National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Colonial National Historical Park Natural Resource Condition Assessment

Virginia

Natural Resource Report NPS/COLO/NRR—2012/544

ON THE COVER

Wormley Creek in the fall.
Photo: Colonial NHP

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June 2012

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

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics 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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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Northeast Coastal and Barrier Network, Northeast Region (http://www.nps.gov/nero/science/final/finalreps.htm) and the Natural Resource Publications Management Web site (http://www.nature.nps.gov/publications/nrpm) on the Internet.

Please cite this publication as:

Lookingbill T,, C. N. Bentsen, T. J. B. Carruthers, S. Costanzo, W. C. Dennison, C. Doherty, S. Lucier, J. Madron, E. Poppell, and T. Saxby. 2012. Colonial National Historical Park natural resource condition assessment: Virginia. Natural Resource Report NPS/COLO/NRR—2012/544. National Park Service, Fort Collins, Colorado.

TIC Number: 333/115250

NPS 333/115250, June 2012

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BACKGROUND AND CONTEXT

Colonial National Historical Park was originally authorized as a national monument in 1930, and later established as a national historical park in 1936. The Park protects the historical units of Jamestown and Yorktown. In 1957, the Colonial Parkway was completed, linking the two units through Williamsburg, and thereby connecting Virginia's historic triangle. The Park offers a vast array of cultural resources, notably the site of the first English settlement at Jamestown in 1607 and the Siege of Yorktown in 1781 that proved to be the last major campaign of the American Revolution. As a result, Jamestown Island and Colonial Parkway are listed on the National Register for Historic Places. The documentation to qualify Yorktown for this designation is underway.

The condition of natural resources in Colonial National Historical Park must be considered in context of its geographic location, legislative mission, and history. Founding documents for the Park require management to certain historical conditions that include the preservation of the original Jamestown Colony site, the landscape and buildings associated with the Revolutionary War, and the scenic Parkway that connects Jamestown Island to Yorktown Battlefield. The surrounding landscape also leaves an indelible mark on the Park's natural resources. The Park crosses four counties with adjacent land owned by the U.S. Navy, U.S. Coast Guard, Cities of Newport News and Williamsburg, the Colonial Williamsburg Foundation, College of William and Mary, and private landowners. These adjacent areas are experiencing rapid development and expansion of commercial, single and multi-family residential properties, while agriculture and silviculture land uses decline throughout the Park's watersheds.

The geography of the Park is important to consider in interpreting the assessment results. The Park stretches between two large rivers, the James and the York, with significant shoreline along each. The location of the Park is within a dynamic tidal region of these water bodies. In 1985, a northeaster destroyed the Yorktown waterfront pier and docks, and required the addition of beach fill and a breakwater to stabilize the shoreline. In 2003, Hurricane Isabel storm surge damaged shoreline stabilization structures, eroded beaches, washed away several archeological sites along the Parkway and on Jamestown Island, and severely damaged the Jamestown visitor center and several tour road bridges. These extreme events are compounded by local eustatic sea level rise of 2.1 millimeters (0.1 inches) per year. This assessment includes few metrics

Photo: Colonial NHP

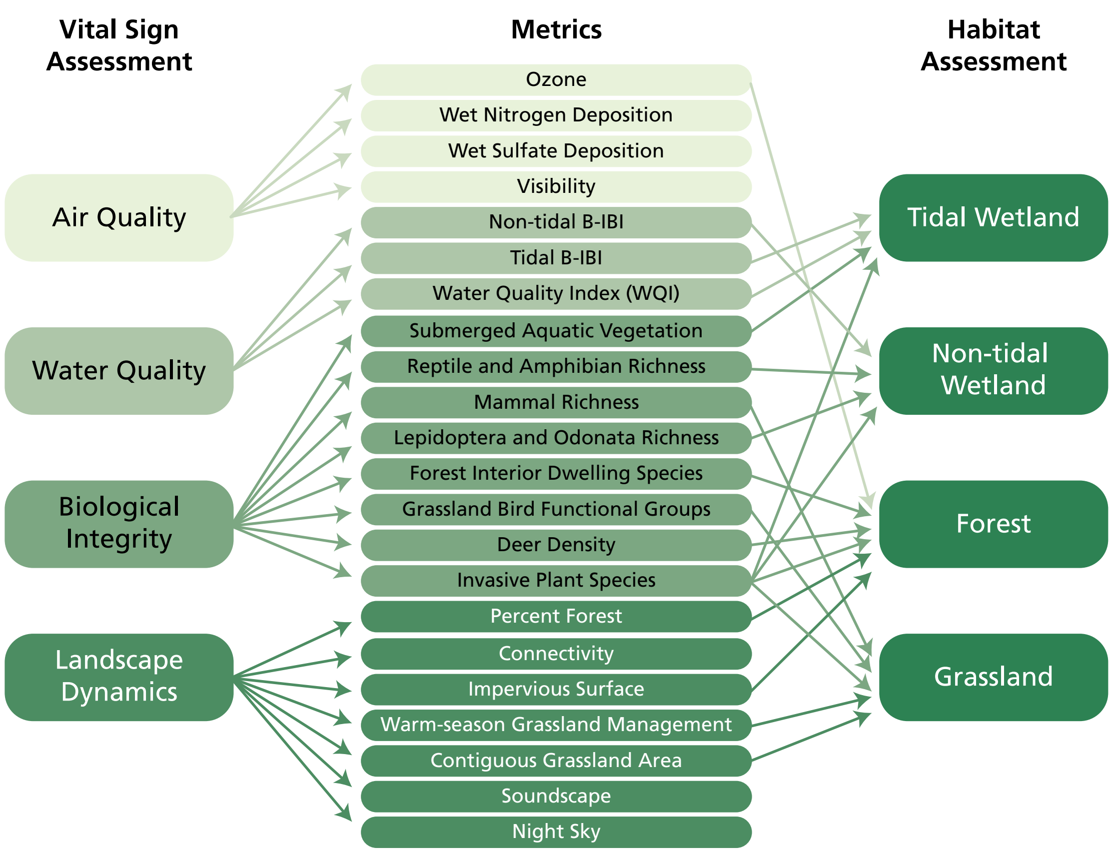
Beach erosion at Black Point in Jamestown has required the construction of sills to capture sand and stabilize the shoreline.

designed specifically to gauge the effects of storm surge and climate-driven fluctuations in water level. However, these effects were captured indirectly within the current assessment framework, for example in measures of water quality, species invasions, and changes in vegetation composition. It is recommended that critical data gaps can be resolved by measuring indices like shoreline erosion, tidal marsh elevation change, changes in salinity regime, or other indices which can directly describe how these two rivers impact the Park and its resources.

The Park is included in the Northeast Coastal and Barrier Network, created by charter in 1999, and is one of 32 Inventory and Monitoring Program networks throughout the country charged with developing inventory and monitoring plans for national parks. The National Park Service Inventory and Monitoring Program has implemented numerous monitoring programs within Colonial aimed at informing park managers of changes in habitat quality and/or species populations. These monitoring programs create a long-term data set for park managers to assess variability over time and are a significant source of information used for this natural resource condition assessment.

APPROACH

Metrics form the basis of this natural resource condition assessment. The NPS Inventory and Monitoring (I&M) program has previously developed a number of ecological monitoring indicators grouped as 'vital signs'. Sixteen metrics from four vital sign groups (air quality; water quality; biotic integrity; and landscape dynamics) were used in this assessment to calculate natural resource condition of four pre-classified habitats (forest, grassland, non-tidal wetland, and tidal wetland). Reference conditions were determined based on published scientific literature, state and federal guidelines, historical data, and expert opinion as appropriate. Attainment of reference condition was assessed for each indicator and summarized by habitat and ultimately for the whole park. Management recommendations were then developed based on these key findings.



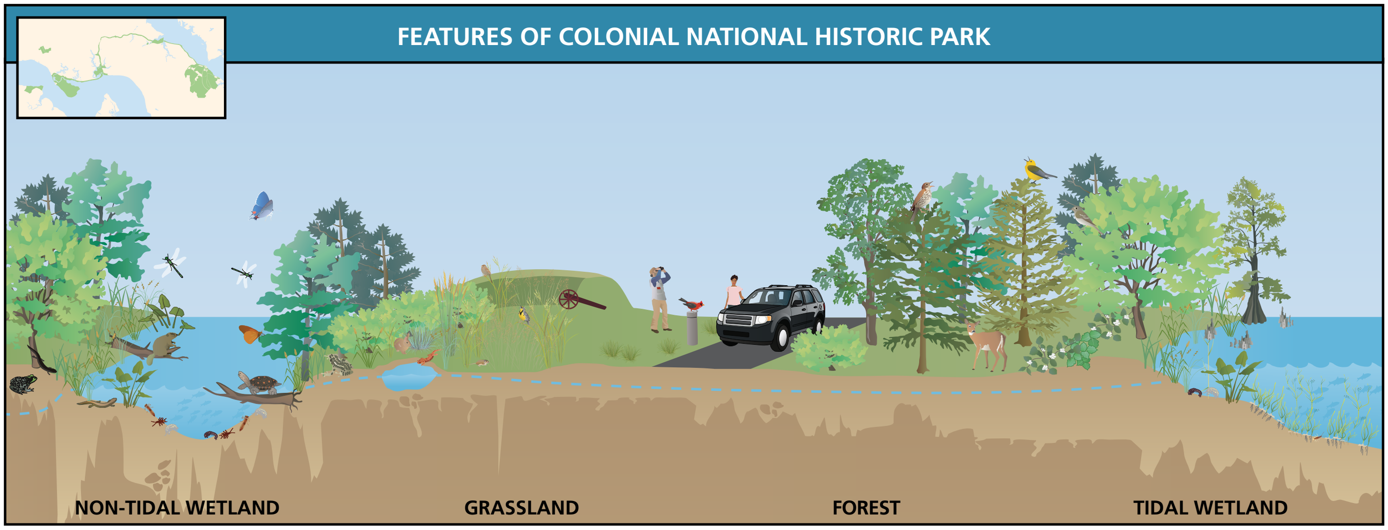
Vital signs, metrics, and habitat assessment framework for Colonial National Historical Park.

FEATURES OF COLONIAL NATIONAL HISTORICAL PARK

Ruins of the ca. 1750 Ambler plantation house in historic Jamestown.

Colonial NHP is a uniquely shaped park bounded by the James River on the west and the York River on the east. The Park consists primarily of three subunits: Jamestown and Yorktown, connected by Colonial Parkway. Complex groundwater geology yields karst formations and sinkholes throughout Yorktown. Four dominant habitat groupings are present within the Park, including forest, grassland, non-tidal wetland, and tidal wetland. These habitats provide shelter, food, and breeding grounds for a range of highly sensitive bird species (e.g., barred owl [*Strix varia*]), imperiled insects (e.g., rare skipper [*Problema bulenta*]), endangered mammals (e.g., Rafinesque's big-eared bat [*Corynorhinus rafinesquii macrotis*]) and rare and threatened reptiles and amphibians (e.g., Mabee's salamander [*Ambystoma mabeei*]). Colonial NHP is an area of significant cultural and historic interest including reconstructed earthworks from the Revolutionary and Civil Wars and the historic Jamestown settlement. The Park attracts approximately five million recreational and non-recreational visitors each year.

Conceptual diagram showing the key features of Colonial National Historical Park.



Physical features

- Three primary subunits of Jamestown, Colonial Parkway, and Yorktown comprise the unique Park shape.
- Lower tributaries of the Chesapeake Bay, the James and York Rivers, bound the Park on the west and east.
- Complex groundwater geology underlies the Park, with karst formations and sinkholes throughout Yorktown and the Parkway.

Ecosystem features

- Four main habitat types—forest, grassland, non-tidal wetland, and tidal wetland—dominate the Park landscape.
- Vegetation includes endemic forest assemblages, rare or endemic wetland communities, and large swathes of warm-season grassland.
- Habitats provide shelter, food, and breeding grounds for imperiled insects, rare and threatened herpetofauna, highly sensitive birds, and endangered mammals.

Human use features

- Significant areas of cultural and historical interest, including Revolutionary and Civil War earthworks and the historic Jamestown settlement, are found throughout the Park.
- More than five million people visit the Park each year, with walking and birdwatching the most common recreational activities.
- Scenic Colonial Parkway connects Jamestown, Williamsburg, and Yorktown through extensive forests, grasslands, and wetlands.

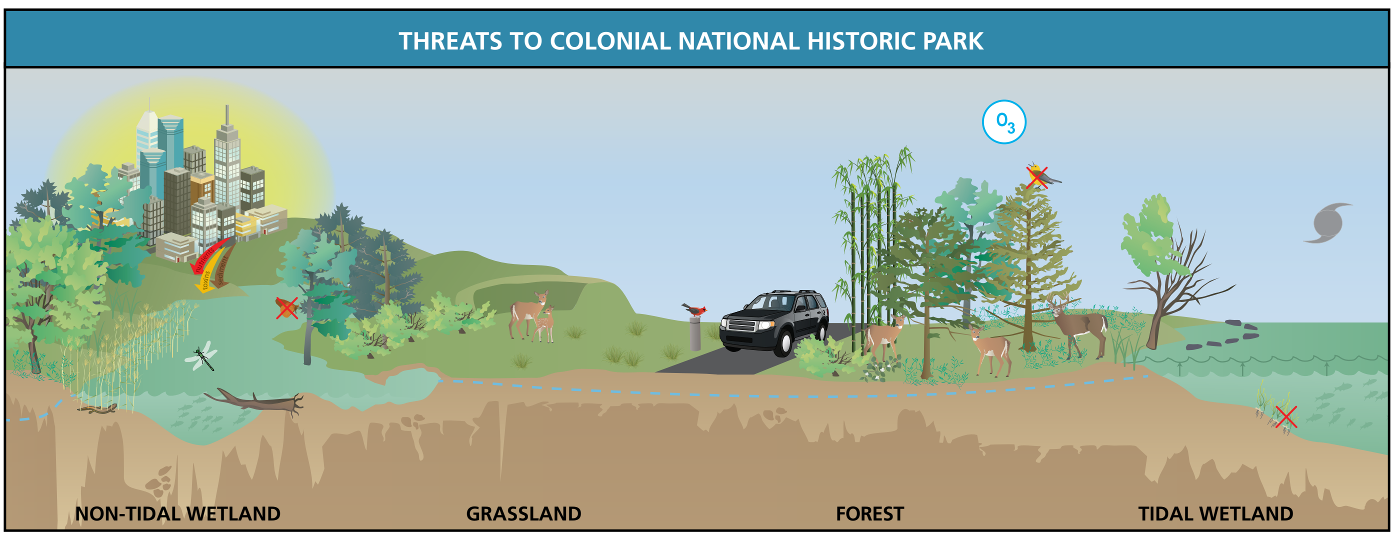
THREATS TO COLONIAL NATIONAL HISTORICAL PARK

Photo: Tood Lookingbill

Invasive species, such as golden bamboo, are a serious threat within Colonial NHP.

