National Park Service
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Natural Resource Stewardship and Science

National Capital Parks-East Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NACE/NRR—2016/1197

ON THE COVER
Photograph of a National Capital Parks-East Ranger leading a canoe trip with staff from Wilderness Inquiry up the Anacostia River.
Photograph courtesy of the National Park Service.

National Capital Parks-East
Natural Resource Condition Assessment

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Natural Resource Report NPS/NACE/NRR—2016/1197

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

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available in digital format from the National Capital Region Network website (http://science.nature.nps.gov/im/units/ncrn/index.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov**.**

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Contents

Contents (contents)

Contents (contents)

Figures

Figures (continued)

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Tables (continued)

Page

Tables (continued)

Tables (continued)

Appendices

Executive Summary

Background

The National Capital Parks–East (NACE) provides a natural haven for the urbanized Washington, D.C., area. NACE includes 14 major park areas that comprise more than 8,000 acres of the Atlantic Coastal Plain from Anne Arundel County, Maryland, through the eastern part of Washington, D.C., to Prince George's and Charles counties, Maryland. In addition to numerous historic and cultural sites, these NPS units protect natural areas for recreation, parkways, historical artifacts and structures, archaeological sites, wetlands, stream valleys, forests, wildlife, and vegetation.

The natural areas within National Capital Parks-East are extremely rich both in biodiversity and in historical context. The park provides islands of refuge for many uncommon plant and animal species in the highly urbanized Washington, D.C. metropolitan area, protecting a variety of cultural and natural resources. Additionally, NACE provides opportunities for the public to foster awareness of the importance of species preservation, biological diversity, natural systems and processes, and the value of natural open space in an urban environment.

Natural Resource Condition Assessment

Assessment of natural resource condition within National Capital Parks-East was carried out using the Inventory and Monitoring Division's National Park Service Vital Signs ecological monitoring framework. Twenty-five metrics were analyzed in four categories: Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. The assessment of condition was based on the comparison of available data collected between 2002 and 2014 to ecological threshold values.

Park units with significant natural resources will be the focus of this natural resource condition assessment. Air quality data is interpolated across all park units, and there will be an air quality assessment and discussion for all sites within NACE. Water resources and fish are monitored at four sites by the NPS National Capital Region Inventory and Monitoring group at Greenbelt Park, Suitland Parkway, Oxon Cove Park, and Piscataway Park. Biological integrity is sampled at 47 sites throughout the park (Baltimore-Washington Parkway, Greenbelt Park, Suitland Parkway, Piscataway Park, Oxon Cove Park, Kenilworth Park and Aquatic Gardens, Civil War Defenses of Washington), with the exception of deer population counts that are estimated only in Greenbelt Park and Piscataway Park. Landscape dynamics data from the 2011 National Landcover database are available for all park areas.

Based on very degraded air quality and landscape dynamics; moderate biological integrity; and good water resources, the natural resources of NACE are in degraded condition overall.

Recommendations and Data Gaps

Degraded air quality is a problem throughout the eastern United States, and while the causes of degraded air quality largely are out of the park's control, the specific implications to the habitats and species in the park are not well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts, particularly in the face of climate change and the conclusion by the U.S. EPA that climate change could increase ozone concentrations and change the amount of particle pollution.

Water resources within the park were in good condition overall, with 61% attainment of reference conditions. The majority of water resource indicators were in a very good condition. A higher overall attainment was, however, offset by very degraded conditions for total phosphorus and degraded conditions for specific conductance and the stream Physical Habitat Index. The majority of water inflows to the park originate from outside the park in developed/urban areas. Data gaps and research recommendations revolve around maintaining good water quality by identifying nutrient sources and sensitive organisms. Water temperature increase is one of the most immediate threats from climate change, and this would result in the loss of fish and other organisms that depend on cooler water.

Biological integrity was, on average, in moderate condition despite variability in the specific indicators. Elevated deer density is negatively impacting stocking index highlighting that deer management should continue to be a top priority. It was also identified that there was a lack of comprehensive information on exotic species, pests and diseases within the park. The park scored very good for area of exotic tree and saplings and presence of forest pest species, despite widespread occurrence of exotic species within the park. This is mainly due to the location of forest monitoring plots on the interior of park natural areas instead of fragmented exterior edges, where exotic species are more likely to be found. Expanded monitoring of these areas is recommended as well as assessment of non-forest bird species and effects of climate change and other stressors on park forests.

Landscape dynamics were in very degraded condition overall, with 3% attainment of reference conditions. Due to the mosaic nature of the park, regional development, and urban encroachment, forest interior area, forest cover, and impervious surface (at both spatial scales) were all in very degraded condition, as was road density within the park. This condition will likely continue with ongoing development of the Washington, D.C. metropolitan area, putting additional stress on the natural habitats of NACE, while also adding pressure on the park to provide recreational opportunities and open space for growing populations.

Conclusions

Under threat from surrounding land use and regionally poor air quality, the natural resources in NACE are in degraded condition overall. Climate change is predicted to negatively affect many of the natural resources of the park, including increasing ozone levels and particle pollution, raising water temperature, changing forest composition, and affecting exotic species and forest pests and disease.

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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 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.

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

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)

[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.

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 on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

2. Introduction and Resource Setting

The National Capital Parks–East (NACE) provides a natural haven for the urbanized Washington, D.C., area. The park was established on May 24, 1965 (NPS 2009) as an administrative unit of the National Park System. NACE includes 14 major park areas that comprise more than 8,000 acres of the Atlantic Coastal Plain from Anne Arundel County, Maryland, through the eastern part of Washington, D.C., to Prince George's and Charles counties, Maryland (Table 2-1) (Thornberry-Ehrlich 2008). In addition to numerous historic and cultural sites, these NPS units protect natural areas for recreation, parkways, historical artifacts and structures, archaeological sites, wetlands, stream valleys, forests, wildlife, and vegetation (Thornberry-Ehrlich 2008).

Table 2-1 National Capital Parks-East Units (NPS).

Park Unit	State
Anacostia Park	District of Columbia
Baltimore-Washington Parkway, Greenbelt Park	Maryland
Capitol Hill Parks	District of Columbia
Carter G. Woodson Home National Historic Site	District of Columbia
Civil War Defenses of Washington-Fort Circle Parks	District of Columbia, Maryland
Fort Washington Park	Maryland
Frederick Douglass National Historic Site	District of Columbia
Harmony Hall	Maryland
Kenilworth Park and Aquatic Gardens	District of Columbia
Mary McLeod Bethune Council House National Historic Site	District of Columbia
Oxon Cove Park/Oxon Hill Farm	District of Columbia, Maryland
Oxon Run Parkway	District of Columbia
Piscataway Park	Maryland
Suitland Parkway	Maryland

This natural resource condition assessment addresses four vital sign categories: Air quality, water resources, biological integrity, and landscape dynamics with data coming from national surveys and the NPS Inventory and Monitoring Network. Park units with significant natural resources will be the focus of this natural resource condition assessment. Air quality data is interpolated across all park units, and will be an assessment and discussion of all sites within NACE. Water resources and fish are monitored at four sites by the NPS National Capital Region Inventory and Monitoring group at Greenbelt Park, Suitland Parkway, Oxon Cove Park, and Piscataway Park. Biological integrity is sampled at 47 sites throughout the park (Baltimore-Washington Parkway, Greenbelt Park, Suitland Parkway, Piscataway Park, Oxon Cove Park, Kenilworth Park and Aquatic Gardens, Civil War

Defenses of Washington), with the exception of deer population counts that are estimated only in Greenbelt Park, Fort Washington, and Piscataway Park. Landscape dynamics data from the 2011 National Landcover database are available for all park areas.

2.1. Park enabling legislation

Several laws and documents guide natural resource management for NACE. The McMillan Commission in 1902 (McMillan Plan of 1902) called for "the improvement of the park system of the District of Columbia" and proposed to have the civil war sites to be developed for recreation and to provide expansive overlooks for viewing the city.

Anacostia River Flats Act of 1914 (Public Law 63, 38 Stat. 549) linked improvements to the navigable waterway of the Anacostia River with the creation of new land to help meet the needs of the growing population of the nation's capital.

The National Park Service Organic Act of 1916 ("Organic Act," Ch. 1, 39 Stat 535) provides the primary mandate NPS has for natural resource protection within all national parks. It states,

> *the service thus established shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to 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.*

Public Law 592, 43 Stat. 463, 1924—established the National Capital Park Commission, which was later renamed the National Capital Planning Commission (NCPC) in 196 (44 Stat. 374), Anacostia Park became a part of the park, parkway, and playground system of the National Capital. The Act stated that land within the park system in the District was to remain under control of the Chief of Engineers of the U.S. Army. It further stated that areas suitable for playground purposes could, at the discretion of the NCPC, be assigned to the control of the Commissioners of the District for playground purposes.

In 1924, a Park Commission was established by Congress and given the task to

> *…to preserve the flow of water in Rock Creek, to prevent pollution of Rock Creek and the Potomac and Anacostia Rivers, to preserve forests and natural scenery in and about Washington, and to provide for the comprehensive systematic, and continuous development of the park, parkway, and playground system of the National Capital.*

In 1926, the National Capital Park and Planning Commission (NCPC) took over for its predecessor, The Park Commission.

The Capper-Cramton Act of May 29 1930, fulfills the purposes of the above 1924 Act by providing for *the acquisition, establishment, and development of the George Washington Memorial Parkway along the Potomac from Mount Vernon and Fort Washington to the Great Falls, and to provide for the acquisition of lands in the District of Columbia and the States of Maryland and Virginia requisite to the comprehensive park, parkway, and playground system of the National Capital.*

The condition for the transfer of administration and management of Forts Washington, Foote, and Hunt, as well as land for the extension of the Anacostia Park system to the NPS was also set in this act, under Section 3 (NPS 2009).

In 1933, Executive Order (EO) 6166 transferred NCPC's responsibilities for management of the park, parkway, and playground system to the NPS. With the transfer, park managers were required to comply with the specific purposes identified in the park's earlier establishing legislation as well as to follow the NPS mission to conserve and protect park resources and to provide for use of the park in a manner that will leave the park unimpaired for the enjoyment of future generations.

In 1949, legislation was introduced for the permanent transfer of the Suitland Parkway along with "all [its] lands and easements heretofore or hereafter acquired by the United States." H.R. 2214 passed Congress on August 17, 1949. This law specified that the parkway be

developed, operated, and administered as a limited access road primarily to provide a dignified, protected, safe, and suitable approach for passenger-vehicle traffic to the National Capital and for an uninterrupted means of access between the several Federal establishments adjacent thereto and the seat of government in the District of Columbia.

On August 3, 1950, the United States Congress passed Public Law 643, providing "for the construction, development, administration, and maintenance of the Baltimore-Washington Parkway," running from the outskirts of Baltimore into the District of Columbia to the entrance of the nation's capital. Under the same law, the National Park Service acquired the land of Greenbelt Park in 1950.

In 1966, Sue Spencer Collins sold 65.7 acres of the remaining Harmony Hall property, including Want Water, to the National Park Service.

On November 6, 1969, Congress approved the Enabling Legislation for Frederick Douglass Home in Public Law 87-633: 76 Stat. 435. On February 12, 1988, the Secretary of the Interior redesignated the site as the Frederick Douglass National Historic Site.

2.2. Geographic Setting

2.2.1. Park description

NACE includes 14 major park areas and a total of 98 locations within the District of Columbia and three nearby counties in Maryland (Figure 2-1).

NACE includes two parkways: the Baltimore-Washington Parkway and Suitland Parkway. The 'parkway concept' involves preserving a wide, scenic, mostly natural corridor along a limited-access divided roadway, following the 'lay of the land'. In addition, Oxon Run Parkway preserves a stream valley corridor, and Shepherd Parkway protects a forested ridgeline. This allows the visitor to experience the local topography and natural scenery, undistracted by billboards, traffic signals, and adjacent dense development (NPS 2011).

Anacostia Park

Authorized by Congress in 1926 to be one of the first U.S. flood plain projects to incorporate multiple uses, Anacostia Park currently occupies over 1,200 acres along five miles of the Anacostia River shoreline within Washington, D.C. On the east bank of the Anacostia River, the park extends from the southernmost tip of the Baltimore-Washington Parkway at the District/Maryland line and south to the South Capitol Street (Frederick Douglass Memorial) Bridge at Poplar Point. On the west bank of the Anacostia River, the park extends from the District/Maryland line to the CSX Railroad Bridge. The Management of Anacostia Park also includes much of the James Creek Marina and Buzzard Point waterfront located in the southwest portion of the District. Anacostia Park is one of the largest and most important parks in Washington, D.C., with diverse recreational opportunities, natural areas, and historic sites. The park also includes the historic Langston Golf Course, River Terrace, and the Kenilworth Park & Aquatic Gardens. The Kenilworth Park & Aquatic Gardens is managed as a separate unit due to its unique resources and habitats.

Frederick Douglass National Historic Site

The Frederick Douglass National Historic Site, located in Southeast Washington, D.C., preserves the home and estate of Frederick Douglass. The site was added to the National Park System by Public Law 87633, approved September 5, 1963 (76 Stat. 435), to memorialize Frederick Douglass (Hinds 1968). The Frederick Douglass home, as part of the park system of the National Capital, was restored, preserved, and interpreted by the National Park Service. Today, the site houses a collection of original furnishings and artifacts from the life of Frederick Douglass.

Piscataway Park

Located along the Potomac River in Prince George's and Charles counties, Maryland (Figure 2-2), Piscataway Park was created as part of a project to protect the views of Mount Vernon and Fort Washington, and to preserve its appearance from George Washington’s time. This 4,625- acre park stretches 10 km (6 miles) from Piscataway Creek to historic Marshall Hall (the circa 1725 plantation of Thomas Marshall) along the Potomac River (Thornberry-Ehrlich 2008). Nearly two thirds of Piscataway Park is private and the NPS owns scenic easement to manage development and achieve park management goals. In addition to nature trails, the park has two boardwalks over freshwater tidal wetlands, and a public fishing pier. Piscataway Park is also home to National Colonial Farm and the Ecosystem Farm, both operated by park cooperators, the Accokeek Foundation. Another major park cooperating organization is the Alice Ferguson Foundation which operates environmental education programs at their Hard Bargain Farm. The State of Maryland manages the Fort Washington Marina and its concessionaires via an agreement with the NPS.

In 2010, the Alice Ferguson Foundation played a lead role with obtaining funding through NOAA and the NPS to complete the “Living Shoreline” along the banks of the Potomac River at Piscataway Park. This project stabilized approx. 2800 feet of severely eroding shoreline, creating two acres of spawning and nursery habitat for more than a dozen fish species, reducing shoreline erosion, improving water quality, and providing protection for freshwater wetlands and Native American archeological sites (Alice Ferguson Foundation 2012).

Greenbelt Park and Baltimore-Washington Parkway

Greenbelt Park and Baltimore-Washington Parkway are one contiguous park unit. They share legislation, lands, and management and staff.

Greenbelt Park covers more than 1,176 acres in Prince George's County, Maryland and provides a natural oasis 12 miles from Washington, D.C., and 23 miles from Baltimore, MD (Thornberry-Ehrlich 2008) (Figure 2-3). It was acquired as part of the historic B-W Parkway in August 1950 under Public Law 643. In June 2000, one of the park's trails was designated a Millennium Trail, and in June 2001, another was designated an American Discovery Trail. The park is located entirely within the Atlantic Coastal Plain physiographic province and in the western shore uplands region. Approximately 1.8 km (1.1 miles) wide and up to 2.1 km (1.3 mile) long, it extends southward from Capitol Drive to Good Luck Road and straddles Deep and Still Creeks. These streams flow into the Northeast Branch of the Anacostia River below Indian Creek. The Baltimore-Washington Parkway bisects the park. Landforms within the park are rolling to steep hills with ravines associated with the two creeks, and elevations range from 8 to 60 m (25 to 200 ft) above sea level (Thornberry-Ehrlich 2008; National Park Service 2003).

The Baltimore-Washington Parkway bisects Greenbelt Park and provides a 47km (29 mile) scenic corridor between the urban areas surrounding Washington, D.C., and Baltimore, Maryland. Opened in 1954, the parkway is consistent with the scenic parkways envisioned in the 1901 McMillan Plan for the nation's capital and in effect, extends the historic Pierre L'Enfant Plan. The National Park Service manages the portion between Washington D.C. and Fort Meade, Maryland. The B-W is a major scenic gateway to the city used by thousands of visitors and commuters each day and is listed on the National Register of Historic Places.

Harmony Hall

Harmony Hall, originally called Battersea, is a mansion located on a 62.5-acre open pasture-land estate along the Potomac River in Prince George's County, Maryland. The estate was purchased by the National Park Service in 1966 to be part of the George Washington Memorial Parkway to protect the scenic values along that Maryland reach of the Potomac River shore. Centuries of southern Maryland cultural represented. Built in 1796, Harmony Hall offers visitors the opportunity to learn about the area's rich cultural and natural landscapes.

Kenilworth Park and Aquatic Gardens

Kenilworth Park and Aquatic Gardens include Kenilworth Marsh and cover 700 acres within Anacostia Park (Thornberry-Ehrlich 2008). The McMillan Plan of 1901 recommended protecting this and other public parklands along the Anacostia River. In 1938, Kenilworth Aquatic Gardens became the only National Park Service unit devoted to the propagation and demonstration of aquatic plants. Kenilworth Aquatic Gardens encompass 8½ acres and abut the Kenilworth Marsh on the east side of the Anacostia River, on the 1500 block of Anacostia Ave. in the northeast quadrant of Washington, D.C. The curving path of Anacostia Ave., N.E. defines its eastern edge, while to the north, south and west the boundary roughly follows the perimeter of the currently existing ponds (Donaldsen 2010). Today, a network of grassy paths on earthen dikes that leads between 45 ponds whose underground drainage pipes control water flow and levels. The Kenilworth Marsh covers 77 acres and surrounds the Aquatic Gardens on three sides. The marsh includes 32 acres of tidal freshwater marshland reconstructed in 1992-3 to provide habitat for an array of native wildlife and wetland plants and to restore a vignette of the once abundant Anacostia marshes for public education. This tidal marsh is nearly all that remains of the once vast tidal wetland areas within the nation's capital. Approximately 200 acres of the adjacent Kenilworth Park is a landfill that was operated by the city government and was reclaimed for recreation in the 1970's.

Suitland Parkway

Suitland Parkway extends from Joint Base Andrews in Camp Springs, Maryland to the Frederick Douglass Memorial (South Capitol Street) Bridge in Washington, D.C. The parkway opened on December 9, 1944. Originally built as a wartime access road to Andrews Air Force Base, the parkway was redeveloped in the 1950s into the scenic, forested park roadway that it is today. Suitland Parkway Legislation was enacted in 1949 (63 stat 612). It extends 15 km (9.35 miles) from Washington to Maryland Route 4 in Prince George's County. The National Park Service manages the 10 km (6 miles) of parkway and 610 acres in Maryland (The DC portion was transferred to the city in 1972). The landscape is forested with numerous streams and wetlands and is a gateway to the nation's capital. Among the cultural features in the park are stone road works and nine stone-faced bridges. Suitland Parkway is listed on the National Register of Historic Places.

Oxon Run Parkway

Oxon Run Parkway is located between Mississippi and Southern Avenues, and 13th Street along Oxon Run within southeast Washington, D.C. (Thornberry-Ehrlich 2008). The 126 acres of protected area include wetlands, floodplains, springs, and forests in a natural sanctuary within the urban area. This unit also includes the only remaining McAteen magnolia bogs in the District of Columbia.

Mary McLeod Bethune Council House

Located in the Logan Circle Historic District in Washington, D.C., the Mary McLeod Bethune Council House NHS commemorates Mary McLeod Bethune's leadership in the black women's right movement. Established in 1935, this historic site held councils from 1943 to 1949. The once home of Bethune served as the first headquarters for the National Council of Negro Women, where she lead strategies and developed programs to advance the interests of African American women. Through this council she raised awareness to help combat racial, class, and gender discrimination not only nationally, but globally. Bethune's influence continues today.

Oxon Cove Park/Oxon Hill Farm

Located in the District of Columbia and Prince George's County, Maryland, Oxon Cove Park features 63-acre Oxon Hill Farm, a working historic farm. Oxon Cove Park has gone through various land changes throughout the years. During the early nineteenth century, the park was once known as the Mount Welby Plantation. Forty-eight years after the property was sold, it was acquired by the United States Government to serve as a therapeutic farm for St. Elizabeth's Hospital, known as

Godding Croft. It wasn’t until 1959 when the National Park Service was entrusted to protect the lands natural and cultural resources from the threat of urban development.

The park is approximately eight miles south of the United States Capitol and serves to link the scenic CWDW corridor at Shepherd Parkway with the proposed NACE sites (Harmony Hall, Fort Foote, Fort Washington) on the Maryland side of the Potomac River. Oxon Run borders the farm site to the north, to the south by Interstate 95/495 and Oxon Cove to the west. A historic road trace known by several different names since it was established, but referred to as the Washington-Piscataway Road Trace in this inventory, borders the farm to the east. Oxon Hill Farm is significant for its association with the agricultural history of Prince George’s County, Maryland during the eighteenth and nineteenth centuries.

<u>Capitol Hill Parks</u>
The Capitol Hill Parks include several sites that have origins in the historic Pierre L’Enfant 1791 plan for the Federal city. Some of the major Capitol Hill Parks include:

Stanton Park consists of all of Reservation 15 in Washington, D.C., and is bounded on the north and south by C Street, NE; on the east by 6th Street, NE; and on the west by 4th Street, NE (Quinn and Wheelock 2007). The reservation was created as part of the implementation of the L'Enfant Plan for the city of Washington and has been a public park since the first improvements in the 1870s. Although modifications were made to the site furnishings, vegetation, and central walkways in the 1960s, most of the significant landscape characteristics were retained (circulation, views and vistas and spatial organization).

Lincoln Park is a 7-acre park located in Washington, D.C., 1 mile east of the U.S. Capitol building. The park is bounded on the north and south by E. Capitol St. 11th St. N.E. and S.E. on the east and 13th St. N.E. and S.E. in the west. The park has a history as both a neighborhood park and a memorial landscape, whose focus is the 1974 Emancipation Monument and the 1974 memorial to Mary McLeod Bethune (Ryberg and Fanning 2009). The site is important as a component of the L’Enfant Plan for Washington, as a prominent African American cultural site, and as a neighborhood park that functions as a community gathering place.

Folger Park is a 2-acre park located in a residential neighborhood on Capitol Hill in SE Washington, D.C. It is a formal urban park bounded on the north and south by D St, on the west by 2nd St., and on the east by 3rd St. The site is important as a component of Andrew Ellicott’s 1792 revision of the 1791 L’Enfant Plan for Washington (Fanning and Zhang 2011).

<u>Civil War Defenses of Washington (Fort Circle Parks)</u>
Built by Union forces to defend the nation’s capital against Confederate troops, the Civil War Defenses formed a 37-mile ring around Washington, D.C. Construction began in the early 1860’s, and by 1865 the defenses included 68 forts. Abandoned after the war, the network of green, open spaces and hilltop views became a catalyst for one of the first urban planning efforts for public recreation. The McMillian Plan of 1902 recommended transforming over 350 acres into the system of CWDW, adding much-needed park space to the city (The Cultural Landscape Foundation). Today

nineteen of the fort sites are administered by the National Park Service. The section of the CWDW under the jurisdiction of the NACE extends southward from Bladensburg Road in Northeast Washington through the segment of the city which lies east of the Anacostia River, and to Fort Foote in Prince George's County, MD. It includes Forts Mahan, Chaplin, Dupont, Davis, Stanton, Ricketts, Greble, Foote and Battery Carroll, and various connecting land parcels, including Shepherd Parkway, which link these sites. Together, these strategically situated parks create a nearly continuous scenic (forested) backdrop to the eastern environs of the Nation's capital and are an important design element to the city. Like other parks of the National Capital Region, the CWDW play valuable ecological roles in an increasingly urban landscape. The natural areas that make up much of the Civil War Defenses of Washington are composed of remnant eastern deciduous forest communities and provide habitat to an impressive array of native plants and wildlife. Shepherd Parkway for example, provides a natural haven for numerous species of wildlife including nesting bald eagles. Also, due to the unique soil conditions, a remnant of glaciation periods, these landscapes support substantial strands of mountain laurel, and it moister areas, spicebush, and arrowwood (Aronica 2001). The fairly intact forests of the forts and their surrounding lands serve as a wildlife corridor within the District of Columbia.

Fort Washington Park

The first fort on the site of today's FOWA was completed in 1809 and guarded Washington, D.C. until it was destroyed by its own garrison in 1814. The existing fort was completed on October 2, 1824, and sits on high ground above the Potomac River on the Maryland shore providing views of Washington, D.C. and Virginia. Except for a few guns at the Washington Arsenal, Fort Washington was the only defense for the Nation's Capital until the Civil War when a circle of temporary forts was built around the city. During World War I, the post was used as a staging area for troops being sent to France. In 1939, the post was abandoned and turned over to the Director of Public Buildings to be used as a terminal point for a bridge across the Potomac River. Before the transfer was complete, the United States entered WWII, and Fort Washington became the Adjutant General's School. After the war ended, the Veterans Administration managed the hospital, and several government agencies occupied the buildings. In 1946 Fort Washington returned to the Department of the Interior. The park is located 17 km (11 miles) south of Washington, D.C. in Prince George's County, Maryland. Fort Washington Park protects 341 acres on a point of land between the confluences of Swan Creek and Piscataway Creek (Thornberry-Ehrlich 2008).

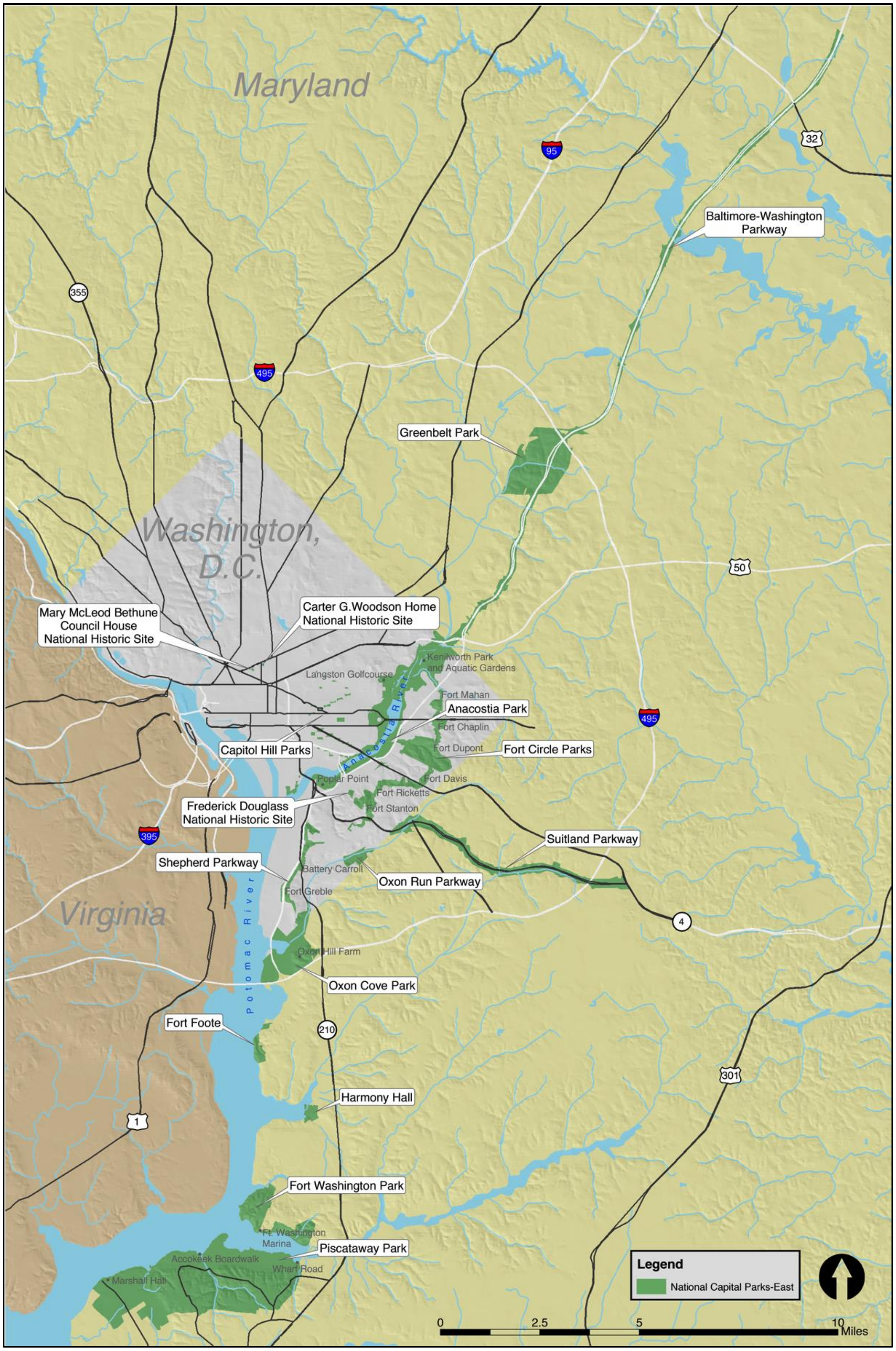

Figure 2-1 NPS Map of National Capital Parks-East (NACE) park units (NPS).

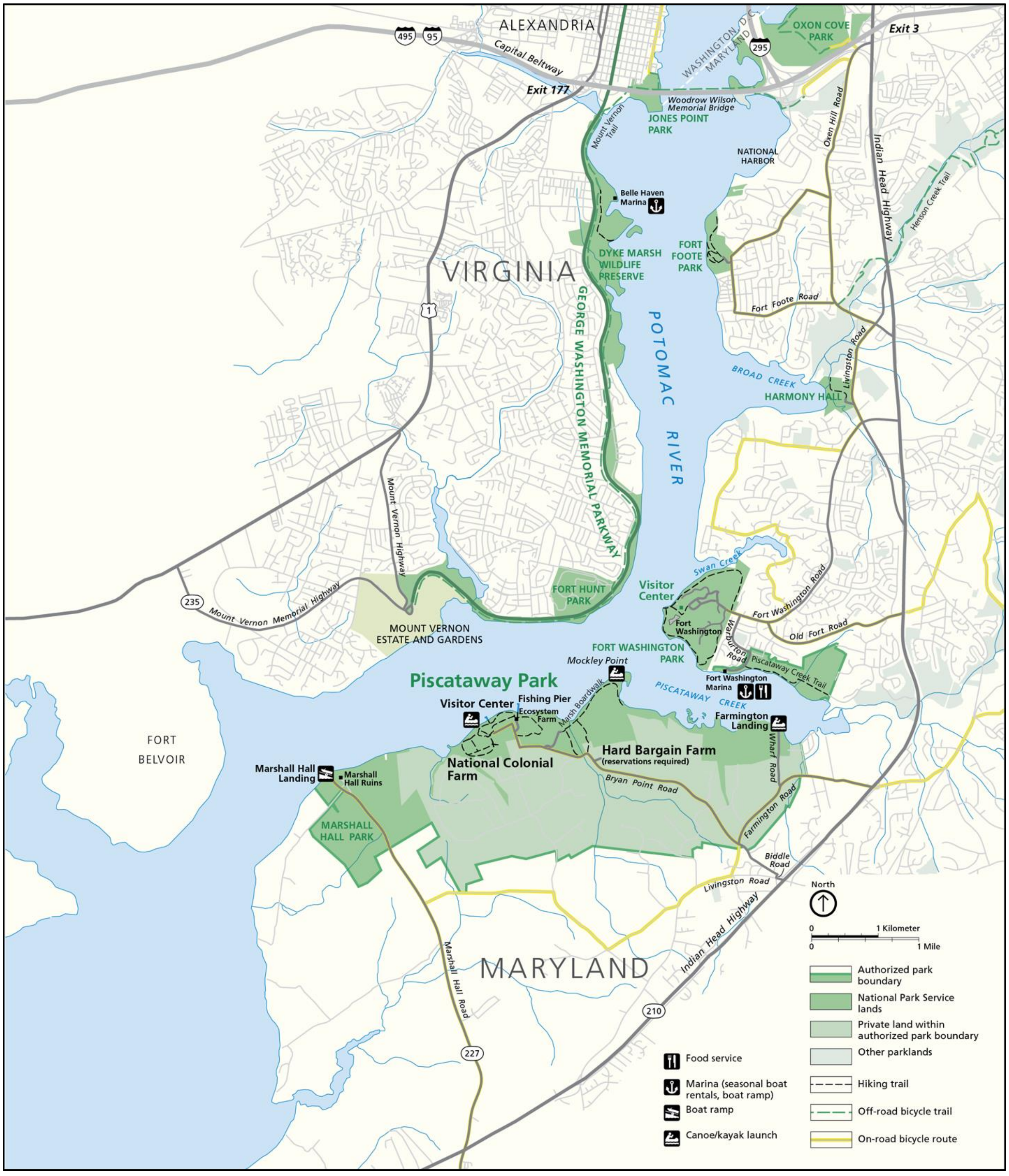

Figure 2-2 NPS Map of Piscataway Park, also showing Oxon Cove Park, Fort Foote, Harmony Hall and Fort Washington (NPS).

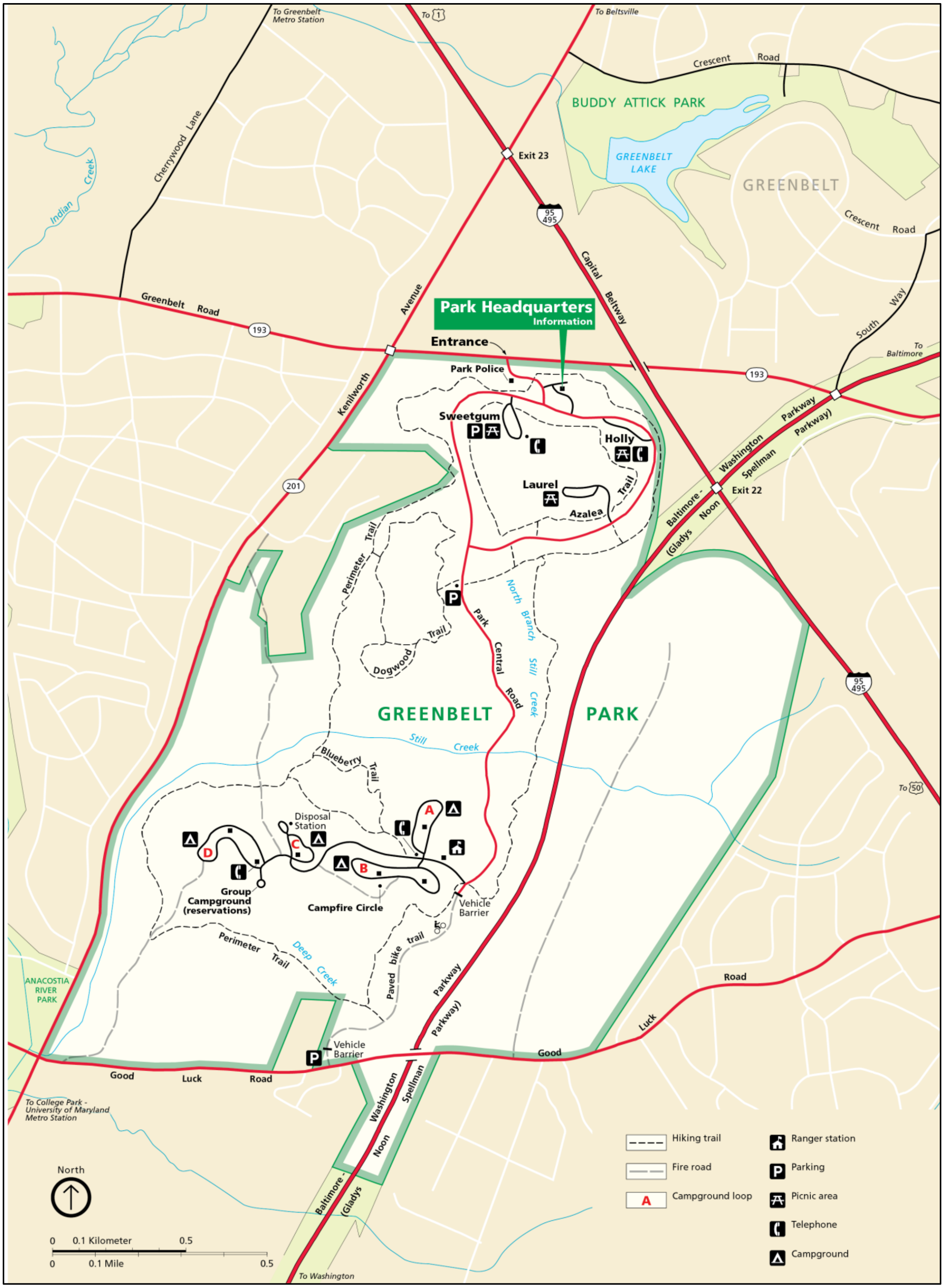

Figure 2-3 NPS map of Greenbelt Park, a subunit of NACE (NPS).

2.2.2. Land Use

Most of the park units of the National Capital Parks-East (NACE) are within the Anacostia and Potomac River Watershed, with the exception of the northernmost portion of the Baltimore-Washington Parkway which is in the Patuxent River watershed (Figure 2-4).

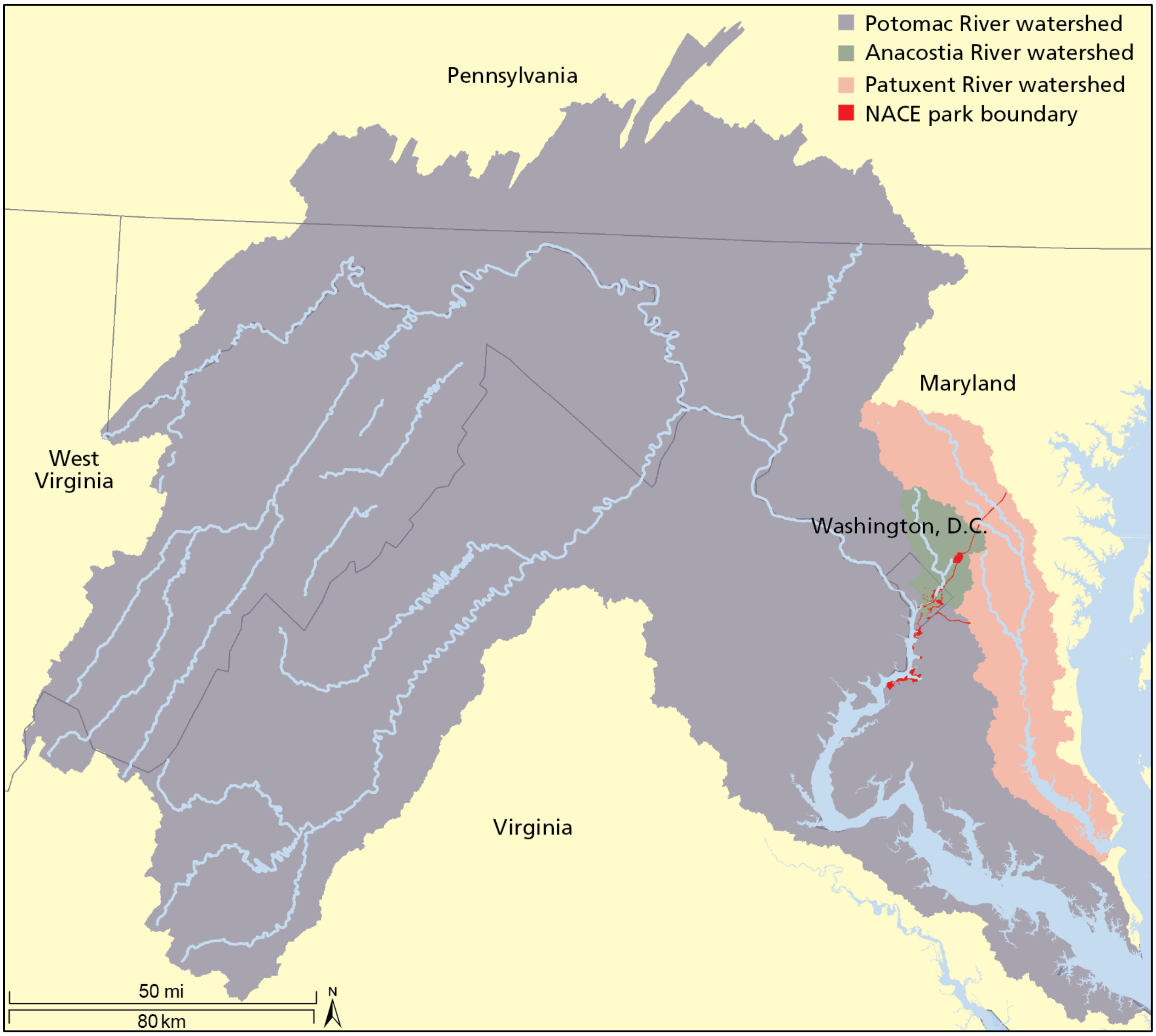

Figure 2-4 Watersheds of the major rivers and streams within NACE.

Land cover in the Potomac River watershed is approximately 58% forest, 32% agriculture, 5% water and wetlands, and 5% developed (Figure 2-6) (ICPRB 2012). The basin's major industries include: agricultural and forestry throughout; coal mining and pulp and paper production along the North Branch Potomac River; chemical production and agriculture in Shenandoah Valley; high-tech, service, and light industry, as well as military and government installations in the Washington metropolitan area; and fishing in the lower Potomac estuary (ICPRB 2012).

Figure 2-5 Map of the counties that NACE park units occur in.

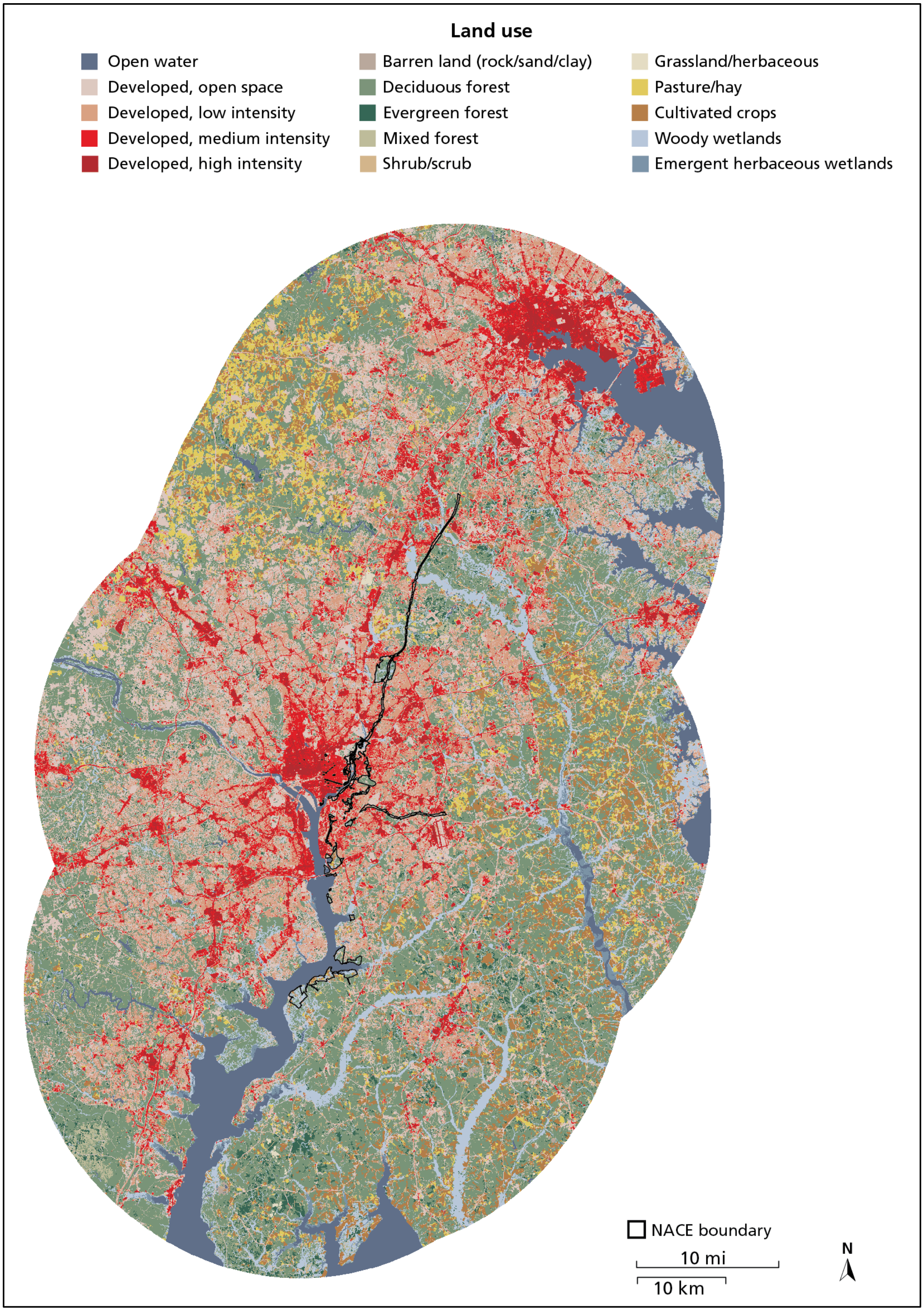

Figure 2-6 Adjacent land use within a 30 km area surrounding NACE in 2011 (Jin et al. 2013; NPS 2011a).

The 176 square mile (456 square kilometer) Anacostia River Watershed (a tributary of the Potomac River) covers portions of the District of Columbia, Prince George's and Montgomery County in Maryland. As of 2000, 70% of the Anacostia River watershed was developed. Residential development, including single-family houses, townhouses, and apartments, is the most common land use and comprises approximately 45% of the watershed (MWCOG 2008). Remaining landcover in the watershed is approximately 45% residential, 30% undeveloped, 9% institutional, 7% commercial, 4% agricultural, 4% industrial, and 1% mining. Most of the parkland (75%) is owned and managed by the M-NCPPC, and the remaining 25% by the National Park Service, District of Columbia Parks and Recreation, and local municipalities. The industrial and manufacturing areas are composed of predominately light industrial (ARP 2010).

The Patuxent River watershed, covering 937 square miles, lies entirely in the state of Maryland. The proportions of land use within a 30 km boundary (Figure 2-6) have remained relatively stable since 2001 (Figure 2-7). Land use in the Patuxent River watershed is roughly 40% urban and 40% forest. Approximately 20% of the watershed is used for agriculture. Agricultural land is predominately in the uppermost portions of the watershed, while the lower portion of the basin is largely forested (MD DNR 2012).

Since the earliest settlements in the Washington, D.C. area, the landscape has been altered by cutting forests, removing soils, flattening hills, filling valleys, construction of roads and parkways, and urban development (Thornberry-Ehrlich 2008). Close to 300 acres within NACE include reclaimed landfills, all of which were operational before environmental standards were enforced by regulations.

2.2.3. Population

An estimated 6.11 million people live in the Potomac River watershed (U.S. Bureau of the Census 2013) (Figure 2-10). Three-quarters of the basin's population (approximately 5.36 million people) live within the Washington, D.C. metropolitan area. As of the 2010 census, Anne Arundel County's population was 537,656, a population increase of just under 10% since 2000. Prince George's County has a population of 863,420 in 2010 while Charles County was at 146,551.

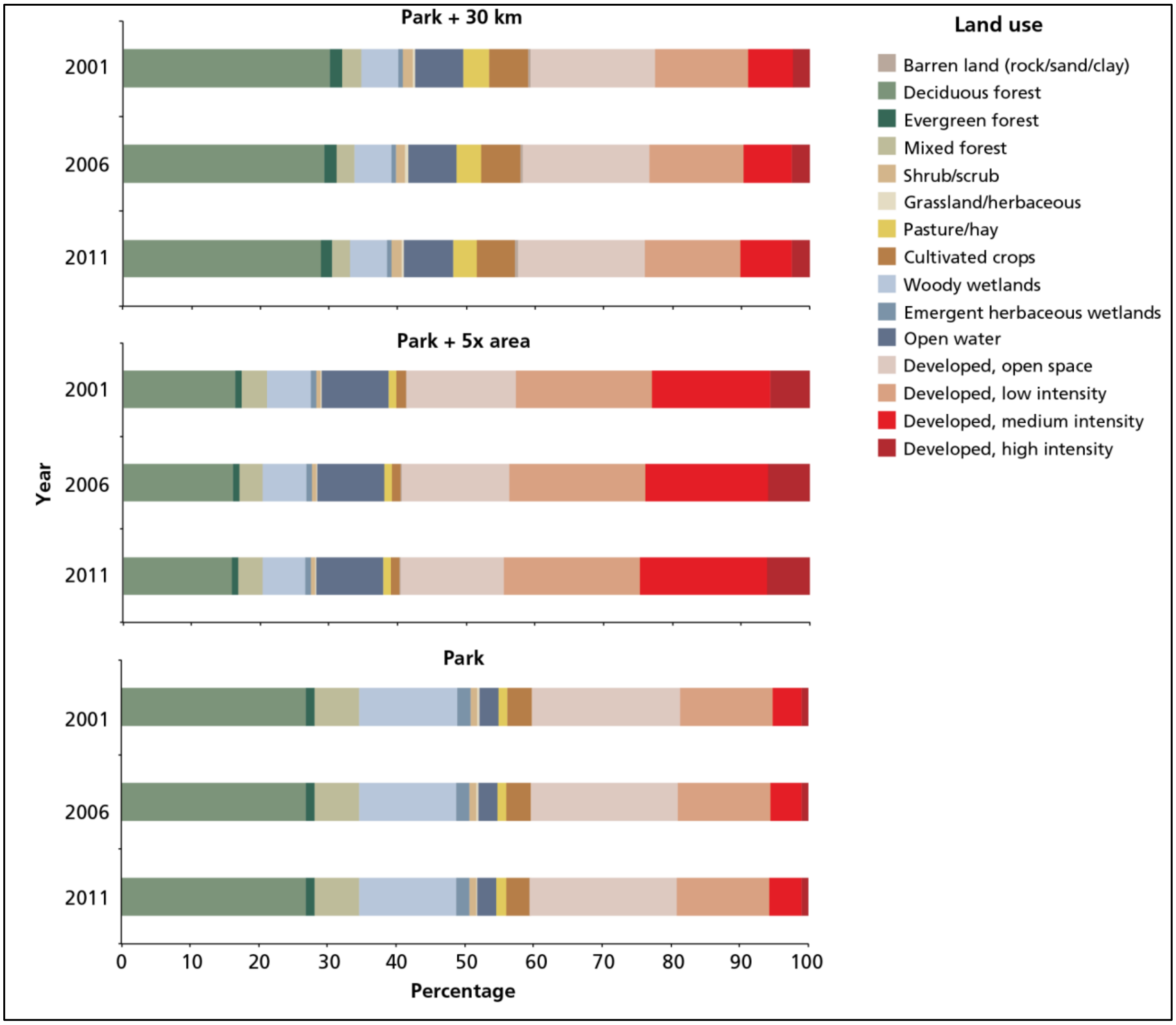

Figure 2-7 Changes in land use from 2001 to 2011 at three scales (Park + 30 km, Park + 5x area, Within Park) surrounding NACE (Jin et al. 2013; NPS 2011a).

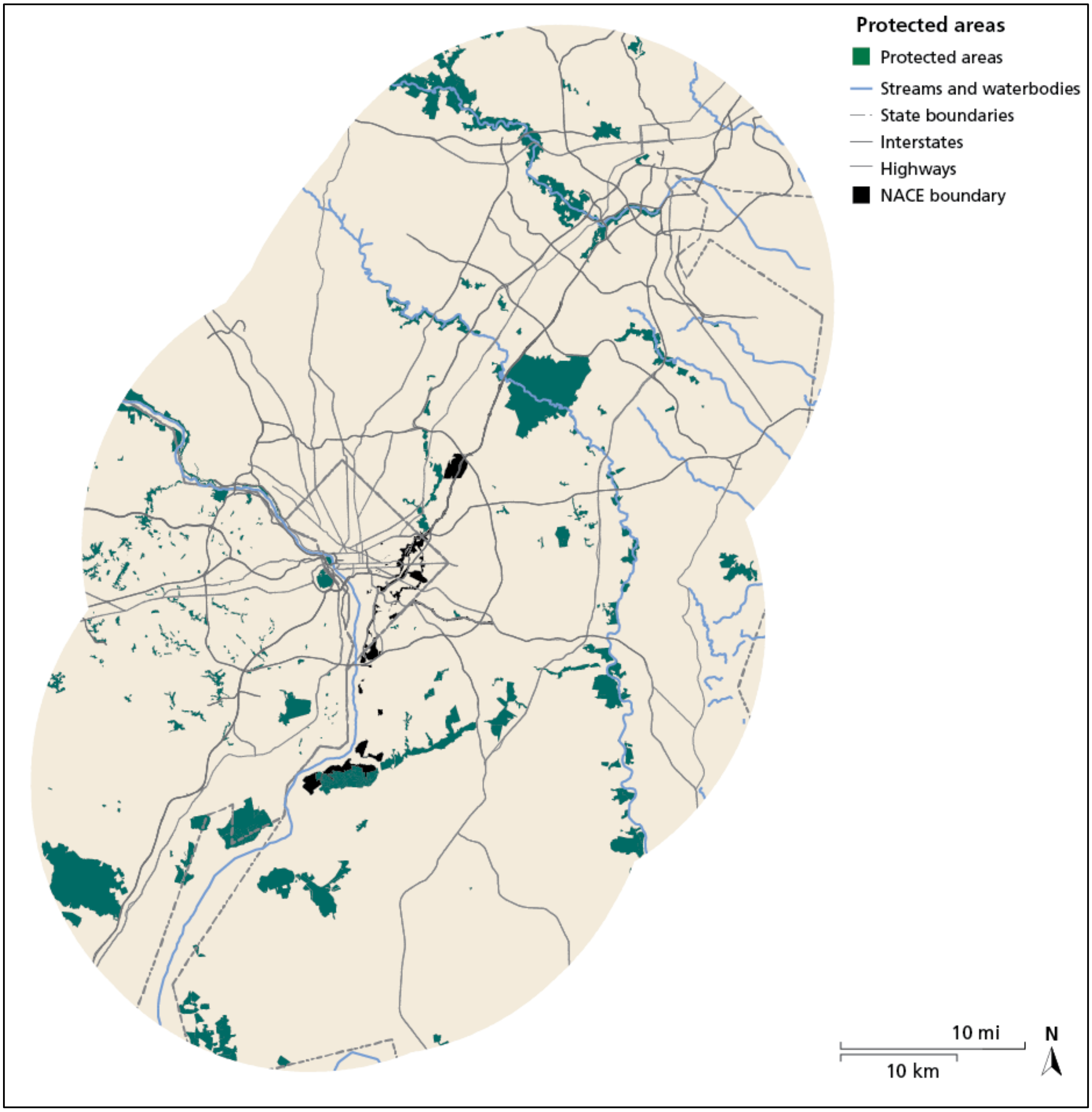

Figure 2-8 Protected areas within a 30-km area surrounding NACE in 2011 (NPS 2011a).

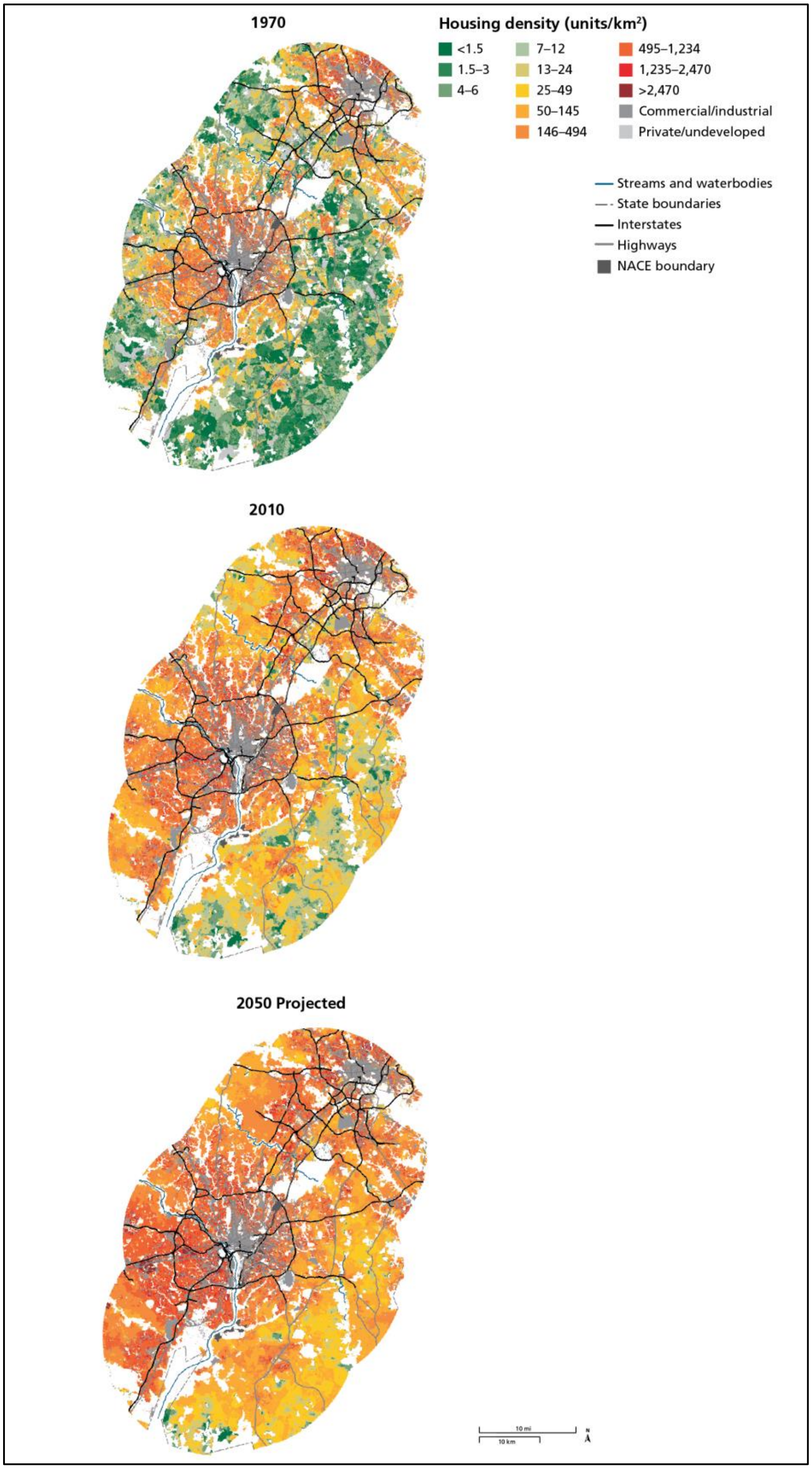

Figure 2-9 Housing density within a 30-km area surrounding NACE in 1970, 2010, and projected for 2050 (NPS 2011a; NPS 2014).

Figure 2-10 Population density around the park in 2000 and 2010 (U.S. Census 2010).

2.2.4. Climate

NACE and the surrounding areas experience all four seasons with an annual average temperature of 14.6°C (58.2°F) (National Weather Service 2014a). Spring and fall are generally comfortable with some precipitation possible. Summers can be hot and humid with an average temperature of 25.4°C (77.7°F). Heat waves during the summer are often accompanied by high humidity levels and corresponding ozone pollution (Davey et al. 2006). Winters are cold with an average temperature of 3.4°C (38.2°F) (National Weather Service 2013a). The average annual precipitation at NACE is 1 meter (39.74 inches) (National Weather Service 2014b), with an annual average total snowfall of 0.4 meters (15.4 inches) (National Weather Service 2014c). Precipitation is a common occurrence throughout the year but is generally more common in the summer (Davey et al. 2006). Occasional extreme precipitation events, such as tropical storms and hurricanes are significant events that can impact the National Capital Region. Although wind damage can accompany these storms, the heavy precipitation and flooding from these storms is by far a more important disturbance factor for NCRN ecosystems. Nor'easter storms during the winter months can also occasionally bring large snowfalls to the National Capital Region. (Davey et al. 2006).

NACE has no weather/climate stations at any of its units. There are, however, 28 active National Weather Service Cooperative Observer Network sites within 10 km of NACE. Numerous near-real-time stations also surround park units at Dulles International Airport and Reagan National Airport providing near real-time climate observations for the area, along with the Surface Aviation Observation station at Joint Base Andrews (Prince George's County, MD) and the Quantico military complex (Davey et al. 2006).

2.2.5. Visitation statistics

More than 1,200,000 people visit the units of NACE each year for recreational purposes (Figure 2-11). Additionally, millions of commuters and other drivers pass through the parks in the Baltimore-Washington and Suitland Parkways, and other NACE sites. In 2013, approximately 1,091,000 people visited NACE for recreational purposes while 21,406,000 non-recreation visitors were recorded (NPS Stats 2014). Low visitations coincide with cold weather months (lowest in February) and high visitations with summer months (highest in August) (NPS Stats 2014).

