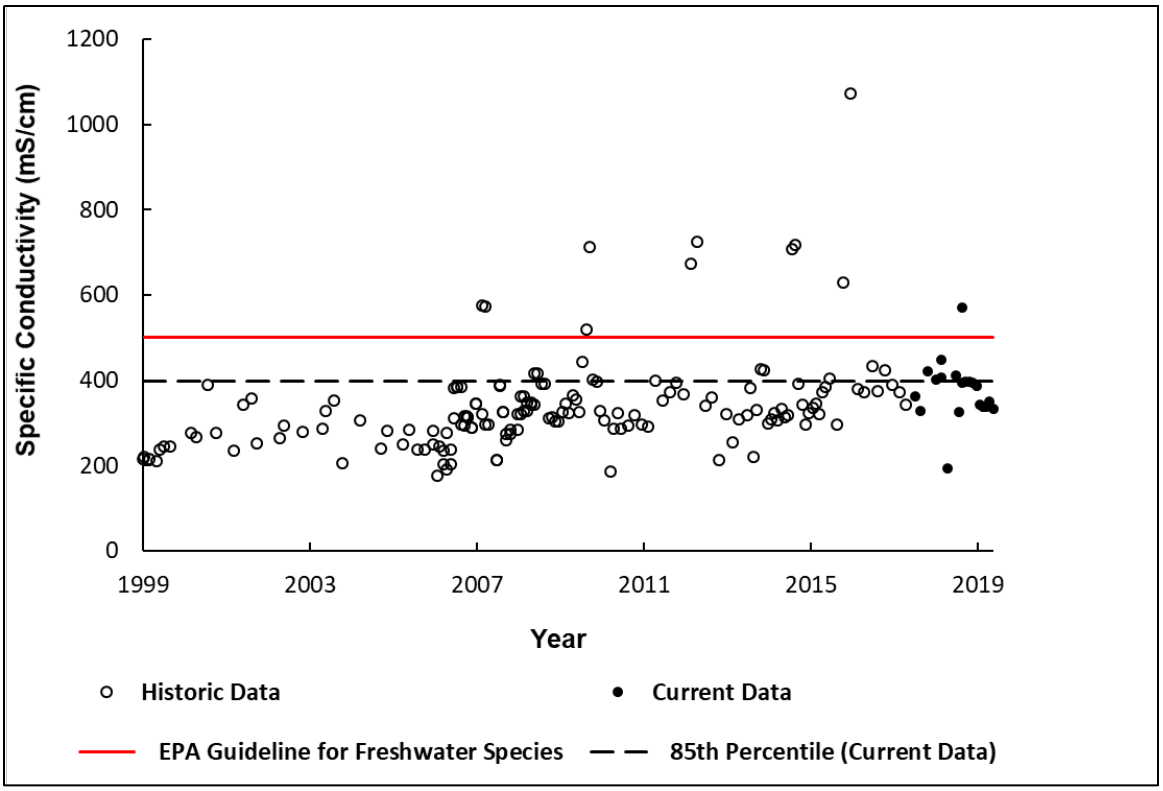


Figure 4.7-5. Specific conductivity measurements for BRAN_MS from 1999 to 2019. Several samples from 1974 to 1980 were omitted to improve graph scale. None of the omitted values were above the EPA guideline of 500 mS/cm (Stroud Water Research Center 2017, NWQMC 2019). The EPA threshold is shown by a red line.

Chloride

The EPA standard for chloride in surface waters is less than or equal to 860 mg/L. Concentrations of chloride at all stations are substantially below the federal standard, indicating good condition (Table 4.7-8, Figure 4.7-6). The trend of chloride in Brandywine Creek is unchanging ($n = 151$, $\tau = 0.21$, $p>0.05$). Confidence in the assessment is high.

Table 4.7-8. Chloride measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n[1]	# exc[2]	Min	Max	Current Mean (St. Dev.)	Current 85th Percentile
BRAN_MS	01/99–06/19	177	0	10.0	257.0	59.3(30.1)	71.2
BEAV_MS	04/16–06/18	5	0	63.1	249.5	113.7(76.5)	–
BEAV_NF	04/16–06/18	3	0	43.4	55.1	48.6(6.0)	–
BEAV_SF	04/16–06/18	3	0	88.7	124.0	109.6(18.5)	–
CASI_MS	04/16–06/18	4	0	5.3	8.8	6.4(1.6)	–
HURR_DS	04/16–06/18	4	0	65.3	244.6	120.8(83.2)	–
HURR_US	04/16–06/18	3	0	81.4	111.9	101.0(17.1)	–
RAMS_MS	04/16–06/18	3	0	41.0	50.0	46.9(5.1)	–
RAMS_UNT	04/16–06/18	3	0	15.0	20.2	17.7(2.6)	–
RAMS_US	04/16–06/18	3	0	46.5	61.6	55.8(8.2)	–
ROCK_DS	04/16–06/18	3	0	110.9	160.5	128.0(28.2)	–
ROCK_MS	04/16–06/18	3	0	88.5	120.6	102.8(16.3)	–
ROCK_US	04/16–06/18	3	0	139.2	190.4	156.7(29.2)	–
TALL_MS	04/16–06/18	3	0	9.4	9.8	9.5(0.2)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

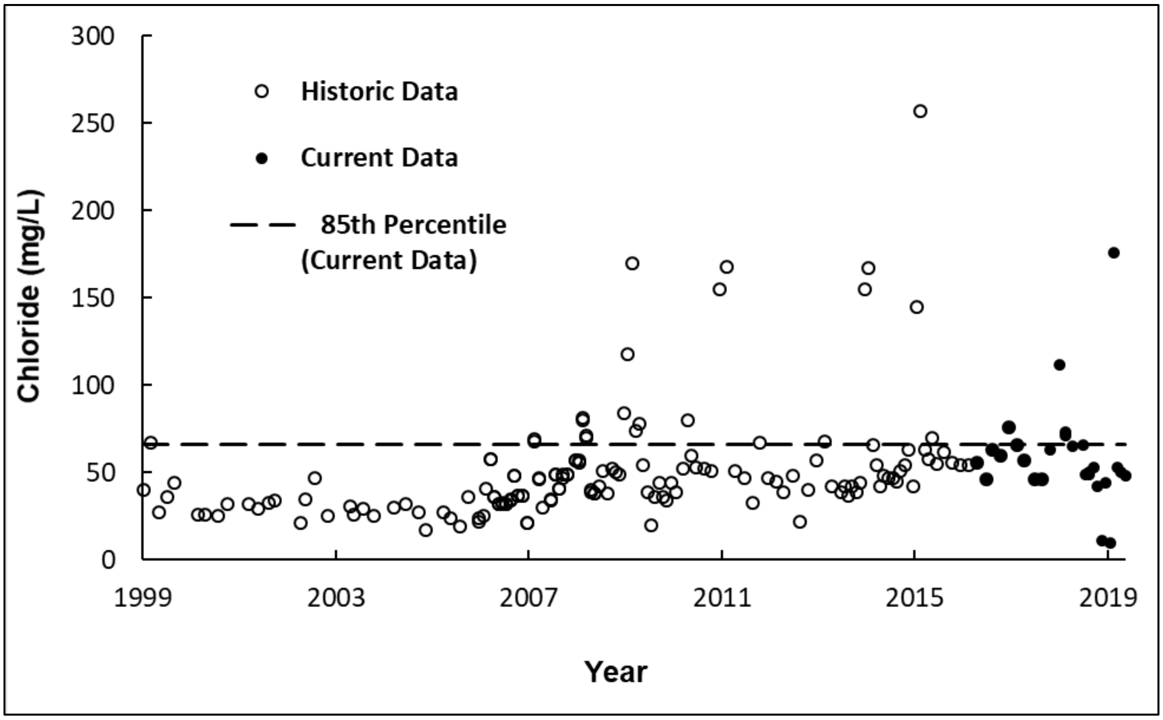


Figure 4.7-6. Chloride measurements for BRAN_MS from 1999 to 2019. To improve scale, the EPA standard of 860 mg/L is not shown (Stroud Water Research Center 2017, NWQMC 2019).

Sulfate

The EPA standard for sulfate is less than or equal to 250 mg/L, while DDNREC does not have a published standard. Measurements of sulfate concentration at all stations are substantially lower than the federal standard (Table 4.7-9, Figure 4.7-7). The trend of sulfate in Brandywine Creek is unchanging ($n = 45$, $\tau < -0.31$, $p > 0.09$). Sulfate is in good condition with an unchanging trend and medium confidence in the assessment.

Table 4.7-9. Sulfate measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n[1]	# exc[2]	Min	Max	Current Mean (St. Dev.)	Current 85th Percentile
BRAN_MS	01/99–06/19	45	0	14.0	26.3	17.7(2.2)	19.7
BEAV_MS	04/16–06/18	5	0	11.6	18.4	13.9(2.6)	–
BEAV_NF	04/16–06/18	3	0	12.4	13.5	12.9(0.6)	–
BEAV_SF	04/16–06/18	3	0	12.1	13.2	12.7(0.6)	–
CASI_MS	04/16–06/18	4	0	10.8	15.7	12.6(2.2)	–
HURR_DS	04/16–06/18	4	0	10.6	13.7	11.5(1.5)	–
HURR_US	04/16–06/18	3	0	11.4	12.1	11.6(0.4)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

Table 4.7-9 (continued). Sulfate measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n[1]	# exc[2]	Min	Max	Current Mean (St. Dev.)	Current 85th Percentile
RAMS_MS	04/16–06/18	3	0	10.9	12.0	11.7(0.4)	–
RAMS_UNT	04/16–06/18	3	0	6.2	7.6	7.0(0.7)	–
RAMS_US	04/16–06/18	3	0	10.3	11.6	10.9(0.7)	–
ROCK_DS	04/16–06/18	3	0	6.7	8.6	7.8(1.0)	–
ROCK_MS	04/16–06/18	3	0	8.7	9.6	9.3(0.5)	–
ROCK_US	04/16–06/18	3	0	9.1	13.2	11.5(2.2)	–
TALL_MS	04/16–06/18	3	0	13.2	16.0	11.6(2.5)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

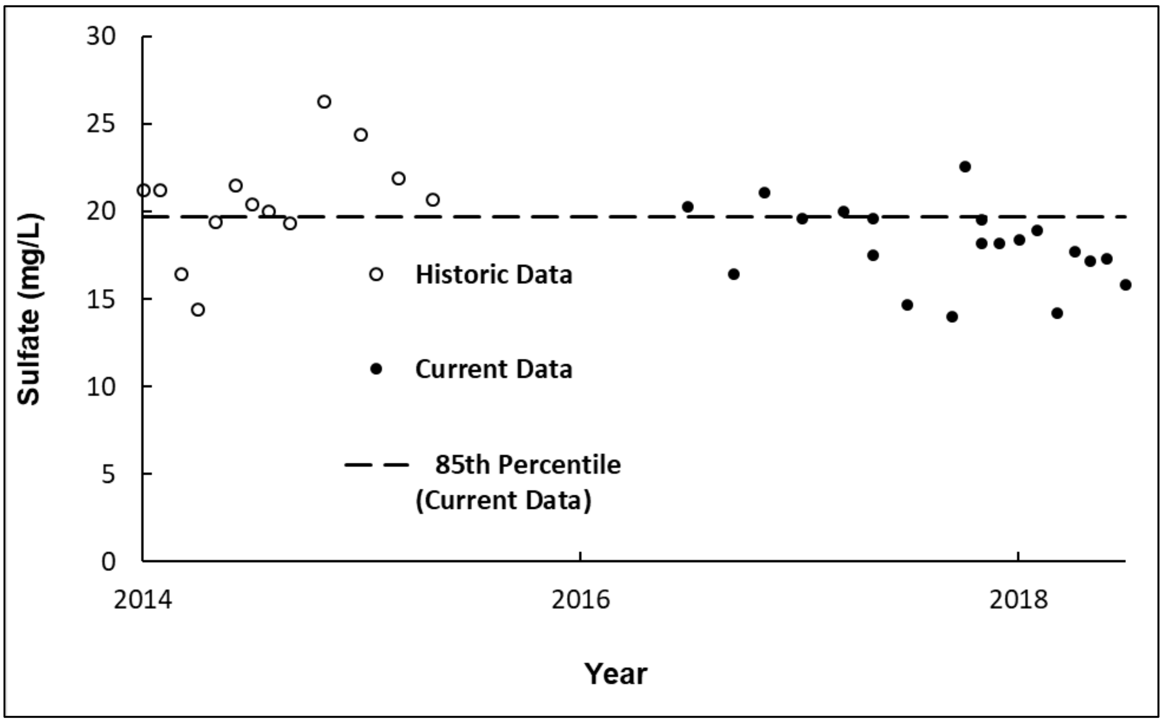


Figure 4.7-7. Sulfate measurements for BRAN_MS from 2014 to 2019. Six samples from 1974 to 1980 have been omitted to improve graph scale. The EPA standard of 250 mg/L has also been removed to improve scale (Stroud Water Research Center 2017, NWQMC 2019).

Escherichia coli

The EPA standard for *E. coli* bacteria in surface waters is less than or equal to 126 CFU/100ml for primary contact recreation, while Delaware's standard is 100 CFU/100ml. Most stations and all stations combined had geometric means well over 100 CFU/100ml (Table 4.7-10, Figure 4.7-8). The only waterbodies with geometric means that did not exceed the state standard were Brandywine Creek, the upstream portion of Ramsey Run, and downstream and midstream Rocky Run. *E. coli* is in poor condition with no trend determined. Confidence in the *E. coli* assessment is considered low due to the timing of the data collected. More than 50 data points were collected; however, they span only seven dates over a time period of less than 14 months.

Table 4.7-10. *E. coli* measurements from 14 monitoring stations including minimum, maximum, and mean values (CFU/100ml). Period of record for all stations is July 2017 to September 2018 (Stroud Water Research Center 2017, NWQMC 2019).

Station	n [1]	# exc [2]	Min	Max	Current Geometric Mean (GSD) [3]
BRAN_MS	5	2	30	272	83.7(2.7)
BEAV_MS	7	5	41	218	126.0(1.9)
BEAV_NF	6	6	108	448	223.6(1.6)
BEAV_SF	6	4	41	216	119.1(2.0)
CASI_MS	6	4	75	1333	316.9(3.3)
HURR_DS	7	3	41	411	104.5(2.3)
HURR_US	6	5	75	2909	386.9(3.5)
RAMS_MS	6	6	122	556	273.2(1.7)
RAMS_UNT	6	4	31	282	125.5(2.3)
RAMS_US	6	2	20	241	77.0(2.4)
ROCK_DS	6	0	10	52	18.7(2.1)
ROCK_MS	6	3	41	228	83.1(1.9)
ROCK_US	7	6	98	538	280.4(1.9)
TALL_MS	6	6	158	1162	378.3(2.4)
All	86	57	10	2909	144.7(3.0)

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] GSD = geometric standard deviation.

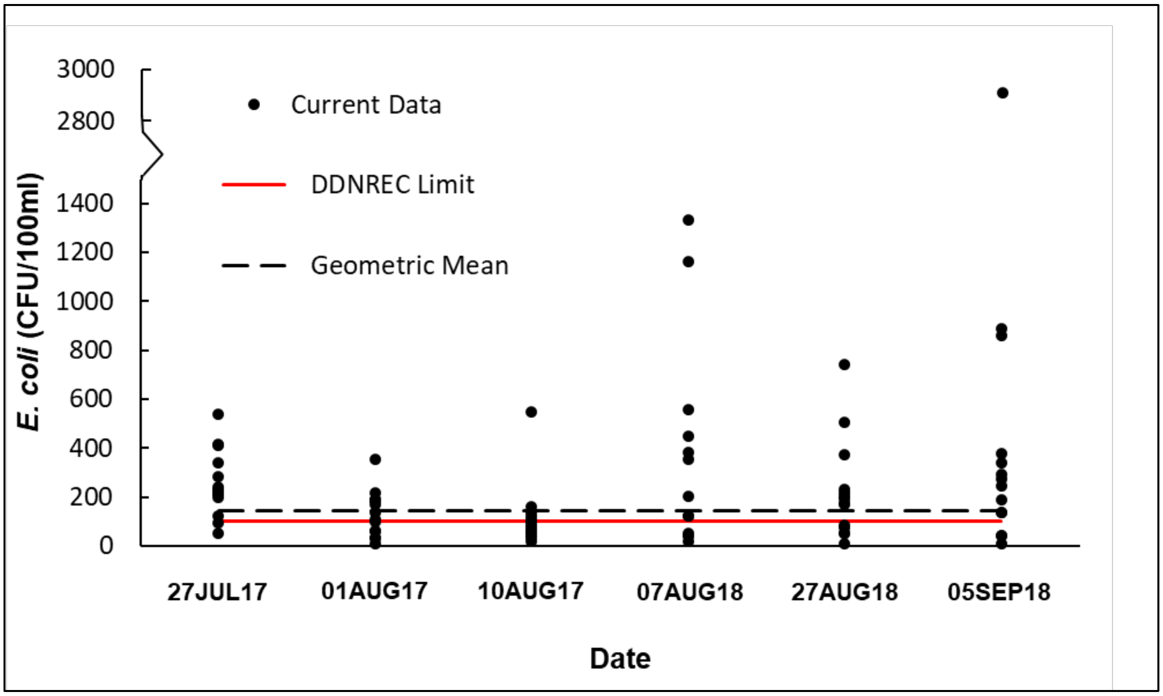


Figure 4.7-8. *E. coli* measurements for all Brandywine Valley stations. The DDNREC limit is shown by a red line (Stroud Water Research Center 2017; NWQMC 2019).

Nitrogen (as Nitrate and Nitrite)

The EPA standard for nitrogen in surface waters is less than or equal to 0.71 mg/L. Every sample for nitrogen at all stations, except for 4 samples from BRAN_MS prior to 1981, exceeded the federal standard by a significant amount (Table 4.7-11, Figure 4.7-9). The condition of nitrogen in Brandywine Creek is poor with an unchanging trend ($n = 129$, $\tau = 0.20$, $p>0.05$). Confidence in the assessment is medium.

Table 4.7-11. Nitrogen measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
BRAN_MS	10/74–06/19	160	156	<0.1	4.5	3.0(0.4)	3.4
BEAV_MS	04/16–06/18	5	5	2.2	2.4	2.3(0.1)	–
BEAV_NF	04/16–06/18	3	3	1.6	1.6	1.6(0.0)	–
BEAV_SF	04/16–06/18	3	3	2.7	3.5	3.1(0.5)	–
CASI_MS	04/16–06/18	4	4	3.4	4.2	3.8(0.5)	–
HURR_DS	04/16–06/18	4	4	2.6	3.1	2.9(0.4)	–
HURR_US	04/16–06/18	3	3	2.4	2.9	2.7(0.4)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

Table 4.7-11 (continued). Nitrogen measurements from 14 monitoring stations including minimum, maximum, and mean values (mg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
RAMS_MS	04/16–06/18	3	3	3.7	3.7	3.7(0.0)	–
RAMS_UNT	04/16–06/18	3	3	4.6	5.2	4.9(0.4)	–
RAMS_US	04/16–06/18	3	3	5.1	5.3	5.2(0.1)	–
ROCK_DS	04/16–06/18	3	3	1.2	1.2	1.2(0.0)	–
ROCK_MS	04/16–06/18	3	3	1.8	2.3	2.0(0.3)	–
ROCK_US	04/16–06/18	3	3	1.7	1.8	1.7(0.1)	–
TALL_MS	04/16–06/18	3	3	1.8	2.1	2.0(0.2)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

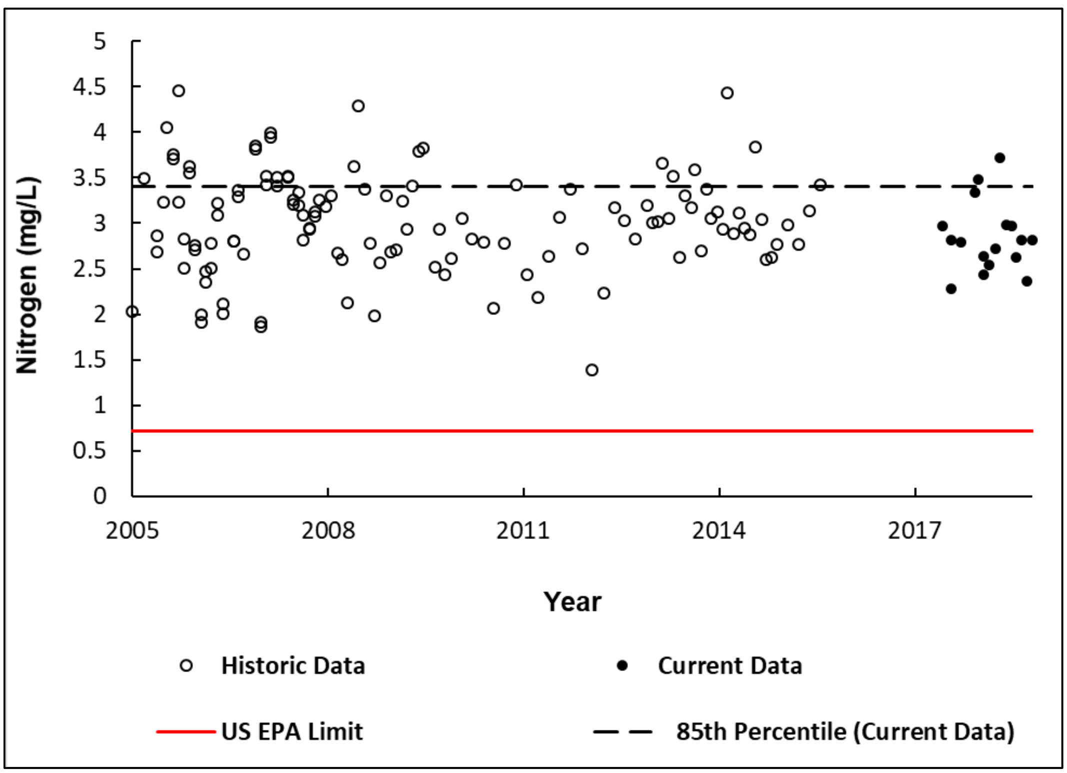


Figure 4.7-9. Nitrogen measurements for BRAN_MS from 2005 to 2019. Ten samples from 1974 to 1980 have been omitted to improve graph scale. Four of the ten omitted were below the EPA standard of 0.71 mg/L (Stroud Water Research Center 2017, NWQMC 2019). The US EPA limit is shown by a solid red line.

<u>Total Phosphorus</u>

The EPA standard for phosphorus in surface waters is less than or equal to 31.25 µg/L. Brandywine Creek has levels of phosphorus in excess of the federal standard (Table 4.7-12, Figure 4.7-10). All other stations are substantially below the standard, suggesting that there may be an additional phosphorus source upstream of the park along Brandywine Creek and somewhere in Rocky Run's catchment. Rocky Run's headwaters are in the middle of a heavily developed shopping area, making runoff from lawns and roads a likely source of this pollutant. The overall condition of phosphorus at Brandywine Valley is poor. However, the trend of phosphorus in Brandywine Creek is improving ($n = 155$, $\tau = -0.36$, $p<0.01$). Confidence in the assessment is high.

Table 4.7-12. Phosphorus measurements from 14 monitoring stations including minimum, maximum, and mean values (µg/L) (Stroud Water Research Center 2017, NWQMC 2019).

Station	Period of record	n [1]	# exc [2]	Min	Max	Current Mean (SD) [3]	Current 85th Percentile
BRAN_MS	10/74–06/19	181	170	13.0	675.0	64.1(22.2)	85.6
BEAV_MS	04/16–06/18	3	0	8.8	16.2	12.4(3.7)	–
BEAV_NF	04/16–06/18	2	0	8.6	10.3	9.5(1.2)	–
BEAV_SF	04/16–06/18	2	0	12.6	13.4	13.0(0.6)	–
CASI_MS	04/16–06/18	2	0	9.8	10.3	10.1(0.4)	–
HURR_DS	04/16–06/18	2	0	7.6	10.7	9.2(2.2)	–
HURR_US	04/16–06/18	2	0	7.9	8.6	8.3(0.5)	–
RAMS_MS	04/16–06/18	2	0	8.7	11.3	10.0(1.8)	–
RAMS_UNT	04/16–06/18	2	0	9.6	16.6	13.1(4.9)	–
RAMS_US	04/16–06/18	2	0	10.7	12.4	11.6(1.2)	–
ROCK_DS	04/16–06/18	2	0	26.1	43.9	35.0(12.6)	–
ROCK_MS	04/16–06/18	2	0	13.3	24.7	19.0(8.1)	–
ROCK_US	04/16–06/18	2	0	35.6	41.1	38.4(3.9)	–
TALL_MS	04/16–06/18	2	0	9.4	14.7	12.1(3.7)	–

[1] n = number of observations.

[2] # exc = number of readings exceeding parameter standard.

[3] SD = standard deviation.

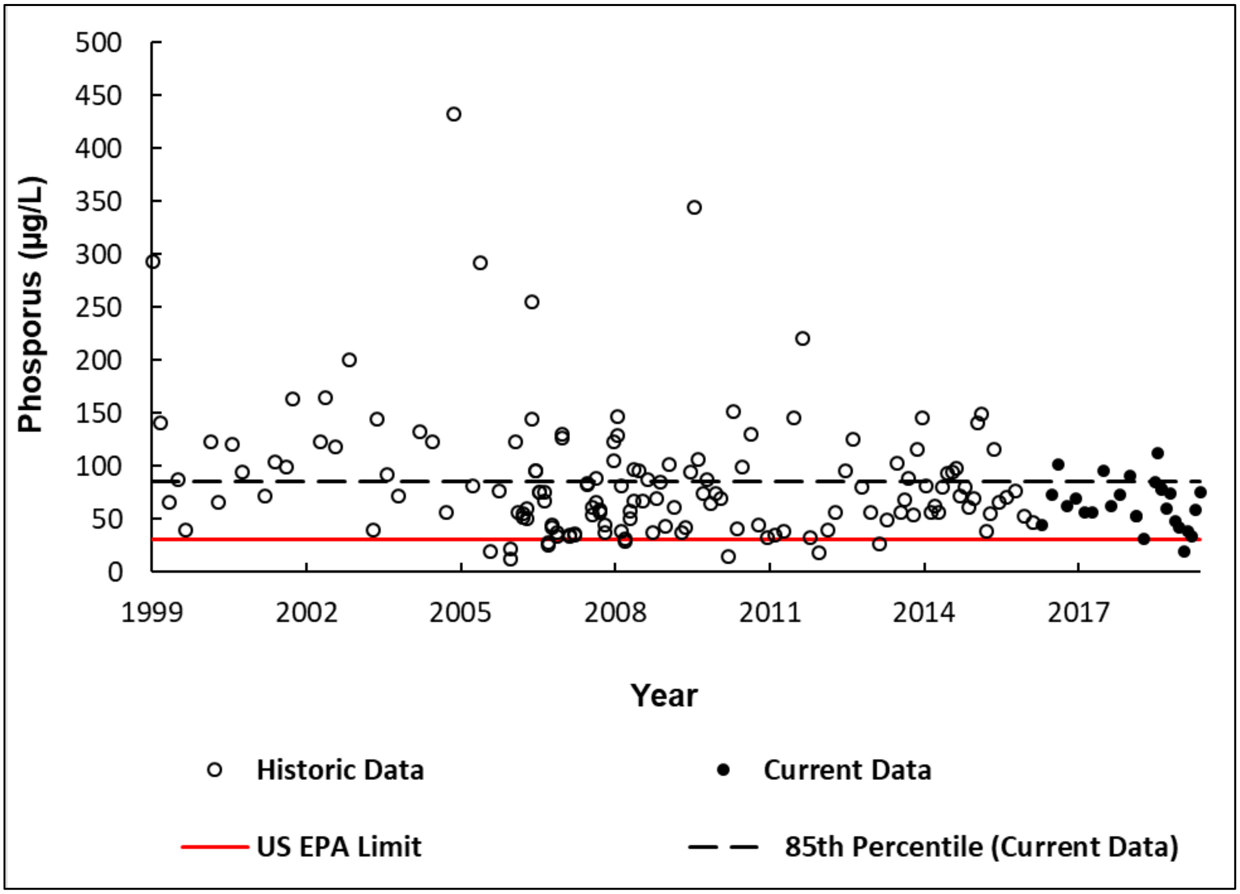


Figure 4.7-10. Phosphorus measurements for BRAN_MS from 1999 to 2019. Six samples from 1974 to 1980 have been omitted to improve graph scale. All of the six omitted were above the EPA standard of 31.25 µg/L (Stroud Water Research Center 2017, NWQMC 2019). The US EPA limit is shown by a solid red line.

Aquatic Macroinvertebrates

Four of the five metrics for aquatic macroinvertebrates indicate that this indicator is in moderate condition, with only taxa richness receiving a good rating (Table 4.7-13). Rocky Run was again of note for its poor rating for three of the indicators assessed (EPT, EPT/C, and HBI). No trend was determined due to the short length of the data record for this indicator. Confidence in the assessment is medium.

Table 4.7-13. Global mean and standard deviation of aquatic macroinvertebrate metrics collected from five locations in the Brandywine Creek Watershed in 2016 and 2017. N=4 is the total number of replicates sampled for each station (Stroud Water Research Center 2017).

Metric	Global Mean(SD)	Condition
Taxa (genus) Richness	75.6(10.6)	Good
EPT Richness	12.6(3.7)	Moderate
EPT/C Ratio	0.36(0.25)	Moderate
Shannon Index	2.09(0.65)	Moderate
Hilsenhoff Biotic Index	5.16(1.42)	Moderate

Condition Summary

Water quality in Brandywine Valley unit is in moderate condition with an unchanging trend (Table 4.7-14). The water quality for FRST can be assessed with a medium level of confidence.

Table 4.7-14. Condition and trend summary for water quality, First State National Historic Park, Delaware.

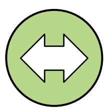
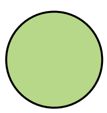
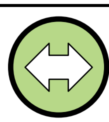
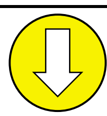
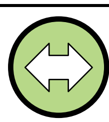
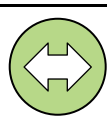
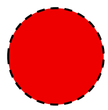
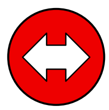
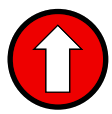
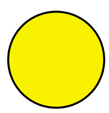
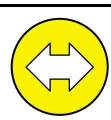
Indicator	Condition Status/Trend	Rationale
Water Temperature		All stations are substantially below the standard for water temperature, and there have been no exceedances in any measurement since sampling began in 1974. All measurements for Beaver Creek are below the cold-water fishery standard.
pH		Both the 15th and 85th percentiles fall within the upper and lower pH standard, indicating that pH is in good condition. The trend for pH in Brandywine Creek is rising (i.e. becoming more basic). The trend for pH is difficult to assess, therefore no official trend will be given. However, it does seem that the trend suggests deterioration due to a recent increase in pH values toward the upper limit. This information should serve as a notice to begin monitoring pH more closely in Brandywine Creek to ensure it does not exceed the upper standard of 8.5.
Dissolved oxygen		Except for a single reading, DO is consistently above the EPA and DDNREC standards. DO measurements for all tributaries were also well above both standards, with a minimum value of 7.5 mg/L.
Specific Conductivity		There are a fairly large number of exceedances and the 85th percentile is nearing the EPA standard of 500 mS/cm. Specific conductance is in moderate condition with a deteriorating trend.
Chloride		All stations have measured chloride values in substantially lower concentrations than the federal standard, indicating good condition.
Sulfate		The EPA standard for sulfate is less than or equal to 250 mg/L, while DDNREC does not have a published standard. All stations have measured sulfate in substantially lower concentrations than the federal standard.

Table 4.7-14 (continued). Condition and trend summary for water quality, First State National Historic Park, Delaware.

Indicator	Condition Status/Trend	Rationale
Escherichia coli		Most stations and all stations combined had geometric means well over the DDNREC primary contact recreation standard of 100 CFU/100ml. The only waterbodies that did not exceed the standard were Brandywine Creek, the upstream portion of Ramsey Run, and upstream and midstream Rocky Run. No trend was assessed due to lack of historical data. Confidence is low due to the sampling timeframe.
Nitrogen		All stations have measured nitrogen in substantially higher concentrations than the federal standard.
Phosphorus		Brandywine Creek and Rocky Run both have levels of phosphorus in excess of the federal standard. All other stations are substantially below the standard, suggesting that there may be an additional phosphorus source upstream of the park along Brandywine Creek and somewhere in Rocky Run's catchment. Rocky Run's headwaters are in the middle of a heavily developed shopping area, making runoff from lawns and roads a likely source of this pollutant. The overall condition of phosphorus at Brandywine Valley is poor.
Aquatic Macro-invertebrates		Four of the five metrics for aquatic macroinvertebrates indicate that this indicator is in moderate condition, with only taxa richness receiving a good rating. Rocky Run was again of note for its poor rating within three of the indicators assessed (EPT, EPT/C, and HBI). No trend was determined due to the short length of the data record for this indicator.
Overall		**Overall water quality condition at FRST is in moderate condition with unchanging trend and a medium level of confidence.**

4.7.5. Uncertainty and Data Gaps

The primary source for water quality data (BRAN_MS) is adequate, although not without limitations. Although there is a long, mostly continuous sampling record, there are not enough data points to assess the condition or trend with a high level of confidence. Confidence could be increased with higher sampling frequency and obtaining flow measurements with all water quality samples so that parameter concentrations can be better assessed. Although historical data for tributaries to Brandywine Creek do not currently exist, the sampling being conducted by Stroud Water Research Center and TNC will allow determination of water quality trends for these tributaries in the future. The continuation of this sampling, as well as the continued operation of the BRAN_MS station, will allow more robust water quality studies to be conducted in the future.

4.7.6. Sources of expertise

- Kim Hachadoorian, Stream Stewards Project Manager, The Nature Conservancy.
- Dr. John Jackson, Senior Research Scientist, Stroud Water Research Center.

4.7.7. Literature Cited

Bukantis, R. 1998. Rapid bioassessment macroinvertebrate protocols: sampling and sample analysis SOP's. Working draft, April 22, 1997. Montana Department of Environmental Quality. Planning Prevention and Assistance Division. Helena, Montana.

Caissie, D. 2006. The thermal regime of rivers: a review. Freshwater Biology 51(8):1389–1406.

Colorado Department of Public Health and Environment (CDPHE). 2017. Section 303(d) listing methodology 2018 listing cycle. CDPHE Water Quality Control Division. Available at: https://www.colorado.gov/pacific/sites/default/files/303d_LM_2018.pdf (accessed 27 March 2019).

Delaware Department of Natural Resources and Environmental Control (DDNREC). 2011. Christina Basin pollution control strategy. Dover, Delaware.