Threats to Colonial NHP have been categorized into three categories: internal (within the park), watershed (outside and around park boundaries), and regional (threats that impact the entire region). Internal threats include invasive plant and animal species; streambank and shoreline erosion; and the cascading effects of deer overbrowsing on habitat condition. Watershed threats include soil and water contamination from surrounding land use activities; land use pressures associated with increasing populations; and eutrophication of waterways. Regional threats are dominated by poor air quality threatening the health of habitats and humans; sea level rise and increased severity and frequency of storms leading to shoreline erosion and loss of historical sites as well as increased salinity of groundwater; and light and sound pollution affecting the aesthetic and ecological values of the Park.

Conceptual diagram showing the key threats to Colonial National Historical Park.



Internal threats


Invasive species, such as golden bamboo, common reed, and Japanese stiltgrass, outcompete native flora.

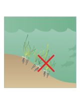

Streambank and shoreline erosion threatens wetlands and ephemeral pools used by the rare skipper .


Deer overbrowsing reduces species richness and abundance of herbs and shrubs, and sensitive songbirds, diminishes regeneration of understory trees, and leads to a competitive advantage for non-native plants.

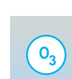
Watershed threats


Fuel and sewage from surrounding hazardous waste sites contaminate soil and water.

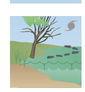

Population expansion and urbanization increases land use pressures and conflicts with neighbors along Park boundaries.


Eutrophication from excessive nutrients degrades waterways, tidal wetlands, and submerged aquatic vegetation.

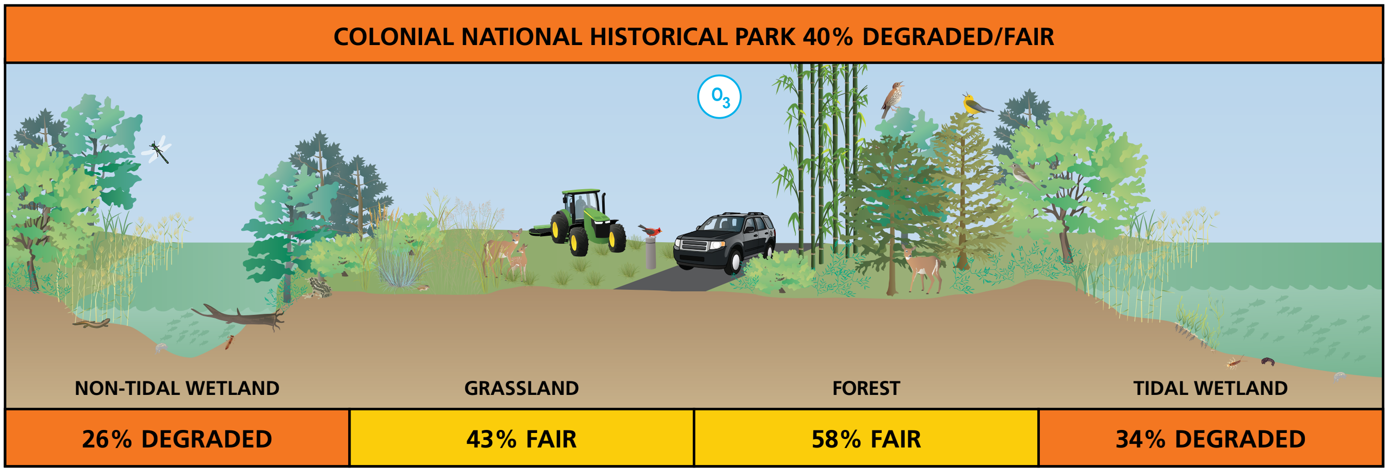
Regional threats



Poor air quality detrimentally affects human health, vegetation, and other natural resources.


Sea level rise, combined with increased severity and frequency of storms, results in shoreline erosion and groundwater intrusion.


Light and sound pollution degrades the aesthetic and ecological values the Park seeks to protect.



CURRENT CONDITION OF NATURAL RESOURCES IN COLONIAL NHP

The combined natural resources of Colonial NHP were assessed as on the border between "degraded" and "fair", attaining 40% of desired threshold scores. Three of the four habitats assessed (grassland, non-tidal wetland, and tidal wetland) achieved less than 50% attainment, while forest habitat attained a score of 58%. Due to deficiencies in the extent and quality of available data, confidence in the accuracy of this assessment is limited and highlights the need for more targeted data collection activities based on the metrics and habitats described in this assessment.

Forest condition assessment was "fair" despite very good attainment of threshold scores for forest interior dwelling bird diversity (including sensitive and very sensitive species), the percentage of forest cover, and the amount of impervious surface. The "fair" rating for forest habitat was primarily due to very degraded, but improving, air quality (ozone). The assessment for forest would likely be worse if deer populations were used as a metric as they are considered to be at unsustainable levels, however, population monitoring data was unavailable.

Warm-season grasslands were assessed as "fair," with very good contiguous grassland areas (four grassland patches > 20 hectares [49 acres] in size) and improving grassland management practices, but low mammal and bird diversity, and widespread invasive plant species (particularly in Yorktown).

Non-tidal wetland condition was assessed as "degraded" due to widespread invasive plant species, poor Lepidoptera and Odonata richness and a very degraded index of biotic integrity for the benthos, based on limited available data. Non-tidal wetland did, however, have a fair-to-good diversity of herpetofauna (including uncommon and very rare species) that contributed to this habitat not receiving a "very degraded" condition assessment.

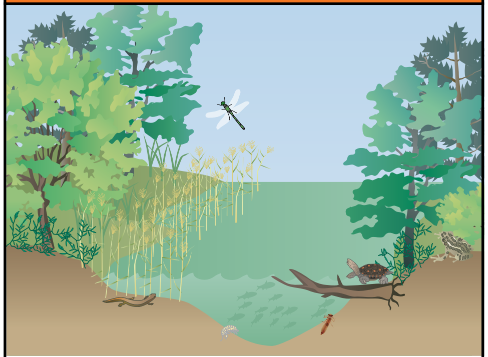
Tidal wetland condition was also assessed as "degraded", due to widespread invasive plant species and a fair condition of submerged aquatic vegetation, water quality, and benthic index of biotic integrity.

Habitat	Reference condition attainment	Current condition	Confidence in assessment
Non-tidal wetland	26%	Degraded	Very limited
Grassland	43%	Fair	Limited
Forest	58%	Fair	Fair
Tidal wetland	34%	Degraded	Limited
Colonial National Historical Park	**40%**	**Degraded/Fair**	**Limited**

Percent Attainment:	0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Habitat Condition:	Very Degraded	Degraded	Fair	Good	Very Good

NON-TIDAL WETLAND HABITAT

26% DEGRADED

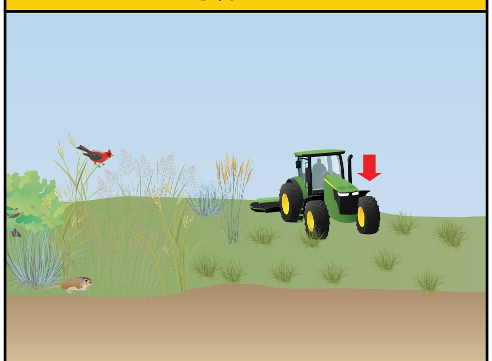


Assessed non-tidal wetland habitat had a low benthic index of biotic integrity, fair/good reptile and amphibian richness, low Lepidoptera and Odonata richness, and a very high cover of invasive plant species.

Key findings	Recommendations
Non-tidal wetland habitat	
• High herpetofauna diversity, including several imperiled amphibians	• Continue to perform annual surveys of key herpetofauna species to analyze trends.
• Several rare or endemic vegetation assemblages threatened by invasive plants	• Conduct more comprehensive wetland mapping and monitoring. • Continue to treat invasive plant species. • Re-plant native species.
• Threats from water quality, groundwater withdrawals, and pollutant contamination	• Use targeted monitoring to identify specific stressor-response relationships. • Work collaboratively with federal, state, and local partners to identify and reduce pollutant sources.

GRASSLAND HABITAT

43% FAIR



Assessed grassland habitat had degraded mammal richness, a low number of grassland bird functional groups, and invasive plant cover is very high. Warm-season grassland management is good, with a reduction in mowing frequency on many fields. Contiguous grassland area is high.

Key findings	Recommendations
Grassland habitat	
• Low grassland bird diversity based on limited data	• Augment data sources by incorporating volunteer birding activities. • Provide a more detailed analysis of Breeding Bird Survey data. • Develop density estimates including effects of detection probabilities in sample efforts.
• Unknown vegetation composition	• Initiate monitoring of relevant vegetation metrics, including diversity and invasive species.
• Too few fields being managed for warm-season grasses	• Decrease mowing frequency on additional fields. • Consider the timing of mowing based on best available advice and potentially restoration planting of warm-season grasses.

FOREST HABITAT

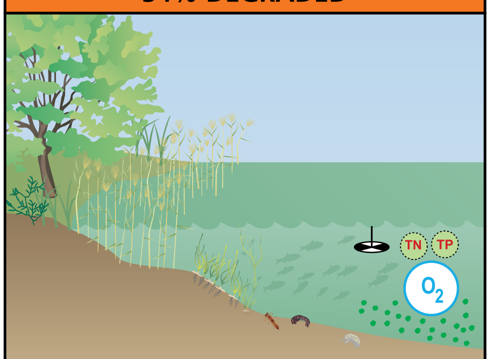
58% FAIR

Assessed forest habitat had high ozone levels, a high diversity of forest interior dwelling birds, and invasive plant cover was high. There is a high percent of forest, and impervious surface cover is low.

Key findings	Recommendations
Forest habitat	
• Deer population potentially at unsustainable level	• Implement monitoring of deer density. • Increase studies of deer impacts to forest structure and composition.
• High invasive plant cover	• Continue to monitor, track, and eradicate invasive plant species. • Prioritize control strategies based on effectiveness monitoring.
• Forest loss to sea level rise	• Proactively manage, intervene, and closely monitor sea level markers and groundwater salinity. • Educate the public about the potential consequences of changes in sea level to park resources.
• Degraded air quality	• Work collaboratively with federal, state, and local partners to identify and reduce sources. • Educate the public about the potential consequences of degraded air quality to park resources.

TIDAL WETLAND HABITAT

34% DEGRADED



Assessed tidal wetland habitat had a fair but declining benthic index of biotic integrity. Water quality is fair with high dissolved oxygen low TN + TP, high chlorophyll *a*, and poor water clarity. Submerged aquatic vegetation is fair, and *Phragmites* cover is very high.

Key findings	Recommendations
Tidal wetlands habitat	
• Several rare vegetation assemblages and species	• Track potential conversion of vegetation to brackish community types. • Coordinate with Inventory and Monitoring to establish monitoring plots within the globally rare Tidal Bald Cypress forest/woodland.
• Water quality is mostly assessed in open water sites, not directly within tidal wetlands	• Initiate water quality monitoring within park boundaries. • Work with neighbors to identify and reduce point and non-point source pollution.
• Sea level rise and saline intrusion will adversely affect wetland habitat	• Implement inundation and salinity monitoring. • Educate the public about the potential consequences of sea level rise and saline intrusion to park resources.

Acknowledgements

This report would not have been possible without the feedback and support from Dorothy Geyer, Dave Frederick (Colonial National Historical Park), and Peter Sharpe (National Park Service). Other NPS staff provided valuable assistance with data, comments, suggestions, and reviews including Dan Smith, Dennis Skidds, Sara Stevens, Penlope Pooler, Holly Salazar, Alan Ellsworth, and Jim Comiskey. The following people graciously provided data and shared their expertise on the park and its resources and stressors: Dana Bradshaw, Tim Christensen, Greg Garman, Rick Berquist, Chris Ludwig, Ken Moore, Jim Perry, Gary Speiran, and Susan Watson. Allison Dungan, Jane Thomas (IAN-UMCES), Bridget Ward, and Audrey Dignan (UR) provided assistance with background research, data analysis, and mapping.

Chapter 1: NRCA background information

1.1 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". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list 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 logical reference conditions/values to compare current condition data against;[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products;[5]
- summarize key findings by park areas;[6] and
- follow national NRCA guidelines and standards for study design and reporting products.

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe 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: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital

***NRCAs strive to provide** credible condition reporting for a subset of important park natural resources and indicators*

Important NRCA success factors

Obtaining good input from park 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.

1. However, 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.
4. 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-on response (e.g., ecological thresholds or management 'triggers').
5. As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
6. 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.

signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures.[8]

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve 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 our present data and knowledge bases across these varied study components.

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 credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Additional NRCA Program information is posted at: *http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm*

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*

7. NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
8. 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.

Chapter 2: Introduction and resource setting

2.1 INTRODUCTION

2.1.1 History and enabling legislation

Historic Jamestown

In 1607, English colonists settled on Jamestown Island and established the colony of Virginia with Jamestown as its capital. Prior to English settlement, American Indians had lived in the area for more than 10,000 years, as evidenced by archeological artifacts. The first English colonists erected a fort, known as "Old Towne", where the colony principally lived. In the 1620s, William Claiborne surveyed the land east of Old Towne; this land was subdivided into lots for buildings and farming. This area of development became known as "New Towne", with an economy based on tobacco, shipping wharves, and political clout through the House of Burgesses. In 1699, the Royal Colonial seat of government was relocated from Jamestown to Williamsburg. At this time, most people had already moved outward from Jamestown; the majority of the Island was owned by the Ambler and Travis farming families, who divided the land into large plantations (NPS 2006).

Control of Jamestown Island changed hands several times during the wars that would ensue. During the Revolutionary War, the Island was controlled by the British before being occupied by colonial troops as a site for outfitting ships. During the Civil War, Confederate forces initially used the Island to control the James River. Later, Union forces took control under Major General George B. McClellan, and the Island was used for slaves escaping to the North (NPS 2006).

In the 1890s, 9.1 ha (22.5 ac) of Jamestown Island, including Old Towne, were donated from the Barney family to the Association for the Preservation of Virginia Antiquities (APVA) (NPS 1993). The remainder of Jamestown Island—New Towne—was acquired by the National Park Service (NPS) in 1934, when archeological excavations commenced with the assistance of the Civilian Conservation Corps (Cotter 1994). In 1902, Congress introduced a bill to build a permanent commemorative monument "upon the place of the first permanent English settlement at Jamestown, Virginia". The Jamestown Monument was completed in 1907 in time for the sesquicentennial celebration of the founding of the colony.