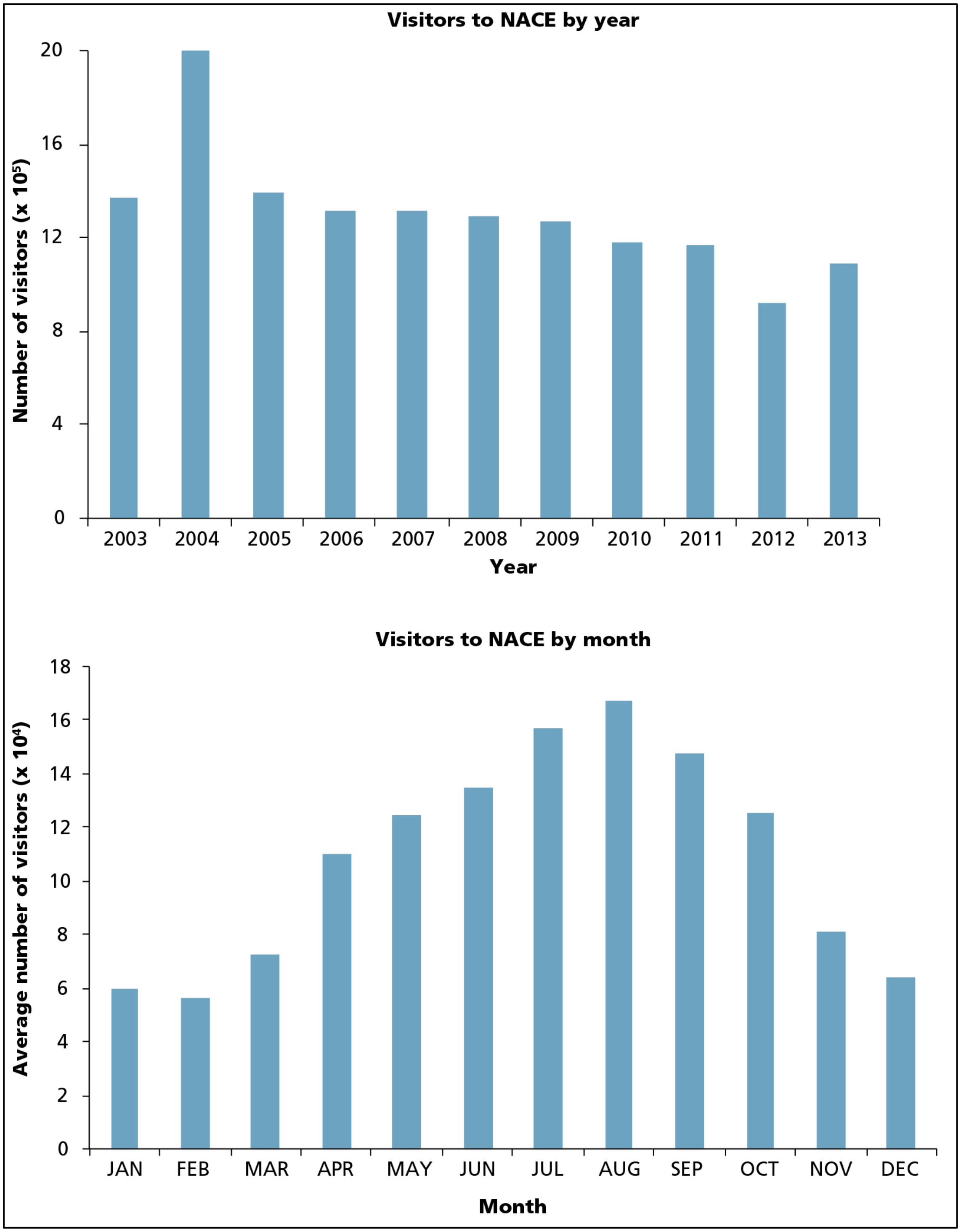

Figure 2-11 Visitors to NACE over the past decade (2003-2013) by year (top) and by month (bottom) (NPS 2013c).

2.3. Natural Resources

2.3.1. Resource descriptions

The natural features of NACE units with significant natural resources include sand and gravel beaches, shoreline bluffs, flood plain and upland forests, shell marl ravine forest with its associated fossil outcrops, vernal pools, two large river systems and numerous streams, a variety of soil types, forested seeps, and numerous other wetlands such as freshwater tidal marshes, swamps, emergent marshes, and bogs.

The natural areas within National Capital Parks-East are extremely rich both in biodiversity and in historical context. The park provides islands of refuge for many uncommon plant and animal species in the highly urbanized Washington, D.C. metropolitan area, protecting a variety of cultural and natural resources. Additionally, NACE provides opportunities for the public to foster awareness of the importance of species preservation, biological diversity, natural systems and processes, and the value of natural open space in an urban environment.

<u>Geology</u>
The sites of National Capital Parks–East are located at the western edge of the Atlantic Coastal Plain physiographic province near the Fall Line, which divides the hard rock of the Piedmont Plateau to the north and west, and the soft sediments of the Atlantic Coastal Plain to the east. The parks contain features that are associated with the long geologic history of the eastern United States (Thornberry-Ehrlich 2008).

The underlying geology of NACE contains a wedge-shaped sequence of mixed sedimentary rocks and deposits of Cretaceous to recent age (Figure 2-12). They include sandstones, clay beds, gravel deposits, and silts. They form part of a thick mantle of relatively young rock debris, alluvium, regolith, slope deposits, and soils that covers the underlying metamorphic bedrock. This wedge of sediments can be as much as 3,000 m (10,000 ft) thick near the Maryland coast. These deposits (specifically the Arundel Clay of the Potomac Formation) contain fossilized remains of the Maryland State Dinosaur, the sauropod *Astrodon johnstoni*, as well as other Cretaceous-age plants, mollusks, and shark teeth (Thornberry-Ehrlich 2008).

A series of rising river terraces extends out from the floodplain of the junction of the Anacostia and Potomac Rivers. These high ridges nearly surround the city, forming a bowl—these are where the earthen Civil War fortifications (CWDW) were strategically built. The highest of these terraces rises 200 feet above sea level and is fronted by an escarpment that is prominent along the east bank of the Anacostia River. Steep sided ravines and small streams cut through the upper terrace east of the Anacostia River—examples of these stream valleys can be observed at Fort Dupont and Fort Stanton Parks.

NACE sites in the Atlantic Coastal Plain are characterized by deeply cut valleys and prominent ridges. Regions of the coastal plain are underlain by limonite deposits, most often found in swamps or bogs, and commonly called ‘bog iron’ (DiLisio 2014). These iron deposits are commonly found within the park, and are the preferred material to use in stream restorations such as the regenerative stormwater conveyance at Park Drive.

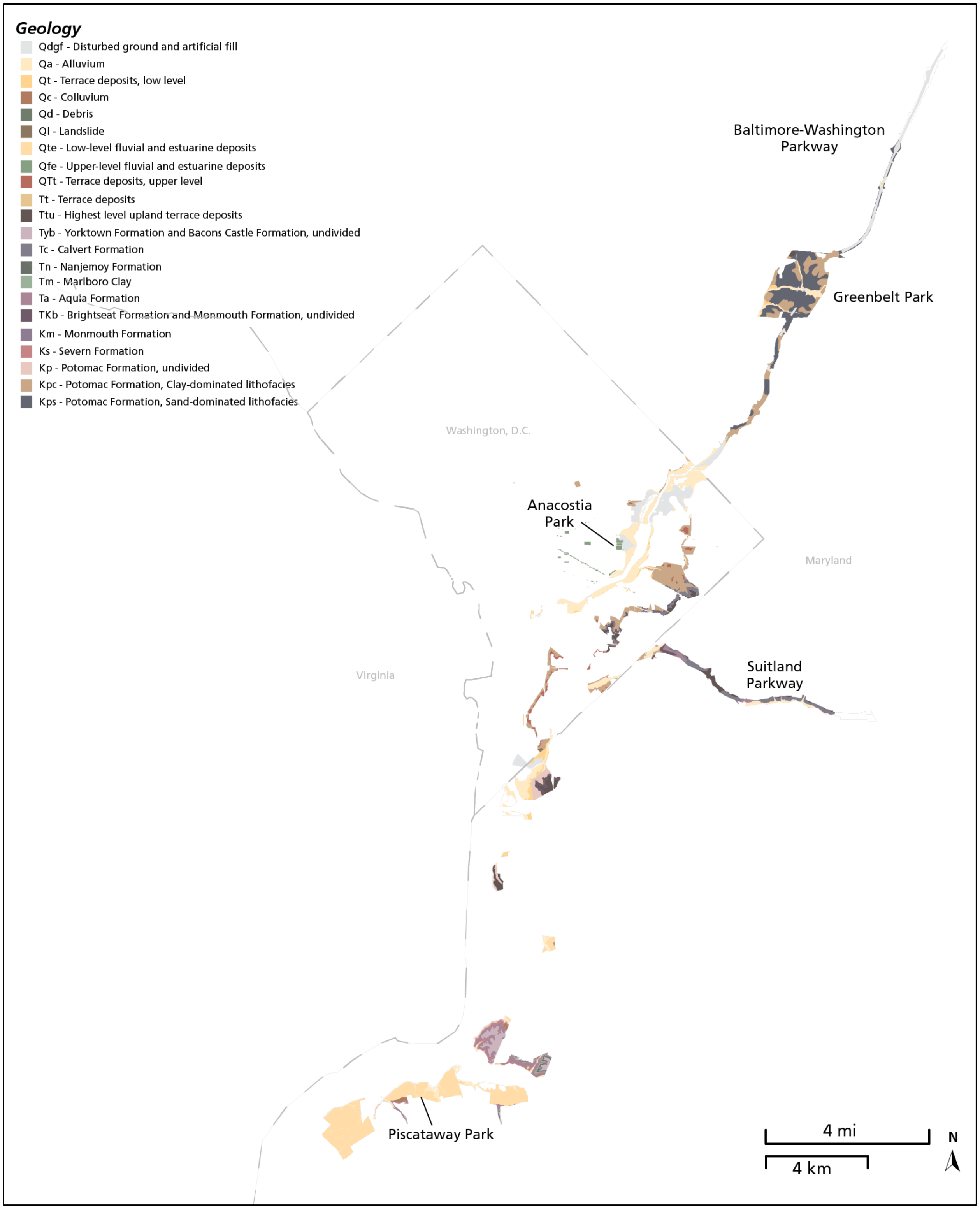

Figure 2-12 Geology of NACE (Thornberry-Ehrlich 2009).

Development has resulted in significant changes in the elevation and slope of the land surfaces at NACE (Figure 2-13). Typically, hills are flattened and stream valleys and marshes are filled in. A man-made seawall along the Anacostia River was constructed in the first half of the 20th century and is a contributing element in the park's National Register of Historic Places nomination and affects shorelines within Anacostia Park and farther downstream (Thornberry-Ehrlich 2008).

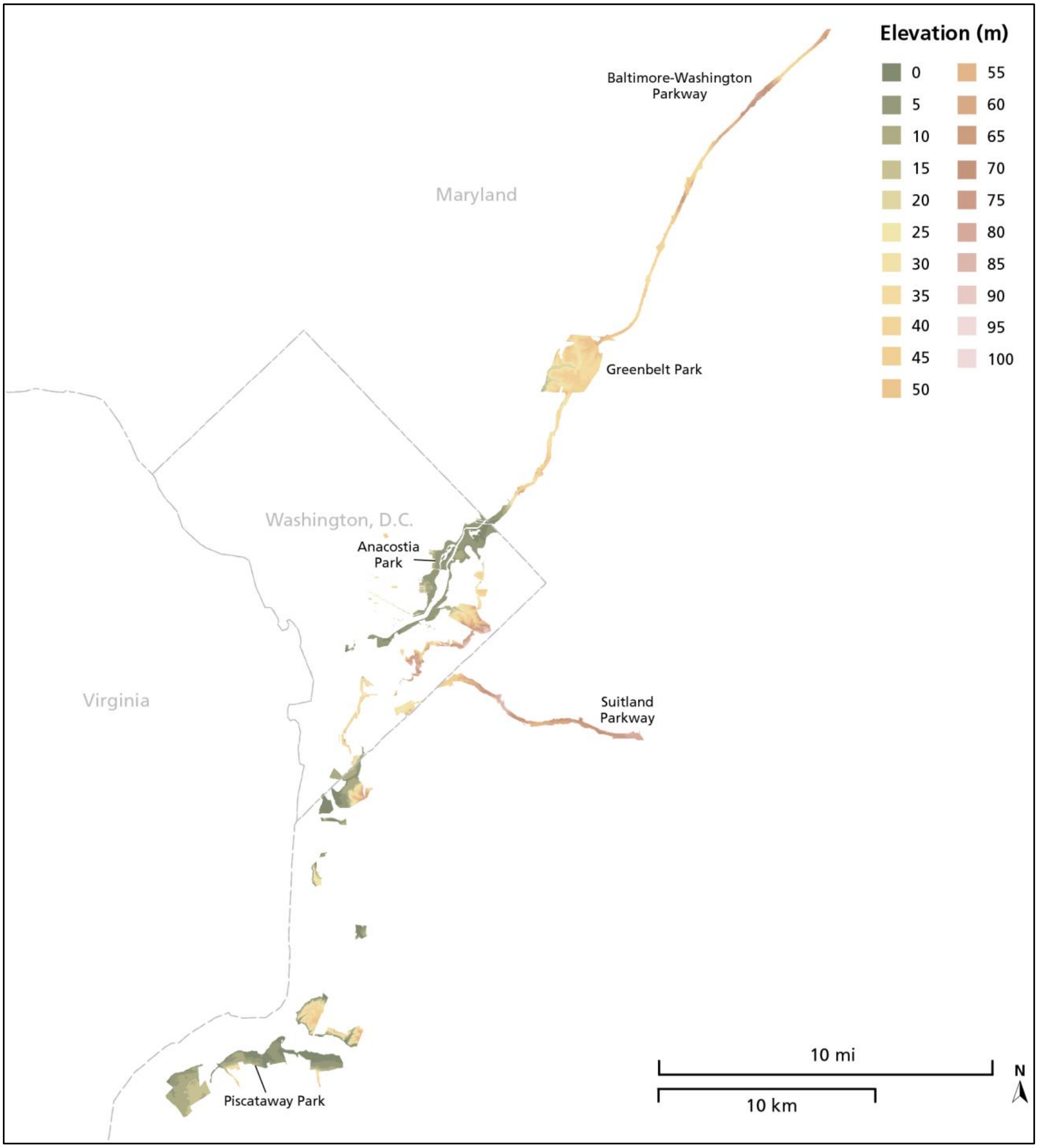

Figure 2-13 Topographic elevation of NACE (NPS 2013).

Soils

Gravels, sands, silts, and clays of Pleistocene and Holocene age alluvium line the creek valleys in National Capital Parks–East (Thornberry-Ehrlich, 2008) (Figure 2-14). The sands are commonly orange to brown, locally cemented with limonite with some interbedded red, white, or gray clay (Thornberry-Ehrlich 2008; Maryland Geological Survey 1968). Soils found in the park were mostly from the Potomac Formation, which consists of massive, mottled, silty clay with minor sand and thin beds of tan, clayey sand. (Southworth and Denenny 2005). It is often overlain by sand and clay of marine origin, with dark-gray, micaceous sand in the lower part and greenish-gray, clayey sand in upper part. Much of the flood plain is underlain by alluvium and may also contain artificial fill (Southworth and Denenny 2005) (Figure 2-14).

The Civil War fort sites of NACE were purposely established on higher elevation points, which still retain the sand, gravel, and clay mix deposited by the Potomac River as glaciation episodes retreated North (Aronica 2001). These Terrace Gravel soils are important for water storage and the associated geologic Fall Line wetlands and plant communities they support. The acidic, low nutrient soils support chestnut oak, shadbush, and various other Ericaceous species that are able to tolerate those conditions (Aronica 2001). Today, development in the region has destroyed most of these habitats.

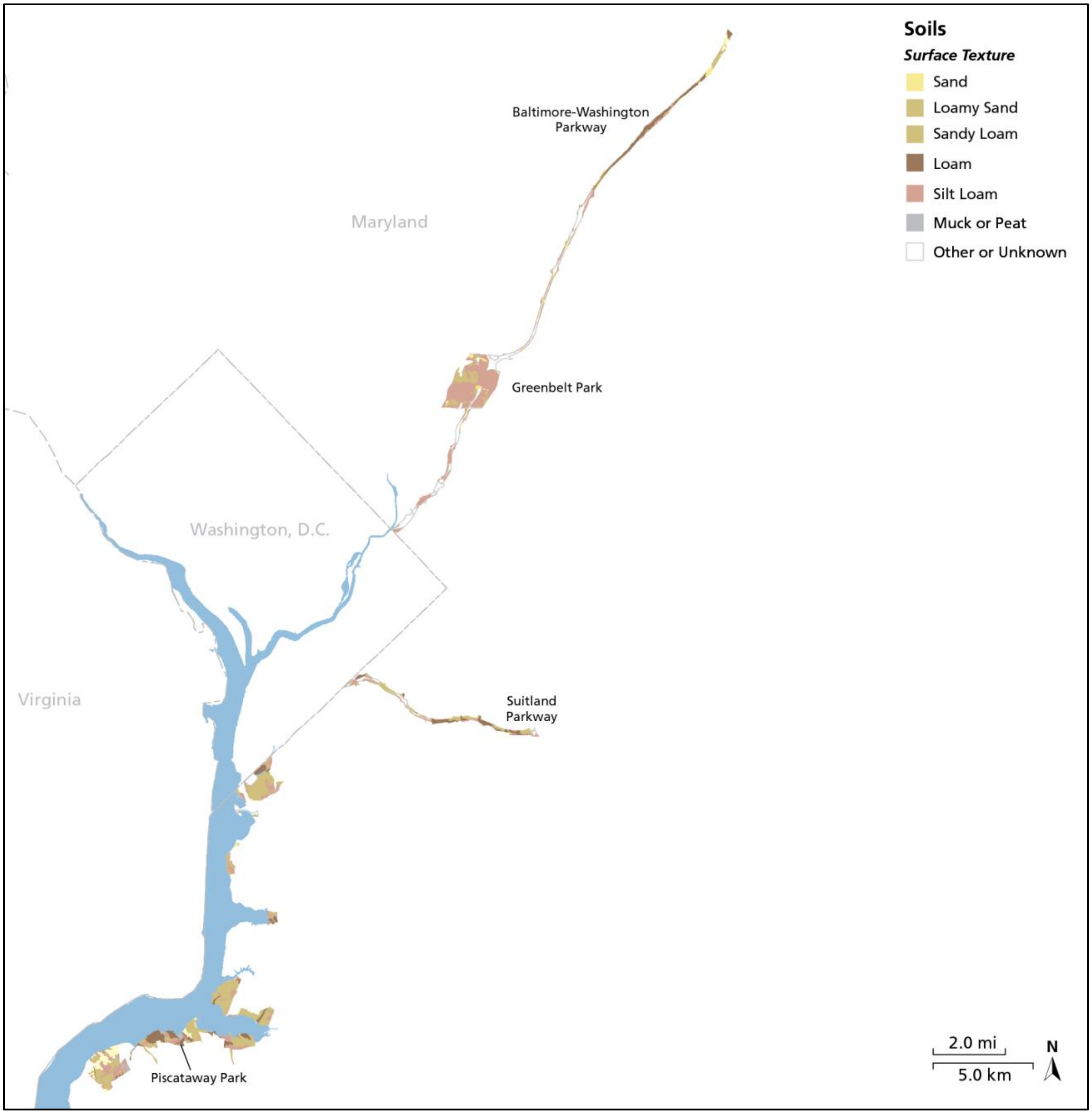

Figure 2-14 Soil surface texture at NACE (NPS 2013).

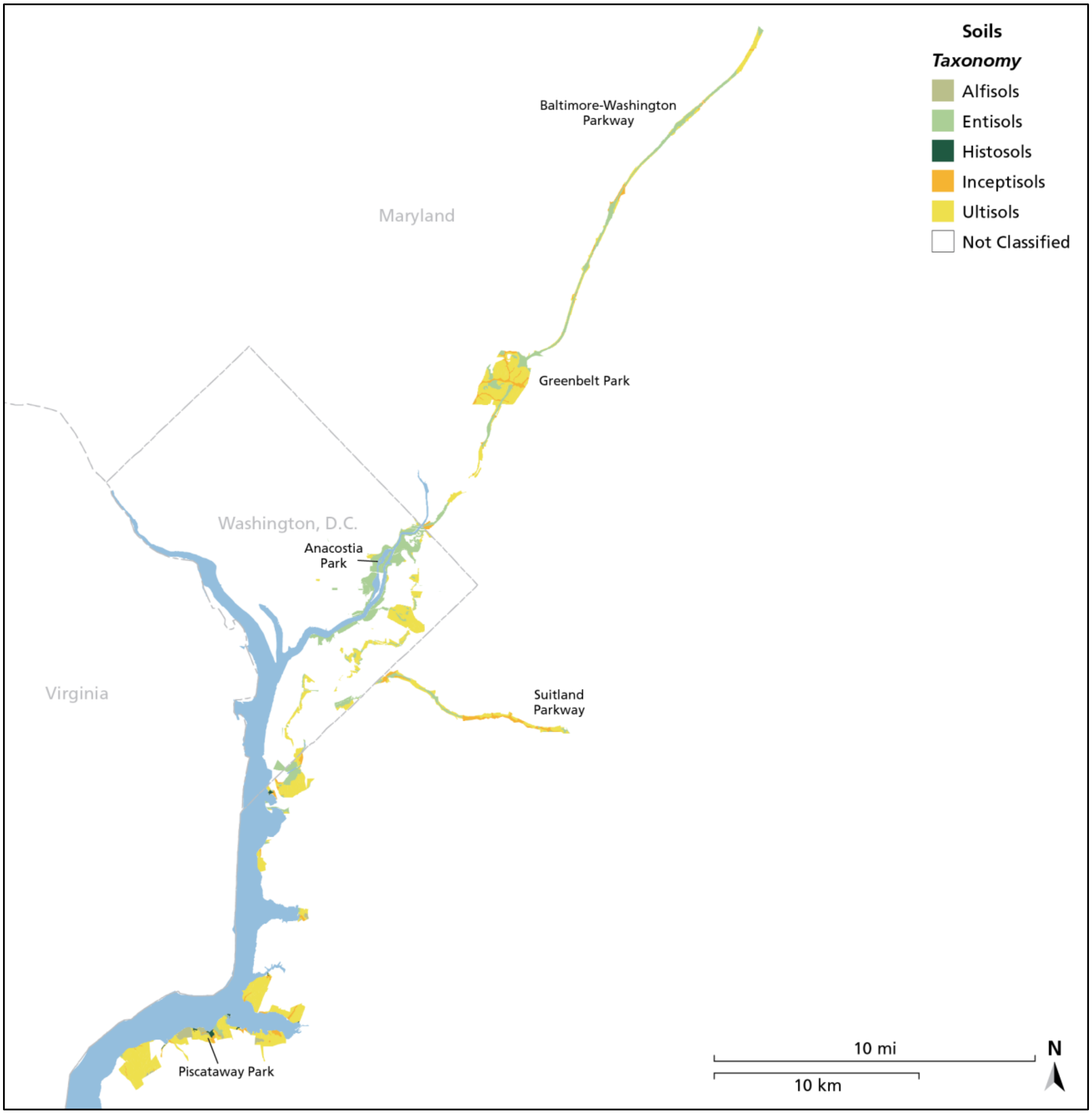

Figure 2-15 Soil taxonomy in NACE (NPS 2013).

Watershed/Waterways

Most of the park units of the National Capital Parks-East (NACE) are within the Potomac and Anacostia River watersheds, with the exception of the northernmost portion of the Baltimore-Washington Parkway, which is in the Patuxent River watershed (Figure 2-4).

Prominent waterways within NACE include Deep and Still Creek (Greenbelt Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove), Broad Creek (Harmony Hall), Swan Creek (Fort Washington), Piscataway Creek (Piscataway Park), Fort Dupont Creek (Fort Dupont), Watts Branch, and Nash Run (Kenilworth Park and Aquatic Gardens), and the Anacostia River (Kenilworth Park and Aquatic Gardens). Most of the streams are part of the Anacostia River watershed, which in turn is part of the greater Potomac River system. Several of these streams emerge from underground pipes into the watershed as part of storm water management facilities. There are also numerous unnamed streams and tributaries that run through most park unites of NACE. Groundwater discharges directly into park streams and local springs from pipes and from those places where the water table intersects the surface.

The Potomac River watershed drains 37,995 km^2 (14,670 mi^2) across Maryland, Virginia, West Virginia, Pennsylvania, and the District of Columbia (ICPRB 2012). The major tributaries to the Potomac River include the Shenandoah River, South Branch, North Branch, Cacapon River, Conococheague Creek, Monocacy River, and Anacostia River (Allen and Flack 2001; ICPRB 2012). After the Susquehanna River, the Potomac is the second largest tributary to Chesapeake Bay. The Bay watershed is 64,000 square miles (166,530 square kilometers, extends into six states—Virginia, Maryland, and Delaware, Pennsylvania, New York; and is home to more than 17 million people (Chesapeake Bay Program 2013).

The Anacostia River watershed drains portions of Montgomery and Prince George's Counties in Maryland as well as the eastern portion of Washington, D.C. The watershed is heavily urbanized, with over 600,000 residents (US EPA 2012). Land use within the Anacostia watershed is about one-half urban, one-third forested and the remainder primarily agriculture (Brittingham and Hammerschlag 2004).

The Patuxent River is the largest river completely in Maryland. Its basin drains 932 square miles of land within Maryland's western shore of the Chesapeake Bay (Karrh 2007). This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties. Three main streams drain into the upper Patuxent River: the Little Patuxent, the Middle Patuxent, and the (upper) Patuxent River. The Patuxent River Basin lies between two large nearby metropolitan areas–Baltimore, Maryland and Washington, D.C. Land use within the basin is predominately rural, and the main stem contains two dams with smaller impoundment elsewhere that together limit the impacts of runoff from developed portions of the landscape.

Wetlands

Wetlands provide unique habitat, help control erosion and regulate flooding, and recharge groundwater and stream flow in drought years. Wetlands also act as natural filters for impurities and pollution in the water and are vital components of healthy ecosystems.

Historically, the Anacostia River was flanked by fully functional freshwater tidal marshland comprising several thousand acres that provided considerable food and habitat for wildlife and thus an invaluable support resource for the local Indians and subsequent colonists (Brittingham and Hammerschlag 2004). However, in the early 20th century, the USACE was charged with a major reclamation effort designed to rid the public health threat posed by Anacostia's "malarial swamps" and improve channel navigation by channeling and containing the river within a stone seawall. Tidal flats and wetlands were drained and filled to help rid the city of mosquito-borne diseases and stench along the river. Essentially, no emergent wetlands remained (except for narrow edges of transitional wetlands) including areas within the dredged out tidal Kenilworth and Kingman Lakes.

Kenilworth Marsh was later reconstructed adjacent to Kenilworth Aquatic Gardens in 1993 as a freshwater tidal marsh (32 acres/13 hectares). In 2000, portions of Kingman Lake along the Anacostia estuary about one quarter mile south of Kenilworth Marsh but on the west bank in Washington, D.C. were reconstructed as emergent freshwater tidal wetlands. These restorations have recreated ~110 acres of emergent tidal wetland, providing habitat for many species including migratory waterfowl and native plants. Vegetation damage by resident Canada geese is an ongoing challenge to the long-term sustainability of the marsh.

The Oxon Run Parkway contains native forested uplands and nearly 58 acres of marshy, palustrine forested wetlands (Mora-Bourgeois 2007). These wetlands include four rare northern magnolia bog remnants—the only such plant communities in the entire National Park System. Magnolia bogs are uncommon, but these critically rare plant communities have become scarcer because of disturbances caused by increased urbanization. Species present in this rare plant community include sweetbay or swamp magnolia (*Magnolia virginiana*), peat moss (*Sphagnum* sp.), poison sumac (*Toxicodendron vernix*), highbush blueberry (*Vaccinium corymbosum*), and bog fern (*Thelypteris simulata*).

Flora

Most NACE sites are small and/or narrow in size and shape. As a result, the park's native plant communities are seriously impacted by disturbances caused by fragmentation and development. Forty-six forest vegetation monitoring plots established and monitored by the National Capital Region Network Inventory & Monitoring (NCRN I&M) program are located in NACE (Schmit et al. 2012a). In those plots, 94 species of trees, shrubs, herbs, and vines have been recorded. The most common tree species in NACE is red maple (*Acer rubrum*).

While most tree species are found throughout all of NACE, some species are more common in certain smaller park units (Schmit et al. 2012a). Greenbelt Park and the Baltimore-Washington Parkway, the northernmost units, are mostly composed of upland forest. In these areas, Virginia pine (*Pinus virginiana*), oak species, and black gum (*Nyssa sylvatica*) are particularly common. Piscataway Park, at the southern end of NACE, has more low-lying forests along the Potomac River (Figure 2-16). In this area species of ash (*Fraxinus* spp.), elm (*Ulmus* spp.), and sassafras spp. are more common. The species with the highest Importance Values within the NCRN, red maple, tulip poplar (*Liriodendron tulipifera*), and sweet gum (*Liquidambar styraciflua*) are common throughout all of NACE. The importance value is an index that is calculated by combining parameters that compare a species to all other species in terms of: density, basal area, and frequency in monitored plots. The importance value ranges from 0 (species not present) to 3 (species is present and nothing else), but high values occur only in forests with very few tree species present (Schmit et al. 2012a).

NCRN I&M vegetation monitoring from 2006-2009 identified more species in NACE monitoring plots than in any other NCR park (Schmit et al. 2012a). The smaller units in NACE have a wide variety of habitats, including both wetland and upland habitats. This diversity of habitat contributes to the diversity of plants. However, exotic species also contributed to high plant diversity observed in NACE (see section 2.3).

Figure 2-16 Vegetation type (community) map of NACE (NPS 2013).

<u>Fauna</u>

NACE provides critical habitat for wildlife populations within the greater Washington, D.C. metropolitan area. Because of its location on the Atlantic Coastal Plain physiographic province and nearly abutting the Piedmont Plateau province—and its location in a transition zone between northern and southern climates, the park has a wide variety of habitats that can support breeding populations of numerous animal species (Thornberry-Ehrlich 2008).

Aside from the parklands that host both small and large mammals, the park also contains habitat conducive to reptiles, amphibians, fish, and invertebrates—including streams and wetland areas. The spotted turtles (*Clemmys guttata*) found at Kilworth Park and Aquatic Gardens and Piscataway Park are included in the International Union for Conservation of Nature Red List, and is only one of two known observances of the species within D.C. The park also serves as a breeding ground for birds with 13 species of conservation concern observed within the park.

<u>Mammals</u>

Thirty-nine species of native mammals are known from National Capital Parks-East (NPSpecies 2014). In addition, feral domestic dogs, cats, and non-native rats occur in NACE.

The NCRN Small Mammal Survey (McShea and O'Brien 2003) found the most common small mammal in NACE to be the white-footed mouse (*Peromyscus leucopus*). Other small mammal species found in NACE are northern short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus*), southeastern shrew (*Sorex longirostris*), eastern grey squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), striped skunk (*Mephitis mephitis*), flying squirrel (*Glaucomys* spp.), meadow jumping mouse (*Zapus hudsonius*), and Norway rat (*Rattus norvegieus*). Signs of activity by the eastern mole (*Scalopus aquaticus*) were observed at NACE but the animal was not captured in the park. The northern short-tailed shrew is included in the District of Columbia's 2015 Wildlife Action Plan list of species of greatest conservation need (SGCN), with a need for habitat restoration and meadow creation (DC DOEE 2015).

A 2003-2004 bat inventory at NACE captured two species within the park; the big brown bat (*Eptesicus fuscus*) and the eastern red bat (*Lasiurus borealis*) (Gates and Johnson 2005). Bat species diversity at NACE was the lowest of any NCR park; however, big brown bat capture success recorded at Greenbelt Park was among the highest in the NCR. Despite high bat activity levels (echolocation calls recorded per acoustic monitoring site), bats were only captured in Greenbelt Park (Gates and Johnson 2005). Little brown bats (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), and eastern pipistrelles (*Pipistrellus subflavus*) were acoustically detected but not captured in NACE.

<u>Birds</u>

The National Capital Region Network Inventory and Monitoring (NCRN I&M) program monitors forest breeding birds annually at 29 points in NACE (Ladin 2013). A Bird Community Index (BCI) is used to evaluate habitat integrity as well as relative changes in habitat integrity over time based on bird species and guilds present (O'Connell et al. 2003).

Birds are monitored at seven forest plots in Greenbelt Park. Between 2007 and 2010, 39 bird species were identified in Greenbelt Park, including seven species of conservation concern. Chickadees – represented by two species – represent the species of highest density of birds per hectare of forest. Two of the most common birds in Greenbelt include the Eastern Towhee and Acadian Flycatcher, both species of conservation concern. Their presence in the park indicates that bird species that are declining or vulnerable as species, are finding valuable habitat within Greenbelt Park (Nortrup 2011).

Within NACE, four regionally abundant species: eastern tufted titmouse (*Parus bicolor*), northern cardinal (*Cardinalis cardinalis*), red-eyed vireo (*Vireo olivaceus*) and blue-gray gnatcatcher (*Polioptila caerulea*), remained stable from 2007-2011. Most of the 13 species of conservation concern had stable abundance (2007-2011). However, chimney swift (*Chaetura pelagica*) abundance has increased, and northern flicker (*Colaptes auratus*) and eastern towhee (*Pipilo erythrophthalmus*) abundance have decreased within the park (Ladin and Shriver 2013). Currently, 243 species of birds have been recorded within NACE (NPSpecies).

Table 2-2 Bird species of conservation concern found within Greenbelt Park between 2007 and 2011 (Nortrup 2011).

List	Common Name	Scientific Name
Partners in Flight Watch List	Wood thrush	*Hylocichla mustelina*
	Worm-eating warbler	*Helmitheros vermivorus*
Stewardship Species List	Acadian flycatcher	*Empidonax virescens***
	Carolina wren	*Thryothorous ludovicianus***
	Eastern towhee	*Pipilo erythrophthalmus*
	Pine warbler	*Dendroica pinus*
	Red-bellied woodpecker	*Melanerpes carolinus*

In Piscataway and Fort Washington Parks, birds are monitored at 14 forest sites. Between 2007 and 2010, 65 bird species were identified in Piscataway and Fort Washington Parks, 12 of which are species of conservation concern. The Cedar Waxwing represents the species of highest density of birds per hectare of forest. Two of the most common birds in Greenbelt Park, the Acadian Flycatcher and Carolina Wren are Partners in Flight stewardship species. Their presence in the park indicates that bird species that are declining or vulnerable as species, are finding valuable habitat within Piscataway and Fort Washington (Nortrup 2011). In addition, the natural areas of Oxon Cove Park and Piscataway Park in particular have an active avian fauna where bald eagles (*Haliaeetus leucocephalus*) can be seen soaring directly over the park (NPS 2014c). Bald eagles are also known to nest along the Shepherd Parkway.

Birds are monitored at 9 forest plots in CWDW, Oxon Cove Park, and Anacostia Park. Between 2007 and 2010, 52 bird species were identified, 9 of which are species of conservation concern. The American Robin represents the species of highest density of birds per hectare of forest. Two of the most common birds within the parks, the Wood Thrush and Carolina Wren are species of conservation concern. Their presence in the park indicates that bird species that are declining or vulnerable as species, are finding valuable habitat within these NACE units (Nortrup 2011).

Table 2-3 Bird species of conservation concern found within Piscataway and Fort Washington Parks between 2007 and 2011 (Nortrup 2011).

List	Common Name	Scientific Name
Partners in Flight Watch List	Kentucky warbler	*Oporornis formosus*
	Prothonotary warbler	*Protonotaria citrea*
	Wood thrush	*Hylocichla mustelin*
Stewardship Species List	Acadian flycatcher	*Empidonax virescens*
	Brown thrasher	*Toxostoma rufum*
	Eastern towhee	*Pipilo erythrophthalmus*
	Hooded warbler	*Wilsonia citrina*
	Indigo bunting	*Passerina cyanea*
	Red-bellied woodpecker	*Melanerpes carolinus*
Stewardship Species List	Red-shouldered hawk	*Buteo lineatus*
	White-eyed vireo	*Vireo griseus*
	Yellow-throated vireo	*Vireo flavifrons*

The open water of the Anacostia and Potomac Rivers and adjacent wetlands provide year-round habitat for waterbirds. These landscape features are important breeding areas and migration corridors, and the presence of waterbirds can be an indicator of environmental health and water quality (Rauch 2011). The District Department of the Environment (DDOE) began a winter waterbird survey in 2002. The 2010-2011 survey recorded 32 species of waterbirds on the Anacostia River, with Kenilworth Aquatic Gardens, and Langston Golf Course-North having the highest species diversity. Four species of conservation concern were recorded: bald eagle, red-shouldered hawk, American black duck, and wood duck. Canada geese, ring-billed gulls, mallards, and American crows were the most common species within the Anacostia and Potomac River watersheds.

Table 2-4 Bird species of conservation concern found within the forests of CWDW, Oxon Cove Park, and Anacostia Park between 2007 and 2011 (Nortrup 2011).

List	Common Name	Scientific Name
Partners in Flight Watch List	Wood thrush	*Hylocichla mustelina*
Stewardship Species List	Acadian flycatcher	*Empidonax virescens*
	Brown thrasher	*Toxostoma rufum*
	Carolina wren	*Thryothorus ludovicianus*
	Eastern towhee	*Pipilo erythrophthalmus*

Table 2-4 (continued) Bird species of conservation concern found within the forests of CWDW, Oxon Cove Park, and Anacostia Park between 2007 and 2011 (Nortrup 2011).

List	Common Name	Scientific Name
Stewardship Species List (continued)	Red-bellied woodpecker	*Melanerpes carolinus*
	Red-shouldered hawk	*Buteo lineatus*
	White-eyed vireo	*Vireo griseus*
	Wood thrush	*Hylocichla mustelina*

Herpetofauna

National Capital Parks-East (NACE) has known extant populations of fifteen species of amphibians including 8 frogs, 6 salamanders or newts, and one toad (NPSpecies 2014). The 7 native species of frogs present in NACE are: Eastern cricket frog (*Acris crepitans*), Green tree frog (*Hyla cinerea*), Gray tree frog (*Hyla versicolor*), Northern spring peeper (*Pseudacris crucifer*), Green frog (*Rana clamitans melanota*), Upland chorus frog (*Pseudacris feriarum*) and the Southern leopard frog (*Rana utricularia*). The lone species of toad recorded in the park is the Fowler's toad (*Bufo woodhousii fowleri*). With the ongoing threat of climate change in the Mid-Atlantic region, the green tree frog population is expected to becoming increasingly unstable, and species shifts are expected (DC DOEE 2015).

The salamanders and newts are represented by the northern dusky salamander (*Desmognathus fuscus fuscus*), two-lined salamander (*Eurycea bislineata*), four-toed salamander (*Hemidactylium scutatum*), red-backed salamander (*Plethodon cinereus*), northern red salamander (*Pseudotriton ruber ruber*), and the red-spotted newt (*Notophthalmus viridescens viridescens*).

NACE is also home to a number of reptile species. There are twelve recorded native species of snakes in NACE (NPSpecies 2014): northern brown (*Storeria dekayi dekayi*), northern copperhead (*Agkistrodon contortrix*), common garter (*Thamnophis sirtalis sirtalis*), rough green (*Opheodrys aestivus*), eastern ribbon (*Thamnophis sauritus*), northern black racer (*Coluber constrictor constrictor*), northern ringneck (*Diadophis punctatus edwardsii*), northern water (*Nerodia sipedon*), corn snake (*Elaphe guttata guttata*), mole king snake (*Lampropeltis calligaster rhombomaculata*), eastern king snake (*Lampropeltis getula getula*) and eastern worm snake (*Carphophis amoenus*). Queen snakes (*Regina septemvittata*) a species listed as uncommon by the Maryland Department of Natural Resources, has also been observed (NPS 2014).

Seven native and one non-native species of turtle have been recorded within NACE (NPSpecies 2014). The native species of turtles are: eastern box (*Terrapene carolina*), eastern mud (*Kinosternon subrubrum*), common musk (*Sternotherus odoratus*), eastern painted (*Chrysemys picta picta*), redbelly (*Pseudemys rubriventris*), snapping (*Chelydra serpentina serpentine*), and spotted (*Clemmys guttata*). The red-eared slider (*Trachemys scripta elegans*) is not native to the area but is widely established within NACE. The spotted turtle is considered a species of conservation need, as they could benefit from habitat restoration (DC DOEE 2015).

The most commonly reported species of lizard in NACE is the five-lined skink (*Eumeces fasciatus*) with some reports of northern fence lizard (*Sceloporus undulatus hyacinthinus*) (NPSpecies 2014).

Fish

A total of 50 species of fish from 16 families have been reported from NACE waterbodies that drain to the Potomac, Anacosita, or Patuxent Rivers (NPSpecies 2014). Six species are considered non-native which include the following: goldfish (*Carassius auratus*), common carp (*Cyprinus carpio*), warmouth sunfish (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), longear sunfish (*Lepomis megalotis*), and largemouth bass (*Micropterus salmoides*). One species is historically reported, but probably no longer present, in the park is the logperch (*Percina caprodes*).

Rare, threatened, endangered species

No federally listed or proposed endangered or threatened species, are known to occur in NACE. One Maryland threatened species, the pearl dace, was found in Henson Creek during 2013 sampling (Nortrup 2014). Due to the urban nature of the park, many of the species observed within NACE are included in the 2015 District of Columbia Wildlife Plan as species of greatest conservation need (Table 2-5).

Table 2-5 District of Columbia Species of Greatest Conservation Need (SGCN) (DDOE 2015). All species have been observed within NACE units in the District of Columbia.

Species Type	Common Name	Scientific Name
Birds	American bittern	*Botaurus lentiginosus*
	American black duck	*Anas rubripes*
	American kestrel	*Falco sparverius*
	American woodcock	*Scolopax minor*
	Bald eagle	*Haliaeetus leucocephalus*
	Baltimore oriole	*Icterus galbula*
	Bay-breasted warbler	*Setophaga castanea*
	Black-and-white warbler	*Mniotita varia*
	Blackburnian warbler	*Setophaga fusca*
	Black-crowned night heron	*Nycticorax nycticorax*
	Black-throated blue warbler	*Setophaga caerulescens*
	Black-throated green warbler	*Setophaga virens*
	Blue-winged warbler	*Vermivora cyanoptera*
	Bobolink	*Dolichonyx oryzivorus*

Table 2-5 (continued) District of Columbia Species of Greatest Conservation Need (SGCN) (DDOE 2015). All species have been observed within NACE units in the District of Columbia.

Species Type	Common Name	Scientific Name
Birds (continued)	Brown creeper	*Certhia americana*
	Brown thrasher	*Toxostoma rufum*
	Canada warbler	*Cardellina canadensis*
	Chestnut sided warbler	*Setophaga pensylvanica*
	Chimney swift	*Chaetura pelagica*
	Common nighthawk	*Chordeiles minor*
	Cerulean warbler	*Setophaga cerulea*
	Eastern meadowlark	*Sturnella magna*
	Eastern screech-owl	*Megascops asio*
	Eastern towhee	*Pipilo erythrophthalmus*
	Eastern whip-poor-will	*Antrostomus vociferus*
	Field sparrow	*Spizella pusilla*
	Forster's tern	*Sterna forsteri*
	Golden-winged warbler	*Vermivora chrysoptera*
	Grasshopper sparrow	*Ammodramus savannarum*
	Hooded warbler	*Setophaga citrina*
	Kentucky warbler	*Geothlypis formosa*
	Least bittern	*Ixobrychus exilis*
	Lesser yellowlegs	*Tringa flavipes*
	Little blue heron	*Egretta caerulea*
	Lousiana waterthrush	*Parkesia motacilla*
	Marsh wren	*Cistothorus palustris*
	Northern bobwhite	*Colinus virginianus*
	Ovenbird	*Seirus aurocapilla*
	Peregrine falcon	*Falco peregrinus*
	Prairie warbler	*Setophaga discolor*
	Prothonotary warbler	*Protonotaria citrea*
	Purple martin	*Progne subis*
	Red-headed woodpecker	*Melanerpes erythrocephalus*

Table 2-5 (continued) District of Columbia Species of Greatest Conservation Need (SGCN) (DDOE 2015). All species have been observed within NACE units in the District of Columbia.

Species Type	Common Name	Scientific Name
Birds (continued)	Rusty blackbird	*Euphagus carolinus*
	Scarlet tanager	*Piranga olivacea*
	Sora	*Porzana carolina*
	Veery	*Catharus fuscenscens*
	Virginia rail	*Rallus limicola*
	White-eyed vireo	*Vireo griseus*
	Willow flycatcher	*Empidonax traillii*
	Wilson's snipe	*Gallinago delicata*
	Wood duck	*Aix sponsa*
	Wood thrush	*Hylocichla mustelina*
	Worm-eating warbler	*Helmitheros vermivorum*
	Yellow-billed cuckoo	*Coccyzus americanus*
	Yellow-breasted chat	*Icteria virens*
	Yellow-crowned night heron	*Nyctanassa violacea*
	Yellow-throated vireo	*Vireo flavifrons*
Mammals	American mink	*Neovison vison*
	North American beaver	*Castor canadensis*
	Big brown bat	*Eptesicus fuscus*
	Eastern chipmunk	*Tamias striatus*
	Eastern cottontail	*Sylvilagus floridanus*
	Eastern red bat	*Lasiurus borealis*
	Eastern small-footed bat	*Myotis leibii*
	Evening bat	*Nycticeus humeralis*
	Gray fox	*Urocyon cinereoargenteus*
	Hoary bat	*Lasiurus cinereus*
	Little brown bat	*Myotis lucifugus*
	Meadow vole	*Microtus pennsylvanicus*
	Muskrat	*Ondatra zibethicus*
	Northern long-eared bat	*Myotis septentrionalis*

Table 2-5 (continued) District of Columbia Species of Greatest Conservation Need (SGCN) (DDOE 2015). All species have been observed within NACE units in the District of Columbia.

Species Type	Common Name	Scientific Name
Mammals (continued)	Northern river otter	*Lontra canadensis*
	Short-tailed shrew	*Blarina brevicauda*
	Silver haired bat	*Lasionycteris noctivagans*
	Southern flying squirrel	*Glaucomys volans*
	Striped skunk	*Mephitis mephitis*
	Tri-colored bat	*Peromyotis subflavus*
	Virginia opossum	*Didephis virginiana*

Magnolia Bogs

One of the most significant (and least known) natural areas in the Capital Region exists within the 126-acre forest of Oxon Run Parkway. Oxon Run (a tributary of the Potomac River) contains native forested uplands and nearly 58 acres of marshy, or palustrine, forested wetlands. These wetlands include four rare northern magnolia bogs—the only such plant communities in the entire National Park System. Only 13 magnolia bogs are known to exist in the Atlantic Coastal Plain area, and these are threatened by habitat destruction and fragmentation (Mora Bourgeois 2007).

Magnolia bogs are uncommon, but these critically rare plant communities have become more scarce because of disturbances caused by increased urbanization. Clearing and development (paving) of the one-time forested recharge area outside of the park for the Southern Avenue Metro Station, stormwater runoff, siltation, and encroaching developments impact the gravel terraces that supply water to the bogs. Runoff from a nearby parking lot cuts directly through the most prominent bog, depositing the most undesirable sediments and incising a channel to Oxon Run. Such erosion disrupts the bog's hydrology and delicate ecological balance by lowering the water table and depriving the system of water. In addition local stormwater drainages funnel high-velocity flows into a wet meadow of the park floodplain where diverse native species exist. Such destructive storm flows deposit large amounts of trash, damaging the wetlands (Mora Bourgeois 2007).

Integrated cultural and natural landscapes

Cultural landscapes are an important part of the National Capital Region's natural heritage. A cultural landscape is a "geographic area, including both cultural and natural resources and the wildlife or domestic animals therein, associated with a historic event, activity, or person or exhibiting other cultural aesthetic values." (Cultural Resource Management Guidelines NPS-28). The National Park Service recognizes four descriptive types of cultural landscapes that are not mutually exclusive and are relevant to properties nationwide in both public and private ownership. These four types are historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes (Slaiby and Mitchell 2003). NACE has the following park units described in Cultural Landscape Inventories:

- Lincoln Park
- Stanton Park
- Folger Park
- Harmony Hall
- Oxon Hill Farm
- Kenilworth Aquatic Gardens
- Fort Washington
- Fort Dupont (historic earthworks area only, boundary does not include entire park)
- Fort Mahan
- Fort Foote
- Pennsylvania Avenue SE (in progress)

Soundscapes

The soundscape within a park comprises both the natural ambient sounds and human-made sounds. Natural sounds include geophysical (e.g. wind, rain, running water) and biological sounds (e.g. insects, frogs, birds) (Pijanowski et al. 2011). This natural ambient environment enhances visitor experience of the natural park landscape (Miller 2008).

NACE units are located within the Washington Metropolitan Area and in great proximity to major cities and thus are greatly affected by residential developments and major highways. It also experiences high land and air traffic through the Oxon Run, Baltimore-Washington, Shepherd, and Suitland Parkways, and from Joint Base Andrews and Baltimore Washington Thurgood Marshall International Airport, including helicopter traffic from multiple jurisdictions.

Lightscapes

The natural darkness associated with the night sky is an important natural, scientific, and cultural resource valued by the National Park Service (NPS 2012b). The clarity of night skies is important to the visitor experience as well as being ecologically important (NPS 2013c).

Light pollution is increasing globally especially in areas of high growth, such as the east coast of the United States and in the parks that make up NACE. Longcore and Rich (2004) recognize two types of light pollution: astronomical and ecological. Astronomical light pollution impedes the ability to see stars and other celestial bodies. Sky glow, or the nighttime illumination of the sky resulting from the multitudes of human caused light scattered into the atmosphere, contributes to astronomical light pollution. Ecological light pollution alters the natural patterns of light and dark in ecosystems and has adverse effects on wildlife (Longcore and Rich 2004). Ecological light pollution includes direct glare, sky glow, and temporary, unexpected fluctuations in lighting. Behavior and population-level ecology is affected based on individual and species differences in orientation or disorientation to increased light availability, attraction or repulsion to light sources, lowered reproductive capacity, and hindered visual and audio intraspecies communication. These factors culminate in changes in community ecology, influencing competition, including resource partitioning, and predation, and ultimately favoring species that are most light tolerant (Longcore and Rich 2004).

Artificial light sources both within and outside NACE have diminished the clarity of night skies by creating a 'haze' of light that obscures views of stars. The primary culprit in NACE is roadside lighting, car lights, and light from urbanized areas adjacent to the park as well as from park buildings and parking lots.

2.4. Natural Resource Overview

2.4.1. Internal park threats

<u>Adverse Recreational Use</u>

National Capital Parks–East provides numerous recreational possibilities including hiking on 14 km (9 miles) of trails, ballfields, golfing (Langston Golf Course), swimming (DC Recreation Center pool in Anacostia Park) musical performances and ice skating (at Fort Dupont's outdoor Summer Theatre), boat ramp access, fishing, farm activities, hiking, bird watching, camping, horseback riding, jogging, nature walks, interpretive programs, bicycling, picnicking, cross-country skiing, and photography. The parks promote activities that do not damage resources or endanger visitors (Thornberry-Ehrlich 2008).

Many trails wind through preserved biologic, historic, and geologic environments at NACE (Thornberry-Ehrlich 2008). Many of these environments are fragile, and off-trail hiking promotes development of social trails which leads to habitat degradation and can spread exotic, invasive species. The unconsolidated soils and sediments along the more than 20 rivers and streams in NACE are often exposed on slopes with sparse vegetation. This exposure and/or flooding render them highly susceptible to erosion and degradation.

Park units generally use designated trails and picnic areas to concentrate the impacts of recreation. Several of the parks within NACE have trail networks—including Kenilworth Park and Aquatic Gardens, Piscataway Park and Oxon Cove Park. In Greenbelt Park, trails, picnic areas, campgrounds and their associated facilities all have an impact on natural resources. Prohibited use in non-designated areas within park units increases the area of human impact and places delicate ecosystems at risk for contamination and physical damage (Thornberry-Ehrlich 2008).

<u>Exotic species</u>

Exotic species can outcompete and displace native species. Many invasive plants thrive on disturbances created within an ecosystem, such as fragmentation, erosion, flooding, or reductions in native vegetation accompanying the burgeoning populations of native, white-tailed deer (*Odocoileus virginianus*). When native species are displaced by these disturbances, invasive species can more rapidly colonize the area, further facilitating competition for resources. Changes in habitat structure and composition of vegetation communities can affect nutrient cycling, water resources, and habitat quality for wildlife. Invasive wildlife creates similar community and ecosystem-level changes detrimental to native organisms.

Exotic species in NACE were evaluated by the National Capital Region Network Inventory & Monitoring (NCRN I&M) program (Schmit et al. 2012b). Exotic trees were found in 17% of forest monitoring plots. Most of the plots with exotic trees were in park units inside the District of Columbia. No exotic trees were found in plots in Greenbelt Park, and only one exotic tree, a Chinese pear (*Pyrus pyrifolia*) was found in Piscataway Park. Exotic trees notably invaded one edge plot in Anacostia Park, next to the railroad tracks. In that plot, of fourteen trees, thirteen were exotic species, including siberian elm (*Ulmus pumila*), white mulberry (*Morus alba*) and tree of heaven (*Ailanthus altissima*). The only native tree was a single box elder (*Acer negundo*).

More than one third of all shrubs in NACE units are exotic species (Schmit et al. 2012b). The exotic shrubs are almost all Amur honeysuckle (*Lonicera maackii*) but also include autumn olive (*Elaeagnus umbellata*) (PISC) and burning bush (*Euonymus alatus*) (FTDU).

Exotic species were common on the forest floor and were found in 78% of all plots (Schmit et al. 2012b). Most of the plots without forest floor exotics were in the northern units of the park. Japanese stiltgrass (*Microstegium vimineum*) has the highest cover of any forest floor exotic. It is common in Greenbelt Park (8.5% cover) and Piscataway Park (8.8% cover). Oriental bittersweet (*Celastrus orbiculatus*) is also commonly found in Piscataway Park (5.0% cover), but is less common in the rest of NACE. English ivy (*Hedera helix*) is commonly found in the District of Colombia units (11.8% cover), but was rarely encountered in the rest of the park.

Exotic vines are found in 41% of all plots and are growing on 13% of all trees (Schmit 2012). Half of those trees have vines growing in the crown. Japanese honeysuckle is the most common vine, and occurs throughout the park. English ivy is the second most common vine, but is mostly found in the District of Columbia.

Table 2-6 Exotic Species found in, or potentially found in NACE (NPSpecies 2014).

Species Type	Common Name	Scientific Name
Birds	Eurasian Wigeon	*Anas Penelope*
	Common pigeon	*Columbia livia*
	Common Pheasant	*Phasianus colchicus*
	House Finch	*Carpodacus mexicanus*
	House Sparrow	*Passer domesticus*
	Common Starling	*Stumus vulgaris*
	Resident Canada Goose	*Branta canadensis*
Herptofauna	Red-eared Slider	*Trachemys scripta elegans*
Mammals	Norway rat	*Rattus norvegicus*
	Domestic dog	*Canis familiaris*
	Domestic cat	*Felis domesticus*

Table 2-7 Species that the National Capital Region exotic plant management team has treated in NACE (Mark Frey, National Capital Region Exotic Plant Management Team Liaison).

Common Name	Scientific Name
American black elderberry	*Sambucus canadensis*
Asian spiderwort	*Murdannia keisak*
Asiatic dayflower	*Commelina communis*
Autumn olive	*Elaeagnus umbellata*
Basket grass	*Oplismenus hirtellus*
Beale's barberry	*Mahonia balei*
Beefsteak plant	*Perilla frutescens*
Bermudagrass	*Cynodon dactylon*
Bigleaf periwinkle	*Vinca major*
Border privet	*Ligustrum obtusifolium*
Caper spurge	*Euphorbia lathyris*
Chicory	*Cichorium intybus*
Chinese bushclover	*Lespedeza cuneata*
Chinese wisteria	*Wisteria sinensis*
Common reed	*Phragmites australis*
Creeping thistle	*Cirsium arvense*
Crownvetch	*Coronilla varia*
Curly dock	*Rumex crispus*
Dandelion	*Taraxacum officinale*
Dwarf lilyturf	*Ophiopogon japonicus*
English ivy	*Hedera helix*
European spindle	*Euonymus europaeus*
Fortune's spindle	*Euonymus fortunei*
Garlic mustard	*Alliaria petiolata*
Great mullein	*Verbascum Thapsus*
Green-stem forsynthia	*Forsythia viridissima*
Ground ivy	*Glechoma hederacea*
Henbit dead-nettle	*Lamium amplexicaule*

Table 2-7 (continued) Species that the National Capital Region exotic plant management team has treated in NACE (Mark Frey, National Capital Region Exotic Plant Management Team Liaison).

Common Name	Scientific Name
Japanese angelica-tree	*Aralia elata*
Japanese barberry	*Berberis thunbergii*
Japanese box	*Buxus microphylla*
Japanese bristlegrass	*Setaria faberi*
Japanese honeysuckle	*Lonicera japonica*
Japanese hops	*Humulus japonicas*
Japanese knotwood	*Polygonum cuspidatum*
Japanese pachysandra	*Pachysandra terminalis*
Japanese wineberry	*Rubus phoenicolasius*
Jimsonweed	*Datura stramonium*
Kudzu	*Pueraria lobata*
Lambsquarters	*Chenopodium album*
Lesser burdock	*Arctium minus*
Mile-a-minute weed	*Polygonum perfoliatum*
Mock strawberry	*Duchesnea indica*
Morrow’s honeysuckle	*Lonicera morrowii*
Mugwort	*Artemisia vulgaris*
Multiflora rose	*Rosa multiflora*
Nepalese browntop	*Microstegium vimineum*
Oriental bittersweet	*Celastrus orbiculatus*
Osage osage	*Maclura pomifera*
Paper mulberry	*Broussonetia papyrifera*
Periwinkle	*Vinca minor*
Porcelain berry	*Ampelopsis brevipedunculata*
Prickly castor oil tree	*Kalopanax septemlobus*
Princess tree	*Paulownia tomentosa*
Purple loosestrife	*Lythrum salicaria*
Queen Anne’s lace	*Daucus carota*

Table 2-7 (continued) Species that the National Capital Region exotic plant management team has treated in NACE (Mark Frey, National Capital Region Exotic Plant Management Team Liaison).

Common Name	Scientific Name
Silktree	*Albizia julibrissin*
Soapweed yucca	*Yucca glauca*
Spear thistle	*Cirsium vulgare*
Sweet autumn clematis	*Clematis terniflora*
Sweet wormwood	*Artemisia annua*
Tall fescue	*Lolium arundinaceum*
White mulberry	*Morus alba*
Wild privet	*Ligustrum vulgare*
Winged spindle	*Euonymus alata*
Yellow grove bamboo	*Phyllostachys aureosulcata*
Yellow iris	*Iris pseudacorus*

Forest pests

Several pests and diseases threaten forest resources within NACE, among them the gypsy moth (*Lymantria dispar*), Dutch elm disease, and dogwood anthracnose. Gypsy moths, by defoliating trees, open the forest canopy and facilitate invasion by non-native vegetation. Repeated defoliation can cause oak tree mortality—oaks are the dominant tree species in several forest community assemblages. Dutch elm disease is an introduced fungus that destroys American elm trees, transmitted by the elm bark beetle (native and European species).

The expanding population of the emerald ash borer threatens the park's ash trees. Emerald ash borer has already killed scattered forest populations within the park (mostly white and green ash), and entire wetland canopies at Piscataway Park and Kenilworth Marsh (mostly pumpkin ash). The loss of wetland ash canopies may effect shoreline erosion, and at Piscataway, the viewsheds from Mount Vernon and Fort Washington which the park was created to protect. As of 2014, pumpkin ash (*Fraxinus produnda*) was the seventh most common tree in NACE forests.

White-Tailed Deer

White-tailed deer (*Odocoileus virginianus*) densities have risen rapidly in the past few decades due to a lack of natural predators, increased forage area due to land fragmentation for urban growth, and declines in hunting (Bates 2009).

Overbrowsing alters the structure and composition of the vegetation by extirpating native plants, and facilitating the spread of invasive species (Krafft and Hatfield 2011, Allen and Flack 2001). Deer populations affect other forest species that depend on vegetation structure. Browsing opens or removes the forest understory and potentially alters the soil moisture content that amphibians depend on; deer can also trample ephemeral ponds used for amphibian breeding (Pauley et al. 2005). Alteration of the shrub layer can eliminate nesting habitat for bird species. Declines in regeneration of oaks and other mast-producing trees affect small mammal populations that depend on mast as a food source (Bates 2009).

When large trees fall in the forests of NACE, there is little native regeneration to replace it. This increases the success of invasive plant populations. This suppression of native forest vegetation is having a negative impact on native insects that rely on native plants. In turn, the bird, reptile, and amphibian species that rely on those insects can be affected along with predatory mammal species (*M. Milton, personal communication*). In addition, deer have been linked to high numbers of ticks that may lead to increases in diseases such as Lyme disease (Wilson et al. 1990; Deblinger et al. 1993). They can also carry and spread chronic wasting disease (Williams et al. 2002).

Resident Canada Geese

Over the past decade, an increasing number of resident Canada geese have been observed within Anacostia Park. Canada geese are a migratory species that have always been seasonal visitors to the area, stopping temporarily in local waters en route to summer breeding areas to the north or winter ranges to the south. However, the region now supports a growing non-migratory population of Canada geese, referred to as resident Canada geese. A subspecies of giant Canada geese (*Branta Canadensis maxima*) were captive birds that were released to restock the depleted migratory populations along the Atlantic Flyway. These geese became non-migratory in their new habitats and formed year round resident populations. The abundance of food and lack of natural predators in the urban areas of Maryland and the District of Columbia have allowed resident Canada goose populations to grow rapidly (NPS 2011a).

Non-migrating, resident Canada geese (*Branta canadensis*), are a confounding factor in Anacostia River marsh restoration. The restoration of tidal marshes has been attempted, to improve water quality of the Anacostia River, improve native plant and animal diversity, and provide a more natural recreation experience for park visitors along the river, as well as meet the Department of the Interior's agreement to the Chesapeake Bay Recovery Program. Following the success of marsh restoration projects within Kenilworth Marsh (1992-1993), a similar, $6 million project was undertaken to restore 40 acres of marsh in Kingman Lake in 2000. After the completion of the project, resident Canada geese ate the majority of restored vegetation. Grazing damage by resident Canada geese results in adverse changes to emergent vegetation and submerged aquatic vegetation structure and composition; erosion and sedimentation problems in the Anacostia River that have negatively impacted the water quality of the river; and potential adverse effects on wildlife and fisheries habitat and the natural distribution, abundance, and diversity of native plant species.

Anacostia Park, which includes both the Kenilworth and Kingman Marsh restorations, is comprised of approximately 590 acres of wetland and 390 acres of grassland (including Langston Golf Course). In July 2009, the mean population of resident Canada geese along the tidal Anacostia River was approximately 414 birds (NPS 2009a, Bates 2010a). In June 2010, the mean population was approximately 550 birds. The 2010 goose population count showed the highest numbers of geese within Kingman Lake, averaging more than 250 on each day of the count (NPS 2011a, Krafft et al. 2013).

Water Quality

Increased urban development and increased surface runoff, which result from the addition of impervious surfaces such as roads, parking lots, and buildings, are having the strongest regional effects on water quality in creeks and rivers (Anderson et al. 2002). Water resources are under constant threat of contamination and damage because of uncontrolled and inadequately managed stormwater runoff from development in surrounding areas. Sedimentation increases when land clearing and earth-moving for development exposes barren soil to erosion. Water temperature increases because of the insulating nature of impervious surfaces (Allen and Flack 2001).

2.4.2. Regional threats

Development/encroachment

National Capital Parks–East provides a substantial, heavily visited, protected area between urbanized Washington, D.C., and Baltimore, Maryland. The population of the entire Baltimore-Washington complex was estimated in 2012 at 9,331,587 (US Census 2012). Local communities in and around the park continue to grow. Millions of people visit the different units of NACE not including the millions of commuters that make use of its four parkway units. The cumulative effect of visitation places increasing demands on protected areas within the parks. Visitor use includes hiking, camping, picnicking, and biking. The landscape response to potential visitor overuse is a resource management concern and includes visitor safety, especially along stream edges, roads, and near waste facilities (Thornberry-Ehrlich 2008).