DDNREC. 2017. 7401 Surface Water Quality Standards. Title 7 natural resources & environmental control Delaware administrative code. DDNREC Division of Watershed Stewardship. Available at: http://www.dnrec.delaware.gov/swc/wa/Documents/2018%20Final%20Delaware%20IR%201-24-2019.pdf.

DDNREC. 2019. State of Delaware 2018 combined watershed assessment report (305(b)) and determination for the Clean Water Act section 303(d) list of waters needing TMDLs. DDNREC Division of Watershed Stewardship. Available at: http://www.dnrec.delaware.gov/swc/wa/Documents/2018%20Final%20Delaware%20IR%201-24-2019.pdf.

Environmental Protection Agency (EPA). 2000. Ambient water quality criteria recommendations: information supporting the development of state and tribal nutrient criteria, rivers and streams in nutrient ecoregion XIV. EPA 822-B-00-022. EPA Office of Water, Office of Science and Technology Health and Ecological Criteria Division, Washington, D.C. Available at: https://www.epa.gov/sites/production/files/documents/rivers14.pdf.

EPA. 2006a. Revisions to total maximum daily loads for nutrient and low dissolved oxygen under high-flow conditions Christina River Basin, Pennsylvania, Delaware, and Maryland. Philadelphia, Pennsylvania. Available at: http://www.dnrec.delaware.gov/swc/wa/Documents/Xia/Christina_High-Flow_NutrientsTMDL_TechReport_2006.pdf.

EPA. 2006b. Total maximum daily loads for bacteria and sediment in the Christina River Basin, Pennsylvania, Delaware, and Maryland. Philadelphia, Pennsylvania. Available at: http://www.dnrec.delaware.gov/swc/wa/Documents/Xia/Christina_High-Flow_BactTMDL_TechReport_2006.pdf.

EPA. 2006c. Revisions to total maximum daily loads for nutrient and low dissolved oxygen under low-flow conditions Christina River Basin, Pennsylvania, Delaware, and Maryland. Philadelphia, Pennsylvania. Available at: http://www.dnrec.delaware.gov/swc/wa/Documents/WAS/TMDL%27s/Christina%20Low-Flow%20NutrientTMDL%20TechReport%20Revised%202006.pdf.

EPA. 2012a. Chapter 4 macroinvertebrates and habitat. Available at: https://archive.epa.gov/water/archive/web/html/vms40.html (accessed 12 December 2019).

EPA. 2012b. Recreational water quality criteria. Office of Water 820-F-12-058. Available at: https://www.epa.gov/sites/production/files/2015-10/documents/rwqc2012.pdf (accessed 27 March 2019).

EPA. 2012c. Conductivity. Available at: https://archive.epa.gov/water/archive/web/html/vms59.html (accessed 05 December 2019).

EPA. 2017. Water quality standards handbook: Chapter 3: water quality criteria. EPA-823-B-17-001. EPA Office of Water, Office of Science and Technology, Washington, D.C. Available at: https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter3.pdf.

EPA. 2018a. National recommended water quality criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm (accessed 06 December 2018).

EPA. 2018b. STORET Warehouse website. Available at: http://www.epa.gov/storet.

EPA. 2019. Nutrient pollution: the issue. Available at: http://www2.epa.gov/nutrientpollution/problem (accessed 12 December 2019).

Evans, M., and C. Frick. 2001. The effects of road salts on aquatic ecosystems. NWRI contribution series no. 02:308. National Water Research Institute and University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Helsel, D. R., D. K. Mueller, and J. R. Slack. 2006. Computer program for the Kendall family of trend tests. Scientific Investigations Report 2005–5275. U.S. Geological Survey, Reston, Virginia.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7:65–68.

Iowa Department of Natural Resources (IDNR). 2009. Water quality standards review: chloride, sulfate and total dissolved solids.

Meals, D. W., J. Spooner, S. A. Dressing, and J. B. Harcum. 2011. Statistical analysis for monotonic trends. Tech Notes 6, November 2011. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, Virginia.

McDaniel, L. 2013. Understanding Iowa's water quality standards. http://www.iowadnr.gov/portals/idnr/uploads/water/standards/ws_fact.pdf (accessed 19 November 2013).

Mesner, N., and J. Geiger. 2005. pH factsheet. Utah State University Extension Publication NR/WQ/2005-19. Available at: https://extension.usu.edu/waterquality/files-ou/Publications/pH.pdf (accessed 18 December 2018).

National Park Service Water Resources Division (NPS WRD). 2006. 2006 Annual Report. Natural Resource Program Center, Fort Collins, Colorado and National Park Service, Washington, D.C.

National Water Quality Monitoring Council (NWQMC). 2019. Water quality data. Available at: https://www.waterqualitydata.us/portal/ (accessed 15 July 2019).

New Hampshire Department of Environmental Services (NHDES). 2017. Environmental, health and economic impacts of road salt.

Peitz, D. G., and J. T. Cribbs. 2005. Bio-monitoring of water quality using aquatic invertebrates and in-stream habitat and riparian condition assessment: status report for Pipestone Creek, Pipestone National Monument, Minnesota 1989–2004. U.S. National Park Service, Heartland I&M Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Missouri.

Resh, V. H., and J. K. Jackson. 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. Pages 195–223 in D. M. Rosenberg and V. H. Resh, editors. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York, New York.

Rounds, S. A., F. D. Wilde, and G. F. Ritz. 2013. Dissolved oxygen (ver. 3.0): U.S. Geological Survey techniques of water resources investigations, book 9, chap. A6, sec. 6.2. Available at: http://water.usgs.gov/owq/FieldManual/Chapter6/6.2_v3.0.pdf.

State of Delaware. Undated. Delaware watersheds. Brandywine Creek. Available at: http://delawarewatersheds.org/piedmont/brandywine-creek/ (accessed 02 December 2019).

Stroud Water Research Center. 2017. Fecal indicator bacteria monitoring at the First State National Park, Delaware. Stroud Water Research Center Unpublished Report, Avondale, Pennsylvania.

U.S. Geological Survey (USGS). 2016. Water properties: temperature. Available at: https://water.usgs.gov/edu/temperature.html (accessed 18 December 2018).

USGS. 2017. Fecal indicator bacteria and sanitary water quality. http://ga.water.usgs.gov/edu/bacteria.html (accessed 12 November 2019).

USGS. 2018. Comparison of 2016–17 water years and historical water-quality data, Yampa River Basin, Colorado. Available at: https://co.water.usgs.gov/infodata/yampa_summaries/index.html (accessed 01 December 2018).

Vermont Department of Environmental Conservation (VDEC). 2004. Biocriteria for fish and macroinvertebrate assemblages in Vermont, wadeable streams and rivers, implementation phase. VDEC Water Quality Division, Biomonitoring and Aquatic Studies Section. Available at: https://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/bs_wadeablestream2.pdf.

VDEC. 2008. Summary of Biological and Chemical assessments conducted in 2005 & 2007 within the Lamoille River and Missisquoi River watersheds in Lowell and Eden Vermont. VDEC Water Quality Division. Available at: http://www.anr.state.vt.us/dec/wastediv/sms/VAG/Reports/1014.Final2008VAGBASS.Summary.pdf.

Wilhm, J. L. 1970. Range of diversity index in benthic macroinvertebrate populations. Journal of the Water Pollution Control Federation 42(5):Suppl. R221+.

4.8. Forest Communities

4.8.1. 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 most of Delaware and Pennsylvania, this ecoregion exhibited vast stretches of unbroken forest that persisted for thousands of years (NPS 2016). This ecosystem covered all of northern Delaware and southern Pennsylvania, including what is now FRST. The historic landscape at FRST was almost completely dominated by oak (*Quercus* spp.) / hickory (*Carya* spp.) forest communities (DFS 2009).

Forest community at the Brandywine Valley Unit at FRST (CSU Photo).

Delaware, like much of the eastern U.S., has been heavily impacted by urbanization and forest clearing (DFS 2009, 2010). Pre-settlement, nearly all of Delaware (90% or 1.1 million acres) was covered by old-growth forests (DFS 2009). After Euro-American settlement, forest cover was reduced to only 28% of the state by the early 1900s (DFS 2009). Today, the state's forest cover has increased to about 30% (including tree plantations) with many of the forests being highly fragmented and occurring predominantly on private lands (DFS 2009). Although forests are no longer the dominant feature on Delaware's landscape, existing forests still provide an important array of essential ecological and agricultural benefits to the state. Wildlife habitat, temperature control, biodiversity, water quality protection, wetland protection, flood attenuation, and a variety of cultural, agricultural, and recreational uses are important benefits provided by Delaware's forests.

At FRST, significant natural vegetation only occurs at the Brandywine Valley unit (hereafter Brandywine Valley). This unit is the sole focus of this Forest Communities section. Brandywine Valley is located along the Piedmont Uplands (64c) Level IV Ecoregion approximately 10 miles from the fall line marking the edge of the coastal plain (Figure 4.8-1). The Piedmont Uplands Level IV ecoregion is characterized by rounded hills, low ridges, relatively high relief, and narrow valleys all underlain by metamorphic rock (Woods et al. 1996). Brandywine Valley includes approximately 1,100 acres of pastures, agricultural lands, and forests within the Brandywine Valley of northern Delaware and southern Pennsylvania. Approximately 291 acres of Brandywine Valley are in Pennsylvania with the remaining acres occurring in Delaware. Brandywine Valley is located approximately 7 miles north of Wilmington, Delaware. Elevation within the unit ranges from approximately 420 feet above mean sea level (MSL) along the northeastern ridges to 135 feet above MSL where the Brandywine Creek exits the unit.

Approximately 38% of Brandywine Valley is used for agriculture (e.g., pasture, row crops, and hay fields). The remaining land cover includes forest, other old fields, and several residences. Brandywine Valley contains numerous historical sites that show signs of more widespread human use and habitation in the past, although there has been no notable development within the unit for at least the last 70 years (Ebert undated). Almost all forests within Brandywine Valley have been logged repeatedly since Euro-American settlement and only a few old-growth patches remain as remnants of the old-growth forest that once covered the entire region (Quigley 2011, Ebert undated). The largest and most mature patches in the unit occur in very steep, rugged, and largely inaccessible stream corridors that were unsuitable for agriculture. Widespread agricultural use was abandoned over the last half-century and non-native shrub-thickets (e.g., buckthorn (*Rhamnus cathartica*) and bittersweet (*Celastrus orbiculatus*)) and even-aged, ruderal forest have developed within the old fields (Ebert undated). Existing forests at Brandywine Valley are primarily examples of mature Piedmont Upland and include Northern Piedmont chestnut oak (*Q. montana*), Piedmont Mesic oak beech (*Fagus grandifolia*), and Piedmont Basic Mesic hardwood forest types.

The structure of the original forests within the Brandywine Valley area would likely have included trees in excess of 300 years old with a mixed-age canopy creating a mosaic of tree sizes and ages. Tree densities would have been distributed among all size classes and would have included trees with diameters greater than 27 inches (70 cm). In addition, large volumes of coarse woody debris would be in various states of decay providing nutrient cycling on the forest floor and standing-dead snags would be present within the canopy providing critical wildlife habitat (Zawadzkas and Abrahamson 2003). The original forests likely had more canopy gaps than seen in today's forests (Hix et al. 2011).

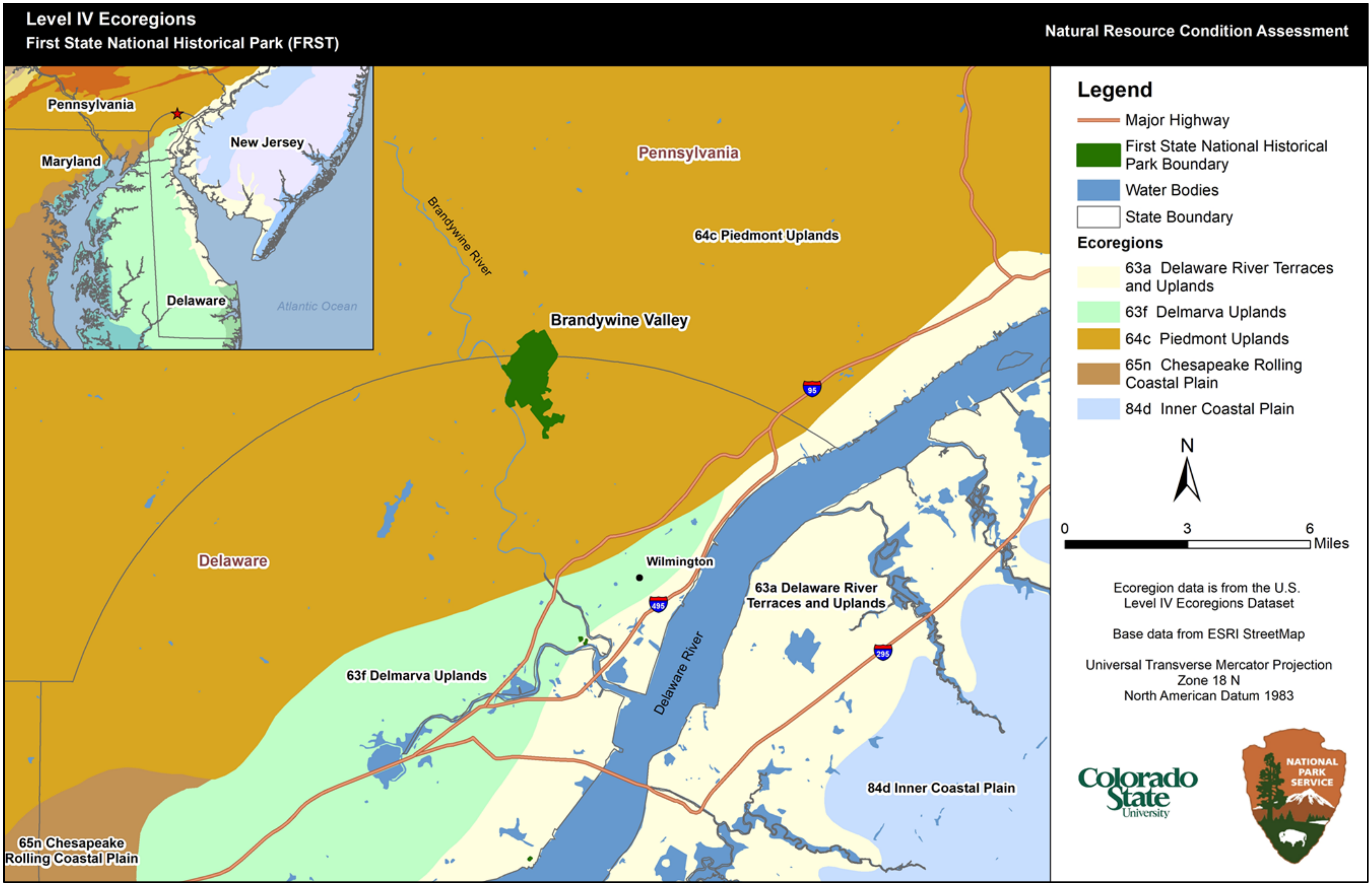


Figure 4.8-1. Level IV Ecoregions. Data source: Woods et al. (1996).

Historical land uses in the Brandywine Valley changed the species composition and age structure of the forest. Although large tracts of forests can be found in the area, most forested areas are somewhat fragmented. Intense urban development in areas surrounding Brandywine Valley also affects the forest ecosystem. As local human populations have increased, so has the suppression of the natural fire regime leading to changes in forest species composition. In the past, in drier oak-hickory-dominated sites, periodic, low-intensity fires maintained the understory vegetation, naturally thinned the canopy density, and limited fire-intolerant species from entering or dominating the canopy.

Because of fire suppression, fire-intolerant species such as maples (*Acer* spp.) and beech have increased in dominance, which has altered and displaced original forest communities.

Given the relatively young age of FRST as an NPS unit, very little vegetation monitoring has occurred within the park. The primary park resource for this assessment is the *First State National Historical Park Botanical Inventory and Assessment* (Ebert undated). Other documents completed prior to the establishment of FRST and focused on all or portions of the NPS-managed property as well as other non-NPS-managed lands also used in this assessment include: *Preliminary Ecological Research and Assessment In support of the Woodlawn Trustees Vision Plan* (Quigley 2011) and *Historical Analysis and Map of Vegetation Communities, Land Covers, and Habitats of the Woodlawn Tract, New Castle County, Delaware* (Coxe 2014).

As outlined in Coxe (2014), 13 vegetation communities are found within the Delaware portion of the Brandywine Valley unit. Community names have been updated to match the latest version of the United States National Vegetation Classification (USNVC) system (version 2.03, March 2019) with the USNVC code in parentheses. The 13 types include:

- Ruderal Boxelder Floodplain Forest (CEGL005033)
- Cultivated Lawn (CGR033)
- Japanese Stiltgrass Meadow (*No USNVC Classification*)
- Northeastern Coastal Plain – Piedmont Oak – Beech / Heath Forest (CEGL006919)
- Northeastern Ruderal Hardwood Forest (CEGL006599)
- Northeastern Old-field Meadow (CEGL006107)
- Northeastern Ruderal Shrubland (CEGL006451)
- Northern Piedmont Mesic Beech – Oak Forest (CEGL006921)
- Rice Cutgrass – Fowl Mannagrass Wet Meadow (CEGL005106)
- Skunk-cabbage – Orange Jewelweed Seep (CEGL006567)
- Southern New England – Northern Piedmont Red Maple Seepage Swamp Forest (CEGL006406)
- Ruderal Tuliptree Forest (CEGL007220)
- Eastern White Pine Plantation (CST007178)

A summary from Coxe (2014) is provided in Table 4.8-1 and the vegetation map is shown in Figure 4.8-2.

Table 4.8-1. Extent of mapped vegetation community associations for map classes in the Delaware portion of Woodlawn Tract (Coxe 2014). Map class names are from Coxe (2014) and may differ from published USNVC (2019) types.

Vegetation Physiognomy	USNVC Identifier	Map Class Name	Ecological Associations	Acres	Hectares
Forests and woodlands	CEGL005033	Box-elder Floodplain Forest	*Acer negundo* Ruderal Floodplain Forest Association	1.0	0.4
	CEGL006919	Northeastern Coastal Plain – Piedmont Oak – Beech / Heath Forest	Fagus grandifolia – Quercus (alba, velutina, montana) / Kalmia latifolia Forest	1.0	0.4
	CEGL006599	Northeastern Modified Successional Forest	Prunus serotina – Liriodendron tulipifera – Acer rubrum – Fraxinus americana – (Robinia pseudoacacia) Ruderal Forest	184.0	74.5
	CEGL006921	Northern Piedmont Mesic Beech – Oak Forest	Fagus grandifolia – Betula lenta – Quercus (alba, rubra) / Carpinus caroliniana Forest	299.0	121.0
	CEGL006406	Southern New England – Northern Piedmont Red Maple Seepage Swamp Forest	Acer rubrum – Fraxinus (pennsylvanica, americana) / Lindera benzoin / Symplocarpus foetidus Swamp Forest	0.5	0.2
	CEGL007220	Successional Tuliptree Forest	*Liriodendron tulipifera* / (*Cercis canadensis*) / (*Lindera benzoin*) Ruderal Forest	69.0	27.9
	CST007178	White Pine Plantation	*Pinus strobus* Forest Plantation	1.0	0.4
Total forests and woodlands	–	–	–	**555.5**	**224.8**
Shrublands	CEGL006451	Northeastern Successional Shrubland	Elaeagnus umbellata – Cornus racemosa – Rosa multiflora – Juniperus virginiana Ruderal Shrubland	31.0	12.5
Total shrublands	–	–	–	**31.0**	**12.5**

Table 4.8-1 (continued). Extent of mapped vegetation community associations for map classes in the Delaware portion of Woodlawn Tract (Coxe 2014). Map class names are from Coxe (2014) and may differ from published USNVC (2019) types.

Vegetation Physiognomy	USNVC Identifier	Map Class Name	Ecological Associations	Acres	Hectares
Herbaceous vegetation	NA	Japanese Stiltgrass Meadow	*Microstegium vimineum* Meadow	0.04	0.016
	CEGL006107	Northeastern Old-field Meadow	Dactylis glomerata – Phleum pratense – Festuca spp. – Solidago spp. Ruderal Meadow	237.0	95.9
	CEGL005106	Rice Cutgrass – Fowl Mannagrass Wet Meadow	Leersia oryzoides – Glyceria striata – (Schoenoplectus spp., Impatiens capensis) Wet Meadow	7.0	2.8
	CEGL006567	Skunk-cabbage – Orange Jewelweed Seep	Symplocarpus foetidus – Impatiens capensis Seepage Meadow	1.0	0.4
Total herbaceous vegetation	–	–	–	**245.0**	**99.1**
Total natural vegetation	–	–	–	**831.5**	**336.4**

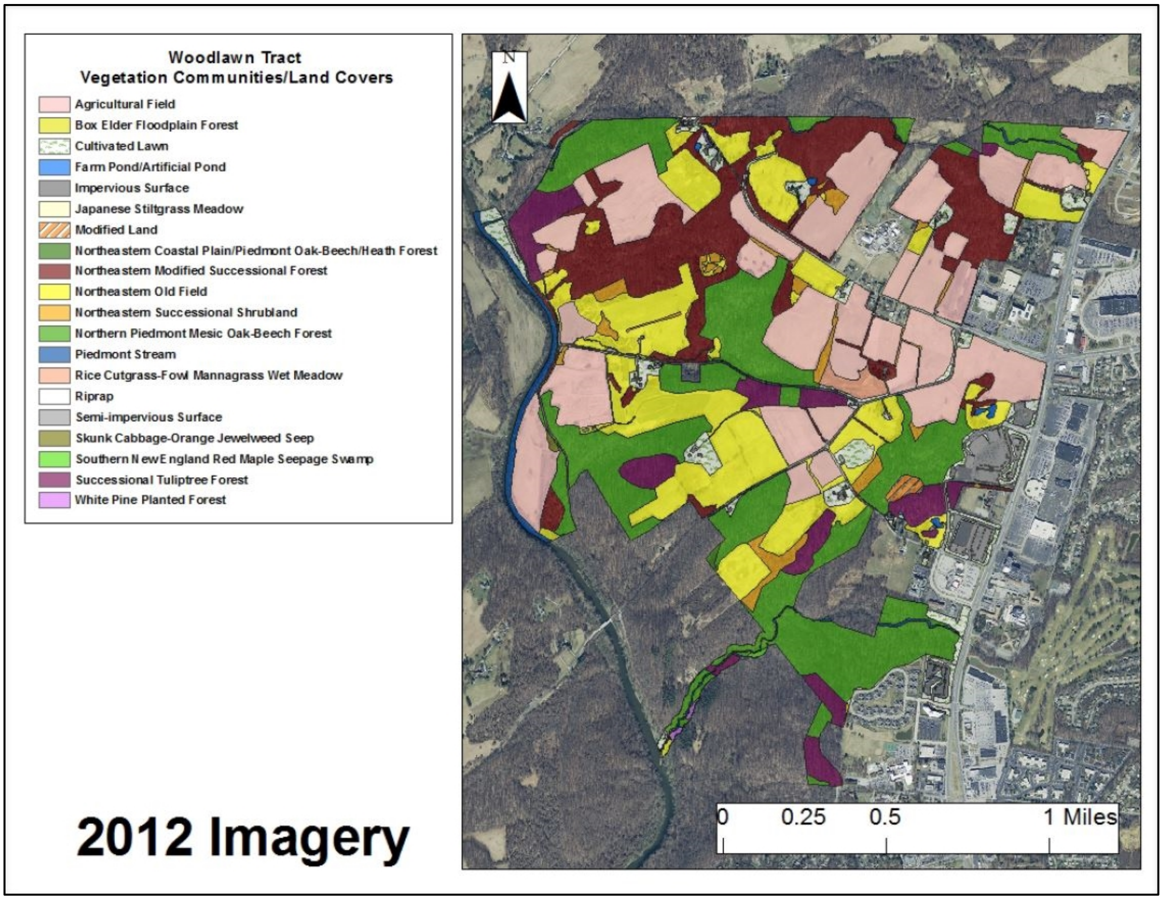


Figure 4.8-2. 2012 vegetation community map of the Delaware portion of the Woodlawn Tract, including the NPS-owned Brandywine Valley Unit. Image from Coxe (2014).

At FRST, upland forest communities are dominated by hardwood trees such as northern red oak (*Q. rubra*), white oak (*Q. alba*), black oak (*Q. velutina*), chestnut oak (*Q. montana*), hickory species (*Carya* spp.), tuliptree (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), and American beech (*Fagus grandifolia*). Red maple (*A. rubrum*), sweetgum (*Liquidambar styraciflua*), black cherry (*Prunus serotina*), tuliptree, and box-elder (*A. negundo*) characterize the early-successional forests. Riparian floodplain and bottomland forests consist largely of box-elder, red maple, silver maple (*A. saccharinum*), tuliptree, American sycamore (*Platanus occidentalis*), black walnut (*Juglans nigra*), green ash (*F. pennsylvanica*), and common hackberry (*Celtis occidentalis*).

Shrubs common to upland communities at FRST include mountain laurel (*Kalmia latifolia*), lowbush blueberry (*Vaccinium pallidum*), multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), buckthorn, and winterberry (*Ilex verticillata*). Common vines include white-leaf greenbrier (*Smilax glauca*), poison ivy (*Toxicodendron radicans*), common greenbrier (*Smilax rotundifolia*), muscadine grape (*Vitis aestivalis*), Virginia creeper (*Parthenocissus quinquefolia*) and Oriental bittersweet. Common upland herbs include mayapple (*Podophyllum peltatum*), garlic mustard (*Alliaria petiolata*), Solomon's seal (*Polygonatum biflorum*), white wood aster (*Eurybia divaricata*), bloodroot (*Sanguinaria canadensis*), sensitive fern (*Onoclea sensibilis*), common blue violet (*Viola sororia*), false Solomon's seal (*Maianthemum racemosum*), trout lily (*Erythronium americanum*), wood nettle (*Laportea canadensis*), and jack-in-the-pulpit (*Arisaema triphyllum*). Upland grasses include red fescue (*Festuca rubra*), Japanese stiltgrass (*Microstegium vimineum*), sweet vernal grass (*Anthoxanthum odoratum*), orchard grass (*Dactylis glomerata*), broom-sedge (*Andropogon virginicus*), common velvet grass (*Holcus lanatus*), and timothy (*Phleum pratense*).

Common wetland species at FRST include rice cutgrass (*Leersia oryzoides*), fowl mannagrass (*Glyceria striata*), Japanese stiltgrass, broadleaf arrowhead (*Sagittaria latifolia*), slender spikerush (*Eleocharis tenuis*), spikerush (*Juncus effusus*), wrinkleleaf goldenrod (*Solidago rugosa*), halbeardleaf tearthumb (*Polygonum arifolium*), orange-spotted jewelweed (*Impatiens capensis*), reed canarygrass (*Phalaris arundinacea*), broadleaf water plantain (*Alisma subcordatum*), hop sedge (*Carex lupulina*), hemlock water-parsnip (*Sium suave*), and large bur-reed (*Sparganium eurycarpum*).

<u>Rare Plants and Plant Communities</u>

Several rare plants and plant communities are documented at Brandywine Valley, including natural plant communities that are rare on a state or global scale. Three forest communities and two herbaceous communities are considered rare in the Delaware portion of Brandywine Valley (Table 4.8-2). Four communities are considered to be state extremely rare and of conservation concern (S1) including Northeastern Coastal Plain-Piedmont Oak – Beech / Heath Forest (CEGL006919, G4/S1), Rice Cutgrass – Fowl Mannagrass Wet Meadow (CEGL005106, GNR/S1), Skunk-cabbage – Orange Jewelweed Seep (CEGL006567, GNR/S1), and Southern New England – Northern Piedmont Red Maple Seepage Swamp Forest (CEGL006406, G4G5/S1). One community, Ruderal Box-elder Floodplain Forest (CEGL005033, G4G5/S2), is considered state very rare and of conservation concern (S2) (Coxe 2014, NatureServe 2019).

Table 4.8-2. Rare plant communities at the Brandywine Valley unit. Data from Coxe (2014).

Vegetation Physiognomy	USNVC Association	Mapped Acreage	NatureServe Conservation Status Ranking *
Forests	Ruderal Box-elder Floodplain Forest	1.0	G4G5 / S2
	Northeastern Coastal Plain – Piedmont Oak – Beech / Heath Forest	1.0	G4 / S1
	Southern New England – Northern Piedmont Red Maple Seepage Swamp Forest	0.5	G4G5 / S1
Herbaceous Vegetation	Rice Cutgrass – Fowl Mannagrass Wet Meadow	7.0	GNR / S1
	Skunk-cabbage – Orange Jewelweed Seep	1.0	GNR / S1

* NatureServe 2019

Forty-five rare plant species occur in the Delaware portion of Brandywine Valley (Ebert undated), including thirteen species ranked S1 (1 to 5 known statewide populations) and thirty-two ranked S2 (6 to 20 known statewide populations) (undated). The large number of Delaware rarities reflects the limited amount of the Piedmont region in the state and the significance of Brandywine Valley as one of the largest tracts in the Brandywine watershed that has so far escaped development (Ebert undated). Only two species found at Brandywine Valley were ranked as rare in both Pennsylvania and Delaware, nodding trillium (*Trillium cernuum*, S2 in both states) and tawny ironweed (*Vernonia glauca*, S1 in PA, S3 in DE). See Ebert (undated) for a full description of all rare plant species and their habitats.

Late-Successional and Old-Growth Forest

It is estimated that approximately 0.4% of the northeast region's forested land consists of primary growth forests (Davis 1996). There is little true old-growth forest remaining in northern Delaware and southern Pennsylvania. Late-successional forest with some old growth characteristics is more abundant than it was in the post-settlement agricultural era but is disappearing from many forest landscapes as land is converted to other uses (e.g., urban development) (Hagan and Whitman 2005).

Key metrics relevant to old-growth forests in eastern North America include stand basal area, maximum size of trees dominant in the canopy, maximum age of trees and age distribution, vertical structural complexity, and amount and relative sizes of woody debris (Barton and Keeton 2018). Old-growth forest types at Brandywine Valley and similar latitudes may display characteristics of several different forest types, including mixed mesophytic forests of the central Appalachians, northern hardwoods of the northeastern U.S., and mixed conifer/hardwood forests of New England. They generally have a natural disturbance regime with small gaps and pests as primary disturbances and moderate-severity wind, ice and fire as the secondary agents (Barton and Keeton 2018). The predominant gap-phase disturbance regime is characterized by small openings in the canopy caused by the death of single trees or small groups of trees. Stand-replacing disturbances occur rarely. Intermediate-intensity disturbances occurring at intervals of several hundred years may play an important role in heterogeneity and persistence of shade midtolerant species (Barton and Keeton 2018).

Several areas within and around Brandywine Valley exhibit late successional or old-growth characteristics (Figure 4.8-3). Quigley (2011) examined legacy old-growth forest of the Woodlawn Tract (most of which became the Brandywine Valley unit) and found that: 1) late-successional forest with some old-growth characteristics occurs in scattered, irregularly-shaped patches, largely along steeply sloped stream valleys; 2) most of the areas within these old-growth-like forested patches were comprised of very mature growth; and 3) most of these patches were of high ecological integrity with high native biodiversity and relatively low disturbance by invasive species.

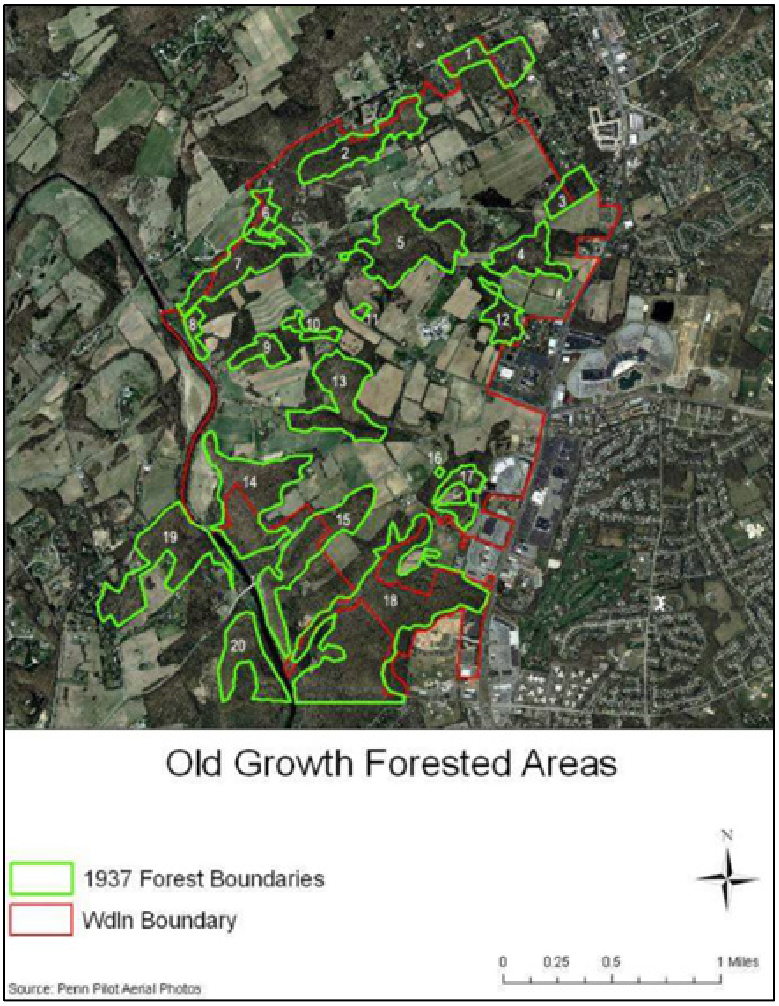


Figure 4.8-3. Extent of forested patches in 1937 at the Woodlawn Tract, some of which persist today. Map from Quigley (2011). Imagery from ArcGIS base map.

Quigley (2011) examined 1937 aerial imagery to determine the extent of older forest patches (i.e., patches exhibiting a mature canopy in 1937) at the Brandywine Valley unit. Comparison with modern imagery revealed that many of the patches remained intact with largely the same boundary (Figure 4.8-3). A summary of changes for each patch is included in Table 4.8-3. In general, most patch boundaries are unchanged. In addition to the known examples, the park might contain more old-growth-like forested areas that warrant additional protection or management. Lack of information regarding conditions of each patch precludes including old growth or late-successional forests as an indicator of vegetation condition at FRST.

Table 4.8-3. A summary of older forest patches (based on 1937 aerial imagery) within and abutting the Woodlawn Tract Study Area. Data from Quigley (2011).