Painting: Sidney E. King

Aerial view of how Jamestown may have looked, approximately seven years after it was founded.

Yorktown Battlefield

The Siege of Yorktown in 1781 proved to be the last major campaign of the American Revolution. At the time, Yorktown was a major Virginia deep water port with a well-developed waterfront, which was attractive to British General Cornwallis who needed to establish a naval supply port in Virginia. He seized control and defended the port and village by building earthwork fortifications around its outer edge of development. General Washington and French General Rochambeau advanced from Rhode Island to challenge and defeat General Cornwallis in what is now known as the Siege of Yorktown. The British Army, led under General Cornwallis, was forced to surrender to General Washington's combined American and French army on October 19, 1781 (NPS 1993).

With news of General Cornwallis' surrender, on October 29, Congress promptly declared a monument to be built to commemorate the victory. The Yorktown Victory monument was not built until 1881, however, in anticipation of the Yorktown centennial. The cornerstone was laid in 1881, with the monument completed in 1884.

Colonial Parkway

The scenic Colonial Parkway has connected Virginia's Historic Triangle of Jamestown, Williamsburg, and Yorktown, since its completion in 1957. Millions of travelers enjoy Virginia's natural and historical beauty each year on the Parkway. In constructing this three-lane parkway through extensive tidal wetlands, the National Park Service was careful to conserve the scenery and natural landscape (NPS 2006). The construction of the Parkway also marked an important change in how the National Park Service went about road building, and how a parkway could be used to join various sites into one park (NPS 2006), as evidenced by the plan for the Parkway:

> *"Its function as a unifying factor transcends mere considerations of transportation. Its location and design should contribute, as far as practicable, to the general commemorative purposes of the Monument."*
>
> *(Colonial Parkway Outline of Development, 1933)*

The Parkway has since been designated as a Virginia Scenic Byway in 2002, and as an All-American Road by the National Scenic Byways Program of the U. S. Department of Transportation in 2005.

Colonial National Historical Park Enabling Legislation

The "Organic Act" that established the National Park Service on August 25, 1916 provides the primary mandate for natural resource protection within all national parks (Congress 1916). It states:

Photo: Cliff Dickey, NPS

The meticulous landscaping undertaken during the construction of Colonial Parkway is evident to this day.

Figure 2.1. Location of the eight parks included in the Northeast Coastal Barrier Network (NCBN). NS = National Seashore; NRA = National Recreational Area; NHS = National Historical Site; NM = National Monument; NHP = National Historical Park.

"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."

Colonial National Monument was authorized on July 3, 1930 (NPS 1993). The decision to connect these historical locations with a scenic parkway comes from the "Crampton Bill," which was signed into law by President Herbert Hoover in December 1930. U.S. Representative Louis Crampton (D-MI) expressed his admiration for this project when he proclaimed:

"I would like a new highway as part of the new park, on a strip sufficiently wide to protect it by trees shutting out all conflicting modern development, this highway not to be a glaring modern pavement but as much as feasible giving the impression of an old-time road."

- Louis Crampton, 1929

On June 5, 1936, the site was designated as Colonial National Historical Park, hereafter referred to in the document as Colonial NHP.

As a result of the early designers' attention to the above directives, the Park embodies the principles of historical interpretation through landscape and parkway design and the opportunity to have beautiful vistas over the James and York Rivers. Despite many land use changes to the Williamsburg area, the Park has retained its original intent of shutting out conflicting modern development. As a result, Jamestown Island and Colonial Parkway are listed on the National Register for Historic Places. The documentation to qualify Yorktown for this designation is underway.

The Park is included in the Northeast Coastal and Barrier Network (NCBN), and is one of 32 networks throughout the country charged with developing inventory and monitoring plans for our national parks. (Figure 2.1).

2.1.2 Geographic setting

Location

Colonial National Historical Park is located on the Virginia Peninsula between the James River and the York River within the Coastal Plain of eastern Virginia, also known as the Tidewater region. The Park is located 72 km (45 mi) southeast of the City of Richmond. It includes parts of four counties—York, James City, Gloucester, and Surry—and two urban areas, Williamsburg and Yorktown.

The Park is bounded on the west and south by the James River, on which Jamestown Island and Glasshouse (587.2 ha [1451 ac]) are located, and bounded on the north and east by the York River, where Yorktown (1683.9 ha [4161 ac]) is located. The 37 km (23 mi) Colonial Parkway (854.3 ha [2111 ac]) connects the historic Jamestown and Yorktown locations. The Park also includes smaller, detached parcels at Green Spring (121.8 ha [301 ac]), once part of the 17th century plantation estate of Sir William Berkeley, one of the Jamestown Colony's governors; Cape Henry Memorial (0.1 ha [0.23 ac]), the first landing site of the Jamestown colonists; Swann's Point (184.5 ha [456 ac]), located across the James River from Jamestown Island with a historic cemetery; and Tyndall's Point (0.4 ha [1 ac]), where several fortifications from the Revolutionary War and Civil War stand (Figure 2.2, Table 2.1; NPS 1994).

Table 2.1. Areas within the boundary of Colonial NHP.

Park Designation	ha	ac
Yorktown	1683.9	4161
Colonial Parkway including Ringfield and Great Neck	854.3	2111
Jamestown Island	587.2	1451
Green Spring	121.8	301
Swann's Point	184.5	456
Cape Henry Memorial	0.1	0.23
Tyndall's Point	0.4	1
Total protected area	**3432.2**	**8481.23**

The National Park Service owns and manages the majority of the land parcels, although 9.1 ha (22.5 ac) of Jamestown Island is owned by the Association for the Preservation of Virginia Antiquities (APVA). Land adjacent to Colonial NHP is owned by the U.S. Navy, U.S. Coast Guard, City of

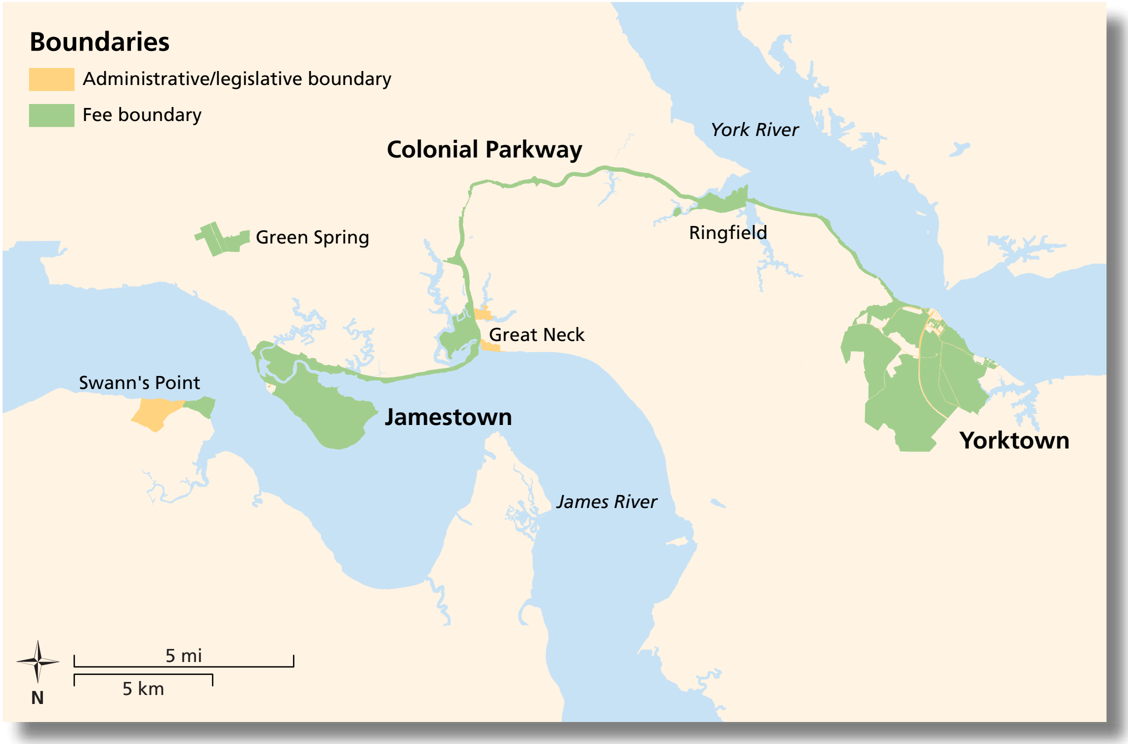


Figure 2.2. Administrative/ legislative and fee boundaries of Colonial NHP. The fee boundary is included in the overall administrative/ legislative boundary.

Photo:Colonial NHP

Cultural events and re-enactments attract visitors to the Park.

Newport, Colonial Williamsburg, College of William and Mary, in addition to various commercial and residential properties. These adjacent areas are experiencing rapid development and expansion of commercial and single and multi-family residential properties, while agricultural and silvicultural land uses decline throughout the Park's watersheds (NPS 1994).

Climate

The climate of Tidewater Virginia is temperate, with mild temperatures in the winter (nighttime lows of -3°C [26°F] and daytime highs of 10°C [50°F]) and warm to hot temperatures in the summer (nighttime lows of 20°C [60°F] and daytime highs of 30°C [86°F]). Humidity is typically around 60%, with higher humidity in the summer. Rainfall is relatively constant year round, with July and August the wettest months, and April, October, and November the driest. Average monthly rainfall is 7–13 cm (3–5 in), with yearly total rainfall about 114 cm (45 in) (NPS 1994).

2.1.3 Visitation statistics

Visitation to Colonial NHP has fluctuated over the past few decades. In the early 1980s, as many as 8.5 million recreational visits were recorded at the Park, with the level declining to around 2 million visits per year between 1983 and 1993. Since 1994, annual visitation has risen and remained constant around 3 million recreational visits (Monz and Leung 2003). Non-recreational visits total approximately 2 million per year. Entrance fees are collected at both Jamestown and Yorktown visitor centers. Fees are collected from approximately 150,000 to 300,000 visitors per year at each visitor center. Recent events, such as the renovation of the Jamestown Visitor Center in 2005 and 2006, followed by the 2007 Historic Jamestown 400th anniversary celebration have decreased and increased visitation, respectively. In general, Jamestown has more paid visitors than Yorktown. Visitation is lowest during winter months and relatively high throughout the rest of the year.

In the summer of 2001, the Cooperative Park Studies Unit at the University of Idaho conducted visitor surveys at Colonial NHP (NPS 2009). The surveys yielded information on the demographics and preferences of summertime Park visitors. Visitors traveled primarily in small groups, with 69% as families and 30% in groups of two. Ages of most visitors were between 36–50 years. Visitors traveled from 37 states, including the District of Columbia and Puerto Rico. A slight majority of visitors traveled from Pennsylvania (10%), with Virginia (9%) and California (7%) following. International visitors comprised 3% of total visitors. The most popular recreational activity was walking (96%), with smaller groups partaking in bird watching (11%) and bicycling (3%).

2.2 NATURAL RESOURCES

2.2.1 Watershed context

Colonial National Historical Park is split between the James River and York River watersheds on the Virginia Peninsula of the Tidewater region. The James and York Rivers flow into the lower mainstem of the Chesapeake Bay, the largest estuary in the United States (Figure 2.3). The Chesapeake Bay watershed stretches over 166,000 km^2 (64,000 mi^2) across six states, and is home to more than 17 million people (CBP 2012).

The James River watershed drains 26,511 km^2 (10,236 mi^2), originating in the Appalachian Mountains in central-western Virginia and flowing across the Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain physiographic provinces until reaching the Chesapeake Bay near Norfolk, Virginia. The watershed accounts for approximately 25% of Virginia's total land area (NPS 1994). The Appomattox River, Maury River, Jackson River, and Rivanna River are major tributaries of the James River. Land use within the watershed is 71% forest, 7% agriculture, 5% urbanized, 4% open water, and 3% wetland (Figure 2.4, Table 2.2; Commonwealth of Virginia 2005). Approximately 2.6 million people live in the James River watershed, concentrated in the eastern portion of the watershed and representing nearly one third of Virginia's population.

The York River watershed, located north of the James River watershed, flows through the Piedmont and Coastal Plain physiographic regions, for a total drainage area of 6,913 km^2 (2,669 mi^2). The Pamunkey and Mattaponi Rivers are the main tributaries to the York River. Land use in the York River watershed is mostly forestland (~65%), with agriculture (~25%), and small pockets of urbanization (~10%) (Figure 2.4, Table 2.2; VA DEQ 2010). Approximately 372,500 people lived in the York River watershed as of 2000, with the population projected to grow over the following decades (Reay and Moore 2009).

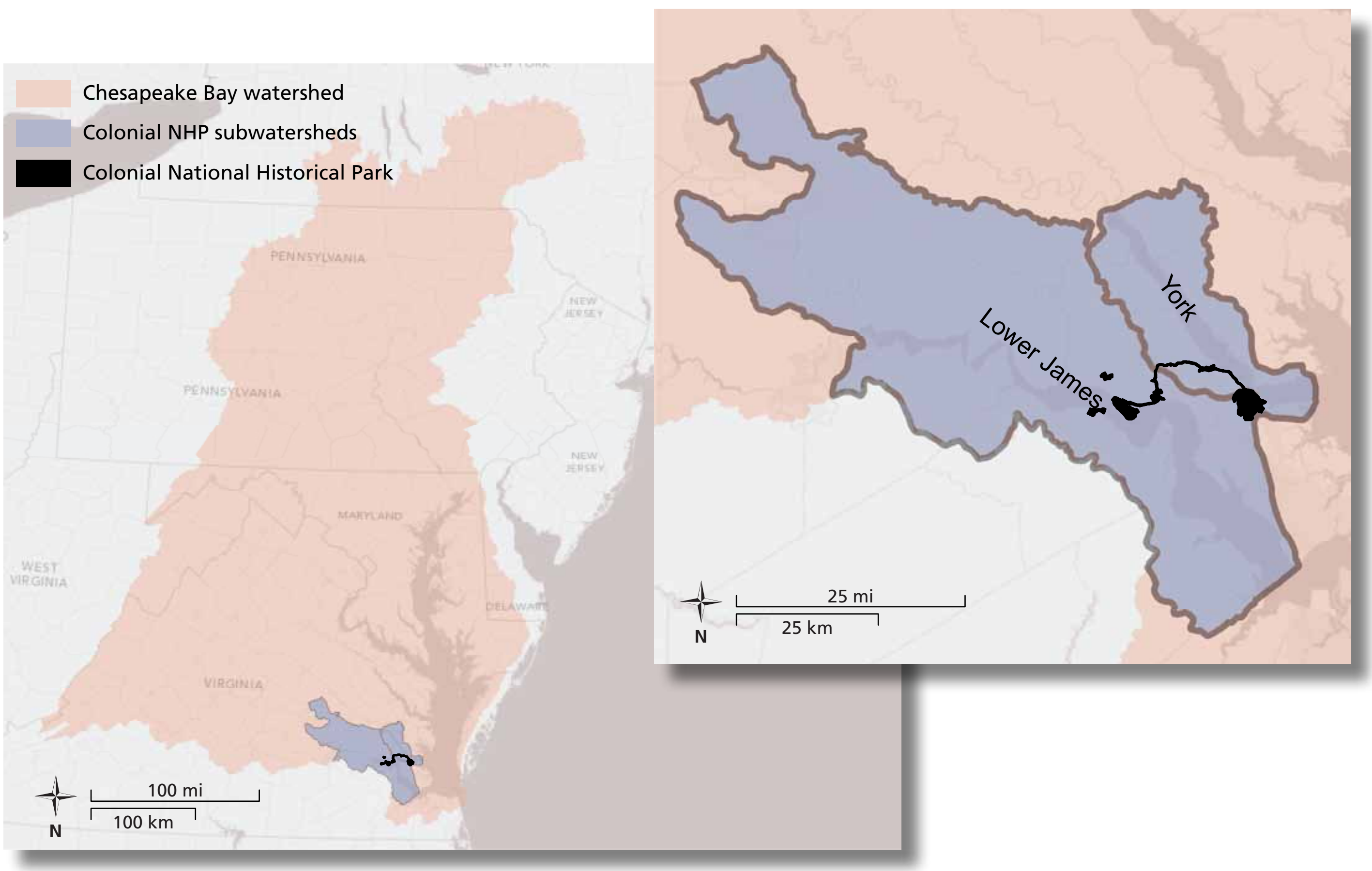


Figure 2.3. Colonial NHP is part of the lower James River and York River sub-watersheds (right), which in turn are part of the Chesapeake Bay watershed (left).