Humans have significantly modified the landscape surrounding the parks as well as the geologic system of the area. Urban developments threaten the health of the ecosystem. The dynamic system is capable of noticeable change within a human life span (Thornberry-Ehrlich 2008). Further impacts to watershed health include chemical pollutants (oil, grease, brake fluid, coolant, etc.) leaking from vehicles along roadways, in parking lots, and in construction areas; litter and trash washed in from other areas; and flushes of sediment from new construction sites (Thornberry-Ehrlich 2008).

Stormwater management, erosion and increased sediment load

Erosion of the landscape within NACE parklands leads to increases in sediment carried by park streams as well as slope instability and gullying of unconsolidated Mesozoic and Cenozoic Atlantic Coastal Plain sediments (including silts and clays). The lack of stormwater management and/or inadequate stormwater management in developed areas surrounding the parks has caused serious deterioration of park streams and wetlands. The likelihood of slumps and slides increases with undercutting of slopes by roads, trails, and other development in addition to natural erosion (Thornberry-Ehrlich 2008).

Many stormwater outfalls in the region deposit stormwater runoff directly into streams throughout NACE, resulting in extreme erosions of streambanks. Sediment loads and distribution affect aquatic and riparian ecosystems, and sediment loading can result in changes to channel morphology and increase the frequency of flash flooding (Thornberry-Ehrlich 2008). Many local streams are in the process of downcutting and widening, threatening habitat and property.

Air quality

Air pollution originates from several different types of sources—stationary sources, such as factories, power plants, and smelters; mobile sources, such as cars, trains, and airplanes; and naturally occurring sources, such as windblown dust (U.S. EPA 2013). The most commonly found air pollutants are particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Nitrogen oxide and lead are the most widespread human health threats (U.S. EPA 2013). The East Coast has some of the worst air pollution in the country, characterized by low visibility, elevated ozone concentrations, and elevated rates of atmospheric nitrogen and sulfur deposition. Elevated ozone levels have been shown to cause premature defoliation in plants while high levels of nitrogen deposition acidify and fertilize soils and waters, thereby affecting nutrient cycling, vegetation composition, biodiversity, and eutrophication. Air pollution can be transported over long distances, making management difficult at the local scale.

Climate change

Climate change, and associated temperature and precipitation shifts, will likely alter the phenology of plant species (NPS 2013d). The timing of flowering is tied to pollinator activity, a relationship that might become decoupled as temperature increases shift the first flowering date earlier in the season (Davis 2011). In the Washington, D.C. area, the timing of first flowering has shifted earlier by 0.2 to 46 days for early-flowering plants and later in the season by 0.3 to 10.4 days for late-flowering plants (Davis 2011). Diversity of native plants will likely decrease with climate change. This increased growing period, as well as changes in biodiversity, provide increased opportunity for exotic invasive species.

Changes in precipitation and stream discharge are also possible with climate change. Weather records for several NCRN parks (Catoctin Mountain Park, George Washington Memorial Parkway, Rock Creek Park, National Capital Parks-East) show that the 30-year period 1982-2012 was wetter than 95% of previous 30-year periods back to 1901 (Monahan and Fisichelli 2014). Stream discharge influences distribution of sediments and nutrients in water, which can impact stream dwelling species. In NACE, increased temperatures and hydraulic changes have the potential to alter the natural and manmade landscapes of the park, impacting a variety of ecological, cultural, and recreational features.

Locally, the Washington, D.C. area is subject to urban heat island effects. Over the past 10 years, the average daily urban-rural temperature difference in Washington, D.C. is 4.7°F. With climate change, urban environments are projected to become even hotter in coming decades. Additionally, ongoing increases in development and impervious surfaces contribute to the urban heat island effects. These increases in urban temperatures, in addition to climatic warming trends, can further exacerbate the impacts to species composition and the health of park flora and fauna (Kenward et al. 2014).

Sea level rise

National Capital Parks-East lies along the tidal freshwater sections of the Anacostia and Potomac Rivers. The impact of sea level rise in these parks is a likely threat to these parks with climate change. The mid-Atlantic region of the United States has experienced almost twice the global mean rate of relative sea level rise over the past century (3 – 4 mm per year), which is predicated to increase a further 19 cm by 2030, resulting in increased coastal flooding and changes to geomorphological processes (Najjar et al. 2000). Rising sea level could result in more frequent inundation, possible displacement of resources, and higher risk of storm damage (Elmore et al. 2015).

2.5. Resource Stewardship

2.5.1. Management directives and planning guidance

Vision statement

National Capital Parks–East is one of the jewels of the National Park System that is managed and promoted by consummate professionals dedicated to conserving resources and providing safe and enjoyable experiences. We strive to inspire this and future generations to recognize, understand, conserve, and protect our natural, cultural, and recreational resources.

Park purpose

National Capital Parks were established to prevent pollution of the Potomac and Anacostia Rivers, to preserve forests and natural scenery in and about Washington, and to provide for the comprehensive systematic, and continuous development of the park, parkway, and playground system of the National Capital (The National Capital Park Commission Act, 1924. U.S. Congress).

Park significance

Significance statements express why National Capital Parks-East resources and values are important enough to merit national park unit designation (NPS 2013a). Significance statements describe the distinctive nature of the park and inform management decisions, focusing efforts on preserving and protecting the most important resources and values of each park unit.

2.5.2. Status of supporting science

Inventory and Monitoring program

The Inventory and Monitoring (I&M) Division of the NPS was formed in response to the Natural Resource Challenge of 1999. The goals of the I&M Division are to (NPS 2013a):

- Inventory the natural resources under National Park Service stewardship to determine their nature and status.
- Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments.
- Establish natural resource inventory and monitoring as a standard practice throughout the National Park system that transcends traditional program, activity, and funding boundaries.
- Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision-making.

- Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

In addition to conducting baseline inventories, I&M monitors vital signs that are indicators of ecosystem health. Vital signs include the following:

- physical, chemical, and biological elements and processes of park ecosystems;
- known or hypothesized effects of stressors; and/or
- elements that have important human values (Fancy et al. 2009).

NACE is one of the 11 parks served by the National Capital Region I&M Network (NCRN I&M). Numerous baseline inventories have been conducted at National Capital Parks – East park units and NRCN vital signs monitoring makes up a large portion of the natural resource data described in this report. The long-term monitoring of these vital signs is meant to serve as an 'early warning system' to detect declines in ecosystem integrity and species viability before irreversible loss has occurred (Fancy et al. 2009).

2.5.3. Research at the park

NCRN I&M performs its own monitoring and has collaborated with a variety of outside researchers to fill gaps in knowledge and have a better understanding of park resources (Table 2-8). Collaborators have included state and federal government agencies, educational institutions, and non-government organizations. A partial bibliography of research that has been completed at NACE can be seen in Table 2-9. In addition, NCRN I&M conducts on-going monitoring in NACE park units as described in Table 2-8.

Table 2-8 Status of NRCN I&M Inventories at National Capital Parks-East.

Inventory	Description	Status
Air Quality Data	One of the 12 core natural resource inventories, the Air Quality Inventory provides actual measured or estimated concentrations of indicator air pollutants such as ozone, wet deposition species (NO_3, SO_4, NH_4, etc.), dry deposition species (NO_3, SO_4, HNO_3, NH_4, SO_2), and visibility (extinction for 20% cleanest days and 20% worst days for visibility).	Completed 2010
Air Quality Related Values	Air quality related values are resources sensitive to air quality, including vegetation, wildlife, water quality, and soils. This inventory identifies whether categories of these values are sensitive for a given park.	Completed 2011
Base Cartography Data	The Base Cartography inventory is one of 12 core inventories identified by the National Park Service as essential to effectively manage park natural resources. Base cartographic information from this inventory provides geographic information systems (GIS) data layers to National Park resource management staff, researchers, and research partners.	Completed 2010

Table 2-8 (continued) Status of NRCN I&M Inventories at National Capital Parks-East.

Inventory	Description	Status
Baseline Water Quality Inventory	This inventory documents and summarizes existing, readily available digital water quality data collected in the vicinity of national parks.	Completed 1996
Climate Inventory	One of the 12 natural resource inventories, the primary objective of the Climate Inventory is to obtain park-relevant baseline climate data useful to NPS biologists, hydrologists and resource managers.	Completed 2006
Geologic Resources Inventory	The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, and researchers with information that can help them make informed management decisions.	Completed 2008
Soil Resources	The Soil Resources Inventory (SRI) includes maps of the locations and extent of soils in a park; data about the physical, chemical, and biological properties of those soils; and information regarding the potential use and management of each soil. The SRI adheres to mapping and database standards of the National Cooperative Soil Survey (NCSS) and meets the geospatial requirements of the Soil Survey Geographic (SSURGO) database. SRI data are intended to serve as the official database for all agency applications regarding soil resources.	Completed 2009
Vegetation Mapping	The Vegetation Inventory Program (VIP) is an effort by the National Park Service (NPS) to classify, describe, and map detailed vegetation communities in more than 270 national park units across the United States. Stringent quality control procedures ensure the reliability of the vegetation data and encourage the use of resulting maps, reports, and databases at multiple scales.	In progress

Table 2-9 A partial bibliography of research that has been completed at NACE.

Study topic	Reference
Air Quality	Hunter 1976; Chen et al. 2002; Kohut 2007; Lawrey 2011; Sullivan et al. 2011a; Sullivan et al. 2011b
Birds	Grue et al. 1984, 1986; Syphax 1995; Sinclair et al. 2004; Fallon 2006; Goodwin 2009, Ladin 2013
Climate	Davey et al. 2006; Gonzales 2011; Rauch 2011
Fish	Sakaris 2005; Doyle et al. 2013
Flora	Steward et al. 1984; Fleming and Kanal 1992; Derico 1999; Steury and Davis 2003; Simmons et al. 2003; Schmit et al. 2010; Schmit et al. 2012a; Schmit et al. 2012b
Geology & Soils	Potter 1980; Short and Patterson, 1984; Thornberry-Ehrlich 2008

Table 2-9 (continued) A partial bibliography of research that has been completed at NACE.

Study topic	Reference
Herpetofauna	Kaufmann 1968; Beyer and Moore 1980; Orr 2001; Pauley and Watson 2003
Hydrology	
Mammals	Clark, 1979; McShea and O'Brien, 2003; Johnson 2008
Water Quality	Wofsy et al. 1981; Means and Wijayaratne 1982; Seliger et al. 1985; Phelps 1993, 2005, 2008; Huanxin 1997; Foster 2000; Devereux 2005, 2006; Hwang 2006, 2008; Miller 2007; Krumins 2009; Pieper et al. 2012
Wetlands	May 1994; Syphax and Hammerschlag 1995; Bowers 1995; Neff and Baldwin 2005

2.6. Legislation

1914. Public Law 63, 38 Stat. 549 Anacostia River Flats Act of 1914. Linked improvements to the navigable waterway of the Anacostia River with the creation of new land to help meet the needs of the growing population of the nation's capital.

1924. U.S. Congress. The National Capital Park Commission Act. (Sess I, Chapter 270, 1924). Enacted July 21, 1932. "An Act Providing for a comprehensive development of the park and playground system of the National Capital."

1930. U.S. Congress. The Capper-Campton Act. Enacted May 29,1930. (46 Stat. 482). "An Act for the acquisition, establishment, and development of the George Washington Memorial Parkway along the Potomac from Mount Vernon and Fort Washington to the Great Falls, and to provide for the acquisition of lands in the District of Columbia and the States of Maryland and Virginia requisite to the comprehensive park, parkway, and playground system of the National Capital."

1933. Executive Order (EO) 6166 transferred NCPC's responsibilities for management of the park, parkway, and playground system to the NPS

1949. H.R. 2214, passed on August 17, 1949. Introduced for the permanent transfer of the Suitland parkway along with "all [its] lands and easements heretofore or hereafter acquired by the United States."

1950. Public Law 643, passed on August 3, 1950, providing "for the construction, development, administration, and maintenance of the Baltimore-Washington Parkway," as well as the acquisition of land for Greenbelt Park.

1966. Sue Spencer Collins sold 65.7 acres of the remaining Harmony Hall property, including Want Water, to the National Park Service.

1969. Public Law 87-633: 76 Stat. 435. Congress approved the Enabling Legislation for Frederick Douglass National Historic Site in On February 12, 1988, the Secretary of the Interior redesignated the site as the Frederick Douglass National Historic Site.

3. Study Scoping and Design

3.1. Preliminary scoping and park involvement

Preliminary scoping for the assessment of NACE began in May 2013 with a meeting at the George Washington Memorial Parkway. In attendance was staff from NACE and GWMP, the NPS National Capital Region Network (NCRN) Inventory and Monitoring (I&M) program, and the University of Maryland Center for Environmental Science Integration and Application Network (UMCES-IAN). Project goals and reporting areas were made during the initial scoping meeting with the NACE park staff. Park staff helped identify key indicators of environmental health for the park. Archived data for park resources from NACE and NCRN I&M were organized into an electronic library comprised of management reports, hard data files, and geospatial data (GIS), which provided the primary sources for this assessment. Additional datasets were obtained from the NPS Air Resources Division (ARD) and the Interagency Monitoring of Protected Visual Environments (IMPROVE).

Figure 3-1 Participants at the preliminary scoping workshop for National Capital Parks-East and the George Washington Memorial Parkway. From left to right: Alex Romero, Brent Steury, Mikaila Milton, Simon Costanzo, Stephen Syphax, Megan Nortrup, Erik Oberg, Patrick Campbell, Brianne Walsh, Jim Pieper, and Mark Lehman.

Several follow-up meetings with staff from NACE, NCRN I&M, and UMCES-IAN were used to identify and locate key resources for completing the assessment, to present work and calculations already completed, and to develop conclusions and recommendations based on the assessment findings.

3.2. Study design

3.2.1. Reporting areas

The focus of the reporting area for this NRCA are the lands within the NACE legislative boundary that are owned by the NPS.

An area five times the total area of the park (evenly distributed around the entire park boundary) was examined for landscape dynamic metric analysis. Lands within 30 km (19 mi) of the park boundary were examined for landscape context (Budde et al. 2009; Gross et al. 2009) but not included in the formal assessment.

3.2.2. Indicator framework

At the initial planning workshop, NACE was originally proposed to be divided and assessed by habitat type. After review of available data, it became clear that this approach was not feasible due to an imbalance of habitat-specific data collected across the park (Table 3-1). It was proposed to continue the assessment based on the four vital signs categories—air quality, water resources, biological integrity, and landscape dynamics.

Table 3-1 Habitat type and availability of monitoring data used to structure the assessment of natural resources within National Capital Parks-East.

		Plots located within each habitat type		
Habitat type	**Square meters**	**Forest**	**Water**	**Maryland Biological Stream Survey**
Tidal wetland	877,964	2	-	-
Open water	1,066,622	-	2	1
Wetland	1,208,130	3	-	-
Grassland/shrub	1,803,150	2	-	-
Agriculture	2,122,510	-	-	-
Developed	8,735,886	-	-	-
Forest	27,448,604	41	2	2

Metrics included in the assessment were sorted into their respective vital signs categories so that they could be utilized in future studies (Figure 3-2). Fancy et al. (2008) identified a key challenge of such large-scale monitoring programs to be the development of information products, which integrate and translate large amounts of complex scientific data into highly aggregated metrics for communication to policy-makers and non-scientists. Aggregated indices were developed and are presented within the current natural resources assessment for National Capital Parks-East.

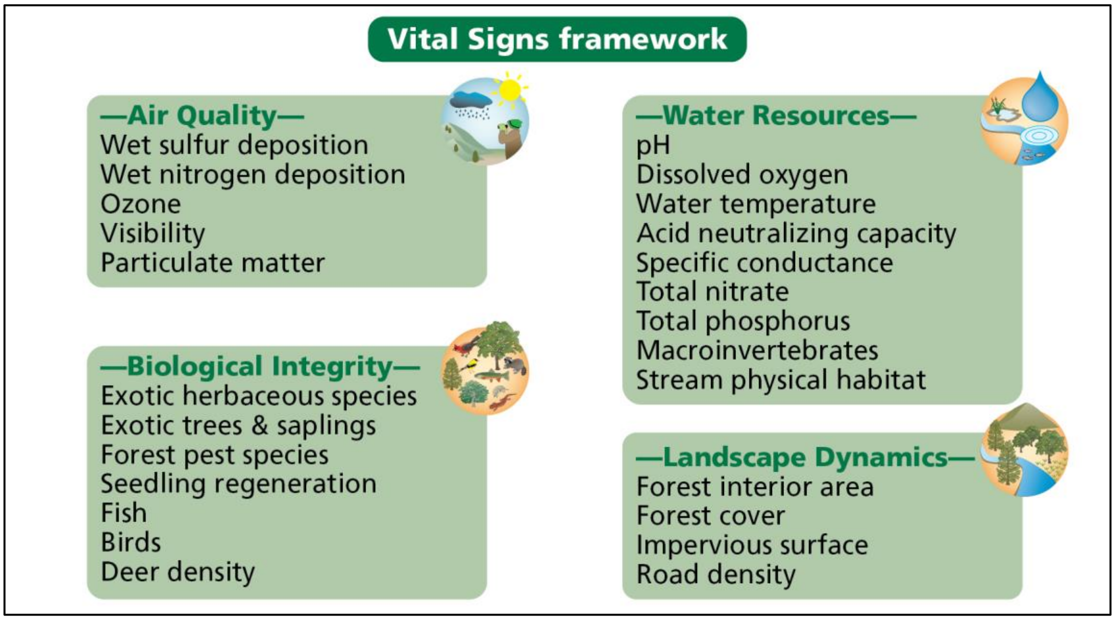

Figure 3-2 Vital signs framework used in this assessment.

3.2.3. General approach and methods

The general approach taken to assess natural resource condition was to determine indicators appropriate to inform current status of each metric, establish a reference condition for each indicator, and then assess the percentage attainment of reference condition. Details of approach, background, and justification are provided on a metric-by-metric basis in Chapter 4. Once attainment was calculated for each indicator, an unweighted mean was calculated to determine the condition for each vital sign category and then similarly to combine vital sign categories to calculate an overall park assessment.

3.2.4. Thresholds

A natural resource condition assessment requires the establishment of criteria for defining reference, as well as current ecological conditions. The current assessment was based upon explicitly defined threshold values. Thresholds represent an agreed upon value or range indicating that an ecosystem is moving away from a desired state and towards an undesirable ecosystem endpoint (Biggs 2004; Bennetts et al. 2007). Even though increasing scientific research has focused upon defining ecological thresholds, uncertainty in definition as well as spatial and temporal variability has often led to disagreement on specific values (Huggett 2005; Groffman et al. 2006). Even with the definition of agreed upon thresholds, there is still the question of how best to use these threshold values in a management context (Groffman et al. 2006). Recognizing these challenges, thresholds can still be effectively used to track ecosystem change and define achievable management goals (Biggs 2004). As long as threshold values are clearly defined and justified, they can be updated in the light of new research or management goals and can therefore provide an important focus for the discussion and implementation of ecosystem management (Jensen et al. 2000; Pantus and Dennison 2005).

3.2.5. Data synthesis

It is increasingly recognized that monitoring data collected for specific purposes, such as assessing the implementation of environmental regulations, does not necessarily allow for regional assessments of ecosystem condition (U.S. EPA 2000, 2002). As a result, one of the key challenges of large-scale monitoring is to develop integrated and synthetic data products that can translate a multitude of diverse data into a format that can be readily communicated to decision makers, policy developers, and the public (Fancy et al. 2008). These timely syntheses of ecosystem condition can provide feedback to managers and stakeholders, so that the effectiveness of management actions as well as future management goals can be determined at multiple scales (Dennison et al. 2007). One approach to synthesizing data is to develop multiple-metric indices to summarize the status of many aspects of a community and then draw inferences on the status of the supporting ecosystem (Karr 1981). Multi-metric indices improve on the use of just one measure, such as fish biomass or abundance, which often shows complex and variable responses to changes in environmental condition (Karr 1981). Multimetric indices are seen as providing greater insight into ecosystem condition than physical measurements alone (e.g., water quality), as biological communities provide an integrated summary of ecosystem condition over time (Roth et al. 1989, 2000; Harrison and Whitfield 2004). Several indices are used in this assessment including the stream physical habitat index (PHI), bird community index (BCI), fish index of biotic integrity (FIBI), and benthic index of biotic integrity (BIBI).

3.2.6. Condition assessment calculations

A total of 25 vital sign metrics were used to determine the natural resource condition of NACE. The approach for assessing resource condition within NACE required establishment of a reference condition (i.e., threshold) for each metric. Thresholds ideally were ecologically based and derived from the scientific literature. However, when data were not available to support peer-reviewed ecological thresholds, regulatory and management thresholds were used.

Due to the wide range of data values for some of the metrics medians were presented as the overall result instead of the mean. For the analysis of exotic herbaceous species, exotic trees and saplings, and forest pests, the mean was chosen for comparison against the threshold.

Threshold attainment of metrics was calculated based on the percentage of sites or samples that met or exceeded threshold values set for each metric. A metric attainment score of 100% reflected that the metric at all sites and at all times met the threshold identified to maintain natural resources. Conversely, a score of 0% indicated that no sites at any sampling time met the threshold value. Once attainment was calculated for each metric, an unweighted mean was calculated to determine the condition of each vital sign. Attainment scores were categorized on a scale from very good to very degraded. Attainment scores for each metric are presented in Chapter 4.

The four vital sign scores were then averaged to produce a single assessment score for the entire park. Key findings, conclusions, and recommendations are given for each vital sign and for the park as a whole in Chapter 5.

4. Natural Resource Conditions

4.1. Air quality

4.1.1 Air quality summary

The Clean Air Act requires the U.S. EPA to set national air quality standards for specific pollutants that can negatively impact human health and the environment (U.S. EPA 2013). The U.S. EPA has established standards for six common air pollutants, and these standards define levels of air quality that are necessary to protect against adverse effects on human health and the environment. These six air pollutants, referred to as “criteria” pollutants, include ozone, particle pollution, lead, nitrogen dioxide, carbon monoxide, and sulfur dioxide (U.S. EPA 2013).

Of the EPA criteria pollutants, the NPS Air Resources Division (ARD) provides assessments of all except lead and carbon monoxide. Five metrics were used to assess air quality in NACE: wet sulfur deposition, wet nitrogen deposition, ozone (ppb and W126), visibility, and particulate matter. A sixth metric (mercury deposition) was included for informational purposes but not included in the overall assessment. Data used for the assessment of current condition of wet sulfur and nitrogen deposition, ozone, and visibility were obtained from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2014a, b, c) (Table 4-1). These data come from national monitoring sites (Table 4-1) and were calculated by ARD on a national scale between 2008 and 2012 using an interpolation model. The values for individual parks within NACE were taken from the interpolation at the park unit centroid, which is the location near the center of the park and within the park boundary. Air quality is calculated for six sites within NACE: Carter G. Woodson Home NHS (DC), Fort Washington Park (MD), Frederick Douglass NHS (DC), Greenbelt Park (MD), Mary McLeod Bethune Council House NHS (DC), and Piscataway Park (MD). To determine the overall condition for NACE, the median value of these six sites was used to compare against the reference conditions (Figure 4-1).

Table 4-1 Ecological monitoring framework data for Air Quality provided by agencies and specific sources included in the assessment of NACE.

Metric	Agency	Reference/source
Wet sulfur deposition	NPS ARD	NPS ARD 2014b; http://nadp.sws.uiuc.edu/data/animaps.aspx
Wet nitrogen deposition	NPS ARD	NPS ARD 2014b; http://nadp.sws.uiuc.edu/data/animaps.aspx
Ozone (ppb and W126)	NPS ARD	NPS ARD 2014a
Visibility	NPS ARD	NPS ARD 2014c
Particulate matter (PM 2.5)	IMPROVE	http://www.epa.gov/airdata
Mercury deposition	NADP-MDN	http://nadp.sws.uiuc.edu/data/mdndata.aspx

Reference conditions were established for each of the five metrics (Table 4-2) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4-3). Multiple reference condition categories were used in accordance with the NPS ARD documentation (NPS ARD 2011) (Table 4-2).

To assess trends, data from the NPS ARD report were used where possible (NPS ARD 2011). Otherwise, monitoring sites closest to NACE from the National Atmospheric Deposition Program (NADP) and Interagency Monitoring of Protected Visual Environments (IMPROVE) program were used (Figure 4-1).

NACE scored 0% attainment (or condition of significant concern) for all air quality metrics except particulate matter (100% attainment). This resulted in an overall air quality condition attainment of 16.7%, or very degraded condition.

Table 4-2 Air Quality reference conditions for NACE.

Metric	Reference conditions	Sites	Samples	Period
Wet sulfur deposition (kg/ha/yr)	< 1; 1-3; >3	6	N/A*	2008-2012
Wet nitrogen deposition (kg/ha/yr)	< 1; 1-3; >3	6	N/A*	2008-2012
Ozone (ppb)	≤ 60; 60.1-75; >75	6	N/A*	2008-2012
Ozone (W126; ppm-hrs)	< 7; 7-13; >13	6	N/A*	2008-2012
Visibility (dv)	<2; 2-8; >8	6	N/A*	2008-2012
Particulate matter (PM2.5; μg/m^3)	≤12; 12.1-15; >15	2	1974	2008-2012
Mercury deposition (ng/L)	N/A	2	701	2008-2012

* one interpolated value represents a five-year average of weekly measurements at multiple sites.

Table 4-3 Categorical ranking of the reference condition attainment categories for Air Quality metrics.

Metric reference condition					Attainment reference condition	Natural resource condition
S & N deposition (kg/ha/yr)	Ozone (ppb)	Ozone (W126)	Visibility (dv)	Particulate matter (μg/m3)		
< 1	≤ 60	< 7	< 2	≤ 12	100%	Good
1-3	60.1-75	7-13	2-8	12.1-15	0-100% (scaled)	Moderate
> 3	> 75	> 13	> 8	> 15	0%	Significant concern

Table 4-4 Summary of resource condition assessment of Air Quality in NACE.

Metric	Result	Reference conditions	% Attainment	Condition	Air quality condition
Wet sulfur deposition (kg/ha/yr)	3.55	< 1; 1-3; >3	0	Significant concern	16.7% Very degraded
Wet nitrogen deposition (kg/ha/yr)	4.15	< 1; 1-3; >3	0	Significant concern	
Ozone (ppb)	77.45	≤ 60; 60.1-75; >75	0	Significant concern	
Ozone (W126; ppm-hrs)	14.20	< 7; 7-13; >13	0	Significant concern	
Visibility (dv)	11.30	<2; 2-8; >8	0	Significant concern	
Particulate matter (PM2.5; µg/m3)	10.80	≤12; 12.1-15; >15	100	Good	
Mercury deposition (ng/L)	7.86	N/A	N/A	N/A	

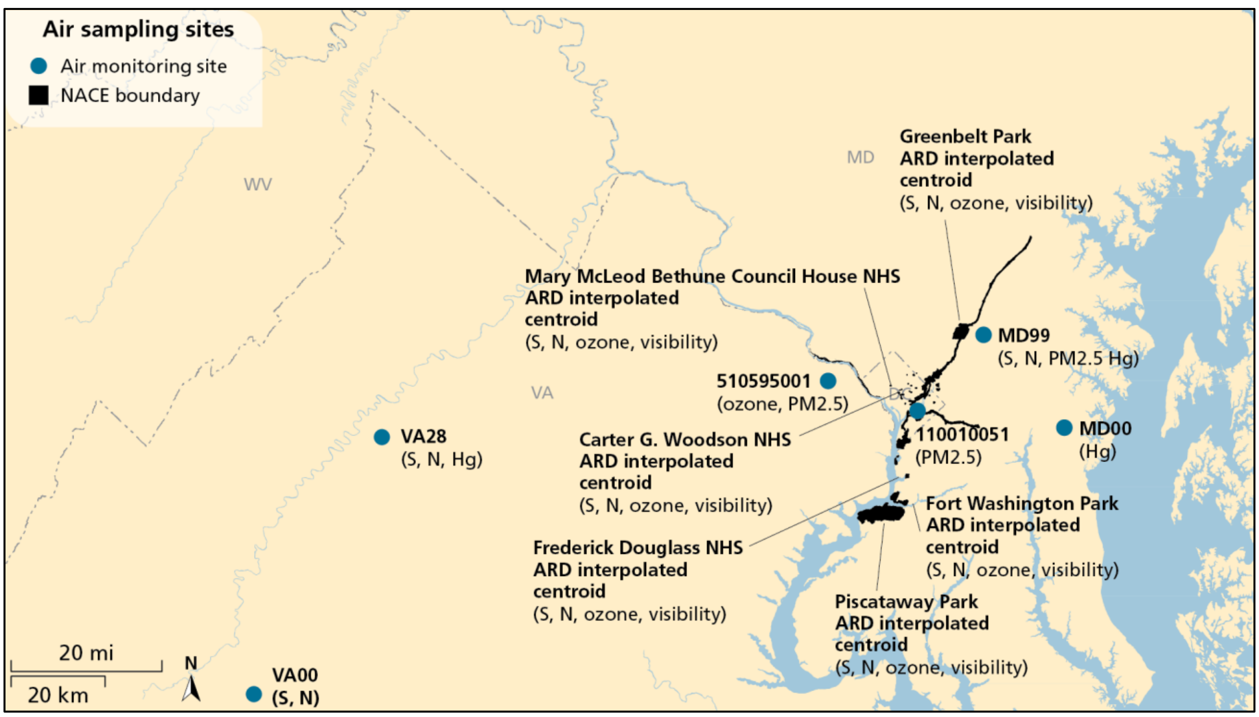

Figure 4-1 Regional air quality monitoring sites for wet deposition of sulfur and nitrogen, ozone, visibility, particulate matter, and mercury deposition. Wet deposition, ozone, and visibility data for 2008-2012 were interpolated by NPS ARD to estimate mean concentrations for NACE.

4.1.2. Wet sulfur deposition

Description

Emissions of sulfur dioxide (SO_2) in the U.S increased from nine million metric tons in 1900 up to 28.8 million metric tons by 1973, with 60% of these emissions coming from electric utilities. Geographically, 41% came from the seven Midwest states centered on the Ohio Valley (Driscoll et al. 2001). Largely as a result of the Clean Air Act, emissions of SO_2 had reduced to 17.8 million metric tons by 1996 and while large areas of the eastern U.S. had annual sulfur wet deposition loads >30 kg/ha/yr over the period 1983-1985, these areas were mostly < 25 kg/ha/yr by the period 1995-1997 (Driscoll et al. 2001). Once in the atmosphere, SO_2 is highly mobile and can be transported distances greater than 500 km (311 miles) (Driscoll et al. 2001). Wet sulfate (SO_4^{2}-) deposition is significant in the eastern parts of the United States (Figure 4-2).

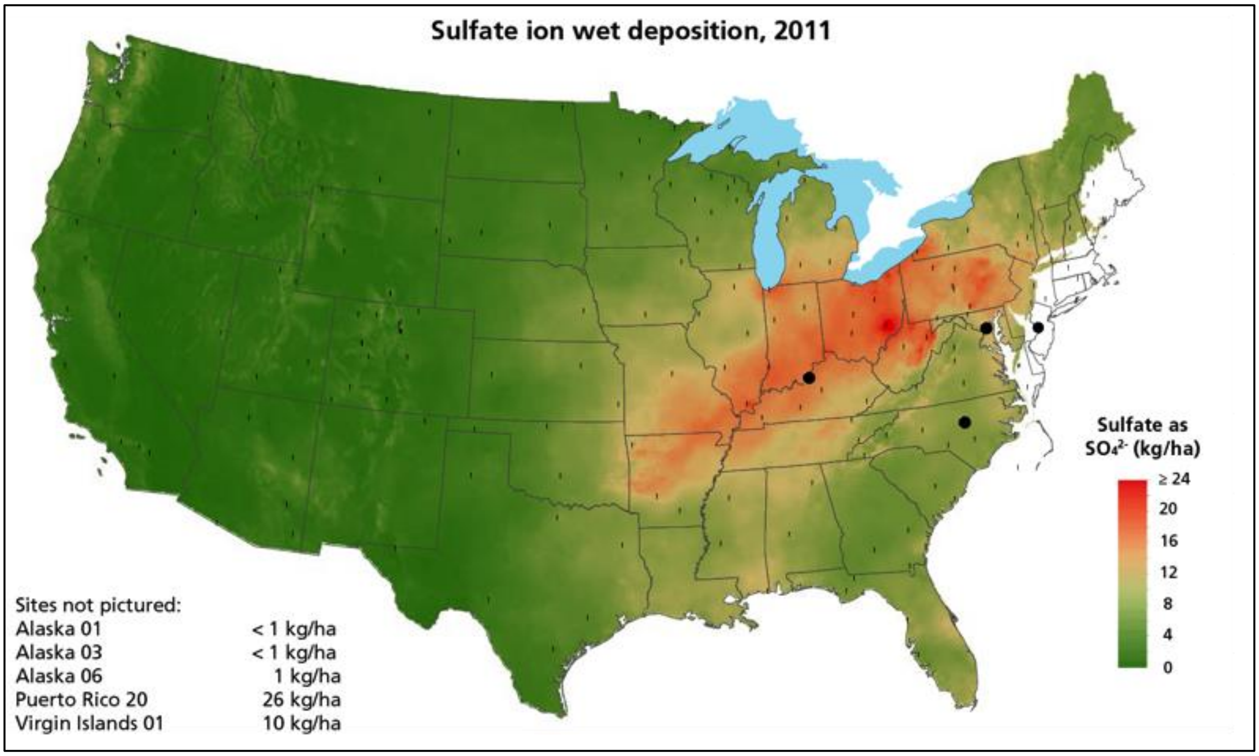

Figure 4-2 Total wet deposition of sulfate (SO_4^{2-}) for the continental United States in 2011 (NADP/NTN 2013).

Data and Methods

The reference condition for total sulfur wet deposition is ecological. Natural background total sulfur deposition (both wet and dry) in the east of the U.S. is 0.5 kg/ha/yr, which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007; NPS ARD 2011).

The wet sulfur deposition data used for this assessment of current condition were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2014b). These estimates were calculated on a national scale between 2008 and 2012 using an interpolation model based on monitoring data.

The values for individual parks within NACE were taken from the interpolation at that unit's centroid, which is the location near the center of the park and within the park boundary. Six sites within NACE are evaluated for wet sulfur deposition: Carter G. Woodson Home NHS (DC), Fort Washington Park (MD), Frederick Douglass NHS (DC), Greenbelt Park (MD), Mary McLeod Bethune Council House NHS (DC), and Piscataway Park (MD) (Table 4-6). To determine the overall condition for NACE, the median value of these six sites was used to compare against the reference conditions for wet sulfur deposition (Figure 4-1).

NPS ARD has established wet sulfur deposition guidelines as < 1 kg/ha/yr indicating good condition (or 100% attainment of reference condition) and > 3 kg/ha/yr indicating significant concern (or 0% attainment). Concentrations of 1-3 kg/ha/yr were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points. For the current assessment, the reported wet deposition value was assessed against these guidelines (NPS ARD 2011).

Table 4-5 Wet sulfur deposition categories, percent attainment, and condition assessment.

Wet sulfur deposition (kg/ha/yr)	% Attainment	Condition
< 1	100%	Good
1-3	0-100% (scaled)	Moderate
> 3	0%	Significant concern

The analysis meant that there was only one value reported for wet sulfur deposition for NACE, so this value was assessed against the three reference condition ranges described above.

NPS ARD used data from National Atmospheric Deposition Program (NADP) monitoring sites closest to NACE: VA00 (Charlottesville) and VA28 (Shenandoah-Big Meadows) in Virginia, and site MD99 (Beltsville, Prince Georges County in Maryland (Table 4-1, Figure 4-1).

Condition and trend

Interpolated wet sulfur deposition between 2008 and 2012 for NACE was 3.55 kg/ha/yr which resulted in 0% attainment of reference condition, or a condition that is of significant concern (NPS ARD 2012) (Figure 4-3).

When deposition data were analyzed from the three locations closest to the park, all three sites showed a significant improvement in wet sulfur deposition over the past decade (p-value < 0.01).

Table 4-6 Wet sulfur deposition values from sites within NACE. The values for individual parks were taken from the interpolation at the park centroid. The median of these values was used to compare against the reference condition for wet sulfur deposition.

Park Name	Total-S (kg/ha/yr)
Carter G. Woodson Home NHS	3.6
Fort Washington Park	3.4
Frederick Douglass NHS	3.5
Greenbelt Park	3.6
Mary McLeod Bethune Council House NHS	3.6
Piscataway Park	3.4

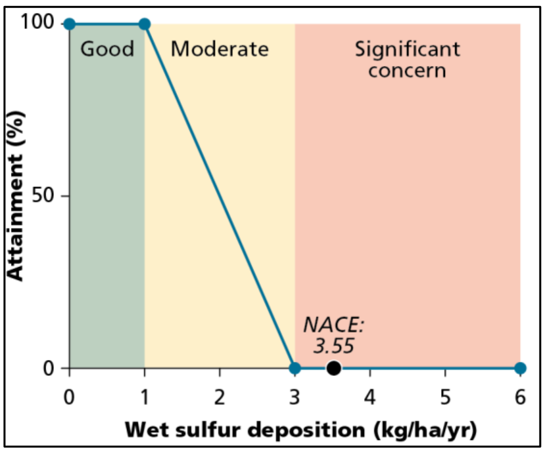

Figure 4-3 Application of the percent attainment categories to the wet sulfur deposition value categories. Wet sulfur deposition at NACE was 3.55 kg/ha/yr, which equated to 0% attainment of the reference condition.

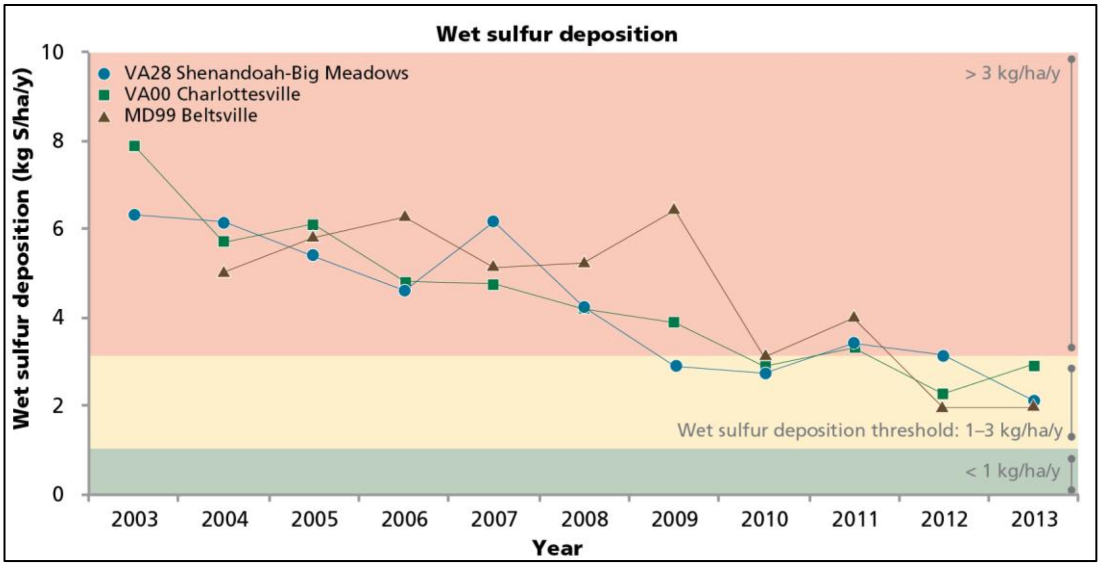

Figure 4-4 Annual wet deposition of sulfate (kg/ha/yr) at the three sites closest to NACE reported as SO_4 deposition.

Sources of expertise

- Holly Salazer, NPS Air Resources Division Coordinator for the Northeast Region
- Air Resources Division, National Park Service. http://www.nature.nps.gov/air/
- National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/

4.1.3. Wet nitrogen deposition

Description

During the 1940s and 1950s, it was recognized in the United States and Great Britain that emissions from coal burning and large-scale industry such as power plants and steel mills were causing severely degraded air quality in major cities. This resulted in severe human health impacts and by the early 1970s the U.S. Environmental Protection Agency had established the National Ambient Air Quality Standards (NAAQs) (Porter and Johnson 2007). Since 1970, in addition to human health effects, it was increasingly recognized that there were significant ecosystem impacts of atmospheric nitrogen deposition, including acidification and nutrient fertilization of waters and soils (Sullivan et al. 2011a). These impacts included such measurable effects as the disruption of nutrient cycling, changes to vegetation structure, loss of stream biodiversity, and the eutrophication of streams and coastal waters (Driscoll et al. 2001; Porter and Johnson 2007). Wet nitrogen deposition is significant in the eastern parts of the United States (Figure 4-5).

Data and Methods

The reference condition for total nitrogen wet deposition is ecological. Natural background total nitrogen deposition in the eastern U.S. is 0.5 kg/ha/yr, which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007; NPS ARD 2011). Some sensitive ecosystems, such as coastal and estuarine waters and upland areas, show responses to wet nitrogen deposition rates of 1.5 kg/ha/yr, while there is no evidence of ecosystem harm at deposition rates less than 1 kg/ha/yr (Fenn et al. 2003).

NPS ARD has established wet nitrogen deposition guidelines as < 1 kg/ha/yr indicating good condition (or 100% attainment of reference condition) and > 3 kg/ha/yr indicating significant concern (or 0% attainment). Concentrations of 1-3 kg/ha/yr were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Table 4-7). For the current assessment, the reported wet deposition value was assessed against these guidelines.

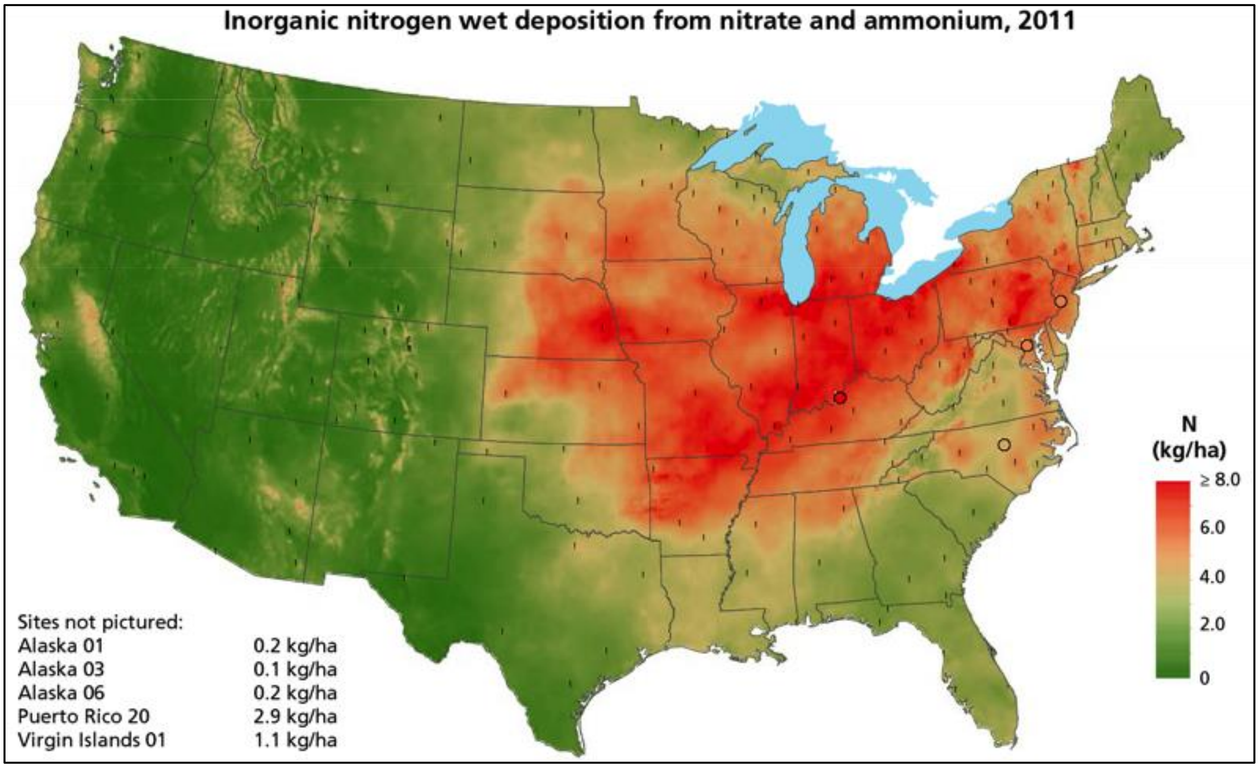

Figure 4-5 Total wet deposition of nitrate (NO_3-) and ammonium (NH_4+) (kg/ha) for the continental United States in 2011 (NADP/NTN).

Table 4-7 Wet nitrogen deposition categories, percent attainment, and condition assessment.

Wet nitrogen deposition (kg/ha/yr)	% Attainment	Condition
< 1	100%	Good
1-3	0-100% (scaled)	Moderate
> 3	0%	Significant concern

The wet nitrogen deposition data used for this assessment of current condition were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2014b). These estimates were calculated on a national scale between 2008 and 2012 using an interpolation model based on monitoring data.

The values for individual parks within NACE were taken from the interpolation at the park centroid, which is the location near the center of the park and within the park boundary. Six sites within NACE are evaluated for wet nitrogen deposition: Carter G. Woodson Home NHS (DC), Fort Washington Park (MD), Frederick Douglass NHS (DC), Greenbelt Park (MD), Mary McLeod Bethune Council House NHS (DC) and Piscataway Park (MD). To determine the overall condition for NACE, the median value of these six sites was used to compare against the reference conditions for wet nitrogen deposition (Figure 4-1).

To assess trends, National Atmospheric Deposition Program (NADP) data from the three monitoring sites closest to NACE were used. These included sites VA00 (Charlottesville) in Virginia, and sites MD99 (Beltsville), and MD07 (Catoctin) in Maryland (Figure 4-1).

Condition and trend

Interpolated wet nitrogen deposition between 2008 and 2012 for NACE was 4.15 kg/ha/yr which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2012) (Figure 4-6).

Table 4-8 Wet nitrogen deposition values from sites within NACE. The values for individual parks were taken from the interpolation at the park centroid. The median of these values was used to compare against the reference condition for wet nitrogen deposition.

Park Name	Total-N (kg/ha/yr)
Carter G. Woodson Home NHS	4.2
Fort Washington Park	3.9
Frederick Douglass NHS	4.1
Greenbelt Park	4.2
Mary McLeod Bethune Council House NHS	4.2
Piscataway Park	3.9

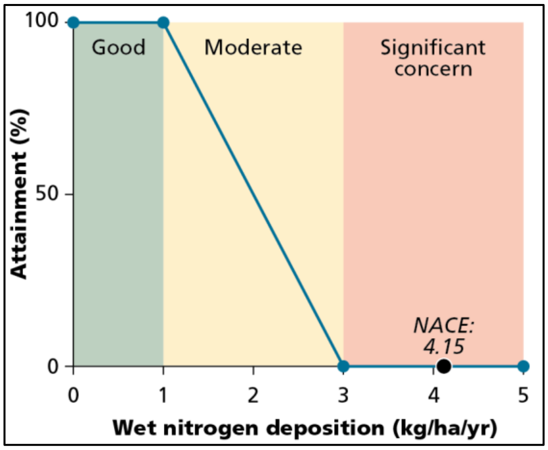

Figure 4-6 Application of the percent attainment categories to the wet nitrogen deposition value categories. Wet nitrogen deposition at NACE was 4.15 kg/ha/yr, which equated to 0% attainment of the reference condition.

When deposition data were analyzed from the three locations closest to the park, there was no significant trend in nitrogen deposition at any of the sites (p-value < 0.01) (Figure 4-7).

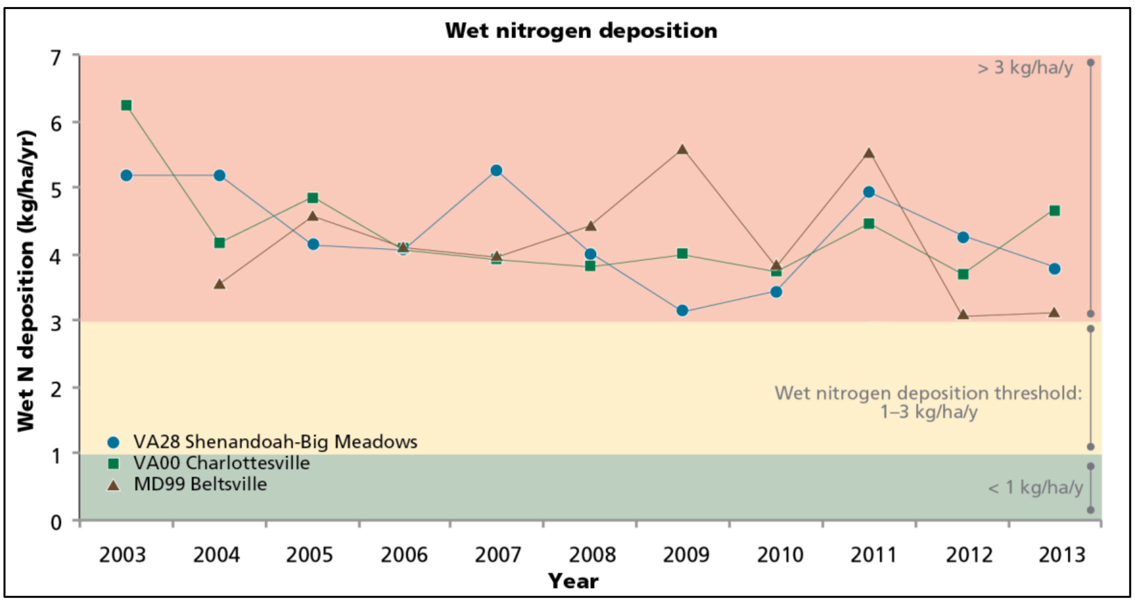

Figure 4-7 Annual wet deposition of total nitrogen (kg/ha/yr) at the three sites closest to NACE.

Sources of expertise

- Air Resources Division, National Park Service. http://www.nature.nps.gov/air/
- National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/

4.1.4 Ozone

Description

Ozone is a secondary atmospheric pollutant, meaning it is not directly emitted but rather is formed by a sunlight-driven chemical reaction on nitrogen oxides and volatile organic compounds emitted largely from burning fossil fuels (Haagen-Smit and Fox 1956). In humans, ozone can cause a number of health-related issues such as lung inflammation and reduced lung function, which can result in hospitalization. Although adverse health effects can occur in very sensitive groups at levels below 60 ppb, the U.S. EPA's 2007 review of the standard concluded that levels between 60 and 70 ppb would likely be protective of most of the population (U.S. EPA 2007). In 2010, the U.S. EPA proposed strengthening the primary standard to a value in the range of 60-70 ppb to protect human health, and establishing a separate secondary standard to protect vegetation based on an ecologically relevant metric, the W126. After receiving public comment on their proposals, EPA deferred setting new standards. Some plant species are more sensitive to ozone than humans. These sensitive plants can develop foliar injury from elevated ozone exposure levels especially when soil moisture levels are moderate to high. Under these conditions, plants have their stomata open, allowing gas exchange for photosynthesis, but also allowing ozone to enter.

Data and methods

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004). The current National Ambient Air Quality Standards (NAAQS) standard is 75 ppb, based on the three-year average annual fourth-highest daily maximum eight-hour ozone concentration at a monitor (NAAQS 2008). Both the three-year average annual fourth-highest daily maximum eight-hour concentration (averaged over five years) and the plant exposure metric, the W126, are incorporated into the benchmarks to assess ozone condition within National Park units by the National Park Service Air Resources Division (NPS ARD 2011).

The ozone concentration data used for the assessment of current condition were taken from the NPS ARD Air Quality Estimates (NPS ARD 2014a) (Table 4-1). These estimates were calculated on a national scale between 2008 and 2012 using an interpolation model based on monitoring data.

The values for individual parks within NACE were taken from the interpolation at the park centroid, which is the location near the center of the park and within the park boundary. Six sites within NACE are evaluated for ozone concentration: Carter G. Woodson Home NHS (DC), Fort Washington Park (MD), Frederick Douglass NHS (DC), Greenbelt Park (MD), Mary McLeod Bethune Council House NHS (DC), and Piscataway Park (MD). To determine the overall condition for NACE, the median value of these six sites was used to compare against the reference conditions for ozone concentration (Figure 4-1).

NPS ARD has established ozone concentration (three-year average fourth-highest daily maximum eight-hour ozone concentration, averaged over five years) guidelines as ≤ 60.0 ppb (set as 80% of the current standard of 75 ppb indicating good condition) and > 75 ppb indicating significant concern (or 0% attainment) (U.S. EPA 2007; NPS ARD 2011). Concentrations of 60.1-75.0 ppb were considered moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points. For the current assessment, the reported ozone value was assessed against these guidelines (Table 4-9).

Table 4-9 Ozone deposition categories, percent attainment, and condition assessment.

Ozone (ppb)	Ozone (W126)	% Attainment	Condition
≤ 60	< 7	100%	Good
61-75	7-13	0-100% (scaled)	Moderate
≥ 76	> 13	0%	Significant concern

NPS ARD also looks at the W126 standard to assess the risk for ozone-induced foliar damage to sensitive plants. W126 provides an index of the cumulative ozone exposure to plants during daylight hours. The W126 weights higher ozone concentration more heavily because they are more likely to cause plant injury. Values less than 7 parts per million-hour (ppm-hrs) are considered safe for sensitive plants (or 100% attainment of reference condition) and > 13 ppm-hrs is considered a significant concern for very sensitive plant species (or 0% attainment). Values of 7-13 ppm-hrs represent a moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (NPS ARD 2010, 2011).

<u>Condition and trend</u>
Interpolated fourth-highest daily maximum eight-hour ozone concentration between 2006 and 2010 for NACE was 77.45 ppb, which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2012) (Figure 4-8). NACE is located in an EPA designated 8-hour ozone nonattainment county, and therefore, the overall air quality condition is automatically placed in the Warrants Significant Concern category (NPS 2013).

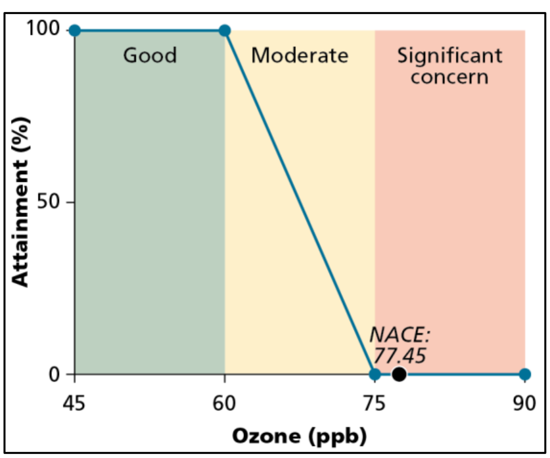

Figure 4-8 Application of the percent attainment categories to the ozone (ppb) value categories. Ozone at NACE was 77.45 ppb, which equated to 0% attainment of the reference condition.

Interpolated W126 value between 2006 and 2010 for NACE was 14.2 ppm-hrs, which resulted in 0% attainment of reference condition, or a condition of significant concern (Figure 4-9, Table 4-4).

Table 4-10 Ozone values from sites within NACE. The values for individual parks were taken from the interpolation at the park centroid. The median of these values was used to compare against the reference condition for ozone.

Park Name	ppb	W126 ppm-hrs
Carter G. Woodson Home NHS	77.5	14.3
Fort Washington Park	77.4	13.9
Frederick Douglas NHS	77.4	14.1
Greenbelt Park	78.1	14.7
Mary McLeod Bethune Council House NHS	77.5	14.3
Piscataway Park	77.4	13.9

Although the trends for all units in NACE were not individually assessed, a country-wide assessment of ozone trends within 159 park units found that in the eastern U.S., ozone trends are generally improving over the past 10 years, largely influenced by the implementation of the NOx State Implementation Plan (SIP) Call rule (EPA 2010; NPS ARD 2010) (Figure 4-10).

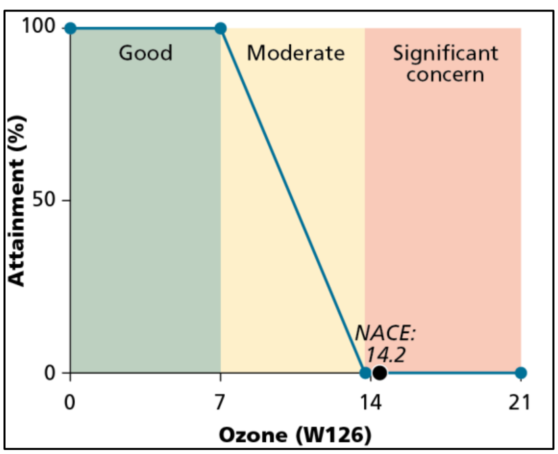

Figure 4-9 Application of the percent attainment categories to the ozone (W126) value categories. W126 at NACE was 14.2, which equated to 0% attainment of the reference condition.

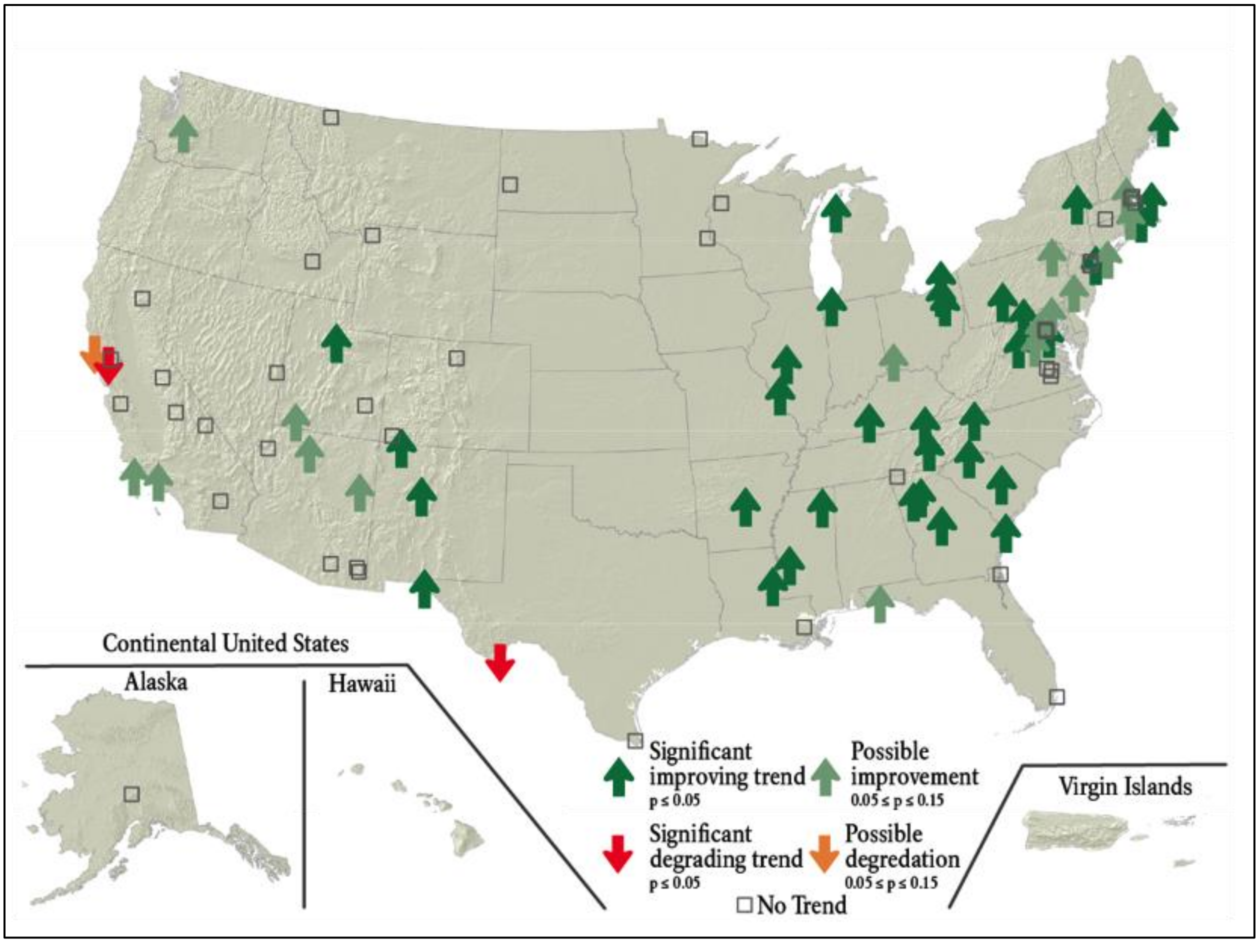

Figure 4-10 Trends in annual fourth-highest eight-hour ozone concentration (ppb/yr), 2000-2009 (NPS ARD).

<u>Sources of expertise</u>

- Drew Bingham, Geographer, NPS Air Resources Division.
- Ellen Porter, NPS Air Resources Division.
- Holly Salazer, NPS Air Resources Coordinator for the Northeast Region.
- Air Resources Division, National Park Service. http://www.nature.nps.gov/air/
- National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/

4.1.5. Visibility

<u>Description</u>

The presence of sulfates, organic matter, soot, nitrates, and soil dust can impair visibility. In the eastern U.S., the major cause of reduced visibility is sulfate particles formed from SO_2 emitted from coal combustion (National Research Council 1993). The Clean Air Act includes visibility as one of its national goals as an indicator of emissions (U.S. EPA 2004).

The NPS has adopted the Clean Air Act "Class I" visibility goal for all parks, including those in the National Capital Region. The aim is to remedy existing and prevent future visibility impairment. The The NPS ARD currently uses visibility and particulate monitoring data to assess seasonal and annual status and trends of visibility, and measure the types and amounts of fine particles that cause visibility impairment (Nortrup 2014).

Data and Methods

Air pollution causes haze and reduces visibility. Visibility is measured using the Haze Index in deciviews (dv). As the Haze Index increases, visibility worsens. Conditions for visibility are based on five-year average visibility minus estimated average natural visibility, where average visibility is the mean of visibility between 40th and 60th percentiles (U.S. EPA 2003; NPS ARD 2012). Interpolated 5-year averages are used within the contiguous U.S. The visibility condition is expressed as:

Visibility condition = average current visibility – estimated average natural visibility

Natural visibility conditions represent the long-term degree of visibility that is estimated to exist in a given mandatory federal Class I area in the absence of human-caused impairment. Natural visibility conditions are calculated on the average or best visibility (20% least haziest) days monitored over several years.

The reference condition for visibility is based on the national goal of restoring natural visibility. The Regional Haze Rule requires remedying existing and preventing any future visibility impairment in the nation's largest parks and wilderness areas, known as the 'Class I' areas (NPS ARD 2010). NPS has adopted this goal for all parks, including NACE and all others designated as Class II under the Clean Air Act.