Map Code	Patch Name (for mapping purposes only)	Approx. Size (ac)	Change from 1937 to Present
1	Smith Bridge and Heyburn Road	32.4	Unchanged within Woodlawn Tract; residential dev on portion outside
2	Smith Bridge Road North PA Line	59.7	Unchanged within Woodlawn Tract
3	Walker Lane Woods	14.0	Unchanged within Woodlawn Tract; residential dev on portion outside
4	Beaver Creek Trib. State Line Road	15.8	Unchanged within Woodlawn Tract
5	Beaver Valley State Line Woods	96.8	Unchanged within Woodlawn Tract
6	Beaver Creek Near Smith Bridge Road	12.5	Unchanged within Woodlawn Tract
7	Lower Beaver Valley Road Woods	58.2	Unchanged within Woodlawn Tract
8	Peters Rock Woods	6.30	Unchanged within Woodlawn Tract
9	Brandywine Creek Road Woods	15.1	Unchanged within Woodlawn Tract
10	Beaver Valley Field Woods	5.33	Unchanged within Woodlawn Tract; expansion of forestland around it
11	Beaver Valley Road Square Woods	2.95	Cleared for unknown use
12	Ziegler Lane Woods	17.8	Unchanged within Woodlawn Tract; commercial uses immediately abut
13	Ramsey Road Quarry Woods	51.8	Unchanged within Woodlawn Tract; expansion of forestland around it
14	Ramsey Farm Woods	80.0	Unchanged within Woodlawn Tract
15	Thompson Bridge Road Woods	42.0	Unchanged within Woodlawn Tract
16	Above Hurricane Patch Woods	0.89	Unchanged within Woodlawn Tract
17	Hurricane Run Woods	39.6	Largely intact in area but impacted by SW and some filling; commercial uses immediately abut
18	Rocky Run Woods	192	Limited clearing on Pilot School property

Specific areas within Brandywine Valley exhibiting late successional or old-growth characteristics have not been evaluated, although forest stands mapped from 1937 aerial photography (see Quigley 2011) have largely persisted as forest and likely contain the best examples of stands with mature and old-growth characteristics. Some of the best examples of older forests are in upper Rocky Run and Hurricane Run (pers. comm., Alan Mcloughlin, July 2019). Observations in these drainages by CSU in the summer of 2019 revealed areas with overstories dominated by various mixes of tuliptree (i.e., tulip poplar), oaks, and hickories with mature trees averaging 22 to 30 inches in diameter at breast height (DBH). Forest understories included a mix of black cherry, sugar maple, *Carpinus*, beech, and hemlock (trace) in the uplands, and included sycamore in the stream bottoms and terraces. Tree seedlings were generally sparse and heavily browsed to less than 1 m in height, and regeneration was dominated by American beech. The herbaceous layer was depauperate in most of the closed forest; some early successional patches of tuliptree, black cherry, sugar and red maple, ashes, oaks and black walnut occupied canopy openings and edges. Occasional examples of large open-grown trees were observed, including oaks with diameters exceeding 36 inches, evidence that the area had been heavily logged or cleared for agriculture in the distant past. One windfall tuliptree approximately 48" DBH in size that had been cut to clear the trail was aged at approximately 120 years old. Very little large downed woody debris was present.

Protected areas within Delaware and surrounding states can provide important reference areas for evaluating and managing stands in Brandywine Valley. Some of the best remaining examples of mature secondary growth and old-growth forests nearby include public and private protected areas that vary in size from scattered patches of less than 10 acres to larger, contiguous tracts up to several hundred acres in size. Tulip Tree Woods Nature Preserve within Brandywine Creek State Park (New Castle County) adjacent to Brandywine Valley contains 24 acres of 200-year old tuliptree forest. The Anne M. McClements Woodland Tract of the Fork Branch Nature Preserve (New Castle County) consists of 230 acres of mesic hardwood forest containing American beech, tuliptree, loblolly pine, and various oaks and hickories, many of which are over 160 years old (Old-Growth Forest Network 2019). Other examples of old growth forests near the unit include: Ferncliff Wildflower and Wildlife Preserve (Lancaster County, Pennsylvania), which is recognized as a National Natural Landmark; Carpenter's Woods at Wissahickon Valley Park (Philadelphia County, Pennsylvania); Kelly's Run and Otter Creek preserves (York County, Pennsylvania); and The Peak Forest Preserve (Montgomery County, Pennsylvania).

<u>Threats and Stressors</u>

Primary threats to vegetation communities at FRST include: 1) historical land uses that have impacted the vegetation community structure; 2) fragmentation from development that has reduced the continuity 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); 4) increases in human population that have led to increased suppression of natural fires, which has changed forest species composition; and 5) white-tailed deer (*Odocoileus virginianus*) populations that may be impacting forest community composition and structure. Compounding the effects of these stressors and potential threats are impacts from climate change, air pollution, acid rain, and changes in atmospheric chemistry (NPS 2016). Selected stressors are further described below.

Non-native Plant Species

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. Executive Order (EO) 13751 defines an invasive species as "… a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health."

White-tailed Deer

White-tailed deer overpopulation has been a resource management concern in northern Delaware and southern Pennsylvania for over 20 years (Ebert undated, Rogerson 2010, PA DCNR 2013). Excessive numbers of deer result in over-browsing of vegetation, which has influenced forest regeneration and impacted native species diversity. Although the deer population fluctuates from year to year, long-term deer densities in northern Delaware and southern Pennsylvania have remained well above levels that are desirable for forest health and regeneration (Rogerson 2010). Since 2005, the deer density in northern Delaware has fluctuated between 1.17 and 3.37 times higher than densities elsewhere that are typically associated with forest ecosystems adversely impacted by excessive deer numbers (Alverson et al. 1988, Tilghman 1989, Anderson 1994, deCalesta 1994 and 1995, Rogerson 2010). The NPS does not yet know if there is an overabundance of deer within the Brandywine Valley unit or if they are having negative impacts to park resources.

Numerous studies within Eastern Deciduous Forest ecosystems have shown that browsing by white-tailed deer can severely diminish forest regeneration success when population densities are greater than 15–20 animals/sq mi (Hough 1965, Behrend et al. 1970, Marquis 1981, Tilghman 1989, NPS 1996, Augustine and deCalesta 2003, Bowersox et al. 2002, Horsley et al. 2003, Sage et al. 2003). Preferential browsing by deer on oak saplings can contribute to a decline in the size of larger diameter oak trees within northeastern forests (Widmann et al. 2009). These impacts of over-browsing can persist long after deer densities have been reduced to appropriate management levels (Royo et al. 2010, White 2012). Impacts to forest vegetation from excessive deer browsing have also been shown to reduce the numbers and diversity of songbirds and understory birds within an area (Petit 1998, NPS 2014a).

Different forest communities vary in their resilience and response to deer density, so site-specific considerations are important when deciding on a management threshold. Numerous NPS units within the region have developed deer management plans and associated environmental impact statements (EISs). Initial deer density objectives to support forest regeneration and other goals vary by unit, but are consistently under 40 deer/sq mi: Cuyahoga Valley National Park – 15–30 deer/sq mi (NPS 2014a); Antietam and Monocacy National Battlefields, Manassas National Battlefield Park – 15–20 deer/sq mi (NPS 2014b); Valley Forge National Historical Park – 31–35 deer/sq mi (NPS 2009); and Rock Creek Park – 15–20 deer/sq mi (NPS 2011). The NPS projects are underway to estimate deer populations and evaluate methods for monitoring deer at Brandywine Valley as the first steps in determining if deer management is needed.

Forest Pests and Disease

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

Forest ecosystems in Delaware and Pennsylvania 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 chestnut blight (*Cryphonectria parasitica*) in the early to mid-20th century (DFS 2009). 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 Delaware include the anthracnose fungus, gypsy moth (*Lymantria dispar dispar*), spotted lanternfly (*Lycorma delicatula*), emerald ash borer (*Agrilus planipennis*), southern pine bark beetle (*Dendroctonus frontalis*), and beech bark disease (*Nectria coccinea*), which have all increased the mortality of overstory trees (DFS 2009, 2019). As a result of these disturbances, the forest is very different from the forest that once covered much of northern Delaware and southern Pennsylvania.

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 instance, there are expected to be several “winners” and “losers” at the species and/or community level in the face of a changing climate with some species’ ranges being reduced, other ranges expanding, and still others being relatively unchanged.

Indicators and Measures

- Extent of natural vegetation cover
- Non-native plant cover
- White-tailed deer population
- Forest pests and diseases
- Forest vulnerability to climate change

4.8.2. Data and Methods

Extent of Natural Vegetation Cover

The current and historic extent of natural vegetation cover within the Delaware portion of the Woodlawn Tract, including a majority of what is now Brandywine Valley unit, was evaluated using data from Coxe (2014). This project classified and mapped vegetation communities and land covers for current (2012) and historic (1954, 2002, and 2007) conditions as part of the Delaware Wildlife Action Plan. Field observations (2012 map only) and aerial imagery were used to describe and map vegetation communities across the Brandywine Valley unit according to the USNVC (2019). The findings were used to determine changes in vegetation communities and land cover across the tract over time. For this condition assessment, these data were used to evaluate changes in the extent of natural vegetation communities over time as well as to provide comparison information for reference conditions.

Non-native Plant Cover

The primary data source used to examine the impact of non-native plants is the FRST Botanical Inventory and Assessment (Ebert undated). The project includes data from the initial survey of the 2,000-acre Woodlawn Tract property from 1995 and a survey of the NPS Brandywine Valley Unit from 2014 and 2015. For the surveys, the area was divided into 69 survey sections and separate plant lists were kept for each section. The sections were determined by habitat type and land use, using roads, trails, or obvious changes in habitat as much as possible, although many sections contained more than one habitat type. Dividing the area into sections helped to efficiently survey the flora and provides a rough picture of species distribution. Given the differences in effort and sections visited in 1985 vs. 2014/2015, the results for the two years are not directly comparable, but still provide valuable information on species composition, rare species presence, and non-native species frequency and abundance.

White-tailed Deer Population

Impacts associated with white-tailed deer in northern Delaware have been summarized in the *Delaware Deer Management Plan 2010–2019* (Rogerson 2010). The purpose of the plan was to support long-term, sustainable management of white-tailed deer while also protecting natural habitats. For this condition assessment, state estimates of white-tailed deer populations from Rogerson (2010) are being examined to evaluate how white-tailed deer populations in the management unit (State management zone 1A) containing Brandywine Valley have changed over time. The most recent state deer density estimates are from 2009.

Forest Pests and Diseases

Given the lack of available data for FRST, impacts associated with forest disease and pests at Brandywine Valley were assessed using results for the nearby Valley Forge National Historical Park (VAFO) (Fisichelli et. al 2014, Fisichelli 2015). VAFO lies approximately 17 miles northeast of Brandywine Valley, so impacts from forest disease and pests should be roughly similar between the two parks. In addition to using the VAFO results as a surrogate for FRST, information from the 2013–2027 National Insect and Disease Risk Map (NIDRM) (Krist et al. 2014) was also used to identify potential looming or emerging diseases and pests. 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 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. The NIDRM has been applied to all 50 states and has been shown to effectively account for regional variations in forest health (Krist et al. 2014). For this condition assessment, NIDRM-modeled results from the Middle Brandywine Creek Watershed (HUC 020402050402), which includes all of the NPS Brandywine Valley Unit, were used.

Forest Vulnerability to Climate Change

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. They evaluated two climate change scenarios ("least" change and "major" change) for 2070–2099. 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. FRST was not included in the Fisichelli analysis given its relatively new induction into the NPS system.

4.8.3. 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 include changes that may have occurred due to the use of the landscape by indigenous populations. The ideal condition at FRST 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 of FRST, 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 FRST is sufficient to maintain the plant community in a stable or improving condition. The reference condition rating framework applied to FRST vegetation community indicators is shown in Table 4.8-4.

Table 4.8-4. Reference condition rating framework for forest community indicators at First State National Historical Park. Thresholds are based on various sources (see sections 4.8.2, 4.8.3).

Indicator	Good Condition	Condition Warrants Moderate Concern	Condition Warrants Significant Concern
Extent of Natural Vegetation Cover	<5% of natural land cover has been altered to a non-natural state.	5–15% of natural land cover has been altered to a non-natural state.	>15% of natural land cover has been altered to a non-natural state.
Non-native Plant Cover (interpreted as extent of occurrences across the park unit (i.e., frequency)	< 10% non-native cover	10–25% non-native cover	> 25% non-native cover
White-tailed Deer Population	15–30 deer / sq mi	31–40 deer / sq mi	>40 deer / sq mi
Forest Pests and Diseases	<20% of the forested land is in imminent risk of abnormally high levels of tree mortality	20–40% of the forested land is in imminent risk of abnormally high levels of tree mortality	>40% of the forested land is in imminent risk of abnormally high levels of tree mortality
Forest Vulnerability to Climate Change	No changes in potential habitat under either change scenario.	Minor predicted increases or decreases in habitat for <10 species with no extirpation being predicted under either change scenario.	Major predicted increases or decreases in habitat for >10 species with species extirpation being predicted under either change scenario.

Extent of Natural Vegetation Cover

Guidance from Potyondy and Geier (2011) states that less than 5% of forest cover should be altered over time in order for a watershed to be rated as "good or functioning properly." For this assessment, we will expand forest cover to include all natural vegetation communities. Additionally, reference condition for this assessment will be based on results from the 1954 mapping effort from Coxe (2014). The reference condition rating framework as it relates to the extent of natural vegetation cover is shown in Table 4.8-4.

Non-native Plant Cover

Increasing cover of non-native species is thought to be an indicator of a declining condition (Djuren and Young 2007). In general, non-native 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, although this value varies based on the type and duration of the disturbance regime. For instance, anthropogenic disturbances have been directly linked to species composition in natural areas located within or adjacent to dense metropolitan areas, with these sites often containing non-native plant cover in excess of 40% (Kowarik 2008, Smith and Kuhn 2015).

The ideal condition for vegetation communities at FRST 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 of FRST, we instead quantify "best attainable condition" using guidance from Potyondy and Geier (2011), which states that vegetation communities should contain less than 10% cover of terrestrial non-native invasive species to be rated as "good or functioning properly." The reference condition rating framework as it relates to non-native cover at FRST is shown in Table 4.8-4.

White-tailed Deer Population

The reference condition for white-tailed deer is based on the deer density goal, as outlined in the *Delaware Deer Management Plan 2010–2019* (Rogerson 2010). In determining the deer density goal, the Delaware Division of Fish and Wildlife (DFW) reviewed pertinent scientific research conducted in forest types similar to those in Delaware to determine the approximate number of deer per square mile that would allow for natural forest regeneration and restoration of native species. DFW recommended that the maximum density of deer in the game management unit containing Brandywine Valley should not exceed 40 animals per square mile of deer habitat. The plan also allows for the density target to be adjusted based on adaptive management approaches as a result of vegetation and/or deer population monitoring. This management target is roughly in line with those developed for other NPS units in the region (see section 4.8.1). Following the state objectives, 15–30 deer/sq mi is considered good condition, a density of 30–40 deer/sq mi warrants moderate concern, and a deer population density greater >40 deer/sq mi warrants significant concern rating. The reference condition rating framework as it relates to white-tailed deer at FRST is shown in Table 4.8-4.

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 pest/

disease issues occurred at background levels. Because this type of reference condition is not feasible for a unit with the history of FRST, we instead quantify "best attainable condition" using guidance from Potyondy and Geier (2011), which states that < 20% of the forested land 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." Areas where 20–40% of the forested land is in imminent risk of abnormally high levels of tree mortality are rated as "Warranting Moderate Concern," and areas where >40% of the forested land is in imminent risk of abnormally high levels of tree mortality are rated as "Warranting Significant Concern." Because the NIDRM results are reported in percent basal area loss, for this assessment we will use forest basal area as an equivalent for forest land area. The reference condition rating framework as it relates to forest disease and pest issues at FRST is shown in Table 4.8-4.

Forest Vulnerability to Climate Change

Given the lack of available data for FRST, impacts associated with forest vulnerability to climate change at Brandywine Valley were assessed using results for the nearby VAFO (Fisichelli et. al 2014, Fisichelli 2015). Given VAFO's proximity to FRST the impacts to forests from climate change should be similar. Fisichelli et al. (2014) 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 for 2017–2099 based on the two scenarios. The reference condition rating system for forest vulnerability to climate change at FRST is shown in Table 4.8-4. 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 predicted is given a rating of Moderate Concern; and finally, a major change in potential habitat for >10 species with extirpation predicted for at least some species under either change scenario is given a Degraded or Significant Concern rating.

4.8.4. Condition and Trend

Extent of Natural Vegetation Cover

The extent of natural vegetation cover along with other land cover types has been mapped four times since 1954 (in 1954, 2002, 2007, and 2012) for the Delaware portion of the Woodlawn Tract encompassing most of the Brandywine Valley unit (Figure 4.8-4; Coxe 2014). Mapped land cover types include anthropogenic land uses (e.g., urban) and non-vegetated land and water.

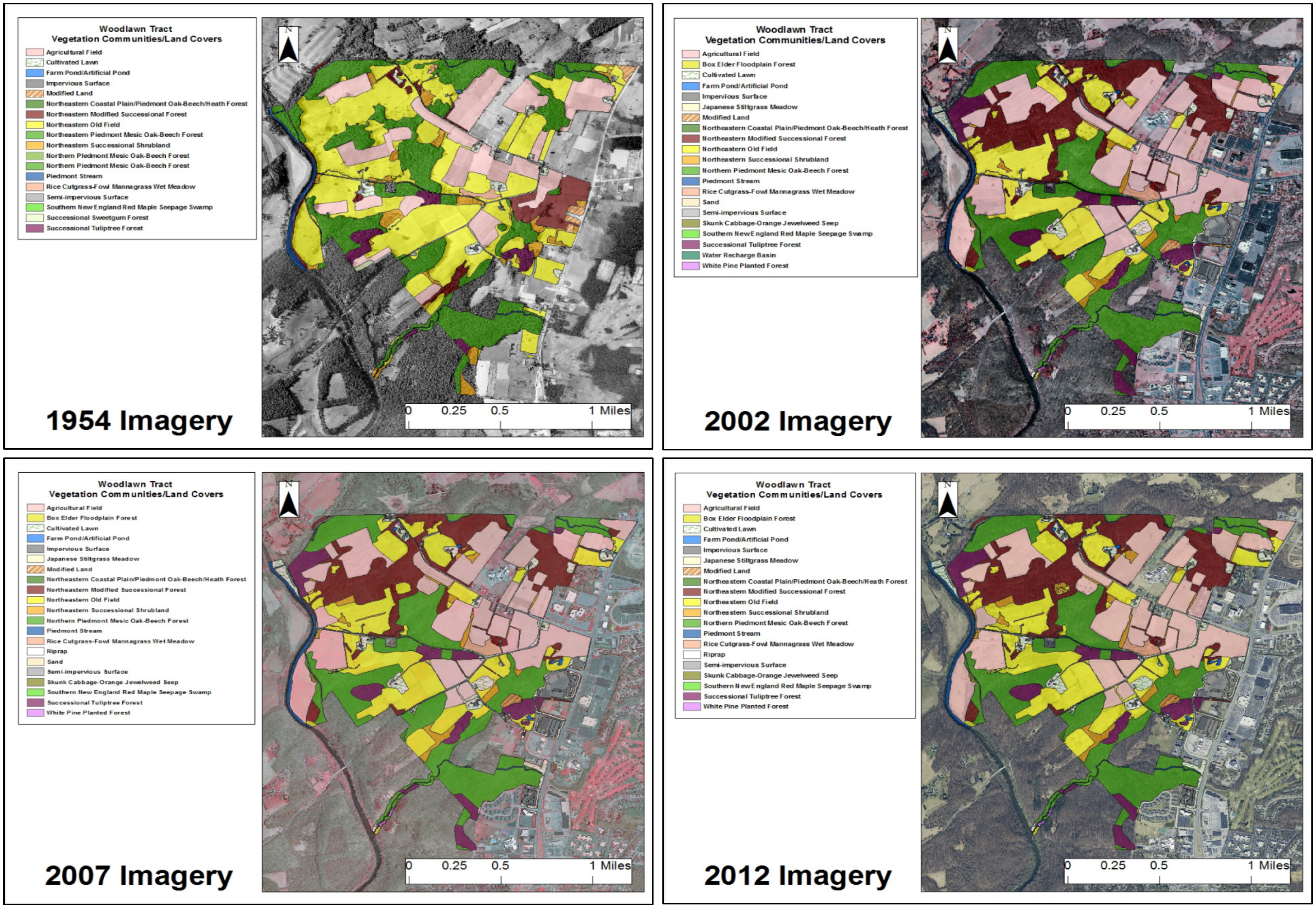


Figure 4.8-4. Vegetation community and land cover maps for four years between 1954 and 2012. Images from Coxe (2014).

The extent of non-natural (e.g., anthropogenic) land use, natural vegetation cover by type (e.g., forest, shrubland, and herbaceous communities), and total natural vegetation cover across all types was calculated for each year (Figure 4.8-5). Percent change was also calculated between 1954 and 2012 for each cover type, including the summed total natural vegetation cover (Table 4.8-5).

Over the 58-year period, changes were marked between 1954 and 2002, and relatively unchanging between 2002 and 2012. Forest cover increased by 25% while shrubland and herbaceous community cover decreased by 35% and 52%, respectively, between 1954 and 2012. Anthropogenic land cover increased 57% over the timeframe. Total natural vegetation (the sum of forest, shrubland, and herbaceous communities—including old fields) decreased by 17% from 1954 to 2012. Overall, a general trend towards decreased natural vegetation cover and increased anthropogenic land cover is observed over the 58-year period. Although human population and associated development are anticipated to increase in the coming decades (see section 4.1 *Land Cover and Land Use*) and may impact natural resources and human dimensions related to the park experience, the aggregate extent of natural vegetation cover may not change appreciably. Moreover, within natural vegetation areas, it is likely that many old fields classified as herbaceous vegetation are already developing into early successional forests. Therefore, the amount of forested area will likely increase in the future.

Park management has yet to determine the specific vision for all areas of the park, including the balance between continued agricultural use and returning previously farmed areas to natural vegetation (Ethan McKinley pers. comm. 2018). If we accept that a certain proportion of the park will continue to be managed as agricultural lands aligned with the park mission, then the remaining areas would be the basis for evaluating degree/extent of departure from natural vegetation cover.

When agricultural areas totaling approximately 350 acres are included in the non-natural vegetation class in 2012, approximately 465 acres out of a total of 12,965 acres or 36% of the land cover is classified as non-natural. If the agricultural acreage is excluded using a similar calculation, then non-natural vegetation occupies approximately 115 acres or about 13% of a total of 965 acres. Therefore, if the vision is to preserve a certain portion of the landscape in an agricultural setting reflecting the park period of significance, then the remaining acreage is currently overwhelmingly "natural."

Using the latter approach and our condition benchmarks in Table 4.8-5, the extent of natural vegetation cover at FRST warrants moderate concern. Based on the 2002–2014 trends summarized in Coxe (2014), the trend in natural vs. non-natural land cover within the Brandywine Valley boundary is unchanging. Due to the *ex post facto* nature of the historic mapping data that relied on present-day interpretation of historic imagery without ancillary data sources, and the fact that only the Delaware portion of the property was mapped, a medium level of confidence is assigned to this assessment.

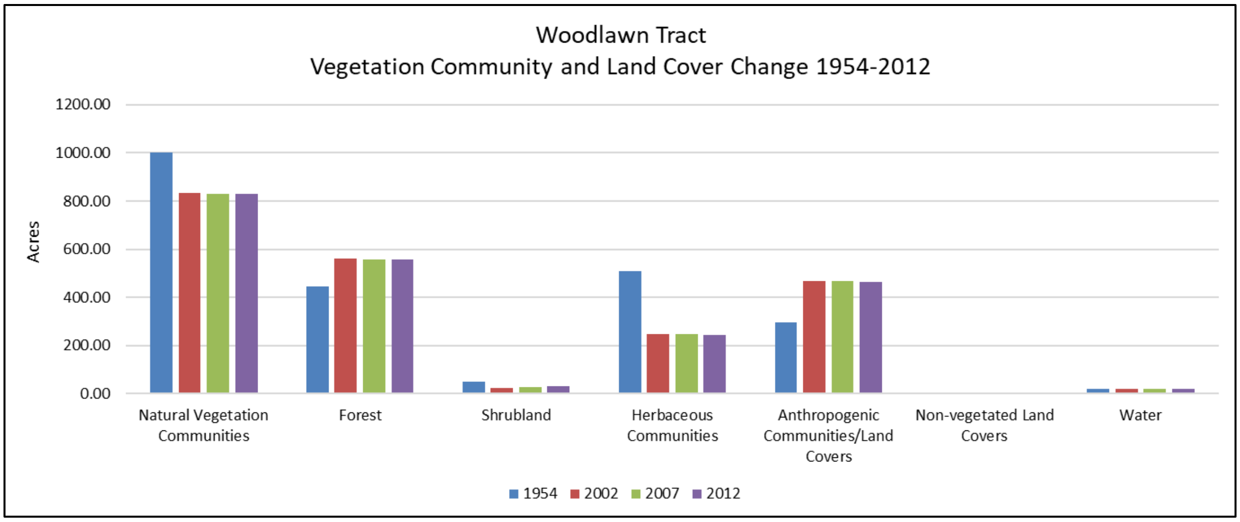


Figure 4.8-5. Extent of natural vegetation and land cover types on the Woodlawn Tract for 1954, 2002, 2007 and 2012. Forest, shrubland and herbaceous community cover values for each year were summed to generate the Natural Vegetation Communities totals. All data from Coxe (2014).

Table 4.8-5. Extent of natural vegetation and land cover types for 1954, 2002, 2007 and 2012. Forest, shrubland and herbaceous community cover values for each year are summed in the Total Natural Vegetation Cover column. Percent change (1954 to 2012) was calculated to determine the deviation from reference condition (1954). Condition status based on ratings from Table 4.8-4. All data from Coxe (2014).

Year	Total Natural Vegetation Cover	Forest	Shrubland	Herbaceous Communities	Anthropogenic Land Covers	Non-vegetated Land Covers	Water
1954	1002.40	444.40	48.00	510.00	295.40	0.0	19.0
2002	832.54	561.50	24.00	247.04	466.00	1.0	18.0
2007	830.54	556.50	27.00	247.04	466.04	0.1	18.0
2012	831.54	555.50	31.00	245.04	465.04	0.0	18.0
Percent Change (1954 to 2012)	−17% [3]	25% [1]	−35% [3]	−52% [3]	57% [3]	0% [1]	−5% [2]

[1] Good condition, also shown in green;

[2] Moderate condition, also shown in yellow;

[3] Degraded condition, also shown in orange.

Non-native Plant Cover

According to Ebert (undated), 761 species were recorded within Brandywine Valley during the 2014 and 2015 surveys including 247 non-native species. Four state-listed noxious weeds occur in the park including three species from the Pennsylvania list and one species on both the Delaware and Pennsylvania lists. Ebert (undated) reported that approximately 32.5% of the species recorded in the park were non-native. Ebert (undated) also reported a local threat level for 53 significant invasives that occurred in the survey area. For this condition assessment, these data were used to evaluate how the extent of non-native plant species has changed over time as well as provide comparison information for reference conditions.

For the available data, presence/absence was interpreted as extent or percentage of the park where the taxon was found. Approximately 32.5% of the species recorded within Brandywine Valley during the 2014 and 2015 survey were non-native. Of the total 247 alien species surveyed, 53 were determined to be significant invasives including four state-listed noxious weeds (Table 4.8-6). Six species, including *Microstegium vimineum* (Japanese stiltgrass), *Lonicera japonica* (Japanese honeysuckle), *Polygonum cespitosum* var. *longisetum* (longbristled smartweed), *Rosa multiflora* (multiflora rose), *Alliaria petiolata* (garlic mustard), and *Celastrus orbiculatus* (Oriental bittersweet) occurred across more than 95% of the park sections. Ten additional species were found across more than 50% of the park sections surveyed. For the 53 species of non-native plants recorded during the 2014 section surveys, the median percent of sections per species was 23%, and the average percent of sections per species was 36%. Twenty-two species were determined to have a high local threat value for FRST (Table 4.8-6; Ebert undated). When the rating system from Potyondy and Geier (2011) is applied and the extent of numerous highly invasive species is considered, the non-native plant cover indicator at FRST warrants significant concern. The trend is unknown due to sampling/survey design differences between 1995 and 2014. Confidence in the assessment is medium.

Table 4.8-6. Significant invasive species, as deteremined by Ebert (undated), present at the Brandywine Valley unit at First State National Historical Park. Four state-listed noxious weeds occur in the park including one from Delaware and four from Pennsylvania (Ebert undated). Plant nomenclature has been updated according to the USDA Plants database (USDA 2019).

Species	Growth Form	% of sections where found in 2014	Local Threat	Regulatory Status
Acer platanoides (Norway maple)	Tree	42%	Medium	–
Aegopodium podagraria (goutweed)	Forb	7%	Medium	–
Ailanthus altissima (tree-of-heaven)	Tree	38%	Medium	–
Alliaria petiolata (garlic mustard)	Forb	97%	High	–
Ampelopsis brevipedunculata (porcelainberry)	Vine	77%	High	–
Arthraxon hispidus (small carpetgrass)	Grass	10%	High, recent	–
Berberis thunbergii (Japanese barberry)	Shrub	62%	High	–
Cardamine impatiens (cut-leaved bittercress)	Forb	35%	Medium	–

* Uncertainty concerning native status

Table 4.8-6 (continued). Significant invasive species, as deteremined by Ebert (undated), present at the Brandywine Valley unit at First State National Historical Park. Four state-listed noxious weeds occur in the park including one from Delaware and four from Pennsylvania (Ebert undated). Plant nomenclature has been updated according to the USDA Plants database (USDA 2019).

Species	Growth Form	% of sections where found in 2014	Local Threat	Regulatory Status
Celastrus orbiculatus (Oriental bittersweet)	Vine	97%	High	–
Cirsium arvense (Canada thistle)	Forb	38%	Medium high	Noxious Weed (DE & PA)
Duchesnea indica (Indian strawberry)	Forb	74%	Medium	–
Elaeagnus umbellata (autumn olive)	Shrub	58%	High	–
Euonymus alatus (winged burningbush)	Shrub	62%	High	–
Euonymus fortunei (winter creeper)	Vine	1%	Low	–
Ficaria verna (lesser celandine)	Forb	41%	Very high	–
Galium mollugo (wild madder)	Forb	22%	Low	–
Glechoma hederacea (ground ivy)	Forb	29%	Medium low	–
Hedera helix (English ivy)	Vine	43%	Medium	–
Hemerocallis fulva (orange daylily	Forb	29%	Low	–
Humulus japonicus (Japanese hops)	Vine	17%	High (local)	–
Ligustrum obtusifolium (broadleaved privet)	Shrub	65%	High	–
Lonicera fragrantissima (fragrant bush honeysuckle)	Shrub	4%	Low	–
Lonicera japonica (Japanese honeysuckle)	Vine	99%	High	–
Lonicera maackii (Amur honeysuckle)	Shrub	88%	High	–
Lonicera morrowii (Morrow’s honeysuckle)	Shrub	22%	Medium high	–
Lonicera standishii (Standish’s honeysuckle)	Shrub	4%	Low?	–

* Uncertainty concerning native status

Table 4.8-6 (continued). Significant invasive species, as deteremined by Ebert (undated), present at the Brandywine Valley unit at First State National Historical Park. Four state-listed noxious weeds occur in the park including one from Delaware and four from Pennsylvania (Ebert undated). Plant nomenclature has been updated according to the USDA Plants database (USDA 2019).

Species	Growth Form	% of sections where found in 2014	Local Threat	Regulatory Status
Lythrum salicaria (purple loosestrife)	Forb	12%	Medium low	–
Malus spp. (crabapple)	Tree	72%	Medium high	–
Microstegium vimineum (Japanese stiltgrass)	Grass	100%	High	–
Miscanthus sinensis (Japanese plumegrass)	Grass	1%	Low	–
Pachysandra terminalis (Japanese pachysandra)	Forb	4%	Medium	–
Paulownia tomentosa (princesstree)	Tree	10%	Low	–
*Phalaris arundinacea** (reed-canary grass)	Grass	39%	High	–
Phellodendron japonicum (Japanese corktree)	Tree	3%	Low now	–
Photinia villosa (photinia)	Shrub	3%	Medium	–
*Phragmites australis** (phragmites)	Grass	4%	High	–
Phyllostachys spp. (giant bamboo)	Shrub	3%	Low	–
Polygonum cespitosum var. *longisetum* (longbristled smartweed)	Forb	99%	High	–
Polygonum cuspidatum (Japanese knotweed)	Forb	7%	High	–
Polygonum perfoliatum (mile-a-minute)	Vine	71%	High	Noxious Weed (PA)
Prunus subhirtella (Higan cherry)	Tree	13%	Medium high	–
Pueraria montana (kudzu)	Vine	1%	Low	Noxious Weed (PA)
Pyrus calleryana (Callery pear)	Tree	14%	High	–
Rhodotypos scandens (jetbead)	Shrub	14%	Medium	–

* Uncertainty concerning native status

Table 4.8-6 (continued). Significant invasive species, as deteremined by Ebert (undated), present at the Brandywine Valley unit at First State National Historical Park. Four state-listed noxious weeds occur in the park including one from Delaware and four from Pennsylvania (Ebert undated). Plant nomenclature has been updated according to the USDA Plants database (USDA 2019).

Species	Growth Form	% of sections where found in 2014	Local Threat	Regulatory Status
Robinia pseudoacacia (black locust)	Tree	13%	High local	–
Rosa multiflora (multiflora rose)	Shrub	99%	High	Noxious Weed (PA)
Rubus phoenicolasius (wineberry)	Shrub	86%	High	–
*Urtica dioica** (stinging nettle)	Forb	23%	Medium high	–
Veronica hederifolia (tawny ironweed)	Forb	16%	Low	–
Viburnum dilatatum (linden viburnum)	Shrub	43%	High	–
Viburnum plicatum (doublefile viburnum)	Shrub	1%	Low now	–
Viburnum setigerum (copperleaf viburnum)	Shrub	1%	Low now	–
Viburnum sieboldii (Siebold's viburnum)	Shrub	7%	Medium	–

* Uncertainty concerning native status

White-tailed Deer Population

The DFW is responsible for monitoring white-tailed deer population trends, density, and health across Delaware including areas in and around Brandywine Valley. Goals and objectives for the DFW deer management program are outlined in Rogerson (2010). Deer population densities (deer/sq mi) across northern Delaware (Deer Management Zone 1) averaged 134.8 deer/sq mi in 2005 and 46.7 deer/sq mi in 2009, which indicates a 65% decline over a four-year period (Rogerson 2010). With an estimated error of +/− 20.75%, the 2009 population for eligible deer habitat within the zone is 37.0–56.4 deer/sq mi. The density for the Brandywine Valley unit may be higher or lower than the estimate for the management unit. The NPS has the authority to manage wildlife within the boundary of the park in consultation with the state.