Table 2.2. Land use in the watersheds of Colonial NHP (Commonwealth of Virginia 2005).

Watershed	Land area (km²)	% of Watershed						
		Forest	Agriculture	Urban	Open water	Barren	Impervious sufaces	Wetlands
James River	26,511	71	7	5	4			3
York River	6,913	70	22	2	?			?
Total Park watershed area	33,424	70.8	10.1	4.4	?			?

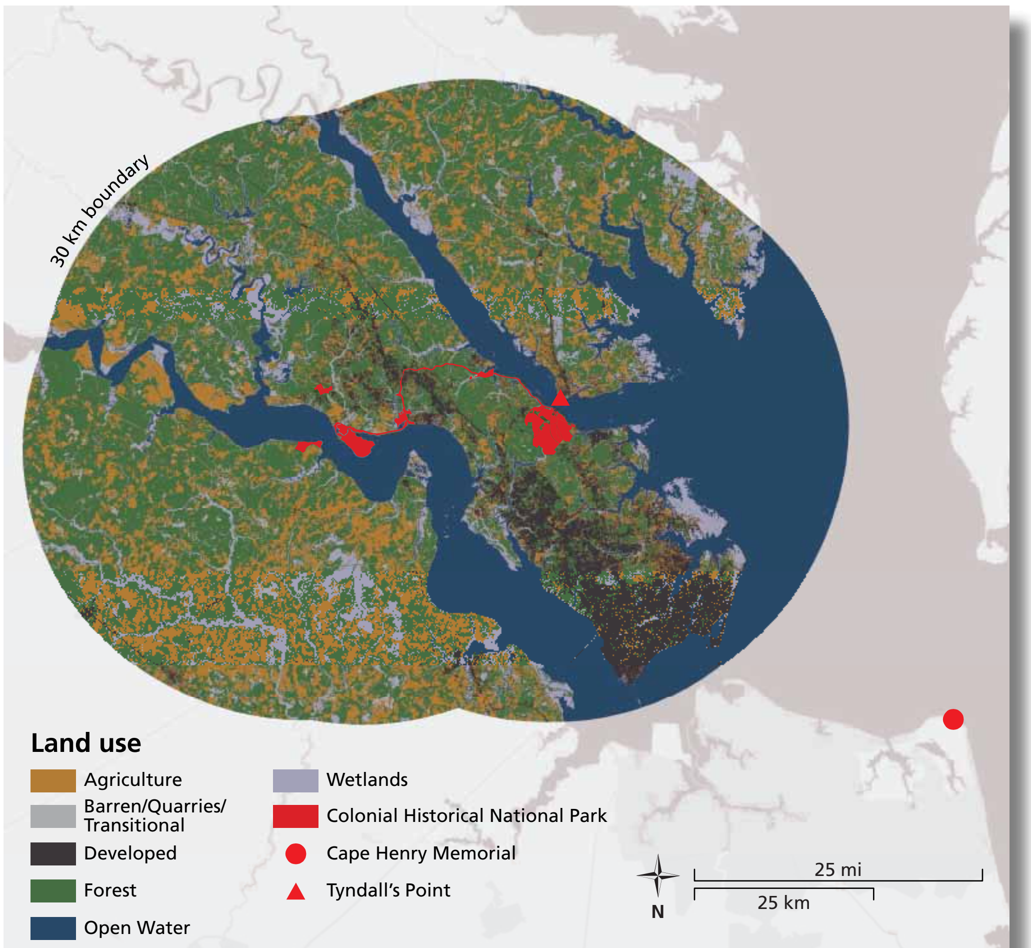


Figure 2.4. Land use 30 km (19 mi) surrounding Colonial NHP. Adapted from NPScape products (Budde et al. 2009) using the 2001 National Landcover Data set.

2.2.2 General resource features

Geology

The geological setting of the James-York Peninsula contains sediments from the Cretaceous Period (beginning 145.5 million years before present) through the Holocene Epoch (beginning 11,700 years before present). During the Eocene Epoch (approximately 35.5 million years ago), a comet or meteor struck the southern part of the Chesapeake Bay. Yorktown is located in the area that edges the Chesapeake Bay Impact Crater (Johnson et al. 1998). Most of the Atlantic Coastal Plain is underlain by the Cretaceous Potomac Formation, above which multiple other formations lie: Aquia, Marlboro Clay, Nanjemoy, Piney Point, Chickahominy, Old Church, Calvert, Choptank, St. Marys, and Eastover Formations.

Above the Eastover Formation lies the Yorktown Formation with 25 m (82 ft) maximum depth. The Yorktown Formation consists of quartz and feldspar sands, with lesser clays, silts, and cross-bedded shell layers. It is the oldest exposed formation through which Colonial NHP's deepest ravines cut. The upper Eastover and lower Yorktown form a shallow aquifer within the Park, with a carbonate layer rich in quartz and shell debris. Acidic groundwater leaches through and dissolves the calcium carbonate layer, leaving cavities that create the Park's numerous sinkholes (NPS 1994). The Yorktown Formation also contains rich fossil remains, including the Virginia state fossil (*Chesapecten jeffersonius*) and remains of a 20,000 year old wooly mammoth (Thornberry-Ehrlich 2005).

This formation is further overlain by Windsor, Bacons Castle, Sedley, Shirley, and Tabb Formations, representing ancient marine and fluvial-estuarine deposits of sands, silts, and clays (Virginia Division of Mineral Resources 1993). The lower Windsor and Bacons Castle Formations contain sand, pebbles, and cobbles, which allow water to infiltrate; once water reaches the clay-rich layer of the Windsor Formation below, it flows laterally until a break in topography causes the groundwater to emerge as a spring or seep. The youngest deposits within the Park are alluvial deposits of sand, gravel, silt, and clays; beach and estuarine deposits; marsh and swamp deposits along waterways; shelly sands; and most recently, artificial fill from building and roadway construction (Figure 2.5).

Hydrology

Several aquifers that underlie the Park supply drinking water for the surrounding area (NPS 1994). One of the aquifers from which James City County draws its water is the Quaternary Aquifer, a shallow aquifer that recharges underlying aquifer systems. The Yorktown and Eocene-Paleocene Aquifers lie below the Quaternary Aquifer. The Yorktown Aquifer supplies water to Williamsburg, from its estimated 170–380 billion liters (45–100 billion gallons) storage. The Eocene-Paleocene Aquifer supplies domestic wells in the vicinity of Jamestown, with storage estimated at around 130–340 billion L (35–90 billion gal). The lowest aquifer unit, the Cretaceous Aquifer, is the most extensive and productive, with about 2060–4000 billion L (545–1050 billion gal) in storage (Speiran and Hughes 2001). Water from this aquifer mainly supplies municipal and industrial users. Yorktown Battlefield is underlain by a system of inter-layered aquifers and confining units. The deep part of the aquifer system (generally deeper than 46 m [150 ft]) is poorly connected to the shallow part of the aquifer system, streams or wetlands. The shallow aquifer system is well connected to the streams and wetlands and is the main source of groundwater discharge. The shallow aquifer system at increasing depth consists of the Columbia Aquifer, the Cornwallis Cave confining unit, the Cornwallis Cave Aquifer, the Yorktown confining unit, and the Yorktown-Eastover Aquifer (Speiran and Hughes 2001).

Topography

The elevation of Colonial NHP varies from sea level to 38 m (120 ft) above sea level (NPS 1994). Jamestown Island is predominantly upland, with Back River marsh to the north and ridges and swales to the south. The ridge and swale topography trends east-west to northwest-southwest, and ranges from near sea level to 5 m (15 ft). Swales hold tidal salt marsh communities, and flood periodically when tropical storms and nor'easters sweep the region. A beach-dune complex

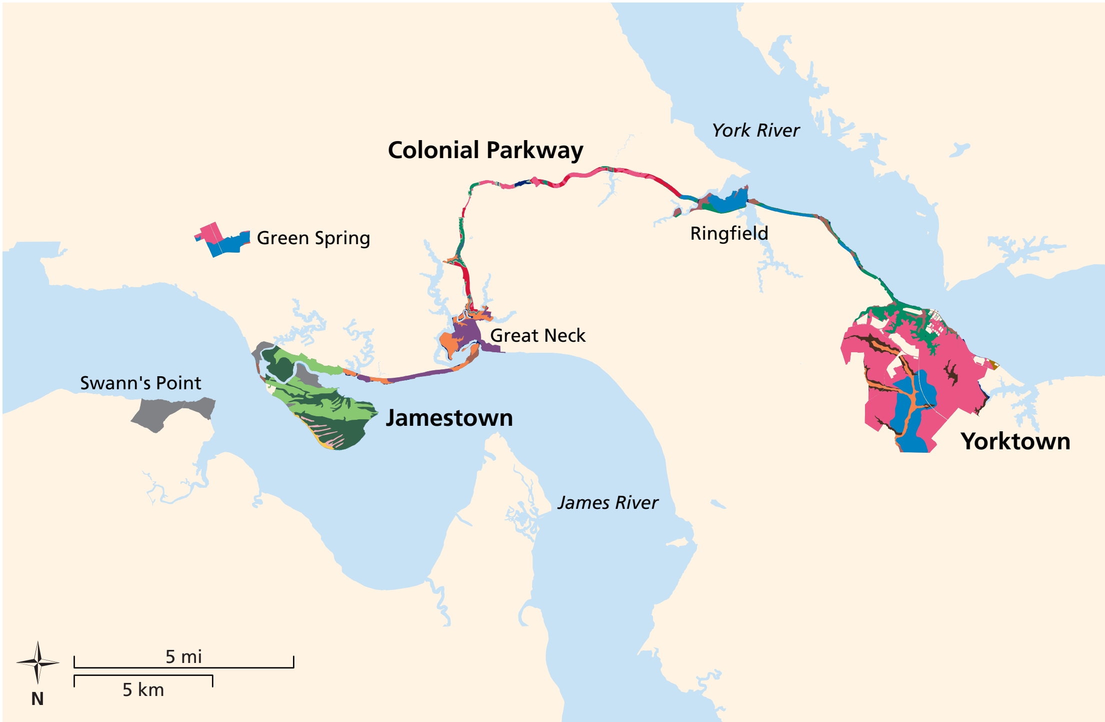
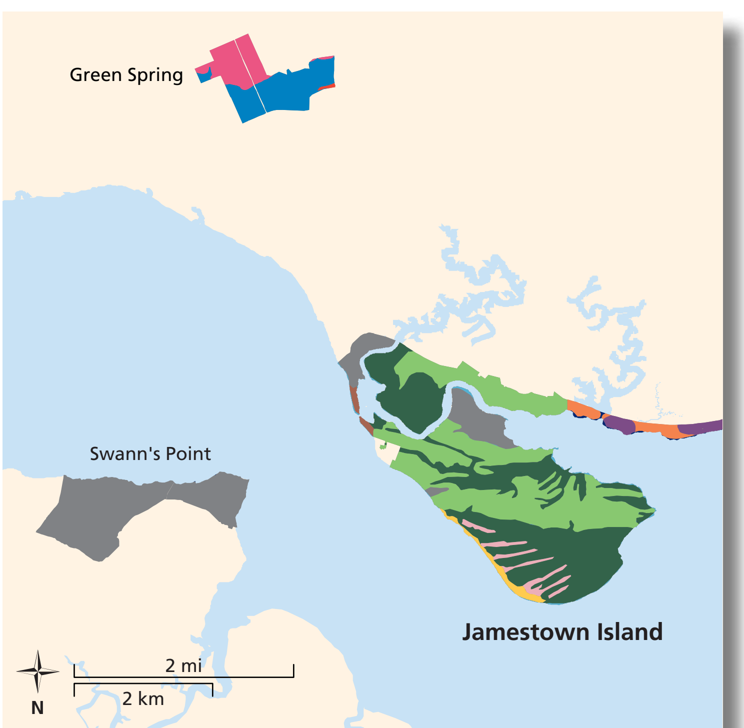
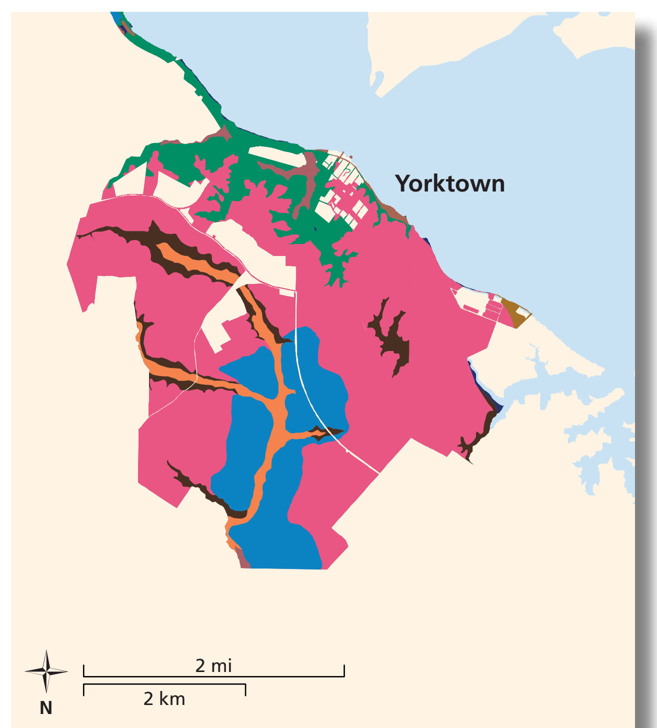


Figure 2.5. Surficial and bedrock geology of Colonial NHP (top), with greater detail for Jamestown, Green Spring, and Great Neck (bottom left), and Yorktown (bottom right).