The Haze Index data used for the assessment of current condition at NACE were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2014b). These estimates were calculated on a national scale between 2008 and 2012 using an interpolation model based on monitoring data.

The values for individual parks within NACE were taken from the interpolation at the park centroid, which is the location near the center of the park and within the park boundary. Six sites within NACE are evaluated for visibility: Carter G. Woodson Home NHS (DC), Fort Washington Park (MD), Frederick Douglass NHS (DC), Greenbelt Park (MD), Mary McLeod Bethune Council House NHS (DC), and Piscataway Park (MD). To determine the overall condition for NACE, the median value of these six sites was used to compare against the reference conditions for visibility (Figure 4-1).

NPS ARD has established visibility guidelines as ≤ 2 dv above natural conditions indicating good condition (or 100% attainment of reference condition) and ≥ 8 dv above natural conditions indicating significant concern (or 0% attainment). Concentrations of 2-8 dv above natural conditions were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points. For this assessment, the reported visibility value was assessed against these guidelines (NPS ARD 2012) (Table 4-11).

This analysis meant that there was only one value reported for the Haze Index for NACE, so this value was assessed against the three reference condition ranges described above.

Table 4-11 Visibility categories, percent attainment, and condition assessment.

Visibility (dv)	% Attainment	Visibility condition
< 2	100%	Good
2 – 8	0-100% (scaled)	Moderate
> 8	0%	Significant concern

Condition and trend

Interpolated Haze Index between 2008 and 2012 for NACE was 11.3 dv, which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2012) (Figure 4-11).

Table 4-12 Visibility values from sites within NACE. The values for individual parks were taken from the interpolation at the park centroid. The median of these values was used to compare against the reference condition for visibility.

Park Name	DV (group 50 visibility – natural conditions)
Carter G. Woodson Home NHS	11.3
Fort Washington Park	11.2
Frederick Douglass NHS	11.3
Greenbelt Park	11.3
Mary McLeod Bethune Council House NHS	11.3
Piscataway Park	11.2

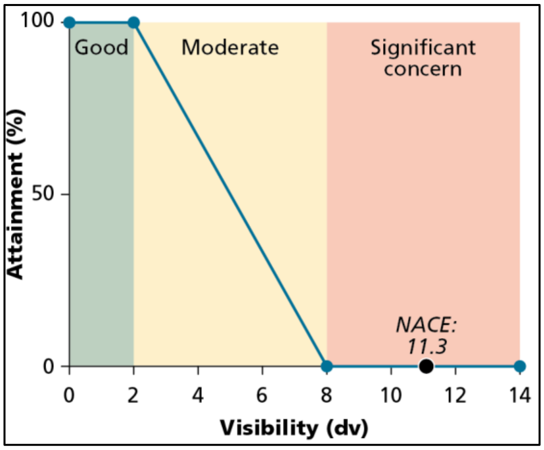

Figure 4-11 Application of the percent attainment categories to the visibility value categories. Visibility at NACE was 11.3 dv, which resulted in 0% attainment of the reference condition.

Based on a countrywide assessment of visibility trends between 1999 and 2008 within 157 parks, general trends in the region are improving (NPS ARD 2010) (Table 4-9).

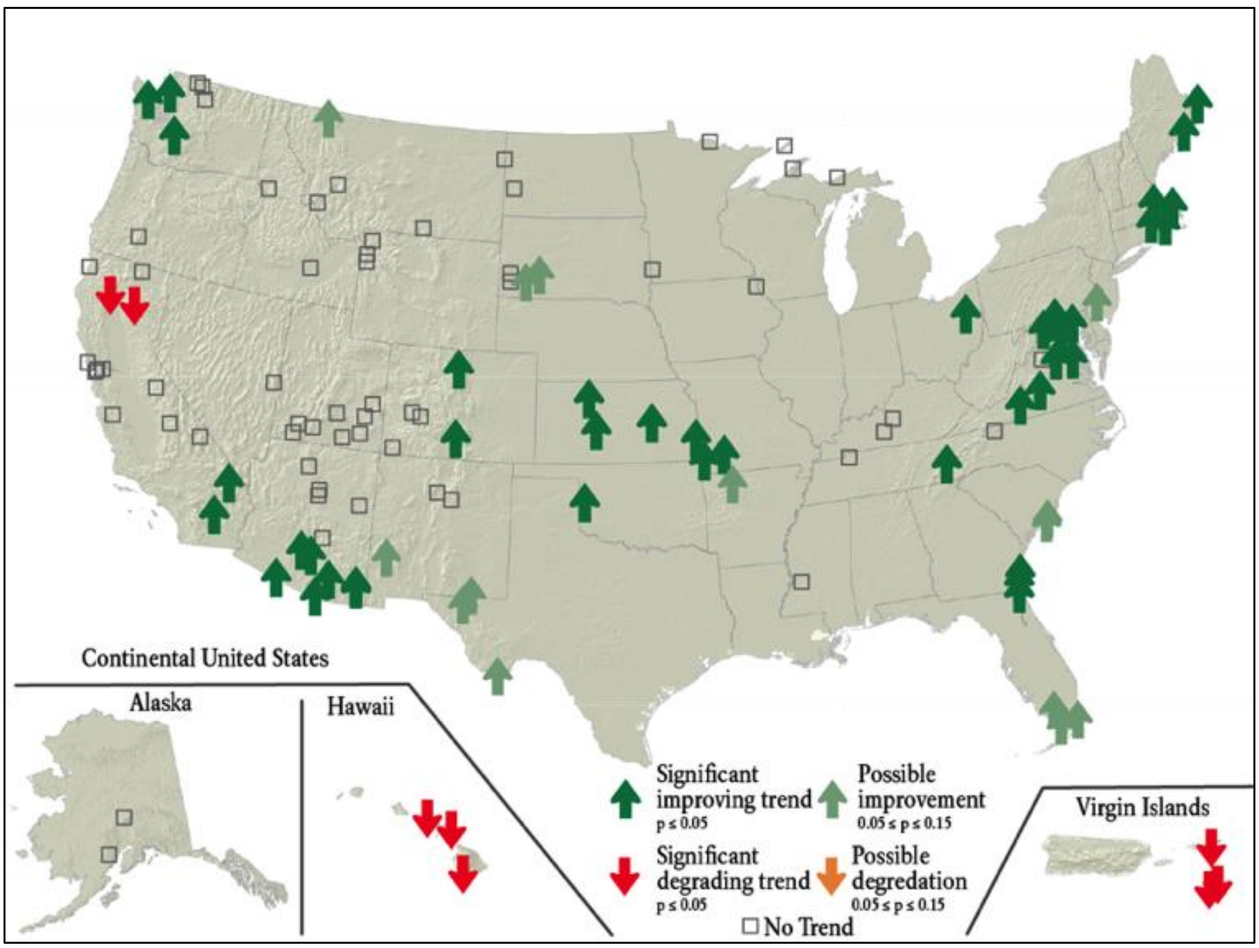

Figure 4-12 Visibility trends measured by the Haze Index (deciview) on haziest days, 2000-2009 (NPS ARD).

Sources of expertise

- Air Resources Division, National Park Service. http://www.nature.nps.gov/air/
- National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/

4.1.6. Particulate matter

Description

Fine particles less than 2.5µm diameter (PM 2.5) are emitted as smoke from power plants, gasoline and diesel engines, wood combustion, steel mills, and forest fires. Fine particles are also created when emissions of sulfur dioxide and nitrogen dioxide transform in the atmosphere to sulfate and nitrate particles. Ground-level particulate matter is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for airborne particulates (U.S. EPA 2004). In the period between 2001 and 2010, national annual and 24-hour PM2.5 concentrations have decreased by 24 and 28 percent respectively (U.S. EPA 2012).

Data and methods

Data was obtained from the Interagency Monitoring of Protected Visual Environments (IMPROVE) database through the U.S. EPA AirData interface for the three sampling locations closest to NACE. These included sites 240330030 (Beltsville, MD), 110010041 (River Terrace, DC) and 510590030 (Lee District Park, VA) (Figure 4-1, Table 4-1).

Data were 24-hour averages; three-year averages of the annual mean concentrations were calculated. The median of all these values was taken and assessed against the three reference condition ranges described in Table 4-2.

The current National Ambient Air Quality Standards (NAAQS) particulate matter regulatory threshold is a concentration of 35µg/m^3 (NAAQS 2008). The annual standard for PM 2.5 is met (air condition is considered acceptable) when the three-year average of the annual mean concentration ≤ 15.0 µg/m^3 (NAAQS 2008; U.S. EPA 2012). The annual standard (≤ 15.0 µg/m^3) was used as the reference condition in the current assessment (Table 4-2, Table 4-3).

Good condition (or 100% attainment) for particulate matter presents 80% or less (or ≤ 12.0 µg/m3) of the current standard. Values > 15 µg/m^3 indicated significant concern (or 0% attainment). Values of 12.1-15.0 µg/m^3 indicated moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Table 4-13).

Table 4-13 Particulate matter categories, percent attainment, and condition assessment.

Particulate matter (µg/m^3)	% Attainment	Condition
≤ 12	100%	Good
12.1-15	0-100% (scaled)	Moderate
> 15	0%	Significant concern

Condition and trend

The three sites closest to NACE had a median of 10.3 µg/m3 between 2003 and 2013, with 100% attainment of the reference condition, or good. Despite having 100% attainment of the reference condition, within the last ten years, there were years at each of the three sites when the annual median PM2.5 was above the reference condition of 12.0 µg/m^3.

Over the data range available, there is a decreasing trend in PM2.5 at one site, Lee District Park, VA (510590030). This site showed a significant improving trend of particulate matter over the past decade (p value < 0.01) (Table 4-14). There was no trend present at River Terrace or Beltsville over the ten-year period (p value < 0.01).

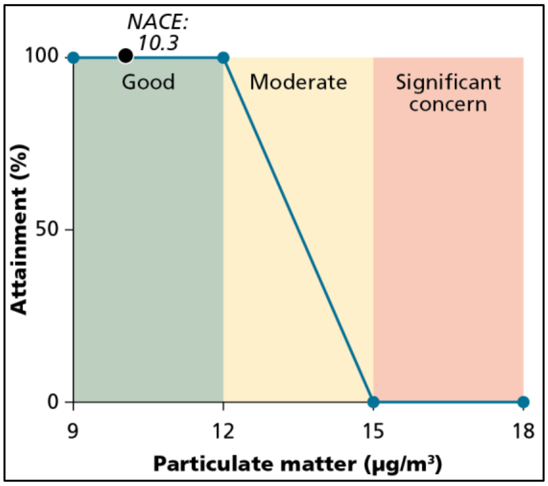

Figure 4-13 Application of the percent attainment categories to the particulate matter value categories. Particulate matter at NACE was 10.3 µg/m^3 which resulted in 100% attainment of the reference condition.

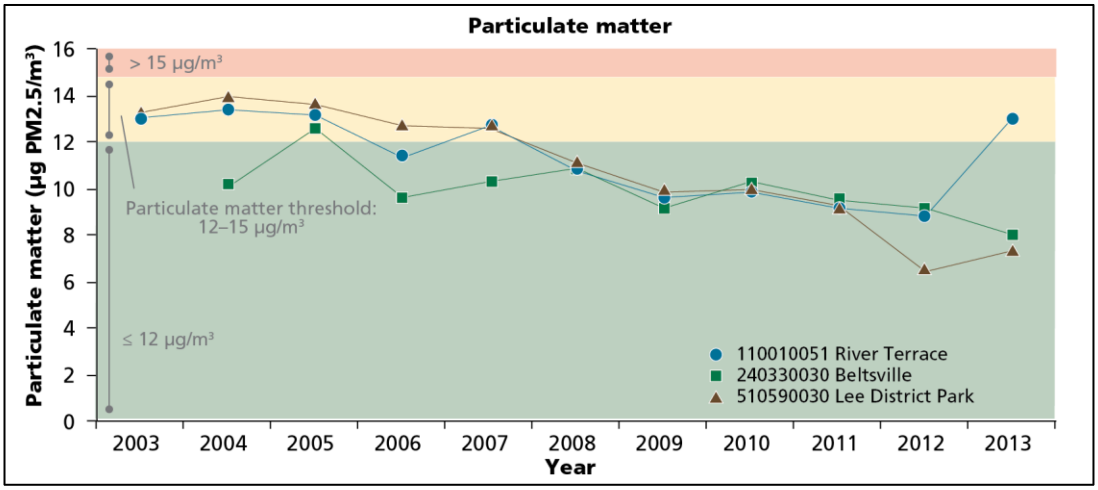

Figure 4-14 Particulate matter (µg/m^3) at the two sites closest to NACE. Reference conditions are shown in gray. Data show the annual mean concentrations.

Sources of expertise

- Interagency Monitoring of Protected Visual Environments (IMPROVE). http://vista.cira.colostate.edu/improve/
- U.S. EPA PM Standards. http://www.epa.gov/airquality/particlepollution/

4.1.7. Mercury deposition

Description

Atmospheric mercury (Hg) comes from natural sources, including volcanic and geothermal activity, geological weathering, and anthropogenic sources such as burning of fossil fuels, processing of mineral ores, and incineration of certain waste products (UNEP 2008). At a global scale, annual anthropogenic emissions of Hg approximately equal all natural marine and terrestrial emissions, with anthropogenic emissions in North America being 153 metric tons in 2005 (UNEP 2008). Exposure of humans and other mammals to Hg in utero can result in developmental disabilities, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and exposure as adults can lead to motor dysfunction and other neurological and mental impacts (U.S. EPA 2001). Avian species' reproductive potential is negatively impacted by mercury. Measured trends in Hg deposition, from west to east across North America, can also be measured in the common loon (*Gavia immer*), and throughout North America in mosquitos (Evers et al. 1998; Hammerschmidt and Fitzgerald 2006). Mercury is also recorded to have a toxic effect on soil microflora, although no ecological depositional threshold is currently established (Meili et al. 2003).

Data and methods

Data was obtained from the National Atmospheric Deposition Program, Mercury Deposition Network (NADP-MDN) for three sites, MD99 (Beltsville, MD), MD00 (Smithsonian Environmental Research Center) and VA28 (Shenandoah-Big Meadows) (Figure 4-1). Samples are collected weekly and within 24 hours of a precipitation event and analyzed for Hg concentration, measured in nanograms per liter (ng/L) of Hg. Annual mean Hg concentrations were calculated for each sampling site.

There are no published thresholds for wet deposition of Hg, so this metric was not included in the overall assessment of NACE, but was included for informational purposes only.

Condition and trend

The median annual mercury concentrations in precipitation from three sites in the region of NACE over the past decade is 7.64 ng/L (Figure 4-15). The Mid-Atlantic region in general has relatively moderate levels of Hg deposition compared to the rest of the U.S. (Figure 4-16). If it is assumed that precipitation constitutes all of the flow in streams in the park, then it can be assumed that mercury concentrations would be comparable to that range observed in precipitation. The U.S. EPA does provide a Hg-related National Recommended Water Quality Criteria for the protection of aquatic life. Criteria for total dissolved Hg are 1400 ng/L (acute criteria) and 770 ng/L (chronic criteria) (U.S. EPA 2012). These criteria values are 1-2 orders of magnitude greater than what has been recorded in rainfall in the region, suggesting a low risk to aquatic life. However, because stream mercury concentration data within the region is not available, Hg has not been included in the overall assessment.

Over the data range available, no significant trend was present (p-value >0.01) (Figure 4-15).

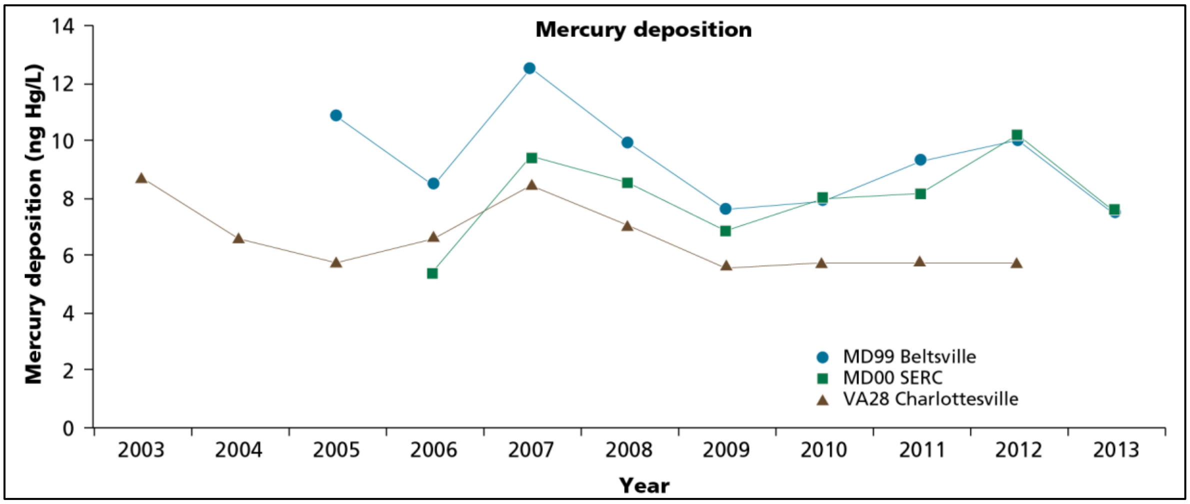

Figure 4-15 Median annual mercury concentrations (ng/L) in precipitation from three sites in the region of NACE.

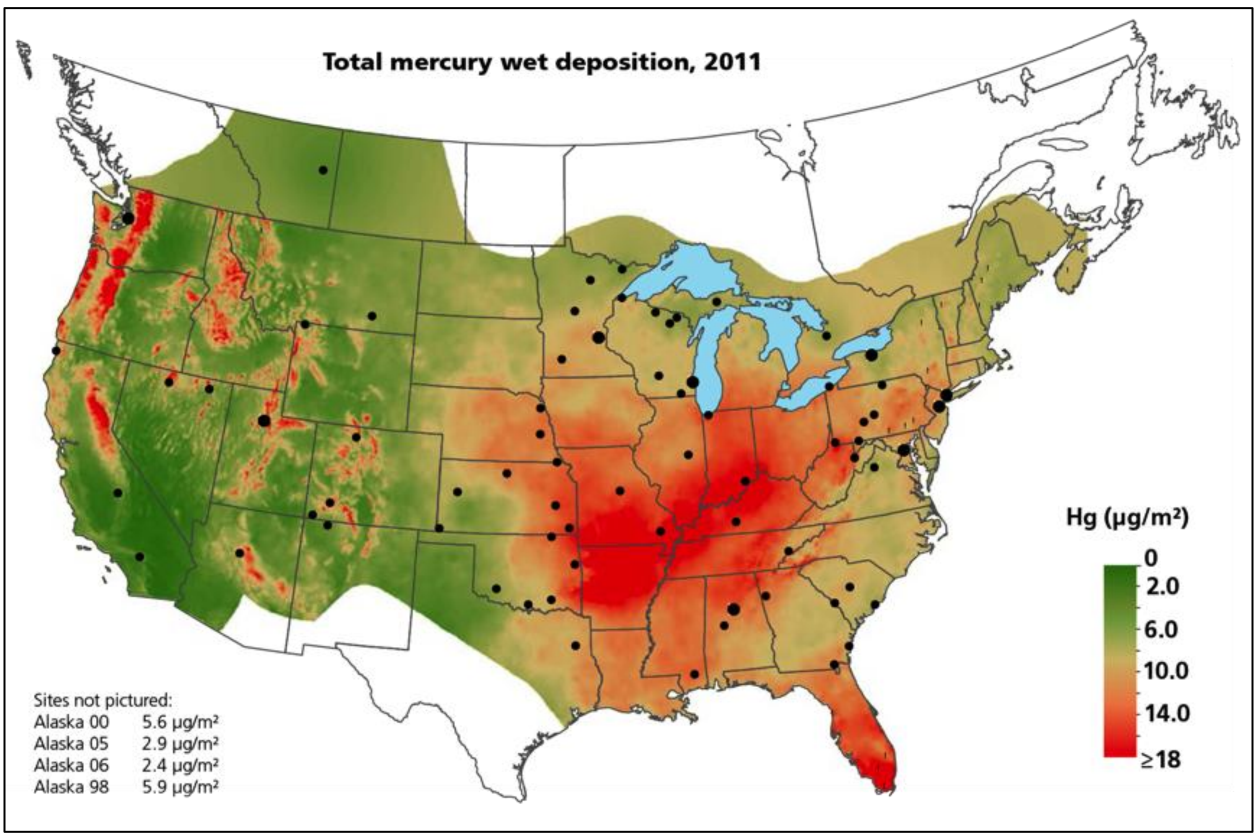

Figure 4-16 Total mercury wet deposition across the United States in 2011 (NADP/MDN 2013).

Sources of expertise

- National Atmospheric Deposition Program, Mercury Deposition Network. http://nadp.sws.uiuc.edu/MDN

4.2. Water resources

4.2.1. Water resources summary

Nine metrics were used to assess water resources in NACE: pH, dissolved oxygen (DO), water temperature, acid neutralizing capacity (ANC), specific conductance, total nitrate, total phosphorus, benthic index of biotic integrity (BIBI), and stream physical habitat index (PHI) (Table 4-14). Data were collected by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff and collaborators. Water quality and BIBI and PHI monitoring sites are shown in Figure 4-17. Within NACE, there are four water monitoring sites used for the water quality analysis. These sites include Accokeek Creek (Piscataway Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove Park), and Still Creek (Greenbelt Park). One additional site, Fort Dupont, was sampled in 2006 and 2007 but not included in the analysis (Fort Circle Parks-Fort Dupont).

Reference conditions were established for each of the nine metrics (Table 4-15) and the data were compared to these reference conditions to obtain the percent attainment, which was then converted to the condition assessment for that metric. Overall (median of four sites), National Capital Parks-East scored high on attainment (good to very good) for pH (92.7%), dissolved oxygen (97.3%) water temperature (100%), ANC (100%), and total nitrate (92.6%). BIBI was fair and PHI was partially degraded (57.3% and 25.9% respectively), and specific conductance, and total phosphorus scored as very degraded (3.8% and 8.9% respectively) (Table 4-16).

Table 4-14 Ecological monitoring framework data for Water Resources provided by agencies and specific sources included in the assessment of NACE.

Metric	Agency	Reference/Source
pH	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Dissolved oxygen	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Water temperature	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Acid neutralizing capacity	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Specific conductance	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Total Nitrate	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Total Phosphorus	NCRN I&M	Pieper et al. 2012; Norris et al. 2011
Benthic Index of Biotic Integrity	NCRN I&M, Versar	Norris and Sanders 2009; MBSS
Physical Habitat Index	NCRN I&M, Versar	Norris and Sanders 2009; MBSS

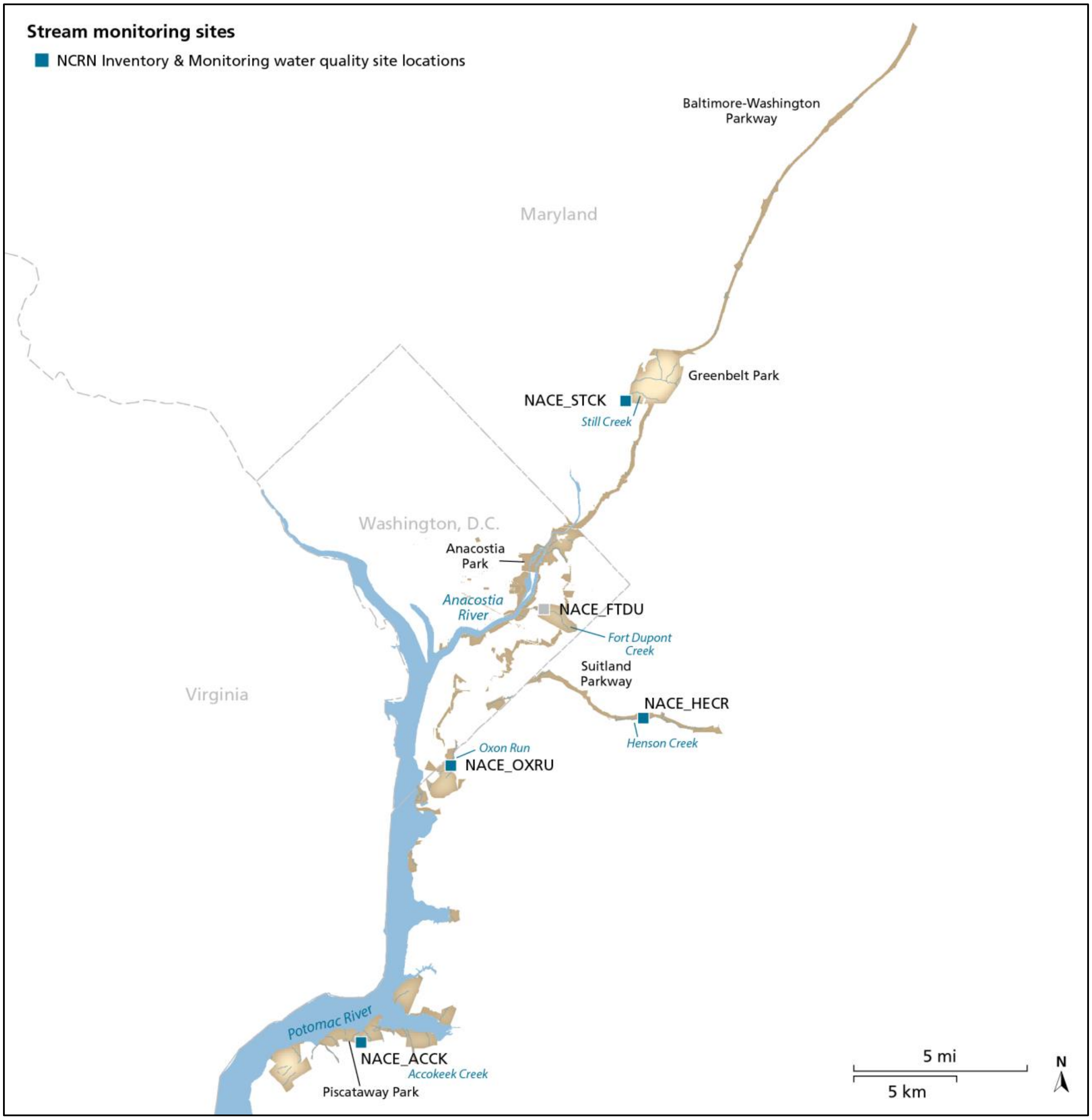

Figure 4-17 Stream sampling locations in NACE used for long-term water quality monitoring (Norris et al. 2007). Site NACE_FTDU was sampled only in 2006 and 2007 and therefore was not included in the analysis.

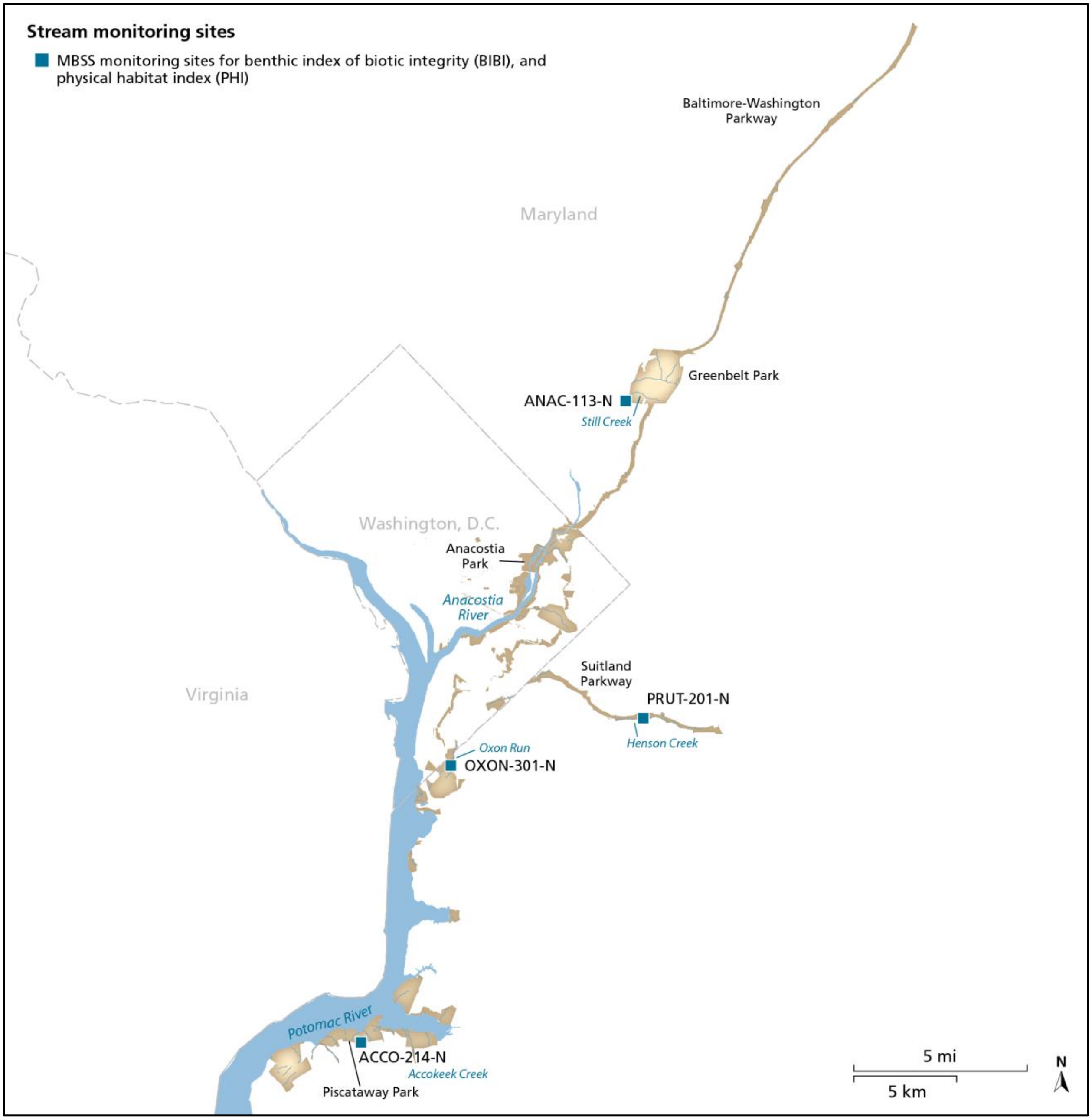

Figure 4-18 Stream sampling locations in NACE used for long-term MBSS water quality monitoring for benthic index of biotic integrity (BIBI) and physical habitat index (PHI).

Table 4-15 Water resource indicators, data availability, reference conditions, and condition assessment categories used in the natural resource condition assessment of National Capital Parks-East.

Water resource indicator	Number of sites	Number of samples	Period of observation	Reference condition	Percent attainment applied
pH	4	287	2005-2013	6.5-8.5 (MD)	0-100% Scaled linearly
Dissolved oxygen (mg/L)	4	292	2005-2013	≥ 5.0	
Water temperature (°C)	4	365	2005-2013	≤ 32	
Acid neutralizing capacity (μeq/L)	4	290	2005-2013	≥ 200	
Specific conductance (μS/cm)	4	292	2005-2013	≤ 171	0-100% Scaled linearly
Nitrate (mg/L)	4	285	2005-2013	≤ 2	
Total phosphorus (mg/L)	4	224	2005-2013	≤ 0.037	
Benthic Index of Biotic Integrity	4	7	2004-2012	1.0-1.9; 2.0-2.9; 3.0-3.9; 4.0-5.0	
Physical Habitat Index	4	7	2004-2012	0-50; 51-65; 66-80; 81-100	

Table 4-16 Summary of resource condition assessment of water resources in NACE.

Metric	NACE result	Percent attainment of reference condition	Condition assessment	Overall water resources condition
pH	7.50	92.7	Very good	64.3% Good
Dissolved oxygen (mg/L)	8.90	97.3	Very good	
Water temperature (°C)	14.80	100.0	Very good	
Acid neutralizing capacity (μeq/L)	1017.00	100.0	Very good	
Specific conductance (μS/cm)	403.70	3.8	Degraded	
Nitrate (mg/L)	1.00	92.6	Very good	
Total phosphorus (mg/L)	0.08	8.9	Very degraded	
Benthic Index of Biotic Integrity	3.29	57.3	Fair	
Physical Habitat Index	51.80	25.9	Partially degraded	

4.2.2. ***Water pH***

Description

The streams in and adjacent to NACE are an important and unique habitat for plants, invertebrates, fish, and amphibians, as well as an important water source for mammals and birds. Deposition of sulfate and nitrogen are a significant regional concern, and freshwater habitats may be impacted by acidification (Sadinski and Dunson 1992; NPS ARD 2010). Aquatic animals are susceptible to extreme pH values and can be limited by food availability even at less extreme acidification by, for example, reduced zooplankton and periphyton communities (Sadinski and Dunson 1992; Barr and Babbitt 2002). Surveys in North Carolina found a decline in amphibian species richness with reduced (more acidic) pH, with some frog and newt species being totally absent in the more acidic ponds (Easton and Fauth 2001). Reduced pH can also result in reduced salamander hatching success, suppression of larval newt survival, and impacts on frog metamorphosis (Sadinski and Dunson 1992).

Data and methods

The data analyzed were collected monthly between 2005 and 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Table 4-14). NCRN followed the sampling protocol specified in Norris et al. 2011.

Measurements were taken monthly as instantaneous records. Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results were used as the percent attainment.

A reference condition pH range of 6.0-8.5 was used for all stream locations, consistent with the Maryland state criteria for this metric (COMAR 2007a, 2007b, 2007c) (Table 4-15). All sites currently monitored by the NCRN I&M network within NACE are located in the state of Maryland.

Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment.

Condition and trend

Condition of pH in NACE was very good, with a median pH of 7.5 and 92.7% of data points attaining the reference condition between 2005 and 2013 (Figure 4-19, Figure 4-20). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4-19).

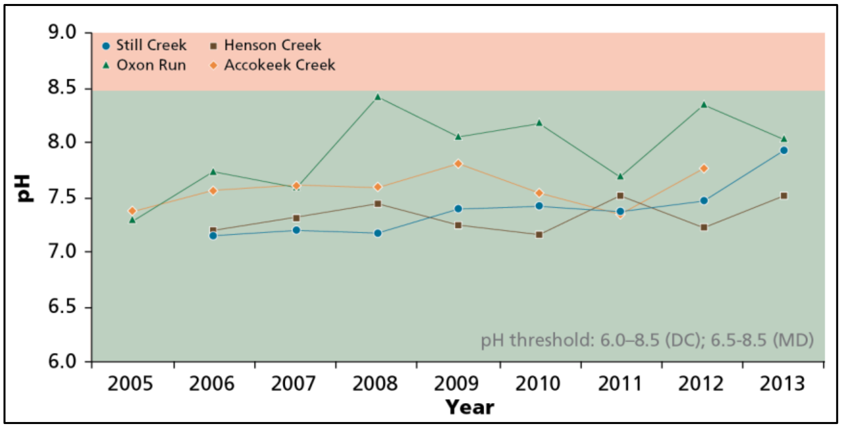

Figure 4-19 Annual median pH values for 2005 to 2013 for each of the four sampling sites in NACE.

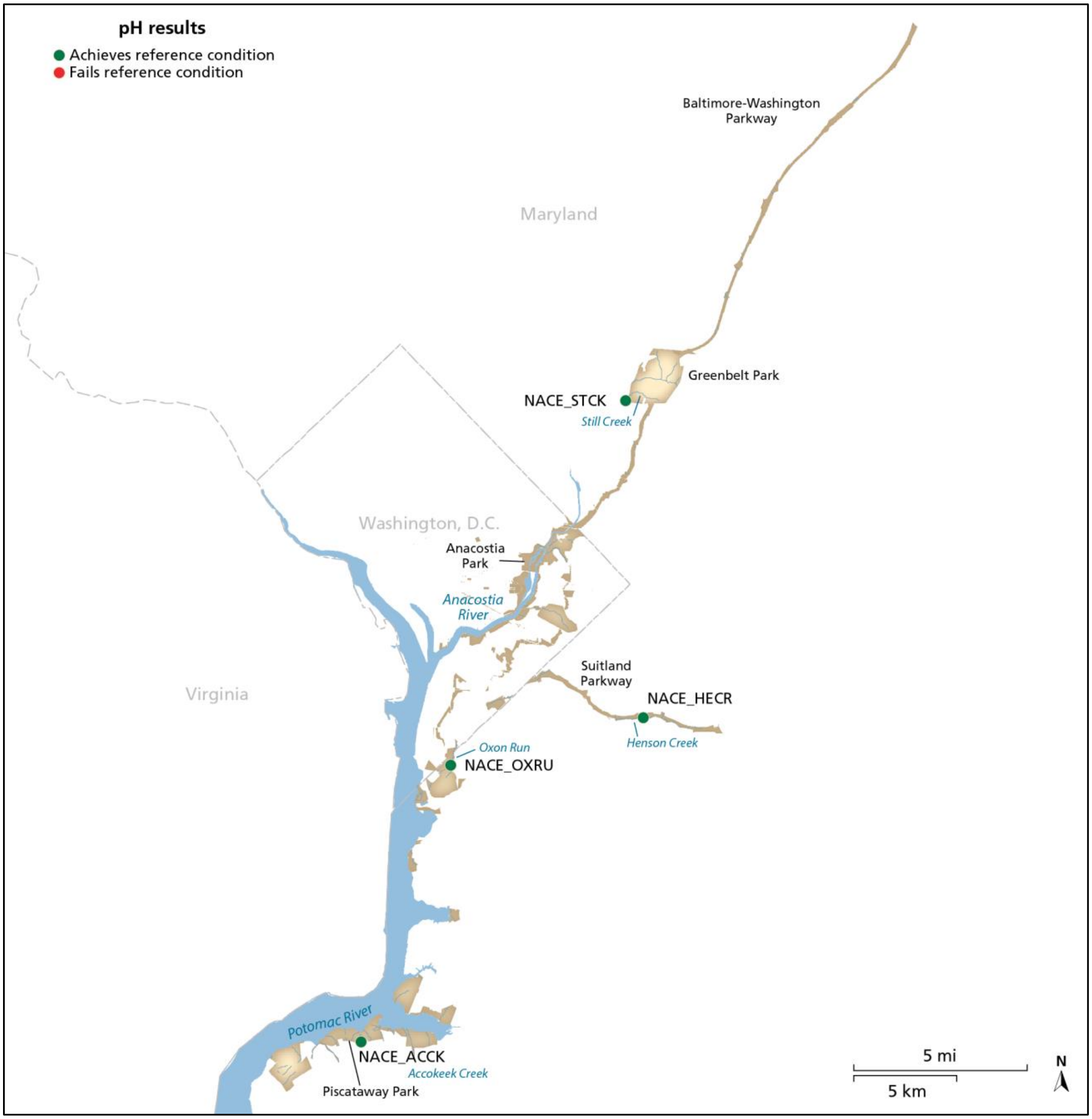

Figure 4-20 Attainment of pH reference condition by site from 2005 to 2013 for four stream sampling locations in NACE. Site medians were used for this analysis.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.3. *Dissolved oxygen*

Description

Dissolved oxygen (DO) concentration in water is often used as an indicator to gauge the overall health of the aquatic environment. It is needed to maintain suitable habitat for the survival and growth of fish and many other aquatic organisms. Low DO is of great concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation and shallow gradients (streams), organic matter inputs, and high respiration rates. Decay of excessive organic debris in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause DO concentrations to be undersaturated or depleted. Insufficient DO can lead to unsuitable conditions for aquatic life and its absence can result in the unpleasant odors associated with anaerobic decomposition. Minimum required DO concentration to support fish varies because the oxygen requirements of fish vary with a number of factors, including the species and age of the fish, prior acclimatization, temperature, and concentration of other substances in the water.

Data and methods

Data was collected monthly between 2005 to 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Figure 4-17, Table 4-14). NCRN followed the sampling protocol specified in Norris et al. 2011.

Measurements were taken monthly as instantaneous records. Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

A reference condition of ≥ 5.0 mg/L DO was used for all stream locations, consistent with the Maryland state criteria for this metric (COMAR 2007a, 2007b, 2007c). All sites currently monitored by the NCRN I&M network within NACE are located in the state of Maryland (Table 4-15).

Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment.

Condition and trend

Condition of dissolved oxygen in NACE was very good, with a median DO of 8.9 mg/L and 97.3% of data points attaining reference conditions between 2005 and 2013 (Figure 4-21, Figure 4-22, Table 4-16). Over the data range available, no significant trend was present (*p*-value >0.01) (Figure 4-21).

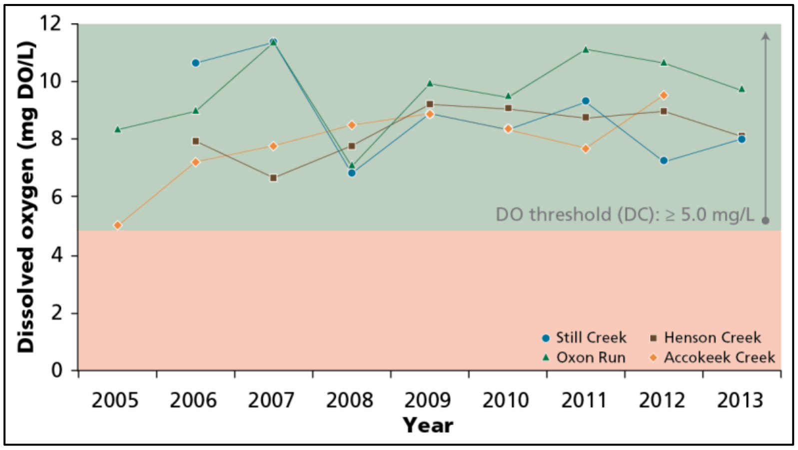

Figure 4-21 Annual median dissolved oxygen concentrations (mg/L) from 2005 to 2013 for each of the four stream sampling locations in NACE.

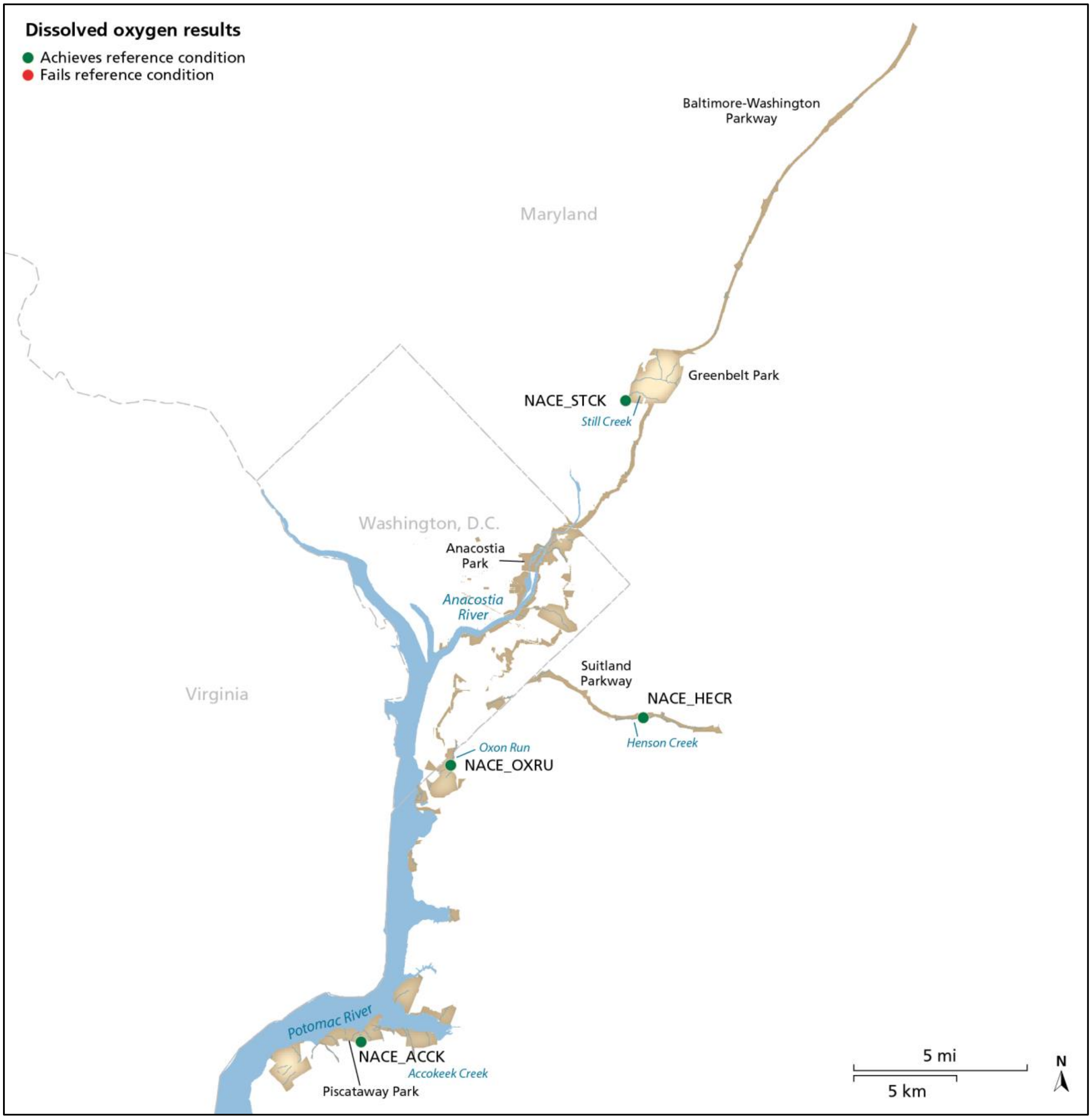

Figure 4-22 Attainment of dissolved oxygen reference condition by site from 2005 to 2013 for four stream sampling locations in NACE. Site medians were used for this analysis.

Sources of expertise

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.4. Water temperature

Description

Aquatic organisms are dependent on certain temperature ranges for optimal health. Temperature affects many other parameters in water, including the amount of dissolved oxygen available, the types of plants and animals present, and the susceptibility of organisms to parasites, pollution, and disease. Causes of temperature changes in the water include weather conditions, shade, and discharges into the water from urban sources or groundwater inflows.

Data and methods

Data was collected monthly between 2005 to 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Figure 4-17, Table 4-14). NCRN followed the sampling protocol specified in Norris et al. 2011.

Measurements were taken monthly as instantaneous records. Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

A reference condition of ≤ 32.2°C temperature was used, which is the reference condition for warm water streams in the state of Maryland. All sites currently monitored by the NCRN I&M network within NACE are located in the state of Maryland and are warm water streams (COMAR 2007a, 2007b, 2007c) (Table 4-15).

Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment.

Condition and trend

Current condition on water temperature in NACE was very good, with a median temperature of 14.7°C and 100% of data points attaining reference condition between 2005 and 2013 (Figure 4-23, Figure 4-24, Table 4-16). When the seasonal median water temperatures were calculated, temperatures were highest in the summer months (median of 24.0°C), and lower in the spring, fall and winter months (13.7°C, 12.4°C, and 5.9°C respectively). Oxon Run, which is sampled just as it enters Oxon Hill Farm had the highest average annual median temperatures from 2005-2013, but all years were well below the threshold of 32°C (Figure 4-24).

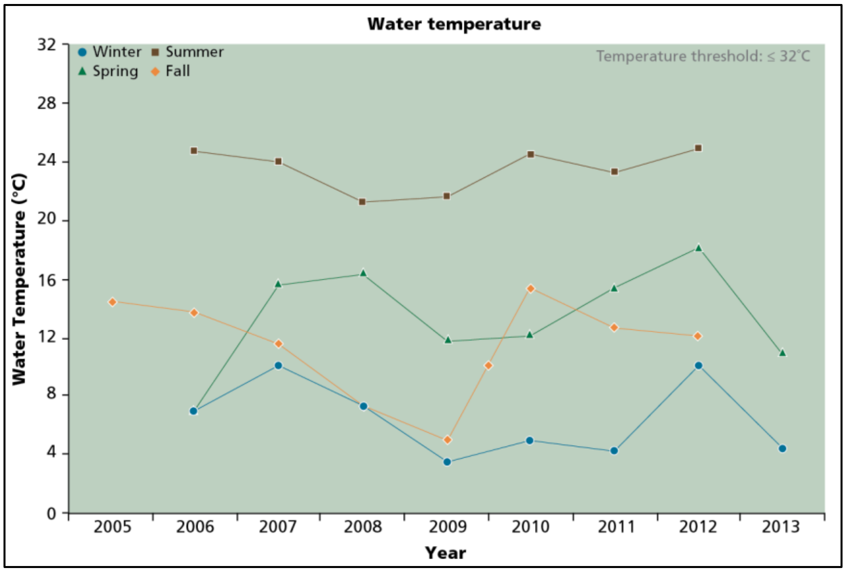

Figure 4-23 Seasonal median water temperature values (°C) from 2005 to 2013 for four stream sampling locations in NACE.

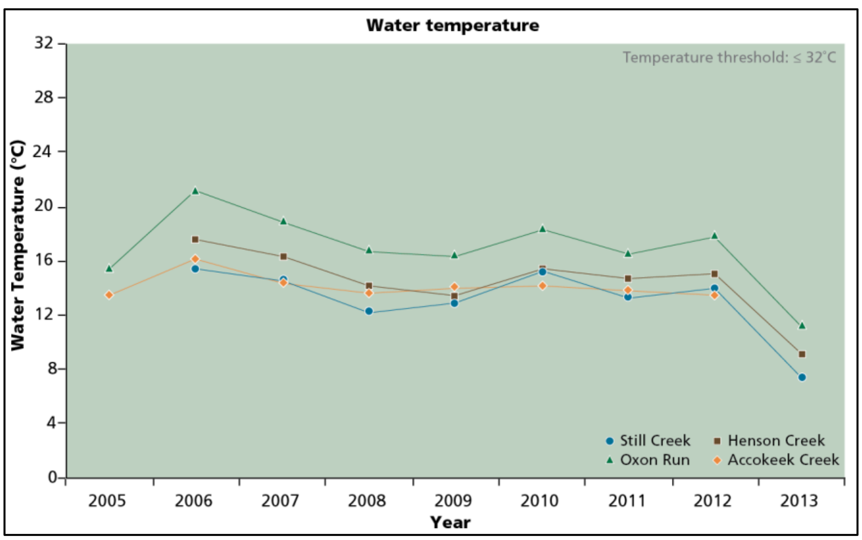

Figure 4-24 Average annual median water temperature values (°C) from 2005 to 2013 for four stream sampling locations in NACE.

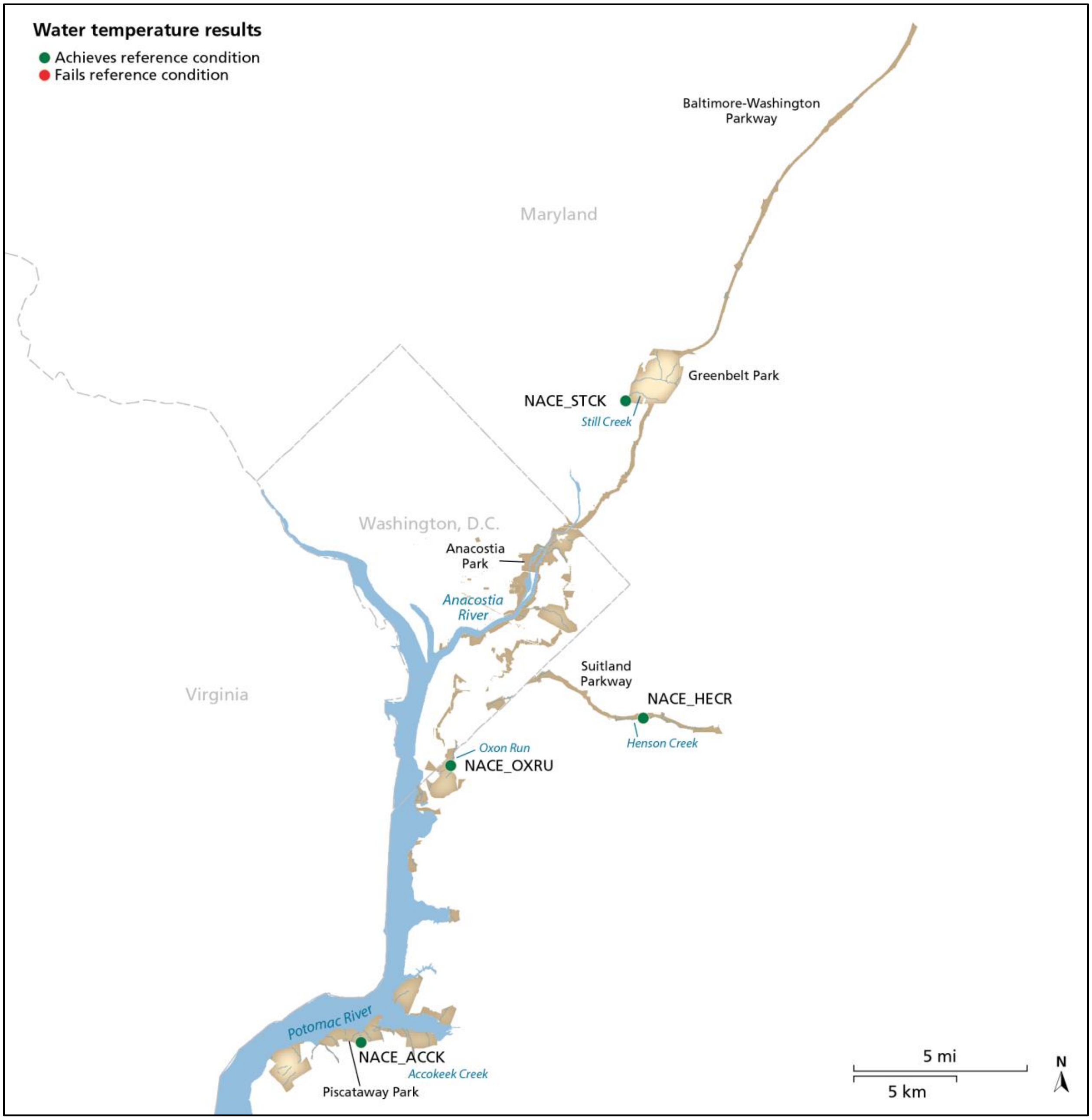

Figure 4-25 Attainment of water temperature reference condition by site from 2005 to 2013 for four stream sampling locations in NACE. Site medians were used for this analysis.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.5. Acid neutralizing capacity

Description

Acid neutralizing capacity (ANC) is the prime indicator of a waterbody's susceptibility to acid inputs. ANC is a measure of the amount of carbonate and other compounds in the water that neutralize low (acidic) pH. Streams with higher ANC levels (better buffering capacity) are affected less by acid rain and other acid inputs than streams with lower ANC values (Welch et al. 1998).

Data and methods

The data analyzed were collected monthly at four sites between 2005 and 2013 by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al.2012) (Figure 4-17, Table 4-15). NCRN followed the sampling protocol specified in Norris et al. 2011.

The acid neutralizing capacity (ANC) threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling (1995–1997). The MBSS data were used to detect stream degradation so as to identify streams in need of restoration and to identify 'impaired waters' candidates (Southerland et al. 2007). A total of 539 streams that received a fish or benthic index of biotic integrity (FIBI or BIBI) rating of poor (2) or very poor (1) were pooled and field observations and site-specific water chemistry data were used to determine stressors likely causing degradation.

The resulting ANC threshold value linked to degraded streams was less than 200 µeq/L, which was used as the threshold in this assessment (Table 4-6) (Southerland et al. 2007; Norris and Sanders 2009) where 1 mg/L [1 ppm] $CaCO_3$ = 20 µeq/L. A less conservative threshold of 50 µeq/L has also been suggested by some authors (Hendricks and Little 2003, Schindler 1988). Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a fail result because the detection limit for ANC is higher than the reference condition.

Condition and trend

Current condition of ANC in NACE was very good, with a median ANC of 1017 µeq/L and 100% of data points attaining reference condition of ≥ 200 µeq/L between 2005 and 2013 (Figure 4-26, Figure 4-27, Table 4-16). Over the data range available, there was no trend in ANC values over the time period evaluated (p-value > 0.01) (Figure 4-26).

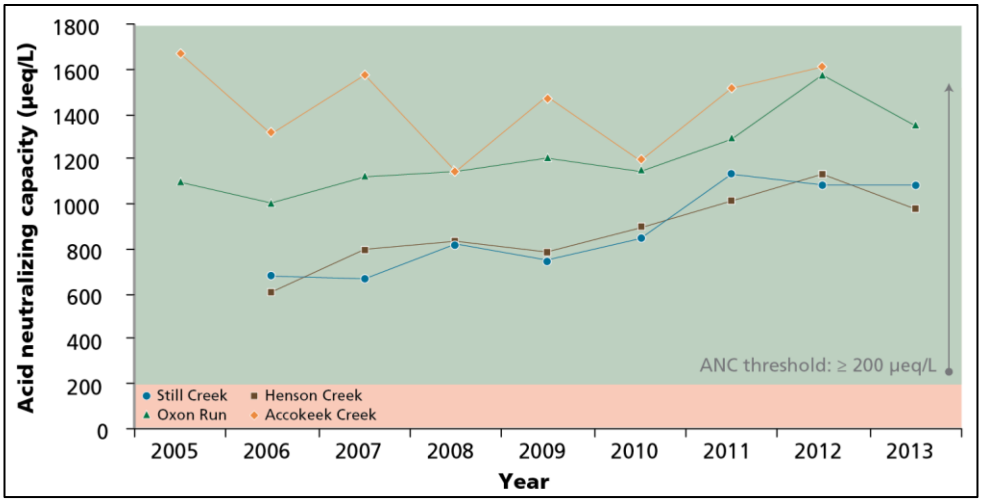

Figure 4-26 Median acid neutralizing capacity values (μeq/L) from 2005 to 2013 for each of the four stream sampling locations in NACE.

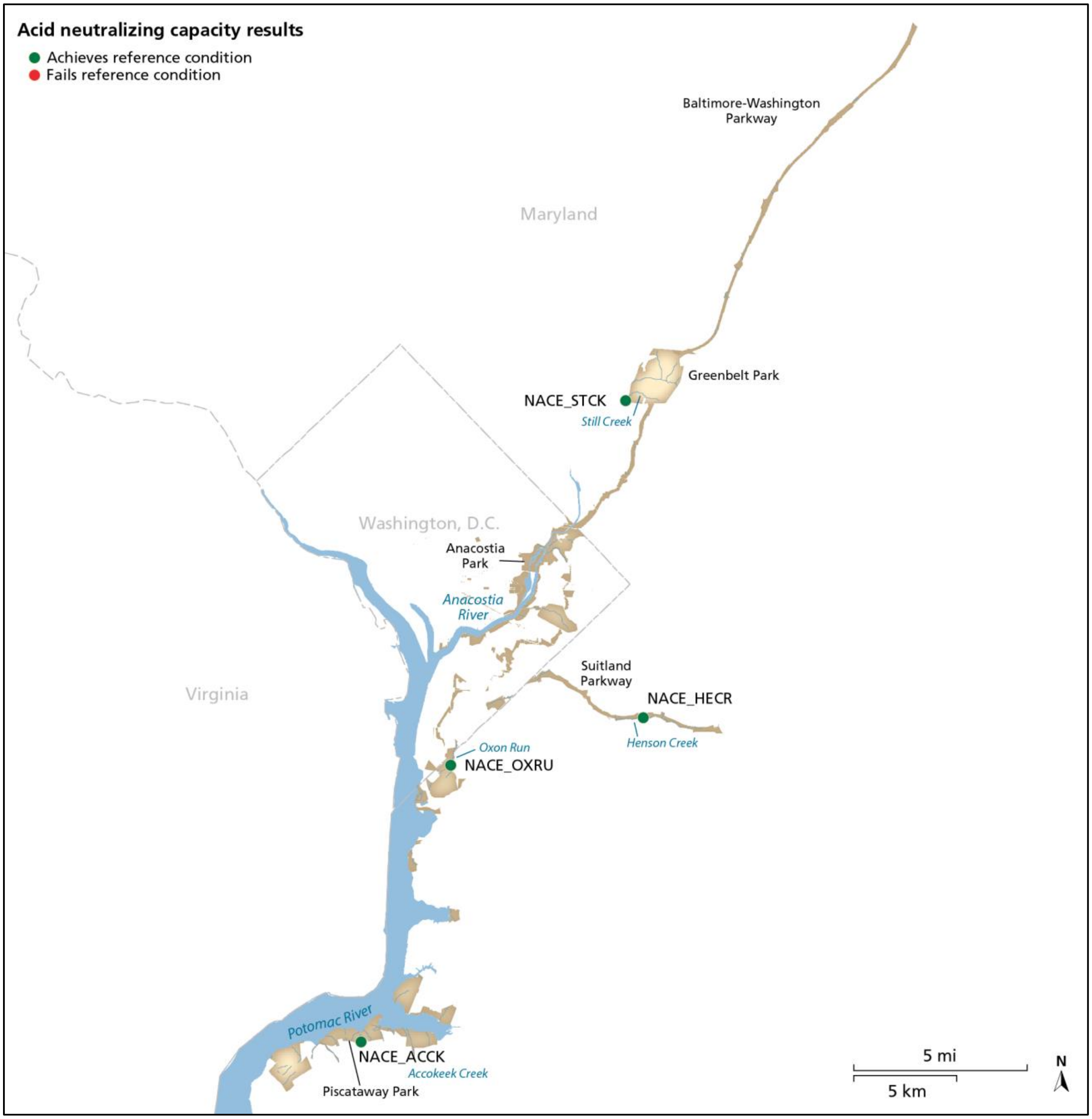

Figure 4-27 Attainment of acid neutralizing condition reference condition by site from 2005 to 2013 for four stream sampling locations in NACE. Site medians were used for this analysis.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.6. *Specific conductance*

Description

Electrical conductivity is a measure of water's ability to conduct electricity, and therefore a measure of the water's ionic activity and content. The higher the concentration of ionic (dissolved) constituents, the higher the conductivity (Radtke et al. 1998). As conductivity changes with temperature, conductivity can be normalized to a temperature of 25°C and reported as specific conductance to enable comparisons.

Common sources of pollution that can affect specific conductance are deicing salts, dust-reducing compounds, agriculture (primarily from the liming of fields), and acid mine drainage associated with mining operations (USGS 1980; Stednick and Gilbert 1998; NPS 2002). De-icing compounds alone are significantly elevating the specific conductance of some streams in the northeast during winter periods (Kaushal et al. 2005; Allan and Castillo 2007).

Data and methods

Data was collected monthly between 2005 and 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Figure 4-17, Table 4-14). NCRN followed the sampling protocol specified in Norris et al. 2011.