Based on the data from 2009, the white-tailed deer density of 37.0–56.4 deer/sq mi at FRST warrants significant concern (density >40 deer/sq mi). Because the most recent data available for this indicator are from 2009 and are not for the park locality, we have a medium level of confidence in the assessment. Trend cannot be determined from existing information, but planned deer surveys will help estimate deer densities more precisely and and determine if deer management for the park is needed.

Forest Pests and Diseases

Today, the exotic pest of greatest concern at FRST is the gypsy moth (*Lymantria dispar dispar*). Native to Europe, the gypsy moth was introduced to North America in 1869 and has since decimated forest ecosystems across the eastern U.S. (Figure 4.8-6). The gypsy moth prefers oak species but will also feed on a variety of other hardwoods such as birch (*Betula* spp.), basswood (*Tilia* spp.), maple, hickory, and beech. Defoliation by gypsy moths directly affects trees by reducing their health and vigor, leading to an increased susceptibility to other diseases and pests, potentially resulting in tree mortality. Defoliation and the resulting loss of mature forest can change community structure and function, impact water quality, and reduce the quality of habitat available for wildlife species (NPS 2000). Future impacts to FRST could be significant as the preferred forest type for gypsy moths are oak forests, which make up a significant portion of Brandywine Valley forest cover (Coxe 2014).

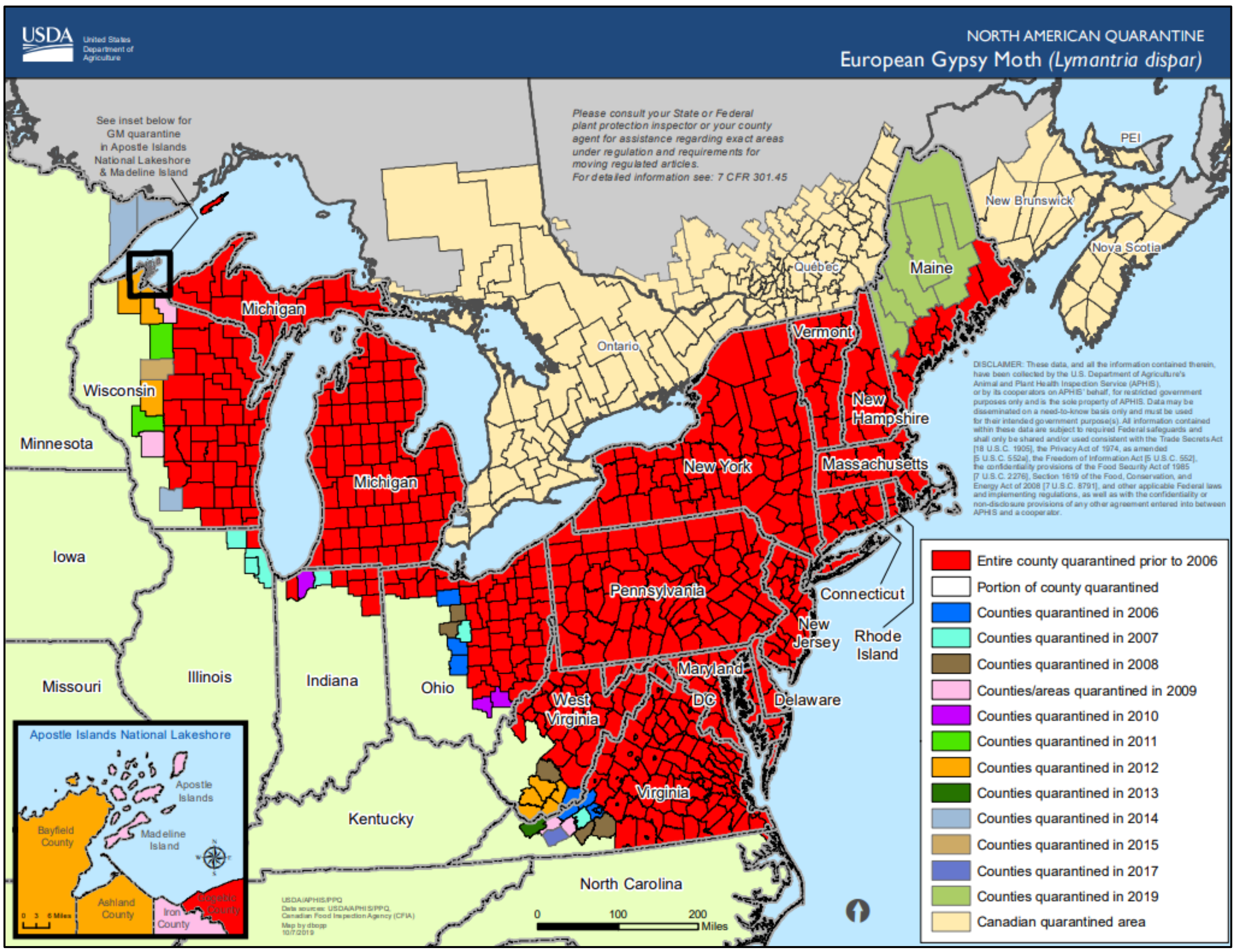
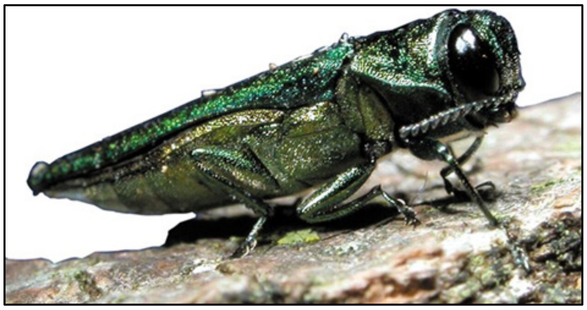


Figure 4.8-6. Gypsy moth quarantine area across the northeastern United States including all of Delaware and Pennsylvania. Map courtesy of USDA APHIS (2019a).

Another species that is just beginning to impact FRST is the emerald ash borer (*Agrilus planipennis*), or EAB, which has recently been documented within New Castle and Sussex counties in Delaware by APHIS and the Delaware Department of Agriculture (DDA). EAB is a wood-boring beetle that kills ash (*Fraxinus* spp.) trees 3 to 5 years after initial infestation. An infestation only becomes evident once the canopy thins due to branch dieback, just as the tree begins to die. EAB has already killed millions of ash trees across the eastern United States and is found in most counties in Delaware and the surrounding states (Figure 4.8-7).



Emerald ash borer (*Agrilus planipennis*). Photo courtesy of NPS.

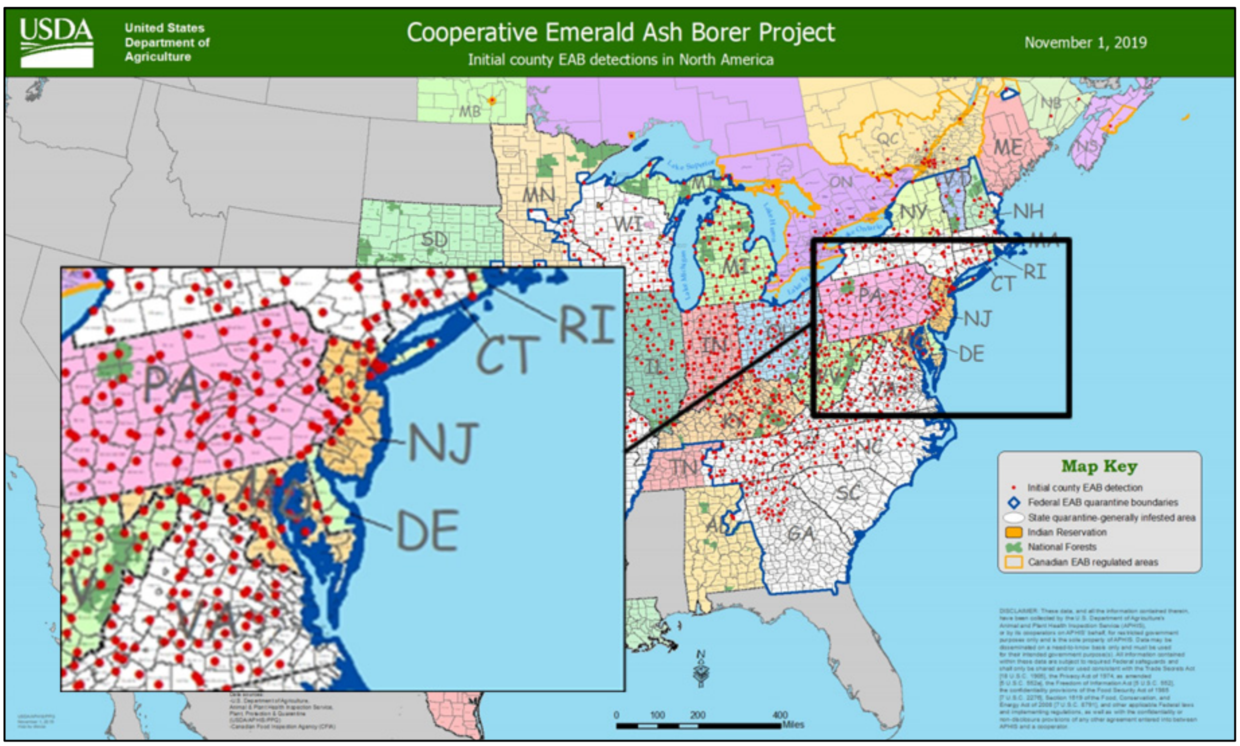


Figure 4.8-7. Emerald ash borer (EAB) range in the United States as of November 1, 2019. EAB has been found in two counties in Delaware and in several surrounding counties in Pennsylvania, New Jersey, and Maryland. Map adapted from USDA APHIS (2019b).

A new forest pest species recently documented at the Brandywine Valley unit at FRST is the spotted lanternfly (*Lycorma delicate*), a destructive invasive planthopper native to China, India, and Vietnam (DDA 2020). The spotted lanternfly impacts many host trees including *Juglans* spp., and *Salix* spp. along with ornamental trees, orchards, hops, and grapes. The insect appears to depend on the invasive tree-of-heaven (*Ailanthus altissima*) to reproduce (DDA 2020). This insect has the potential to impact interstate commerce and could be extremely detrimental to Delaware's agricultural industries, the natural environment, and residential areas (DDA 2020). In a February 2019, a quarantine area was establishied in northern DE and southern PA including the Brandywine Valley unit at FRST (DDA 2020; Figure 4.8-8).

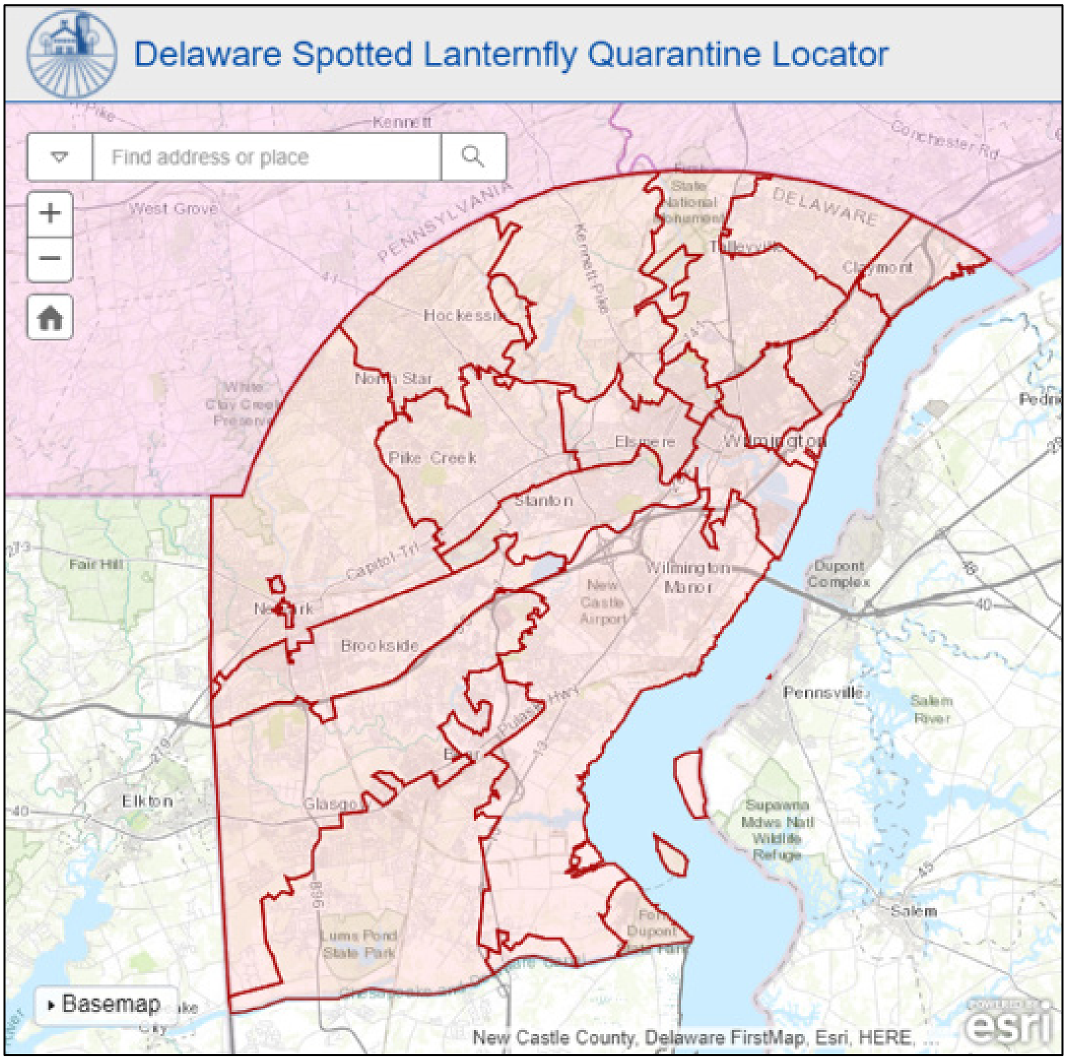


Figure 4.8-8. Spotted lanternfly quarantine area across northern Delaware and southern Pennsylvania. Map courtesy of DDA (2020).

Given the lack of available data for FRST, impacts associated with forest diseases and pests at Brandywine Valley were assessed using results for the nearby VAFO (Fisichelli et. al 2014, Fisichelli 2015). Including the gypsy moth and emerald ash borer, Fisichelli et al. (2014) and Fisichelli (2015) identified 55 tree pests and diseases that are or could be at Valley Forge (Table 4.8-7). Eight additional pest and disease species were added to the list based on concerns from the DFS (DFS 2009, 2019). Tree species affected by these diseases and pests include, but are not limited to, red and white oak species, red maple, ash species, beech, American elm, and sassafras (*Sassafras albidum*).

Table 4.8-7. Non-native tree pests and diseases with infestation areas that may include First State National Historical Park. Detection scale is the finest spatial scale at which infestation data were available for the park area. Original table from Fisichelli (2015).

Scientific Name	Common Name	Detection Scale
Acantholyda erythrocephala	pine false webworm	county
Adelges abietis	eastern spruce gall adelgid	state
Adelges tsugae	hemlock woolly adelgid	county
Agrilus planipennis [1,2]	emerald ash borer	state
Anarsia lineatella	peach twig borer	state
Anoplophora glabripennis [1]	Asian longhorned beetle	NA
Anthracnose spp. [1]	anthracnose fungus	county
Asterolecanium minus	oak pit scale	county
Asterolecanium variolosum	golden oak scale	state
Caliroa cerasi	pear sawfly	state
Callidellum rufipenne	Japanese cedar longhorn beetle	county
Carulaspis juniperi	juniper scale	county
Caulocampus acericaulis	maple petiole borer	state
Cephalcia lariciphila	European web-spinning larch sawfly	state
Coleophora laricella	larch casebearer	county
Contarinia baeri	European pine needle midge	state
Cronartium ribicola	white pine blister rust	county
Cryphonectria parasitica	chestnut blight	county
Cryptodiaporthe populea	Dothichiza canker of poplar	county
Cryptorhynchus lapathi	poplar-and-willow borer	state
Cyrtepistomus castaneus	Asiatic oak weevil	state
Dendroctonus frontalis (*native*) [1]	southern pine bark beetle	state
Diaspidiotus perniciosus	San Jose scale	state
Diprion similis	introduced pine sawfly	county
Discula destructiva	dogwood anthracnose	county
Dryocosmus kuriphilus	chestnut gall wasp	state
Epinotia nanana	European spruce needleminer	state
Eulecanium cerasorum	calico scale	state
Fenusa pusilla	birch leafminer	state
Fiorinia externa	elongate hemlock scale	state
Gilpinia hercyniae	European spruce sawfly	state
Homadaula anisocentra	mimosa webworm	state
Hylastes opacus	European bark beetle	county

[1] Species added to list based on concerns from DFS (2009, 2019)

[2] Species confirmed in Delaware in 2016 (USDA APHIS 2019b).

Table 4.8-7 (continued). Non-native tree pests and diseases with infestation areas that may include First State National Historical Park. Detection scale is the finest spatial scale at which infestation data were available for the park area. Original table from Fisichelli (2015).

Scientific Name	Common Name	Detection Scale
Kaliofenusa ulmi	elm leafminer	state
Lepidosaphes ulmi	oystershell scale	state
Lycorma delicatula [1]	spotted lanternfly	county
Lymantria dispar	gypsy moth	county
Matsucoccus resinosae	red pine scale	state
Nectria coccinea	beech bark disease	county
Neodiprion sertifer	European pine sawfly	state
Ophiostoma novo-ulmi	Dutch elm disease	state
Otiorhynchus ovatus	strawberry root weevil	state
Otiorhynchus sulcatus	black vine weevil	state
Periphyllus lyropictus	Norway maple aphid	state
Phyllaphis fagi	woolly beech aphid	state
Physokermes piceae	spruce bud scale	state
Phytophthora cinnamomi	littleleaf disease / phytophthora root rot	state
Phytophthora ramorum [1]	sudden oak death	NA
Plagiodera versicolora	imported willow leaf beetle	county
Popillia japonica	Japanese beetle	county
Pristiphora erichsonii	larch sawfly	county
Pristiphora geniculata	mountain-ash sawfly	state
Rhyacionia buoliana	European pine shoot moth	state
Scolytus multistriatus	smaller European elm bark beetle	state
Scolytus schevyrewi	banded elm bark beetle	state
Sirex noctilio [1]	Sirex woodwasp	state
Sirococcus clavigignenti juglandacearum	butternut canker	county
Taeniothrips inconsequens	pear thrips	county
Tomicus piniperda	pine shoot beetle	county
Trichiocampus viminalis	poplar sawfly	state
Venturia saliciperda	willow scab	state
Xanthogaleruca luteola	elm leafbeetle	state
Xylella fastidiosa [1]	bacterial leaf scorch	county

[1] Species added to list based on concerns from DFS (2009, 2019)

According to the modeled results from the 2013–2027 NIDRM (Krist et al. 2014), only 2% of FRST (i.e., Middle Brandywine Creek Watershed HUC 020402050402) is thought to be susceptible to high levels of tree mortality (defined as mortality in excess of 25% over the 15-year period running from 2013 to 2027) (Figure 4.8-9). Modeled losses in basal area for specific tree species at VAFO (used as a surrogate for FRST due to its proximity) include a 31% decline in ash species due to EAB, a 21% decline in oak species due to oak decline, a 30% decline in beech due to beech bark disease, and a 22% decline in American elm due to Dutch elm disease (Krist et al. 2014). All modeled results assume no active management over the timeframe (Krist et al. 2014).

Based on the condition rating framework (Table 4.8-5) and the best available data, including modeled data from the NIDRM, the forest pest and disease indicator at FRST is considered to be in good condition. A deteriorating trend is assigned due to ongoing impacts of existing pests, primarily on oaks and beech, and forecasted future impacts on ashes and other species as pest species become more established in the FRST area. Due to the modeled nature of these data and the use of data from the nearby VAFO, a medium level of confidence is assigned.

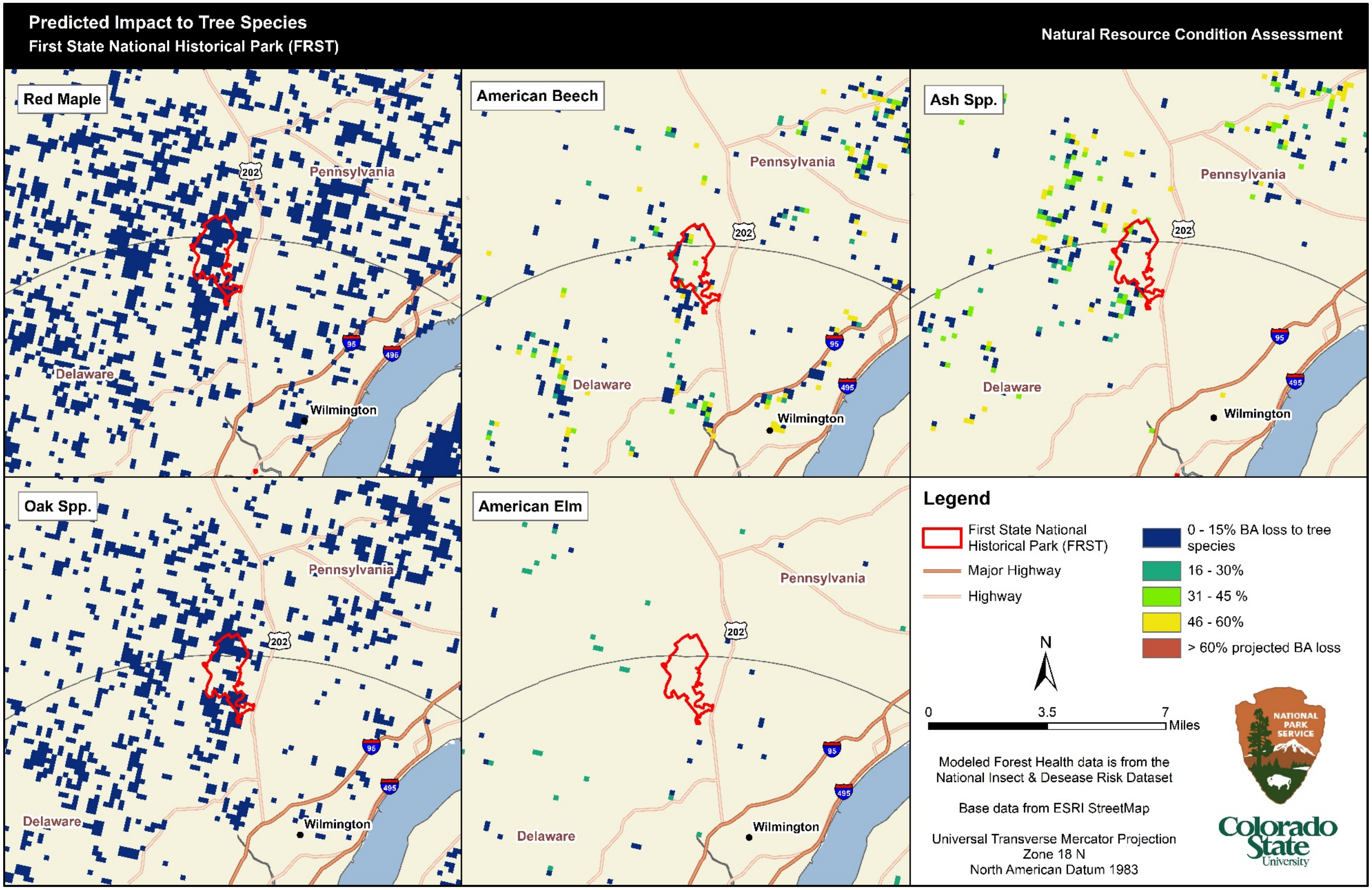


Figure 4.8-9. Modeled predicted impacts to five tree species from 2013 to 2027 at the Brandywine Valley Unit of First State National Historical Park based on the results of the NIDRM (Krist et al. 2014). Data indicate predicted loss in tree basal area (BA) due to a variety of forest diseases and pests.

Forest Vulnerability to Climate Change

Predicted changes to climate at FRST are substantial, based on modeled data from Fisichelli (2015) for the nearby VAFO (Table 4.8-8) and section 4.2 of this report (Climate Change). Indications are that the climate in this region is already becoming hotter, possibly wetter, and is potentially more prone to more extreme weather events. Trends in the indicators are projected to continue or accelerate by the end of the century. Predicted changes to forest habitats are shown in Table 4.8-9. 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, a large decrease is a ratio ≤ 0.5, meaning that in 2100, less than or equal to 50% of the 1990 habitat will still be suitable for that species. A small decrease is defined as a ratio > 0.5 and ≤ 0.8, no change is > 0.8 and ≤ 1.2, a small increase is > 1.2 and ≤ 2.0, and a large increase is > 2.0). A species is predicted to be extirpated if modeling indicates there will be no suitable habitat in 2100.

Table 4.8-8. Modeled changes in climate from baseline (1961–1990) to future (2070–2099) based on two climate change scenarios. These data were used to predict impacts to individual tree species at Valley Forge National Historic Site near First State National Historical Park. Data from Fisichelli (2015).

Climate Variable	Baseline (1961–1990)	Least Change (2070–2099)	Major Change (2070–2099)
Mean annual temperature	10.8 °C (51.5 °F)	+2.2 °C (+3.9 °F)	+7.3 °C (+13.2 °F)
Mean January temperature	−1.4 °C (29.6 °F)	+1.8 °C (+3.3 °F)	+5.9 °C (+10.6 °F)
Mean July temperature	23 °C (73.4 °F)	+2 °C (+3.6 °F)	+8.6 °C (+15.5 °F)
Seasonality (July–January temp.)	24.3 °C (43.8 °F)	+0.2 °C (+0.3 °F)	+2.7 °C (+4.9 °F)
Mean May–September temp.	19.9 °C (67.8 °F)	+2.2 °C (+4 °F)	+7.9 °C (+14.3 °F)
Annual precipitation	1133 mm (44.6 in)	+10.7 %	+16.5 %
May–September precipitation	522 mm (20.6 in)	+7.2 %	+11 %

Modeled results indicate that 15 tree species will face small-to-large decreases in potential habitat under either climate change scenario (Table 4.8-9). Additionally, two of these species are predicted to face extirpation by the year 2100 regardless of scenario (i.e., *Picea glauca* and *Populus grandidentata*). Nineteen species are predicted to see an increase in suitable habitat by 2100 and three species are predicted to have no change in their potential habitat under either climate change scenario (Table 4.8-9). Predicted impacts from climate change were not always straightforward as 24 species were predicted to have mixed impacts from the two scenarios. Fisichelli (2015) also predicted 21 new species' ranges could expand into FRST resulting in new species or communities occurring within the park by the year 2100. While the exact degree of impacts from climate change to individual species is unknown at FRST, modeled results from Fisichelli (2015) predict that FRST forest communities likely will be dramatically different in the future in the face of a changing climate.

Based on the best available data, the indicator of forest vulnerability to climate change at FRST appears to be in a degraded condition warranting significant concern. Major increases or decreases in potential habitat range is predicted for over 75 tree species under one or both climate change scenarios. A decreasing trend is also applied to this indicator due to the high potential for future impacts to FRST forest communities from climate change. We assign a low level of confidence to this assessment due to the modeled nature of the data and the use of data from VAFO.

Table 4.8-9. Modeled predicted changes in potential habitat for tree species at First State National Historical Park (2100 compared with 1990) based on data from Fisichelli et al. (2014) and Fisichelli (2015). Species are grouped based on change class designations for two future climate scenarios: Least Change and Major Change.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
Decreases in Potential Habitat	*Acer rubrum*	red maple	small decrease	large decrease
	Betula lenta	sweet birch	large decrease	large decrease
	Catalpa speciosa	northern catalpa	large decrease	large decrease
	Chamaecyparis thyoides	Atlantic white-cedar	large decrease	large decrease
	Fraxinus americana	white ash	small decrease	large decrease
	Liriodendron tulipifera	yellow-poplar	small decrease	large decrease
	Picea glauca	white spruce	extirpated	extirpated
	Pinus rigida	pitch pine	small decrease	small decrease
	Pinus strobus	eastern white pine	large decrease	extirpated
	Pinus virginiana	Virginia pine	small decrease	large decrease
	Populus grandidentata	bigtooth aspen	extirpated	extirpated
	Prunus serotina	black cherry	large decrease	large decrease
	Quercus coccinea	scarlet oak	small decrease	large decrease
	Quercus montana	chestnut oak	small decrease	large decrease
	Quercus rubra	northern red oak	small decrease	large decrease
No Change in Potential Habitat	*Carpinus caroliniana*	American hornbeam	no change	no change
	Nyssa sylvatica	blackgum	no change	no change
	Tsuga canadensis	eastern hemlock	no change	no change
Increases in Potential Habitat	*Carya ovata*	shagbark hickory	small increase	small increase
	Carya tomentosa	mockernut hickory	small increase	small increase
	Celtis occidentalis	hackberry	large increase	large increase
	Diospyros virginiana	common persimmon	large increase	large increase
	Ilex opaca	American holly	small increase	small increase
	Juniperus virginiana	eastern redcedar	small increase	small increase

Table 4.8-9 (continued). Modeled predicted changes in potential habitat for tree species at First State National Historical Park (2100 compared with 1990) based on data from Fisichelli et al. (2014) and Fisichelli (2015). Species are grouped based on change class designations for two future climate scenarios: Least Change and Major Change.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
Increases in Potential Habitat (continued)	*Liquidambar styraciflua*	sweetgum	small increase	large increase
	Nyssa sylvatica var. *biflora*	swamp tupelo	large increase	large increase
	Ostrya virginiana	eastern hophornbeam	small increase	large increase
	Pinus echinata	shortleaf pine	large increase	large increase
	Pinus taeda	loblolly pine	large increase	large increase
	Platanus occidentalis	sycamore	small increase	large increase
	Quercus falcata	southern red oak	large increase	large increase
	Quercus muehlenbergii	chinkapin oak	small increase	large increase
	Quercus palustris	pin oak	small increase	small increase
	Quercus phellos	willow oak	large increase	large increase
	Quercus stellata	post oak	large increase	large increase
	Salix nigra	black willow	small increase	large increase
	Ulmus rubra	slippery elm	small increase	small increase
Mixed Results	*Acer negundo*	boxelder	small increase	small decrease
	Acer saccharinum	silver maple	small decrease	large increase
	Acer saccharum	sugar maple	small increase	extirpated
	Asimina triloba	pawpaw	large increase	large decrease
	Betula nigra	river birch	extirpated	large increase
	Carya cordiformis	bitternut hickory	no change	large increase
	Carya glabra	pignut hickory	small increase	small decrease
	Cercis canadensis	eastern redbud	small increase	large decrease
	Cornus florida	flowering dogwood	no change	small decrease
	Fagus grandifolia	American beech	no change	large decrease
	Fraxinus pennsylvanica	green ash	no change	small increase

Table 4.8-9 (continued). Modeled predicted changes in potential habitat for tree species at First State National Historical Park (2100 compared with 1990) based on data from Fisichelli et al. (2014) and Fisichelli (2015). Species are grouped based on change class designations for two future climate scenarios: Least Change and Major Change.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
Mixed Results (continued)	*Juglans cinerea*	butternut	no change	large decrease
	Juglans nigra	black walnut	no change	extirpated
	Maclura pomifera	osage-orange	small decrease	large increase
	Magnolia virginiana	sweetbay	no change	large increase
	Morus rubra	red mulberry	large decrease	large increase
	Populus deltoides	eastern cottonwood	no change	large increase
	Quercus alba	white oak	small increase	no change
	Quercus bicolor	swamp white oak	no change	small decrease
	Quercus ilicifolia	bear oak	small decrease	no change
	Quercus velutina	black oak	no change	small decrease
	Robinia pseudoacacia	black locust	no change	large decrease
	Sassafras albidum	sassafras	no change	large decrease
	Ulmus americana	American elm	no change	large increase
New Potential Habitat	*Carya illinoinensis*	pecan	–	new entry
	Carya texana	black hickory	new entry	new entry
	Celtis laevigata	sugarberry	new entry	new entry
	Gleditsia triacanthos	honeylocust	–	new entry
	Nyssa aquatica	water tupelo	new entry	new entry
	Oxydendrum arboreum	sourwood	–	new entry
	Persea borbonia	redbay	–	new entry
	Pinus elliottii	slash pine	new entry	new entry
	Pinus palustris	longleaf pine	new entry	new entry
	Pinus serotina	pond pine	–	new entry
	Quercus pagoda	cherrybark oak	new entry	new entry

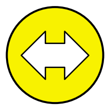
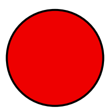
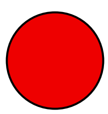
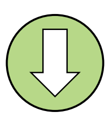
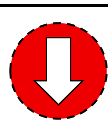
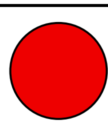
Table 4.8-9 (continued). Modeled predicted changes in potential habitat for tree species at First State National Historical Park (2100 compared with 1990) based on data from Fisichelli et al. (2014) and Fisichelli (2015). Species are grouped based on change class designations for two future climate scenarios: Least Change and Major Change.

Change in Potential Habitat	Scientific Name	Common Name	Least Change	Major Change
New Potential Habitat (continued)	*Quercus imbricaria*	shingle oak	new entry	new entry
	Quercus laevis	turkey oak	–	new entry
	Quercus laurifolia	laurel oak	–	new entry
	Quercus macrocarpa	bur oak	–	new entry
	Quercus marilandica	blackjack oak	new entry	new entry
	Quercus nigra	water oak	new entry	new entry
	Quercus shumardii	Shumard oak	–	new entry
	Taxodium distichum	baldcypress	new entry	new entry
	Ulmus alata	winged elm	new entry	new entry
	Ulmus crassifolia	cedar elm	–	new entry

Condition Summary

The indicators examined suggest the condition of forest communities at FRST warrants significant concern (Table 4.8-10).

Table 4.8-10. Condition and trend summary for forest communities, First State National Historical Park (FRST).