Geological deposits

- Beach deposits
- Estuarine deposits
- Fill
- Lynnhaven deposits
- Marsh deposits
- Poquoson deposits
- Unknown/not available
- Alluvium
- Bacons castle formation
- Chesapeake group
- Eastover formation
- Marsh
- Norfolk formation
- Sedley formation
- Shirley formation
- Swamp
- Tabb formation, sedgefield member
- Water
- Windsor formation
- Yorktown formation





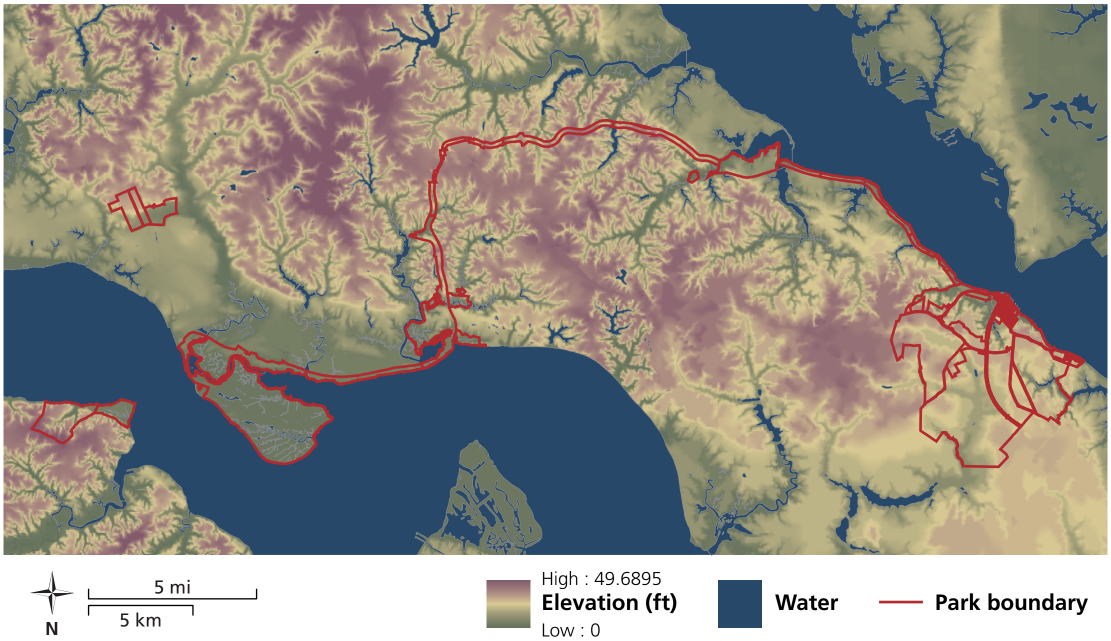


Figure 2.6. Elevation for Colonial NHP and surrounding lands.

also occurs along the southern length of Jamestown Island. The Green Spring site crosses over three terraces and two scarps, varying between 6 m (20 ft) in the flats and 23 m (75 ft) on the scarps. Colonial Parkway crosses over multiple terraces and scarps, to form a stair-step landscape over which the emergent river bottoms of the James and York Rivers historically flowed to the Chesapeake Bay. Sinkholes occur on the Yorktown Battlefield. Yorktown sits on the Lackey Plain (elevation 24 m [80 ft]) and Grafton flat (15–18 m [50–60 ft]) (Figure 2.6; NPS 1994).

Soils

The Soil Survey Geographic (SSURGO) databases for James City and York counties and the City of Williamsburg, Virginia (USDA 2007a), and for Surry County, Virginia (USDA 2007b) map 37 unique soil series within the boundaries of Colonial NHP. The soils in the Park are primarily ultisols (57%), entisols (25%), and inceptisols (13%), with small areas classified as alfisols and histosols (Patterson 2008). Utisols are characterized as acidic forest soils strongly leached of minerals (i.e., calcium, magnesium, and potassium), typically with clay accumulation in lower horizons. Ultisols are found on older, more stable landscapes, in contrast with entisols and inceptisols, which are young in development and typically found on steeper rocky topography. Alfisols are similar to ultisols but with less mineral leaching. Histosols are peats and mucks that are rich in decaying organic matter (Figure 2.7; University of Idaho 2011).

The deep, well-drained to moderately well drained upland soils of the Park were formed in interbedded layers of loamy and clayey fluvial or marine Coastal Plain sediments. These soils are typically very strongly to extremely acidic in reaction (pH less than 5.0). Common soils on upland terraces, ridges, and side slopes in the Park include the series Emporia, Craven, Slagle, and Uchee, or complexes of these soil series (ultisols). Thirteen soil series are mapped on well-drained to somewhat poorly-drained stream terraces in the Park; the most common of these are State, Tetotum, Peawick, Dogue, Newflat (ultisols), and Pamunkey (alfisol) (Figure 2.7). These soils are not considered hydric, but are found on low-lying stream terraces often associated with wetland vegetation.

Hydric soils encompass 18% of the Park and develop under conditions of saturation, flooding, or ponding for sufficient duration during the growing season to develop anaerobic conditions in the upper portion. Soils along creeks and rivers in tidal marshes that are inundated twice daily by saline, brackish, or fresh water are very poorly drained entisols of the series Axis, Bohicket, Lawnes, and Levey. Poorly drained to very

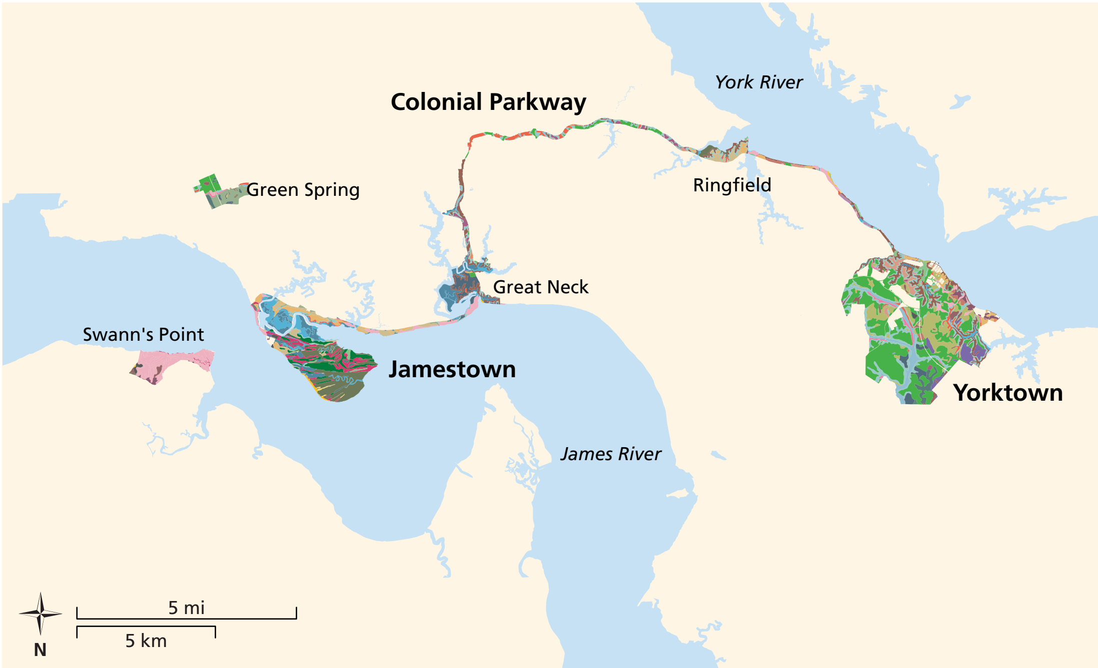
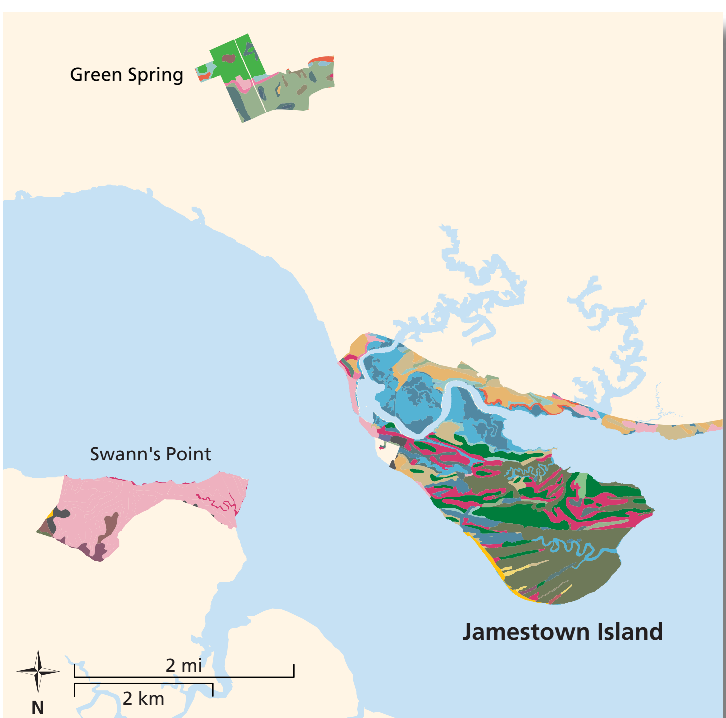
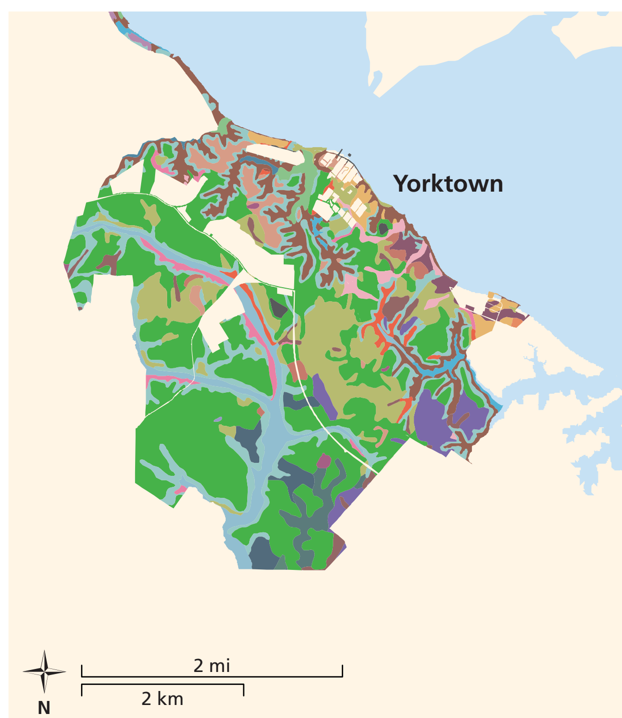


Figure 2.7. Soil types found in Colonial NHP (top), with greater detail for Jamestown, Green Spring, and Swann's Point (bottom left), and Yorktown (bottom right).

Soil types

- Augusta fine sandy loam
- Axis very fine sandy loam
- Beaches
- Bethera silt loam
- Bohicket muck
- Bojac sandy loam
- Bojac sandy loam
- Chickahominy silt loam
- Craven fine sandy loam 2-6%
- Craven-Uchee complex 2-6%
- Craven-Uchee complex 6-10%
- Dogue loam
- Dragston fine sandy loam
- Emporia fine sandy loam 2-6%
- Emporia fine sandy loam 6-10%
- Emporia complex 10-15%
- Emporia complex 15-25%
- Emporia complex 25-50%
- Izagora loam
- Johnston complex
- Kempsville fine sandy loam 2-6%
- Kempsville-Emporia fine sandy loams, 2-6%
- Kenansville loamy fine sand 2-6%
- Levy silty clay
- Newflat silt loam
- Norfolk fine sandy loam 2- 6%
- Pamunkey soils 2-6%
- Peawick silt loam
- Seabrook loamy fine sand
- Slagle fine sandy loam 0-2%
- Slagle fine sandy loam 2-6%
- State fine sandy loam
- Suffolk fine sandy loam 2-6%
- Tetotum silt loam
- Uchee loamy fine sand 2-6%
- Udorthents, loamy
- Urban land
- Water





poorly drained soils of non-tidal floodplains, swamps, and bottomlands are mapped as Chickahominy (ultisol), Johnston (inceptisol), Nawney (entisol), and Matten (histosol) series. The Bethera series (ultisol) is mapped on wet upland flats and depressions not associated with streams. Alluvial beach deposits occur along the James and York Rivers (Figure 2.7; Patterson 2008).

Surface waters

Approximately 89 km (55.3 mi) of streams—39.3 km (24.4 mi) perennial and 49.7 km (30.9 mi) intermittent—flow through the Park (NPS 1994). These waters originate as freshwater tributaries and become tidally influenced as they approach either the James River or York River. Surface waters within and surrounding Jamestown Island are Sandy Bay, Back River, the Thorofare Pitch and Tar Swamp, Kingsmill Creek, and Passmore Creek. Colonial Parkway passes over Ballard Creek, Roosevelt Pond, Brackens Pond, Indian Field Creek, Felgate's Creek, King's Creek, Queen's Creek, Cheatham Pond, Jones Mill Pond, Halfway Creek, College Creek, Papermill Creek, and Powhatan Creek. Streams near Yorktown include Wormley Creek, Great Run, Baptist Run, Beaver Dam Creek, Yorktown Creek, and Ballard Creek. Several springs exist at Yorktown Battlefield, and one spring is located at Green Spring (Figure 2.8).