The reference condition for specific conductance is ≤ 171 µS/cm, above which conditions are said to be degraded (Morgan et al. 2007) (Table 4-15). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment.

Condition and trends

Condition of specific conductance in NACE between 2005 and 2013 was very degraded, with a median conductance of 403.7 µS/cm and 3.8% of data points attaining the reference condition of ≤ 171 µS/cm (Figure 4-28, Figure 4-29, Table 4-15). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4-28). Most streams in the National Capital Region network fail to meet the reference condition for specific conductance.

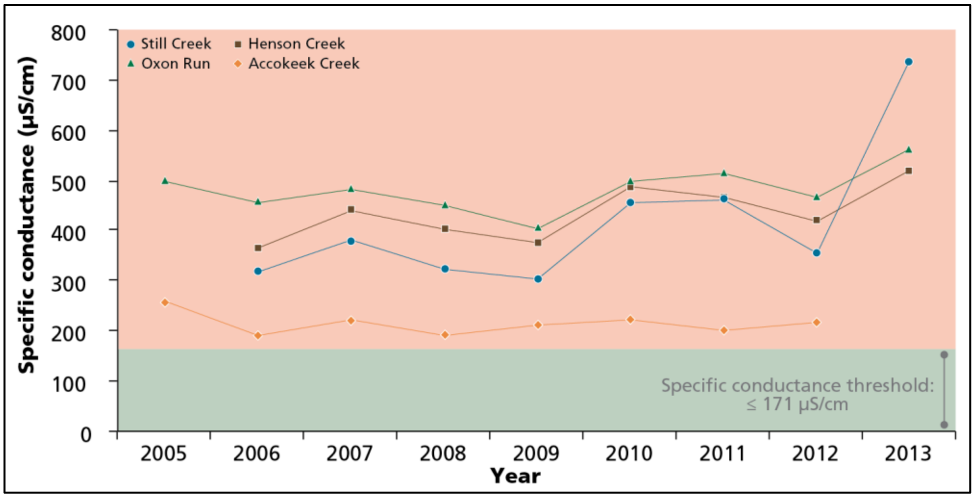

Figure 4-28 Annual median specific conductance values (µS/cm) from 2005 to 2013 for each of the four stream sampling locations in NACE.

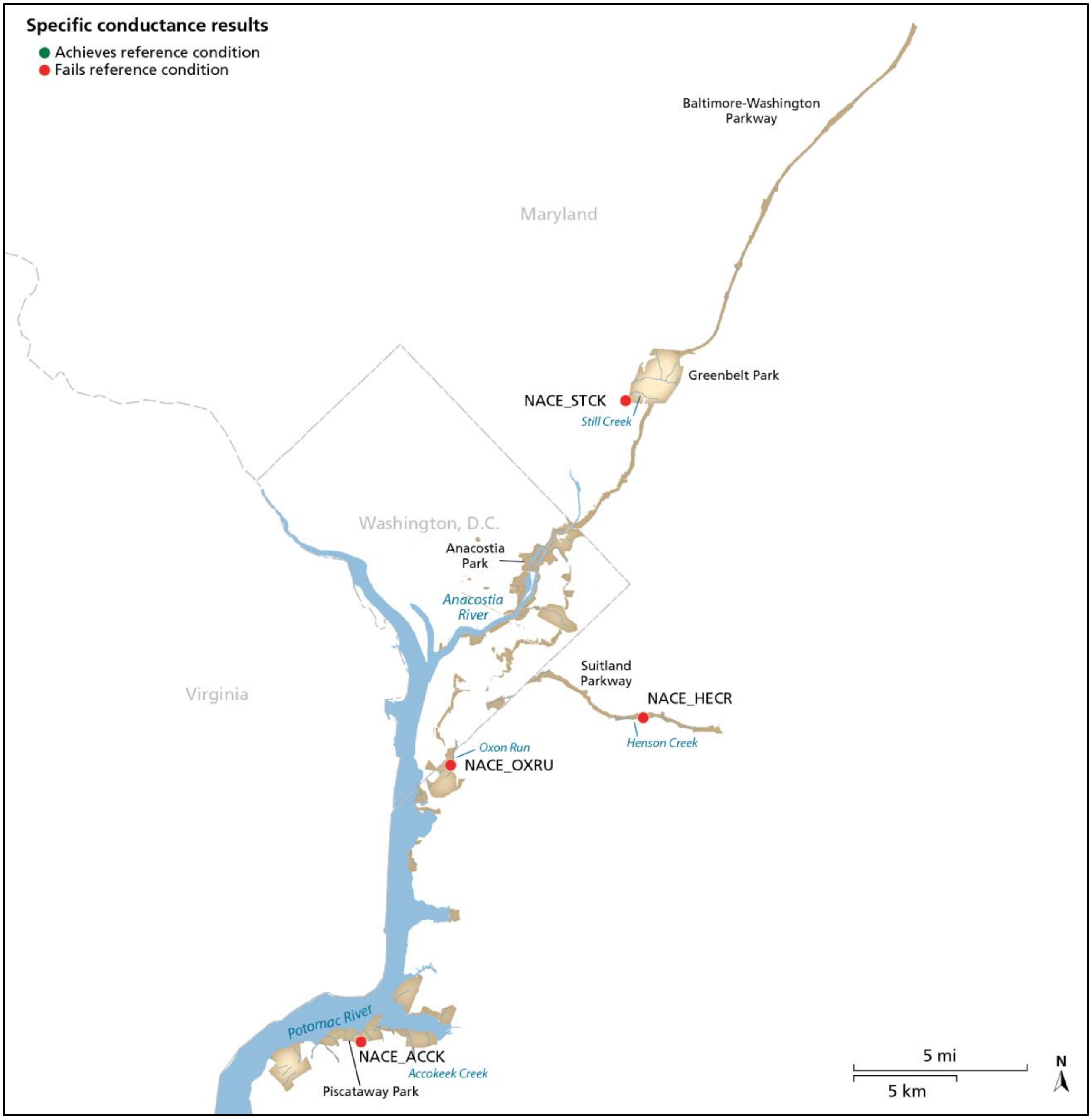

Figure 4-29 Attainment of specific conductance reference condition by site between 2005 and 2013 for five stream sampling locations in NACE. Site medians were used for this analysis.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.7. Total nitrate

Description

Nitrate (NO_3) is a form of nitrogen which aquatic plants can absorb and incorporate into proteins, amino acids, nucleic acids, and other essential molecules. Nitrate is highly mobile in surface and groundwater and may seep into streams, lakes, and estuaries from groundwater enriched by animal or human wastes and commercial fertilizers. High concentrations of NO_3 can enhance the growth of algae and aquatic plants in a manner similar to enrichment in phosphorus and thus cause eutrophication of a water body. In most natural waters, inorganic nitrogen as ammonium or NO_3 is not the growth-limiting nutrient unless phosphorus is unusually high. Nitrate is typically indicative of agricultural pollution. Nitrate in surface water may occur in dissolved or particulate form. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation. Nitrate also travels freely through soil and therefore may pollute groundwater.

Data and methods

Data was collected monthly between 2005 and 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Figure 4-17). NCRN followed the sampling protocol specified in Norris et al. 2011.

It should be noted that the current methodology for measuring nitrate has been in use since July 2007. During the month of July 2007, a different method was used after an equipment malfunction. A third method was utilized prior to July 2007 (Norris and Pieper 2010).

Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "Present <QL," it was assigned a pass result because the detection limit for nitrate is lower than the reference condition (J. Pieper, *pers. comm.*).

The nitrate concentration threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling as described for the ANC threshold. The MBSS determined that a nitrate concentration of 2.0 mg NO_3/L and above indicated stream degradation (Southerland et al. 2007; Norris and Sanders 2009) (Table 4-15). Each data point was compared against the reference condition to determine the percent attainment and condition.

Condition and trend

Condition of total nitrate in NACE was very good, with a median concentration of 1.0 mg/L and 92.6% of data points attaining reference condition of < 2.0 mg/L between 2005 and 2013 (Figure 4-30, Figure 4-31, Table 4-16). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4-30).

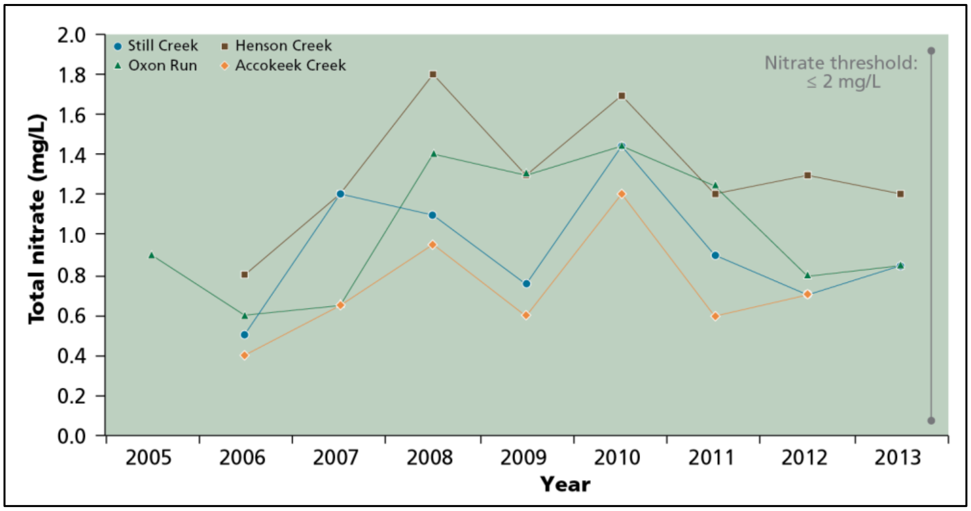

Figure 4-30 Annual median nitrate concentrations (mg/L) from 2005 to 2013 for four stream sampling locations in NACE.

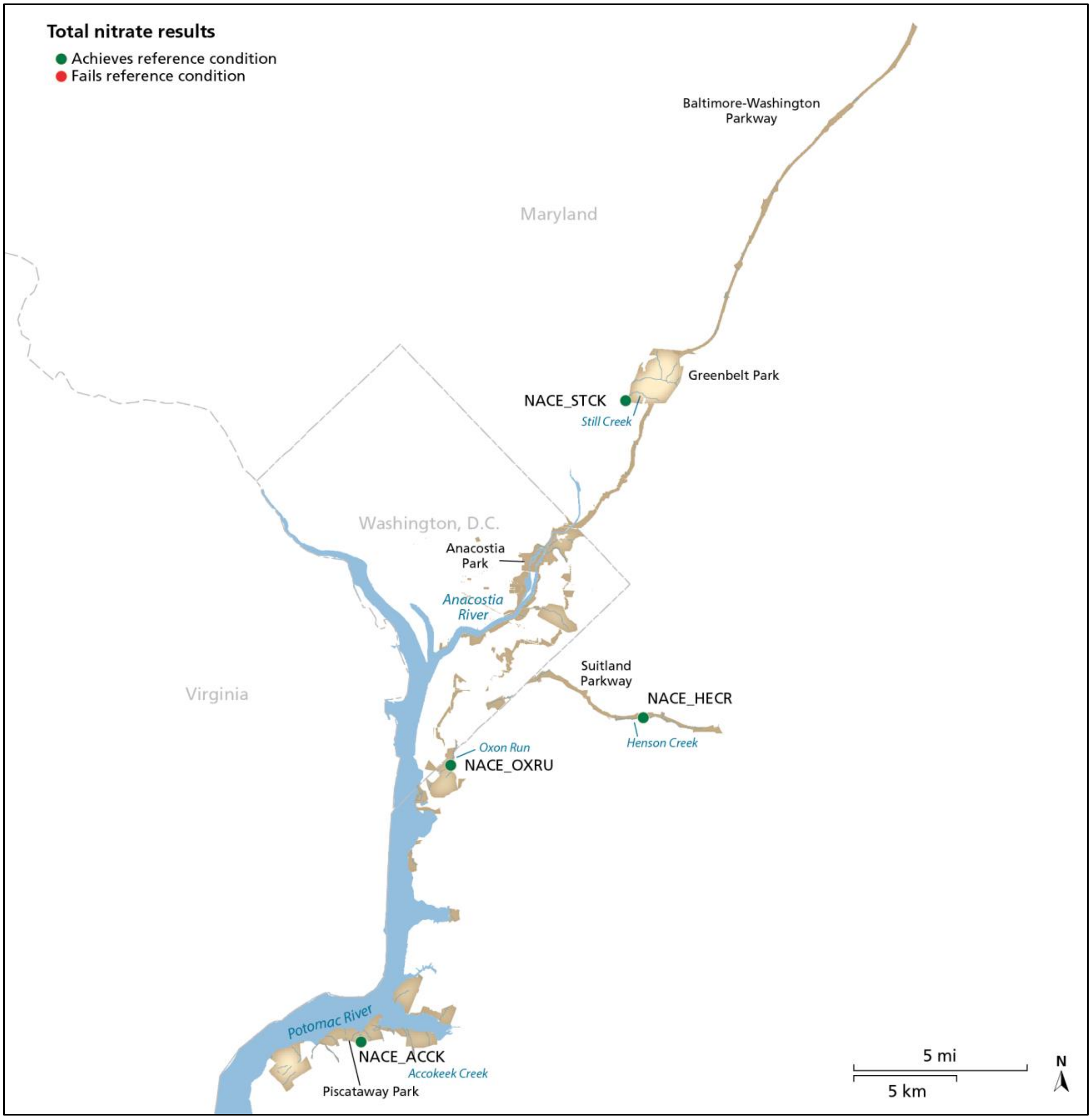

Figure 4-31 Attainment of nitrate reference condition by site from 2005 to 2013 for five stream sampling locations in NACE. Site medians were used for this analysis.

Sources of expertise

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.8. Total phosphorus

Description

Phosphorus is an essential nutrient for plants to live and is frequently the limiting nutrient for plant growth in aquatic systems. A minor increase in phosphorus concentration can significantly affect water quality by changing the population and community dynamics of algae and diatoms leading to eutrophication (Allan 1995). The most common form of phosphorus pollution is in the form of phosphate (PO_4). Sources of phosphate pollution include sewage, septic tank leachate, fertilizer runoff, soil erosion, animal waste, and industrial discharge.

Data and methods

Data was collected monthly between 2005 and 2013 at four sites by National Capital Region Network (NCRN) Inventory & Monitoring staff (Norris and Pieper 2010; Pieper et al. 2012) (Figure 4-17, Table 4-15). NCRN followed the sampling protocol specified in Norris et al. 2011. No data was available for any of the sites in 2008.

Measurements were taken monthly as instantaneous measurements. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for phosphate is lower than the assessment threshold (J. Pieper, pers. comm.)

The phosphate threshold is based on the U.S. EPA Ecoregional Nutrient Criteria for total phosphorus. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria are developed as baselines for specific geographic regions. NACE is located in Ecoregion IX or the Southeastern Temperate Forested Plains and Hills (Pieper et al. 2012). The ecoregional reference condition value for total phosphorus is <0.037 mg/L (37 ppb) (U.S. EPA 2000) (Table 4-15). Each data point was compared against the reference condition to determine the percent attainment and condition.

Condition and trend

Current condition of total phosphorus at NACE was very degraded, with a median total phosphorus concentration of 0.08 mg/L and only 8.9% of data points attaining reference condition of <0.037 mg/L between 2005 and 2013 (Figure 4-32, Figure 4-33, Table 4-16). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4-32). The results at NACE are consistent with results throughout the National Capital Region, where streams fail to meet the acceptable threshold for total phosphorus.

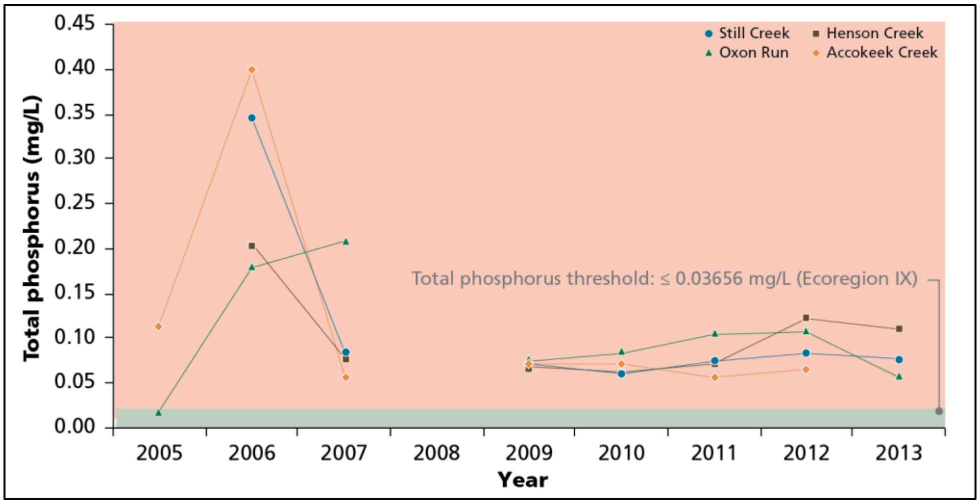

Figure 4-32 Annual median total phosphorus concentrations (mg/L) from 2005 to 2013 for each of the four stream sampling locations in NACE. No data are available for 2008.

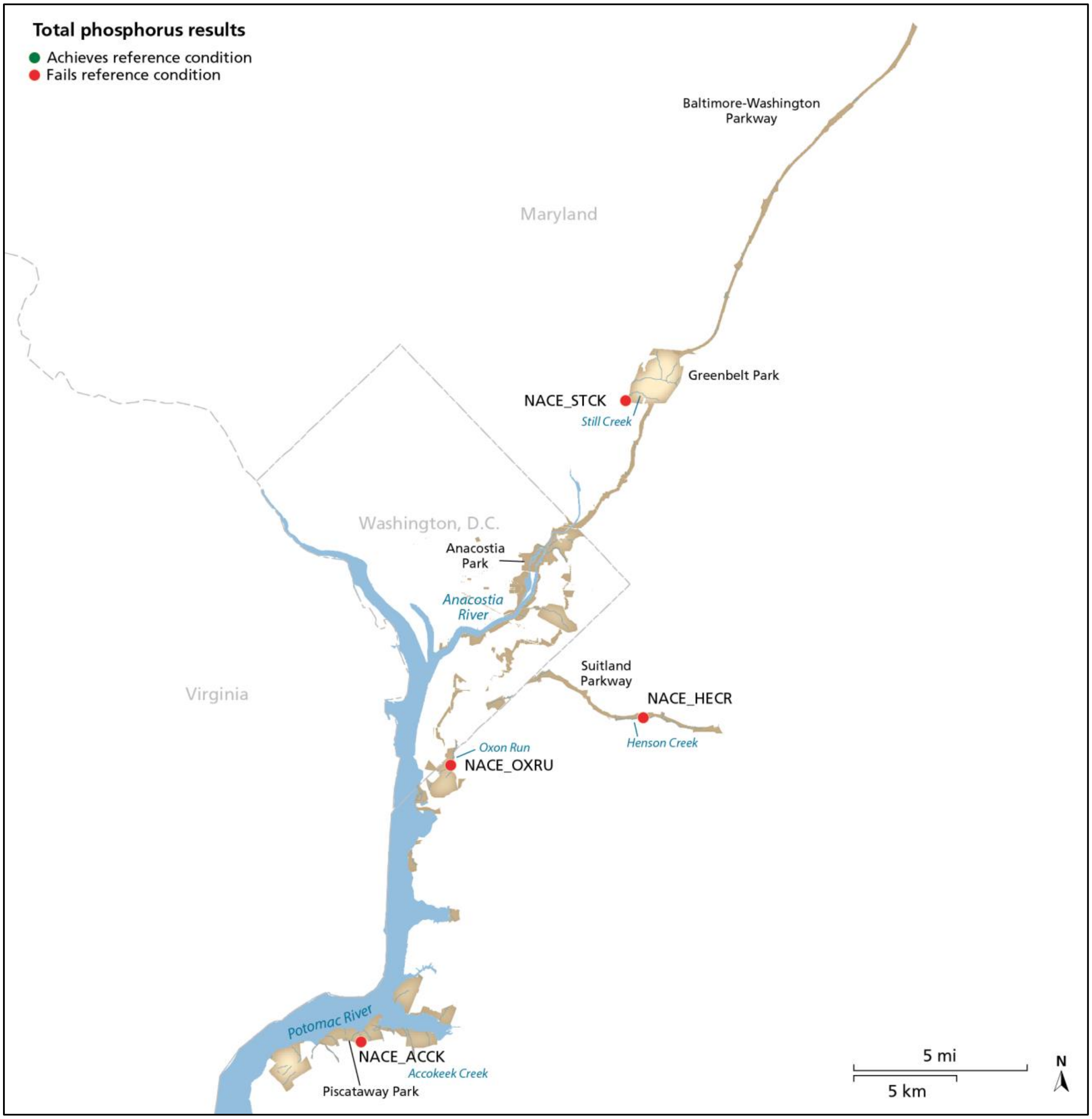

Figure 4-33 Attainment of phosphorus reference condition by site from 2005 to 2013 for four stream sampling locations in NACE. Site medians were used for this analysis.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.9. Benthic index of biotic integrity

<u>Description</u>

BIBI is an indicator of the health of the benthic macroinvertebrate communities in a stream. The

Benthic Index of Biotic Integrity (BIBI) is a multi-metric index used by the Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS). Taxonomic information for each monitoring site was used to calculate a Benthic Index of Biotic Integrity developed specifically for Maryland streams, but is applicable to nearby Virginia and West Virginia sites (Hildebrand 2005).

Data and Methods

Data were collected at four sites between 2004 and 2013 by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) collaborators (Figure 4-18, Table 4-15; Norris and Pieper 2010). Not all sites were sampled in every year. NCRN followed the sampling protocol specified in Norris et al. 2011. Within the parks that make up NACE, monitoring is done in Accokeek Creek (Piscataway Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove Farm Park), and Still Creek (Greenbelt Park).

To calculate a stream's benthic index of biotic integrity (BIBI) score, streams are sorted by physiographic province and then compared against high quality reference streams in the same physiographic class. All of the streams monitored in NACE fall into the Coastal Plain stream class. The reference conditions are based on the MBSS interpretation of the BIBI. The BIBI scores range from 1 to 5 and are calculated by comparing the site's benthic assemblage to the assemblage found at minimally impacted sites (Norris and Sanders 2009). A score of 3 indicates that a site is considered to be comparable to (i.e., not significantly different from) reference sites. Any sites with BIBIs less than 3 are in worse condition than reference sites (Southerland et al. 2007; Norris and Sanders 2009). BIBI values were ranked as follows: 1.0-1.9 (very poor), 2.0-2.9 (poor), 3.0-3.9 (fair), 4.0-5.0 (good), and these were the scale and categories used in this assessment (Southerland et al. 2007).

The range of BIBI scores from 1 to 5 were scaled linearly from 0 to 100% attainment. The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment.

Table 4-17 Benthic Index of Biological Integrity (BIBI) categories, percent attainment, and condition assessment.

BIBI range	% Attainment	Condition
4.0-5.0	75-100	Good
3.0-3.9	50-<75	Fair
2.0-2.9	25-<50	Poor
1.0-1.9	0- <25	Very poor

Condition and trend

Current condition of benthic macroinvertebrates in NACE was fair, with a median BIBI of 3.29 and 57.3% attainment of reference condition (Table 4-18, Figure 4-34, Figure 4-35). Median BIBI was lowest in Oxon Run, with a value of 2.71, or degraded, due to low numbers of sensitive macroinvertebrate taxa. Oxon Run, a tributary of the Potomac River, had the lowest median score for ANC, nitrate, and phosphorus for the years sampled.

No trend analysis was possible with the current data set.

Table 4-18 Benthic Index of Biotic Integrity (BIBI) in NACE.

Year	Site ID	NRCN Site	Location	BIBI
2013	ACCO-214-N-2013	NCRN_NACE_ACCK	Accokeek Creek	3.86
2013	PRUT-201-N-2013	NCRN_NACE_HECR	Henson Creek	3.29
2013	OXON-301-N-2013	NCRN_NACE_OXRU	Oxon Run	3.29
2013	ANAC-113-N-2013	NCRN_NACE_STCK	Still Creek	3.86
2006	OXON-301-N-2006	NCRN_NACE_OXRU	Oxon Run	2.14
2004	ANAC-113-N-2004	NCRN_NACE_STCK	Still Creek	3.00
2004	ACCO-214-N-2004	NCRN_NACE_ACCK	Accokeek Creek	3.57

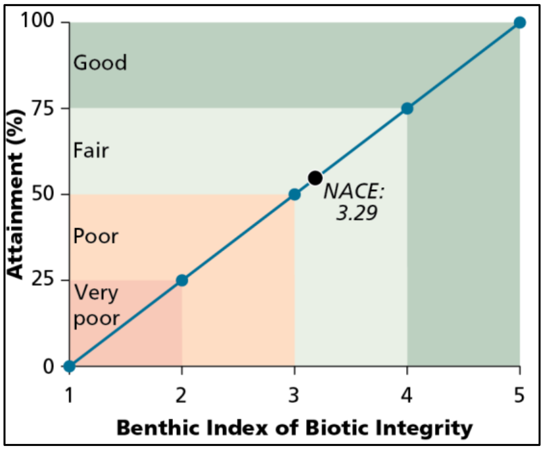

Figure 4-34 Application of percent attainment categories to the Benthic Index of Biotic Integrity (BIBI) categories. BIBI at NACE was degraded, with a median of 3.29 which equated to 57.3% of the reference condition.

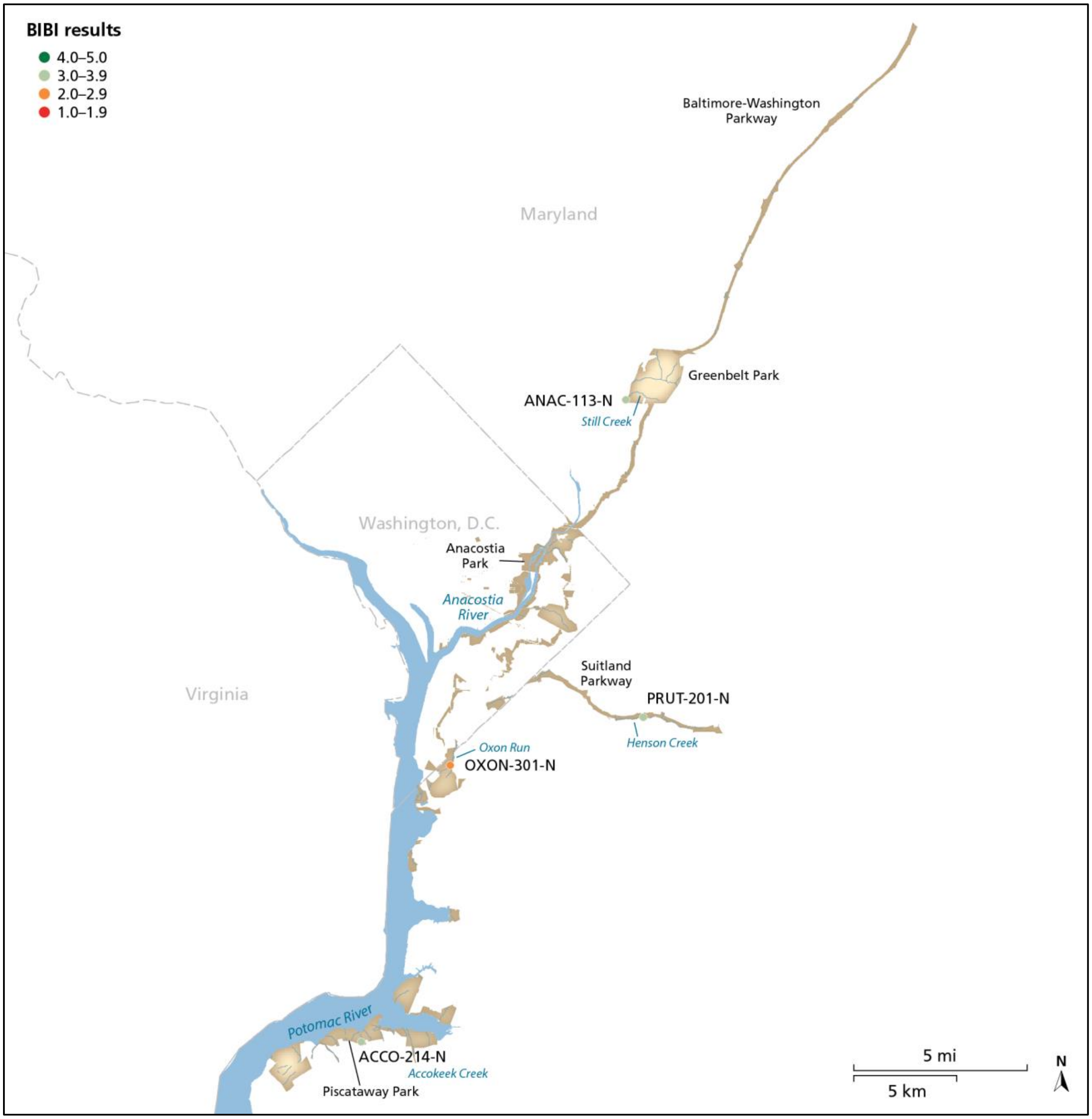

Figure 4-35 Attainment of Benthic Index of Biotic Integrity (BIBI) reference condition by site for four stream sampling locations in NACE.

<u>Sources of expertise</u>

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.2.10. Physical habitat Index

<u>Description</u>

Physical habitat is an integral part of overall stream condition. Components of physical habitat include the diversity of flow conditions, the diversity and stability of substrates, the degree and extent of erosion, the amount of woody debris, and many other factors. These physical factors affect the biological potential of streams by providing the physical template upon which aquatic communities of fish and macroinvertebrates must live (Paul et al. 2012; Nortrup 2013).

Data and methods

Data for the Physical Habitat Index (PHI) were collected at four sites between 2004 and 2013, but all sites were not sampled every year. NCRN followed the National Capital Region Biological Stream Survey protocol (Norris and Sanders 2009). To calculate a stream's Physical Habitat Index (PHI) score, streams are sorted by physiographic province and then compared against high quality reference streams in the same physiographic class. All of the streams monitored in NACE fall into the Coastal Plain stream class. As a result, the following eight characteristics are evaluated: riffle quality, stream bank stability, woody debris, instream habitat available for fish, epifaunal substrate (hard, stable materials that stream biota can live on), shading, remoteness, and embeddedness of substrates (the amount of space around large stream bottom particles) (Norris and Sanders 2009).

Sites are given scores for each of the applicable categories and then those scores are adjusted to a percentile scale (Norris and Sanders 2009). Reported data are for one PHI assessment per site (per year when sites were visited in multiple years).

The PHI threshold was developed by the Maryland Biological Stream Survey (MBSS) program after initial sampling as described for the ANC threshold (see Section 4.2.5). The MBSS determined the scale for PHI values to be 0-50 (severely degraded), 51-65 (degraded), 66-80 (partially degraded), and 81-100 (minimally degraded), and these were the scale and categories used in this assessment (Paul et al. 2002; Southerland et al. 2005). Each of the four PHI value categories was assigned a percent attainment range.

The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment.

Condition and trend

Current condition of PHI in NACE was partially degraded, with a median PHI of 51.84, which equated to a 25.92% attainment of the reference condition (Table 4-19, Figure 4-36, Figure 4-37). Accokeek Creek, Henson Creek, and Still Creek all suffer from close proximity to roadways. Accokeek Creek, Henson Creek, and Oxon Run also scored poorly on stream shading while Still Creek had low streambank stability and Oxon Run had low levels of beneficial woody debris. No trend analysis was possible with the current data set.

Table 4-19 Stream Physical Habitat Index (PHI) in NACE.

Year	Site ID	NRCN Site	Location	PHI
2013	ACCO-214-N-2013	NCRN_NACE_ACCK	Accokeek Creek	45.96
2013	PRUT-201-N-2013	NCRN_NACE_HECR	Henson Creek	46.64
2013	OXON-301-N-2013	NCRN_NACE_OXRU	Oxon Run	48.76
2013	ANAC-113-N-2013	NCRN_NACE_STCK	Still Creek	67.52
2006	OXON-301-N-2006	NCRN_NACE_OXRU	Oxon Run	51.84
2004	ANAC-113-N-2004	NCRN_NACE_STCK	Still Creek	52.97
2004	ACCO-214-N-2004	NCRN_NACE_ACCK	Accokeek Creek	73.88

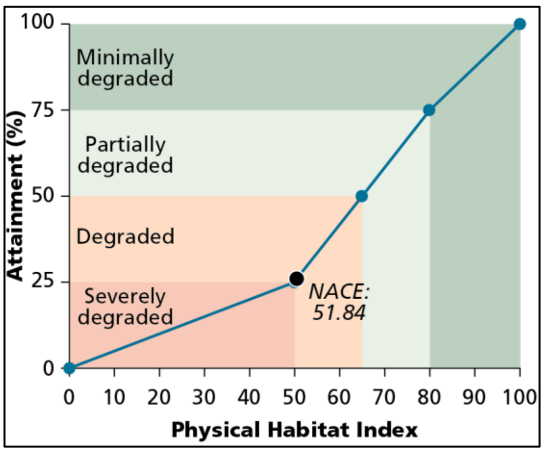

Figure 4-36 Application of the percent attainment categories to the Physical Habitat Index (PHI) value categories.

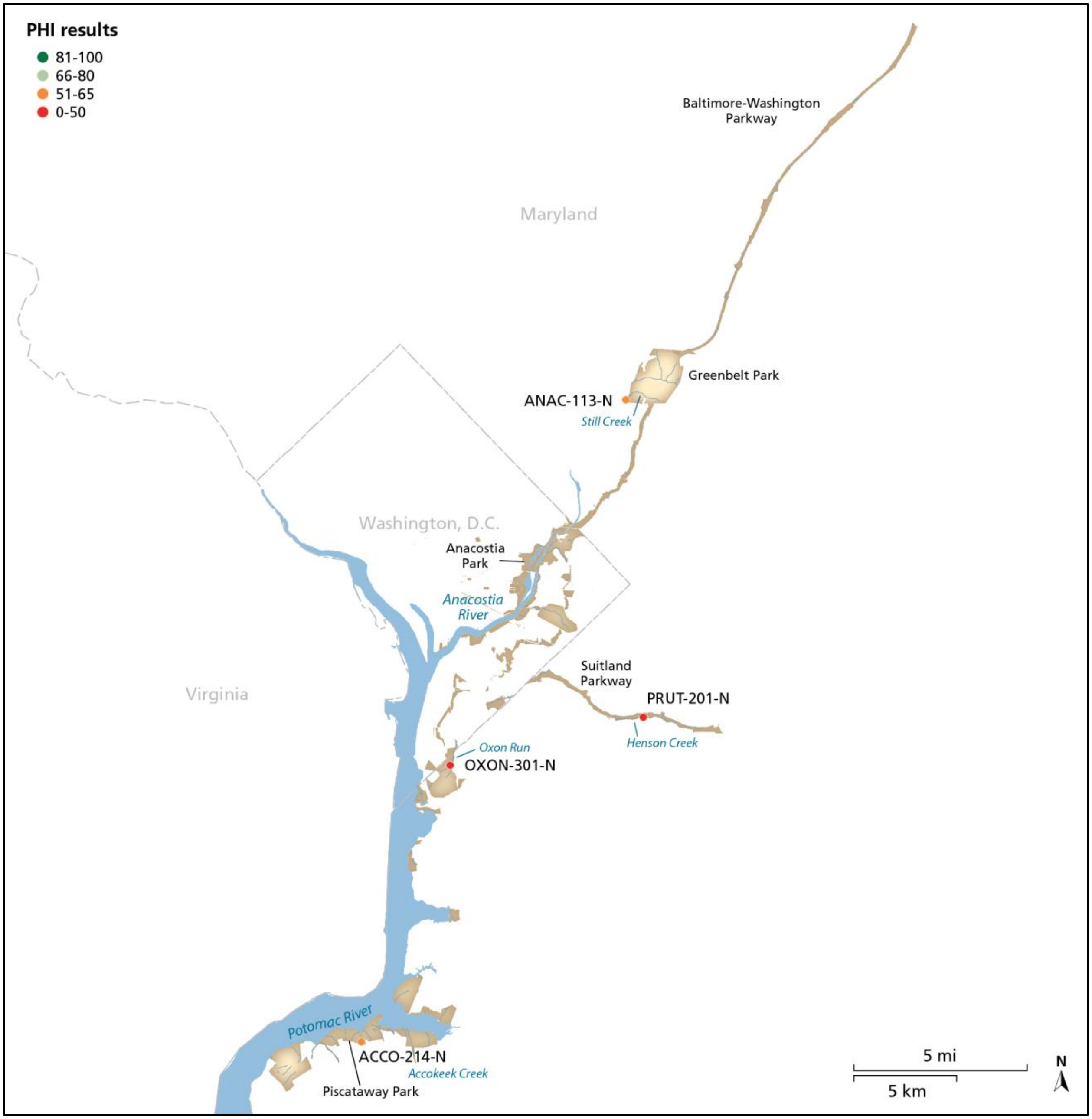

Figure 4-37 Attainment of Physical Habitat Index (PHI) reference condition by site for four stream sampling locations in NACE.

Sources of expertise

- James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

4.3. Biological integrity

4.3.1. Biological integrity summary

Seven metrics were used to assess biological integrity in National Capital Parks-East—cover of exotic herbaceous species, area of exotic trees and saplings, presence of forest pest species, stocking index, fish index of biotic integrity (FIBI), bird community index (BCI), and deer density (Table 4-20). All data were collected by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff and collaborators except for deer data, which was gathered by the NCR Regional Wildlife Biologist. Forest monitoring sites and deer counting routes are shown in Figure 4-38, FIBI monitoring sites are shown in Figure 4-41, and bird community index sites are shown in Figure 4-38, Figure 4-39, and Figure 4-40.

Table 4-20 Ecological monitoring framework data for biological integrity provided by agencies and specific sources included in the assessment of NACE.

Metric	Agency	Reference/Source
Cover of exotic herbaceous species	NCRN I&M	Schmit et al. 2009, 2010, 2012
Area of exotic trees & saplings	NCRN I&M	Schmit et al. 2009, 2010, 2012
Presence of forest pest species	NCRN I&M	Schmit et al. 2009, 2010, 2012
Stocking index	NCRN I&M	Schmit et al. 2009, 2010, 2012
Fish index of biotic integrity	NCRN I&M	Norris and Sanders 2009; MBSS
Bird community index	NCRN I&M	Ladin and Shriver 2013
Deer density	NPS NCR	Bates 2009, 2012

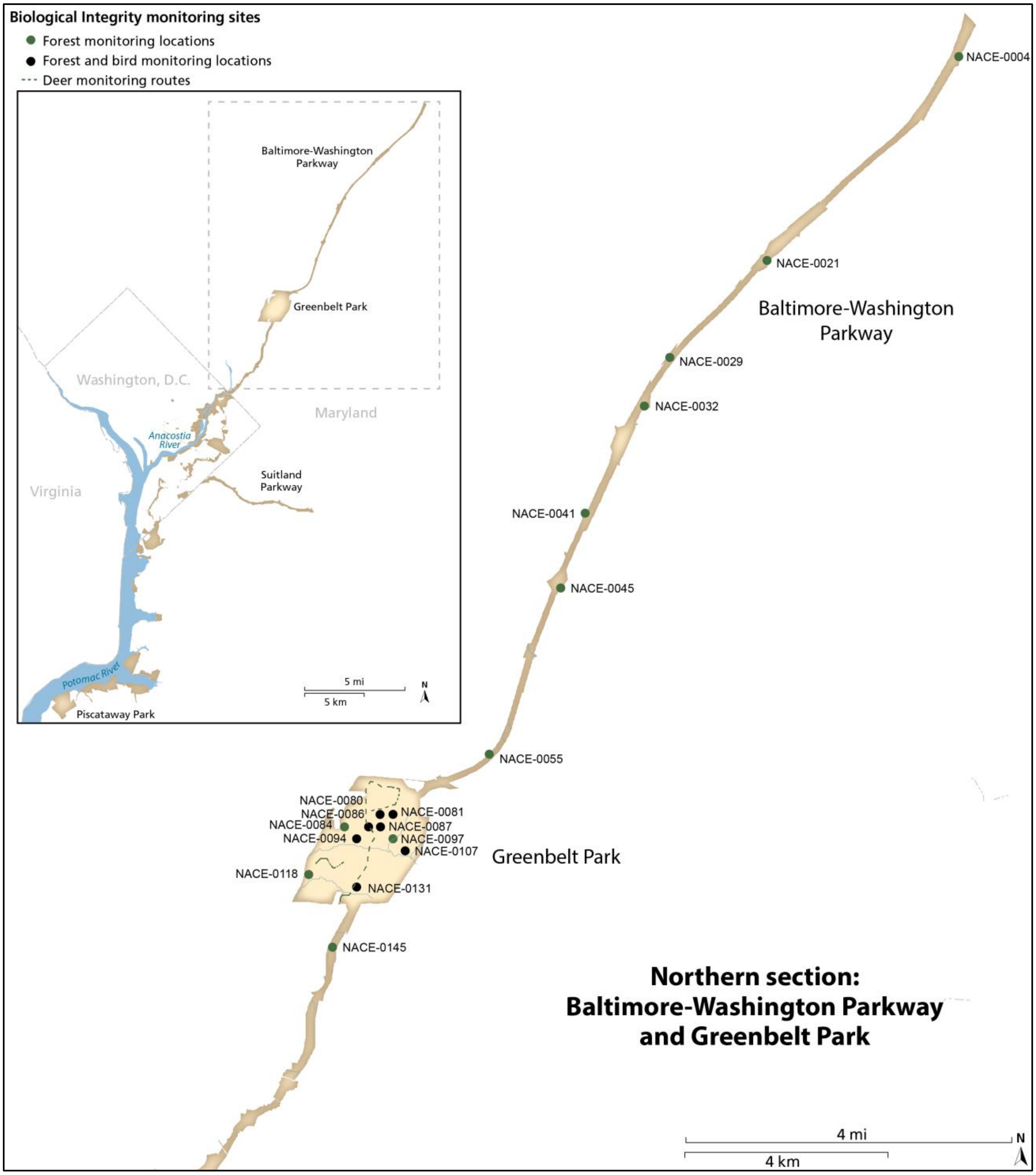

Figure 4-38 Forest monitoring sites, bird community index monitoring sites, and deer counting routes in NACE – northern section.

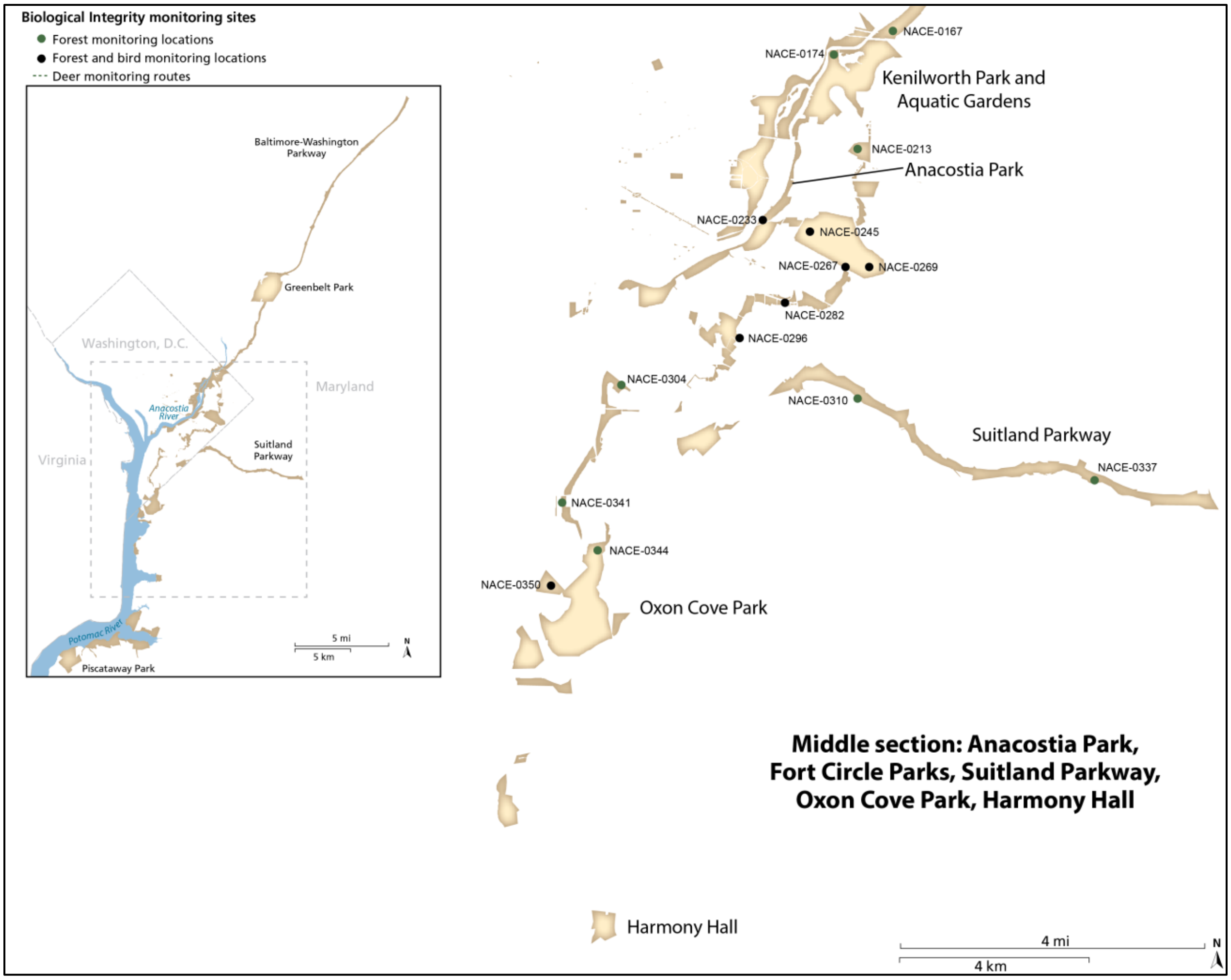

Figure 4-39 Forest monitoring sites, bird community index monitoring sites, and deer counting routes in NACE – middle section.

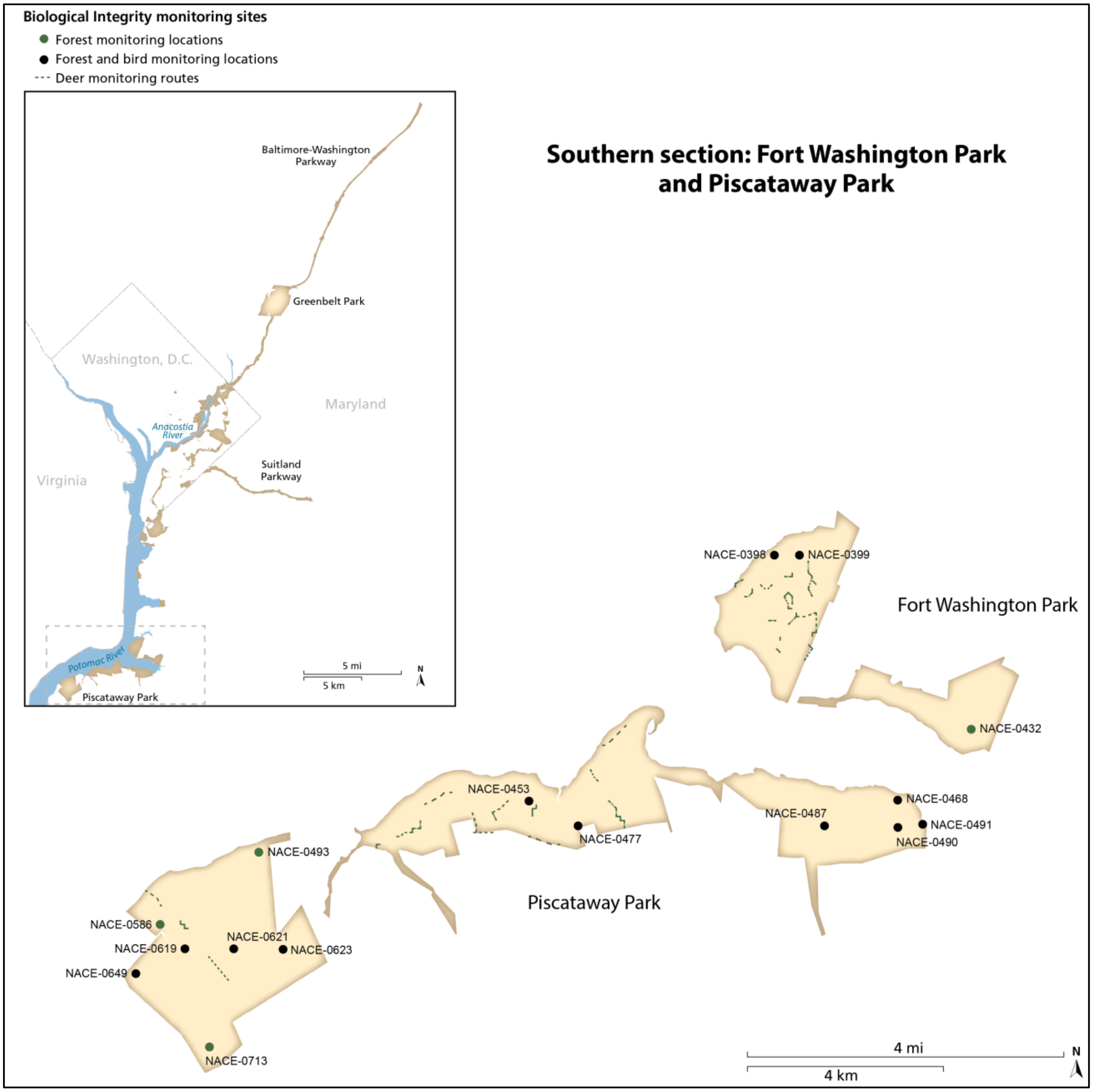

Figure 4-40 Forest monitoring sites, bird community index monitoring sites, and deer counting routes in NACE – southern section.

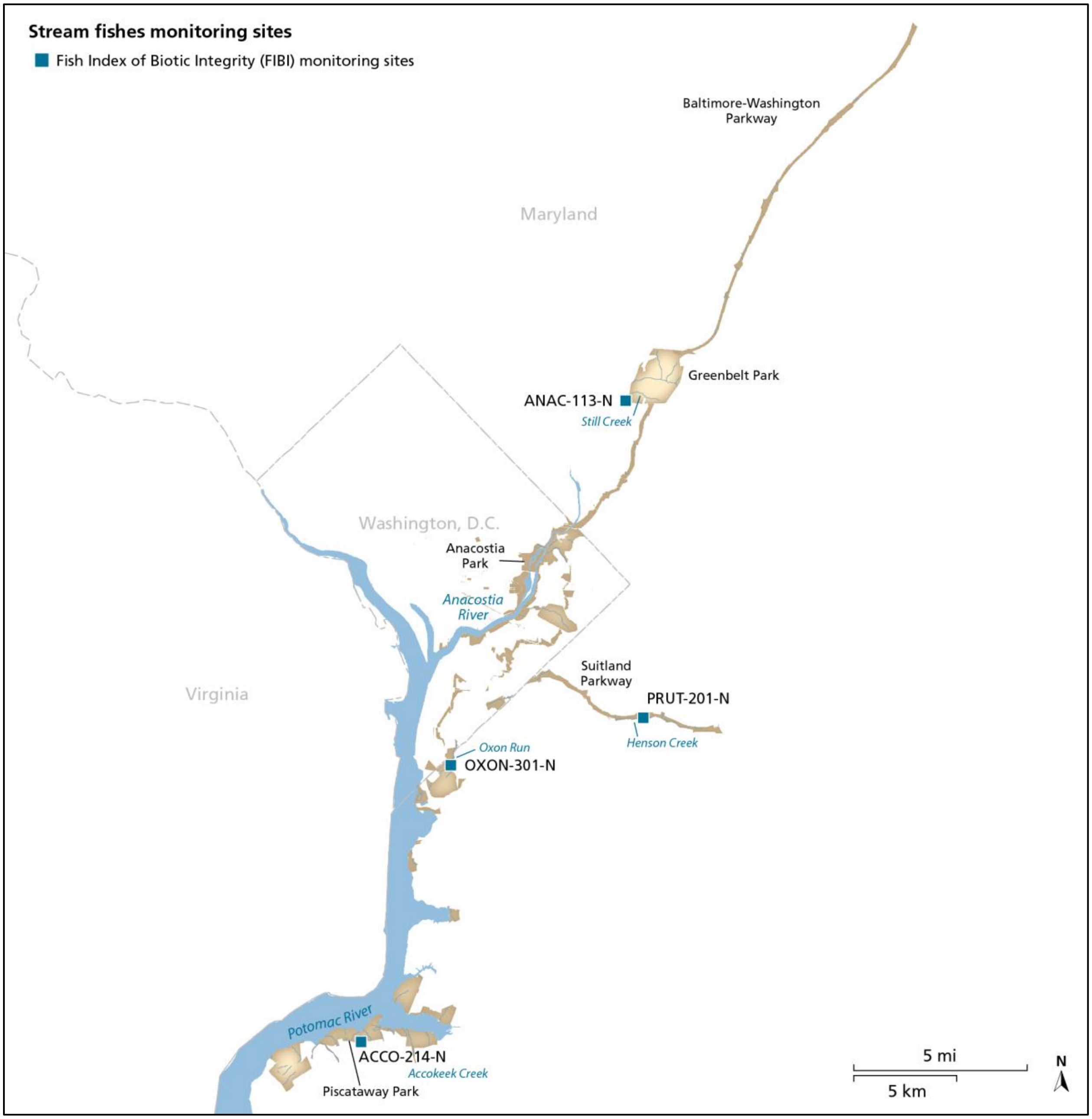

Figure 4-41 Fish monitoring sites in NACE.

Reference conditions were established for each of the seven metrics (Table 4-21) and the data were compared to these reference conditions to obtain the percent attainment, which was then converted to the condition assessment for that metric. Single reference conditions were used for exotic plants, forest pests, and tree regeneration, while multiple reference conditions were used for FIBI and BCI scores.

National Capital Parks-East had variable results for biological integrity. The park scored as very good condition for presence of forest pest species (95.7% attainment), area of exotic trees and saplings (91.5% attainment), and good condition for FIBI (85.7%); degraded condition for BCI (39.4% attainment); and very degraded for cover of exotic herbaceous species, stocking index and deer density (19.1 %, 6.38%, and 0% attainment respectively) (Table 4-22).

Table 4-21 Biological integrity indicators, data availability, reference conditions, and condition assessment categories used in the natural resource condition assessment of National Capital Parks-East.

Biological integrity indicator	Number of sites	Number of samples	Period of observation	Reference condition/s	Percent attainment applied
Cover of exotic herbaceous species	47	47	2010-2013	0% (absence)	0-100% Scaled linearly
Area of exotic trees & saplings	47	94	2010-2013	< 5%	
Presence of forest pest species	47	47	2010-2013	< 1%	
Stocking index	47	47	2010-2013	> 115	
Fish index of biotic integrity	4	6	2004-2013	1.0-1.9; 2.0-2.9; 3.0-3.9; 4.0-5.0	
Bird community index	30	202	2007-2013	< 40; 40.1-52; 52.1-60; >60	
Deer density (deer/km^2)	4	34	2004-2014	< 8	

Table 4-22 Summary of resource condition assessment of Biological Integrity in NACE.

Biological integrity indicator	NACE result	Percent attainment of reference condition	Condition assessment	Overall biological integrity condition
Presence of exotic herbaceous species (% of plots with exotic species)	5.3	19.1%	Very degraded	47.9% Moderate
Area of exotic trees & saplings (% of basal area)	3.9	91.5%	Very good	
Presence of forest pest species (% trees infested)	0.1	95.7%	Very good	
Seedling stocking index	19.3	6.38%	Very degraded	
Fish index of biotic integrity (FIBI)	4.3	85.7%	Good	
Bird community index (BCI)	47	39.4%	Medium Integrity	
Deer density (deer/km2)	43.5	0.0%	Very degraded	

4.3.2. Exotic herbaceous species

Description

Invasive exotic plants are species that aggressively compete with and displace native plant communities. The result can be loss and destruction of forage and habitat for wildlife, reduced biodiversity, loss of forest productivity, soil degradation, diminished recreational enjoyment, and economic harm (Mack et al. 2000). Although certain plant species were introduced in the United States for agriculture, erosion control (kudzu), or ornamental purposes (Japanese barberry, English ivy), many are now considered invasive threats. Exotic herbaceous plants are a ubiquitous and growing threat in the National Capital Region (NCRN 2008, 2010).

Data and methods

Forest monitoring took place annually at 47 sites in NACE, but not all plots were measured every year (Schmit et al. 2009). This analysis used data from 2010-2013 (Figure 4-38). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

The cover of exotic herbaceous species in a plot was calculated from the percent cover of the single exotic species with the greatest cover. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

The Organic Act that established the National Park Service in 1916 and the U.S. Department of Interior NPS Management Policies (U.S. Dept. of Interior 2006) mandate the conservation of natural resources (see Section2.1.1). Because of the threat to the park posed by exotic herbaceous plants, the threshold used for this assessment was that exotic herbaceous plants should be completely absent (Table 4-23). Each data point was compared against the reference condition to determine the percent attainment and condition.

Condition and trend

Current condition for cover of exotic herbaceous species in NACE was very degraded, with a mean cover of 5.3% and 19.1% of data points attaining reference condition (Figure 4-23, Figure 4-44). Sites in the northern section of the park, Baltimore Washington Parkway and Greenbelt Park were generally above the threshold for exotic herbaceous species, as well as sites in the southern portion of the park in Fort Washington and Piscataway Park. Monitoring sites in the middle section of the park—Kenilworth Park, Anacostia Park, Fort Circle Parks, Harmony Hall, and Suitland Parkway, generally scored below the threshold for exotic species.

No trend analysis was possible with the current data set.

Table 4-23 Presence of exotic herbaceous plants. Site locations are shown in Figure 4-38.

Site	Year	Exotic plants
NACE-0041	2013	Absent
NACE-0045	2013	Absent
NACE-0055	2013	Absent
NACE-0097	2013	Present
NACE-0167	2013	Present
NACE-0269	2013	Present
NACE-0304	2013	Present
NACE-0344	2013	Present
NACE-0432	2013	Present
NACE-0493	2013	Present
NACE-0586	2013	Present
NACE-0713	2013	Absent
NACE-0029	2012	Present
NACE-0032	2012	Present
NACE-0080	2012	Absent
NACE-0107	2012	Present
NACE-0145	2012	Present
NACE-0296	2012	Present
NACE-0310	2012	Present
NACE-0350	2012	Present
NACE-0453	2012	Present
NACE-0619	2012	Present
NACE-0649	2012	Present
NACE-0021	2011	Present
NACE-0081	2011	Present
NACE-0084	2011	Absent
NACE-0086	2011	Absent
NACE-0094	2011	Present
NACE-0118	2011	Present

Table 4-23 (continued) Presence of exotic herbaceous plants. Site locations are shown in Figure 4-38.

Site	Year	Exotic plants
NACE-0267	2011	Present
NACE-0282	2011	Absent
NACE-0337	2011	Present
NACE-0341	2011	Present
NACE-0398	2011	Present
NACE-0477	2011	Present
NACE-0487	2011	Present
NACE-0621	2011	Present
NACE-0623	2011	Absent
NACE-0004	2010	Present
NACE-0087	2010	Present
NACE-0131	2010	Present
NACE-0174	2010	Present
NACE-0233	2010	Present
NACE-0245	2010	Present
NACE-0399	2010	Present
NACE-0468	2010	Present
NACE-0491	2010	Present

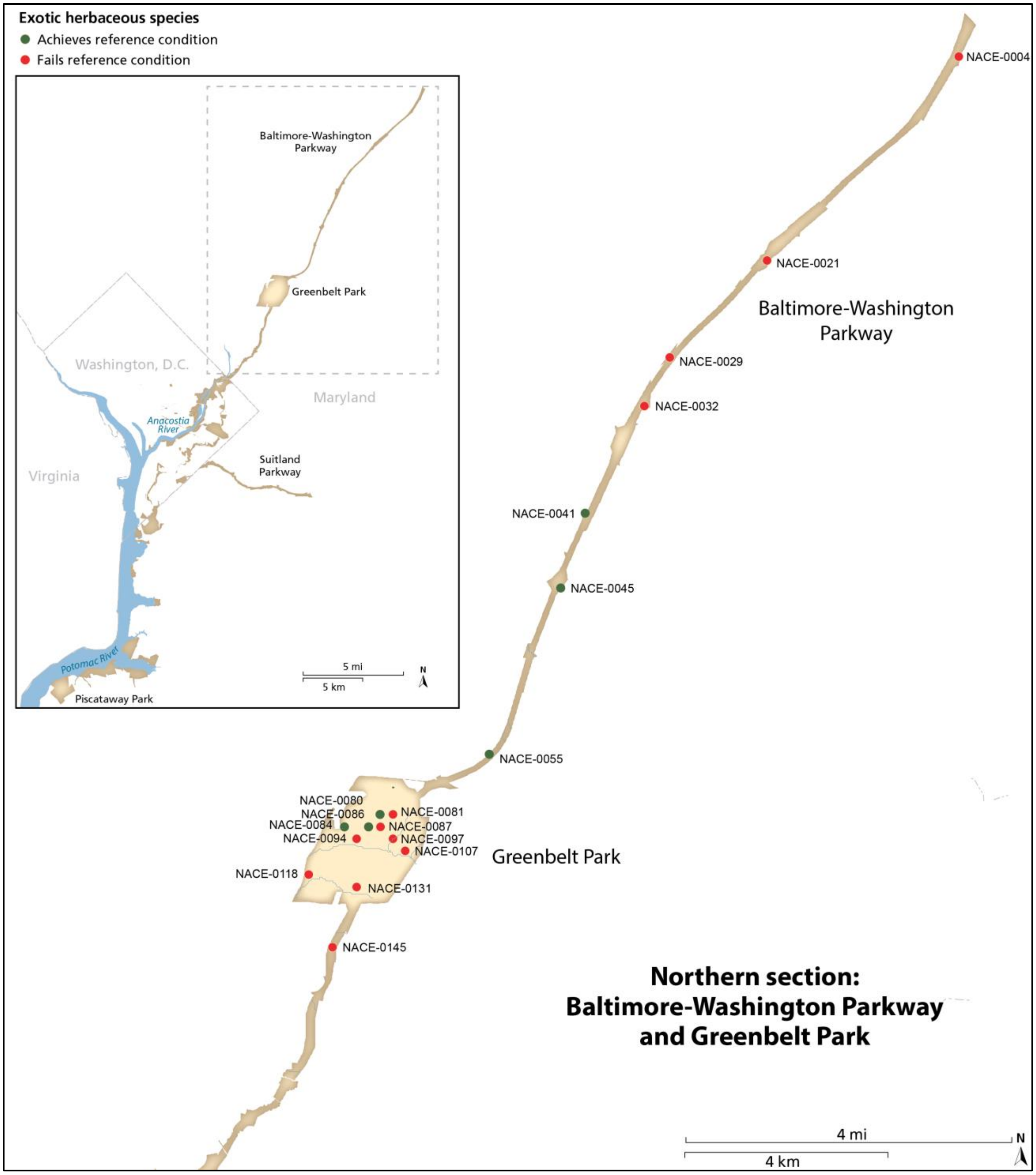

Figure 4-42 Exotic herbaceous species results by site for NACE – northern section.