Indicator	Condition Status/Trend	Rationale
Extent of Natural Vegetation Cover		When agricultural areas are excluded as part of the desired landscape, approximately 13% of the land cover is classified as natural vegetation cover. Forested areas will increase as old fields develop into forest communities. Anthropogenic land use areas are not currently increasing within the Brandywine Valley boundaries.
Non-native Plant Cover/Frequency of Occurrence		For the 53 significant invasive species of non-native plants recorded during the 2014 section surveys, the average percent of occupied survey sections per species was 36%. Six species, including *Microstegium vimineum* (Japanese stiltgrass), *Lonicera japonica* (Japanese honeysuckle), *Polygonum cespitosum* var. longisetum (longbristled smartweed), *Rosa multiflora* (multiflora rose), *Alliaria petiolata* (garlic mustard), and *Celastrus orbiculatus* (Oriental bittersweet) occurred across more than 95% of the surveyed sections. Ten additional species were found across more than 50% of the park sections surveyed. Twenty-two species were determined to have a high local threat value for FRST.
White-tailed Deer Population		Deer population densities (deer/sq mi) across northern Delaware averaged 134.8 deer/sq mi in 2005 and 46.7 +/−9.7 deer/sq mi in 2009. While the deer density may vary across Delware deer management zone 1A, the deer density at the Brandywine Valley unit is unknown. The trend for this indicator is currently unknown.
Forest Pests and Diseases		A variety of forest disease and pest issues are impacting or are predicted to impact FRST. Based on modeled results from the NIDRM, only 2% of FRST is thought to be susceptible to high levels of tree mortality over the 15-year period from 2013 to 2027. The predicted declines in particular species (e.g., 31% decline in ash species) may warrant moderate concern. A deteriorating trend is assigned due to ongoing impacts of existing pests, primarily on oaks and beech, and forecasted future impacts on ashes (emerald ash borer) and other species. Confidence in the results is medium due to the modeled nature of the data and the use of data from the nearby Valley Forge National Historical Park.
Forest Vulnerability to Climate Change		A number of species are predicted to be severely impacted by a changing climate at FRST. A low confidence level is placed on this assessment due to the modeled nature of the data.
Overall		**The condition of forest communities at FRST warrants significant concern with an unknown trend. Confidence in the assessment is medium.**

Overall trends are difficult to assess but there are indications that current forest conditions will change in the near future. Over decadal or longer time frames, diseases, pests, other stressors, changes in disturbance processes, and changes in climate have the potential to drastically affect future forest composition and structure (Fisichelli et al. 2014, Fisichelli 2015). The combined and synergistic effects of these factors along with other anthropogenic disturbances (e.g., fire suppression, urban development, hydrologic changes) will determine the future trajectory of FRST forest condition.

4.8.5. Uncertainty and Data Gaps

Uncertainty exists about the interactive and synergistic effects of anthropogenic stressors, white-tailed deer populations, forest health, and climate change impacts. Additional modeling and continued vegetation monitoring should be done to help understand these cumulative impacts and better inform park managers of the likely future makeup of FRST vegetation communities. Other gaps and needs identified during this assessment include:

- Strategic invasive plant species management given the abundance and dominance of many invasive plant species.
- A comprehensive inventory of forest areas exhibiting late successional and old-growth characteristics and potential. Such areas occur on FRST, are rare within the state, and often harbor rare species and high levels of diversity.
- Classification and mapping of vegetation communities using the U.S. National Vegetation Classification System.
- Monitoring of vegetation beyond the initial survey work. There is currently no landscape or community-scale vegetation monitoring in the park.
- Expanded forest restoration, prescribed fire, species re-introductions, and long-term ecological monitoring of restoration and management effectiveness.
- Rare plant inventories and monitoring.

4.8.6. Sources of Expertise

- Nicholas Fisichelli, President and CEO, the Schoodic Institute (https://schoodicinstitute.org/).
- Robert Coxe, Delaware Natural Heritage and Endangered Species Program, Delaware Division of Fish and Wildlife. Vegetation communities and mapping.

4.8.7. Literature Cited

Alverson, W. S., D. W. Waller, and S. L. Solheim. 1988. Forests to deer: edge effects in northern Wisconsin. Conservation Biology 2:348–358.

Anderson, R. C. 1994. Height of white-flowered trillium (*Trillium grandiflorum*) as an index of deer browsing intensity. Ecological Applications 4:104–109.

Augustine, D. J., and D. deCalesta. 2003. Defining deer overabundance and threats to forest communities: from individual plants to landscape structure. Ecoscience 10:472–486.

Barton, A. and W. Keeton, editors. 2018. Ecology and Recovery of Eastern Old-growth Forests. Island Press, Washington, D.C.

Behrend, D. F., G. F. Mattfeld, W. D. Tierson, and J. E. Wiley III. 1970. Deer density control for comprehensive forest management. Journal of Forestry 68:695–700.

Berryman, A. A. 1986. Forest insects: principles and practice of population management. Plenum Press, New York City, New York.

Bowersox, T. W., D. S. Larrick, G. L. Storm, and W. M. Tzilkowski. 2002. Regenerating mixed-oak historic woodlots at Gettysburg National Military Park. Technical Report NPS/PHSO/NRTR-02/086. School of Forest Resources, Pennsylvania State University, University Park, Pennsylvania.

Castello, J. D., D. J. Leopold, and P. J. Smallidge. 1995. Pathogens, patterns, and processes in forest ecosystems. BioScience 45(1):16–24.

Coxe, R. 2014. Historical analysis and map of vegetation communities, land covers, and habitats of the Woodlawn Tract, New Castle County, Delaware. Report submitted to the National Park Service Mid-Atlantic Network, Inventory and Monitoring Program.

Davis, M. B. 1996. Eastern Old-growth Forests: Prospects for Rediscovery and Recovery. Island Press, Washington, D.C.

deCalesta, D. S. 1994. Effects of white-tailed deer on songbirds within managed forests in Pennsylvania. Journal of Wildlife Management 58:711–718.

deCalesta, D. S. 1995. Effect of white-tailed deer and silvicultural practices on herbs and shrubs in northern hardwood forests. Bulletin of the Ecological Society of America 76:318.

Delaware Department of Agriculture (DDA). 2020. Spotted lanternfly quarantine. Available at: https://agriculture.delaware.gov/plant-industries/spotted-lanternfly/.

Delaware Forest Service (DFS). 2009. Delaware forest resource assessment. Delaware Department of Agriculture.

DFS. 2010. Delaware statewide forest strategy. Delaware Department of Agriculture Report to the U.S. Forest Service.

DFS. 2019. Delaware forest health highlights. Delaware Department of Agriculture.

Delcourt, H. R., and P. A. Delcourt. 2000. Eastern deciduous forests. Pages 357–396 *in* M. G. Barbour and W. D. Billings, editors. North American Terrestrial Vegetation, second edition. Cambridge University Press, Cambridge, United Kingdom.

Djuren, C. M., and C. C. Young. 2007. Invasive Exotic Plant Monitoring at Cuyahoga Valley National Park: Year 1 (2007). Natural Resource Technical Report NPS/HTLN/NRTR-2007/063. National Park Service, Fort Collins, Colorado.

Ebert, J. Undated. First State National Historical Park botanical inventory and assessment. Report prepared for the Brandywine Conservancy.

Fisichelli, N. A., S. R. Abella, M. Peters, and F. J. Krist, Jr. 2014. Climate, trees, pests, and weeds: change, uncertainty, and biotic stressors in eastern U.S. national park forests. Forest Ecology and Management 327:31–39.

Fisichelli, N. A. 2015. Climate, trees, pests, and weeds: change, uncertainty, and biotic stressors at Valley Forge National Historical Park. NPS Climate Change Response Program, National Park Service, Fort Collins, Colorado.

Hagan, J. M., and A. A. Whitman. 2005. Final report, Northeastern Region late-successional/old-growth (LSOG) dialogue, April 27–28, 2005. National Commission on Science for Sustainable Forestry.

Hix, D. M., P. C. Goebel, and H. L. Whitman. 2011. Canopy gap characteristics of an old-growth and an adjacent second-growth beech-maple stand in North-Central Ohio. Proceedings of the 17th Central Hardwood Forest Conference GTR-NRS-P-78, pages 177–185.

Horsley, S. B., S. L. Stout, and D. S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13(1):98–118.

Hough, A. F. 1965. A twenty-year record of understory vegetation change in a virgin Pennsylvania Forest. Ecology 46:370–373.

Kowarik, I. 2008. On the role of alien species in urban flora and vegetation. Urban Ecology:321–338.

Krist, F. J., J. R. Ellenwood, M. Woods, A. McMahan, J. Cowardin, D. Ryerson, F. Sapio, M. Zweifler, and S. A. Romero. 2014. 2013–2027 National Insect and Disease Forest Risk Assessment. FHTET-14-01. U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team, Fort Collins, Colorado.

Marquis, D. A. 1981. Effect of deer browsing on timber production in Allegheny hardwood forests of northwestern Pennsylvania. Northeastern Forest Experiment Station, U.S. Department of Agriculture, Forest Service, Broomall, Pennsylvania.

National Park Service (NPS). 1996. The effects of deer browsing on white-flowered trillium in Cuyahoga Valley National Park. Cuyahoga Valley National Recreation Area, Brecksville, Ohio.

NPS. 2000. Final Gypsy Moth Management Plan and Environmental Assessment Cuyahoga Valley National Park, National Park Service U.S. Department of the Interior. Dec. 2000.

NPS. 2009. Final White-tailed Deer Management Plan/Environmental Impact Statement, Valley Forge Natinoal Historical Park. National Park Service.

NPS. 2011. Final White-tailed Deer Management Plan/Environmental Impact Statement, Rock Creek Park. National Park Service.

NPS. 2014a. Final White-tailed Deer Management Plan/Environmental Impact Statement, Cuyahoga Valley National Park. National Park Service, Brecksville, Ohio.

NPS. 2014b. Final White-tailed Deer Management Plan/Environmental Impact Statement, Antietam and Monocacy National Battlefields, Manassas National Battlefield. National Park Service.

NPS. 2016. Inventory and Monitoring, Eastern Deciduous Forest Ecosystem. Available at: https://www.nps.gov/im/ncrn/eastern-deciduous-forest.htm.

NatureServe. 2019. NatureServe Explorer web site, ecological communities. Available at: https://explorer.natureserve.org/ (accessed 14 September 2019).

Old-Growth Forest Network. 2019. Old-Growth Forest Network web site. Available at: https://www.oldgrowthforest.net/ (accessed 12/5/2020).

Pennsylvania Department of Conservation and Natural Resources (PA DCNR). 2013. White-tailed deer plan 2013–2018. Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, Ecological Services.

Petit, L. J. 1998. Impacts of white-tailed deer on forest understory birds in the Cuyahoga Valley National Recreation Area and surrounding public forest lands. Progress report, Cuyahoga Valley National Recreation Area, Brecksville, Ohio.

Potyondy, J. P., and T. W. Geier. 2011. Watershed condition classification technical guide. FS978. U.S. Forest Service, Washington, D.C.

Quigley, P. 2011. Preliminary ecological research and assessment in support of the Woodlawn Trustees Vision Plan.

Rogerson, J. 2010. Delaware deer management plan 2010–2019. A guide to how and why deer are managed in the First State. Delaware Department of Natural Resources & Environmental Control, Division of Fish and Wildlife Game Species Management Program.

Royo, A. A., S. L. Stout, D. S. deCalesta, T. G. Pierson. 2010. Restoring forest herb communities through landscape-level deer herd reductions: is recovery limited by legacy effects? Biological Conservation 143:2425–2434. Available at: http://www.nrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_royo_002.pdf.

Sage, R. W., W. F. Porter, and H. B. Underwood. 2003. Windows of opportunity: white-tailed deer and the dynamics of northern hardwood forests of the Northeastern U.S. Journal for Nature Conservation 10:213–220.

Smith, P., and B. Kuhn. 2015. Survey and Assessment of Critical Urban Wetlands: City and County of Denver, EPA Wetland Grant, Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 14:1267–1276.

Stolte, K. W. 1997. 1996 national technical report on forest health, FS-605. U.S. Department of Agriculture, Forest Service Southern Research Station, Asheville, North Carolina.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3):524–532.

U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS). 2019a. Gypsy Moth program overview. Available at: https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/gypsy-moth (accessed 15 November 2019).

U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS). 2019b. Emerald Ash Borer program overview. Available at: https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/emerald-ash-borer (accessed 15 November 2019).

U.S. Department of Agriculture (USDA). 2019. The PLANTS database. National Plant Data Team, U.S. Department of Agriculture, Greensboro, North Carolina. Available at: http://plants.usda.gov (accessed 30 October 2019).

U.S. National Vegetation Classification (USNVC). 2019. United States national vegetation classification database, version 2.03. Federal Geographic Data Committee, Vegetation Subcommittee, Washington D.C. Available at: http://www.usnvc.org (accessed 30 October 2019).

Vitousek, P. M., C. M. D'Antonio, L. L. Loope, and R. Westbrooks. 1996. Biological invasions as global environmental change. American Scientist 84(5):218–228.

White, M. A. 2012. Long-term effects of deer browsing: composition, structure, and productivity in a northeastern Minnesota old-growth forest. Forest Ecology and Management 269:222–228.

Widmann, R. H., D. Balser, C. Barnett, B. J. Butler, D. M. Griffith, T. W. Lister, W. K. Moser, C. H. Perry, P. Riemann, and C. W. Woodall. 2009. Ohio Forests 2006. Resource Bulletin NRS-36. U.S. Forest Service, Northern Research Station, Newtown Square, Pennsylvania. Available at: http://www.nrs.fs.fed.us/pubs/rb/rb_nrs36.pdf (accessed 15 November 2016).

Woods, A. J., J. M. Omernik, D. D. Brown, and C. W. Kiilsgaard. 1996. Level III and IV Ecoregions of Pennsylvania and the Blue Ridge Mountains, the Ridge and Valley, and the Central

Appalachians of Virginia, West Virginia, and Maryland. EPA/600R-96/077. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. Available at: https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-epa-region.

Zawadzkas, P. P., and W. G. Abrahamson. 2003. Composition and tree-size distributions of the Snyder-Middleswarth old-growth forest, Snyder County, Pennsylvania. Castanea 68(1):31–42.

4.9. Birds

4.9.1. Background and Importance

Birds are an important component of park ecosystems. Their prominent position in most food webs makes them a good sentinel of local and regional ecosystem change (Ladin et al. 2016). Birds are also conspicuous components of parks, with high "public interest" value. Moreover, birds are sensitive to habitat features such as canopy structure, nesting sites, food supplies, and escape cover (Adams and Matthews 2019, Bradfer-Lawrence et al. 2018). The NPS Mid-Atlantic Inventory and Monitoring Network uses forest breeding birds as a biotic indicator to assess the effects of habitat loss and fragmentation because they are highly visible, are a reliable indicator of ecological integrity, face numerous population threats in the region, and are good indicators of changes in ecosystems (Stolen et al. 2005, Butler et al. 2012, Johnson 2014). Birds are excellent indicators of ecological condition because they occur across a continuum of anthropogenic disturbances, species assemblages are predictive of these disturbance levels, birds are easily detected and through the use of numerous standardized methods they 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). Understanding changes in the number and composition of birds may help direct management actions used to restore and maintain the landscape at FRST.

The oak forests, mesic hardwood forests, wetland, and pastureland at the Brandywine Valley unit of FRST have the potential to support bird foraging and nesting habitat and both resident and migrating bird species. The rich food resources found throughout the diversity of habitats within the park make it regionally important for a wide variety of avian species. The oak and hardwood forests of the eastern United States and their associated wetlands have been significantly reduced in geographic extent since European settlement, including a four percent decline in the late twentieth century (Drummond and Loveland 2010). This ongoing decline has been caused by multiple factors. Three of the most prominent causes in the northeastern coastal zone are development, conversion to agriculture, and timber harvesting (Drummond and Loveland 2010). This change in the hardwood forests of the region has impacted the avian fauna of the region since the 1970s (Rosenberg et al. 2019). The NPS formally recognizes this decline and the need to understand the long-term trends in community composition and abundance of breeding bird populations, and how understanding these trends offers one measure of a park's ecosystem integrity (Comiskey and Callahan 2008). Ecosystem integrity refers to the system's ability to maintain a balanced, integrated, adaptive community of species having a composition, diversity, and functional organization comparable to that of the natural habitats of the region (Karr and Dudley 1981).

The oak forest, mixed hardwood forest, and wetland habitat present at FRST support wintering, feeding, and breeding populations of both resident and migrating avian species. Because of the lack of urban development relative to the surrounding landscape, FRST is especially valuable by providing relatively unfragmented patches of native oak forest, hardwood forest, and wetlands that serve as a refuge within a highly altered landscape. However, habitat fragmentation outside the park can negatively impact populations of some breeding and resident birds at FRST, 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 abundance in these habitats is important for detecting ecosystem change caused by these outside activities. Avian community composition and diversity should improve with the restoration of the oak forest, hardwood forest, and wetland communities within both FRST and the surrounding landscape (Johnson 2006, Boren et al. 1999).

Threats

The primary threats to the birds at the Brandywine Valley unit are habitat loss and fragmentation associated with the high rates of human population growth in the region (Watts 1999). A summary of recent changes in the vicinity of the park are presented in section 4.1, *Land Cover and Land Use*. Maintaining functional natural ecosystems in the face of population growth and associated development is the greatest conservation challenge faced by avian biologists within the region. Hardwood forests have been reduced to a fraction of their original size by agricultural, urban, and suburban development. Nearly 95% of the original habitat types of the region have been lost (Dettmers and Rosenburg 2000). Practically no old growth forest remains in this ecoregion and there are no blocks of intact habitat more than 250 km^2 in area (Davis et al 2019). The remaining forests have been subjected to ongoing disturbances (e.g., selective timber harvests, fragmentation, modified fire regime, exotic insects, and disease), causing a decline in their quality (Steinkamp 2008, Watson 2014). Of these disturbances, fragmentation has had the greatest impact on forest birds (Steinkamp 2008, Watson 2014). This habitat loss and fragmentation has disrupted ecological functions important to ecosystem integrity and important to maintaining the community and composition of species at FRST comparable to that of the natural habitat of the region (Jørgensen and Müller 2000). Consequently, the ecological functioning of FRST depends upon maintaining the natural systems within and outside the park boundaries.

Changes in land use are linked to ecological function by five mechanisms (Hansen and Gryskiewicz 2003): 1. land use activities reduce the functional size of a reserve, eliminating important ecosystem components lying outside the park boundary; 2. land use activities alter the flow of energy or materials across the landscape irrespective of the park's political boundary, disrupting the ecological processes dependent upon those flows both outside and inside the park and across its boundaries; 3. habitat conversion outside the park may eliminate unique habitats, such as seasonal habitats and migration corridors; 4. the negative influences of land use activities may extend into the park and create edge effects; and 5. increased population density may directly impact parks through increased recreation and human disturbance.

Indicators and Measures

- Bird index of biotic integrity (IBI)

4.9.2. Data and Methods

Little historical survey data exist for FRST. Comprehensive and statistically rigorous bird sampling using the point count method have not been completed at FRST. Walking surveys of the Brandywine Valley unit were done in 2014 and 2015 (DNREC 2015, Stoner 2014, White 2015), producing data suitable for an IBI analysis. The 2014 survey was conducted during August through October, while the 2015 survey was conducted in September and October.

A bird index of biotic integrity was calculated using the protocol created for the NPS Mid-Atlantic Inventory and Monitoring Network breeding bird survey monitoring project (Johnson 2014). 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. 2003). The bird IBI takes advantage of the fact that avian guilds, or groups of species occupying similar ecological niches, are diverse and can be used for assessing response to environmental changes and ecosystem stressors. Changes in the environment can impact guilds, causing changes in bird community species composition and diversity (Severinghaus 1981, Verner 1984). Guilds are defined based on foraging behavior and substrate, nesting substrate, migratory distance, and various other life history traits (Johnson 2014). Assessments using a bird IBI generate a quantitative metric that is used to define the ecological integrity of a sampled area based on the avian community present. The bird IBI measures how changes in habitat quality that birds within a guild are dependent upon impacts the representation of that guild within the entire bird community of the assessed site (Johnson 2014).

Guilds are ranked based on specialization, with specialist guilds receiving higher weights than generalist guilds. Specialist guilds included in the IBI tend to be associated with oak forest and old growth hardwood forest. Therefore, higher IBI scores reflect bird communities associated with aspects of mature oak and hardwood forests that include natural plant communities with intact functionality. For example, sites with higher bird IBI scores consist of a bird community with more interior forest-dependent species, park probers, upper canopy foragers, ground foragers, and single-brooded species (i.e. specialists) but with fewer urban/suburban, exotic, and nest predators/brood parasite species (i.e. generalists). An extensive discussion for why these guilds are chosen over others can be found in O'Connell et al. (2003).

To calculate the IBI score, species are first assigned to guilds after O'Connell et al. (2003) (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 4 (naturalistic) to 1 (humanistic) (O'Connell et al. 2003, Johnson 2014). For specialist guilds, the highest occurring category is ranked a "4," the next highest a "3," etc. For generalist guilds, the ranking is reversed; a "4" is assigned to the least occurring category. Therefore, a site can receive a rank of "4" 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.

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 absolute scale from 0.25–1.00 as determined by O'Connell et al. (2003).

The biotic or ecological "condition" described by the bird IBI therefore falls along a disturbance gradient from relatively intact, extensive, oak and hardwood forest with high IBI scores to more disturbed, developed or urban forest with low IBI scores. The response guilds incorporated into the bird IBI are listed in Table 4.9-1. Some bird guilds are not present in the park.

Table 4.9-1. Bird species guilds used to calculate IBI scores (from O'Connell et al. 2003).

Biotic Integrity Element	Guild Category	Response Guild	Number of Species in Guild	Guild Classification
Functional	Insectivore Foraging Behavior	bark prober	6	specialist
	Insectivore Foraging Behavior	upper canopy forager	9	specialist
	Insectivore Foraging Behavior	ground forager	3	specialist
Compositional	Number of Broods	single-brooded	26	specialist
	Population Limiting	nest predator/brood parasite	5	generalist
	Origin	exotic	2	generalist
Structural	Primary Habitat	interior forest	14	specialist
	Primary Habitat	urban/suburban	20	generalist

4.9.3. Reference Conditions

Quality of the bird community composition as defined by the IBI score is determined by comparing the score to thresholds recommended by O'Connell et al. (2003), including four categories of condition corresponding to the proportional species richness of each specialist guild and generalist guild. These thresholds include the following categories: humanistic (0.250–0.460), moderately disturbed (0.461–0.600), largely intact (0.601–0.730), and naturalistic (0.731–1.00). The condition classes were modified by combining the top two categories to determine the resource condition indicator scoring for the FRST bird IBI using a three-tiered rating system (Table 4.9-2).

Table 4.9-2. Resource condition rating framework for birds at First State National Historical Park, Delaware (adapted from O'Connell et al. 2003).

Indicator	Condition Status		
	Resource is in Good Condition	Condition Warrants Moderate Concern	Condition Warrants Significant Concern
Index of Biotic Integrity	0.601–1.00	0.461–0.600	0.250–0.460

4.9.4. Condition and Trend

The bird IBI score of 0.59 indicates that composition of the bird community at the Brandywine Valley unit of FRST warrants moderate concern, but the score is at the threshold between moderate concern and good condition (Table 4.9-2).

A total of 111 species were identified at the Brandywine Valley unit of FRST during the 2014 and 2015 surveys (Table 4.9-3), 58 species in specialist guilds and 27 species in generalist guilds (Table 4.9-1). Nineteen of those species are considered species of conservation concern either nationally or locally by Partners in Flight (PIF) (https://partnersinflight.org) or are listed as endangered by the State of Delaware. PIF is 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).

Table 4.9-3. Bird species recorded in 2014 and 2015 at First State National Historic Park, Delaware. Data from Stoner (2014), DNREC (2015) and White (2015).

Common name	Scientific name	Order	Breeding and Seasonal Occurrence [1]
Acadian flycatcher [2]	***Empidonax virescens***	**Passeriformes**	**Sb**
American crow	*Corvus brachyrhychos*	Passeriformes	Yb
American goldfinch	*Spinas tristis*	Passeriformes	Yb
American kestrel [2]	***Falco sparverius***	**Falconiformes**	**Yb**
American redstart	*Setophaga ruticillia*	Passeriformes	M
American robin	*Turdus migratorius*	Passeriformes	Yb
Bald eagle	*Haliaeetus leucocephalus*	Accipitriformes	M
Baltimore oriole	*Icterus galbula*	Passeriformes	Sb
Barn swallow	*Hirundo rustica*	Passeriformes	Sb
Barred owl	*Strix varia*	Strigiformes	Yb
Belted kingfisher	*Megaceryle alcyon*	Coraciiformes	Yb
Black and white warbler	*Mniotilta varia*	Passeriformes	M
Black vulture	*Coragyps atratus*	Cathartiformes	Yb
Black-throated blue warbler	*Setophaga caerulescens*	Passeriformes	M
Black-throated green warbler	*Setophaga virens*	Passeriformes	M
Blue grosbeak	*Passerina caerulea*	Passeriformes	Sb
Blue jay	*Cyanocitta cristata*	Passeriformes	Yb
Blue-gray gnatcatcher	*Polioptila caerulea*	Passeriformes	Sb
Broad-winged hawk [2]	***Buteo platypterus***	**Accipitriformes**	**M**
Brown thrasher [2]	***Toxostoma rufum***	**Passeriformes**	**Sb, W**
Brown-headed cowbird	*Molothrus ater*	Passeriformes	Yb
Canada goose	*Branta canadensis*	Anseriformes	Yb, M, W
Canada warbler	*Cardellina canadensis*	Passeriformes	M
Carolina chickadee	*Poecile carolinensis*	Passeriformes	Yb
Carolina wren [2]	***Thryothorus ludovicianus***	**Passeriformes**	**Yb**
Cedar waxwing	*Bombycilla cedrorum*	Passeriformes	Yb

[1] Occurrence codes are as follows: B = potential breeder, Yb = year round and potential breeder, Ynb = year-round and non-breeder, Sb = summer and potential breeder, Snb = summer and non-breeder, W = winter, and M = migrant.

[2] Species of conservation concern, also shown in bold.

Table 4.9-3 (continued). Bird species recorded in 2014 and 2015 at First State National Historic Park, Delaware. Data from Stoner (2014), DNREC (2015) and White (2015).

Common name	Scientific name	Order	Breeding and Seasonal Occurrence [1]
Chestnut-sided warbler	*Setophaga pensylvanica*	Passeriformes	M
Chimney swift	*Chaetura pelagica*	Apodiformes	Yb
Chipping sparrow	*Spizella passerina*	Passeriformes	Yb
Common grackle	*Quiscalus quiscula*	Passeriformes	Yb
Common merganser	*Merous merganser*	Anseriformes	M, W
Common yellowthroat	*Geothlypis trichas*	Passeriformes	Sb
Connecticut warbler [2]	***Oporornis agilis***	**Passeriformes**	**M**
Cooper's hawk	*Accipiter cooperii*	Accipitriformes	M, W
Dark-eyed junco	*Junco hyemalis*	Passeriformes	W
Downy woodpecker	*Dryobates pubescens*	Piciformes	Yb
Eastern bluebird	*Sialia sialis*	Passeriformes	Yb
Eastern kingbird	*Tvrannus tyrannus*	Passeriformes	Sb
Eastern phoebe	*Sayornis phoebe*	Passeriformes	Sb
Eastern screech owl	*Megascops asio*	Strigiformes	Yb
Eastern towhee [2]	***Pipilo erythrophythalmus***	**Passeriformes**	**Yb**
Eastern wood-pewee [2]	***Contopus virens***	**Passeriformes**	**Sb**
Field sparrow [2]	***Spizella pusilla***	**Passeriformes**	**Yb**
Fox sparrow	*Passerella iliaca*	Passeriformes	–
Golden-crowned kinglet	*Regulus satrapa*	Passeriformes	M, W
Gray catbird [2]	***Dumetella carolinensis***	**Passeriformes**	**Sb**
Gray-cheeked thrush	*Catharus minimus*	Passeriformes	–
Great blue heron	*Ardea herodias*	Pelecaniformes	Snb
Great crested flycatcher	*Myiarshus crinitus*	Passeriformes	Sb
Great egret [2]	***Ardea albus***	**Pelecaniformes**	**Snb**
Great horned owl	*Bubo virginianus*	Strigiformes	Yb
Green heron	*Butorides virescens*	Pelecaniformes	Sb
Hairy woodpecker	*Dryobates villosus*	Piciformes	Yb
Hermit thrush	*Catharus guttatus*	Passeriformes	W
House finch	*Haemorhous mexicanus*	Passeriformes	Yb
House sparrow	*Passer domesticus*	Passeriformes	–
House wren	*Troalodytes aedon*	Passeriformes	Sb

[1] Occurrence codes are as follows: B = potential breeder, Yb = year round and potential breeder, Ynb = year-round and non-breeder, Sb = summer and potential breeder, Snb = summer and non-breeder, W = winter, and M = migrant.

[2] Species of conservation concern, also shown in bold.

Table 4.9-3 (continued). Bird species recorded in 2014 and 2015 at First State National Historic Park, Delaware. Data from Stoner (2014), DNREC (2015) and White (2015).

Common name	Scientific name	Order	Breeding and Seasonal Occurrence [1]
Indigo bunting	*Passerina cvanea*	Passeriformes	Sb
Louisiana waterthrush [2]	***Parkesia montacilla***	**Passeriformes**	**Sb**
Magnolia warbler	*Setophaga magnolia*	Passeriformes	M
Mallard	*Anas platyrhynchos*	Anseriformes	Yb
Mourning dove	*Zenaida macroura*	Columbiformes	Yb
Northern cardinal	*Cardinalis cardinalis*	Passeriformes	Yb
Northern flicker	*Colaptes auratus*	Piciformes	Yb
Northern harrier [2]	***Circus hudsonius***	**Accipitriformes**	**M, W**
Northern mockingbird	*Mimus polygottos*	Passeriformes	Yb
Northern parula	*Setophaga americana*	Passeriformes	Sb, M
Northern rough-winged swallow	*Stelgidooteryx serripennis*	Passeriformes	Sb
Orchard oriole	*Icterus spurius*	Passeriformes	Sb
Osprey	*Pandion haliaetus*	Accipitriformes	M
Ovenbird	*Seiurus aurocapilla*	Passeriformes	Sb
Palm warbler	*Setophaga palmarum*	Passeriformes	M
Pileated woodpecker	*Dryocoous pileatus*	Piciformes	Yb
Prairie warbler	*Setophaga discolor*	Passeriformes	M
Purple martin	*Progne subis*	Passeriformes	Sb
Red-bellied woodpecker	*Melanerpes carolinus*	Piciformes	Yb
Red-breasted nuthatch	*Sitta canadensis*	Passeriformes	M, W
Red-eyed vireo	*Vireo olivaceus*	Passeriformes	Sb
Red-shouldered hawk	*Buteo lineatus*	Accipitriformes	Yb
Red-tailed hawk	*Buteo jamaicensis*	Accipitriformes	Yb
Red-winged blackbird	*Aaelaius phoeniceus*	Passeriformes	Yb
Ring-billed gull	*Larus delawarensis*	Charadriiformes	Ynb
Rock pigeon	*Columbia livia*	Columbiformes	Yb
Rose-breasted grosbeak	*Pheucticus ludovicianus*	Passeriformes	M
Ruby-crowned kinglet	*Regulus calendula*	Passeriformes	M
Ruby-throated hummingbird	*Archilochus colubris*	Apodiformes	Yb
Savannah sparrow	*Passerculus sandwichensis*	Passeriformes	–
Scarlet tanager [2]	***Piranga olivacea***	**Passeriformes**	**Sb**

[1] Occurrence codes are as follows: B = potential breeder, Yb = year round and potential breeder, Ynb = year-round and non-breeder, Sb = summer and potential breeder, Snb = summer and non-breeder, W = winter, and M = migrant.

[2] Species of conservation concern, also shown in bold.

Table 4.9-3 (continued). Bird species recorded in 2014 and 2015 at First State National Historic Park, Delaware. Data from Stoner (2014), DNREC (2015) and White (2015).

Common name	Scientific name	Order	Breeding and Seasonal Occurrence [1]
Sharp-shinned hawk	*Accipiter striatus*	Accipitriformes	M, W
Snow goose	*Anser caerulescens*	Anseriformes	M
Song sparrow	*Melospiza melodia*	Passeriformes	Yb
Spotted sandpiper	*Actitus macularia*	Charadriiformes	M
Swainson's thrush	*Catharus ustulatus*	Passeriformes	–
Swamp sparrow	*Melospiza melodia*	Passeriformes	–
Tree swallow	*Tachycineta bicolor*	Passeriformes	Sb
Tufted titmouse	*Baeolophus bicolor*	Passeriformes	Yb
Turkey vulture	*Cathartes aura*	Accipitriformes	Yb
Veery	*Catharus fuscescens*	Passeriformes	Sb
Warbling vireo	*Vireo gilvus*	Passeriformes	Sb
White-breasted nuthatch	*Sitta carolinensis*	Passeriformes	Yb
White-eyed vireo [2]	***Vireo ariseus***	**Passeriformes**	**Sb**
White-throated sparrow	*Zonotrichia albicollis*	Passeriformes	M, W
Willow flycatcher	*Empidonax trailii*	Passeriformes	Sb
Wood duck	*Aix sponsa*	Anseriformes	Sb, M
Wood thrush [2]	***Hylocichia mustelina***	**Passeriformes**	**Sb**
Yellow warbler	*Setophaga petechia*	Passeriformes	Sb
Yellow-bellied sapsucker	*Sphyrapicus varius*	Piciformes	M, W
Yellow-billed cuckoo [2]	***Coccyzus americanus***	**Cuculiformes**	**Sb**
Yellow-breasted chat [2]	***Icteria virens***	**Passeriformes**	**Sb**
Yellow-rumped warbler	*Setophaga coronata*	Passeriformes	M,W
Yellow-throated vireo [2]	***Vireo flavifrons***	**Passeriformes**	**–**

[1] Occurrence codes are as follows: B = potential breeder, Yb = year round and potential breeder, Ynb = year-round and non-breeder, Sb = summer and potential breeder, Snb = summer and non-breeder, W = winter, and M = migrant.

[2] Species of conservation concern, also shown in bold.

Condition Summary

The value for the bird IBI indicates the bird community at FRST warrants moderate concern. Numerous species within the interior forest and single-brooded specialist guilds were detected, along with many species in the urban/suburban generalist guild and few in the bark prober and ground forager specialist guilds (Table 4.9-1). This community structure is representative of a moderately disturbed landscape (Table 4.9-4). No trend assessment is currently possible for this measure of condition due to the lack of monitoring data for the Brandywine Valley unit. Comprehensive data collected from across the entire unit are only available for two years, 2014 and 2015. For these reasons the confidence in the assessment is low.

Table 4.9-4. Condition and trend summary for birds at First State National Historic Park, Delaware.

Indicator	Condition Status/Trend	Rationale
Bird Index of Biotic Integrity		The bird IBI score was 0.59 (warrants moderate concern). However, the score is near the threshold between moderate concern and good condition.
Overall		**The resource warrants moderate concern with an unknown trend. Confidence in the assessment is low.**

Even though the condition of the bird community at the Brandywine Valley unit as measured by our metric warrants moderate concern, it is still an important park resource. First, the score is at the threshold between moderate concern and good condition (Table 4.9-2). Second, the threat posed to birds in the eastern United States by development makes FRST an important resource in the effort to prevent additional declines of eastern bird species. Third, the American kestrel (*Falco sparverius*), broad-winged hawk (*Buteo platypterus*), and northern harrier (*Circus hudsonius*) are listed as endangered in Delaware by Natural Resources and Environmental Control and an additional 16 species identified at the park are considered of conservation concern by PIF (Table 4.9-3). Consequently, the Brandywine Valley unit of FRST has an important role to play in conservation of bird populations both at the park and within the surrounding landscape.