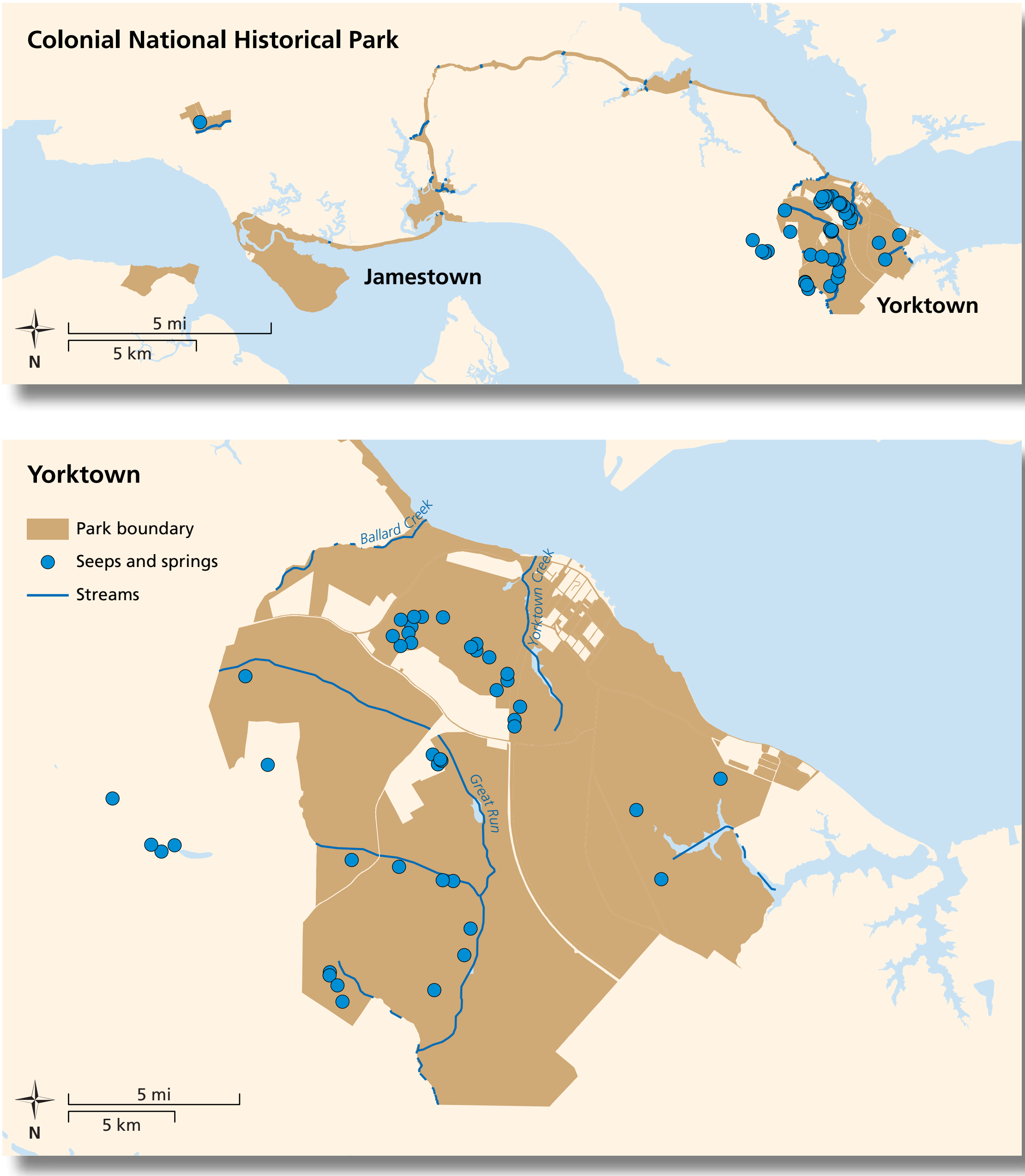


Figure 2.8. Stream network, springs, and sinkholes for Colonial NHP (top), with greater detail for Yorktown (bottom).

Rare, threatened, & endangered species

Three plant species—pink thoroughwort (*Fleischmannia incarnata* = *Eupatorium incarnatum*), hoary skullcap (*Scutellaria incana var. incana*), and sandpaper vervain (*Verbena scabra*)—are considered imperiled in the state of Virginia based on very restricted ranges, very few populations, and steep population declines, among other factors (Patterson 2008; Townsend 2009). Seven plants are listed on the Vascular Plant Watchlist of the Virginia Department of Conservation and Recreation. Watchlist species are uncommon, but not considered rare; those in Colonial NHP include: rigid sedge (*Carex tetanica*), creeping burrhead (*Echinodorus cordifolius*), common spikerush (*Eleocharis palustris*), beaked spikerush (*Eleocharis rostellata*), hairy shadow witch (*Ponthieva racemosa*), drooping bulrush (*Scirpus lineatus*), and white crownbeard (*Verbesina virginica var. virginica*) (Patterson 2008). Sensitive joint vetch (*Aeschynomene virginica*) is federally listed as a threatened plant species, imperiled in Virginia. There are 20 documented occurrences, six of which are in Virginia (NatureServe 2009), where it lives in tidally influenced freshwater habitat.

Several rare and threatened amphibians are present within Colonial NHP habitats (Mitchell 2004). The state-listed critically imperiled Mabee's salamander (*Ambystoma mabeei*) is found in the Park's vernal pools. Uncommon herpetofauna that exist in the Park include Brimley's chorus frog (*Pseudacris brimleyi*) and the two-toed amphiuma (*Amphiuma means*). Brimley's chorus frog lives in hardwood forest, swamp, and shallow pond habitat. The two-toed amphiuma is habitat-specific, in that it is fully aquatic and occupies ponds, pools, swamps, and ditches where muddy bottoms with sufficient debris allow for burrowing. It has been documented in Colonial NHP at Jamestown Island impoundments.

The rare skipper (*Problema bulenta*) is a state-listed critically imperiled butterfly found in the tidal marsh habitats of the Park (Roble 2010). The butterfly is found in tidal marshes varying from fresh to saltwater; nectar from swamp milkweed, common milkweed, dogbane, and buttonbush provide important food sources. Five Lepidoptera and Odonata species are on the Virginia watchlist: Aaron's skipper (*Poanes aaroni*), comet darner (*Anax longipes*), blue-faced meadowhawk (*Sympetrum ambiguum*), furtive forktail (*Ischnura prognata*), and duckweed firetail (*Telebasis byersi*) (Chazal 2006).

Photo: Anne C. Chazal, Virginia Natural Heritage Program

The rare skipper (*Problema bulenta*) is a state-listed critically imperiled butterfly found in the tidal marsh habitats of the Park.

Atlantic sturgeon (*Acipenser oxyrinchus*), found in the James and York Rivers, are listed as very rare in Virginia, with special concern for state listing. In April 2012, the Chesapeake Bay Distinct Population Segment (DPS) of Atlantic sturgeon was listed as endangered according to the Endangered Species Act (NOAA 2012).

Vegetation

Vegetation mapping completed by the Virginia Division of Natural Heritage in Colonial NHP yielded 40 vegetation assemblages over 3498.2 ha (8644.2 ac). Classification was based on leaf-off aerial photography from 2002 and field sampling from 2003–2005 with an assessment of overall accuracy of thematic classes of 84.7% (Patterson 2008).

2.2.3 Resource descriptions by habitat

Forests

Forest area comprises the largest vegetation classification in the Park (Patterson 2008). Due to an extensive history of agriculture, clearing, and development within the Virginia Coastal Plain, the species composition of historical forests within the Park area is very difficult to discern. The majority of forestland (58.2%) consists of Successional Tuliptree–Loblolly Pine Forest, with the other 18 forest assemblages comprising the remaining area. Several forest types are locally or globally rare, notably Coastal Plain Mesic Calcareous Ravine Forest, Coastal Plain Dry Calcareous Forest, and Tidal Bald Cypress Forest/ Woodland. Two assemblages—Succesional Tree-of-Heaven Forest and Golden Bamboo Shrubland—are formed entirely from invasive species, while many others are threatened by the encroachment of non-native invasive plants (Figure 2.9).

Successional Tuliptree – Loblolly Pine Forest

Successional Tuliptree – Loblolly Pine Forest covers the largest extent of forest classes in Colonial NHP, with 1250.5 ha (3090 ac). This forest exists as second- or third-growth following agricultural abandonment or other disturbances on upland flat areas. Prior stages of forest succession might have been Mesic Mixed Hardwood Forest or Coastal Plain Mesic Calcareous Ravine Forest assemblages. Tuliptree (*Liriodendron tulipifera*) and loblolly pine (*Pinus taeda*) form the dominant canopy; subcanopy trees might include sweetgum (*Liquidambar styraciflua*) or red maple (*Acer rubrum*). Two invasive species are commonly present: Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*).

Canopy of a successional tuliptree - loblolly pine forest.

Photo: Allison Dungan

Mesic Mixed Hardwood Forest

Mesic Mixed Hardwood Forest covers almost 10% of Park land at 338.2 ha (835.8 ac). This forest is found on mesic lower slopes and ravines over well-drained, acidic soils. Vegetation characteristic of this forest type include American beech (*Fagus grandifolia*), American holly (*Ilex opaca var. opaca*), tuliptree (*Liriodendron tulipifera*), partridgeberry (*Mitchella repens*), Christmas fern (*Polystichum acrostichoides*), and white oak (*Quercus alba*).

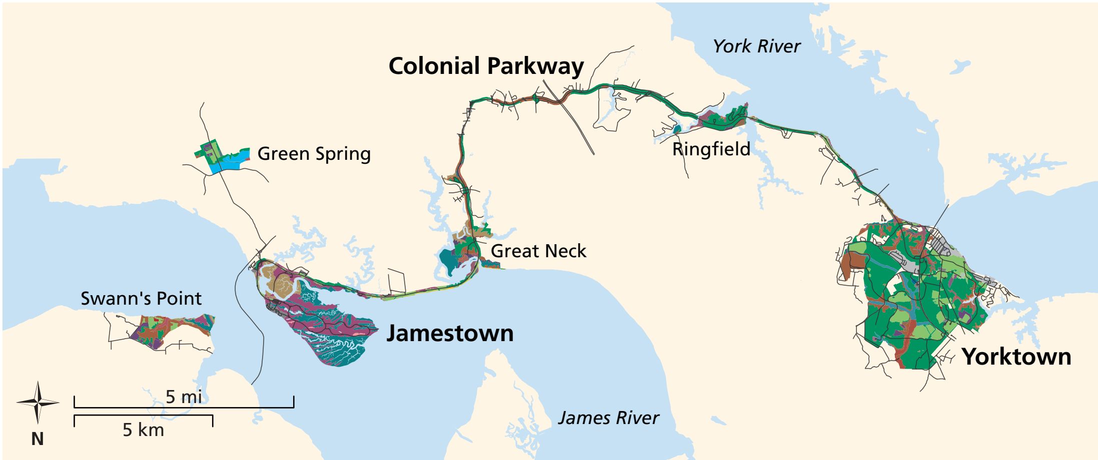
Coastal Plain Loblolly Pine – Oak Forest

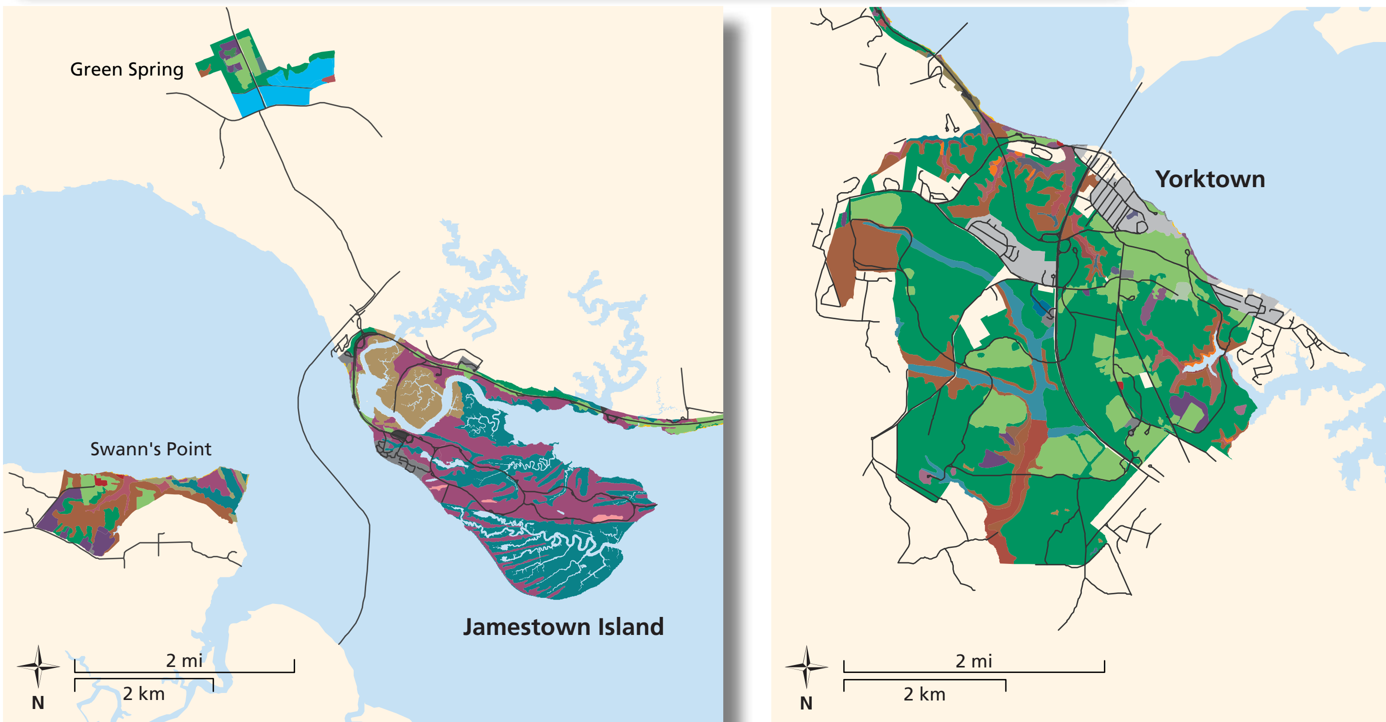
Coastal Plain Loblolly Pine – Oak Forest (310.7 ha [767.8 ac]) forms the dominant vegetation type of Jamestown Island and surrounding area, in low lying areas or sandy soils surrounded by tidal wetlands. Oaks (*Quercus* spp.), interspersed with coastal shrubs of wax murtle (*Morella cerifera*) and swamp bay (*Persea palustris*), are common. Ground cover is sparse or otherwise covered with invasive Japanese stiltgrass (*Microstegium vimineum*). This assemblage is middle to late successional forest.

Coastal Plain/Piedmont Small-Stream Floodplain Forest

Coastal Plain/Piedmont Small-Stream Floodplain Forest covers 65.9 ha (162.9 ac), primarily within the floodplains of small streams at Yorktown Battlefield in Baptist Run and Great Run, with smaller sections along Colonial Parkway north of Jones Millpond. Vegetation is suited to well-drained, sandy, alluvial soils, and includes sweetgum (*Liquidambar styraciflua*), tuliptree (*Liriodendron tulipifera*), American sycamore (*Platanus occidentalis*), northern spicebush (*Lindera benzoin*), New York fern (*Thelypteris noveboracensis*), and Jack in the pulpit (*Arisaema triphyllum*). While a common habitat assemblage, it is

Figure 2.9. General location of the 40 habitat types within Colonial NHP.