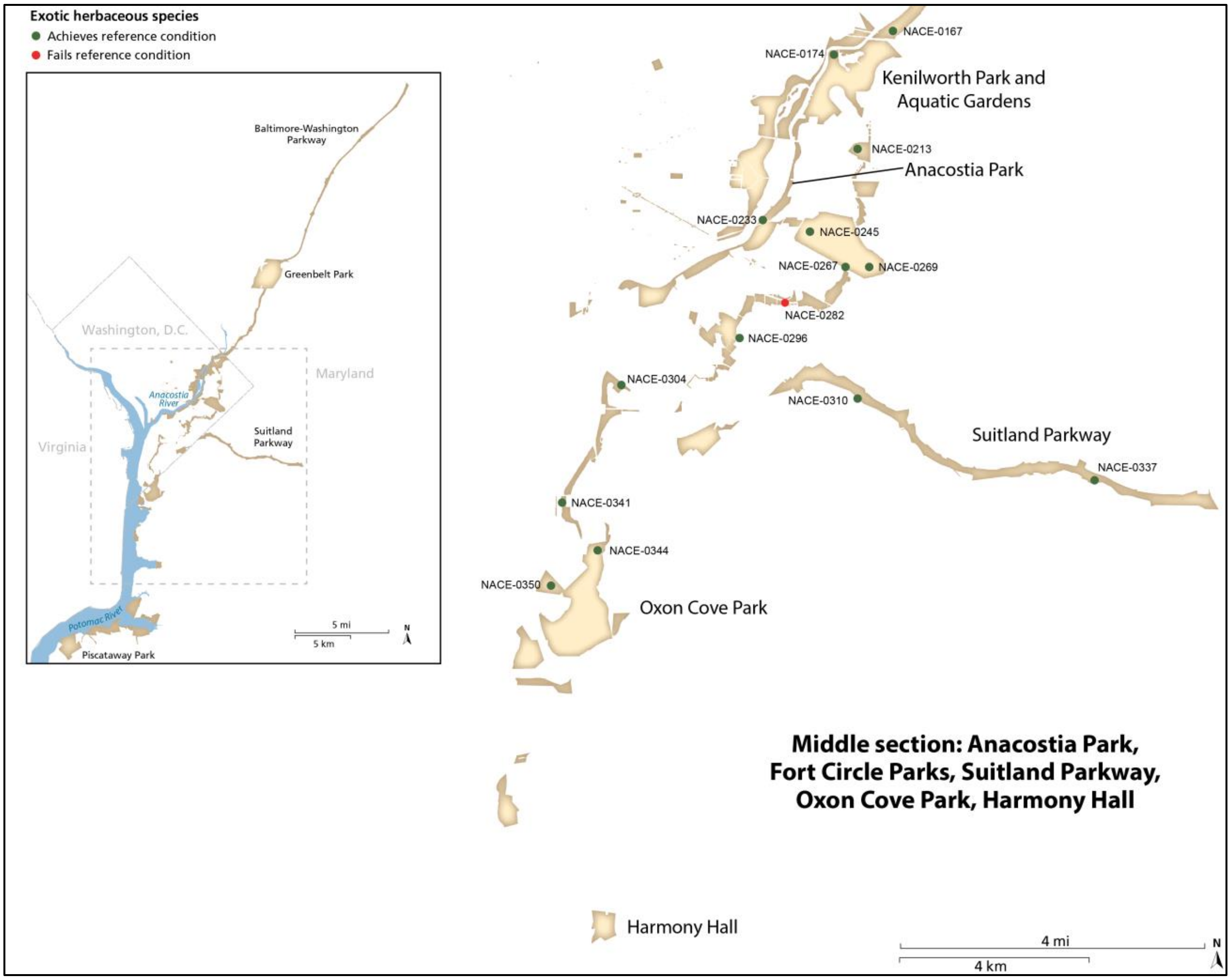

Figure 4-43 Exotic herbaceous species results by site for NACE – middle section.

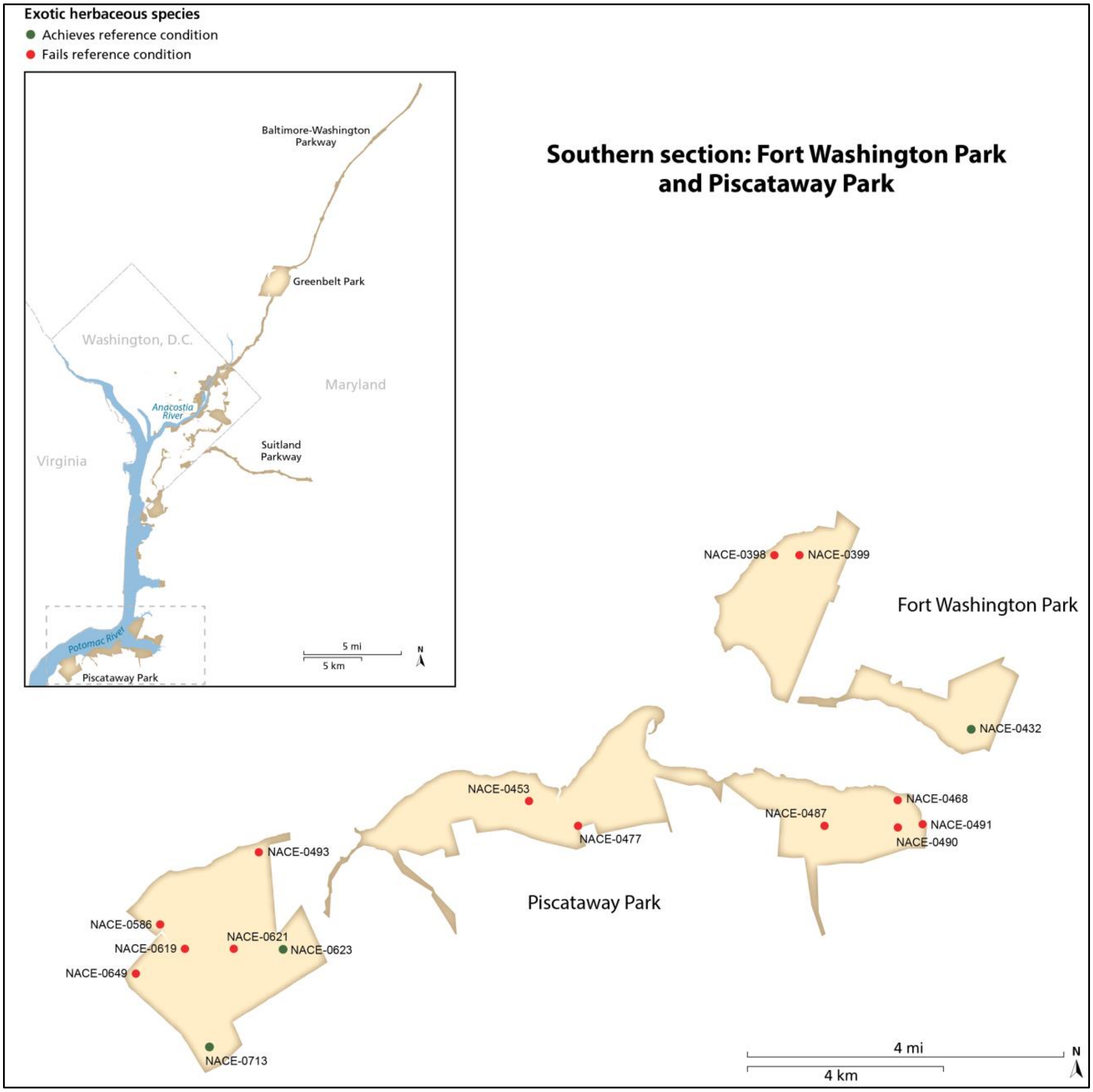

Figure 4-44 Exotic herbaceous species results by site for NACE – southern section.

Sources of expertise

- John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

4.3.3. *Exotic trees & saplings*

Description

Invasive exotic plants are non-native species that can reduce abundance and diversity of native plant communities (Vila et al. 2011). The result can be loss and destruction of forage and habitat for wildlife, reduced biodiversity, loss of forest productivity, reduced groundwater levels, soil degradation, diminished recreational enjoyment, and economic harm (Mack et al. 2000). Exotic tree species, especially those that are invasive, are a ubiquitous and growing threat in the National Capital Region (NCRN 2008, 2010).

Data and methods

Forest monitoring took place annually but not all plots were measured every year (Schmit et al. 2009). This analysis used data recorded for 2010-2013 (Figure 4-38). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

The basal area of exotic trees and saplings in a plot was calculated as a percentage of total tree basal area. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

The threshold used for this assessment was that the abundance of these invasive exotic plants should not exceed 5% of total basal area. Because 100% eradication is not a realistic goal, the threshold is intended to suggest more than just simple presence of these exotic species but that the observed abundance has the potential to establish and spread, i.e., 5% cover may be considered as the point where the exotic plants are becoming established rather than just present. This threshold is a guide to commence active management of an area by removal of these species. Each data point was compared against the reference condition to determine the percent attainment and condition.

To determine the overall condition assessment for exotic trees and saplings in NACE, the mean of all values was compared against the reference condition. Due to the large number of plots with no exotic species present, using the median calculation resulted in a value of 0, and 100% attainment. Because there were plots that had exotic trees present, and the median value did not represent the presence of exotic species, the mean of all values was compared against the reference condition.

Condition and trend

Condition for basal cover of exotic trees and saplings in NACE was very good, with a mean of 3.9 percent cover and 91.5% of data points attaining the reference condition of ≤ 5% of total basal area (Table 4-22, Figure 4-47). Despite the high score for exotic trees and saplings, there are numerous exotic species present within NACE. Due to the randomized sampling methods of NCRN I&M, the sample locations does not detect many of these exotic species because sites are located inside the forest and away from the edge. The forests within NACE are extremely fragmented with a log of exposed forest edge, which allows for exotic species dominance. In many of the sites within NACE, where forest fragmentation has occurred, exotic species populations are able to succeed and expand.

No trend analysis was possible with the current data set.

Table 4-24 Percent basal area of exotic trees and saplings. Site locations are shown in Figure 4-38.

Site	Year	Exotic trees	Exotic saplings
NACE-0713	6/21/13	0	0
NACE-0432	6/18/13	0.8	0
NACE-0304	6/12/13	0	0
NACE-0041	6/10/13	0	0
NACE-0045	6/10/13	0	0
NACE-0269	6/6/13	1.7	0
NACE-0344	6/6/13	0	0
NACE-0055	6/5/13	0	0
NACE-0097	6/5/13	0	0
NACE-0167	6/4/13	5.7	15.1
NACE-0493	5/30/13	0	0
NACE-0586	5/30/13	0	0
NACE-0296	8/2/12	9.9	55.6
NACE-0619	7/24/12	4.9	0
NACE-0649	7/24/12	3.3	0
NACE-0310	7/16/12	1.9	1.8
NACE-0350	7/16/12	3.6	0
NACE-0453	7/11/12	0	0
NACE-0029	6/22/12	0	0
NACE-0032	6/22/12	0	0
NACE-0145	6/19/12	0	0
NACE-0080	6/18/12	0	0
NACE-0107	6/18/12	0	0
NACE-0477	9/28/11	0	0
NACE-0487	9/27/11	0	0
NACE-0341	9/19/11	4.2	0
NACE-0623	9/13/11	0	0
NACE-0021	9/8/11	0	0
NACE-0267	**9/7/11**	**12.3**	**0**

Table 4-24 (continued) Percent basal area of exotic trees and saplings. Site locations are shown in Figure 4-38.

Site	Year	Exotic trees	Exotic saplings
NACE-0081	8/23/11	0	0
NACE-0094	8/23/11	0	0
NACE-0337	6/22/11	0	0
NACE-0398	6/21/11	0	0
NACE-0621	6/17/11	0	0
NACE-0086	6/14/11	0	0
NACE-0118	6/14/11	0	0
NACE-0084	6/1/11	0	0
NACE-0282	5/27/11	0	0
NACE-0174	8/30/10	0	39
NACE-0233	8/18/10	98.4	100
NACE-0491	7/26/10	0	0
NACE-0399	7/1/10	0	0
NACE-0468	7/1/10	0	0
NACE-0087	6/22/10	0	0
NACE-0131	6/21/10	0	0
NACE-0004	5/28/10	0	0
NACE-0245	5/27/10	0	0

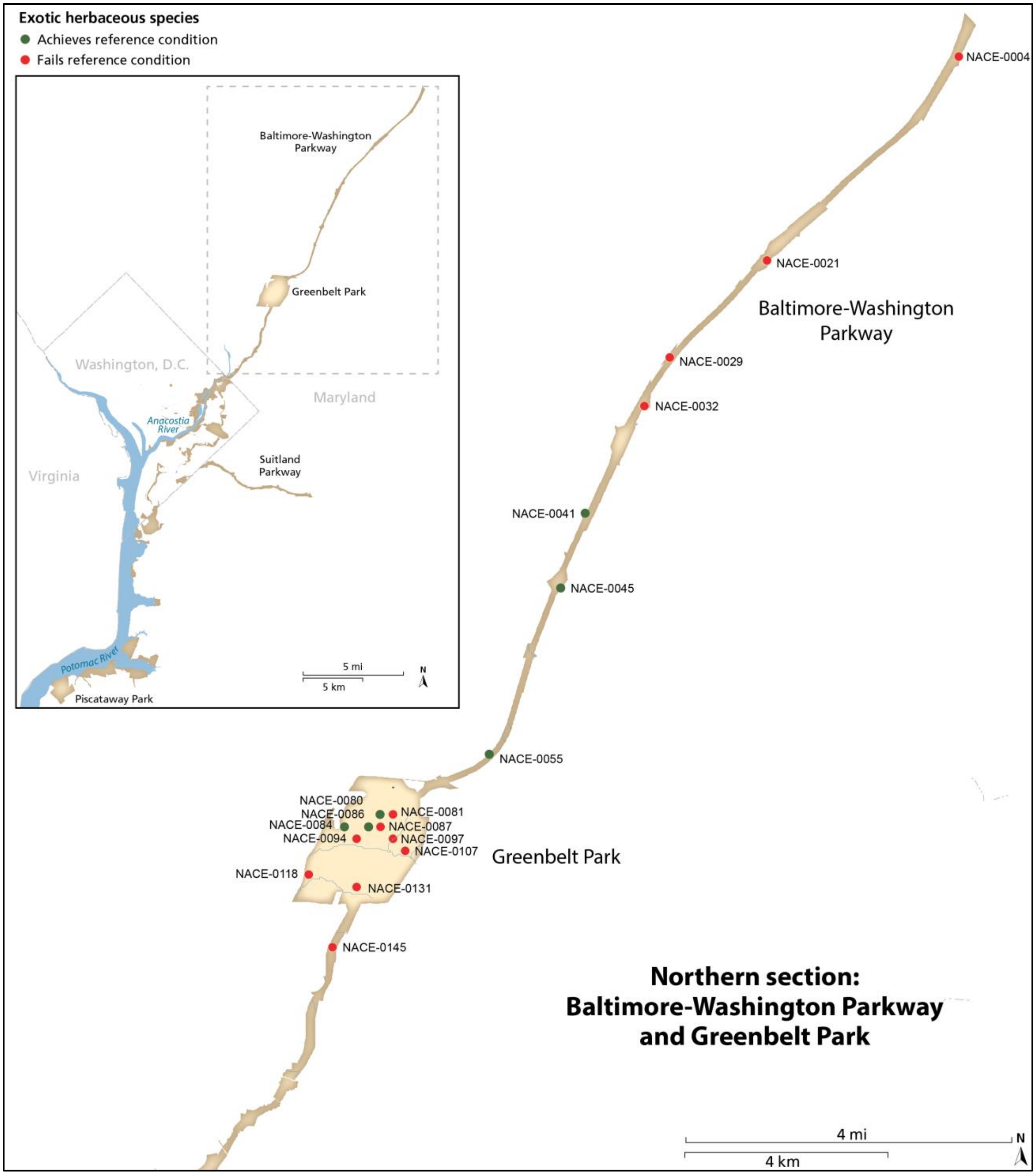

Figure 4-45 Exotic tree and sapling results by site for NACE – northern section.

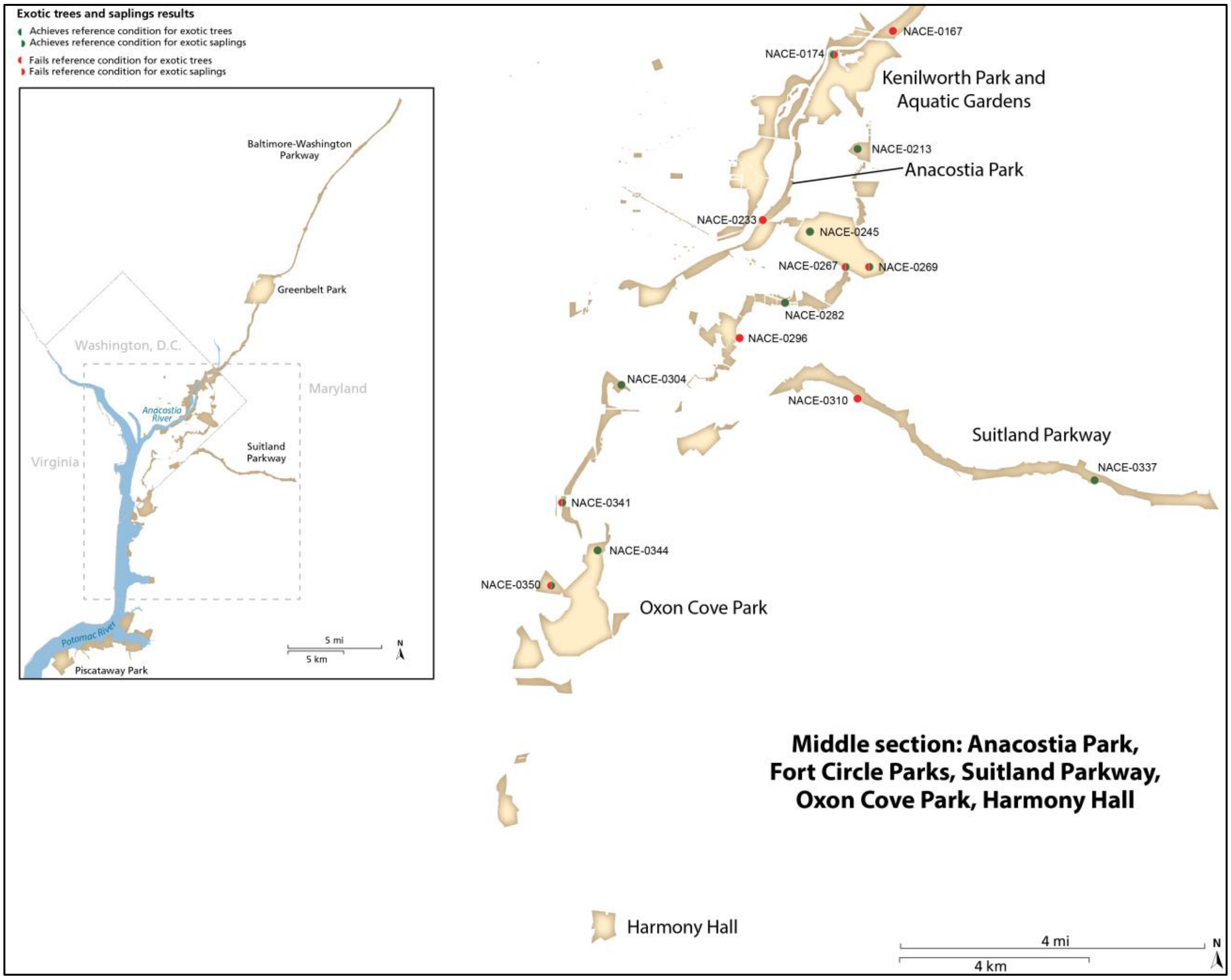

Figure 4-46 Exotic tree and sapling results by site for NACE – middle section.

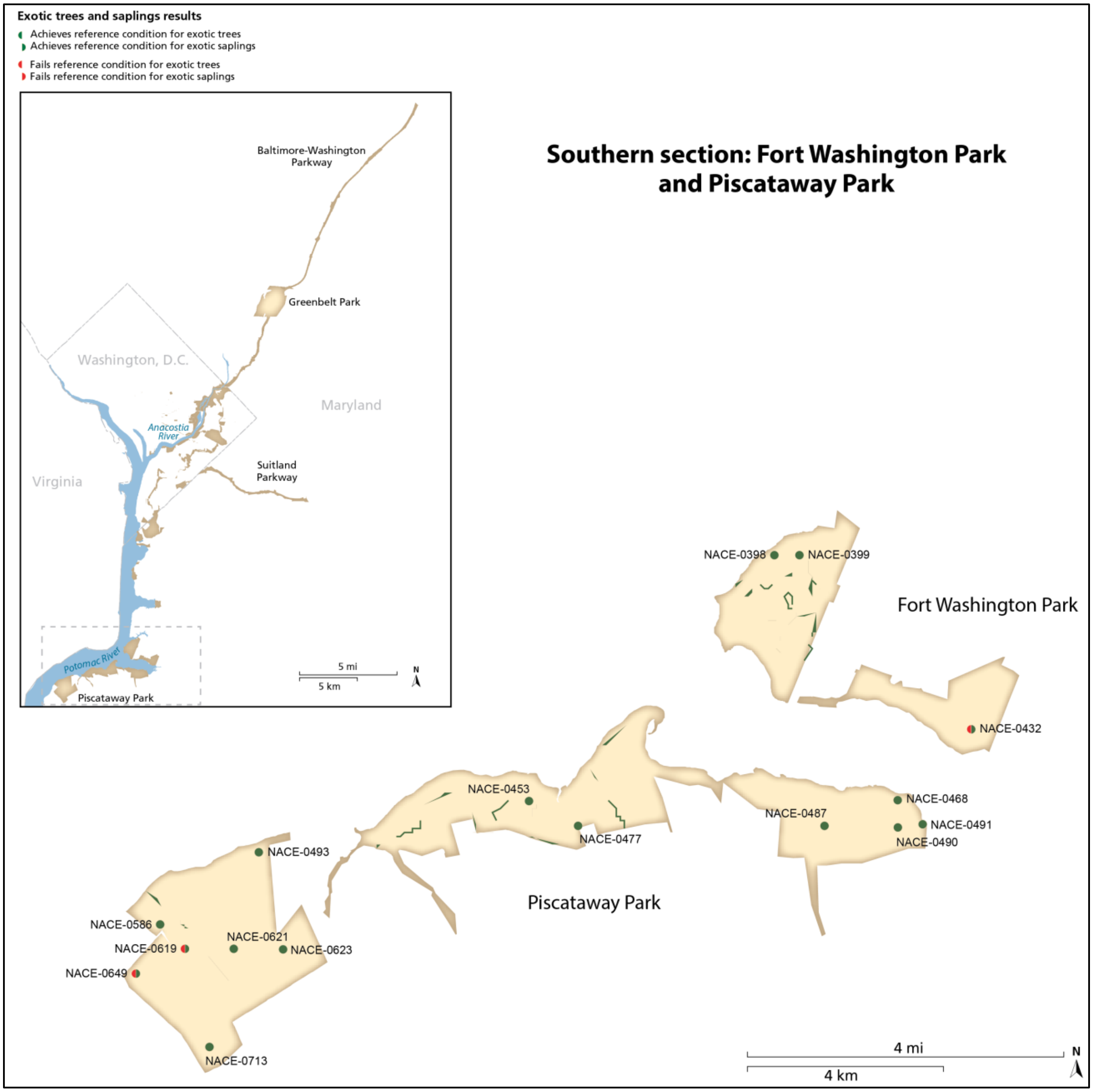

Figure 4-47 Exotic tree and sapling results by site for NACE – southern section.

<u>Sources of expertise</u>

- John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

4.3.4. Forest pests

<u>Description</u>

Emerald ash borer feeds on and kills ash trees, an important native forest canopy species, one to three years after infestation. The insect adults can fly at least ½ mile from the tree where they emerge, but humans can spread EAB much faster by moving infected wood and tree material. Preliminary results

(Knight and Long et al.) found that once infested, healthy ash stands can reach nearly 100% mortality of ash trees >1 inch diameter within six years. Initially the decline is slow and symptoms of EAB are not obvious, but later in the infestation mortality rates accelerate rapidly (NPS 2012).

The gypsy moth (*Lymantria dispar*) was accidentally introduced to North America in the late 1860s and has spread widely, resulting in an estimated 160,000 km^2 (62,500 mi^2) of forest defoliation during the 1980s alone (Liebhold et al. 1994; Montgomery 1990). Gypsy moth larvae feed on the foliage of hundreds of species of plants in North America, but its most common hosts are oak (*Quercus* spp.) and aspen (*Populus* spp.) trees (USDA Forest Service 2009a). Defoliation caused by gypsy moth caterpillars stresses and weakens trees leaving them more susceptible to secondary infections and infestations and other cumulative impacts. These impacts, both directly and indirectly caused by the gypsy moth infestation, weaken and eventually kill some forest trees. This in turn has adverse effects on water quality, wildlife and habitat, rare plants, visitor use and experience, safety, the cultural landscape and the wildland fire fuel load.

Hemlock woolly adelgid (*Adelges tsugae*) is another insect pest first reported in the eastern United States in 1951 near Richmond, Virginia (USDA Forest Service 2009b). This aphid-like insect is originally from Asia and feeds on Eastern hemlock trees (*Tsuga canadensis*), which are often damaged and killed within a few years of becoming infested.

<u>Data and methods</u>
Forest monitoring takes place annually at 47 sites but not all plots are measured every year. This analysis used data collected between 2010 and 2013 (Schmit et al. 2009) (Figure 4-38). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

The percentage of trees infested with a forest pest was calculated by dividing the number of trees afflicted by pests in each plot by the total number of trees in each plot. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Due to the destructive nature and potential for forest damage from these pests, the threshold used was established as any observation of these pests (i.e., > 1% of trees infested) being considered degraded (Table 4-21). Each data point was compared against the reference condition to determine the percent attainment and condition.

<u>Condition and trend</u>
Current condition for forest pests was very good, with a mean of 0.1% of trees infested and 95.7% of data points attaining reference condition (Table 4-25, Figure 4-48). Despite the high score for forest pests, there are numerous pest species present within NACE. Due to the randomized sampling methods of NCRN I&M, the sample locations do not detect all infested areas.

Emerald ash borer is prevalent and has already killed scattered forest populations within NACE (mostly white and green ash), and entire wetland canopies at Piscataway Park and Kenilworth Marsh (mostly pumpkin ash). As of 2014, pumpkin ash (*Fraxinus produnda*) was the seventh most common tree in NACE forests.

No trend analysis was possible with the current data set.

Table 4-25 Monitoring sites with trees with evidence of forest pest species.

Site	Year	Percent Trees with Pests
NACE-0041	2013	0
NACE-0045	2013	0
NACE-0055	2013	0
NACE-0097	2013	0
NACE-0167	2013	0
NACE-0269	2013	0
NACE-0304	2013	0
NACE-0344	2013	0
NACE-0432	2013	0
NACE-0493	2013	0
NACE-0586	2013	0
NACE-0713	2013	0
NACE-0029	2012	2.86
NACE-0032	2012	0
NACE-0080	2012	0
NACE-0107	2012	0
NACE-0145	2012	0
NACE-0296	2012	0
NACE-0310	2012	0
NACE-0350	2012	0
NACE-0453	2012	0
NACE-0619	2012	0
NACE-0649	2012	0
NACE-0021	2011	0
NACE-0081	2011	0

Table 4-25 (continued) Monitoring sites with trees with evidence of forest pest species.

Site	Year	Percent Trees with Pests
NACE-0084	2011	0
NACE-0086	2011	0
NACE-0094	2011	0
NACE-0118	2011	0
NACE-0267	2011	0
NACE-0282	2011	0
NACE-0337	2011	0
NACE-0341	2011	0
NACE-0398	2011	0
NACE-0477	2011	0
NACE-0487	2011	0
NACE-0621	2011	0
NACE-0623	2011	0
NACE-0004	2010	2.27
NACE-0087	2010	0
NACE-0131	2010	0
NACE-0174	2010	0
NACE-0233	2010	0
NACE-0245	2010	0
NACE-0399	2010	0
NACE-0468	2010	0
NACE-0491	2010	0

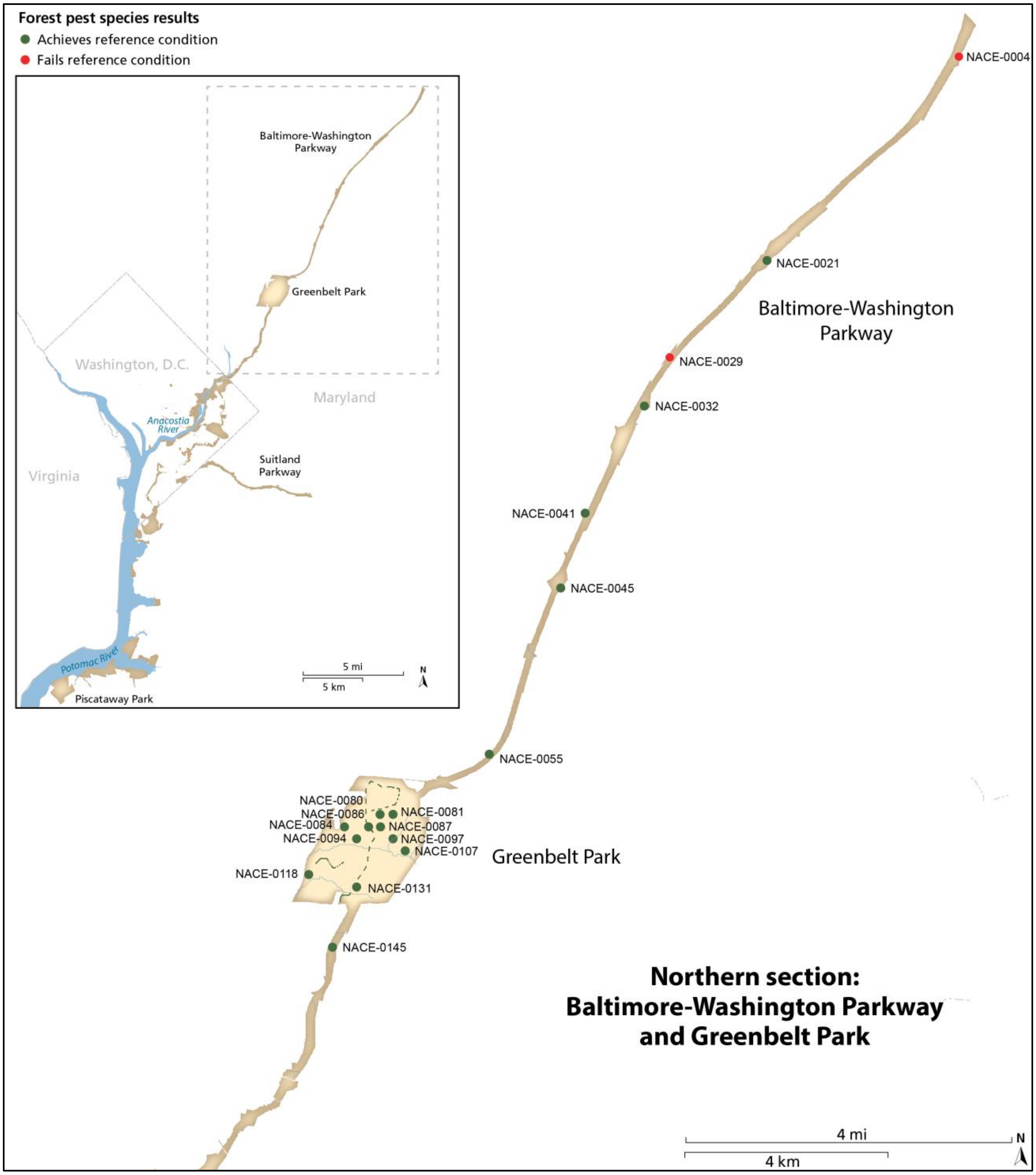

Figure 4-48 Forest pest species results by site for NACE – northern section.

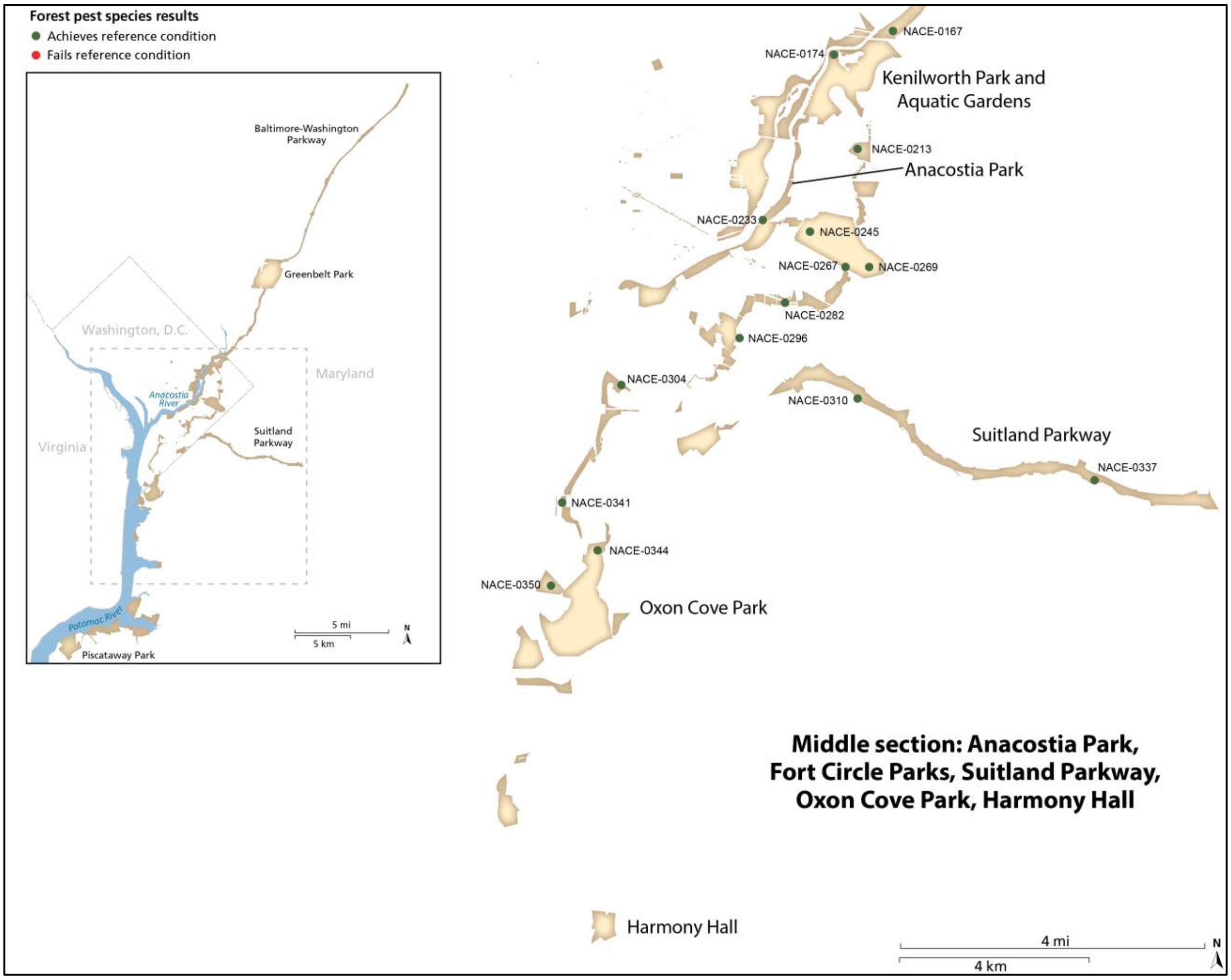

Figure 4-49 Forest pest species results by site for NACE - middle section.

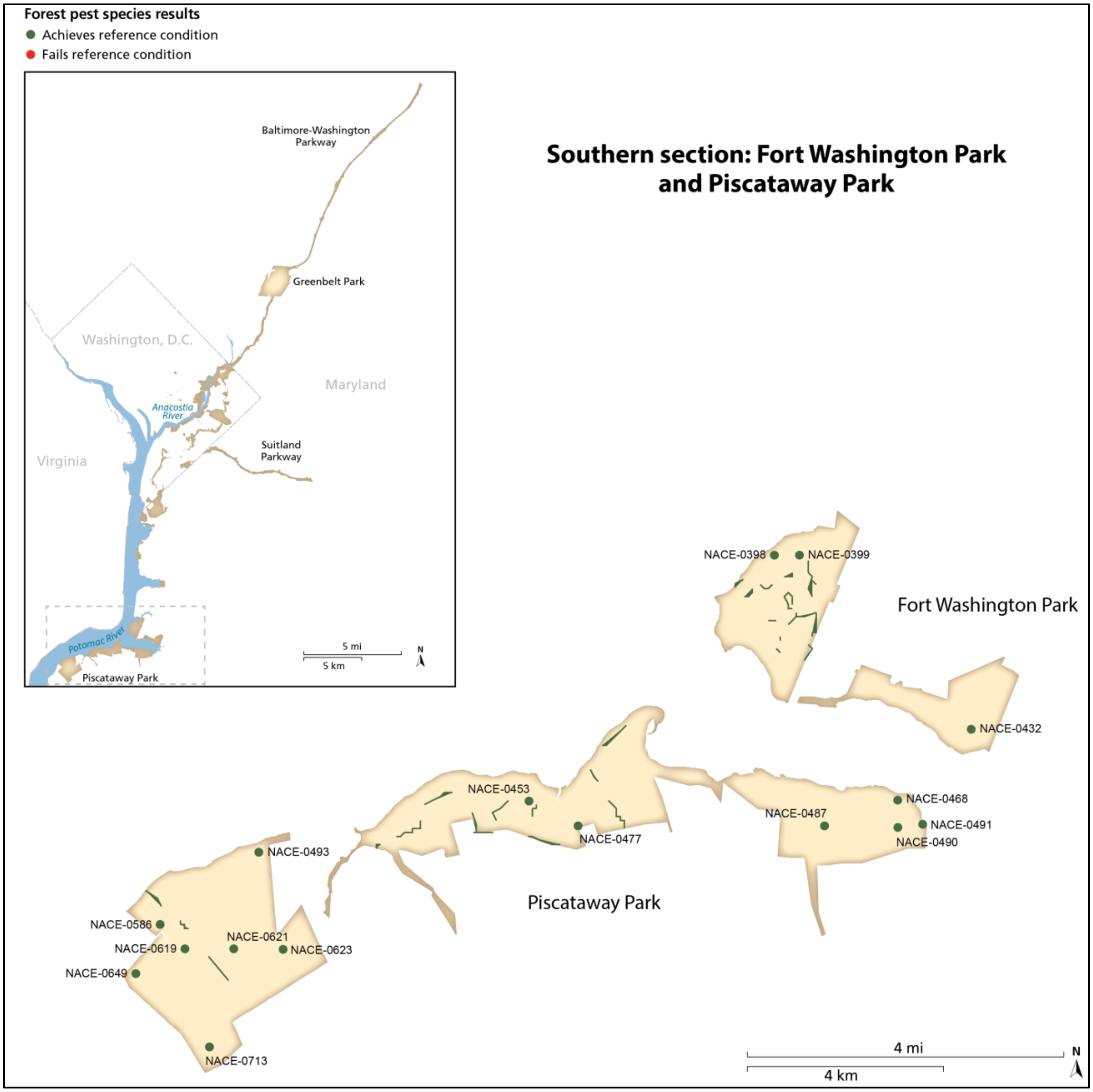

Figure 4-50 Forest pest species results by site for NACE - southern section.

<u>Sources of expertise</u>

- John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

4.3.5. Seedlings and forest regeneration

<u>Description</u>

Forests are the dominant natural vegetation in the parks of the National Capital Region Network. Many factors including dense white-tailed deer populations and fire suppression in forested regions can alter forest stand development and reduce wildlife habitat by reducing or eliminating young tree seedlings, shrubs, and herbaceous plants (Tierson et al. 1996; Jordan 1967; Marquis 1981; Tilghman 1989; Horsely et al. 2003; Coté et al. 2004; Nowacki and Abrams 2008). In response to regeneration concerns, scientists at the U.S. Forest Service developed a measure, called the 'stocking index' to determine if regeneration is sufficient (Marquis and Bjorkman 1982). The index takes into account three different aspects of forest regeneration: the number of seedlings recorded, the size of the seedlings, and the geographic distribution of the seedlings. The more seedlings and small saplings present the better. Size is important, as taller seedlings are more likely to survive than smaller seedlings. Finally, a forest is more likely to successfully regenerate if the seedlings are spread out than if they are concentrated in only a few places (Schmit and Nortrup 2013).

Data and methods

Forest monitoring takes place annually but not all plots are measured every year (Schmit et al. 2009) (Figure 4-38). This analysis looked at data gathered from 2010-2013. Seedling and forest regeneration in NACE is sampled at 47 sites, grouped into 4 areas: Baltimore-Washington Parkway (BAWA), Greenbelt Park (GREE), the middle portion of NACE including Kenilworth Park and Aquatic Gardens, Suitland Parkway, and Oxon Cover Park (NACE), and Piscataway Park and Fort Washington (PISC). To minimize soil compaction and trampling of the understory, plots are sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed. At each plot, seedlings within twelve quadrats were counted and the height of each seedling was determined. Based on these measurements, each plot is given a score, with older/larger seedlings and saplings receiving a higher score than smaller plants. Seedlings were defined as trees less than 1 cm diameter at breast height and at least 15 cm in height. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

The Stocking Index reference condition used in this assessment was 115, above which a plot is considered to be adequately stocked at high densities of white-tailed deer (Table 4-21). This threshold is used in forests with high deer density to take into account deer browse effects on seedling growth and survival (Schmit and Nortrup 2013). Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. An entire park is considered to be adequately stocked if 67% of plots score above the threshold (Schmit and Nortrup 2013).

Condition and trend

Current condition for tree seedling regeneration in NACE was very degraded, with a median stocking index value of 19.3 and 6.38% of data points attaining reference condition of > 115 (Table 4-26, Figure 4-51, Figure 4-52, Figure 4-53). The sections for GREE and PISC (which includes Fort Washington) have the highest median stocking index values for the time period sampled (32.8 and 30.6, respectively) yet these two values still fall in the inadequately stocked class. BAWA had a median seedling stocking index of 13.6, and the remainder of NACE had a stocking index of 7.25 (Table 4-27). Over the data range available, no significant trend was present (p-value > 0.01).

Table 4-26 Stocking Index values.

Plot	Park	Stocking index
NACE-0004	BAWA	16.25
NACE-0021	BAWA	25.25
NACE-0029	BAWA	21.75
NACE-0032	BAWA	11.00
NACE-0041	BAWA	8.00
NACE-0045	BAWA	8.00
NACE-0055	BAWA	9.25
NACE-0080	GREE	0
NACE-0081	GREE	58.50
NACE-0084	GREE	6.00
NACE-0086	GREE	4.25
NACE-0087	GREE	36.00
NACE-0094	GREE	223.25
NACE-0097	GREE	25.25
NACE-0107	GREE	10.50
NACE-0118	GREE	39.00
NACE-0131	GREE	44.00
NACE-0145	BAWA	52.25
NACE-0167	BAWA	71.25
NACE-0174	NACE	7.25
NACE-0233	NACE	0
NACE-0245	NACE	12.25
NACE-0267	NACE	3.00
NACE-0269	NACE	10.50
NACE-0282	NACE	44.00
NACE-0296	NACE	10.25
NACE-0304	NACE	167.00
NACE-0310	NACE	40.25
NACE-0337	NACE	4.00

Table 4-26 (continued) Stocking Index values.

Plot	Park	Stocking index
NACE-0341	NACE	1.00
NACE-0344	NACE	2.00
NACE-0350	NACE	3.00
NACE-0398	PISC	65.75
NACE-0399	PISC	32.25
NACE-0432	PISC	36.00
NACE-0453	PISC	32.75
NACE-0468	PISC	40.25
NACE-0477	PISC	5.00
NACE-0487	PISC	13.75
NACE-0491	PISC	38.25
NACE-0493	PISC	19.25
NACE-0586	PISC	5.00
NACE-0619	PISC	2.00
NACE-0621	PISC	22.00
NACE-0623	PISC	162.25
NACE-0649	PISC	54.25
NACE-0713	PISC	37.25

Table 4-27 Median Stocking Index values for the four park units monitored in NACE (2006-2013).

Park Unit	# of Sites	Median Stocking Index Value (2005-2013)
BAWA	9	13.60
GREE	10	30.60
NACE	13	7.25
PISC	15	32.80

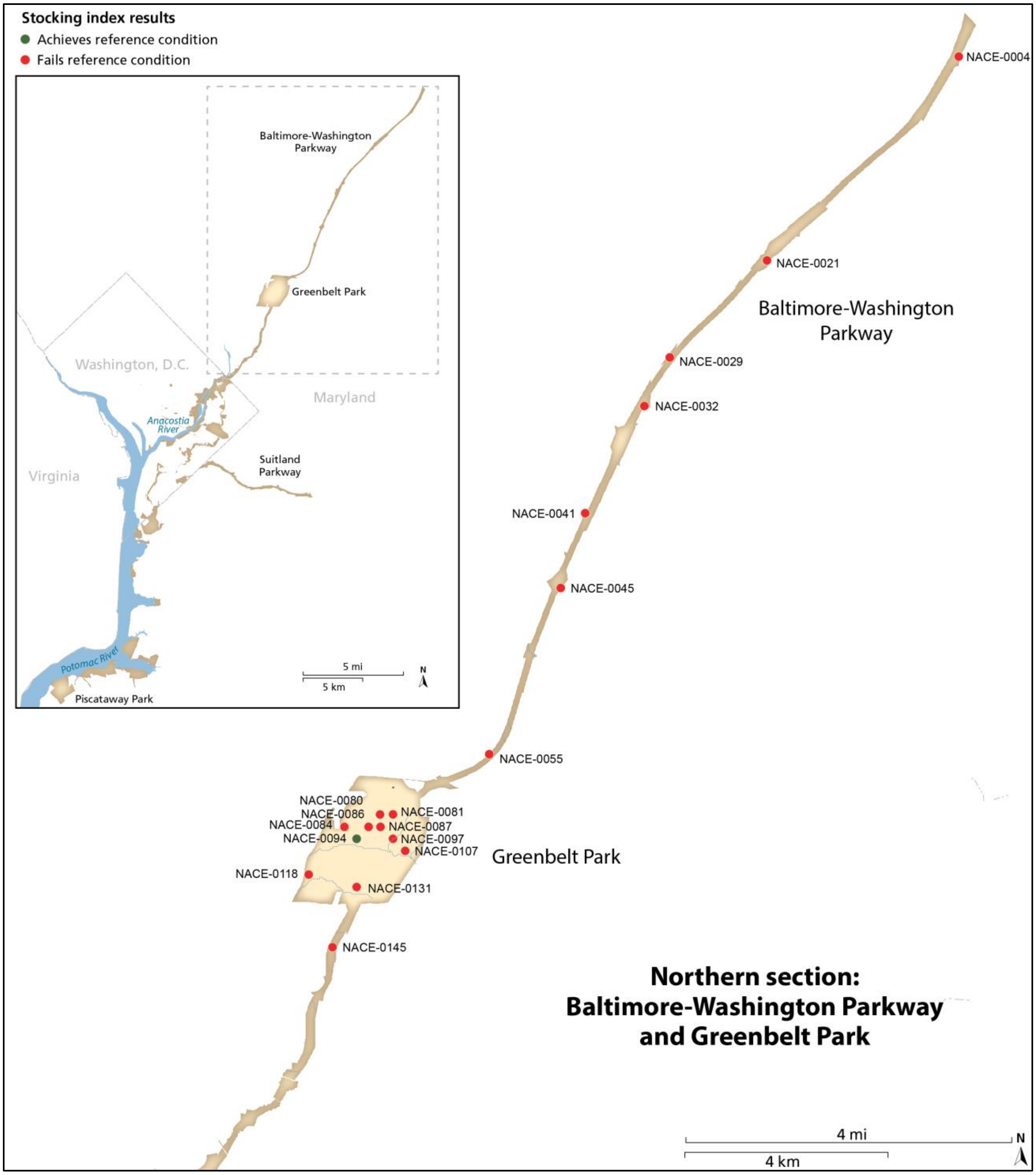

Figure 4-51 Stocking index results by site for the northern section of NACE – northern section.

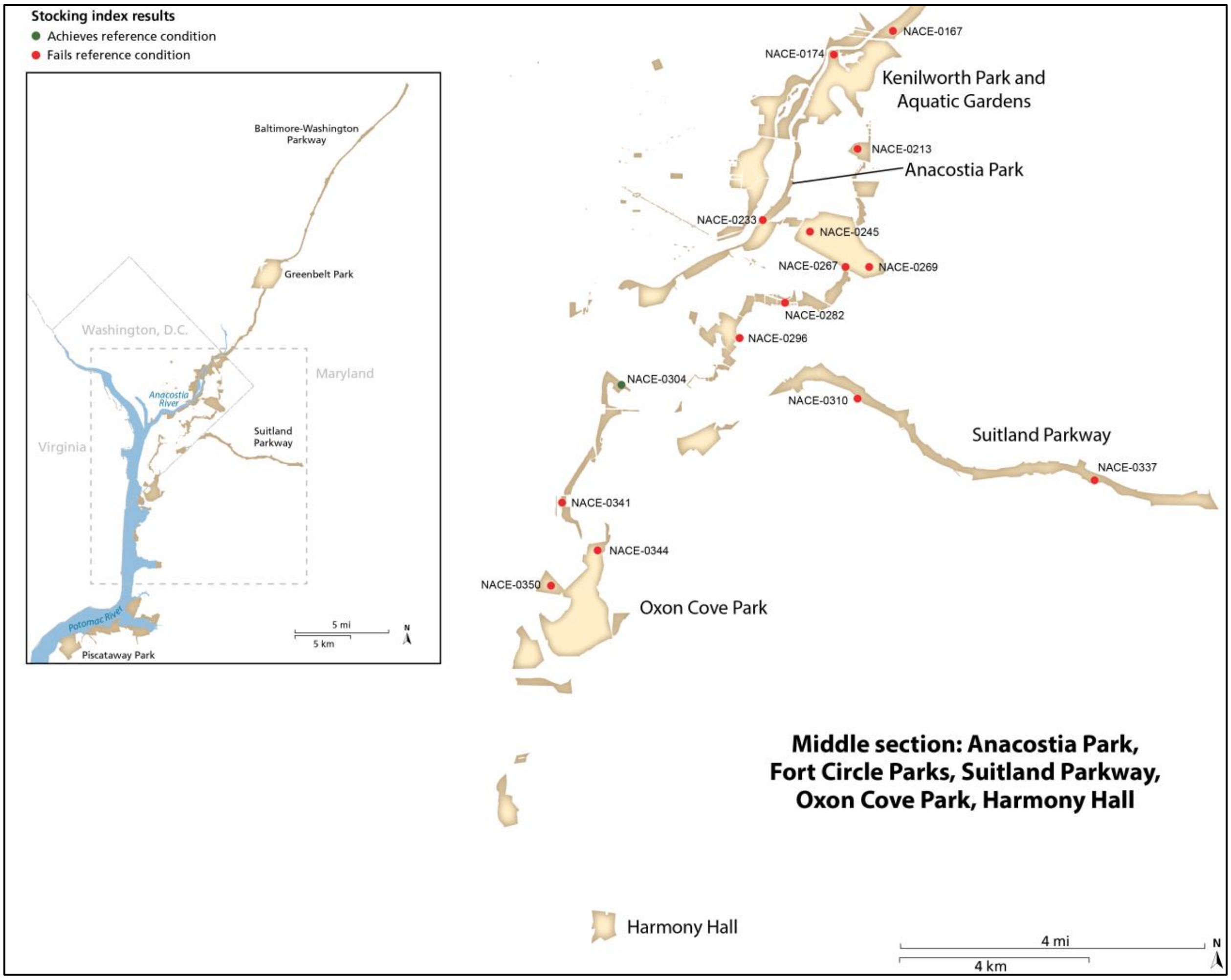

Figure 4-52 Stocking index results by site for the middle section of NACE – middle section.

Figure 4-53 Stocking index results by site for the southern section of NACE – southern section.

<u>Sources of expertise</u>

- John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

4.3.6. Fish

<u>Description</u>

The Fish Index of Biotic Integrity (FIBI) was proposed as a way of providing a more informative measure on anthropogenic influence on fish communities and ecological integrity than measurements of physiochemical metrics alone (Karr 1981). The metric was then adapted and validated for streams of Maryland using a reference condition approach, based on 1994-1997 data from a total of 1,098 sites.

Data and methods

Data were collected at four sites during 2004, 2006, and 2012 following the National Capital Region Biological Stream Survey protocol (Norris and Sanders 2009). Sites were classified based on physical and chemical data and fish assemblages were compared to identified reference sites. Within the parks that make up NACE, monitoring is done in Accokeek Creek (Piscataway Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove Park), and Still Creek (Greenbelt Park). Streams monitored are small (first- to third- order) and non-tidal. At each site, monitoring teams electrofish two passes along a designated 75-meter stream segment. Captured fish are counted, identified to species, weighed in aggregate, and released (Nortrup 2014). Reported data are for one FIBI assessment per site.

FIBI values were ranked as follows: 1.0-1.9 (very poor), 2.0-2.9 (poor), 3.0-3.9 (fair), 4.0-5.0 (good), and these were the scale and categories used in this assessment (Southerland et al. 2007). The range of FIBI scores from 1 to 5 were scaled linearly from 0 to 100% attainment. The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment.

Table 4-28 Fish Index of Biotic Integrity (FIBI) categories, percent attainment, and condition assessment.

FIBI range	% Attainment	Condition
4.0-5.0	75-100	Good
3.0-3.9	50-<75	Fair
2.0-2.9	25-<50	Poor
1.0-1.9	0-<25	Very poor

Condition and trends

Current condition of FIBI in NACE was fair, with a median FIBI of 4.33 and 85.7% attainment of reference condition (Figure 4-29, Figure 4-54, Figure 4-55). In 2013, all four streams had a wide range of fish species present. Six Maryland-threatened pearl dace (*Margariscus margarita*) were found in Henson Creek.

No trend analysis was possible with the current data set.

Table 4-29 Fish Index of Biotic Integrity (FIBI) in NACE. Monitoring sites are shown in Figure 4-40.

Year	Site	Site Name	FIBI
2013	ACCO-214-N-2013	Accokeek Creek	4.33
2013	PRUT-201-N-2013	Henson Creek	4.33
2013	OXON-301-N-2013	Oxon Run	4.00
2013	ANAC-113-N-2013	Still Creek	4.33
2006	OXON-301-N-2006	Oxon Run	1.33
2004	ANAC-113-N-2004	Still Creek	3.33
2004	ACCO-214-N-2004	Accokeek Creek	4.33

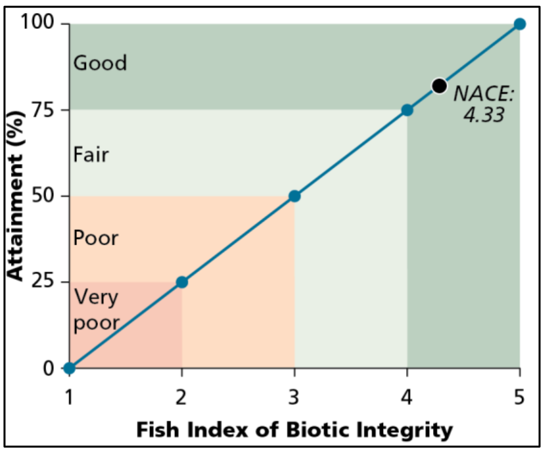

Figure 4-54 Application of the percent attainment categories to the Fish Index of Biotic Integrity (FIBI) value categories. FIBI at NACE was 4.33, which equated to 85.7% attainment of the reference condition.

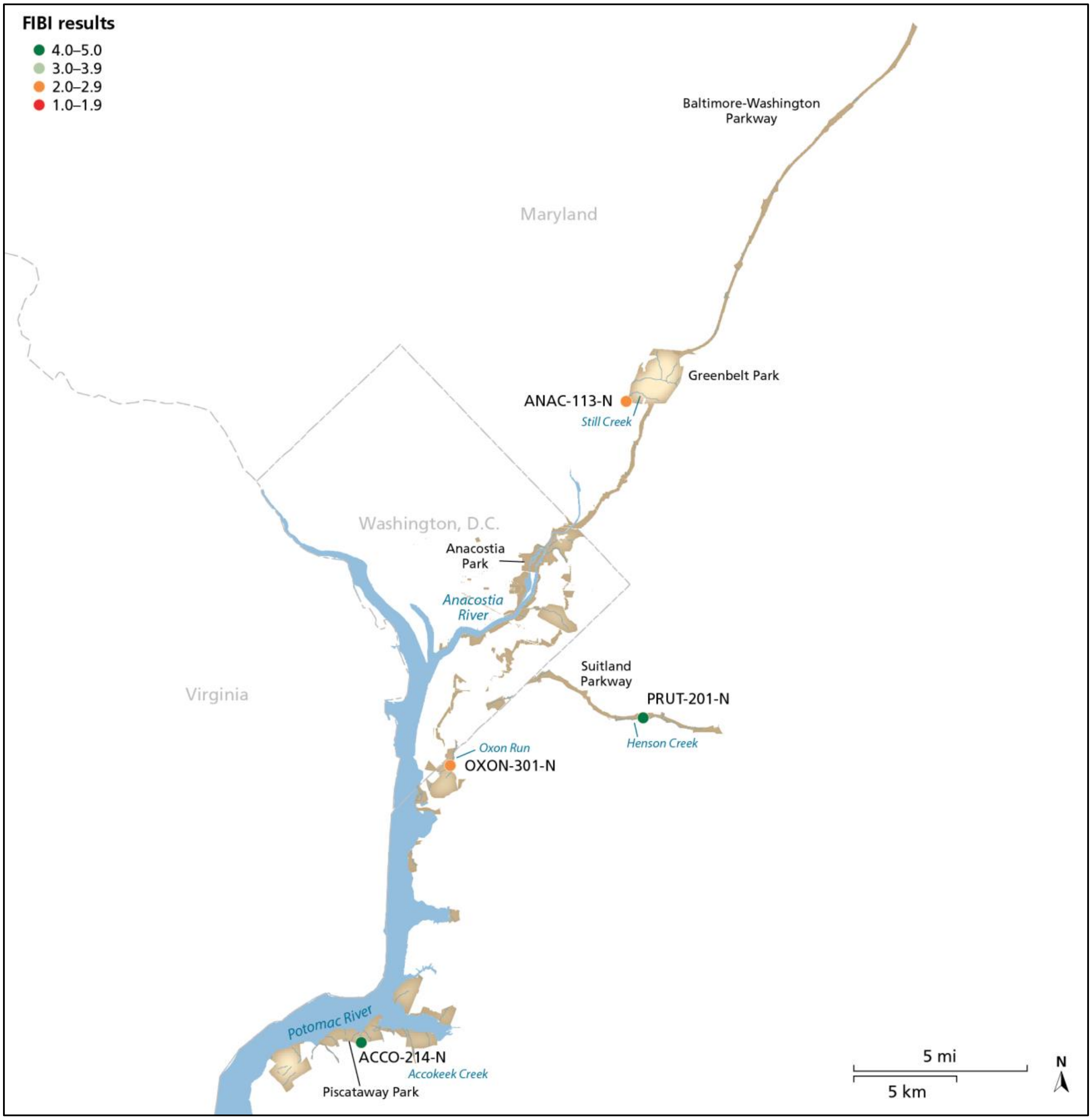

Figure 4-55 Attainment of Fish Index of Biotic Integrity (FIBI) reference condition by site for 4 sampling locations in NACE.

<u>Sources of expertise</u>

- Marian Norris, Water Resources Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

4.3.7. Birds

Description

Birds exhibit numerous characteristics that make them appropriate as ecological indicators. They are conspicuous components of terrestrial ecosystems in the National Capital Region, they can integrate conditions across major habitat types, and many require specific habitat conditions (O'Connell et al. 1998).

Modeled after previously developed Indices of Biotic Integrity (IBIs), a Bird Community Index (BCI) was developed as a multi-resource indicator of biotic integrity in the central Appalachians (O'Connell et al. 1998).

Data and methods

Data was available for 30 sites between 2007 and 2013 (Figure 4-38, Figure 4-39, and Figure 4-40). Point count data was used to calculate the BCI using the O'Connell et al. (1998) scoring and guild assignments for the Appalachian bird conservation region (Ladin and Shriver 2013). BCI scores were ranked as follows: highest integrity (60.1– 77.0), high integrity (52.1– 60.0), medium integrity (40.1–52.0), and low integrity (20.0–40.0). These were the scale and categories used in this assessment (O'Connell et al. 1998) (Table 4-21).

Each of the four BCI value categories was assigned a percent attainment range. Each BCI value was compared to these reference conditions and given a percent attainment and converted to a condition assessment.

Condition and trend

The 2007-2013 BCI in NACE showed medium integrity, with a median of 47.0 and a value of 39.4% attainment of reference condition (Table 4-30, Table 4-22, Figure 4-56, Figure 4-59). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4-60).

Table 4-30 Median Bird Community Index (BCI) at all bird monitoring sites within NACE. Monitoring site locations shown in Figure 4-23.

Year	BCI Score
2013	47.0
2012	47.0
2011	45.5
2010	47.0
2009	47.0
2008	45.0
2007	46.5

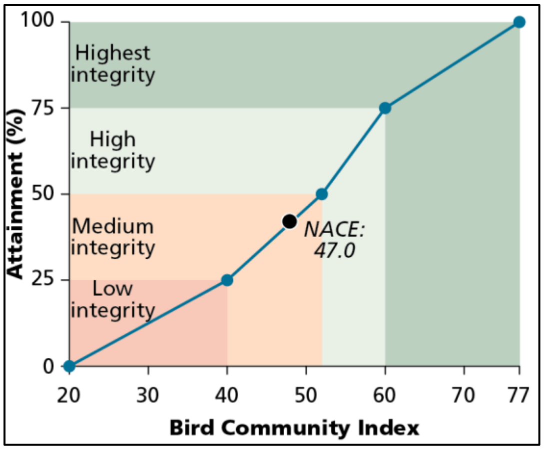

Figure 4-56 Application of the percent attainment categories to the Bird Community Index (BCI) value categories. BCI at NACE was 47.0, which equated to 39.4% attainment of the reference condition.