4.9.5. Uncertainty and Data Gaps

Confidence in this assessment is low and the trend cannot be assessed statistically. The key uncertainty related to the assessment of the bird community at FRST is the lack of available data. Survey data were limited to only two sampling periods (2014 and 2015) and no subsequent monitoring data were available. Therefore, the trend for birds was not determined. Further uncertainty in the assessment stems from the methods used to collect the available survey data. Inventory surveys documented species detected on site; however, the lack of detection of a species does not equate to a local extirpation. The absence of a species may be an artifact of the sampling design or the seasonal timing of the survey. Also, this assessment is based upon data collected by two different independent observers who may vary in their skills of bird identification. This variation could introduce bias into the data making it difficult to identify statistically significant trends in the indicator (Dornelas et al. 2012). Another significant source of uncertainty is the inability to correct for incomplete detection during surveys, which can influence estimates of both abundance and community richness.

Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades rather than the two years available for this assessment (Holmes 2010, Magurran et al. 2010). It is preferred that birds be sampled at randomly-selected sites, rather than at subjectively-located, expert-selected sites as was done for the surveys at FRST. The data should be collected over an extended time period to compensate for the natural temporal fluctuation in bird presence and detectability and to assure accuracy of the assessment (Dornelas et al. 2012).

The implementation of a monitoring program for birds at FRST should avoid differences in sampling effort among the years monitored. If monitoring of multiple sites is instituted at FRST, then sampling all sites or at least a subset using all of the same sites every year will minimize spatial variability among the data over time. Since the sampling effort can be related to the number of detections, such an approach can confound the results and make it difficult to identify whether differences in the indicator values, by year, result from true changes in the resource or are an artifact of the variation in sampling effort. Sampling the same sites and the same number of sites in every year of monitoring would help minimize this variability and bias.

Another factor affecting the quality of the data is the probability that a bird that is present during the time the survey is occurring is detected. A protocol relying on a 5 to 10-minute count interval may assist in detecting any species that are present. Also, surveying more than once per year will increase the likelihood that less vocal species are detected. Detecting as many bird species as possible is essential for generating the most accurate index of biotic integrity, which is calculated based on the number of species within different guilds.

4.9.6. Sources of Expertise

- Jim White of Hyla Associates, Hockessin, Delaware, conducted the 2015 bird survey at the Brandywine Valley unit of FRST. Mr. White is currently the coordinator for region 1 of the DNREC-administered Delaware Breeding Bird Survey, which is where the Brandywine Valley unit is located.
- Derek Stoner of Derek Stoner Consulting, Hockessin, Delaware, and past president of the Delaware Ornithological Society conducted the 2014 bird survey at Brandywine Valley.

4.9.7. Literature Cited

Adams, B. T., and S. N. Matthews. 2019. Diverse temperate forest bird assemblages demonstrate closer correspondence to plant species composition than vegetation structure. Ecography 42: 1752–1764.

Bibby, C. J, N. D. Burgess, D. A. Hill and S. Mustoe. 2000. Bird Census Techniques, second edition. Academic Press, London, United Kingdom.

Boren J. C., D. M. Engle, M. W. Palmer, R. E. Masters, and T. Criner. 1999. Land use change effects on breeding bird community composition. Journal of Range Management 52:420–430.

Browder, S. F., D. H. Johnson, and I. J. Ball. 2002. Assemblages of breeding birds as indicators of grassland condition. USGS Northern Prairie Wildlife Research Center. Paper 201. Available at: http://digitalcommons.unl.edu/usgsnpwrc/201 (accessed 23 February 2013).

Bradfer-Lawrence, T., N. Gardner, and D. H. Dent. 2018. Canopy bird assemblages are less influenced by habitat age and isolation than understory bird assemblages in Neotropical secondary forest. Ecology and Evolution 8:5586–5597. doi:10.1002/ece3.4086.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310.

Butler, S. J., R. P. Freckleton, A. R. Renwivk, and K. Norris. 2012. An objective, niche-based approach to indicator species selection. Methods in Ecology and Evolution 3:317–326.

Comiskey, J. A., and K. K. Callahan. 2008. Mid-Atlantic Network vital signs monitoring plan. Natural Resource Report NPS/MIDN/ NRR—2008/071. National Park Service, Fort Collins, Colorado.

Davis, M., W. Eichbaum, and J. Adams. 2019. Northeastern coastal forests. World Wildlife Fund, Washington, D.C. Available at: https://www.worldwildlife.org/ecoregions/na0411 (accessed 16 October 2019).

Delaware Department of Natural Resources and Environmental Control (DNREC). 2015. Bird surveys of the Brandywine Tract, New Castle County, Delaware. Prepared by Jim White.

Dettmers, R., and K. Rosenberg. 2000. Partners in Flight Bird Conservation Plan for Southern New England. Cornell Lab of Ornithology, Ithaca, NY.

Devictor V., R. Julliard, J. Clavel, F. Jiguet, A. Lee, and D. Couvet. 2008. Functional biotic homogenization of bird communities in disturbed landscapes. Global Ecology and Biogeography 17:252–261.

Dornelas, M., A. E. Magurran, S. T. Buckland, A. Chao, R. L. Chazdon, R. K. Colwell, T. Curtis, K. J. Gaston, N. J. Gotelli, M. A. Kosnik, B. McGill, J. L. McCune, H. Morlon, P. J. Mumby, L. Ovreas, A. Studeny, and M. Vellend. 2012. Quantifying temporal change in biodiversity: challenges and opportunities. Proceedings of The Royal Society B 280:1–10.

Drummond, M. A., and T. R. Loveland. 2010. Land-use pressure and a transition to forest-cover loss in the eastern United States. BioScience 60: 286–298.

Hansen, A., and D. Gryskiewicz. 2003. Interactions between Heartland National Parks and surrounding land use change: development of conceptual models and indicators for monitoring. Final Report to the National Park Service Heartland Network. National Park Service, Fort Collins, Colorado.

Holmes, R. T. 2010. Avian population and community processes in forest ecosystems: Long-term research in the Hubbard Brook Experimental Forest. Forest Ecology and Management 262:20–32.

Johnson, T. N. 2006. Ecological restoration of tallgrass prairie: grazing management benefits plant and bird communities in upland and riparian habitats. Thesis. Kansas State University, Manhattan Kansas.

Johnson, M. J. 2014. Breeding bird monitoring: Mid-Atlantic Network 2013 summary report. Natural Resource Data Series NPS/MIDN/NRDS—2014/736. National Park Service, Fort Collins, Colorado.

Jørgensen, S. E., and F. Müller, editors. 2000. Handbook of Ecosystem Theories. CRC Publishers, New York, New York.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 5:55–68.

Keinath, D. A., D. F. Doak, K. E. Hodges, L. R. Prugh, W. Fagan, C. H. Sekercioglu, S. H. M. Buchart, M. Kauffman, and K. Bohning-Gaese. 2017. A global analysis of traits predicting species sensitivity to habitat fragmentation. Global Ecology and Biogeography 26:115–127.

Ladin, Z. S., C. D. Higgins, J. P. Schmit, G. Sanders, M. J. Johnson, A. S. Weed, M. R. Marshall, J. P. Campbell, J. A. Comiskey, and W. G. Shriver. 2016. Using regional bird community dynamics to evaluate ecological integrity within national parks. Ecosphere 7(9):e01464. 10.1002/ecs2.1464.

La Sorte, F. A. 2006. Geographical expansion and increased prevalence of common species in avian assemblages: implications for large-scale patterns of species richness. Journal of Biogeography 33:1183–1191.

Magurran, A. E., S. R. Baillie, S. T. Buckland, J. McP. Dick, D. A. Elston, E. M. Scott, R. I. Smith, P. J. Somerfield, and A. D. Watt. 2010. Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends in Ecology and Evolution 25:574–582.

Matthews, T. J., H. E. Cottee-Jones, and R. J. Whitaker. 2014. Habitat fragmentation and the species-area relationship: a focus on the total species richness obscures the impact of habitat loss on habitat specialists. Diversity and Distributions 20:1136–1146.

North American Bird Conservation Initiative (NABCI), U.S. Committee. 2009. The state of the birds, United States of America. U.S. Department of the Interior, Washington, D.C.

O'Connell, T. J., R. P. Brooks, M. J. Lanzone, and J. A. Bishop. 2003. A bird community index for the Mid-Atlantic Piedmont and Coastal Plain. Final Report to the USGS Patuxent Wildlife Research Center. Report No. 2003-02. Penn State Cooperative Wetlands Center, University Park, Pennsylvania.

Rosenberg, K. V., J. A. Kennedy, R. Dettmers, R. P. Ford, D. Reynolds, J. D. Alexander, C. J. Beardmore, P. J. Blancher, R. E. Bogart, G. S. Butcher, A. F. Camfield, A. Couturier, D. W.

Demarest, W. E. Easton, J. J. Giocomo, R. H. Keller, A. E. Mini, A. O. Panjabi, D. N. Pashley, T. D. Rich, J. M. Ruth, H. Stabins, J. Stanton, and T. Will. 2016. Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States. Partners in Flight Science Committee. Available at: http://www.partnersinflight.org/wp-content/uploads/2016/08/pif-continental-plan-final-spread-single.pdf (accessed 16 July 2018).

Rosenberg, K. V., A. M. Dokter, P. J., Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. S. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra. 2019. Decline of the North American avifauna. Science 10.1126/science.aaw1313.

Severinghaus, W. D. 1981. Guild theory development as a mechanism for assessing environmental impact. Environmental Management 5:187–190.

Steinkamp, M. 2008. New England-Atlantic Coast Bird Conservation Region (BCR 30) implementation plan. Atlantic Coast Joint Venture, Laurel, Maryland.

Stolen, E. D., D. R. Breininger, and P. C. Frederick. 2005. Using waterbirds as indicators in estuarine systems: successes and perils. Pages 409–422 *in* S. A. Bortone, editor. Estuarine Indicators. CRC Press, Boca Raton, Florida.

Stoner, D. 2014. Bird surveys, Beaver Valley, Brandywine Conservancy lands. Prepared by Derek Stoner Consulting.

Verner, J. 1984. The guild concept applied to management of bird populations. Environmental Management 8:1–13.

Watts, B. D. 1999. Partners in Flight Mid-Atlantic Coastal Plain bird conservation plan. Center for Conservation Biology, College of William and Mary, Williamsburg, Virginia.

Watson, J. K. 2014. The Piedmont Bird Conservation Region (BCR 29) implementation plan. Southern Appalachian Bird Conservancy, Sevierville, Tennessee.

White, J. 2015. First State National Historical Park – Bird Survey 2014–2015. Prepared by Hyla Associates.

4.10. Bats

4.10.1. Background and Importance

Bats are relatively inconspicuous components on the landscape, roosting in obscure places and emerging at night to forage under the cover of darkness. Because of their cryptic nature, members of the public often fear bats and view them in a negative light when in fact bats are economically and ecologically important throughout North America (O'Shea and Bogan 2003, Hoffmaster et al. 2016). As predators of night-flying insects, bats regulate agricultural pests. In the continental U.S. alone, insectivorous bats are estimated to save agricultural producers $3 billion U.S. dollars annually due to their impact on agricultural pests (Boyles at al 2011). Bats also function as important pollinators and seed dispersers (Kunz et al. 2011).

The life histories of bats, including their low reproductive rates and need for some species to aggregate in large numbers, make them vulnerable to decline. As a result, many bats are species of conservation concern (O'Shea et al. 2018). The International Union for Conservation of Nature and Natural Resources has categorized 186 bat species as critically endangered, endangered, or vulnerable (IUCN 2019). Concerns regarding the status of bats at Brandywine Valley prompted an inventory to establish baseline data on bats within the park (Nagel and Gates 2017).

The oak forests, mesic hardwood forests, wetlands, pastureland, and a single cave at FRST have the potential to provide bat foraging and roosting habitat for both resident and migrating bat species. Because of the lack of urbanization relative to the surrounding area, FRST is especially valuable by providing relatively unfragmented patches of native forest that serve as a refuge within a highly altered urban and agrarian landscape. Monitoring the change in bat community composition and abundance in this habitat is important for detecting ecosystem change. The fragmentation of habitat, introduction of disease, and conversion of native vegetation to urban landscapes outside the park will negatively impact populations of some bats at FRST, particularly specialist species that have evolved within stable environments (Keinath et al. 2017, Matthews et al. 2014, Devictor et al. 2008, La Sorte 2006). Bat community composition and diversity should improve with the protection and the restoration of the vegetation communities both within FRST and within the surrounding landscape (Johnson 2006, Boren et al. 1999).

<u>Threats</u>

The threats to bats at FRST and in the surrounding region include white-nose syndrome (WNS), wind turbines, climate change, and roost destruction and deforestation resulting in habitat loss. These threats result in the further spread of WNS, bat mortality, and the loss and fragmentation of habitat causing the disruption of ecological functions important to ecosystem integrity and important to maintaining the community and composition of species at FRST.

White-nose syndrome is a fungal disorder caused by the fungus *Psuedogymnoascus destructans* that can result in the entire loss of a bat colony. Alves et al. (2014) note that WNS has killed millions of bats in North America. As of 2020, there have been 13 species confirmed with diagnostic symptoms of WNS in North America including five with the potential to occur at FRST: the big brown bat (*Eptesicus focus*), eastern small footed bat (*Myotis leibii*), little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), and tri-colored bat (*Perimyotis subflavus*) (White-Nose Syndrome Response Team 2020).

Wind energy is a fast-growing source of a clean, renewable energy. However, rates of bat mortality can be high at large wind facilities (Arnett et al. 2016). Most species of bats affected by wind turbines are migratory, tree-roosting species. These include the hoary bat (*Lasiurus cinereus*), the Eastern red bat (*Lasiurus borealis*), and the silver-haired bat (*Lasiurus borealis*), all of which occur at FRST (Arnett et al. 2016, Nagel and Gates 2017).

Climate change is widely regarded as being of major and growing importance for influencing the future distribution and abundance of organisms. Rapid, unpredictable, or unusual changes in seasonal weather patterns, like those associated with climate change, can make it difficult for bats to survive. Climate disruption is likely to cause long-term changes in habitats affecting roost availability and the quality of foraging habitat. This is likely to prompt both changes in bat distribution and range shifts in bats (LaVal 2004, Rebelo et al. 2010). In turn, these changes are likely to cause declines in bat populations as a result of the delay to develop suitable roosting and foraging habitat in these newly occupied ranges (Jones and Rebelo 2013). Additionally, in the short term, events such as hurricanes can destroy both roosting and/or foraging areas paramount for bat survival. Ultimately, bat species may face immense challenges to their survival, especially those more dependent on colder climates or those with narrow ecological niches (Jones and Rebelo 2013).

Bats exploit a number of different features on the landscape including trees and caves that occur in close proximity to water. Different species of bats survive in different ecosystems, but a variety of factors are reducing the amount of suitable habitat. Deforestation and fragmentation related to urbanization and conversion of land to agriculture has constributed to declines in bat populations and the loss of species diversity (Estrada-Villegas et al. 2010, Henry et al. 2010, Jung and Threlfall 2016, Meyer et al. 2016).

Changes in land use are linked to ecological function by five mechanisms (Hansen and Gryskiewicz 2003):

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

The threats and disturbances described above disrupt ecological functions important to ecosystem integrity and important to maintaining the community and composition of species at FRST comparable to that of the natural habitat of the region (Jørgensen and Müller 2000). Consequently, the ecological functioning of FRST depends upon maintaining the natural systems within and outside the park's boundaries.

Indicators and Measures

- Proportion of the expected bat species present

4.10.2. Data and Methods

Bat surveys were conducted at FRST during July 21–July 24, 2015, by Juliet Nagel and J. Edward Gates of the University of Maryland Center for Environmental Science, Appalachia Laboratory, Frostburg, Maryland (Figure 4.10-1) (Nagel and Gates 2017). Five mist-net and six acoustic sampling sites were selected based on expert opinion, with the aim of capturing the full complement of species in the area (Nagel and Gates 2017). One or two 3-tier, 38 mm mesh mist nets of varying lengths (dependent on the habitat being sampled) were used at each mist-net site. Mist netting was conducted for four hours, starting 30 minutes after sunset. No trapping was conducted during rain, high wind (≥20 kph [≥12 mph]), or cold temperatures (<9º C [<48º F]). Passive acoustic recording surveys were used in tandem with the mist-net surveys to increase detection of bat species that are difficult to capture with mist-nets. A Binary Acoustic's BAT AR125 125 kHz ultrasonic receiver (Binary Acoustic Technology, Tucson, Arizona) was used to record bat calls. Recordings were made for 20 minutes at each site, which allowed any bat that used a given site the potential to be recorded (Nagel and Gates 2017).

In addition to the 2015 surveys, a roost survey to estimate numbers of bats by species was conducted every few years at a small cave on the Brandywine Valley unit during February 2, 2010; February 21, 2011; March 3, 2015; and January 11, 2018 (Holly Niederriter, pers. comm. 2020). Data from the mist-netting, bat call, and cave surveys were used to determine the condition of the bat community at the Brandywine Valley unit of FRST.

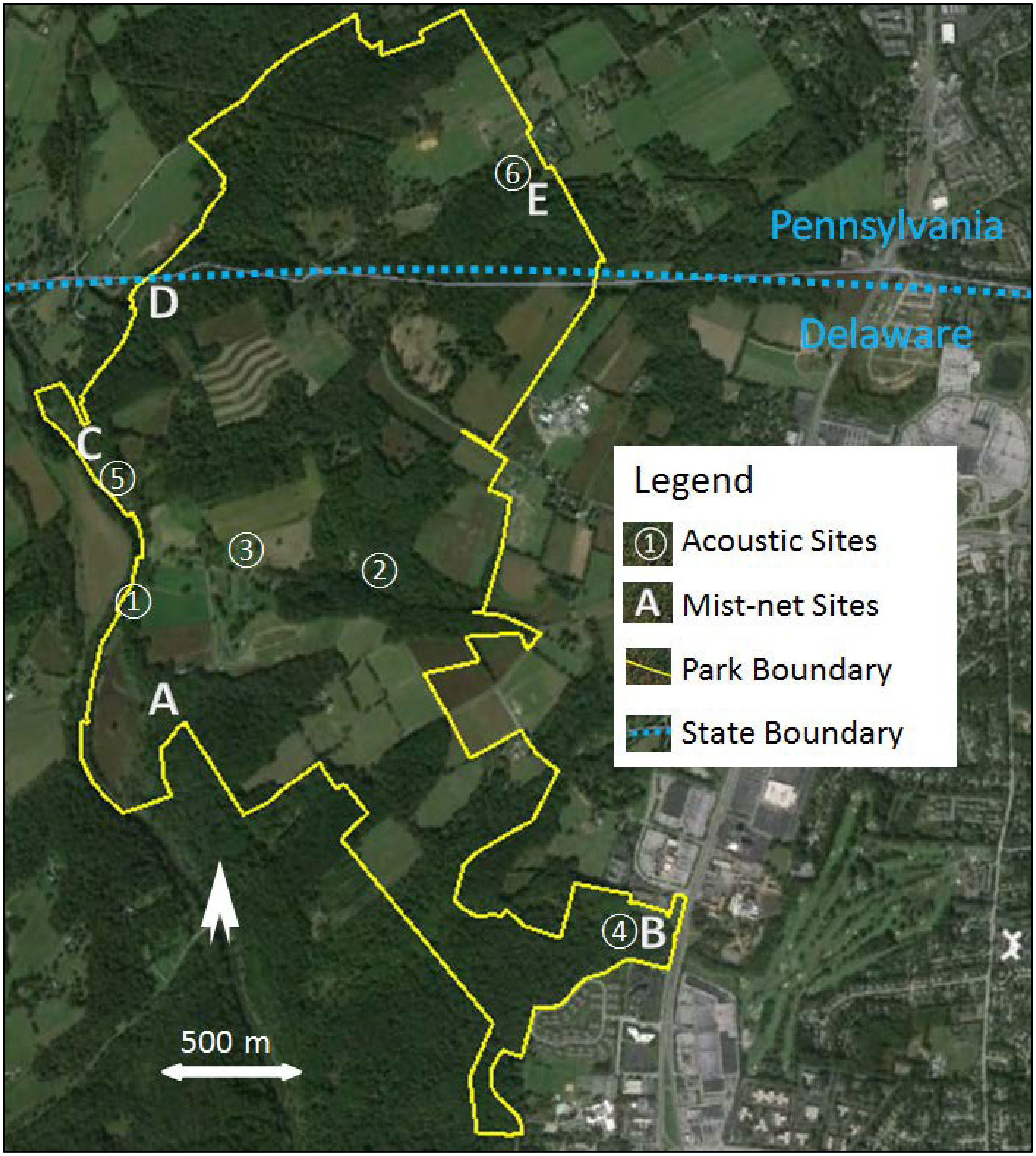


Figure 4.10-1. Bat acoustic and mist-net sites surveyed on First State National Historic Park (Location data from Nagel and Gates (2017); background imagery via ArcGIS license).

The NPSpecies database (NPS 2019) was examined to determine which bat species might be expected to occur at FRST, but no species were listed for the park. This is likely due to the newness of the park. Therefore, it was decided to use all of the species listed for the other eight parks within the Northeast Coastal and Barrier Inventory and Monitoring Network (NCBN) as the reference condition for FRST. In addition, bat species expected in the region that includes FRST, as determined by Delaware Department of Natural Resources and Environmental Control (DNREC) biologists, were added to the list. The resulting list identified nine bat species, all in the family Vespertilionidae, with the potential to occur within the Brandywine Valley unit (Table 4.10-1).

Table 4.10-1. Native bat species expected and confirmed at First State National Historic Park, Brandywine Valley unit (data from Nagel and Gates 2017).

Common Name	Scientific Name	Confirmation Status
Big brown bat	*Eptesicus fuscus*	confirmed
Eastern red bat	*Lasiurus borealis*	confirmed
Eastern small-footed bat	*Myotis leibii*	unconfirmed
Evening bat	*Nycticeius humeralis*	unconfirmed
Hoary bat	*Lasiurus cinereus*	confirmed
Indiana bat	*Myotis sodalis*	unconfirmed
Little brown myotis	*Myotis lucifugus*	unconfirmed
Northern long-eared bat	*Myotis septentrionalis*	observed in 2013
Seminole bat	*Lasiurus seminolus*	unconfirmed
Silver-haired bat	*Lasionycteris noctivagans*	confirmed
Tri-colored bat	*Perimyotis subflavus*	unconfirmed

4.10.3. Reference Conditions

The reference condition is based on the number of species with the potential to occur at the park and the condition metric is the percent of expected species confirmed during the surveys. A condition rating framework for bats at FRST was developed using professional opinion of the authors (Table 4.10-2). The choice of this reference condition reflects the lack of robust data on the bat populations at FRST, which is limited to one survey (Nagel and Gates 2017). A lack of data on population trends for the bat species found at FRST makes it impossible to assess the impact WNS may have had on those population even though the devastating effects the WNS has had on bat populations from throughout eastern North America is well known (White-Nose Syndrome Response Team 2020).

Table 4.10-2. Resource condition rating framework for bats at First State National Historic Park, Brandywine Valley unit, Delaware.

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

4.10.4. Condition and Trend

The Nagel and Gates (2017) bat surveys at FRST detected four out of 11 or 36% of the bat species expected to occur (Table 4.10-1), indicating that the bat community at FRST warrants significant concern (Table 4.10-3). Nagel and Gates captured six eastern red bats and 15 big brown bats (*Eptesicus fuscus*) by mist-net and identified through acoustic monitoring 35 eastern red bats, 45 hoary bats, and 55 individuals that were either big brown bats or silver-haired bats. Surveys conducted by DNREC did not detect any bats at the cave located on the Brandywine Valley unit of FRST, but an amphibian survey crew observed one northern long-eared bat in March 2013, boosting the number of species using the park to a possible five out of nine suspected species or 56%. Because surveys only indicate presence of a species, the lack of an observation does not indicate species absence or local extirpation. The lack of a species observation may be an artifact of the sampling design or sampling season. No trend assessment is currently possible for this measure of condition due to the limited sampling effort. Comprehensive data collected from across the entire unit is only available for a single sample period, and no bats were recorded during the years in which cave surveys were conducted. For these reasons the confidence in the assessment is low.

Table 4.10-3. Condition and trend summary for bats at First State National Historic Park, Brandywine Valley unit, Delaware.

Indicator	Condition Status/Trend	Rationale
Percent of Expected Species Confirmed		Thirty-six percent of expected bat species were confirmed (warrants significant concern). Analysis of the bat data for trend was not possible because of the limited data available.
Overall		**Condition warrants significant concern with an unknown trend and low confidence.**

Due to the effects of WNS, two of the five bat species confirmed at FRST, the northern long-eared bat and tri-colored bat, are now considered at risk of extinction by Alves et al. (2014). Additionally, the northern long-eared bat is listed as threatened by the U.S. Fish and Wildlife Service and as endangered by the DNREC. The status of northern long-eared bat, the eastern red bat, hoary bat, and silver-haired bat is tracked by the Delaware Natural Heritage Program. Consequently, the Brandywine Valley unit of FRST has an important role to play in conservation of bat populations both at the park and within the surrounding landscape.

4.10.5. Uncertainty and Data Gaps

Bat data were limited to only a few sample periods and no monitoring data were available, resulting in low confidence in the assessment. Inventory surveys were able to document species present on site, however, the lack of detection of a species does not equate to a local extirpation. The absence of a species may be an artifact of the sampling design or the seasonal timing of the survey. Bias associated with incomplete detection is also a concern, likely reducing abundances and possibly species richness estimates. Trends could not be determined from available data.

Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades rather than the periods of survey data available for this assessment (Holmes 2010, Magurran et al. 2010). Continued monitoring could either support or refute the outcome of the current assessment. Comprehensive data collected from numerous randomly selected sites would provide more robust data versus using subjectively selected sites, as was done for the 2015 survey (Dornelas et al. 2012).

The implementation of a monitoring program for bats at FRST should avoid differences in sampling effort across the years monitored. If monitoring of multiple sites is instituted at FRST, then all of these sites or at least a subset using all of the same sites every year will eliminate any difference in sampling effort by year. The issue that occurs when sampling effort varies by year is that the greater the number of individual samples taken, the greater is the number of species that will be found. This confounding influence makes it difficult to identify whether differences in the indicator values, by year, result from true changes in their values or are an artifact of the variation in sample effort. Sampling the same sites and the same number of sites in every year of monitoring would control for this bias.

4.10.6. Sources of Expertise

- Juliet Nagel and J. Edward Gates of the University of Maryland Center for Environmental Science, Appalachia Laboratory, Frostburg, Maryland, conducted the bat sampling at FRST in 2015.
- Holly Niederriter, Wildlife Biologist for the DNREC Division of Fish & Wildlife, Wildlife Species Conservation & Research Program supplied data for this assessment and is responsible for coordinating the State of Delaware’s bat monitoring program.

4.10.7. Literature Cited

Alves, D. M. C. C., L. C. Terribile, and D. Brito. 2014. The potential impact of White-Nose Syndrome on the conservation status of North American bats. PLoS ONE 9:1–7.

Arnett, E. B., E. F. Baerwald, F. Mathews, L. Rodrigues, A. Rodríguez-Durán, J. Rydell, R. Villegas-Patraca, and C. C. Voigt. 2016. Impacts of wind energy development on bats: a global perspective. Pages 295–323 *in* C. Voigt and T. Kingston, editors. Bats in the Anthropocene: conservation of bats in a changing world. Springer, Cham.

Boren J. C., D. M. Engle, M. W. Palmer, R. E. Masters, and T. Criner. 1999. Land use change effects on breeding bird community composition. Journal of Range Management 52:420–430.

Boyles, J. G., P. M. Cryan, G. F. McCracken, and T. H. Kunz. 2011. Economic importance of bats in agriculture. Science 332:41–42.

Devictor V., R. Julliard, J. Clavel, F. Jiguet, A. Lee, and D. Couvet. 2008. Functional biotic homogenization of bird communities in disturbed landscapes. Global Ecology and Biogeography 17:252–261.

Dornelas, M., A. E. Magurran, S. T. Buckland, A. Chao, R. L. Chazdon, R. K. Colwell, T. Curtis, K. J. Gaston, N. J. Gotelli, M. A. Kosnik, B. McGill, J. L. McCune, H. Morlon, P. J. Mumby, L.

Ovreas, A. Studeny and M. Vellend. 2012. Quantifying temporal change in biodiversity: challenges and opportunities. Proceedings of The Royal Society B 280:1–10.

Estrada-Villegas, S., C. F. J. Meyer, and E. K. V. Kalko. 2010. Effects of forest fragmentation on aerial insectivorous bats in a land-bridge island system. Biological Conservation 143:597–608.

Hansen, A., and D. Gryskiewicz. 2003. Interactions between Heartland National Parks and surrounding land use change: development of conceptual models and indicators for monitoring. Final Report to the National Park Service Heartland Network. National Park Service, Fort Collins, Colorado.

Henry, M., J. F. Cosson, and J. M. Pons. 2010. Modelling multi-scale spatial variation in species richness from abundance data in a complex neotropical bat assemblage. Ecological Modelling 221:2018–2027.

Hoffmaster, E., J. Vonk, and R. Mies. 2016. Education in action: improving public perception of bats. Animals 6(1):6. https://doi.org/10.3390/ani6010006.

Holmes, R. T. 2010. Avian population and community processes in forest ecosystems: Long-term research in the Hubbard Brook Experimental Forest. Forest Ecology and Management 262:20–32.

International Union for Conservation of Nature and Natural Resources (IUCN). Red List Category Summary for All Animal Classes and Orders. Available at: https://nc.iucnredlist.org/redlist/content/attachment_files/2019_2_RL_Table_4a.pdf (accessed 9 October 2019).

Johnson, T. N. 2006. Ecological restoration of tallgrass prairie: grazing management benefits plant and bird communities in upland and riparian habitats. Thesis. Kansas State University, Manhattan Kansas.

Jones, G., and H. Rebelo. 2013. Responses of bats to climate change: learning from the past and predicting the future. Pages 457–478 *in* R. Adams and S. Pedersen, editors. Bat evolution, ecology, and conservation. Springer, New York, New York.

Jørgensen, S. E., and F. Müller, editors. 2000. Handbook of Ecosystem Theories. CRC Publishers, New York, New York.

Jung, K., and C. G. Threlfall. 2016. Urbanization and its effects on bats: a global meta-analysis. Pages 13–33 *in* C. Voigt and T. Kingston, editors. Bats in the Anthropocene: conservation of bats in a changing world. Springer, Cham.

Keinath, D. A., D. F. Doak, K. E. Hodges, L. R. Prugh, W. Fagan, C. H. Sekercioglu, S. H. M. Buchart, M. Kauffman, and K. Bohning-Gaese. 2017. A global analysis of traits predicting species sensitivity to habitat fragmentation. Global Ecology and Biogeography 26:115–127.

Kunz, T. H., E. de Braun Torrez, D. Bauer, T. Lobova, and T. H. Fleming. 2011. Ecosystem services provided by bats. Annals of the New York Academy of Sciences 1223:1–38.

La Sorte, F.A. 2006. Geographical expansion and increased prevalence of common species in avian assemblages: implications for large-scale patterns of species richness. Journal of Biogeography 33:1183–1191.

LaVal, R. K. 2004. Impact of global warming and locally changing climate on tropical cloud forest bats. Journal of Mammalogy 85:237–244.

Magurran, A. E., S. R. Baillie, S. T. Buckland, J. McP. Dick, D. A. Elston, E. M. Scott, R. I. Smith, P. J. Somerfield, and A. D. Watt. 2010. Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends in Ecology and Evolution 25:574–582.

Matthews, T. J., H. E. Cottee-Jones, and R. J. Whitaker. 2014. Habitat fragmentation and the species-area relationship: a focus on the total species richness obscures the impact of habitat loss on habitat specialists. Diversity and Distributions 20:1136–1146.

Meyer, C. F. J., M. J. Struebig, and M. R. Willig. 2016. Responses of tropical bats to habitat fragmentation, logging, and deforestation. Pages 63–103 *in* C. Voigt and T. Kingston, editors. Bats in the Anthropocene: conservation of bats in a changing world. Springer, Cham.

Nagel, J., and J. E. Gates. 2017. Bat community composition and monitoring for white-nose syndrome at First State National Historical Park, Delaware and Pennsylvania. Natural Resource Report NPS/FRST/NRR—2017/1482. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2019. NPSpecies – the National Park Service biodiversity database, online portal version. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/NPSpecies (accessed September 2018).

O’Shea, T. J., and Bogan, M. A., editors. 2003. Monitoring trends in bat populations of the United States and territories: problems and prospects. Information and Technology Report USGS/BRD/ITR--2003–0003. U.S. Geological Survey, Biological Resources Discipline, Fort Collins, Colorado.

O’Shea, T. J., P. M. Cryan, and M. A. Bogan. 2018. United States bat species of concern: a synthesis. Proceedings of the California Academy of Sciences Series 4, Volume 65, Supplement I:1–279.

Rebelo, H, P. Tarroso, and G. Jones. 2010. Predicted impact of climate change on European bats in relation to their biogeographic patterns. Global Change Biology 16:561–576.

White-Nose Syndrome Response Team. 2020. White-Nose Syndrom Response Team website. Available at: https://www.whitenosesyndrome.org/ (accessed 04 June 2020).

4.11. Reptiles and Amphibians

4.11.1. Background and Importance

Amphibians and reptiles are valued park resources that also serve as bioindicators of environmental stress from changes in wetland extent and quality, atmospheric deposition, climatic change, habitat degradation and habitat loss (Tierney and Gibbs 2016). Habitats that are known to support relatively unique assemblages of herpetofauna at FRST include oak and hardwood forests, seasonal ponds, springs and seepages, and freshwater sources (Lookingbill et al. 2012). Amphibians, due to their relatively sedentary lifestyles, porous and highly permeable skin, and multistage life histories that use diverse habitat types, are sensitive to environmental stress (Petranka et al. 2003, Grant et al. 1992). Streamside salamanders (*Desmognathus*, *Eurycea* spp.) constitute a unique assemblage with potential to occur at springs and associated wet areas within FRST that are sensitive to environmental stress (Lookingbill et al. 2012). Herpetofauna species are also widely considered to be effective indicators of the quality and condition of terrestrial and aquatic habitats because they are sensitive to habitat changes including wetland filling or draining, non-point source pollution, urbanization, and clearcutting that can change moisture regimes (Pechmann et al. 1991, Blaustein et al. 1994, Fontenot et al. 1996, Welsh and Droege 2001, Mifsud 2014). In fact, herpetofauna have experienced worldwide declines caused by combinations of multiple factors including habitat loss, habitat fragmentation, disease, pollution, and climatic shifts, among others (Cushman 2006, Becker et al. 2007, Gardner et al. 2007).