Forests

- Acidic Oak - Hickory Forest
- Coastal Plain / Piedmont Floodplain Swamp Forest (Green Ash - Red Maple Type)
- Coastal Plain / Piedmont Small-Stream Floodplain Forest
- Coastal Plain Dry Calcareous Forest
- Coastal Plain Loblolly Pine - Oak Forest
- Coastal Plain Mesic Calcareous Ravine Forest
- Dense Hardwood Regeneration
- Disturbed Calcareous Forest
- Golden Bamboo Shrubland
- Loblolly Pine Plantation
- Mesic Mixed Hardwood Forest
- Piedmont / Coastal Plain Oak - Beech / Heath Forest
- Piedmont / Low Elevation Mixed Oak / Heath Forest
- Successional Black Walnut Forest
- Successional Mixed Scrub
- Successional Sweetgum Forest
- Successional Tree-of-Heaven Forest
- Successional Tuliptree - Loblolly Pine Forest

Non-tidal wetlands

- Coastal Plain Calcareous Seepage Swamp
- Coastal Plain Depression Wetland (Red Maple - Sweetgum - WIllow Oak Type)
- Coastal Plain Depression Wetland (Swamp Tupelo Type)
- Disturbed Depressional Wetland
- Disturbed Seepage Swamp
- Non-Riverine Saturated Forest
- Semipermanent Impoundment

Tidal wetlands

- Beaches
- Disturbed Tidal Hardwood Swamp
- Salt Scrub
- Tidal Bald Cypress Forest / Woodland
- Tidal Freshwater Marsh
- Tidal Mesohaline and Polyhaline Marsh
- Tidal Oligohaline Marsh
- Tidal Shrub Swamp (Wax Myrtle Type)

Grasslands

- Cultural Meadow

Developed

- Industrial and Commercial Complexes
- Mixed Urban or Built-up Land
- Other Urban or Built-up Land
- Residential
- Transportation, Communications, & Utilities

Water

- Water

Photo: Gary P. Fleming, Virginia Natural Heritage Program

Coastal Plain Mesic Calcareous Ravine Forest is endemic to the Virginia Coastal Plain.

highly vulnerable to invasion by non-native species, in this case by Japanese stiltgrass (*Microstegium vimineum*).

Loblolly Pine Plantation

Loblolly Pine Plantation exists as monospecific stands of loblolly pine (*Pinus taeda*) that have been planted in rows, or cleared and subsequently regenerated as dense, scrubby loblolly pine; in Colonial NHP, 51.4 ha (127.1 ac). While loblolly pine is the dominant overstory plant, little understory exists, with the exception of Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*), both invasive species in Virginia.

Coastal Plain/Piedmont Floodplain Swamp Forest

Coastal Plain/Piedmont Floodplain Swamp Forest (Green Ash – Red Maple Type) is found on poorly drained floodplain soils subject to pronounced seasonal flooding. This assemblage is mapped on 30.9 ha (76.4 ac) at Yorktown Battlefield along Beaverdam Creek, with adjacent Coastal Plain/Piedmont Small-Stream Floodplain Forest. Characteristic vegetation includes the namesake green ash (*Fraxinus pennsylvanica*) and/or red maple (*Acer rubrum*), with cover from lizard's tail (*Saururus cernuus*), threeway sedge (*Dulichium arundinaceum*), and other species that prefer poorly drained soils with longer hydroperiods.

Coastal Plain Mesic Calcareous Ravine Forest

Coastal Plain Mesic Calcareous Ravine Forest is found on mesic, north-northwest aspect ravine slopes that cut through Tertiary shell deposits or limesands. Soils, therefore, have high concentrations of base cations. Within Colonial NHP, these forests are mapped over 20.4 ha (50.3 ac) at College Creek/Kingsmill, Yorktown Creek ravine slopes, and slopes adjacent to Wormley Pond. This assemblage tends to be species rich. Common, characteristic canopy trees include southern sugar maple (*Acer barbatum*), bitternut hickory (*Carya cordiformis*), Eastern redbud (*Cercis canadensis var. canadensis*), and chinkapin oak (*Quercus muehlenbergii*). The understory typically has 50–75% cover; shrubs (e.g., pawpaw [*Asimina triloba*] and northern spicebush [*Lindera benzoin*]) and herbs (e.g., northern maidenhair [*Adiantum pedatum*], black bugbane [*Actaea racemosa* =*Cimicifuga racemosa*], and bloodroot [*Sanguinaria canadensis*]) are prevalent. This assemblage is endemic to the Virginia Coastal Plain.

Acidic Oak – Hickory Forest

Acidic Oak – Hickory Forest (18.9 ha [46.8 ac]) represents an upland forest type with underlying acidic, nutrient poor soils. These forests are found in small patches on short, steep slopes and adjacent flat areas above tidal marshes at Ringfield/King Creek and College Creek/Kingsmill. Multiple oak species characterize this assemblage: chestnut oak (*Quercus prinus*), white oak (*Quercus alba*), post oak (*Quercus stellata*), among others; hickories that may be present include sand hickory (*Carya pallida*), pignut hickory (*Carya glabra*), and mockernut hickory (*Carya alba*). Poverty oatgrass (*Danthonia spicata*) and cypress panicgrass (*Dichanthelium dichotomum*) dominate the herb cover.

Successional Mixed Scrub

Successional Mixed Scrub occurs along the edges of Cultural Meadow and roadways near Yorktown Battlefield and Yorktown, and varies from site to site in its composition of vines and shrubs. Multiple invasives are found on its 11.6 ha (28.7 ac) mapped area.

Dense Hardwood Regeneration

Dense Hardwood Regeneration is found on 10.9 ha (26.9 ac) at Ringfield/King Creek and Yorktown Battlefield. It occurs where vegetation has been cleared within the past 20 years, and subsequent regeneration of hardwoods is currently taking place. Stumps and small trees form an impenetrable thicket about 4–6 m (13–20 ft) tall. Species vary based on stand history.

Disturbed Calcareous Forest

Disturbed Calcareous Forest accounts for 8.8 ha (21.7 ac) along a 4 km (2.5 mi) stretch of Colonial Parkway near the York River. Originally either Coastal Plain Mesic Calcareous Ravine Forest or Coastal Plain Dry Calcareous Forest, disturbance from wind damage, non-native plant growth, and Colonial Parkway construction have rendered this habitat an early successional forest. Prominent invasives are Japanese stiltgrass (*Microstegium vimineum*) and Japanese honeysuckle (*Lonicera japonica*).

Piedmont/Coastal Plain Oak – Beech/Heath Forest

Piedmont/Coastal Plain Oak – Beech/ Heath Forest grows on acidic, nutrient poor soils on steep slopes, such as those at College Creek/Kingsmill, Papermill Creek, Ballard Creek, and Yorktown Creek (7.6 ha [18.7 ac]). American beech (*Fagus grandifolia*) dominates the canopy layer, with various oak species (white oak [*Quercus alba*], chestnut oak [*Quercus prinus*]) as associates, while mountain laurel (*Kalmia latifolia*) forms a dense shrub layer.

Coastal Plain Dry Calcareous Forest

Coastal Plain Dry Calcareous Forest has restricted ranges and small patches, limited to conditions of dry, convex, southeast-southwest aspect slopes. Dry Calcareous Forest occurs on 5.8 ha (14.3 ac) in ravines of Ballard Creek, Wormley Pond, and King Creek/Ringfield. Chinquapin oak (*Quercus muehlenbergii*) forms the dominant canopy cover, Eastern redbud (*Cercis canadensis*) may also be common. In contrast to Coastal Plain Mesic Calcareous Ravine Forest, the Dry Calcareous Forest has more open canopy structure, more graminoid species cover (especially Bosc's panicgrass [*Dichanthelium boscii*]), and the presence of Eastern redcedar (*Juniperus virginiana var. virginiana*) in place of mesophytic species. This forest type is found only within the Coastal Plain of Maryland and Virginia.

Successional Black Walnut Forest

Successional Black Walnut Forest grows predominantly on former homesites or disturbed areas, such as the Ringfield/King Creek areas of Yorktown Battlefield (5.6 ha [13.8 ac]). Black walnut (*Juglans nigra*) forms the canopy, almost exclusively. Understory is dominated by grass cover, with both exotic (Japanese stiltgrass [*Microstegium vimineum*]) and native (meadow ryegrass [*Lolium pretense*]) species present.

Successional Tree-of-Heaven Forest

Successional Tree-of-Heaven Forest thrives on disturbed landscapes with rich substrates, ideal for growth of the non-native tree-of-heaven (*Ailanthus altissima*). North of Wormley Pond near Yorktown Battlefield, the single 4.0 ha (10.0 ac) unit of this forest type grows in Colonial NHP, though individual trees are found scattered throughout the Park.

Successional Sweetgum Forest

Successional Sweetgum Forest follows early forest succession from such disturbances as

Photo: Gary P. Fleming, Virginia Natural Heritage Program

Coastal Plain Dry Calcareous Forest is found only within the Coastal Plain of Maryland and Virginia.

logging and clearing. Short, shrubby stands of sweetgum (*Liquidambar styraciflua*) overwhelmingly dominate, with some occurrence of loblolly pine (*Pinus taeda*) or lespedeza (*Lespedeza* sp.). Green Springs hosts this forest type, with 2.9 ha (7.1 ac) mapped.

Golden Bamboo Shrubland

Golden Bamboo Shrubland exists as a monospecific stand of non-native golden bamboo (*Phyllostachys aurea*) that has been either planted or naturalized. No other species grow in the dense, 10–20 m (33–66 ft) tall bamboo stands. While 2.1 ha (5.2 ac) have been mapped at Yorktown Battlefield, other stands smaller than the 0.5 ha (1.2 ac) minimum vegetation mapping unit are likely within the Park.

Piedmont/Low Elevation Mixed Oak/Heath Forest

Piedmont/Low Elevation Mixed Oak/Heath Forest grows on xeric sites with well-drained sandy soils of fluvial terrace gravel origin. These conditions are met in one 0.9 ha (2.2 ac) location in the Park, at College Creek/Kingsmill. White oak (*Quercus alba*) and black huckleberry (*Gaylussacia baccata*) are dominant, with some chestnut oak (*Quercus prinus*).

Grasslands (warm-season)

Cultural Meadow

Cultural Meadow is found on 363 ha (897 ac) of Colonial NHP (Patterson 2008). Herbaceous vegetation in Cultural Meadow is maintained as fields, lawns, and mowed roadsides. Fields are managed to evoke the historical context for which Colonial NHP was made a Park and to preserve key viewsheds interpreting the period associated with the location. Areas managed as meadows and lawns include Colonial Parkway corridor, the Yorktown Battlefield and its reconstructed earthworks, and areas that were once encampment sites for the Allied forces. Fields consist of dense, sod-forming, primarily non-native grass species: meadow ryegrass (*Lolium pratense*), broomsedge bluestem (*Andropogon virginicus*), and orchardgrass (*Dactylis glomerata*), among others. Field grasses grow to a height of about 50–75 cm (20–30 in) before being mowed. Mowed grass areas along the Parkway comprise multiple non-native plant species (Figure 2.9).

An example of Cultural Meadow along the shoreline at Yorktown.

Photo: Allison Dungan

Wetlands

Wetland classes account for 19.1% (668.3 ha [1651.4 ac]) of total Park area (Patterson 2008). Tidal wetlands comprise 16.4% of this total (573.0 ha [1415.9 ac]); non-tidal wetlands account for the remaining 2.7% (95.3 ha [235.5 ac]). Open water, 2% (70.6 ha [174.5 ac]) of Park area, is found on larger tidal creeks in and around Jamestown Island and as standing water in ponds. The occurrence of wetlands in Colonial NHP is dependent upon hydrology (groundwater, fluvial, or tidal) and soils, upon which vegetation community is determined. Salinity delineates tidal wetland communities. Tidal Oligohaline Marsh is the most prevalent wetland assemblage. Both Non-Riverine Saturated Forest and Coastal Plain Calcareous Seepage Swamp are rare or endemic to the Virginia Coastal Plain (Figure 2.9).

Non-tidal wetlands

Non-Riverine Saturated Forest

Non-Riverine Saturated Forest is found on broad, flat, inactive floodplain terraces; at Colonial NHP this is along Powhatan Creek and Green Spring. Total area mapped is 53.4 ha (132.0 ac). The floodplains where Non-Riverine Saturated Forests occur no longer have alluvial stream movement, but instead are saturated or flooded seasonally due to a high water table. Hydric oaks (e.g.,

Photo: Colonial NHP

A depression wetlands at Moats Springs.

swamp chestnut oak [*Quercus michauxii*], cherrybark oak [*Quercus pagoda*], willow oak [*Quercus phellos*]) are common in this wetland forest type; at Green Spring, sweetgum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*) are co-dominant. Sedges (*Carex sp.*) are common. Mature examples, such as the ones found at Colonial NHP, are globally rare.

Coastal Plain Calcareous Seepage Swamp

Coastal Plain Calcareous Seepage Swamp, a non-alluvial wetland, forms in ravine bottoms cut through Tertiary shell deposits or limesands. The ravines are underlain by soils with moderate to high basic concentrations. Groundwater seepage keeps ravine bottoms constantly saturated. Calcareous Seepage Swamp is located at Swann's Point, along Colonial Parkway near Papermill Creek, and in ravine bottoms at Yorktown Battlefield, areas that total 30.9 ha (76.3 ac). Species characteristic to this swamp type include: red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), golden ragwort (*Packera aurea*), lesser clearweed (*Pilea fontana*), lizard's tail (*Saururus cernuus*), and drooping bulrush (*Scirpus lineatus*). Due to the unique conditions required for this vegetation type, it represents a globally rare assemblage, restricted to the Virginia Coastal Plain ravines of the James River and York River watersheds.

Semipermanent Impoundment

Semipermanent Impoundment consists of non-tidal open water with shrubby or emergent vegetation (green arrow arum [*Peltandra virginica*], swamp loosestrife [*Decodon verticillatus*], common reed [*Phragmites australis*], and broadleaf cattail [*Typha latifolia*]) with floating aquatics such as duckweed (*Lemna* sp.). Impoundments may have been caused by beavers or anthropogenic influence. Areas at Green Springs, Yorktown Battlefield, and along Colonial Parkway collectively account for 12.9 ha (31.9 ac).