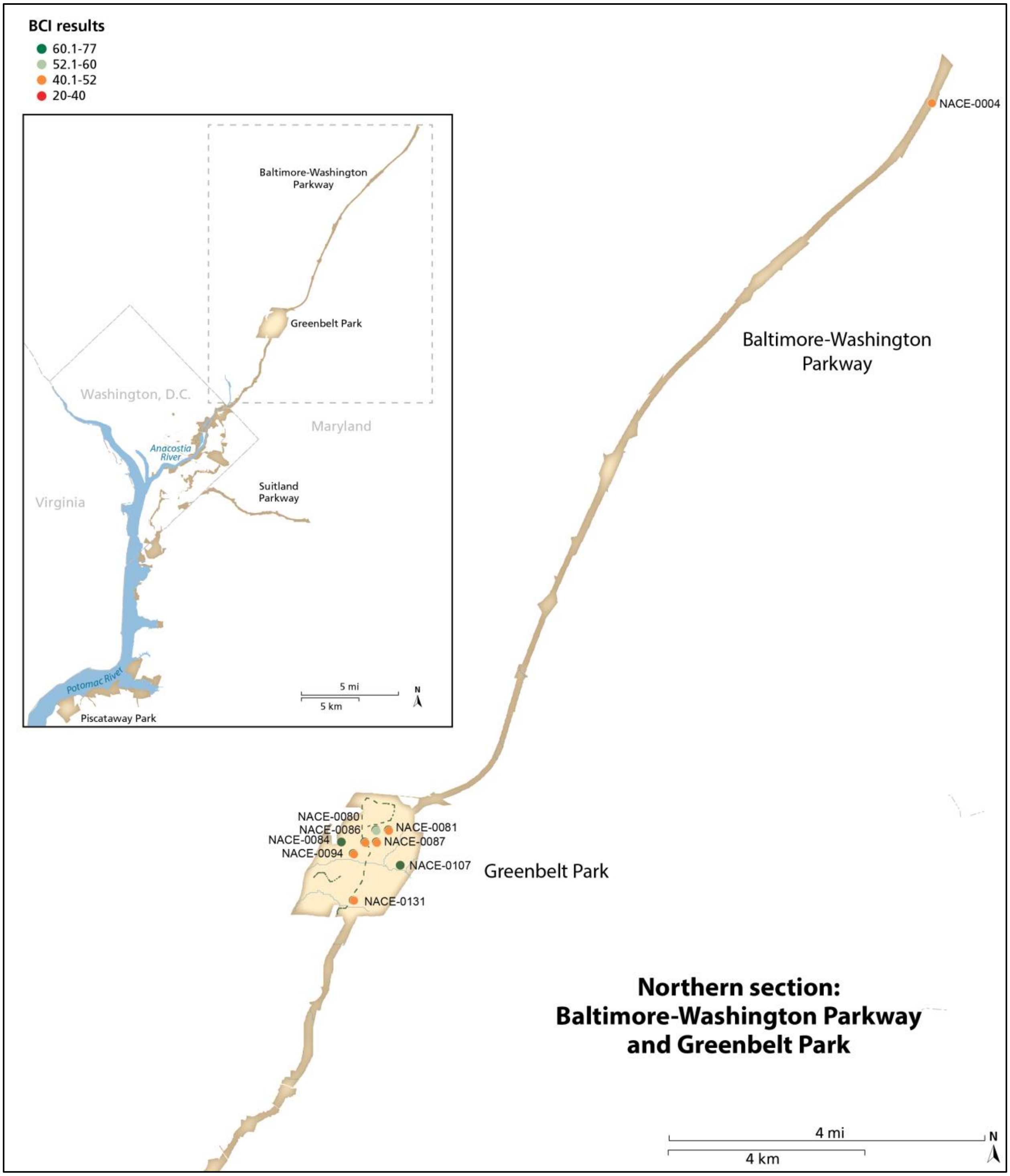

Figure 4-57 BCI results for bird monitoring sites in NACE – northern section. Result is the median BCI value from 2007-2013 sampling period.

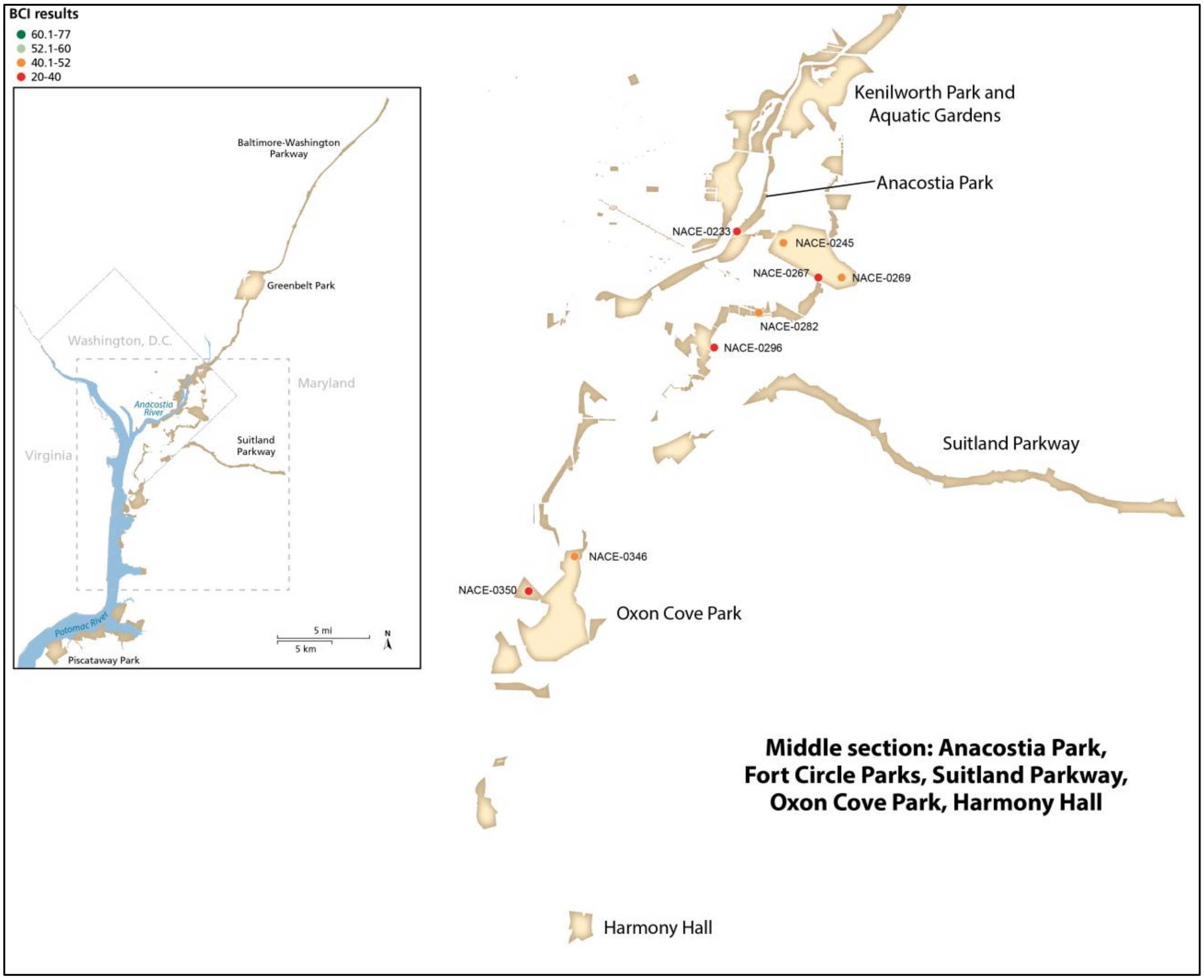

Figure 4-58 BCI results for bird monitoring sites in NACE – middle section. Result is the median BCI value from 2007-2013 sampling period.

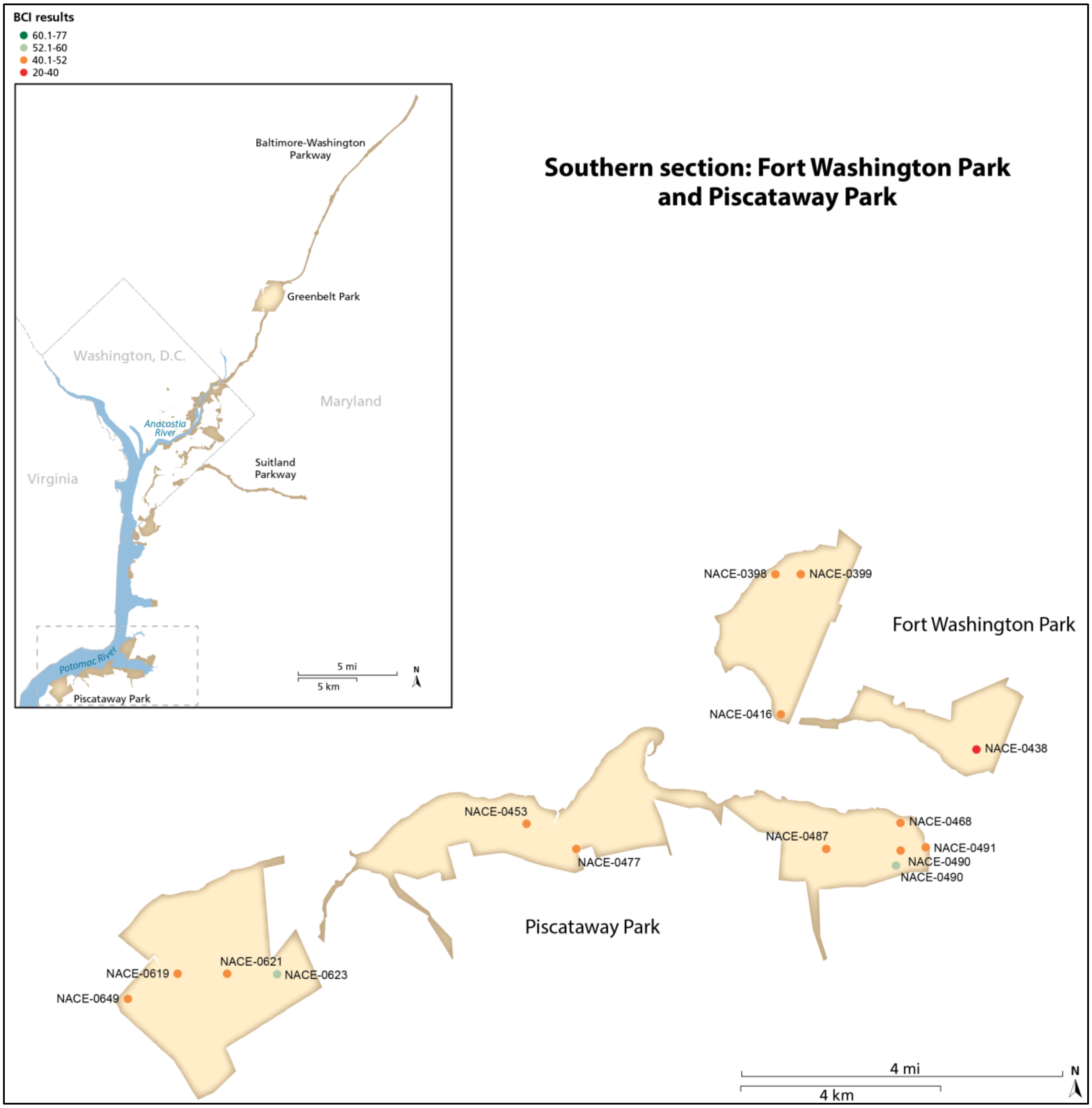

Figure 4-59 BCI results for bird monitoring sites in NACE – southern section. Result is the median BCI value from 2007-2013 sampling period.

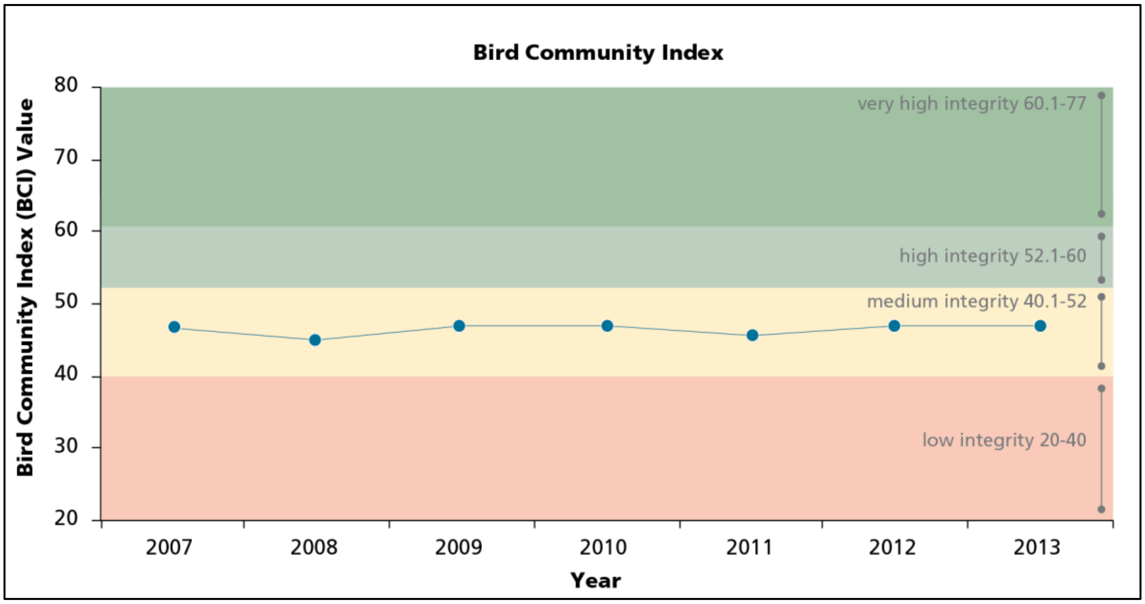

Figure 4-60 Median Bird community index (BCI) values at all sites in NACE between 2007 and 2013. Reference conditions are shown on right with gray bars.

Sources of expertise

- John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

4.3.8. Deer density

Description

White-tailed deer (*Odocoileus virginianus*) are considered a significant stressor on forests of the National Capital Region. White-tailed deer densities throughout the eastern deciduous forest zone increased rapidly during the latter half of the 20th century and may now be at historically high levels. McCabe and McCabe (1997) estimate that pre-European deer densities in the eastern United States ranged between 3.1 and 4.2 deer/km^2 (8.0 and 10.9 deer/ mi^2) in optimal habitats. Today, examples of deer populations exceeding 20 deer/ km^2 (52 deer/ mi^2) are commonplace (e.g., Knox 1997; Russell et al. 2001; Augustine and deCalesta 2003; Rossel Jr. et al. 2005; Griggs et al. 2006; McDonald Jr. et al. 2007).

The currently high population numbers for white-tailed deer regionally have been recognized since the 1980s as being of concern due to potentially large impacts upon regeneration of woody tree species as well as the occurrence and abundance of herbaceous species and consequent alterations to trophic interactions (deCalesta 1997; Waller and Alverson 1997; Côté et al. 2004). Besides directly impacting vegetative communities, deer overbrowsing can contribute to declines in breeding bird abundances by decreasing the structural diversity and density in the forest understory (McShea and Rappole 1997).

Data and methods

Deer population density was estimated annually within three units of NACE: Greenbelt Park (MD) and Piscataway Park (MD) 2001 to 2014, and at Fort Washington (MD) 2009 to 2014, using the distance survey method (Bates 2006, 2009) (Figure 4-31, Table 4-18). Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. For the purpose of this assessment, the last 10 years of data (2004-2014) was used to obtain the percent attainment. Trend analysis was completed on all data available (2001-2014).

The forest threshold for white-tailed deer density (8.0 deer/ km^2 [21 deer/ mi^2]) is a well-established ecological threshold (Horsley et al. 2003) (Table 4.21). Species richness and abundance of herbs and shrubs are consistently reduced as deer densities approach 8.0 deer/ km^2 (21 deer/ mi^2), although shown in some studies to change at densities as low as 3.7 deer/ km^2 (9.6 deer/ mi^2) (deCalesta 1997). One large manipulation study in central Massachusetts found deer densities of 10–17 deer/ km^2 (26–44 deer/mi^2) inhibited the regeneration of understory species, while densities of 3–6 deer/ km^2 (8–16 deer/mi^2) supported a diverse and abundant forest understory (Healy 1997). There are multiple sensitive species of songbirds that cannot be found in areas where deer grazing has removed the understory vegetation needed for nesting, foraging, and protection. Even though songbird species vary in how sensitive they are to increases in deer populations, these changes generally occur at deer densities greater than 8 deer/km^2 (21 deer/mi^2) (deCalesta 1997). Annual densities were compared against the reference condition to determine the percent attainment and condition.

Condition and trend

Current condition of deer population density (2004-2014) in NACE was very degraded, with 0% of years attaining the reference condition of < 8.0 deer/km^2. Population estimates for deer population for 2004–2014 exceeded the reference condition of < 8 deer/km^2 in all sampling years in all sampling locations, with a median of 40.0 deer/km^2 in Greenbelt Park, 30.1 deer/km^2 in Piscataway Park, and 86.2 deer/km^2 in Fort Washington.

In Piscataway Park, deer densities have been lower for seven of the last eight years, and it is now a statistically significant decrease. Biologically, deer continue to have a negative impact on native vegetation. The Moyoane Reserve community within the park has been culling 50-90 deer annually for the past eight years and may be helping to decrease the density. In Greenbelt Park, deer density has increased significantly over the last five years. Between 2001 and 2009 it was common to see between 7 and 18 groups per night. Since 2011, an average of 25 or more groups per night has been recorded. In Fort Washington, there is not a significant trend in deer densities. (Figure 4-61, Figure 4-62, Figure 4-63).

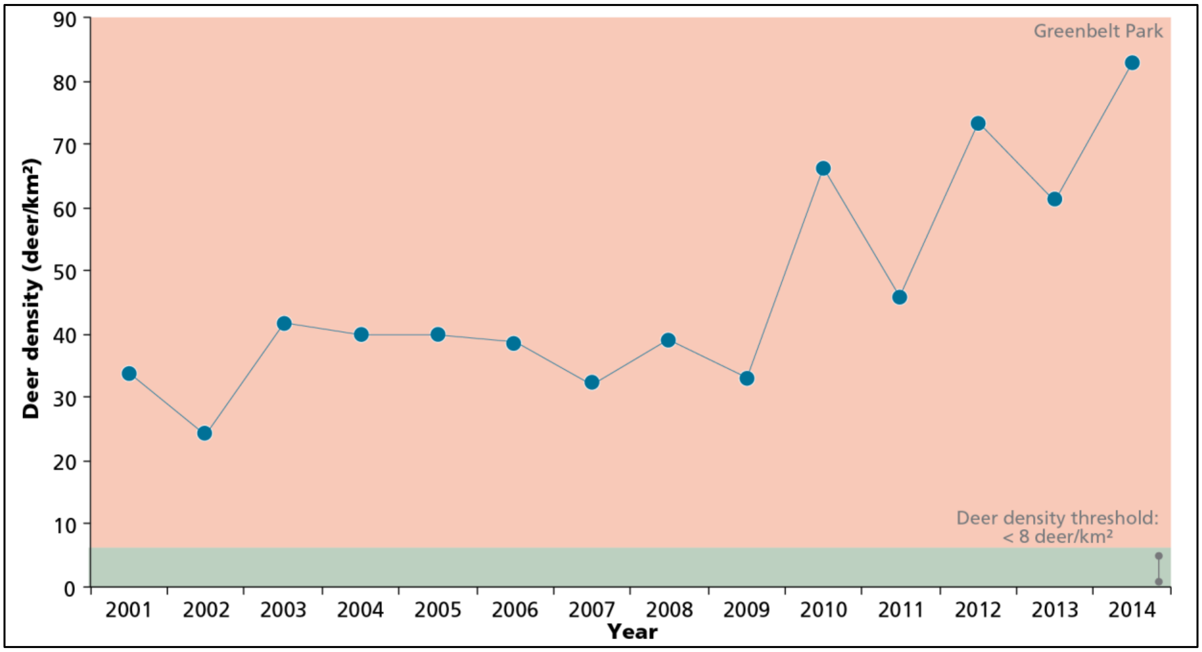

Figure 4-61 Annual mean deer density (deer/km^2) from 2001 to 2014 at Greenbelt Park. Reference condition (< 8 deer/km^2) is shown in gray.

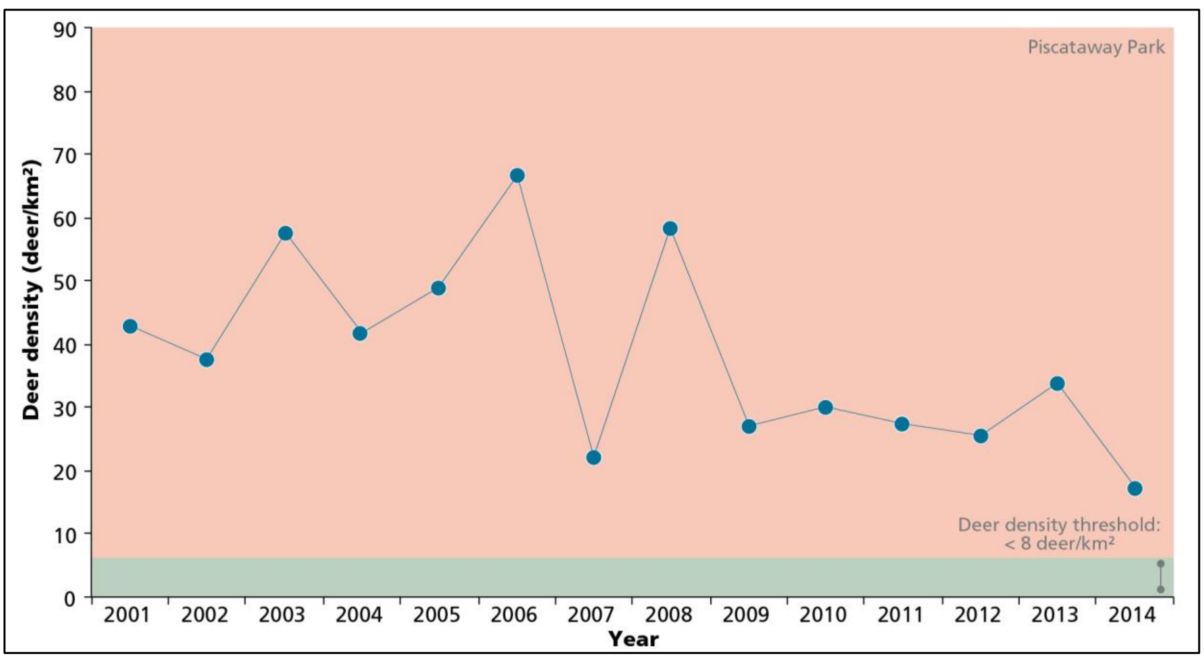

Figure 4-62 Annual mean deer density (deer/km^2) from 2001 to 2014 at Piscataway Park. Reference condition (< 8 deer/km^2) is shown in gray.

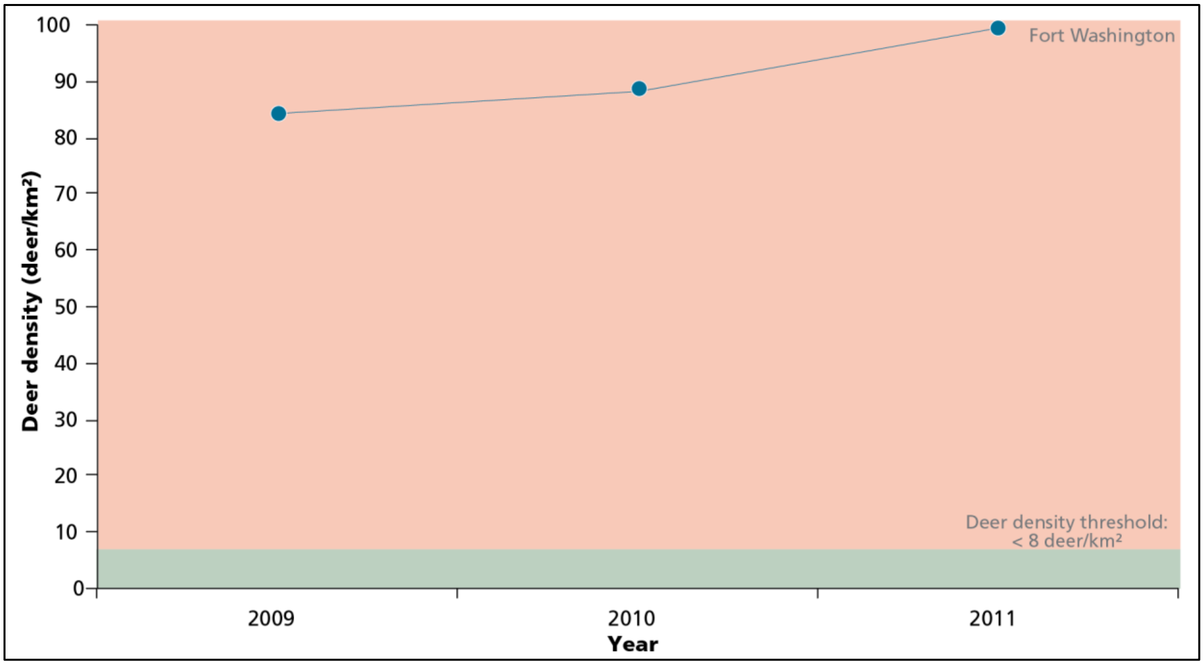

Figure 4-63 Annual mean deer density (deer/km^2) from 2009 to 2011 at Fort Washington. Reference condition (< 8 deer/km^2) is shown in gray.

<u>Sources of expertise</u>

- Scott Bates, Wildlife Biologist, National Park Service, Center for Urban Ecology.

4.4. Landscape dynamics

4.4.1. Landscape dynamics summary

Four metrics were used to assess landscape dynamics in NACE—forest interior area, forest cover, impervious surface, and road density (measured at two different scales) (Table 4-31). Data from the 2011 National Land Cover database and the 2010 ESRI Streets layer were analyzed by National Capital Region Network (NRCN) Inventory & Monitoring (I&M) staff (ESRI 2010; NPS 2010a; NPS 2010b; Fry et al. 2011; Jin et al. 2013).

The two spatial scales used for the analyses were: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary. Because of minimum are requirements for NLCD analyses, all parcels and park units within NACE were evaluated as a whole. The purpose of this analysis is to assess the influence on ecosystem processes of land use immediately surrounding the park.

Reference conditions were established for each metric (Table 4-32) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric. This resulted in an overall landscape dynamics condition attainment of 3%, or very degraded condition (Table 4-33).

Table 4-31 Ecological monitoring framework data for Landscape Dynamics provided by agencies and specific sources included in the assessment of NACE.

Metric	Agency	Reference/Source
Forest interior area (within park)	NPS NPScape, National Land Cover Database 2011	NPS 2010a, Jin et al. 2013; NPS 2014a
Forest interior area (within park + 5x buffer)	NPS NPScape, National Land Cover Database 2011	NPS2010a, Jin et al. 2013; NPS 2014a
Forest cover (within park)	NPS NPScape, National Land Cover Database 2011	NPS2010a, Jin et al. 2013; NPS 2014a
Forest cover (within park + 5x buffer)	NPS NPScape, National Land Cover Database 2011	NPS2010a, Jin et al. 2013; NPS 2014a
Impervious surface (within park)	NPS NPScape, National Land Cover Database 2011	NPS2010a, Jin et al. 2013; NPS 2014a
Impervious surface (within park + 5x buffer)	NPS NPScape, National Land Cover Database 2011	NPS2010a, Jin et al. 2013; NPS 2014a
Road density (within park)	NPS NPScape	NPS2010b; NPS 2014b
Road density (within park + 5x buffer)	NPS NPScape	NPS2010b; NPS 2014b

Table 4-32 Landscape Dynamics indicators, data availability, reference conditions, and condition assessment categories used in the natural resource condition assessment of National Capital Parks-East.

Landscape dynamics indicators	Number of sites	Number of samples	Period of observation	Reference condition	Percent attainment applied
Forest interior area (within park)	Park	1	2011	% of total potential forest area translates to % attainment	0-100% Scaled linearly
Forest interior area (within park + 5x buffer)	Park	1	2011	% of total potential forest area translates to % attainment	0-100% Scaled linearly
Forest cover (within park)	Park	1	2011	> 59%	0-100% Scaled linearly
Forest cover (within park + 5x buffer)	Park	1	2011	> 59%	0-100% Scaled linearly
Impervious surface (within park)	Park	1	2011	< 10%	0-100% Scaled linearly
Impervious surface (within park + 5x buffer)	Park	1	2011	< 10%	0-100% Scaled linearly
Road density (within park)	Park	1	2010	< 1.5 km/km^2	0-100% Scaled linearly
Road density (within park + 5x buffer)	Park	1	2010	< 1.5 km/km^2	0-100% Scaled linearly

Table 4-33 Summary of resource condition assessment of Landscape Dynamics at NACE.

Landscape dynamics indicator	NACE result	Percent attainment of reference condition	Condition assessment	Overall landscape dynamics condition
Forest interior area (within park)	18.8%	19%	Very degraded	3.4% Very degraded
Forest interior area (within park + 5x buffer)	8.2%	8%	Very degraded	
Forest cover (within park)	48.8%	0%	Very degraded	
Forest cover (within park + 5x buffer)	26.6%	0%	Very degraded	
Impervious surface (within park)	9.6%	0%	Very degraded	
Impervious surface (within park + 5x buffer)	25.2%	0%	Very degraded	
Road density (within park)	4.9 km/km^2	0%	Very degraded	
Road density (within park + 5x buffer)	8.1 km/km^2	0%	Very degraded	

4.4.2. Forest interior

Description

Forest interior habitat functions as the highest quality breeding habitat for forest interior dwelling species (FIDS) of birds. When a forest becomes fragmented, areas that once functioned as interior breeding habitat are converted to edge habitat and are often associated with a significant reduction in the number of young birds that are fledged in a year (Jones et al. 2000).

Higher rates of nest predation occur in forest edges. In addition, forest edges provide access to the interior for mammalian predators that include foxes, raccoons, squirrels, dogs, and cats. These predators eat eggs and young birds still in the nest. They tend to be abundant near areas of human habitation and can be detrimental to nesting success (Jones et al. 2000).

Data and methods

Forest interior area as percent of the park area (or buffered area) was calculated using the NPScape Phase 1 Landcover methods and script tools (NPS 2010) (Table 4-31) for forest morphology. The source data for this analysis was the 2011 National Land Cover Database (NLCD) (Jin et al. 2013) from which a Morphological Spatial Pattern Analysis (MSPA) dataset was generated using the GUIDOS software package (http://forest.jrc.ec.europa.eu/download/software/guidos) with the edge distance defined as 90 m (3 pixels). The number of acres of forest interior or 'core' area was extracted from the MSPA dataset for the park and the buffered areas.

The threshold attainment was expressed as the number of acres of interior forest in the park as a percentage of the total potential acres of interior forest within the park (if the total forest area was one large circular patch). The data used in this assessment represents a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area 5 times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary. The purpose of this analysis is to assess the influence on ecosystem processes of land use immediately surrounding the park. The percentage of potential forest interior area translated directly to the percent attainment and condition assessment.

Interior forest was defined as mature forested land cover ≥ 100 m (330 ft) from non-forest land cover or from primary, secondary, or country roads (i.e., roads considered large enough to break the canopy) (Temple 1986).

Condition and trend

Forest interior area in NACE at the scale of the park and at the scale of the park plus the 5x buffer was 18.8% and 8.2%, respectively (Figure 4-64, Table 4-34). This indicated very degraded condition at the scale of the park, as well as at the 5x area scale. Note: forest interior area at an additional scale (park boundary plus a 30 km buffer is also shown in Table 4-34 for reference but was not included in the current assessment.

No trend analysis was possible with the current data set.

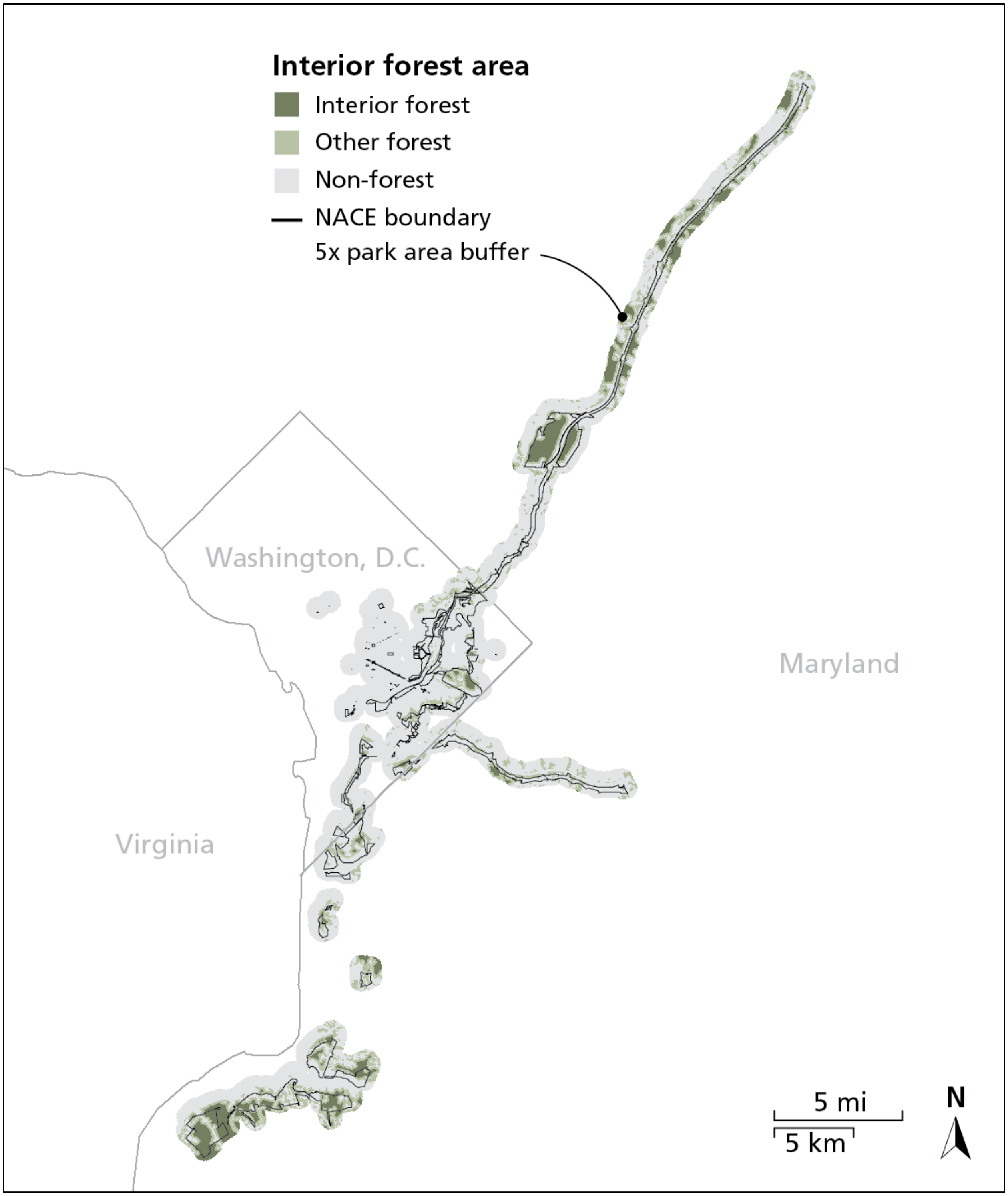

Figure 4-64 Extent of forest interior area within and around NACE. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

Table 4-34 Forest interior area (%) in NACE.

Area	Forest Interior area (%)
Park	18.8
Park + 5x area	8.2
Park + 30 km	11.5

Sources of expertise

- Mark Lehman, GIS Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service

4.4.3. Forest cover

Description

Forest is the dominant historical land use in the region surrounding NACE and is still the dominant land cover within the park itself (Figure 4-65). Because intact and connected forest provides habitat, wildlife corridors, and ecosystem services, forest cover was chosen as a Landscape Dynamics metric.

Data and methods

Forest cover as a percent of the park area (or buffered area) was calculated using the NPScape Phase 1 Landcover methods and script tools (NPS 2010) (Table 4-31). The source data for this analysis was the 2011 National Land Cover Database (NLCD) (Jin et al. 2013). Three of the NLCD classifications were considered to be forested areas for this analysis: Deciduous Forest, Evergreen Forest, and Mixed Forest.

Modelling studies have found that in ecological systems, there is a ‘tipping point’ of forest cover below which a system becomes so fragmented that it no longer functions as a single system (Hargis et al. 1998). USGS digital land use data were used for forest cover in areas of North Carolina, West Virginia, and Alabama to determine the critical value of 59.28% (Gardner et al. 1987). Forest was chosen, as it is a dominant vegetation type within the region, providing major structure to faunal and floral communities.

A forest cover threshold of > 59% was used in this assessment and the data used represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a ‘buffer’ around the entire park boundary (Table 4-32). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the result of the one-off calculation.

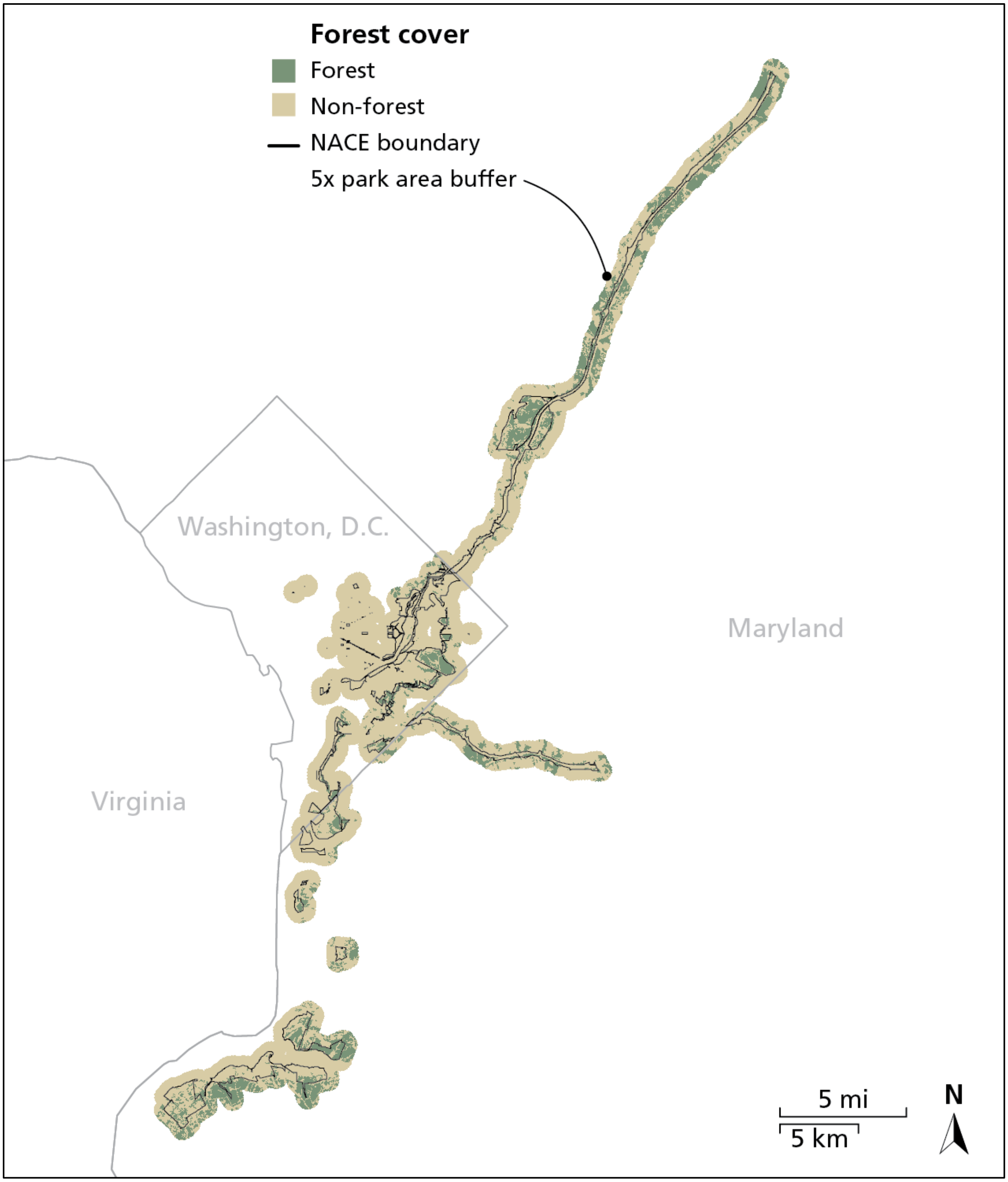

Figure 4-65. Extent of forest and non-forest landcover within and around NACE. The 5x area buffer shown is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

Condition and Trend
At the scale of the park, forest cover in NACE was 48.8%, which is below the reference condition of 59%. This resulted in 0% attainment and very degraded condition (Table 4-33).

When a buffer of five times the park was added, forest cover dropped to 46.9%, also below the reference condition of 59, resulting in 0% attainment of the reference condition and indicating very degraded condition (Table 4-33) Note: forest cover at an additional scale (park boundary plus a 30 km buffer) is also shown in Table 4-35 for reference but was not included in the current assessment.

Table 4-35 Forest cover in NACE.

Area	Forest cover (%)
Park	48.8
Park + 5x	26.6
Park + 30km	38.4

No trend analysis was possible with the current data set.

Sources of expertise

- Mark Lehman, GIS Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

4.4.4. Impervious surface

Description
Impervious surface is a representation of human impact on the landscape and directly correlates to land development (Conway 2007). It includes roads, parking lots, rooftops, and transport systems that decrease infiltration of precipitation, water quality, and habitat while increasing runoff.

Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact above 10% impervious surface (Arnold and Gibbons 1996). Recent studies on stream macroinvertebrates show shifts to more disturbance tolerant species and reductions in biodiversity at around this same threshold (Lussier et al. 2008). A study of nine metropolitan areas in the United States demonstrated measurable effects of impervious surface on stream macroinvertebrate assemblages at impervious surface cover below 5% (Cuffney et al. 2010). Percent urban land is correlated to impervious surface and can provide a good approximation of watershed degradation due to increases of impervious surface.

Data and methods
A single mean impervious surface percentage was calculated for the park (and buffered areas) using ESRI zonal statistics on the 2011 National Land Cover Database impervious surface layer (NPS 2010b, Jin et al. 2013, NPS 2014b) (Table 4-32).

Ecosystem components such as floral and faunal communities show considerable impact when impervious surface comprises 10% or more of habitat area, therefore the reference condition was for total impervious surface to be less than 10% (Arnold and Gibbons 1996; Lussier et al. 2008).

An impervious surface threshold of < 10% was used in this assessment and data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4-66, Table 4-32). The purpose of this analysis is to assess the influence of land use immediately surrounding the park on ecosystem processes. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

<u>Condition and trend</u>

Impervious surface in NACE at the scale of the park and the scale of the park plus the 5x buffer was 9.6% (100% attainment) and 25.2% (0% attainment), respectively (Figure 4-66). The areas adjacent to the park with the highest cover of impervious surface include the greater Washington, D.C. metropolitan area, and the regions surrounding the Baltimore Washington Parkway and Suitland Parkway. Note: impervious surface at an additional scale (park boundary plus a 30 km buffer) is also shown in Table 4-36 for reference but was not included in the current assessment.

No trend analysis was possible with the current data set.

Table 4-36 Impervious surface (%) in NACE.

Area	Impervious surface (%)
Park	9.58
Park + 5x area	25.23
Park + 30km	13.07

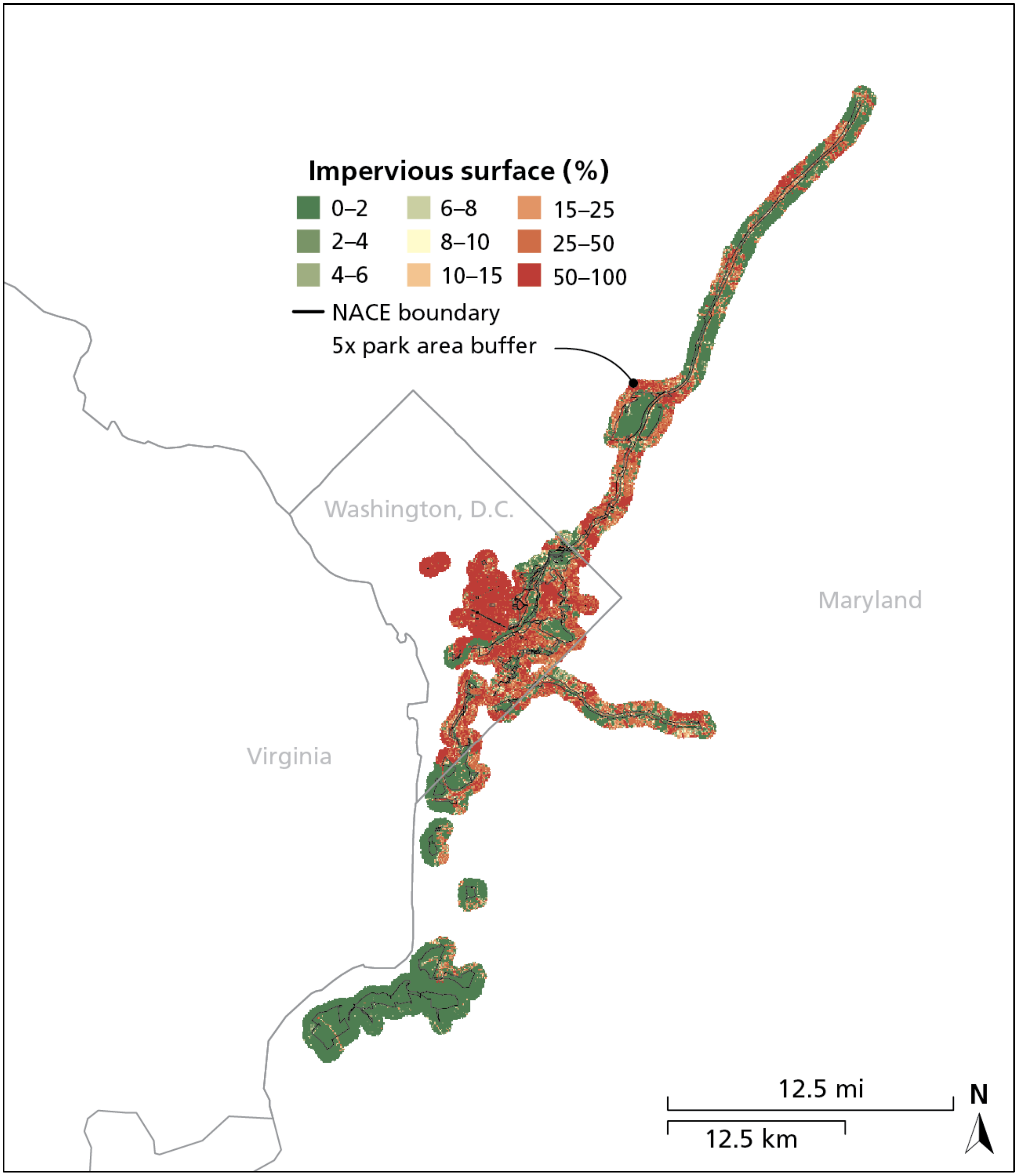

Figure 4-66. Percent impervious surface within and around NACE. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

<u>Sources of expertise</u>

- Mark Lehman, GIS Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

4.4.5. Road density

Description

Roads and other forest-dividing cuts such as utility corridors can act as barriers to wildlife movement and increase habitat fragmentation. High road density or the presence of a large roadway can decrease the quality of wildlife habitat by fragmenting it, and increases the risk of wildlife mortality by vehicle strike (Forman et al. 1995).

Data and methods

Road density (km of road per square km) and distance from roads were calculated using the NPScape Phase 2 Road Metrics Processing SOP (NPS 2010) for the park and buffered areas (Table 4-31). The 2010 ESRI Streets layer (ESRI 2010) was used as the source data. All of the features in this layer were included in this analysis with the exception of ferry routes.

Road densities higher than 1.5km/km2 have been shown to impact turtle populations, while densities higher than 0.6 km/km2 can impact natural populations of large vertebrates (Forman et al. 1995, Gibbs and Shriver 2002, Steen and Gibbs 2004). A road density threshold of < 1.5km/km2 was used in this assessment and data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a ‘buffer’ around the entire park boundary. The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Condition and trend

At the scale of the park, and at the scale of the park plus the 5x buffer road density in NACE was 4.9 km/km^2, and 8.1 km/km^2, respectively. These both exceeded the reference condition of 1.5km/km^2, resulting in 0% attainment and very degraded condition at both scales.

No trend analysis was possible with the current data set.

Table 4-37 Road density (km/km2) in NACE.

Area	**Road density (km/km^2)**
Park	4.9*
Park +5x	8.1*
Park + 30km	5.3*

*Values outside of reference condition of < 1.5 km/km^2.

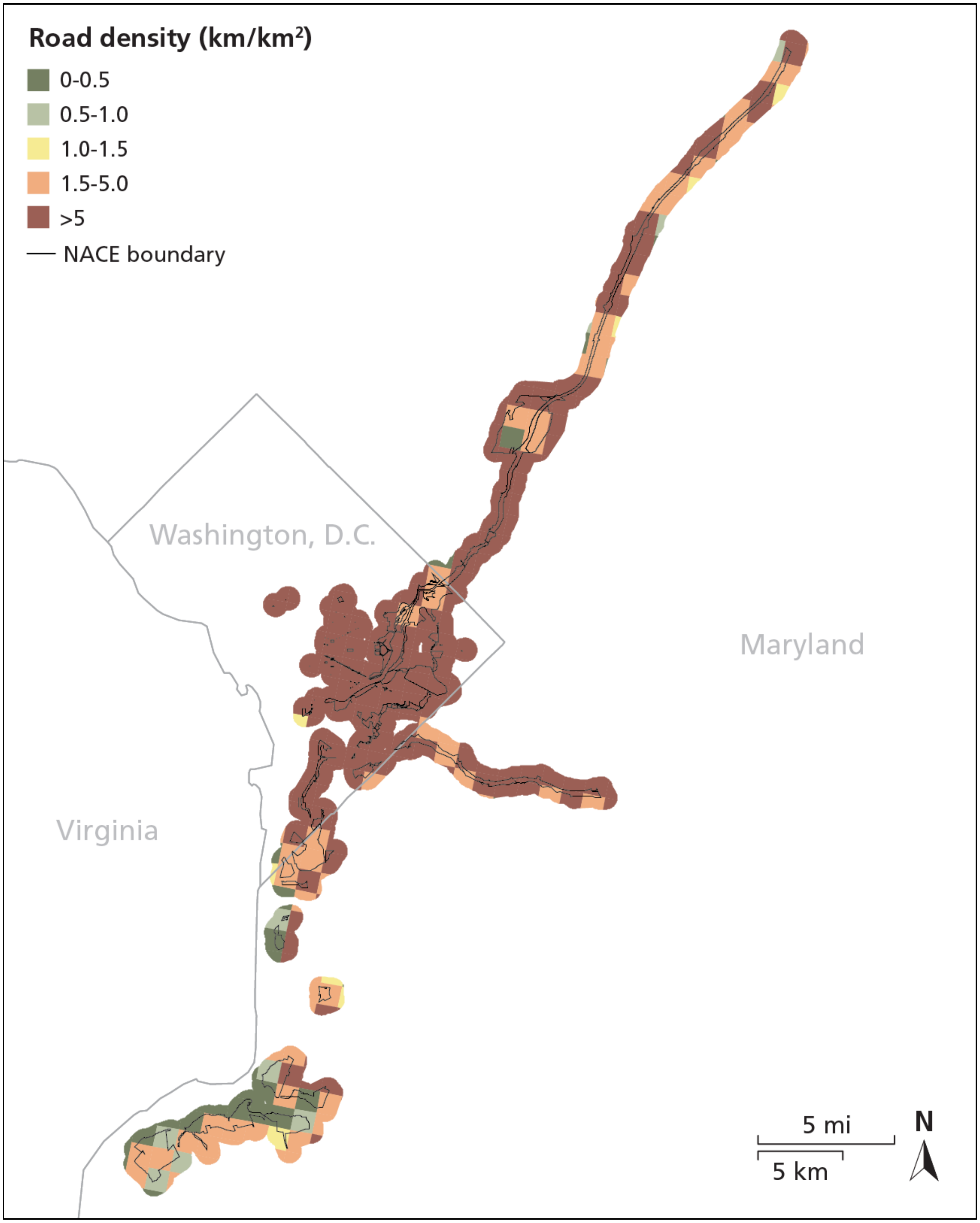

Figure 4-67 Road density within and around NACE. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

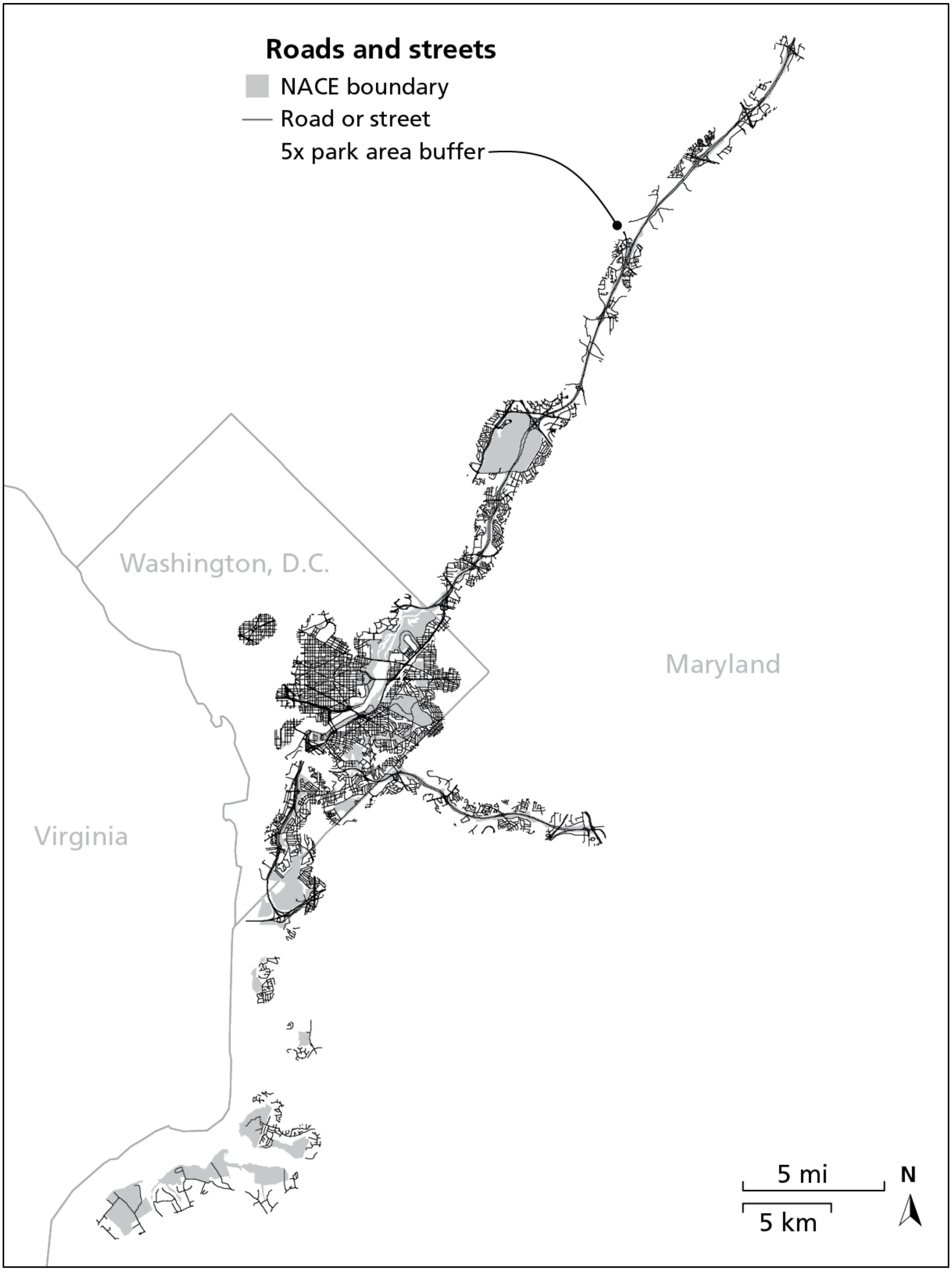

Figure 4-68. Map of the roads and streets in and around NACE.

Sources of expertise

- Mark Lehman, GIS Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

5. Summary and Discussion

With 29% achievement of reference conditions overall, natural resources of National Capital Parks-East were classified as in **degraded condition**. The good condition of water resources and moderate condition of biological integrity were offset by very degraded conditions for air resources and landscape dynamics (Table 5-1). The very degraded condition for landscape dynamics was not unexpected for a metropolitan park with extensive landscape manipulation. Similarly, the very degraded condition for air resources is driven by external forces and cannot be expected to be improved though management actions within the park. Despite these findings, it is widely recognized that NACE adds critical green space in an increasingly urbanized region, providing refuge for many species, and serving as a migration rest stop for wildlife.

Table 5-1 Natural resource condition assessment of NACE.

Vital sign	Reference attainment	Condition
Air quality	17%	Very degraded
Water resources	65%	Good
Biological integrity	48%	Moderate
Landscapes dynamics	3%	Very degraded
NACE Overall	**33%**	**Degraded**

5.1. Air quality

Air quality conditions at NACE were in a ***very degraded*** condition with 17% attainment of reference conditions (Table 5-2). Since most NACE park units are surrounded by urban development and roadways it was expected that air quality would be in degraded condition. However, it must be noted that degraded air quality is a problem throughout the northeastern United States, the causes of which (e.g. power generation) are out of the park's control. Specific implications of poor air quality to the habitats and species in the park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts. Management implications and recommended next steps for air resources are outlined in Table 5-3.

Table 5-2 Summary of air quality in NACE.

Metric	Percent attainment	Condition
Wet sulfur deposition	0%	Very degraded
Wet nitrogen deposition	0%	Very degraded
Ozone (ppb)	0%	Very degraded
Ozone (W126)	**0%**	**Very degraded**

Table 5-2 (continued) Summary of air quality in NACE.

Metric	Percent attainment	Condition
Visibility	0%	Very degraded
Particulate matter	100%	Very good
Overall Air Quality	**17%**	**Very degraded**

Table 5-3 Key findings, management implications, and recommended next steps for air quality in NACE.

Key findings	Management implications	Recommended next steps
Air quality is very degraded and is a regional problem	• Impacts of poor air quality on park largely unknown. • Nearby parks (e.g. Shenandoah NP) have clear ecological impacts of poor air quality (i.e. acid rain impacts).	• Investigate effects of poor air quality on sensitive habitats and species within the park (e.g. ozone damage to vegetation). • Develop park-specific management actions. • Stay engaged with the wider community in terms of air quality education and activities.

Table 5-4 Data gaps, justification, and research needs for air quality in National Capital Parks-East.

Data gaps	Justification	Research needs
Lack of park-specific air quality data	• Air quality is only measured and interpolated on regional and national scales.	• Use transport and deposition models to analyze and estimate park specific air quality data and trends. • Implementing in-park air quality monitoring would give better insights into park air quality condition and possible effects on park habitats and species. • Planting and monitoring a garden of ozone-sensitive plants.
Effects of poor air quality on park habitats and species	• Implement park-specific management actions.	• Investigate effects of poor air quality on sensitive habitats and species within the park.
Ecological references for mercury wet deposition	• Mercury deposition is reported for NACE but no reference exists for protection of species.	• Adopt standards once NPS Air Resources Division establishes mercury wet deposition reference.
Minimal soundscape information	• Traffic noise from Baltimore-Washington Parkway and other roads potentially affects wildlife behavior and distribution and the recreational experience. • Noise is greater in fall and winter when there is no foliage to dampen it.	• Minimal soundscape information • Explore weekend/holiday road closures at select park roads to thru-traffic (Fort Dupont Park)

5.1.1. Water resources

Water resources within NACE were in a *good condition*, with 61% attainment of reference conditions (Table 5-5). Four sites in NACE are monitored for water quality (Pieper 2012). Sites were located in an unnamed tributary of Accokeek Creek (Piscataway Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove Park), and Still Creek (Greenbelt Park). They were monitored on a monthly basis for dissolved oxygen, pH, specific conductance, temperature, acid neutralizing capacity, total nitrate, total phosphorus, depth, wetted width, flow, and discharge. Both pH and acid neutralizing capacity were in the acceptable range. Specific conductance exceeded ecological thresholds for aquatic life stress at all sites except the tributary to Accokeek Creek, which fell within the acceptable range. Salinity was consistently within the acceptable range for fresh water. Total nitrate levels were consistently within the acceptable range, with a handful of exceedances. Total phosphorus levels regularly exceeded the threshold value. Water temperatures always fell within the acceptable range, and followed air temperatures, suggesting that the streams are primarily surface-fed. Dissolved oxygen was consistently acceptable, and displayed a typical seasonal pattern.

A higher overall attainment was, however, offset by very degraded conditions for total phosphorus and Benthic Index of Biotic Integrity (BIBI), and degraded conditions for specific conductance and the Physical Habitat Index (PHI). Management implications and recommended next steps are outlined in Table 5-6.

Table 5-5 Summary of water resources in NACE.

Indicator	**Percent attainment**	**Condition**
pH	93.0%	Very good
Dissolved oxygen	97.0%	Very good
Water temperature	100.0%	Very good
Acid neutralizing capacity	100.0%	Very good
Specific conductance	4.0%	Degraded
Nitrate	93.0%	Very good
Total phosphorus	9.0%	Very degraded
Benthic Index of Biological Integrity	60.7%	Fair
Physical Habitat Index	25.9%	Slightly degraded
Water resources	**65.0%**	**Good**

Table 5-6 Key findings, management implications, and recommended next steps for water resources in NACE.