Amphibians and reptiles at FRST require a number of habitats for breeding, foraging, and dispersal activities and, with the exception of the eastern red-backed salamander (*Eurycea longicauda*), depend on aquatic habitat for reproduction (Wagner et al. 2014). The spring peeper (*Pseudacris crucifer*), gray treefrog (*Hyla versicolor*), wood frog (*Lithobates sylvaticus*), spotted salamander (*Ambystoma maculatum*), and American toad (*Anaxyrus americanus*) leave wetland habitats following the breeding season, foraging and hibernating in the uplands within and surrounding FRST (Conant and Collins 1998, Petranka 1998).

Suitable habitat for herpetofauna is of particular management interest for the state and federally listed bog turtle (*Glyptemys muhlenbergii*). The bog turtle is listed as threatened under the Endangered Species Act (USFWS 1997) and as endangered by the Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife (DNREC 2015). Consequently, the turtle is protected in Delaware by both state and federal laws. Throughout the bog turtle's range, residential and commercial development pressure continues to alter and destroy habitat and fragment populations (NatureServe 2019). Bog turtles are occasionally killed on roads, and road mortality may be significant where bog turtle subpopulations are found along roads (Arndt 1977, USFWS 2001). Unfortunately, bog turtles are still targeted in the illegal pet trade (USFWS 2001) and poaching is currently suspected at a small proportion of bog turtle sites; even this relatively isolated collection pressure may cause such severe declines that subpopulations are entirely eliminated or driven so low that they become functionally extinct (Ernst and Lovich 2009). Currently, the bog turtle occurs only in pockets of habitat in their former range that have been fragmented by development and agriculture (NatureServe 2019). Suitable habitat includes spring-fed wetlands that are maintained in the middle stages of hydrarch succession by beaver activity, ungulate grazing, and wildfire (NatureServe 2019).

The decline and disappearance of these natural disturbance regimes require that spring-fed wetlands suitable for bog turtles be prescriptively managed to prevent the further degradation of habitats (NatureServe 2019).

NPS lands provide some of the least impacted habitat remaining in the northeastern coastal zone serving as refugia for some species by providing seasonally wet areas, backwaters, ponds, lakes, and important older forest structure for native herpetofauna (Miller 2016, Gibbons et al. 2000). Nearly all the natural habitat in the northeast has been fragmented by agriculture and development (Drummond and Loveland 2010, Auch et al. 2012). Because of the rarity of undisturbed lands in the region, FRST is especially valuable by providing patches of habitat critical for sustaining natural aquatic water resources and native forest within a highly altered landscape (Hansen and Gryskiewicz 2003). The habitat fragmentation and conversion of native vegetation to agricultural and urban landscapes occurring outside the park will negatively impact populations of some herpetofauna species resident to FRST, particularly intolerant species that have evolved within stable environments (Palmeirim et al. 2017, Newbold et al. 2016, Devictor et al. 2008). Herpetofauna community composition and diversity should improve with restoration projects such as identifying, maintaining and restoring seasonal wetlands, native forest cover, and downed woody material and forest litter both within FRST and within the surrounding landscape (Bailey et al. 2006).

Threats

The primary threat for reptile and amphibian species of the region is residential and commercial development causing permanent conversion to non-habitat or degradation or fragmentation of existing habitat (Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission 2015). Since its colonization approximately 400 years ago, the Northeast continues to be the most densely populated region in the United States (Moore et al. 1997), and this population is projected to increase by nearly 6 million (10%) between 2000 and 2030 (Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission 2015). Herpetofauna exploit a number of different features on the landscape at FRST including freshwater marshes, spring seeps, vernal pools, ponds, and rock structures. Research has shown that urbanization and conversion to agriculture impacts these environments resulting in the decline of herpetofauna populations and the loss of species diversity (Hamer and McDonnell 2010, Grundel at al. 2015, Sullivan et al. 2017, Ljustina and Barratt 2018).

Roads are also a major threat to herpetofauna. Roads are major sources of pollutants, and can be barriers to dispersal for herpetofauna, fragmenting habitat and leading to genetic isolation of local populations (Andrews et al. 2008, Sullivan et al. 2017). Roads can also cause high rates of mortality to herpetofaunal populations (Evans et al. 2011, Balsas 2019). Salts from road de-icing have serious detrimental effects on wildlife, especially amphibians (Sanzo and Hecnar 2006). The amphibians most affected are often vernal pool breeders (Karraker et al. 2008), which are already some of the rarest and most threatened species of conservation concern in Delaware due to many other factors, such as development, wetland loss, and climate change effects (DNREC 2015).

Collecting, primarily for the pet trade, is another threat for many reptiles and amphibians. Species most impacted by collecting are the bog turtle, spotted turtle (*Clemmys guttata*), red corn snake

(*Pantherophis guttatus*), eastern kingsnake (*Lampropeltis getula*), eastern milk snake (*Lampropeltis triangulum*), and tiger salamander (*Ambystoma tigrinum*) (DNREC 2015).

Disease is also a concern for many herpetofauna. Frog, salamander, and turtle species are susceptible to ranaviruses that are distributed worldwide, including all Delaware counties (DNREC 2015). Ranaviruses are a group of highly infectious viruses that are often lethal and can cause mass die-offs. Sampling for ranaviruses in the Mid-Atlantic region identified mortality rates of 50–99% in the larval life stage compared to low mortality rates in adults (DNREC 2015). Additional research is needed to understand the effects of these pathogens on Delaware herpetofauna (DNREC 2015). Climate and weather also pose challenges for amphibians including changes to the local environment inhabited by amphibians (e.g., soil temperature, prey availability), the phenology (timing) of activities such as foraging and breeding, the presence of pathogens and exotic species, and the interactions of climate with other stressors such as pollutants (Blaustein et al. 2010).

The above threats acting both inside and outside the park have disrupted ecological functions important to ecosystem integrity and important to maintaining the community and composition of species at FRST comparable to that of the natural habitat of the region (Jørgensen and Müller 2000). Consequently, the ecological functioning of FRST depends upon maintaining the natural systems outside the park's boundaries a well as inside the park. Environmental changes occurring outside the park are linked to ecological function at FRST by five mechanisms (Hansen and Gryskiewicz 2003):

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

Indicators and Measures

- Percent of the expected herpetofauna species present
- Amphibian index of biotic integrity (IBI)

4.11.2. Data and Methods

Herptofauna were surveyed at FRST between September 2014 and October 2015 by White and White (2015). The sampling of herpetofauna at FRST was performed at 17 locations and included 14 separate sampling events (White and White 2015). Sampling was conducted on foot and species were identified by visual observation and sound (e.g., frog calls) with the locations of observation documented using a GPS unit. Sampling was aided using various field equipment including field notebooks, dip nets, a herping stick, measuring devices, binoculars, and cameras. Microhabitats preferred by herpetofauna were given special attention (e.g., under logs and man-made debris, and in moist or wetland areas). Five of the 16 sample sites fell just outside the park. The information presented in this report is the summary of White and White's sampling (2015).

The NPSpecies database identifies 33 species of herpetofauna that could potentially occur within FRST (National Park Service 2019). This list was cross-referenced with the Pennsylvania Amphibian and Reptile Survey list for Delaware County, Pennsylvania (39 species); the list of verified species in iNaturalist for New Castle County, Delaware (41 species); and White and White (2007) to generate a total of 36 species with the potential to occur at the Brandywine Valley unit of FRST given the habitat types present at the unit. These species include 8 species of frogs and toads, 8 salamanders and newts, 12 snakes, and 7 turtles with 15 species listed as species of greatest conservation need (SGCN) in need of conservation action in Delaware (DNREC 2015) (Table 4.11-1). The SGCN designation has several tiers for prioritizing species and are defined in the Delware Wildlife Action Plan (DEWAP) as wildlife species indicative of the overall health of the state's wildlife resources. Some may be rare or declining. Others may be a vital component of specific habitats.

Table 4.11-1. Native herpetofauna species that could potentially occur at First State National Historical Park, their status as species of greatest conservation need (SGCN) (DNREC 2015), those species confirmed by NPS (2019) and those species confirmed during the White and White (2015) surveys.

Category	Order	Common Name	Scientific Name	SGCN Status *	Confirmation Status
Amphibians	Anura	American bullfrog	*Lithobates catesbeianus*	–	Present
	Anura	Eastern American toad	*Anaxyrus americanus americanus*	–	Present
	Anura	Gray treefrog	*Hyla versicolor*	–	Present
	Anura	Green frog	*Lithobates clamitans*	–	Present
	Anura	Northern cricket frog	*Acris crepitans*	–	Unconfirmed
	Anura	Pickerel frog	*Lithobates palustris*	–	Present
	Anura	Spring peeper	*Pseudacris crucifer*	–	Present
	Anura	Wood frog	*Lithobates sylvaticus*	Tier 3	Present
	Caudata	Eastern long-tailed salamander	*Eurycea longicauda longicauda*	Tier 2	Present
	Caudata	Eastern red-backed salamander	*Plethodon cinereus*	–	Present
	Caudata	Four-toed salamander	*Hemidactylium scutatum*	Tier 2	Unconfirmed – not observed in the First State NHP but considered "Probable" by Jim White
	Caudata	Northern dusky salamander	*Desmognathus fuscus*	Tier 3	Present
	Caudata	Northern red salamander	*Pseudotriton ruber ruber*	Tier 2	Present
	Caudata	Northern two-lined salamander	*Eurycea bislineata*	Tier 3	Present
	Caudata	Red-spotted newt	*Notophthalmus viridescens viridescens*	Tier 3	Present
	Caudata	Spotted salamander	*Ambystoma maculatum*	Tier 2	Present
Reptiles	Squamata	Common ribbonsnake	*Thamnophis sauritus sauritus*	–	Unconfirmed – not observed in the First State NHP but considered "Possible" by Jim White
	Squamata	Eastern gartersnake	*Thamnophis sirtalis sirtalis*	–	Present

* Tier 1 = species with the highest need of conservation action, Tier 2 = species of moderate conservation concern, Tier 3 = species that are still relatively common but need conservation action for various reasons.

Table 4.11-1 (continued). Native herpetofauna species that could potentially occur at First State National Historical Park, their status as species of greatest conservation need (SGCN) (DNREC 2015), those species confirmed by NPS (2019) and those species confirmed during the White and White (2015) surveys.

Category	Order	Common Name	Scientific Name	SGCN Status *	Confirmation Status
Reptiles (continued)	Squamata	Eastern milksnake	*Lampropeltis triangulum triangulum*	Tier 2	Present
	Squamata	Eastern ratsnake	*Pantherophis alleghaniensis*	–	Present
	Squamata	Eastern smooth earthsnake	*Virginia valeriae valeriae*	Tier 2	Unconfirmed – not observed in the First State NHP but considered "Possible" by Jim White
	Squamata	Eastern worm snake	*Carphophis amoenus*	–	Unconfirmed
	Squamata	Northern black racer	*Coluber constrictor constrictor*	–	Unconfirmed – observed by the surveyor in the parcel during the previous 30 years Probably Present
	Squamata	Northern brownsnake	*Storeria dekayi dekayi*	–	Unconfirmed – observed by the surveyor in the parcel during the previous 30 years
	Squamata	Northern copperhead	*Agkistrodon contortrix mokasen*	Tier 2	Unconfirmed – not observed in the First State NHP but considered "Possible" by Jim White
	Squamata	Northern watersnake	*Nerodia sipedon sipedon*	–	Present
	Squamata	Queensnake	*Regina septemvittata*	Tier 2	Present
	Squamata	Ring-necked snake	*Diadophis punctatus*	–	Unconfirmed – observed by the surveyor in the parcel during the previous 30 years
	Testudines	Eastern box turtle	*Terrapene carolina*	Tier 1	Present
	Testudines	Eastern musk turtle	*Sternotherus odoratus*	–	Unconfirmed – not observed in the First State NHP but considered "Probable" by Jim White
	Testudines	Eastern painted turtle	*Chrysemys picta picta*	–	Present
	Testudines	Northern red-bellied cooter	*Pseudemys rubriventris*	Tier 2	Unconfirmed – observed by the surveyor in the parcel during the previous 30 years

* Tier 1 = species with the highest need of conservation action, Tier 2 = species of moderate conservation concern, Tier 3 = species that are still relatively common but need conservation action for various reasons.

Table 4.11-1 (continued). Native herpetofauna species that could potentially occur at First State National Historical Park, their status as species of greatest conservation need (SGCN) (DNREC 2015), those species confirmed by NPS (2019) and those species confirmed during the White and White (2015) surveys.

Category	Order	Common Name	Scientific Name	SGCN Status *	Confirmation Status
Reptiles (continued)	Testudines	Red-eared slider	*Trachemys scripta elegans*	–	Unconfirmed – observed by the surveyor in the parcel during the previous 30 years
	Testudines	Snapping turtle	*Chelydra serpentina*	–	Present
	Testudines	Spotted turtle	*Clemmys guttata*	Tier 1	Unconfirmed – observed by Jim White and other surveyors in adjacent Woodlawn Truste property

* Tier 1 = species with the highest need of conservation action, Tier 2 = species of moderate conservation concern, Tier 3 = species that are still relatively common but need conservation action for various reasons.

An amphibian index of biotic integrity (IBI) was calculated using the protocol created for the mid-Atlantic region (Farr 2003, Turner and Brooks unpublished). The amphibian IBI takes advantage of the fact that amphibians are sensitive to the degree of habitat alteration, substrate disturbance, and habitat development (Turner and Brooks unpublished). Therefore, changes in the environment can alter the species composition of the amphibian community and amphibian diversity (Turner and Brooks unpublished). Assessments using an amphibian IBI generate a quantitative metric that is used to define the ecological integrity of a sampled area based on the amphibian community present (Turner and Brooks unpublished). The Amphibian IBI is calculated from five component metrics describing amphibian communities:

1. amphibian species richness;
2. the number of intolerant species found at a site;
3. the percent of intolerant species at a site;
4. the presence of intolerant pond breeding species (either wood frog or spotted salamander); and
5. presence of northern dusky salamander (an intolerant stream-breeding species).

Higher scores for each metric at a site are associated with less anthropogenic habitat disturbance and higher levels of ecological integrity (Turner and Brooks unpublished).

4.11.3. Reference Conditions

Little historical survey data exist for FRST. Comprehensive, repeated, and statistically rigorous herpetofauna sampling has not been done at the park. The reference condition for the percent of the expected herpetofauna present was set to the number of species with the potential to occur at the park, as identified from the NPSpecies database (National Park Service 2019), the Pennsylvania Amphibian and Reptile Survey, iNaturalist, and White and White (2002).

Available data from walking surveys of the Brandywine Valley unit are suitable for an amphibian IBI analysis. The reference condition for the amphibian IBI score was based on thresholds recommended by Turner and Brooks (unpublished) and Julian et al. (2013). Julian et al. (2013) proposed that amphibian communities can change rapidly at intermediate disturbance scores, transforming into depauperate assemblages consisting of disturbance-tolerant, pond-breeding anurans. Turner and Brooks (unpublished) identified that this critical threshold of rapid change corresponds to an amphibian IBI score of 0.4, with scores $\geq$ 0.4 indicative of reference wetlands and sites with amphibian IBI scores < 0.4 considered disturbed. The resource condition indicator for FRST was based on the breakpoint amphibian IBI score of 0.4 but was modified to create a framework based on a three-tiered NRCA rating system (Table 4.11-2).

More quantitative metrics and thresholds describing the population dynamics of specific species or the herptofauna group could not be determined at this time due to limitations associated with the data available. However, the White and White (2015) study does allow us to make some inference regarding the condition of herptofauna within the park and should be used as the basis for future monitoring efforts.

Table 4.11-2. Resource condition rating framework for herpetofauna at First State National Historic Park, Delaware.

Indicator	Condition Status		
	Resource is in Good Condition	**Warrants Moderate Concern**	**Warrants Significant Concern**
Percent of Expected Species Confirmed	> 85–100+% of expected	70–85% of expected	<70% of expected
Amphibian Index of Biotic Integrity	≥ 0.4	> 0.25 < 0.4	≤ 0.25

4.11.4. Condition and Trend

Percent of Expected Species Confirmed

The number of expected species that were confirmed during the 2014 and 2015 herpetofauna survey at the Brandywine Valley unit of FRST indicates that the resource warrants significant concern (Table 4.11-1). White and White (2015) found 88% of expected amphibians, but only 40% of expected reptiles. Overall, 61%, or 22 of the 36 expected species, were confirmed, which warrants significant concern (Table 4.11-2). Ratios of observed to expected species were as follows: 7 out of 8 frogs and toads (89%), 7 out of 8 salamanders (89%), 5 out of 12 snakes (42%); and 2 out of 7 turtles (29%). Because surveys only indicate presence of a species, the lack of an observation does not indicate species absence or local extirpation. The lack of a species observation may be an artifact of the sampling design or sampling season. No trend assessment is currently possible for this measure of condition due to the single sample period. For this reason, confidence in the assessment is low.

Amphibian Index of Biotic Integrity

The score of 0.85 for the amphibian IBI indicates the amphibian community at FRST is in good condition (Table 4.11-2) with seven species of intolerant amphibians, including spotted salamanders, wood frogs, and the northern dusky salamander all present (Table 4.11-1). This community structure is representative of a landscape where the wetlands have a high degree of ecological integrity. No trend assessment is currently possible for this measure of condition due to the limited sampling effort currently completed at the Brandywine Valley unit of FRST. Comprehensive data collected from across the entire unit is only available for one period. For this reason, the confidence in the assessment is low.

Condition Summary

The values for the metrics of percent of expected species confirmed and the amphibian IBI indicate that the FRST herpetofauna community is in moderate condition (Table 4.11-3), with a structure that represents a moderately disturbed landscape. No trend assessment is currently possible for this measure of condition due to the limited sampling effort currently completed at the Brandywine Valley unit of FRST. Comprehensive data collected from across the entire unit is only available for one period. For this reason, confidence in the assessment is low.

Table 4.11-3. Condition assessment interpretation for herpetofauna at First State National Historical Park, Delaware.

Indicator	Condition Status/Trend	Rationale
Percent of Expected Species Confirmed	Red dashed circle	The percent of herpetofauna confirmed in 2014 and 2015 was 61 percent (warrants significant concern), less than the management target of 85 percent of 36 expected species. Eighty-eight percent of expected amphibian species were observed vs. only 40% of expected reptile species. Analysis of the herpetofauna data for trend was not possible because only one period of sampling data was available for analysis.
Amphibian Index of Biotic Integrity	Green dashed circle	The amphibian IBI score of 0.85 was greater than the threshold value of 0.4, the cutoff for an amphibian community that is in good condition. Analysis of the herpetofauna data for trend was not possible because only one period of sampling data was available for analysis.
Overall	Yellow dashed circle	**Condition warrants moderate concern with an unknown trend. Confidence in the assessment is Low.**

Historically, bog turtles inhabited wet meadows that were maintained by fire, beavers, and grazers like bison. These natural disturbances have declined on the landscape due to human population growth, causing bog turtle habitat to decline. Most bog turtle sites will require periodic, active habitat management to maintain favorable early-succession conditions and limit invasive species (NatureServe 2019). Many tools exist to accomplish these goals, but most require considerable effort. Tree and shrub thinning can be accomplished through manual cutting, girdling, the use of herbicides, or grazing. Invasive species removal may involve herbicide application or manual removal. In some cases, it may be prudent to restore hydrology that was manipulated by draining, channelization, or flooding.

Wetlands inhabited by bog turtles perform important ecological functions on the landscape including purifying water, recharging underground aquifers and absorbing floodwaters (USFWS 2010). These wetlands are also home to many increasingly rare plants and animals, like the bobolink (*Dolichonyx oryzivorus*), American woodcock (*Scolopax minor*), Baltimore checkerspot butterfly (*Euphydryas phaeton*), and dragon's mouth orchid (*Arethusa bulbosa*) all of which have the potential to occur at the Brandywine Valley unit of FRST.

4.11.5. Uncertainty and Data Gaps

Herptofauna data were limited for the Brandywine Valley unit. Survey data were only available for a single time period and no monitoring data were available. Inventory surveys were able to document species present on site, but the lack of detection of a species does not equate to a local extirpation. The absence of a species may be an artifact of the sampling design or the seasonal timing of the survey. Trends were not identified for herptofauna within the park because results were available for only a single survey effort.

Inventory and monitoring surveys should be conducted at regular intervals to establish trend data for species of interest. Assessments of ecological change should use long-term data spanning decades (Holmes 2010, Magurran et al. 2010). Comprehensive data collected from numerous sites within FRST and over an extended time period is needed to assess the natural temporal fluctuation of the condition indicators used in this assessment and to assure the accuracy of the assessment (Dornelas et al. 2012).

The implementation of a monitoring program for herpetofauna at FRST should avoid differences in sampling effort across the years monitored. If monitoring of multiple sites is instituted at FRST, then all of these sites or at least a subset using all of the same sites every year will eliminate any difference in sampling effort by year. The issue that occurs when sampling effort varies across years is that more intensive or widespread searching typically results in a higher number of individuals and/or species found. This confounding influence makes it difficult to identify whether differences in the indicator values, by year, result from true changes in their values or are an artifact of the variation in sampling effort.

Collecting monitoring data over a long timespan usually requires the use of multiple data collectors. Variation among collectors in sampling execution could introduce measurement error into the data, leading to bias, which could reduce the ability to identify statistically significant trends in the resource (Dornelas et al. 2012). The bias associated with data collection is reduced by having researchers adhere to standardized data collection methods and training all data collectors on that protocol.

4.11.6. Sources of Expertise

- Jim White and Amy White of Hyla Associates, Hockessin, Delaware, conducted the herpetofauna survey at FRST. They are the authors of *Amphibians and Reptiles of Delmarva* (White and White 2002).
- Brian Marsh, Fish and Wildlife Biologist, Delaware Bay Estuary Project, is responsible for the restoration activities at the Brandywine Valley unit of FRST. He supplied information on that effort for this assessment.
- Nathan Nazdrowicz is a biologist with Delaware Division of Fish & Wildlife, Species Conservation and Research Program, and is responsible for directing research on the bog turtle and directing the Delaware amphibian and reptile atlas effort. Mr. Nazdrowicz supplied information for this assessment.

4.11.7. Literature Cited

Andrews, K. M., J. W. Gibbons, D. M. Jochimsen, and J. Mitchell. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. Herpetological Conservation 3:121–143.

Arndt, R. G. 1977. Notes on the natural history of the bog turtle, *Clemmys muhlenbergi* (Schoepff), in Delaware. Chesapeake Science 18(1):67–76.

Auch, R. F., D. E. Napton, S. Kambly, T. R. Moreland Jr., and K. L. Sayler. 2012. The driving forces of land change in the northern piedmont of the United States. The Geographical Review 102:53–75.

Bailey, M. A., J. N. Holmes, K. A. Buhlmann, and J. C. Mitchell. 2006. Habitat management guidelines for amphibians and reptiles of the southeastern United States. Technical Publication HMG-2. Partners in Amphibian and Reptile Conservation, Montgomery, Alabama.

Balsas, C. J. L. 2019. Why did the turtle cross the street? An examination of herpetofauna habitat road fragmentation. Proceedings of the Fábos Conference on Landscape and Greenway Planning 6:7. Available at: https://scholarworks.umass.edu/fabos/vol6/iss1/7.

Becker, C. G., C. R. Fonseca, C. F. Baptista Haddad, R. F. Batista, and P. I. Prado. 2007. Habitat split and the global decline of amphibians. Science 318:1775–1777.

Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8(1):60–71.

Blaustein A. R., S. C. Walls, B. A. Bancroft, J. J. Lawler, C. L. Searle, and S. S. Gervasi. 2010. Direct and indirect effects of climate change on amphibian populations. Diversity 2:281–313.

Conant, R., and J. T. Collins. 1998. A field guide to reptiles and amphibians: eastern and central North America, third edition expanded. Houghton Mifflin Co., Boston, Massachusetts.

Cushman, S. A. 2006. Effects of habitat loss and fragmentation on amphibians: a review and prospectus. Biological Conservation 128:231–240.

Delaware Department of Natural Resources and Environmental Control (DNREC). 2015. 2015–2025 Delaware Wildlife Action Plan. DNREC, Dover, Delaware.

Devictor V., R. Julliard, J. Clavel, F. Jiguet, A. Lee, and D. Couvet. 2008. Functional biotic homogenization of bird communities in disturbed landscapes. Global Ecology and Biogeography 17:252–261.

Dornelas, M., A. E. Magurran, S. T. Buckland, A. Chao, R. L. Chazdon, R. K. Colwell, T. Curtis, K. J. Gaston, N. J. Gotelli, M. A. Kosnik, B. McGill, J. L. McCune, H. Morlon, P. J. Mumby, L. Ovreas, A. Studeny, and M. Vellend. 2012. Quantifying temporal change in biodiversity: challenges and opportunities. Proceedings of The Royal Society B 280:1–10.

Drummond, M. A., and T. R. Loveland. 2010. Land-use pressure and a transition to forest-cover loss in the eastern United States. BioScience 60:286–298.

Ernst, C. H., and J. E. Lovich. 2009. Turtles of the United States and Canada, second edition, revised and updated. Johns Hopkins University Press, Baltimore, Maryland.

Evans, J. E., L. Wewerka, E. M. Everham III, and A. J. Wohlpart. 2011. A large-scale snake mortality event. Herpetological Review 42:177–180.

Farr, M. M. 2003. Amphibian assemblage response to anthropogenic disturbance in Pennsylvania wetlands. M.S. Thesis. Wildlife and Fisheries Science. Pennsylvania State University, University Park, Pennsylvania.

Fontenot, L. W., G. Pittman-Noblet, S. G. Platt, and J. M. A. Akins. 1996. A survey of herpetofauna inhabiting polychlorinated biphenyl contaminated and reference watersheds in Pickens County, South Carolina. Journal of the Elisha Mitchell Scientific Society 112(1):20–30.

Gardner, T. A., J. Barlow, and C. A. Peres. 2007. Paradox, presumption and pitfalls in conservation biology: the importance of habitat change for amphibians and reptiles. Biological Conservation 138:166–179.

Gibbons, J. W., D. E. Scott, T. J. Ryan, K. A. Buhlmann, T. D. Tuberville, B. S. Metts, J. L. Greene, T. Mills, Y. Leiden, S. Poppy, and C. T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50:653–666.

Grant, B. W., A. D. Tucker, J. E. Lovich, A. M. Mills, P. M. Dixon, and J. W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pages 379–403 *in* R. Seigel and N. Scott, editors. Wildlife 2001. Elsevier Science Publications, Inc., London, England.

Grundel, R., D. A. Beamer, G. A. Glowacki, K. J. Frohnapple, and N. B. Pavlovic. 2015. Opposing responses to ecological gradients structure amphibian and reptile communities across a temperate grassland–savanna–forest landscape. Biodiversity Conservation 24:1089–1108.

Hamer, A. J., and M. J. McDonnell. 2010. The response of herpetofauna to urbanization: Inferring patterns of persistence from wildlife databases. Austral Ecology 35:568–580.

Hansen, A. and D. Gryskiewicz. 2003. Interactions between Heartland National Parks and Surrounding Land Use Change: Development of Conceptual Models and Indicators for Monitoring. Final Report to the National Park Service Heartland Network.

Holmes, R. T. 2010. Avian population and community processes in forest ecosystems: long-term research in the Hubbard Brook Experimental Forest. Forest Ecology and Management 262:20–32.

Jørgenson, S. E., and F. Müller, editors. 2000. Handbook of ecosystem theories and management. CRC Press, Boca Raton, Florida.

Julian, J. T., G. Rocco, M. Turner, and R. Brooks. 2013. Wetland dependent wildlife: amphibians and reptiles. Pages 313–338 *in* Mid-Atlantic Freshwater Wetlands: Advances in Science, Management, Policy and Practice. Brooks, R., and D. Wardrop, editors. Springer Press, New York, New York.

Karraker, N. E., J. P. Gibbs, and J. R. Vonesh. 2008. Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. Ecological Applications 18:724–734. Available at: https://loe.org/images/content/090220/Karraker_et_al_2008.pdf.

Ljustina, O., and S. Barrett. 2018. Using canals in southern Florida to measure impacts of urbanization on herpetofaunal community composition. Southeastern Naturalist 17:202–210.

Lookingbill T., C. N. Bentsen, T. J. B. Carruthers, S. Costanzo, W. C. Dennison, C. Doherty, S. Lucier, J. Madron, E. Poppell, and T. Saxby. 2012. Colonial National Historical Park natural resource condition assessment: Virginia. Natural Resource Report NPS/COLO/NRR—2012/544. National Park Service, Fort Collins, Colorado.

Magurran, A. E., S. R. Baillie, S. T. Buckland, J. McP. Dick, D. A. Elston, E. M. Scott, R. I. Smith, P. J. Somerfield, and A. D. Watt. 2010. Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends in Ecology and Evolution 25:574–582.

Mifsud, D. A. 2014. A status assessment and review of the herpetofauna within the Saginaw Bay of Lake Huron. Journal of Great Lakes Research 40:183–191.

Miller, K. M., F. W. Dieffenbach, J. P. Campbell, W. B. Cass, J. A. Cmiskey, E. R. Matthews, B. J. McGill, B. R. Mitchell, S. J. Perles, S. Sanders, J. P. Schmit, S. Smith, and A. S. Weed. 2016. National parks in the eastern United States harbor important older forest structure compared with matrix forests. Ecosphere 7:1–20.

Moore, M. V., M. L. Pace, J. R. Mather, P. S. Murdoch, R. W. Howarth, C. L. Folt, C. Y. Chen, H. F. Hemond, P. A. Flebbe, and C. T. Driscoll. 1997. Potential effects of climate change in freshwater ecosystems of the New England/Mid-Atlantic Region. Hydrological Processes 11:925–947.

NatureServe. 2019. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://explorer.natureserve.org (accessed 23 October 2019).

Newbold, T., L. N. Hudson, S. L. L. Hill, S. Contu, C. L. Gray, J. P. W. Scharlemann, L. Börger, H. R. P. Phillips, D. Sheil, I. Lysenko, and A. Purvis. 2016. Global patterns of terrestrial assemblage turnover within and among land uses. Ecography 39:1151–1163.

National Park Service. 2019. NPSpecies – the National Park Service biodiversity database, online portal version. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/NPSpecies (accessed October 2019).

Palmeirim, A. F., M. V. Vieira, and C. A. Peres. 2017. Herpetofaunal responses to anthropogenic forest habitat modification across the neotropics: insights from partitioning β-diversity. Biodiversity Conservation 26:2877–2891.

Pechmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892–895.

Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission. 2015. Pennsylvania Wildlife Action Plan, 2015–2025. C. Haffner and D. Day, editors. Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission, Harrisburg, Pennsylvania.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, D.C.

Petranka, J. W., C. A. Kennedy, and S. S. Murray. 2003. Response of amphibians to restoration of a southern Appalachian wetland: a long-term analysis of community dynamics. Wetlands 23(4):1030–1042.

Sanzo, D., and S. J. Hecnar. 2006. Effects of road de-icing salt (NaCl) on larval wood frogs (*Rana sylvatica*). Environmental Pollution 140:247–256.

Sullivan, B. K., D. J. Leavitt, and K. O. Sullivan. 2017. Snake communities on the urban fringe in the Sonoran Desert: influences on species richness and abundance. Urban Ecosystems 20:199–206.

Tierney, G., and J. Gibbs. 2016. Natural resource condition assessment: Weir Farm National Historical Site. Natural Resource Report NPS/NETN/NRR—2016/1256. National Park Service, Fort Collins, Colorado.

Turner, M., and R. Brooks. Unpublished. Amphibian index of biological integrity for headwater complex wetlands in the Ridge and Valley Province of Pennsylvania, USA. Available at: https://riparia.psu.edu/.

U.S. Fish and Wildlife Service (USFWS). 1997. Final rule to list the northern population of the bog turtle as threatened and the southern population as threatened due to similarity of appearance. Federal Register 62(213):59605–59623.

USFWS. 2001. Bog turtle (*Clemmys muhlenbergii*), northern population, recovery plan. Hadley, Massachusetts.

USFWS. 2010. Bog turtle *Clemmys muhlenbergii*. U.S. Fish and Wildlife Service Pennsylvania Field Office, State College, Pennsylvania.

Wagner, R., C. A. Cole, M. Brittingham, C. P. Ferreri, L. Gorenflo, M. W. Kaye, B. Orland, and K. Tamminga. 2014. Morristown National Historical Park natural resource condition assessment. Natural Resource Report NPS/NERO/NRR—2014/869. National Park Service, Fort Collins, Colorado.

Welsh, H. H., and S. Droege. 2001. A case for using Plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. Conservation Biology 15:558–569.

White, J. F., and A. W. White. 2002. Amphibians and reptiles of Delmarva. Tidewater Publishers, Centreville, Maryland.

White, J, and A. White. 2007. Amphibians and Reptiles of Delmarva. Tidewater Publishers, Atglen, Pennsylvania.

White, J. F., and A. W. White. 2015. Amphibian and reptile survey, First State National Historical Park, Woodlawn Tract. Hyla Associates, Hockessin, Delaware.

4.12. Wetlands

4.12.1. Background and Importance

The U.S. Fish and Wildlife Service (USFWS) defines wetlands as: "transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season." (Cowardin et al. 1979). Wetlands generally include marshes, bogs, swamps, fens, prairie potholes, and other areas temporarily or permanently inundated by shallow water.

Healthy wetlands provide many benefits (Mitsch and Gosselink 2000). It is well established that water quality is improved as wetland areas filter out nutrient loads and pollutants before they reach rivers and streams. Wetlands are sometimes regarded as "the kidneys of the landscape" due to their pollutant and nutrient attenuating abilities (Mitsch and Gosselink 2000). Wetlands also moderate floodwaters and maintain low water flows. Another function of wetlands, which is especially important in terms of the NPS and FRST mission, is to provide habitat for a diversity of plants and wildlife, many of which are becoming increasingly scarce both locally and regionally due to continuing wetland losses. Wetlands can also serve as important stopover areas for migrating birds. In addition to their ecological significance, wetlands exhibit a variety of educational, recreational, and aesthetic values.

NPS Management Policies (NPS 2001, Section 4.6.5) and Executive Order 11990 "Protection of Wetlands" direct the NPS to minimize and mitigate the destruction, loss or degradation of wetlands; preserve, enhance and restore the natural and beneficial values of wetlands; and avoid direct and indirect support of new construction in wetlands unless there are no practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. NPS policies for implementing Executive Order 11990 at NPS properties are found in Director's Order 77-1 "Wetland Protection" and the associated Procedural Manual. The NPS has set a goal of "no net loss of wetlands" and requires that parks avoid adverse impacts to wetlands to the extent practicable for any new development or projects.