Key findings	Management implications	Recommended next steps
Very degraded condition for stream total phosphorus	• Nutrient enrichment affects stream flora and fauna (eutrophication). • Visible signs of eutrophication reduces quality of visitor experience.	• Elevated total phosphorus levels have been found in parks throughout the NCR and could also be largely due to underlying geology (C*arruthers* et al. *2009, Norris and Pieper 2010, Thomas* et al. 2011a, b, c). • Minimize soil disturbance. • Implement best management practices such as expanding riparian buffers and no-mow areas.
Fair condition for Benthic Index of Biotic Integrity (BIBI)	• Affects stream flora and fauna. • Reduces quality of visitor experience	• Implement stream restoration and manage volume and velocity of water from impervious surfaces (e.g. swales, riparian buffers and no-mow areas). • Implement monitoring to identify sources and patterns of pollution affecting stream biota.
Degraded condition for specific conductance	• Affects stream flora and fauna • Reduces quality of visitor experience	• Identify sources (e.g. salting of roads) and conductance-sensitive organisms and locations for management initiatives. • Explore alternative de-icing solutions. • Implement best management practices such as riparian buffers and no-mow areas.
Slightly degraded Physical Habitat Index	• Affects stream flora and fauna • Reduces quality of visitor experience	• Implement stream restoration and manage volume and velocity of water entering the park (e.g. swales, riparian buffers and no-mow areas). • Implement monitoring to identify sources and patterns and then develop management alternatives.

Table 5-7. Data gaps, justification, and research needs for water resources in NACE.

Data gaps	Justification	Research needs
Origins of nitrogen and phosphorus pollution are uncertain	• Affects stream flora and fauna. • Reduces quality of visitor experience.	• Identify sources of nutrients.

5.1.2. Biological integrity

Biological integrity was in *moderate condition*, with 47.9% attainment of reference conditions. Conditions for the seven biological integrity indicators ranged from very good (i.e. limited exotic trees and forest pest species) to very degraded (i.e. widespread coverage of exotic herbaceous species, high deer density, and low stocking index) (Table 5-8). Management implications and recommended next steps are outlined in Table 5-9.

Table 5-8 Summary of biological integrity in NACE.

Indicator	Percent attainment	Condition
Cover of exotic herbaceous species	19%	Very degraded
Area of exotic tree & saplings	92%	Very good
Presence of forest pest species	100%	Very good
Stocking index	6%	Very degraded
Fish Index of Biological Integrity	58%	Moderate
Bird Community Index	39%	Moderate
Deer Density	0%	Very degraded
Biological Integrity	**47.9%**	**Moderate**

Table 5-9 Key findings, management implications, and recommended next steps for biological integrity in NACE.

Key findings	Management implications	Recommended next steps
Overall, forest community was represented well by native plant species, though seedling regeneration is a problem.	• Future lack of forest regeneration and subsequent habitat. • Deer overbrowse can contribute to introduction of invasive species.	• Manage deer over-browse through deer population control measures, repellant, tree tubes, barriers (e.g. fencing portions of the park). • Implement planting initiatives where appropriate.
Presence of exotic plants.	• Displacement of native species, reducing biodiversity.	• Prioritize species and locations for implementing control measures. • Restore and maintain native species and communities. • Identify and map areas of exotic invasion that are not reflected in I&M Monitoring (e.g. floodplain areas are not currently represented); and initiate population monitoring.
Deer overpopulation may be impacting forest regeneration throughout park.	• Increased herbivory reducing seedling density. • Potential for spread of chronic wasting disease among deer.	• Make, and expand, ongoing population size counts.

Table 5-10. Data gaps, justification, and research needs for biological integrity in NACE.

Data gaps	Justification	Research needs
Limited geographic range of forest monitoring plots	• Current monitoring sites are not capturing extent of exotic species presence or forest species loss.	• Make, and expand, ongoing forest monitoring.
Limited knowledge on how forests might change in light of new and future stressors (climate change, pests, and diseases)	• These stressors are already present or will be present in the near future.	• Research and modeling into the effects of these stressors on the region's forests.

5.1.3. Landscape dynamics

Landscape dynamics within National Capital Parks-East were in *very degraded* condition, with 3% attainment of reference conditions (Table 5-11). The park shows very degraded conditions for forest interior area, forest cover and road density (Table 5-11). Management implications and recommended next steps for landscape dynamics are outlined in Table 5-12.

Table 5-11 Summary of landscape dynamics in NACE.

Indicator	Percent attainment	Condition
Forest interior area (within park)	19%	Very degraded
Forest interior area (within park + 5x buffer)	8%	Very degraded
Forest cover (within park)	0%	Very degraded
Forest cover (within park + 5x buffer)	0%	Very degraded
Impervious surface (within park)	0%	Very degraded
Impervious surface (within park + 5x buffer)	0%	Very degraded
Road density (within park)	0%	Very degraded
Road density (within park + 5x buffer)	0%	Very degraded
Landscape Dynamics	**3%**	**Very degraded**

Table 5-12 Key findings, management implications, and recommended next steps for landscape dynamics in NACE.

Key findings	Management implications	Recommended next steps
Very degraded forest interior area and forest cover – within and outside the park boundary	• Reduction in bird breeding habitat. • Reduction in birds fledged each year. • Increased predation.	• Improve quality of existing forest habitat by managing for exotic species.
Large areas of impervious surface – inside and outside the park boundary	• Increased rainfall runoff volume and velocity (with pollutants).	• Assess and mitigate drainage issues for existing impervious areas. • Change asphalt parking lots to porous surfaces (e.g. pervious pavers, grass). • Retrofit existing impervious areas (e.g. install rain gardens/bio-retention systems, etc.)
High road density surrounding park boundary	• Road density increases surface runoff/stormwater that enters park water resources, and may decrease water quality conditions, resulting in lower water quality and biological integrity. • Disrupts habitat of forest interior area.	• Difficult to manage. Potential traffic calming/reduction measures.

Table 5-13. Data gaps, justification, and research needs for landscape dynamics in National Capital Parks-East.

Data gaps	Justification	Research needs
Implications of external land use changes on park resources	• Connectivity of ecological processes from park to watershed	• Landscape analysis at multiple scales.
Habitat corridor function	• Needed for migration and movement of fauna.	• Assessment of current and potential use by fauna. • Modeling of the potential effects of climate change on habitats within the park and surrounding region.

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Appendix A: Raw data

Table A-1 Particulate matter, PM2.5 (μg/m^3).

Site	Years	3-year mean PM2.5 (μg/m^3)
5105900030	2003-2005	13.6
	2004-2006	13.4
	2005-2007	13.0
	2006-2008	12.1
	2007-2009	11.1
	2008-2010	10.3
	2009-2011	9.6
	2010-2012	8.5
	2011-2013	7.7
110010051	2003-2005	13.2
	2004-2006	12.6
	2005-2007	12.4
	2006-2008	11.6
	2007-2009	11.0
	2008-2010	10.1
	2009-2011	9.6
	2010-2012	9.3
	2011-2013	10.4
240330030	2004-2006	10.8
	2005-2007	10.8
	2006-2008	10.3
	2007-2009	10.1
	2008-2010	10.1
	2009-2011	9.7
	2010-2012	9.6
	2011-2013	8.9

Table A-2 Water quality data.

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_ACCK	11/29/05	7.37	5.01	13.5	1664	258.9	*Present <QL	0.1142
NACE_ACCK	1/31/06	6.72	9.57	8.8	1000	178.7	1.2	
NACE_ACCK	3/30/06	8.21	4.03	15.05	1312	198.3	*Present <QL	0.2414
NACE_ACCK	4/24/06	7.57	2.51	17.1	1400	177.7	0.4	0.4209
NACE_ACCK	6/14/06	8.02	7.26	17.8	1702	230.1	0.4	0.2153
NACE_ACCK	7/5/06	7.38	7.42	21.5	1032	179.1	0.4	0.0881
NACE_ACCK	7/31/06	7.91	6.75	25.4	1504	209.2	0.3	0.5514
NACE_ACCK	10/2/06	7.24	7.9	16.8	1646	237	0.5	2.8711
NACE_ACCK	11/15/06	7.28	7.1	13.4	1106	190.8	0.4	
NACE_ACCK	12/14/06	7.61	9.07	9.15	1124	186.6	*Not Reported	0.3980
NACE_ACCK	3/20/07	7.58	8.1	13.3	766	137.6	1.35	0.0489
NACE_ACCK	4/17/07	7.25	10.27	10.6	766	143.55	0.12	0.0457
NACE_ACCK	5/21/07	7.82	7.46	17.4	1592	193.5	0.16	0.0620
NACE_ACCK	6/20/07	7.96	6.29	22.2	2004	256.1	0.3	0.2219
NACE_ACCK	7/23/07	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported		
NACE_ACCK	9/10/07	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_ACCK	10/1/07	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	10/30/07	7.44	8.12	11.6	1560	260.8	1	
NACE_ACCK	11/27/07	7.65	6.35	11	2016	287.5	1.6	
NACE_ACCK	1/10/08	*Not Reported	9.72	7.6	1508	242	1.3	
NACE_ACCK	2/5/08	7.21	8.6	8.65	940	179.85	0.9	
NACE_ACCK	3/10/08	7.54	11.3	7.85	1026	130.95	0.8	
NACE_ACCK	4/2/08	8.04	11.46	12.6	1330	203.05	1	
NACE_ACCK	5/5/08	7.56	8.53	16.1	922	166.2	1	
NACE_ACCK	6/3/08	7.54	9.66	17.35	926	172.85	1	
NACE_ACCK	7/1/08	7.85	5.09	20.55	1014	179	0.4	
NACE_ACCK	8/4/08	7.58	4.87	22.55	1258	236.45	1.1	
NACE_ACCK	9/2/08	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	10/7/08	7.86	5.38	13.85	1328	252.65	0.8	
NACE_ACCK	11/12/08	7.59	7.41	9.5	2328	281.3	0.8	
NACE_ACCK	1/29/09	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	3/25/09	7.88	8.77	8	1554	245.1	0.6	0.0392
NACE_ACCK	4/22/09	7.2	9.43	11.8	1028	175	1.5	0.0620
NACE_ACCK	6/1/09	7.77	8.9	16.6	1476	207.4	0.6	0.0816

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_ACCK	6/30/09	7.84	8.3	19.9	1428	191.6	0.4	0.0620
NACE_ACCK	8/3/09	8.04	7.9	22.6	2104	255.8	0.7	0.0587
NACE_ACCK	9/3/09	8	7.1	18.7	1460	230.8	0.2	0.0946
NACE_ACCK	10/1/09	7.87	9.2	14.3	1804	143.8	*Present <QL	0.0783
NACE_ACCK	10/29/09	7.3	8.6	14	1468	210.7	0.9	0.0555
NACE_ACCK	11/23/09	7.48	9.4	10.3	1486	211.5	0.4	0.1011
NACE_ACCK	12/17/09	7.53	13.6	4	1002	165.8	0.5	0.0783
NACE_ACCK	1/28/10	7.35	12	5.9	1152	189.4	0.6	0.0457
NACE_ACCK	2/25/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	3/25/10	7.5	10.5	11.6	1040	165.7	0.7	0.0555
NACE_ACCK	4/19/10	7.74	10.9	12.3	1014	190.8	2.2	0.1860
NACE_ACCK	5/20/10	7.99	9.4	15.6	1614	224.6	0.8	0.0718
NACE_ACCK	6/24/10	8.11	7.3	24.8	1192	271.9	1.2	0.1077
NACE_ACCK	7/29/10				*Non-detect		*Not Reported	
NACE_ACCK	8/24/10				*Non-detect		*Not Reported	
NACE_ACCK	9/29/10						*Not Reported	
NACE_ACCK	10/25/10	7.4	5.71	16.5	2182	283.4	1.2	0.0718

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_ACCK	11/17/10	7.53	7.3	12.9	1648	272.3	1.8	0.2055
NACE_ACCK	12/17/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	1/19/11	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	2/14/11	*Not Reported	*Not Reported	*Not Reported	*Non-detect	*Not Reported	*Not Reported	
NACE_ACCK	4/20/11	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	5/18/11	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	6/29/11	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	8/30/11	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	9/22/11	7.62	7.1	19.7	1336	188.6	0.6	0.0653
NACE_ACCK	10/27/11	7.28	6.8	14.9	1808	217.6	0.6	0.0555
NACE_ACCK	11/17/11	7.01	7.7	10.6	1696	250.8	0.6	0.0555
NACE_ACCK	12/15/11	7.4	9.4	9.7	1136	164.2	0.8	0.0457
NACE_ACCK	1/26/12	7.21	11.4	7.8	1584	197.1	0.8	0.0848
NACE_ACCK	2/23/12	7.77	9.9	10.9	1608	219.1	0.8	0.0392
NACE_ACCK	3/13/12	7.7	10.4	13.7	1376	215.1	0.5	0.0489
NACE_ACCK	5/3/12	7.92	9.1	15.7	2064	238.2	0.5	0.0881

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_ACCK	5/24/12	7.97	8.2	19.3	2072	162.8	0.7	0.0816
NACE_ACCK	6/28/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	7/18/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	8/23/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	9/27/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	10/25/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_ACCK	11/15/12	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_HECR	3/6/06	7	8.01	6.9	418	479.2	0.9	
NACE_HECR	3/30/06	7.81	5.34	14.35	482	436.4	0.8	0.1207
NACE_HECR	4/24/06	7.12	2.6	18	576	375	0.7	0.2055
NACE_HECR	6/14/06	7.47	7.8	18.9	852	351.2	0.8	0.1892
NACE_HECR	7/5/06	7.26	5.7	24.3	736	311.5	0.6	0.0979
NACE_HECR	7/31/06	8.44	9.64	26.7	732	422.9	0.8	0.2871
NACE_HECR	8/24/06	6.35	8.2	24.85	548	399.4	1.3	0.5971
NACE_HECR	10/2/06	7.13	7.74	17.76	654	338.3	0.9	1.0343
NACE_HECR	11/14/06	7.15	9.01	14.85	628	301.25	0.9	

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_HECR	12/14/06	7.273	8.24	9.7	532	340.6	*Not Reported	0.2055
NACE_HECR	3/20/07	7.37	8.63	11.733	534	569.667	1.54	0.0326
NACE_HECR	4/17/07	6.87	5.398	9.55	544	405.363	0.21	0.0424
NACE_HECR	5/18/07	7.33	6.27	15.5	702	436.225	0.4	0.1109
NACE_HECR	6/20/07	6.99	5.62	22.9	668	274.6	0.7	0.2023
NACE_HECR	7/23/07	7.29	8.32	21.9	828	437.6	1.1	
NACE_HECR	9/10/07	8.7	9.24	24.7	1020	450.2	1.2	
NACE_HECR	10/1/07	7.62	7.53	17.4	890	405.4	1.8	
NACE_HECR	10/30/07	7.22	8.08	11.5	798	496	2	
NACE_HECR	11/27/07	7.32	7.56	11.5	902	459.6	1.9	
NACE_HECR	1/10/08	7.06	11.87	7.47	724	500.98	2.1	
NACE_HECR	2/5/08	6.92	9.68	7.4	644	489.35	1.8	
NACE_HECR	3/10/08	7.24	10.26	6.45	616	519	2.4	
NACE_HECR	4/2/08	7.74	12.92	11.28	696	461.88	2	
NACE_HECR	5/5/08	7.49	9.97	16.52	858	425.4	2.1	
NACE_HECR	6/3/08	7.29	8.63	18.35	814	402.58	2.1	
NACE_HECR	7/1/08	7.12	7.73	21.15	838	237.92	0.5	
NACE_HECR	8/4/08	7.68	8.77	22.9	900	380.02	1.3	
NACE_HECR	9/2/08	7.68	7.9	21.13	914	394.05	1.6	

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_HECR	10/7/08	7.57	9.51	14.47	1024	403.58	1.6	
NACE_HECR	11/12/08	7.44	11.07	9.55	1296	402.78	1.1	
NACE_HECR	1/29/09	6.77	19.41	3.5	888	3490	1.9	0.0489
NACE_HECR	3/25/09	7.22	11.92	8.35	612	716.5	1.1	0.0294
NACE_HECR	4/22/09	7.12	9.43	11.63	792	422.67	1.2	0.1207
NACE_HECR	6/1/09	7.45	8.35	17.4	880	343.05	1.3	0.0620
NACE_HECR	7/1/09	7.25	6.6	20.6	820	370.23	1.3	0.1044
NACE_HECR	8/3/09	7.41	7.27	22.9	772	303.53	1.3	0.0848
NACE_HECR	9/3/09	7.56	8.45	18.75	798	421.8	1.8	0.0587
NACE_HECR	10/1/09	7.34	8.8	14.75	852	382.45	1.4	0.0620
NACE_HECR	10/29/09	7.11	9.07	14.73	784	301.73	0.9	0.0685
NACE_HECR	11/23/09	7.3	10.15	10.7	746	375.9	1.3	0.1044
NACE_HECR	12/17/09	7.24	12.87	4.1	790	368.77	0.9	0.0848
NACE_HECR	1/28/10	7.32	12.25	4.75	962	505.45	1.4	0.0424
NACE_HECR	2/25/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NACE_HECR	3/25/10	7.23	10.85	10.6	684	493.65	1.2	0.0457
NACE_HECR	4/19/10	7.49	11.35	11.8	806	517.45	2.1	0.1142
NACE_HECR	5/20/10	7.42	8.75	15.45	772	507.7	1.7	0.0653
NACE_HECR	6/24/10	7.37	6.35	24.3	728	487.35	1.5	0.0620

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_HECR	7/29/10	7.52	7.1	25	1000	475.8	1.5	0.0555
NACE_HECR	8/24/10	7.3	6.77	22.17	888	270.73	1.6	0.0848
NACE_HECR	9/29/10	7.41	7.5	18.7	946	379.5	2.1	0.0718
NACE_HECR	10/25/10	7.08	8.59	15.4	896	419.8	2.3	0.0522
NACE_HECR	11/17/10	7.24	8.77	13.07	1616	244	2	0.1697
NACE_HECR	12/17/10	7.45	14.5	8.1	792	866	2.6	0.0587
NACE_HECR	1/19/11	7.26	11.97	3.87	968	2599.67	1	0.0620
NACE_HECR	2/14/11	7.18	12.77	4.7	1232	633.53	1.2	0.0979
NACE_HECR	3/23/11	7.13	10.37	10.3	824	558.1	1.2	0.0392
NACE_HECR	4/20/11	7.12	9.4	15.43	856	518.43	1.1	0.1468
NACE_HECR	5/18/11	7.11	7.73	17.4	888	379.1	1.7	0.1860
NACE_HECR	6/29/11	7.66	7.8	23.15	1064	510.75	1.5	0.1697
NACE_HECR	7/26/11	7.41	6.5	26.1	1104	325.9	1.2	0.0914
NACE_HECR	8/30/11	7.25	8.03	20	1008	414.07	1.3	0.0750
NACE_HECR	9/22/11	7.3	7.8	20.1	1088	446.73	1.1	0.0522
NACE_HECR	10/27/11	7.14	8.1	15.1	1008	442	1.5	0.0653
NACE_HECR	11/17/11	6.98	8.67	12.13	928	489.57	0.9	0.0685
NACE_HECR	12/15/11	7.03	10.37	8.37	*Non-detect	385.93	1.4	0.0294
NACE_HECR	1/26/12	6.98	8.33	9.37	1328	532.23	1.2	1.0082
NACE_HECR	2/23/12	7.3	11	8.4	808	1000.5	1.6	0.0555

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NACE_HECR	3/13/12	7.34	10.9	12.65	872	446.7	1.3	0.0816
NACE_HECR	5/3/12	7.42	9.1	14.9	944	405.5	1.5	0.0881
NACE_HECR	5/24/12	7.51	8.6	19.6	840	163.7	1.5	0.0750
NACE_HECR	6/28/12	7.74	7.5	19.8	1128	429.65	1.3	0.1370
NACE_HECR	7/18/12	7.7	6.75	25.05	1128	397.35	1.1	0.2610
NACE_HECR	8/23/12	7.97	9	21.35	1208	453.6	1.3	0.0816
NACE_HECR	9/27/12	7.78	8.9	18.85	1144	458.55	1.4	0.1925
NACE_HECR	10/25/12	7.54	8.25	16.4	1288	387.7	1.1	0.1762
NACE_HECR	11/15/12	7.34	12.27	8.27	1272	375.63	1.2	0.1175
NACE_HECR	12/20/12	7.69	14.8	6.7	1184	403.7	1.4	0.1240
NACE_HECR	1/29/13	7.51	13.53	5.27	1232	1739.33	1.5	0.1240
NACE_HECR	2/25/13	7.51	13.3	4.4	952	522.13	1.4	0.0555
NACE_HECR	3/28/13	7.55	11.8	6.37	976	521.13	1.2	0.1109
NACE_HECR	4/23/13	7.33	9.97	10.9	872	456.3	0.633	
NACE_HECR	5/21/13	7.52	8.87	18.5	1040	403.33	0.866	
NCRN_NACE_OXRU	11/29/05	7.28	6.2	15.37	1096	495.8	0.9	0.0163
NCRN_NACE_OXRU	1/31/06	6.91	10.87	10.85	576	328.8	0.34	
NCRN_NACE_OXRU	3/30/06	9.38	4.11	18.4	904	458	0.6	0.0653
NCRN_NACE_OXRU	4/24/06	7.75	2.9	21.7	1000	443.5	0.8	0.1501
NCRN_NACE_OXRU	6/14/06	7.71	7.07	21.3	1328	478.6	0.6	0.1207

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_OXRU	7/5/06	7.86	6.06	28.6	974	331.1	0.5	0.1109
NCRN_NACE_OXRU	7/31/06	8.43	9.66	32.9	1588	472.3	0.4	0.5024
NCRN_NACE_OXRU	8/24/06	8.39	12.68	32	1398	474	0.4	0.5122
NCRN_NACE_OXRU	10/2/06	7.08	6.72	19.7	1116	495.23	0.8	0.7080
NCRN_NACE_OXRU	11/14/06	7.65	7.65	15.825	1008	395.1	1.2	
NCRN_NACE_OXRU	12/14/06	7.397	7.66	10.38	916	456.2	*Not Reported	0.2088
NCRN_NACE_OXRU	3/20/07	7.38	6.985	14.3	844	654.425	2.87	0.0620
NCRN_NACE_OXRU	4/17/07	7.135	8.785	11.4	858	456.338	0.49	0.4992
NCRN_NACE_OXRU	5/18/07	7.408	5.643	17.067	1018	480.25	0.4	0.1501
NCRN_NACE_OXRU	6/20/07	7.59	5.54	25.5	946	375.6	0.8	0.2675
NCRN_NACE_OXRU	7/23/07	7.99	9.79	26.8	1676	567	0.3	
NCRN_NACE_OXRU	9/10/07	9	10.18	29.6	1308	490	0.3	
NCRN_NACE_OXRU	10/30/07	7.58	8.01	13.8	1232	472.5	2.2	
NCRN_NACE_OXRU	11/27/07	8.3	9.92	13	1516	484.6	1.6	
NCRN_NACE_OXRU	1/10/08	*Not Reported	11.99	7.33	1150	495.02	2.1	
NCRN_NACE_OXRU	2/5/08	7.35	9.97	8.1	1010	505.17	2.1	
NCRN_NACE_OXRU	3/10/08	7.67	14.92	7.7	946	541.67	2.6	
NCRN_NACE_OXRU	4/2/08	9.47	15	11.97	1036	479.27	1.5	
NCRN_NACE_OXRU	5/5/08	8.56	10.3	21.03	1130	435.02	1.4	

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_OXRU	6/3/08	7.73	9.18	21.83	1148	418.07	1.9	
NCRN_NACE_OXRU	7/1/08	8.03	8.29	24.18	986	269.25	0.8	
NCRN_NACE_OXRU	8/4/08	8.33	7.46	27.62	1356	441.55	1	
NCRN_NACE_OXRU	9/2/08	9.09	11.38	26.75	1572	460.45	0.7	
NCRN_NACE_OXRU	10/7/08	8.52	11.49	17.59	1664	451.85	1.1	
NCRN_NACE_OXRU	11/12/08	8.89	14.14	10.15	1912	449.05	0.7	
NCRN_NACE_OXRU	1/29/09	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_OXRU	3/25/09	8.88	14.83	9.23	1198	753.5	1.5	0.0457
NCRN_NACE_OXRU	4/22/09	7.35	9.49	12.8	1104	393.25	2.2	0.3491
NCRN_NACE_OXRU	6/1/09	8.06	9.3	20.8	1188	379.4	1.6	0.0718
NCRN_NACE_OXRU	6/30/09	8.26	9.87	24.4	1330	433.13	0.8	0.0653
NCRN_NACE_OXRU	8/3/09	7.9	8	25.9	1242	304.15	1	0.0750
NCRN_NACE_OXRU	9/3/09	9.04	12.4	22.65	1226	403.6	0.9	0.0685
NCRN_NACE_OXRU	10/1/09	8.24	10.75	17.15	1302	397.75	1.3	0.0750
NCRN_NACE_OXRU	10/29/09	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_OXRU	11/23/09	7.78	10.6	10.45	1130	423.9	1.3	0.2121
NCRN_NACE_OXRU	12/17/09	7.68	14	3.23	1016	414.63	1.2	0.0914
NCRN_NACE_OXRU	1/28/10	7.52	13.15	5.05	616	586.75	1.6	0.0359

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_OXRU	2/25/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_OXRU	3/25/10	8.23	12.47	11.57	900	544.5	1.4	0.0457
NCRN_NACE_OXRU	4/19/10	8.11	11.57	13.8	766	542.87	2.3	0.1305
NCRN_NACE_OXRU	5/20/10	8.25	10	19.55	1078	481.75	1.2	0.0685
NCRN_NACE_OXRU	6/24/10	8.65	9.85	29.6	1216	497	1.5	0.1011
NCRN_NACE_OXRU	7/29/10	8.52	9.05	29.1	1472	501	1.3	0.0783
NCRN_NACE_OXRU	8/24/10	7.97	7.63	23.9	1208	339.37	1.3	0.0979
NCRN_NACE_OXRU	9/29/10	8.61	10.63	20.63	1594	518.6	0.7	0.0653
NCRN_NACE_OXRU	10/25/10	8.11	12.96	17.1	1368	481.1	1.8	0.0881
NCRN_NACE_OXRU	11/17/10	7.74	9.7	13.2	952	280.27	2	0.1925
NCRN_NACE_OXRU	12/17/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_OXRU	1/19/11	7.66	13.5	4.77	1096	4258.33	1.4	0.1044
NCRN_NACE_OXRU	2/14/11	7.52	13.67	5.37	1192	839.33	1.4	0.1044
NCRN_NACE_OXRU	3/23/11	7.71	11.25	10.32	1104	575.9	1.2	0.0587
NCRN_NACE_OXRU	4/20/11	8.25	10.5	18.35	1192	514.72	0.8	0.1044
NCRN_NACE_OXRU	5/18/11	7.73	7.92	19.38	1136	328.65	1.4	0.1566
NCRN_NACE_OXRU	6/29/11	8.98	12.25	28.8	1744	544	0.9	0.1860
NCRN_NACE_OXRU	7/26/11	8.59	9.1	30.95	1864	521	0.9	0.0979
NCRN_NACE_OXRU	8/30/11	7.61	7.7	22.52	1512	458.28	1.3	0.0653

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_OXRU	9/22/11	8.3	10.83	21.8	1416	511.8	1.4	0.0979
NCRN_NACE_OXRU	10/27/11	7.55	8.9	15.2	1296	496.9	0.9	0.0718
NCRN_NACE_OXRU	11/17/11	7.32	9.68	11.3	1280	363.98	0.7	0.1175
NCRN_NACE_OXRU	12/15/11	7.37	10.73	8.63	1336	472.67	1.6	
NCRN_NACE_OXRU	1/26/12	7.18	11.55	7.2	1296	845	1.7	0.1109
NCRN_NACE_OXRU	2/23/12	8.18	12.53	10.67	1168	683.27	1.4	0.0750
NCRN_NACE_OXRU	3/13/12	8.34	13.1	14.25	1208	527.25	1	0.0946
NCRN_NACE_OXRU	5/3/12	8.23	10.03	17.3	1440	460.17	0.9	0.0914
NCRN_NACE_OXRU	5/24/12	8.66	10.6	24.8	1576	158.9	0.9	0.1011
NCRN_NACE_OXRU	6/28/12	9.05	10.73	25.8	1680	517	0.6	0.1272
NCRN_NACE_OXRU	7/18/12	8.8	10.47	30.37	1720	446.63	0.7	0.2577
NCRN_NACE_OXRU	8/23/12	8.88	9.7	26.57	1680	409.27	0.5	0.0848
NCRN_NACE_OXRU	9/27/12	9.18	12.13	22.77	1848	529.67	0.4	0.0979
NCRN_NACE_OXRU	10/25/12	8.25	10	17.9	1936	467.73	0.4	0.1175
NCRN_NACE_OXRU	11/15/12	7.97	12.83	8.53	1280	401.43	0.8	0.1631
NCRN_NACE_OXRU	12/20/12	8.36	15.4	7.17	1560	469.5	0.8	0.1272
NCRN_NACE_OXRU	1/29/13	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_OXRU	2/25/13	8.06	14.1	5.2	1248	647.3	1.2	0.0457
NCRN_NACE_OXRU	3/28/13	8.15	12.57	6.33	1360	771.03	1.2	0.0685

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_OXRU	4/23/13	7.78	10.18	12.12	1344	459.28	0.497	
NCRN_NACE_OXRU	5/21/13	7.97	9.17	20.83	1592	472.03	0.364	
NCRN_NACE_STCK	3/6/06	6.85	8.23	5.1	438	421.3	0.2	
NCRN_NACE_STCK	3/30/06	7.13	7.63	9.1	470	428.35	*Present <QL	0.4176
NCRN_NACE_STCK	4/24/06	7.01	2.27	14.6	654	315.8	0.5	0.1175
NCRN_NACE_STCK	6/14/06	7.38	6.82	17.9	912	348.3	0.5	0.0979
NCRN_NACE_STCK	7/5/06	7.17	6.73	24	664	194.8	0.4	
NCRN_NACE_STCK	7/31/06	7.43	6.3	24.6	796	329.4	0.5	0.3458
NCRN_NACE_STCK	8/24/06	6.76	6.81	23.75	748	318.8	0.7	0.3850
NCRN_NACE_STCK	10/2/06	6.97	8.84	14.1	692	245.6	0.7	2.0424
NCRN_NACE_STCK	11/14/06	7.36	9.265	13.575	690	255.35	0.6	
NCRN_NACE_STCK	12/14/06	7.23	8.1	6.8	514	246.1	*Not Reported	0.2545
NCRN_NACE_STCK	3/20/07	7.3	9.833	7.733	376	470.117	2.25	0.0261
NCRN_NACE_STCK	4/17/07	6.86	3.573	7.867	378	211.417	1.44	0.0914
NCRN_NACE_STCK	5/18/07	7.16	7.017	14.833	656	383.217	0.1	0.0750
NCRN_NACE_STCK	6/20/07	6.8	7.23	21.9	568	353.8	0.6	0.1077
NCRN_NACE_STCK	7/23/07	7.19	5.88	20	746	414.6	0.3	
NCRN_NACE_STCK	9/10/07	7.28	6.07	23.3	666	407.9	0.7	
NCRN_NACE_STCK	10/1/07	6.83	6.09	15.5	776	365.8	1.2	

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_STCK	10/30/07	7.22	8.88	9.1	734	327.9	2.1	
NCRN_NACE_STCK	11/27/07	7.23	7.58	10.1	848	417.1	1.8	
NCRN_NACE_STCK	1/10/08	6.94	11.76	5.5	852	518.5	1.2	
NCRN_NACE_STCK	2/5/08	6.94	9.75	5.8	530	343.95	2.1	
NCRN_NACE_STCK	3/10/08	7.71	11.9	4.25	702	753.5	1.1	
NCRN_NACE_STCK	4/2/08	7.5	11.1	9.28	804	517.5	1.1	
NCRN_NACE_STCK	5/5/08	7.28	9.4	14.05	776	290.35	1.4	
NCRN_NACE_STCK	6/3/08	7.23	8.35	17.18	802	271.88	1.6	
NCRN_NACE_STCK	7/1/08	7.4	10	20.23	870	287.05	0.5	
NCRN_NACE_STCK	8/4/08	7.02	5.97	20.7	826	322.3	0.8	
NCRN_NACE_STCK	9/2/08	7.18	6.82	18.1	820	301.7	1	
NCRN_NACE_STCK	10/7/08	7.16	8.48	11.85	928	307.25	0.9	
NCRN_NACE_STCK	11/12/08	6.94	7.16	7.7	1008	351.12	0.7	
NCRN_NACE_STCK	1/29/09	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_STCK	3/25/09	7.14	12.02	4.9	772	1461.25	1.1	0.0392
NCRN_NACE_STCK	4/22/09	7.05	10.28	11.3	680	426	1.5	0.0555
NCRN_NACE_STCK	6/1/09	7.54	8.5	15.95	960	318.45	0.7	0.0750
NCRN_NACE_STCK	6/30/09	7.27	7.25	19.55	730	299.9	0.7	0.0620
NCRN_NACE_STCK	8/3/09	7.66	7.45	22.55	1172	368.05	1.5	0.0816

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (µeq/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_STCK	9/3/09	7.54	8.05	17.1	662	299.35	1.1	0.0685
NCRN_NACE_STCK	10/1/09	7.4	8.95	13	798	303.25	0.6	0.0587
NCRN_NACE_STCK	10/29/09	7.37	9.3	14.2	780	250.3	0.6	0.0783
NCRN_NACE_STCK	11/23/09	7.46	10.7	9	734	303.45	0.8	0.1272
NCRN_NACE_STCK	12/17/09	7.31	13.75	2	604	274	0.6	0.0816
NCRN_NACE_STCK	1/28/10	7.42	12.85	3.2	604	788.05	0.9	0.0359
NCRN_NACE_STCK	2/25/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_STCK	3/25/10	7.37	11.35	9.4	630	618.9	0.8	0.0457
NCRN_NACE_STCK	4/19/10	7.48	10.4	10	736	471.75	2.1	0.1436
NCRN_NACE_STCK	5/20/10	7.54	8.8	13.7	878	491.9	0.8	0.0685
NCRN_NACE_STCK	6/24/10	7.27	5.85	23.8	640	460.4	1	0.0555
NCRN_NACE_STCK	7/29/10	7.38	6.5	24.8	1344	354.6	1.3	0.0587
NCRN_NACE_STCK	8/24/10	7.42	6.75	21.5	1032	401.1	1.6	0.0620
NCRN_NACE_STCK	9/29/10	7.56	7.2	18	1084	447	1.7	0.1403
NCRN_NACE_STCK	10/25/10	7.42	7.08	13	816	312	1.6	0.0555
NCRN_NACE_STCK	11/17/10	8.3	6.83	*Not Reported	896	383.1	2.1	0.1272
NCRN_NACE_STCK	12/17/10	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	*Not Reported	
NCRN_NACE_STCK	1/19/11	7.62	13.45	1.25	1128	3571	1.1	0.0685

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_STCK	2/14/11	7.62	13.65	2.4	1304	1099	0.6	0.0555
NCRN_NACE_STCK	3/23/11	7.22	10.15	10	856	507.1	0.9	0.0555
NCRN_NACE_STCK	4/20/11	7.22	9.2	13	848	421.7	0.9	0.0914
NCRN_NACE_STCK	5/18/11	7.36	7.4	17.8	912	511.35	1.3	0.0914
NCRN_NACE_STCK	6/29/11	7.3	6.3	22.3	944	430.2	1.1	0.1599
NCRN_NACE_STCK	7/26/11	7.67	6.25	23.9	1128	405.8	1.3	0.0783
NCRN_NACE_STCK	8/30/11	7.51	8.05	18.5	1200	301.95	0.9	0.0783
NCRN_NACE_STCK	9/22/11	7.4	7.45	19	1168	428.6	1.1	0.0326
NCRN_NACE_STCK	10/27/11	7.44	7.55	13.3	1200	788	0.9	0.0946
NCRN_NACE_STCK	11/17/11	7.14	8.4	11.6	1232	426.6	0.6	0.0620
NCRN_NACE_STCK	12/15/11	7.06	10.8	6	896	493.5	0.8	0.0326
NCRN_NACE_STCK	1/26/12	7.3	11.9	5.1	816	627.8	1.1	0.0718
NCRN_NACE_STCK	2/23/12	7.41	10.25	6.9	736	682.3	0.8	0.0326
NCRN_NACE_STCK	3/13/12	7.28	10.45	10.9	816	413.5	0.6	0.0750
NCRN_NACE_STCK	5/3/12	7.54	7.95	16	1240	487.35	0.6	0.0685
NCRN_NACE_STCK	5/24/12	7.46	6.3	19	968	365.95	0.8	0.0555
NCRN_NACE_STCK	6/28/12	7.64	6.15	19.4	1056	345.75	0.7	0.2153
NCRN_NACE_STCK	7/18/12	7.39	5.3	24.9	1120	289	0.7	0.1599
NCRN_NACE_STCK	8/23/12	7.5	6.65	20.4	1144	297.55	0.7	0.0620
NCRN_NACE_STCK	9/27/12	7.78	6.9	17.9	1048	333.5	0.5	0.0914

Site	Date	pH	Dissolved oxygen (mg/L)	Temperature (°C)	Acid neutralizing capacity (ANC) (μeq/L)	Conductivity (μS/cm)	Nitrate (NO_3) (mg/L)	Total phosphorus (TP) (mg/L)
NCRN_NACE_STCK	10/25/12	7.28	6.4	15.7	1176	337.3	0.2	0.1109
NCRN_NACE_STCK	11/15/12	7.73	12.7	6.25	1184	325.9	0.8	0.1403
NCRN_NACE_STCK	12/20/12	7.48	12.2	5.25	1144	360.05	0.8	0.1175
NCRN_NACE_STCK	1/29/13	7.94	14.65	0.2	1024	4763	0.9	0.1240
NCRN_NACE_STCK	2/25/13	8.02	12.75	2.2	1080	860.5	0.8	0.0653
NCRN_NACE_STCK	3/28/13	8.07	10.1	5.1	1176	736.7	0.9	0.0783
NCRN_NACE_STCK	4/23/13	7.49	9.5	10.8	856	355.85	*Present <QL	
NCRN_NACE_STCK	5/21/13	7.34	7.75	18.5	1096	369.15	0.25	

Table A-3 Deer density (deer/km^2) at the three units surveyed for deer in NACE, Piscataway Park, Fort Washington, and Greenbelt Park.

Year	Piscataway Deer Density	Greenbelt Deer Density	Fort Washington Deer Density
2001	42.93	33.90	
2002	37.53	23.88	
2003	57.73	41.79	
2004	41.65	40.02	
2005	48.86	39.84	
2006	66.59	38.88	
2007	22.22	32.09	

2008	58.20	39.14	
2009	27.18	32.97	84.06
2010	30.13	66.19	88.34
2011	27.51	45.89	99.5
2012	25.57	73.29	45.27
2013	33.96	60.98	79.04
2014	17.39	82.90	92.12
Median	**30.13**	**40.02**	**86.20**

Appendix B: Executive Summary

Background

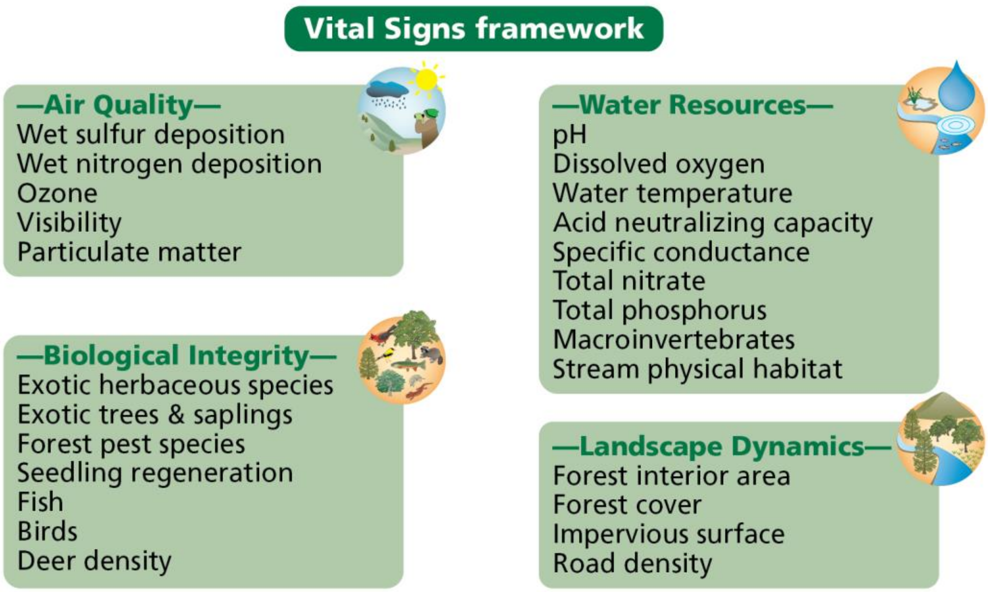
The National Capital Parks–East (NACE) provides a natural haven for the urbanized Washington, D.C., area. NACE includes 14 major park areas that comprise more than 8,000 acres of the Atlantic Coastal Plain from Anne Arundel County, Maryland, through the eastern part of Washington, D.C., to Prince George's and Charles counties, Maryland. In addition to numerous historic and cultural sites, these NPS units protect natural areas for recreation, parkways, historical artifacts and structures, archaeological sites, wetlands, stream valleys, forests, wildlife, and vegetation.

The natural areas within National Capital Parks-East are extremely rich both in biodiversity and in historical context. The park provides islands of refuge for many uncommon plant and animal species in the highly urbanized Washington, D.C. metropolitan area, protecting a variety of cultural and natural resources. Additionally, NACE provides opportunities for the public to foster awareness of the importance of species preservation, biological diversity, natural systems and processes, and the value of natural open space in an urban environment.

The natural resources of NACE are challenged by multiple regional and local stressors. Air pollution from power plants, industry, and vehicle emissions results in reduced air quality through large regions of the central eastern seaboard of North America. The park is therefore subjected to high ozone and atmospheric deposition, potentially impacting flora, fauna, and park visitors. Watershed-wide urbanization and development result in challenges to water quality. Population and housing densities continue to increase in the areas adjacent to the park, which reduces the habitat available to native flora and fauna. Increased nutrients, pollutants, and flashiness of river flow can result in impacts to aquatic flora and fauna as well as stream bank erosion. Adverse recreational use within the park can lead to the trampling and loss of vegetation, potential introduction of non-native species, and disturbance or displacement of flora and fauna. Exotic and invasive plants compete with native species, while insects and other pests cause damage to forest trees. Exotic plants are prevalent within the park. Excessive numbers of white-tailed deer use the park as a refuge, resulting in overgrazing of native flora, particularly tree seedlings.

Approach

The Vital Signs framework was used to assess natural resource condition within NACE. Within each vital sign, indicators were identified that would inform the assessment and data was sourced for these indicators. Reference conditions were established for each indicator, and the percentage attainment of reference condition was calculated. Once attainment was calculated for each indicator, an unweighted mean was calculated to determine the condition for each vital sign category and the similarly to combine vital sign categories to calculate an overall park assessment. Based on these key findings, management recommendations and data gaps were developed. Twenty-five metrics were synthesized in four categories: Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. The assessment of condition was based on the comparison of available data collected between 2002 and 2014 to justified ecological threshold values.



Park units with significant natural resources will be the focus of this natural resource condition assessment. Air quality data is interpolated across all park units, and will be an assessment and discussion of all sites within NACE. Water resources and fish are monitored at four sites by the NPS National Capital Region Inventory and Monitoring Network (NCRN I&M) at Greenbelt Park, Suitland Parkway, Oxon Cove Park, and Piscataway Park. Biological integrity is sampled at 47 sites throughout the park (Baltimore-Washington Parkway, Greenbelt Park, Suitland Parkway, Piscataway Park, Oxon Cove Park, Kenilworth Park and Aquatic Gardens, Civil War Defenses of Washington), with the exception of deer population counts that are estimated only in Greenbelt Park and Piscataway Park. Landscape dynamics data from the 2011 National Landcover database are available for all park areas.

Features of National Capital Parks-East

Significant natural areas occur throughout NACE and are extremely rich in both biodiversity and in historical context. The park provides islands of refuge for many rare and unique plant and animal species in the highly urbanized Washington, D.C. metropolitan area. Additionally, NACE provides opportunities to foster public awareness of the importance of species preservation, biological diversity, natural systems and processes, and the value of natural open space in an urban environment.

The natural features of NACE units with significant natural resources include: sand and gravel beaches, shoreline bluffs, flood plain and upland forests, shell marl ravine forest with its associated fossil outcrops, vernal pools, two large river systems and numerous streams, a variety of soil types, forested seeps, and numerous other wetlands such as freshwater tidal marshes, swamps, emergent marshes, and bogs.

Threats to National Capital Parks-East

With the growth of Washington, D.C., and the surrounding areas, associated development pressures have consistently posed a significant problem for National Capital Parks-East. Population and housing densities continue to increase in the areas adjacent to the park, which reduces the habitat available for native flora and fauna. Intense visitation and demands for park services from commuters on the Baltimore-Washington parkway to birders at Piscataway Park, place increasing demands on its protected areas. Off-trail traffic by visitors threatens vegetation, can lead to the possible introduction of non-native species and disturbance or displacement of wildlife. Some areas of NACE are threatened by exotic invasive species that compete with native species. Excessive numbers of white-tailed deer use the park as a refuge, resulting in overgrazing of native flora, particularly tree seedlings.

The Potomac River experiences daily 1 meter (3 feet) tidal fluctuations at Washington, D.C., which strongly influence the flow regime of the river and its subsequent channel morphology. Relative sea level rise and surges of water associated with hurricanes and storms affect the estuarine Potomac River and the shoreline of GWMP. Shoreline erosion is a continuing issue, especially in areas like Kenilworth Park & Aquatic Gardens and as global sea levels continue to rise, these inundation issues will only become more prevalent at the parkway.

Key findings, recommendations, and data gaps

The good condition of water resources and moderate condition of biological integrity in NACE were offset by very degraded conditions for air resources and landscape dynamics, yielding an overall classification of degraded condition for the park's natural resources. The very degraded condition for landscape dynamics was not unexpected for a metropolitan park with extensive landscape manipulation. Similarly, the very degraded condition for air resources is driven by external forces and should not be expected to improve though management actions within the park. Despite these findings, it is widely recognized that NACE adds critical green space in an increasingly urbanized region, providing refuge for many species, and serving as a migration rest stop for wildlife.

Table B-1 Vital signs, reference attainment percentages, and condition.

Vital sign	Reference attainment	Condition
Air quality	17%	Very degraded
Water resources	65%	Good
Biological integrity	48%	Moderate
Landscape dynamics	3%	Very degraded
NACE Overall	**33%**	**Degraded**

Air quality

Air quality conditions at NACE were in a very degraded condition. Degraded air quality is a problem throughout the eastern United States, and while the causes of degraded air quality are largely out of the park's control, the specific implications to the habitats and species in the park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts.

The close connection between climate and air quality is reflected in the impacts of climate change on air pollution levels. In particular, U.S. EPA has concluded that climate change could increase ozone concentrations and change amounts of particle pollution.

Table B-2 Key findings, management implications, and recommended next steps for air quality in NACE.

Key findings	Management implications	Recommended next steps
Air quality is very degraded and is a regional problem	• Impacts of poor air quality on park largely unknown. • Nearby parks (e.g. Shenandoah NP) have clear ecological impacts of poor air quality (i.e. acid rain impacts).	• Investigate effects of poor air quality on sensitive habitats and species within the park (e.g. ozone damage to vegetation). • Develop park-specific management actions. • Stay engaged with the wider community in terms of air quality education and activities.

Table B-3 Data gaps, justification, and research needs for air quality in National Capital Parks-East.

Data gaps	Justification	Research needs
Lack of park-specific air quality data	• Air quality is only measured and interpolated on regional and national scales.	• Use transport and deposition models to analyze and estimate park specific air quality data and trends. • Implementing in-park air quality monitoring would give better insights into park-level air quality condition and possible effects on park habitats and species. • Planting and monitoring a garden of ozone-sensitive plants.
Effects of poor air quality on park habitats and species	• Implement park-specific management actions.	• Investigate effects of poor air quality on sensitive habitats and species within the park.
Ecological references for mercury wet deposition	• Mercury deposition is reported for NACE but no reference exists for protection of species.	• Adopt standards once NPS Air Resources Division establishes mercury wet deposition reference.
Minimal soundscape information	• Traffic noise from Baltimore-Washington Parkway and other roads potentially affects wildlife behavior and distribution and the recreational experience. • Noise is greater in fall and winter when there is no foliage to dampen it.	• Minimal soundscape information • Explore weekend/holiday road closures at select park roads to thru-traffic (Fort Dupont Park)

Water Resources

Water resources within NACE were in a good condition overall, with 65% attainment of reference conditions. Four sites in NACE are monitored for water quality (Pieper 2012). Sites were located in an unnamed tributary of Accokeek Creek (Piscataway Park), Henson Creek (Suitland Parkway), Oxon Run (Oxon Cove Park), and Still Creek (Greenbelt Park). Total phosphorus was in very degraded condition, which is similar to results found in parks throughout the region. The majority of water inflows to the park originate from outside the park in developed/urban areas. Data gaps and research recommendations revolve around maintaining good water quality by identification of nutrient sources and sensitive organisms. Water temperatures at all streams were well below the thresholds, but should continue to be monitored, as water temperature increase is one of the most immediate threats from climate change, and this would result in the loss of fish and other organisms that depend upon cooler water.

Table B-4 Key findings, management implications, and recommended next steps for water resources in NACE.

Key findings	Management implications	Recommended next steps
Very degraded condition for stream total phosphorus	• Nutrient enrichment affects stream flora and fauna (eutrophication). • Visible signs of eutrophication reduces quality of visitor experience.	• Elevated total phosphorus levels have been found in parks throughout the NCR and could also be largely due to underlying geology (C*arruthers* et al. *2009, Norris and Pieper 2010, Thomas* et al. 2011a, b, c). • Minimize soil disturbance. • Implement best management practices such as expanding riparian buffers and no-mow areas.
Fair condition for Benthic Index of Biotic Integrity (BIBI)	• Affects stream flora and fauna. • Reduces quality of visitor experience	• Implement stream restoration and manage volume and velocity of water from impervious surfaces (e.g. swales, riparian buffers and no-mow areas). • Implement monitoring to identify sources and patterns of pollution affecting stream biota.
Degraded condition for specific conductance	• Affects stream flora and fauna • Reduces quality of visitor experience	• Identify sources (e.g. salting of roads) and conductance-sensitive organisms and locations for management initiatives. • Explore alternative de-icing solutions. • Implement best management practices such as riparian buffers and no-mow areas.
Slightly degraded Physical Habitat Index	• Affects stream flora and fauna • Reduces quality of visitor experience	• Implement stream restoration and manage volume and velocity of water entering the park (e.g. swales, riparian buffers and no-mow areas). • Implement monitoring to identify sources and patterns and then develop management alternatives.

Table B-5 Data gaps, justification, and research needs for water resources in National Capital Parks-East.

Data gaps	Justification	Research needs
Origins of nitrogen and phosphorus pollution are uncertain	• Affects stream flora and fauna. • Reduces quality of visitor experience.	• Identify sources of nutrients.

Biological integrity

Biological integrity was in ***moderate condition***, with 48% attainment of reference conditions. Deer density and the stocking index were both in very degraded condition. Studies show a relationship between high deer density and poor forest regeneration; therefore, deer management should continue to be a top priority. Other monitoring recommendations include expanded exotic species monitoring and education, and continuing to monitor pests and diseases. Data gaps and research needs include a method for modeling the effects of climate change and other stressors on the regions forests and natural resources. How climate change may affect park resources and habitats should be an ongoing research focus, in particular how it might affect the introduction and spread of exotic species and forest pests and diseases.

Table B-6 Key findings, management implications, and recommended next steps for biological integrity in NACE.

Key findings	Management implications	Recommended next steps
Overall, forest community was represented well by native plant species, though seedling regeneration is a potential problem.	• Future lack of forest regeneration and subsequent habitat. • Deer overbrowse can contribute to introduction of invasive species.	• Manage deer over-browse through deer population control measures, repellant, tree tubes, barriers (e.g. fencing portions of the park). • Implement planting initiatives where appropriate.
Presence of exotic plants.	• Displacement of native species, reducing biodiversity.	• Prioritize species and locations for implementing control measures. • Restore and maintain native species and communities. • Identify and map areas of exotic invasion that are not reflected in I&M Monitoring (e.g. floodplain areas are not currently represented); and initiate population monitoring.
Deer overpopulation may be impacting forest regeneration throughout park.	• Increased herbivory reducing seedling density. • Potential for spread of chronic wasting disease among deer.	• Make, and expand, ongoing population size counts.

Table B-7 Data gaps, justification, and research needs for biological integrity in NACE.

Data gaps	Justification	Research needs
Limited geographic range of forest monitoring plots	• Current monitoring sites are not capturing extent of exotic species presence or forest species loss.	• Make, and expand, ongoing forest monitoring.
Limited knowledge on how forests might change in light of new and future stressors (climate change, pests, and diseases)	• These stressors are already present or will be present in the near future.	• Research and modeling into the effects of these stressors on the region's forests.

Landscape dynamics

Landscape dynamics within National Capital Parks-East were in very degraded condition overall, with 3% attainment of reference conditions—mainly due to the cultural design of the park, regional development, and urban encroachment. The park shows very degraded conditions for forest interior area, forest cover and road density.

Table B-8 Key findings, management implications, and recommended next steps for landscape dynamics in NACE.

Key findings	Management implications	Recommended next steps
Very degraded forest interior area and forest cover – within and outside the park boundary	• Reduction in bird breeding habitat. • Reduction in birds fledged each year. • Increased predation.	• Improve quality of existing forest habitat by managing for exotic species.
Large areas of impervious surface – inside and outside the park boundary	• Increased rainfall runoff volume and velocity (with pollutants).	• Assess and mitigate drainage issues for existing impervious areas. • Change asphalt parking lots to porous surfaces (e.g. pervious pavers, grass). • Retrofit existing impervious areas (e.g. install rain gardens/bio-retention systems, etc.)
High road density surrounding park boundary	• Road density increases surface runoff/stormwater that enters park water resources, and may decrease water quality conditions, resulting in lower water quality and biological integrity. • Disrupts habitat of forest interior area.	• Difficult to manage. Potential traffic calming/reduction measures.

Table B-9 Data gaps, justification, and research needs for landscape dynamics in NACE.

Data gaps	Justification	Research needs
Implications of external land use changes on park resources	• Connectivity of ecological processes from park to watershed	• Landscape analysis at multiple scales.
Habitat corridor function	• Needed for migration and movement of fauna.	• Assessment of current and potential use by fauna. • Modeling of the potential effects of climate change on habitats within the park and surrounding region.

Conclusions

Natural resources in NACE are in degraded condition overall and are under threat from surrounding land use, regionally poor air quality, and overpopulation of deer. Climate change is predicted to negatively affect many of the natural resources of the park, including increasing ozone levels and particle pollution, raising water temperature, changing forest composition, and affecting exotic species and forest pests and disease.

Appendix C: Resource Brief

National Capital Parks-East
Natural Resource Condition Assessment Brief

National Park Service
U.S. Department of the Interior

Natural Resource Condition Assessments (NRCAs) evaluate the current condition of a subset of natural resources and resource indicators in a national park. This brief summarizes the findings of the 2015 NRCA for National Capital Parks-East.

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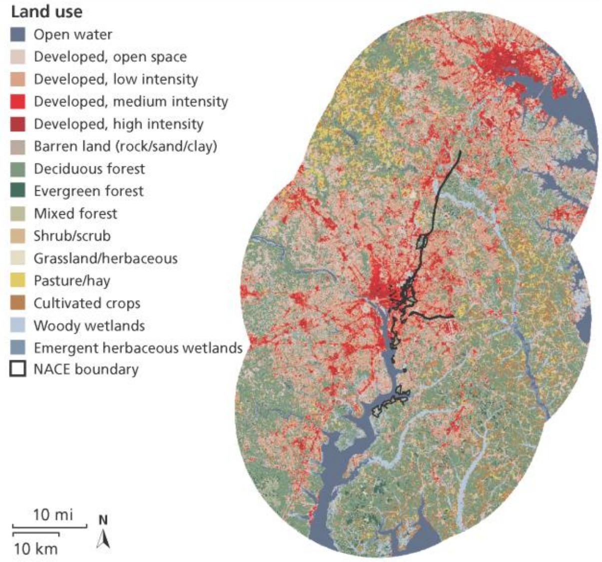
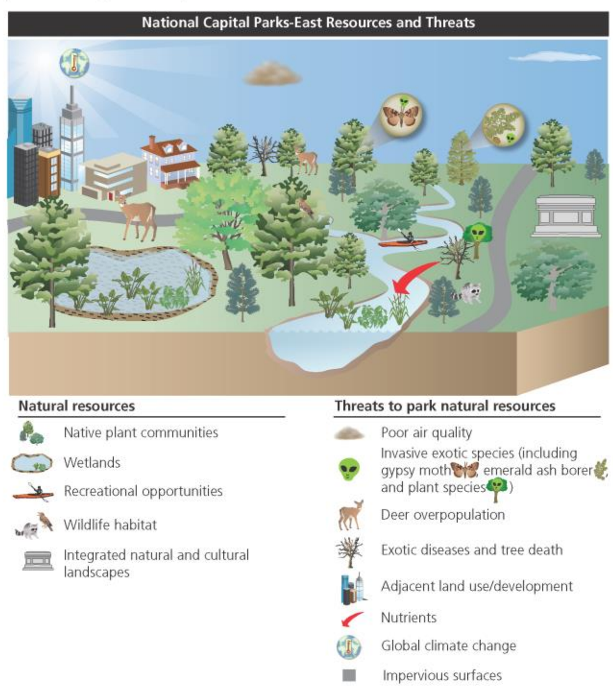
The natural resources of NACE are challenged by multiple regional and local stressors. Air pollution from power plants, industry, and vehicle emissions result in reduced air quality through large regions of the central eastern seaboard of North America. The park is therefore subjected to high ozone and atmospheric deposition, potentially impacting flora, fauna, and park visitors. Watershed-wide urbanization and development result in challenges to water quality. Population and housing densities continue to increase in the areas adjacent to the park, which reduces the habitat available to native flora and fauna. Increased nutrients, pollutants, and flashiness of river flow can result in impacts to wetland flora and fauna as well as stream bank erosion. Adverse recreational use within the park can lead to the trampling and loss of vegetation, potential introduction of non-native species, disturbance or displacement of flora and fauna. Exotic and invasive plants compete with native species, while insects and other pests cause damage to forest trees. Exotic plants are prevalent within the park. An overabundant population of white-tailed deer use the park as a refuge, resulting in overgrazing of native flora, particularly tree seedlings.

Natural resource condition in National Capital Parks-East

A total of 25 vital sign indicators were used to determine the natural resource condition of NACE. Reference conditions (or ideal scenarios) were established as benchmarks for each indicator. Percentage scores were calculated for each indicator to represent where the state of the indicator was in comparison to reference conditions. Based on key vital sign findings, management recommendations were developed and data gaps were identified.



Adjacent land use within a 30 km area surrounding National Capital Parks-East in 2011 (Jin et al. 2013; NPS 2011b).



Features of, and threats to natural resources in National Capital Parks-East.

KEY FINDINGS AND RECOMMENDATIONS

Overall, the natural resources of National Capital Parks-East were in degraded condition.

The vital signs framework showed that air quality condition was generally very degraded, water resources condition was generally good, biological integrity condition was variable but moderate overall, and landscapes dynamics condition was very degraded.

Air Quality Air quality was in a very degraded condition. Degraded air quality is a problem throughout the eastern United States, and while the causes of degraded air quality begin beyond the park's borders, the specific implications to the habitats and species in the park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts. The close connection between climate and air quality is reflected in the impacts of climate change on air pollution levels. In particular, the U.S. EPA has concluded that climate change could increase ozone concentrations and change the amount of particle pollution in the air.

Water Resources Stream water resources were in good condition overall. The majority of water resource indicators were in a very good condition. A higher overall attainment was offset by very degraded conditions for total phosphorus and degraded conditions for specific conductance and stream physical habitat. Macroinvertebrates were on the borderline of being classified as in degraded condition, so more data about sensitive locations and specieswould be informative. Data gaps and research recommendations revolve around maintaining good water quality by identification of nutrient sources and sensitive organisms.

Biological Integrity Biological integrity was in a moderate condition overall, although results for individual metrics were variable. Deer density and a measure of tree seedling regeneration were both in degraded condition. Studies show a relationship between high deer density and poor forest regeneration and as such, deer management should continue to be a top priority. Other monitoring recommendations include expanded exotic species monitoring and education, and continuing to monitor pests and diseases. Data gaps and research needs include models of the effects of climate change and other stressors on the region's forests. How climate change may affect the park's resources and habitats should be an ongoing research focus, in particular how it might affect the introduction and spread of exotic species and forest pests and diseases.

Vital Signs Framework

Air Quality
- Wet sulfur deposition
- Wet nitrogen deposition
- Ozone
- Visibility
- Particulate matter

Biological Integrity
- Exotic herbaceous species
- Exotic trees & saplings
- Forest pest species
- Seedling regeneration
- Fish
- Birds
- Deer density

Water Resources
- pH
- Dissolved oxygen
- Water temperature
- Acid neutralizing capacity
- Specific conductance
- Total nitrate
- Total phosphorus
- Macroinvertebrates
- Stream physical habitat

Landscape Dynamics
- Forest interior area
- Forest cover
- Impervious surface
- Road density

The vital signs framework used to assess National Capital Parks-East.

Vital Sign	Reference condition attainment	Current condition
Air Quality	17%	Very degraded
Water Resources	64%	Good
Biological Integrity	48%	Moderate
Landscape Dynamics	3%	Very degraded
NACE	**33%**	**Degraded**

The overall reference condition attainment and current condition of each of the four vital signs within National Capital Parks-East.

Landscape Dynamics Landscape dynamics were in very degraded condition overall. All landscape dynamics indicators were assessed as very degraded. Related research needs for the park mostly relate to its function as habitat corridor in the region. How climate change may affect the park's resources and habitats should be an ongoing research focus.

CONCLUSIONS

Natural resources in National Capital Parks-East are in degraded condition overall and are under threat from surrounding land use (increased development), regionally poor air quality, overpopulation of deer, and exotic species and pests. Climate change is predicted to negatively affect many of the natural resources of the park, including increasing ozone levels and particle pollution, raising the water temperature of streams, changing forest composition, and allowing for the success of exotic species and forest pests and disease.

This brief is excerpted from: Walsh BM and Others. 2015. National Capital Parks-East natural resource condition assessment: National Capital Region. Natural Resource Report NPS/PRWI/NRR—2015/XXX. National Park Service. Fort Collins, Colorado. Published Report-XXXXXX.

For more information, please visit the Park's Visitor Center or call (202) 690-5185.
National Capital Parks-East
National Park Service
www.nps.gov/nace

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University of Maryland Center for Environmental Science
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