The State of Delaware was once approximately 36% wetland. By the late-20th century, only 46% of this original wetland acreage was left (Dahl 1990, DDNREC 2008). Of the 320,000 remaining acres of wetland in the state, the majority are located on private lands with little or no protected status (DDNREC 2008, DDNREC 2015). The Delaware Wetlands Conservation Strategy (DDNREC 2008) and Delaware Wetlands Management Plan (DDNREC 2015), as well as various federal and NPS statutes, guide the management and protection of wetlands in Delaware and at FRST. Wetlands provide habitat for several federal or state-listed endangered or threatened species in the Christina River Basin (within which Brandywine Valley lies), including the cerulean warbler (*Setophaga cerulea*) and long-tailed salamander (*Eurycea longicauda*) (DDNREC 2011).

Wetland Types at FRST

Overview of Wetlands at FRST

The first documented characterization of wetlands at Brandywine Valley was done in 2011 (Quigley 2011), followed by a historical analysis of land use in the Woodlawn Tract that included current land cover for change detection purposes (Coxe 2014). This report is the first attempt to bring together all sources of wetland information for FRST.

Hydrogeomorphic Classification of Wetlands and Types Present at FRST

The hydrogeomorphic (HGM) classification system for wetlands (Brinson 1993) was designed for evaluating wetland function. It has been used by numerous agencies to assess the physical and biological function of wetlands (Mitsch and Gosselink 2000). The HGM system is useful in comparing functional integrity of a wetland within each functional class. HGM classification is based on three primary components: geomorphology (topographic location), water source (precipitation, surface flow, groundwater discharge), and hydrodynamics (direction and strength of water movement) (Mitsch and Gosselink 2000).

At least three of the seven HGM types listed by the Natural Resources Conservation Service (NRCS 2008) are present at FRST. Listed in order of decreasing acreage at FRST, they are riverine, depressional, and slope types (see Table 4.12-1 for acreages). Riverine wetlands are located in flood plains and riparian corridors near streams and rivers. Depressional wetlands form in topographical depressions. Slope wetlands are usually found where groundwater discharge meets the land surface. For more information on each of the HGM types, see NRCS (2008). A generalized diagram of the three wetland types found at FRST and their position within the landscape is shown in Figure 4.12-1.

Table 4.12-1. Acreage of wetlands by hydrogeomorphic (HGM) class at First State National Historical Park. (Sharpe 2016, USFWS 2019, State of Delaware 2019).

Hydrogeomorphic Class	Acreage (% of total)
Riverine [1]	198.7 (76.0)
Depressional	62.6 (24.0)
Slope [2]	Unknown
Total	**261.3 (100)**

[1] Riverine wetland acreage does not include Brandywine Creek wetland acreage outside of or tributaries upstream of the Brandywine Valley boundary. The area used for the riverine wetland metric analyses is 206.2 acres because the entirety of Brandywine Creek wetlands along the Brandywine Valley boundary and tributaries upstream of the boundary were included.

[2] Quigley 2011 shows evidence of slope wetlands within the park boundary. However, none of the wetlands within Brandywine Valley were designated as slope wetlands by any of the three data sources for wetland extent used in this analysis. Slope wetlands are likely present within the park but the acreage is not substantial.

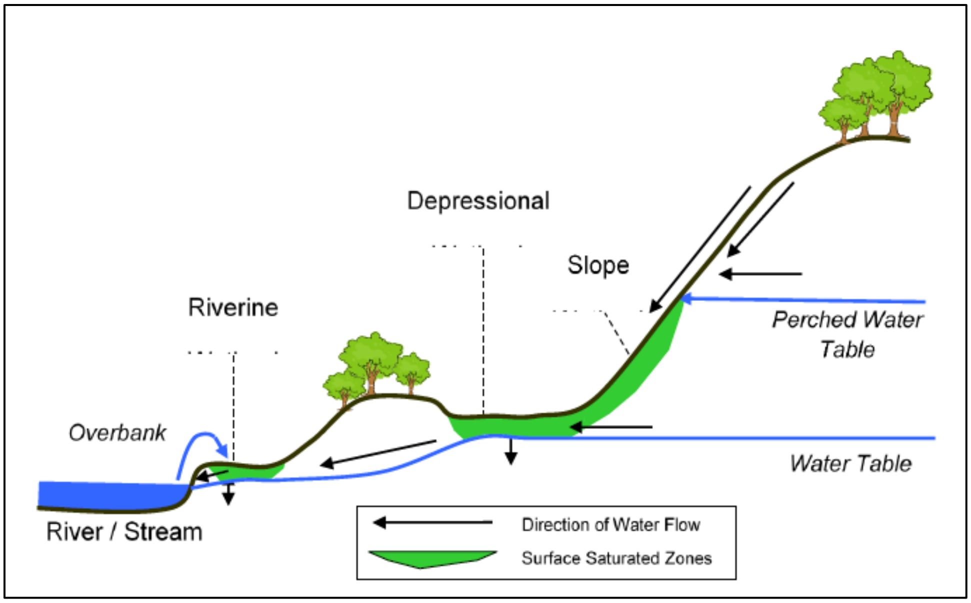


Figure 4.12-1. Cross-sectional schematic of dominant wetland hydrogeomorphic (HGM) classes found at Brandywine Valley (Bingham et al. 2016).

Wetland Classification by Dominant Vegetation and Types Present at FRST

Several vegetation classification schemes for wetlands have been produced at both the national and local level. The most widely used in the United States is the U.S. Fish and Wildlife Service system (Cowardin et al. 1979). The higher levels of this system are based on geomorphology and hydrology; lower-level classification focuses on vegetation types, with broad vegetation types included at the class level (Mitsch and Gosselink 2000). Once at the class level, vegetation becomes the primary determinant of wetland class for wetlands with greater than 30% vegetative cover, while substrate is used for those with less than 30% cover (Mitsch and Gosselink 2000). For more information on this classification system, see Cowardin et al. (1979).

Wetland types found at FRST include forested, emergent, and open water/unconsolidated bottom (Table 4.12-2). Emergent wetlands, which can occur in several hydrogeomorphic settings, are characterized by "erect, rooted, herbaceous hydrophytes, excluding mosses and lichens" (Cowardin et al. 1979). A classic example of an emergent wetland would be the highly recognizable cattail marsh. Forested wetlands are categorized by woody vegetation that is ≥ 6 m in height. Open water is generally characterized by deep water and lack of standing vegetation. Emergent wetlands may revert to open water in some years due to flooding or other disturbances.

Table 4.12-2. Acreage of wetlands by vegetation type at FRST (Sharpe 2016, USFWS 2019, State of Delaware 2019).

Hydrogeomorphic Class	Acreage (% of total)
Open Water/Unconsolidated Bottom (Riverine)	198.7 (76.1)
Open Water/Unconsolidated Bottom (Non-riverine)	0.6 (<0.1)
Forested	61.7 (23.7)
Emergent	0.3 (<0.1)
Total	**261.3 (100)**

Threats and Stressors

The most commonly cited threat to wetlands is adjacent land use. This is evidenced by the fact that many states have established indicators and metrics to assess the impact of surrounding development and land use on wetlands, similar to the Delaware Comprehensive and Rapid Assessment Procedures (Jacobs et al. 2009, Jacobs 2010) as well as various federal agency methodologies for assessing wetland integrity, including the one used in this chapter developed by the NPS Northeast Temperate Inventory and Monitoring Network and the EPA (Faber-Langendoen 2009, Faber-Langendoen et al. 2012). Effects of adjacent land use on wetlands include destruction of ecological buffer zones, hydrologic and habitat isolation, runoff of pollutants and excessive nutrients from agricultural and other non-point source pollution sources, and other effects (DDNREC 2008, DDNREC 2015).

Another major wetland stressor is the filling of wetlands for numerous purposes. Fill can consist of soil, rock, concrete, brick or other natural or synthetic materials. The "no net loss of wetlands" policy established in the 1990s has largely stopped the practice of filling wetlands without proper mitigation and compensation, but the effects of past activities persist. Other stressors include trash dumping, hydrologic alteration by ditching and drainage tiling, off-highway vehicle use, and others (Davey Resource Group 2006).

Indicators and Measures

- Extent of wetlands
- Surrounding Land Use Index
- Landscape connectivity
- Buffer Index

4.12.2. Data and Methods

The indicators used to assess the wetland communities at FRST were adapted from Faber-Langendoen (2009) and from the NRCA for Richmond National Battlefield Park (RICH) (Schneider et al. 2012), which is similar in ecological makeup and climate to the Brandywine Valley unit. Appendix E of Schneider et al. (2012) details the methods and datasets used for our analyses. Wetland condition was rated using three metrics: 1) landscape connectivity, 2) buffer index, and 3) surrounding land use. The only departure from the framework used at RICH is the combining of the

"Excellent" and "Good" ratings from RICH into a single "good condition" category for FRST. No trends are determined for any of these metrics due to a lack of historical data. The metrics defined and calculated for FRST wetlands will act as a useful baseline for determining future changes in the condition of wetlands at the park.

Individual wetlands were combined into wetland complexes for analysis purposes based on proximity and type (riverine vs. non-riverine wetlands). Five complexes were created: the four non-riverine complexes of North Fork Beaver Creek (NFBC), South Fork Beaver Creek (SFBC), Rocky Run (RR), and Thompson Mill Bridge (TMB), and Riverine Wetlands (Figure 4.12-2). The area of analysis for riverine wetlands was created by clipping Brandywine Creek at the northern and southern end of its run adjacent to the western park boundary; all tributaries that flow into this section of Brandywine Creek were included up to their point of origin, even if the point of origin is outside the park boundary. Most tributaries flowing through the park have their headwaters in or near the urbanized area surrounding Wilmington, Delaware, along the Hwy 202 corridor just outside the eastern boundary of Brandywine Valley.

Wetland Extent

This is a measure of the current absolute size of the entire wetland polygon or patch. Patch size can be an important feature of wetland integrity. Species diversity is often higher in larger wetlands than in smaller ones that are otherwise similar. In wetland mosaics (such as those found in the North and South Fork Beaver Creek complexes), larger total area often means more micro-habitat features, which increases habitat complexity and often results in higher biodiversity. Larger wetlands are also more resilient to outside stressors (Faber-Langendoen et al. 2012). This metric will not be rated but can be used as a baseline for future assessments.

Surrounding Land Use Index

The Surrounding Land Use Index is a measure of the intensity of human-dominated land uses within a specific landscape area (here we used the HUC8 watershed, which aligned with the Christina Basin). Each land use type occurring in the landscape area is assigned a coefficient from 0.0 to 1.0 (as per Faber-Langendoen et al. 2012) indicating its relative impact to the target system, with 0.0 indicating the most impact and 1.0 indicating the least.

Landscape Connectivity

Landscape connectivity is a measure of the percentage of unfragmented landscape within 500 m of non-riverine wetlands. For riverine types, it is a measure of how much of the riverine corridor above and below a floodplain area is connected with adjacent natural systems (Faber-Langendoen et al. 2012).

Buffer Index

Buffer Index is an index of the overall area and condition of the vegetated, non-anthropogenic buffer immediately surrounding a wetland complex. The index incorporates three measures: (1) percent of the wetland's perimeter with non-anthropogenic buffer, (2) average non-anthropogenic buffer width (with slope correction), and (3) buffer condition (Faber-Langendoen et al. 2012).

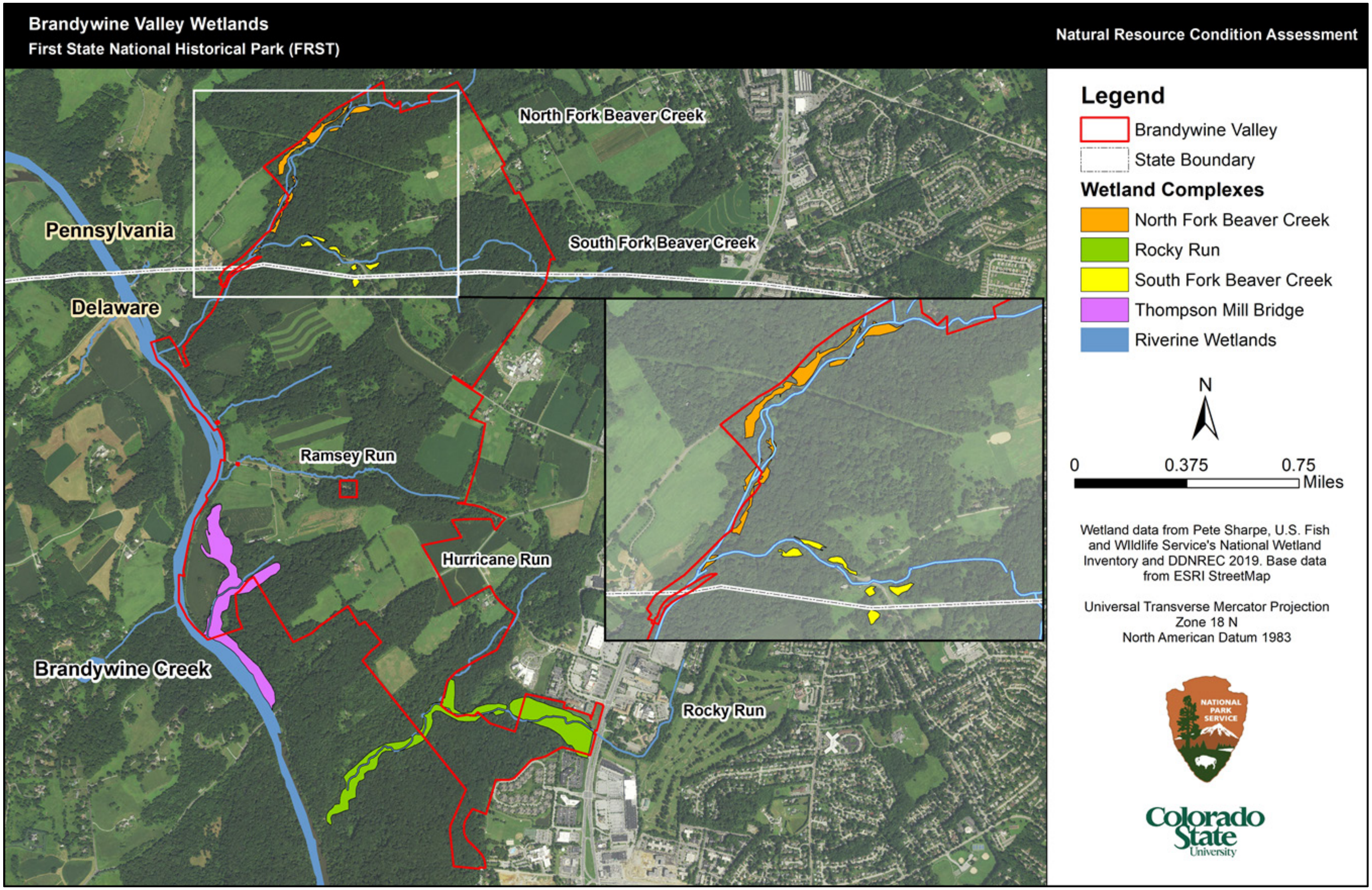


Figure 4.12-2. Extent of wetlands at First State National Historical Park. Data from Sharpe (2016), USFWS (2019), State of Delaware (2019), background imagery via ArcGIS license.

4.12.3. Reference Conditions

The reference condition rating framework for wetlands at FRST follows published scoring ranges from Faber-Langendoen et al. 2012 and Schneider et al. 2012 (Table 4.12-3). Reference conditions for wetland extent are not shown in this framework but can be used as a baseline for future comparison.

Table 4.12-3. Reference condition rating framework for wetlands at First State National Historical Park.

Indicator	Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Surrounding Land Use Index	0.80–1.00	0.40–0.79	≤ 0.40
Landscape Connectivity	60–100%	20–59%	<20%
Buffer Index	2.5–4.0	1.5–2.4	<1.5

4.12.4. Condition and Trend

Wetland Extent

The Rocky Run and Thompson Mill Bridge wetland complexes are the largest non-riverine wetland complexes at Brandywine Valley (Table 4.12-4).

Table 4.12-4. Wetland acreage by wetland complex at First State National Historical Park. Data from Sharpe (2016), USFWS (2019), and State of Delaware (2019).

Class	Wetland Complex	Acreage (% of total)
Riverine	–	206.2 (76.7)
Non-Riverine	NFBC	5.4 (2.0)
	SFBC	1.9 (0.7)
	RR	31.2 (11.6)
	TMB	24.1 (9.0)
All Non-Riverine	–	62.6 (23.3)
Total	**–**	**268.8 (100)**

Surrounding Land Use Index

At FRST, riverine wetlands scored 0.60, while the combined non-riverine wetland score was 0.81 for surrounding land use. Overall, the condition of wetlands at Brandywine Valley in terms of surrounding land use index warrants moderate concern. There is medium confidence in the assessment (Table 4.12-5).

Table 4.12-5. Surrounding land use index scores and condition by wetland complex at First State National Historical Park.

Class	Wetland Complex	Score	Condition
Riverine	–	0.60	Moderate
Non-Riverine	NFBC	0.87	Good
	SFBC	0.87	Good
	RR	0.73	Moderate
	TMB	0.87	Good
All Non-Riverine	–	0.81	Good
All Wetlands	–	0.65	Moderate

Landscape Connectivity

All wetland types and complexes at Brandywine Valley were rated as being in good condition based on the landscape connectivity metric. There is medium confidence in the assessment (Table 4.12-6).

Table 4.12-6. Landscape connectivity scores and condition by wetland complex at First State National Historical Park. Scores calculated from data in Sharpe (2016), USFWS (2019), and State of Delaware (2019).

Class	Wetland Complex	% Non-Anthropogenic	Condition
Riverine	–	81.1	Good
Non-Riverine	NFBC	70.3	Good
	SFBC	71.4	Good
	RR	64.9	Good
	TMB	68.5	Good
All Non-Riverine	–	65.2	Good
All Wetlands	–	71.2	Good

Buffer Index

The buffer index scores indicate that the NFBC and TMB complexes warrant moderate concern and all other complexes, as well as wetlands overall, are in good condition (Table 4.12-7). There is low confidence in the assessment overall due to difficulties assessing irregularly shaped buffers using the method prescribed by Faber-Langendoen et al. 2012.

Table 4.12-7. Buffer index scores and condition by wetland complex at First State National Historical Park.

Class	Wetland Complex	Score	Condition
Riverine *	–	2.8	Good
Non-Riverine	NFBC	2.4	Moderate
	SFBC	2.9	Good
	RR	3.1	Good
	TMB	2.1	Moderate
All Non-Riverine *	–	2.6	Good
All Wetlands	–	2.7	Good

* The confidence level for riverine and all non-riverine wetlands is low due to the difficulty in assessing the width of non-anthropogenic buffer for such irregularly-shaped assessment areas.

Condition Summary

The metrics presented above suggest that, in general, wetlands at FRST are in good condition (Table 4.12-8). Although the condition of wetlands within FRST has room for improvement, they are in good condition when compared with wetlands in the region. Wetland-associated efforts at FRST should concentrate on protecting current wetland buffers within the park boundaries, as well as continuing and refining ground-based wetland characterization efforts. The overall confidence associated with these ratings is medium due to the limited availability of data over time.

Table 4.12-8. Condition and trend summary for wetlands at Brandywine Valley.

Indicator	Condition Status/Trend	Rationale
Wetland Extent		The compilation of wetland extent by wetland complex in this chapter will allow future assessment of this metric.
Surrounding Land Use Index		At FRST, riverine wetlands scored 0.60, while the combined non-riverine wetland score was 0.81 for surrounding land use. Overall, the condition of wetlands at Brandywine Valley in terms of surrounding land use index warrants moderate concern.
Landscape Connectivity		All wetland types and complexes at Brandywine Valley were rated as being in good condition based on the landscape connectivity metric.
Buffer Index		The buffer index scores for NFBC and TMB complexes were in the moderate condition category. All other complexes, as well as wetlands overall, were in good condition. There is low confidence in this indicator due to the difficulty in assessing an irregularly shaped buffer using the method prescribed by Faber-Langendoen et al. 2012.
Overall		**The resource is in good condition, with an unknown trend due to lack of historical data. Confidence in the assessment is medium.**

4.12.5. Uncertainty and Data Gaps

Refinement of wetland boundaries and ground-based characterization of wetland attributes would allow more advanced measures of wetland integrity to be assessed in the future.

4.12.6. Sources of Expertise

- Peter Sharpe (wetland ecologist) provided wetland data as well as recommended the assessment framework used in this chapter.

4.12.7. Literature Cited

Bingham, S. N., C. C. Young, J. L. Haack-Gaynor, L. W. Morrison, and G. A. Rowell. 2016. Wetland monitoring protocol for Cuyahoga Valley National Park: Narrative. Natural Resource Report NPS/HTLN/NRR—2016/1336. National Park Service, Fort Collins, Colorado.

Brinson, M. M. 1993. A hydrogeomorphic classification for wetlands. Technical Report WRP-DE-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service.

Coxe, R. 2014. Historical analysis and map of vegetation communities, land covers, and habitats of the Woodlawn Tract, New Castle County, Delaware. Report submitted to the National Park Service Mid-Atlantic Network, Inventory and Monitoring Program.

Dahl, T. E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Fish and Wildlife Service, Washington, D.C.

Davey Resource Group. 2006. GIS Wetlands Inventory and Restoration Assessment: Cuyahoga Valley National Park, Cuyahoga and Summit Counties, Ohio. Report prepared by Davey Resource Group for HNTB Ohio, Inc.

Delaware Department of Natural Resources and Environmental Control (DDNREC). 2008. Delaware wetlands conservation strategy. Dover, Delaware.

DDNREC. 2011. Christina Basin pollution control strategy. Dover, Delaware.

DDNREC. 2015. Delaware wetland management plan. Dover, Delaware.

Executive Order No. 11990, 42 FR 26961, 3 CFR, 1977 Comp., p. 121, Protection of Wetlands.

Faber-Langendoen, D. 2009. A freshwater wetlands monitoring and assessment framework for the Northeast Temperate Network, National Park Service. Natural Resource Report NPS/NETN/NRR— 2009/143. National Park Service, Fort Collins, Colorado.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2012. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part A. Ecological Integrity Assessment overview and field study in Michigan and

Indiana. EPA/600/R-12/021a. U.S. Environmental Protection Agency Office of Research and Development, Washington, D.C.

Jacobs, A. D., D. F. Whigham, D. Fillis, E. Rehm, and A. Howard. 2009. Delaware comprehensive assessment procedure version 5.2. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.

Jacobs, A. D. 2010. Delaware rapid assessment procedure version 6.0. Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.

Mitsch, W. J., and J. G. Gosselink. 2000. Wetlands, third edition. John Wiley & Sons, New York City, New York.

NPS. 2001. Management Policies. National Park Service, Washington, D.C.

Natural Resources Conservation Service (NRCS). 2008. Hydrogeomorphic wetland classification system: an overview and modification to better meet the needs of the Natural Resources Conservation Service. Technical Note No. 190-8-76.

Quigley, P. 2011. Preliminary ecological research and assessment in support of the Woodlawn Trustees Vision Plan.

Schneider, R. M., A. F. Teets, and J. L. Dorr. 2012. Natural resource condition assessment for Richmond National Battlefield Park, Virginia. Natural Resource Report NPS/NER/NRR—2012/548. National Park Service. Fort Collins, Colorado.

Sharpe, P. 2016. Unpublished wetlands survey data for Beaver Valley unit, First State National Historical Park. NPS Northeast Region Office.

State of Delaware. 2019. FirstMap. Wetland data. Available at: https://opendata.firstmap.delaware.gov/datasets/wetlands/data (accessed 15 October 19).

United States Fish and Wildlife Service (USFWS). 2019. National Wetlands Inventory mapper. Available at: https://www.fws.gov/wetlands/data/mapper.html (accessed 02 September 2019).

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 twelve focal resources were examined: five addressing landscape context – system and human dimensions, two addressing chemical and physical attributes, and five addressing biological or integrated attributes. Status and trend assigned to each focal resource and a synopsis of supporting rationale are presented in Table 5.1-1. The authors recommend reviewing each section in Chapter 4 for details regarding the ratings for indicators used for each focal resource.

5.1.1. Landscape Context – System and Human Dimensions

Landscape context – system and human dimensions included land cover and land use, climate change, night sky, natural sounds, and visual resources (Table 5.1-1). Climate change and land cover/land use were not assigned a condition or trend—they provide important context about the park and many natural resources and can be stressors. Some of the land cover and land use-related stressors at FRST 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 FRST to also include natural night skies, natural sounds, scenery, and air and water quality. Climate change is happening and is affecting resources but is not considered *good* or *bad* per se. Night skies and natural sounds warrant significant concern. Visual resources are in good condition. 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 supporting chemical and physical environment at the park include its air quality and water quality (Table 5.1-1). The condition of these resources can affect human dimensions of the park such as visibility and scenery as well as biological components such as vegetation health and stream biota. Air quality warrants significant concern, while water quality warrants moderate concern. Air quality and water quality at FRST are significantly impacted by historical and current land uses outside the park boundary. Management options are limited for the park and require the establishment of working relationships with other governmental and private entities.

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

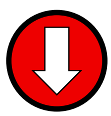
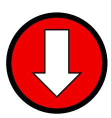
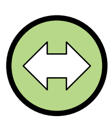
Category	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Landscape Context – System and Human Dimensions	Land Cover and Land Use	condition and trend not assigned	Most of the land cover and land use-related stressors at FRST and in the larger region are related to the development 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 First State National Historical Park to also include natural night skies, natural sounds and scenery.
	Climate Change	condition and trend not assigned	The region'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.
	Night Skies		ALR values for Brandywine Valley averaged 24.2, with a range between 20.5 and 40.0, warranting significant concern. Although the Brandywine Valley night sky is degraded due to high levels of light pollution from Philadelphia and relatively high levels along the Interstate 95 corridor including Wilmington, Delaware, the conditions at Brandywine Valley are better than surrounding residential areas and commercial corridors. ALR values for John Dickinson Plantation averaged 7.4, with a range between 5.1 and 10.2, also warranting significant concern. John Dickinson Plantation is near the boundary of moderate light pollution from the Dover, Delaware, metropolitan area, and is affected by light from Dover Air Force Base and associated housing areas, as well as numerous suburban developments to the west and toward Dover.
	Natural Sounds		The condition of the soundscape at FRST warrants significant concern, with a deteriorating trend due to projections for traffic and housing development. Noise from aircraft is prevalent in the region and an NPS management concern, especially at John Dickinson Plantation, but no data have been collected at FRST units. Overall confidence associated with the assessment is medium.
	Visual Resources		Scenic quality ratings were very good overall. For some views, information gaps reduced the confidence of the importance rating to low. Trends in the condition of viewed landscapes is unknown, although most lilkely unchanging due to relative constancy in ownership and land uses. Confidence in the assessment is high because nearly all important views were inventoried.

Table 5.1-1 (continued). Summary of focal resource condition and trend for First State National Historical Park.

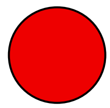
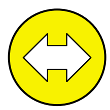
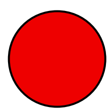
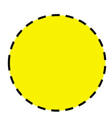
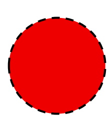
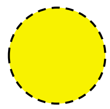
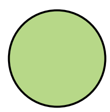
Category	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Chemical and Physical Environment	Air Quality		Based on the evaluation of air quality indicators, air quality condition warrants significant concern, with no trend determined due to insufficient on-site or nearby monitoring data. Confidence in the assessment is medium. Impacts to air quality appear to be largely from distant sources that are affecting regional air quality.
	Water Quality		Water quality in Brandywine Valley warrants moderate concern with an unchanging trend. The water quality for FRST can be assessed with a medium level of confidence. Water quality issues are largely from sources outside of Brandywine Valley and out of the park's control. Substantial issues include recreational contact due to *E. Coli* and excessive nutrients.
Biological – Plants	Forest Communities		The indicators examined suggest the condition of forest communities at FRST warrants significant concern. Only 13% of non-agricultural areas are classified as natural vegetation. However, this metric should improve as former agricultural fields develop into forest communities. For the 53 significant invasive species of non-native plants recorded during surveys in 2014, the average percent of occupied survey sections per species was 36%. Six species occurred across more than 95% of the surveyed sections. Twenty-two species were determined to have a high local threat value for FRST. It is unknown whether the Brandywine Valley unit deer density is higher or lower than the state target of fewer than 40 deer/sq mi needed to allow for forest tree regeneration and other benefits. A variety of forest disease and pest issues are impacting or are predicted to impact FRST. A number of species are predicted to be severely impacted by a changing climate at FRST.
Biological – Animals	Birds		The value for the bird IBI indicates the bird community at FRST warrants moderate concern. Numerous species within the interior forest and single-brooded specialist guilds were detected, along with many species in the urban/suburban generalist guild and few in the bark prober and ground forager specialist guilds. This community structure is representative of a moderately disturbed landscape. No trend assessment is currently possible for this measure of condition due to the lack of monitoring data for the Brandywine Valley unit.
	Bats		Bat surveys at FRST detected four out of 11 or 36% of the bat species expected to occur there, indicating that the bat community at FRST warrants significant concern. Due to the effects of white-nose syndrome, two of the five bat species confirmed at FRST, the northern long-eared bat and tri-colored bat, are now considered at risk of extinction. No trend assessment is currently possible for this measure of condition due to the limited monitoring data.

Table 5.1-1 (continued). Summary of focal resource condition and trend for First State National Historical Park.

Category	Resource	Condition and Trend	Rationale for Overall Condition/Trend Rating
Biological – Animals (continued)	Reptiles and Amphibians		The values for the metrics of percent of expected species confirmed and the amphibian IBI indicate that the FRST herpetofauna community warrants moderate concern, with a structure that represents a moderately disturbed landscape. No trend assessment is currently possible for this measure of condition due to the limited survey data for the Brandywine Valley unit of FRST. Comprehensive data collected from across the entire unit is only available for one period. For this reason, confidence in the assessment is low.
Integrated Biological/ Environmental	Wetlands		Although the condition of wetlands within FRST has room for improvement, they are in good condition when compared with wetlands in the region. Wetland-associated efforts at FRST should concentrate on protecting current wetland buffers within the park boundaries, as well as continuing and refining ground-based wetland characterization efforts. The overall confidence associated with these ratings is medium due to the limited availability of data.

5.1.3. Biological Component – Plants

The sole floral biological component examined was forests (Table 5.1-1). Forest resources at FRST have been influenced by historical land uses that have changed the species composition and age structure of the forest. Brandywine Valley contains some of the largest remaining forest tracts in the area, helping to support biodiversity as well as provide corridors for migratory wildlife species. The majority of the forested areas are fragmented, but some areas within Brandywine Valley exhibit late-successional or old-growth characteristics, existing mostly on steeply sloped stream valleys that were spared from development and agriculture. Condition metrics included extent of native vegetation cover, invasive nonnative plants, forest pests and diseases, white-tailed deer population, and climate change. Forest communities at FRST have a long history of being impacted by a variety of stressors and threats including noxious and invasive weeds, diseases and insect pests, compounding effects of climate change, air pollution, acid rain/atmospheric chemistry, past land uses, and impacts associated with white-tailed deer populations. These stressors and threats have collectively shaped and continue to impact forest community condition and ecological succession. The condition of forests warrants significant concern.

5.1.4. Biological Component – Animals

The faunal biological components examined included bats, birds, reptiles, and amphibians (Table 5.1-1). Birds, reptiles, and amphibians warrant moderate concern, while bat populations warrant significant concern and are in decline. The fragmentation of habitat and conversion of native vegetation to urban landscapes outside the park can negatively impact populations of some bats and birds at FRST. The park contains some relatively unfragmented patches of habitat that provide refugia within an altered and urbanized regional landscape. Increased protection and restoration of caves, riparian forests, and wetlands increase community abundance and diversity for bats and birds over time.

5.1.5. Integrated Biological/Environmental

Wetlands provide key habitat for numerous species and are sensitive to changes in water quality and hydrology. In general, wetlands in Brandywine Valley are in good condition, with no trend assessed due to lack of data over time. Although the condition of wetlands within FRST has substantial room for improvement, they are in good condition when compared with wetlands in the region. Wetland-associated efforts at FRST should concentrate on protecting current wetland buffers within the park boundaries, as well as continuing and refining ground-based wetland characterization efforts.

5.2. Data Gaps and Uncertainties

The identification of data gaps during 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 First State National Historical Park.

Category	Resource	Data Gaps
Landscape Context – System and Human Dimensions	Land Cover and Land Use	Condition/status of other protected lands in the region.
	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 FRST.
	Night Sky	No on-site night sky monitoring studies have been conducted by the NPS at FRST. Additional measures for night skies could include Bortle Dark Sky Scale assessments, assessment of sky brightness using a charged couple device (CCD), and Unihedron Sky Quality Meter (SQM).
	Natural Sounds	No evaluative data to determine the impacts of existing soundscape conditions on visitor experiences have been collected on-site at FRST. Condition and trend are based on traffic volumes and modelled data.
	Visual Resources	The assessment team lacked the requisite local expertise to complete the view importance portion of the visual resource assessment. Input from park staff regarding cultural, historic, or regulatory importance of the area associated with each viewpoint and viewed landscape was not available but could easily be added to the assessment to improve accuracy and completeness.

Table 5.2-1 (continued). Data gaps identified for focal resources examined at First State National Historical Park.

Category	Resource	Data Gaps
Chemical and Physical Environment	Air Quality	Local air monitoring stations vs. interpolated regional data would improve accuracy.
	Water Quality	Although there is a long, relatively continuous sampling record, there are not enough data points to assess the condition or trend with a high level of confidence. Confidence could be increased with higher sampling frequency and obtaining flow measurements with all water quality samples so that parameter concentrations can be better assessed. Although historical data for tributaries to Brandywine Creek do not currently exist, sampling conducted by the Stroud Water Research Center and TNC will allow determination of water quality trends for these tributaries in the future.
Biological – Plants	Forest Communities	Uncertainty exists regarding the interactive and synergistic effects of anthropogenic stressors, white-tailed deer population, forest health, and climate change impacts. Vegetation monitoring should be done to help understand these cumulative impacts and better inform park managers of the likely future makeup of FRST vegetation communities.
Biological – Animals	Birds	Confidence in this assessment is low and an analysis of trend is not possible. The key uncertainties related to the assessment of the bird community at FRST is the lack of available data and lack of bird detectability information. Survey data were limited to only two sampling periods (2014 and 2015) and no subsequent monitoring data were available.
	Bats	Bat data were limited to only a few sample periods and no monitoring data were available, resulting in low confidence in the assessment.
	Reptiles and Amphibians	Herptofauna data were limited for the Brandywine Valley unit. Survey data were only available for a single time period and no monitoring data were available.
Integrated Biological/ Environmental	Wetlands	Refinement of wetland boundaries and ground-based characterization of wetland attributes would allow more advanced measures of wetland integrity to be assessed in the future.

5.3. Conclusions

First State 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. Impacts associated with development outside the park, especially for the Brandywine Valley unit, 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). 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.

5.4. Literature Cited

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

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 207/177418, September 2021

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525