Disturbed Seepage Swamp

Disturbed Seepage Swamp occurs along Colonial Parkway for 5.9 ha (14.6 ac) near Papermill Creek, Yorktown, and upper reaches of Yorktown Creek. Disturbance from Colonial Parkway likely altered this habitat from its original Coastal Plain Calcareous Seepage Swamp or other seepage wetland characteristics. Red maple (*Acer rubrum*) is dominant, as are invasives (Japanese stiltgrass [*Microstegium vimineum*]).

Coastal Plain Depression Wetland

Coastal Plain Depression Wetland (Red Maple – Sweetgum – Willow Oak Type) habitats are small, isolated patches of seasonally flooded non-alluvial wetland, surrounded by a matrix of upland assemblages. In Colonial NHP, these wetlands comprise 1.8 ha (4.4 ac). The species characteristic of this wetland type—red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and willow oak (*Quercus phellos*)—favor the strongly acidic

Photo: Maggie McCain

Green arrow arum (*Peltandra virginica*) in Tidal Oligohaline Marsh habitat.

soils present, in conjunction with fluctuating, seasonally perched water tables. Herbaceous vegetation is adapted to periods of flooding in winter and spring months.

Disturbed Depressional Wetland

Disturbed Depressional Wetland exists at a single location (1.5 ha [3.7 ac]) at Green Springs. It occurs in an upland habitat with no fluvial inputs, likely anthropogenic in origin. The wetland floods seasonally to a depth of 1 m (3.3 ft). Young sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*) occur with various grasses and sedges, such as common rush (*Juncus effusus*).

Coastal Plain Depression Wetland

Coastal Plain Depression Wetland (Swamp Tupelo Type), similar to Coastal Plain Depression Wetland (Red Maple – Sweetgum – Willow Oak Type), assemblages form with seasonal flooding on perched water tables with acidic underlying soils. Swamp Tupelo Type flooding, however, is deeper and of longer duration: wetland ponds are often filled with water during winter and spring months. This type, with its characteristic swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and cypress swamp sedge (*Carex joorii*), is less common and smaller in size, occupying only 0.3 ha (0.7 ac) in Colonial NHP at Yorktown Battlefield.

Tidal wetlands

Tidal Oligohaline Marsh

Tidal Oligohaline Marsh occurs where salinity concentrations are 0.5–5 parts per thousand (ppt) (Cowardin et al. 1979); in the Park these conditions are met at Swann's Point, Jamestown Island, Kingsmill/College Creek, and along parts of King Creek. This marsh type occupies 367.8 ha (908.9 ac), the most area of any wetland type found in Colonial NHP. Tidal Oligohaline Marsh is subdivided into five classifications based on dominant vegetation type; in the Park these associations can occur singly or in a complex. Tidal Oligohaline Marsh (Mixed Forbs Type) has a mixture of tidal forbs, including dotted smartweed (*Polygonum punctatum*), green arrow arum (*Peltandra virginica*), crimsoneyed rosemallow (*Hibiscus moscheutos* ssp. *moscheutos*), and narrowleaf cattail (*Typha angustifolia*). Tidal Oligohaline Marsh (Big Cordgrass Type) is dominated by its namesake big cordgrass (*Spartina cynosuroides*), which forms tall monospecific stands, typically along the edges of tidal channels. The two aforementioned associations form the majority of Tidal Oligohaline Marsh classifications within the Park. Other associations include Tidal Oligohaline Marsh (Common Reed Tidal Marsh), in which common reed (*Phragmites australis*) forms dense stands. Common reed is a non-native invasive species in Colonial NHP. Tidal Oligohaline Marsh (Saltmeadow Cordgrass – Olney Three-Square Low Interior Marsh Type) is found in small patches on Jamestown Island. This marsh association is dominated by saltmeadow cordgrass (*Spartina patens*) and chairmaker's bulrush (*Schoenoplectus americanus*). Bulrush rhizomes contribute to the presence of a floating mat of decomposing organic material. Tidal Oligohaline Marsh (Interior Depression Marsh) is found within Jamestown Island, but occurs in patches smaller than the minimum 0.5 ha (1.2 ac) established for vegetation mapping. Interior Depression Marsh occurs due to subsidence of surrounding substrate, which forms the characteristic depression. Vegetation is more sparse than the surrounding oligohaline marsh association, and includes green arrow arum (*Peltandra virginica*), coast cockspur grass (*Echinochloa walteri*), dotted smartweed (*Polygonum punctatum*), common threesquare (*Schoenoplectus pungens*), and softstem bulrush (*Schoenoplectus tabernaemontani*).

Tidal Freshwater Marsh

Tidal Freshwater Marsh (areas of 0.0–0.5 ppt salinity [Cowardin et al. 1979]) occurs on 124.8 ha (308.4 ac) where freshwater input allows the growth of green arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), dotted smartweed (*Polygonum punctatum*) and annual wildrice (*Zizania aquatica var. aquatica*) as dominant species. This marsh type is found on Jamestown Island at Sandy Bay, upper sections of Back River, Papermill Creek, and College Creek/Kingsmill along Halfway Creek. It is relatively uncommon, and is especially impacted by dams and pollution along its habitat range from Virginia to Maine.

Tidal Mesohaline and Polyhaline Marsh

Tidal Mesohaline and Polyhaline Marsh habitat is determined by salinity concentrations: 5–18 ppt for mesohaline and 18–30 ppt for polyhaline (Cowardin et al. 1979). These two wetland types occur over 42.7 ha (105.6 ac) along the York River from Ringfield/King Creek to Yorktown Creek and near College Creek/Kingsmill. Tidal Mesohaline and Polyhaline Marsh have two associations: Low Salt Marsh and Transitional Marsh. The Low Salt Marsh association is characterized by smooth cordgrass (*Spartina alterniflora*), interspersed with saltmeadow cordgrass (*Spartina patens*) and inland saltgrass (*Distichlis spicata*)—species associated with mesohaline conditions. Transitional Marsh is also dominated by smooth cordgrass (*Spartina alterniflora*), but found with big cordgrass (*Spartina cynosuroides*), green arrow arum (*Peltandra virginica*), and annual wildrice (*Zizania aquatica* var. *aquatica*)—those plants indicative of more oligohaline or freshwater conditions.

Tidal Bald Cypress Forest/Woodland

Tidal Bald Cypress Forest/Woodland occurs in the transition zone between open tidal water and tidal marsh, on 12.0 ha (29.6 ac) along the James River at Swann's Point and a few patches on Jamestown Island. Salinity conditions range from oligohaline to fresh. Bald cypress (*Taxodium distichum*) dominates the canopy, wax myrtle (*Morella cerifera*) can dominate the shrub layer, and shoreline sedge (*Carex hyalinolepis*) typically dominates the herb layer. Tidal Bald Cypress Forest/Woodland is globally rare.

Beaches

Beaches are classified as accumulations of sand along shorelines, perhaps with some shrubby vegetation (although the map class is considered non-vegetated). It occurs on 11.4 ha (28.2 ac) throughout the Park.

Globally rare Tidal Bald Cypress Forest/Woodland along the James River.

Photo: Allison Dungan

Photo: Sr. Heather Rollins

Beach and Salt Scrub habitat along Colonial Parkway.

Salt Scrub

Salt Scrub occurs in small, linear fringes along the James River near Kingsmill, and along the York River north of Yorktown. It is found on 5.5 ha (13.6 ac) within the Park; many smaller patches were likely not included due to the 0.5 ha (1.2 ac) minimum mapping unit. Eastern baccharis (*Baccharis halimifolia*), Jesuit's bark (*Iva frutescens*), and smooth cordgrass (*Spartina alterniflora*) are typical.

Disturbed Tidal Hardwood Swamp

Disturbed Tidal Hardwood Swamp habitat, on Jamestown Island, has been divorced from tidal inundation by roads or berms. Its 4.6 ha (11.4 ac) receive periodic flooding from storm surge, and cultivate red maple (*Acer rubrum*), wax myrtle (*Morella cerifera*), and broadleaf cattail (*Typha latifolia*).

Tidal Shrub Swamp

Tidal Shrub Swamp (Wax Myrtle Type) is found in patches totaling 4.2 ha (10.4 ac) scattered along Colonial Parkway, Ringfield/King Creek, at College Creek/Kingsmill, and near Yorktown. Tidal Shrub Swamp frequently exists in transition zones between emergent tidal wetland and swamp forests or uplands; vegetation tends to share species characteristic of these related communities. Dense stands of shrub wax myrtle (*Morella cerifera*) dominate, in association with narrowleaf cattail (*Typha angustifolia*), usually found in close proximity to tidal marshes.

Water

Open water accounts for 70.6 ha (174.5 ac) of the Park and is comprised of the James River at Swann's Point, tidal creek sections at Jamestown Island, and the York River where Colonial Parkway crosses the river at College Creek (Figure 2.9; Patterson 2008).

Non-habitat

Mixed Urban or Built-up Land

Mixed Urban or Built-up Land is an amalgamation of developed lands, including those that might otherwise be classified as Residential or Other Urban or Built-up Land. It accounts for 109.7 ha (271.1 ac) at Yorktown and Yorktown Battlefield at the Moore House.

Transportation, Communications, and Utilities

The Transportation, Communications, and Utilities habitat type is found throughout the Park on 93.5 ha (231.0 ac) of paved roads, interchange, parking lots, and utility line corridors. Mowed roadsides (less than 0.5 ha [1.2 ac]) were lumped into this classification.

Other Urban or Built-up Land

Other Urban or Built-up Land comprises buildings and structures associated with park maintenance, recreation, or historical interpretation, as well as urban parks, golf courses, cemeteries, and water control structures (e.g., spillways, riprap). It occurs at Swann's Point, Jamestown Island, along Colonial Parkway near Williamsburg, and at Yorktown Battlefield, for 38.8 ha (95.9 ac) total area.

Industrial and Commercial Complexes

Industrial and Commercial Complexes includes all buildings, walkways, and minor roads associated with warehousing, wholesaling, and retailing purposes. It is mapped on 3.8 ha (9.4 ac) near Yorktown Battlefield.

Residential

Residential occurs on 3.4 ha (8.4 ac) of Park land that has single family dwellings and their associated outbuildings, lawns, and plantings (Figure 2.9).

2.2.4 Resource issues overview

Internal park threats

Invasive species

Vegetation mapping in Colonial NHP yielded 38 non-native species, 20 of which are considered invasive by the Virginia Department of Conservation and Recreation (VA DCR 2003; Patterson 2008). The Coastal Plain Dry Calcareous Forest, a rare vegetation assemblage endemic to the Virginia Coastal Plain, hosts 16 non-native species, the greatest species diversity for any assemblage in the Park. Wetland and disturbed or successional vegetation typically had the greatest invasive species cover. Two community assemblages, Successional Tree-of-Heaven Forest (*Ailanthus altissima*) and Golden Bamboo Shrubland (*Phyllostachys aurea*), are formed entirely from invasive species, while many others are threatened by the encroachment of non-native invasive plants.

The most persistent and widespread invasives on upland sites are Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*), which commonly invade forest habitats. Wetlands of the Park are threatened by invasive species encroachment, particularly common reed (*Phragmites australis*). These invasive species, with characteristic rapid opportunistic growth and tolerance of myriad environmental conditions, outcompete native species and threaten the structure and function of natural communities. Disturbed areas tend to provide ideal conditions for the spread of invasive species. Other highly invasive plants include autumn olive (*Elaeagnus umbellata* var. *parvifolia*) and Chinese lespedeza (*Lespedeza cuneata*); moderately invasive plants include English ivy (*Hedera helix*), princesstree (*Paulownia tomentosa*), Canada bluegrass (*Poa compressa*), rough bluegrass (*Poa trivialis*), white poplar (*Populus alba*), curley dock (*Rumex crispus*), and Chinese wisteria (*Wisteria sinensis*).

Non-native animals have also been documented within Park boundaries. Domestic cats (*Felis catus*) and dogs (*Canis lupis*), possibly feral or associated with adjacent residential buildings, have been observed. House mice (*Mus musculus*), an introduced species, have been trapped during mammal sampling in Yorktown and Green Spring fields, habitat commonly colonized by the house mouse (Table 2.3; Barry et al. 2010).

Erosion and altered hydrology

Streams cut through the Coastal Plain deposits and create the rolling hills, ravines, and bluffs of Colonial NHP. As the stream meanders over its natural floodplain, it threatens cultural resources, such as unexcavated archeological ruins.

Invasive *Phragmites australis* at Mill Creek.

Photo: Dorothy Geyer, NPS

Table 2.3. List of non-native and/or invasive plant species found in Colonial NHP. Data were obtained during vegetation mapping surveys (Patterson 2008), with non-native and invasive classifications derived from the Virginia Department of Conservation and Recreation (VA DCR 2003).

Scientific name	Common name	Status
Grasses		
Dactylis glomerata	Orchardgrass	non-native invasive
Lolium pratense	Meadow ryegrass	non-native
Microstegium vimineum	Japanese stiltgrass	non-native invasive
Phragmites australis	Common reed	non-native invasive
Phyllostachys aurea	Golden bamboo	non-native invasive
Poa compressa	Canada bluegrass	non-native invasive
Poa trivialis	Rough bluegrass	non-native invasive
Herbs		
Ajuga chamaepitys	Yellow bugle	non-native
Allium ampeloprasum var. *atroviolaceum*	Broadleaf wild leek	non-native
Cerastium fontanum ssp. *vulgare*	Big chickweed	non-native
Commelina communis	Asiatic dayflower	non-native invasive
Daucus carota	Queen Anne's lace	non-native
Duchesnea indica	Indian strawberry	non-native
Hypochaeris radicata	Hairy cat's ear	non-native
Kummerowia striata	Japanese clover	non-native
Lespedeza cuneata	Chinese lespedeza	non-native invasive
Leucanthemum vulgare	Oxeye daisy	non-native
Murdannia keisak	Wartremoving herb	non-native invasive
Polygonum caespitosum var. *longisetum*	Oriental ladysthumb	non-native invasive
Prunella vulgaris ssp. *vulgaris*	Common selfheal	non-native
Ranunculus bulbosus	St. Anthony's turnip	non-native
Rumex crispus	Curly dock	non-native invasive
Sonchus asper	Spiny sowthistle	non-native
Taraxacum officinale	Common dandelion	non-native
Verbascum thapsus	Common mullein	non-native
Veronica arvensis	Corn speedwell	non-native
Vinca minor	Common periwinkle	non-native invasive
Viola arvensis	European field pansy	non-native
Shrubs		
Elaeagnus umbellate var. *parvifolia*	Autumn olive	non-native invasive
Ligustrum sinense	Chinese privet	non-native invasive
Lonicera japonica	Japanese honeysuckle	non-native invasive

Table 2.3. List of non-native and/or invasive plant species found in Colonial NHP. Data were obtained during vegetation mapping surveys (Patterson 2008), with non-native and invasive classifications derived from the Virginia Department of Conservation and Recreation (VA DCR 2003).

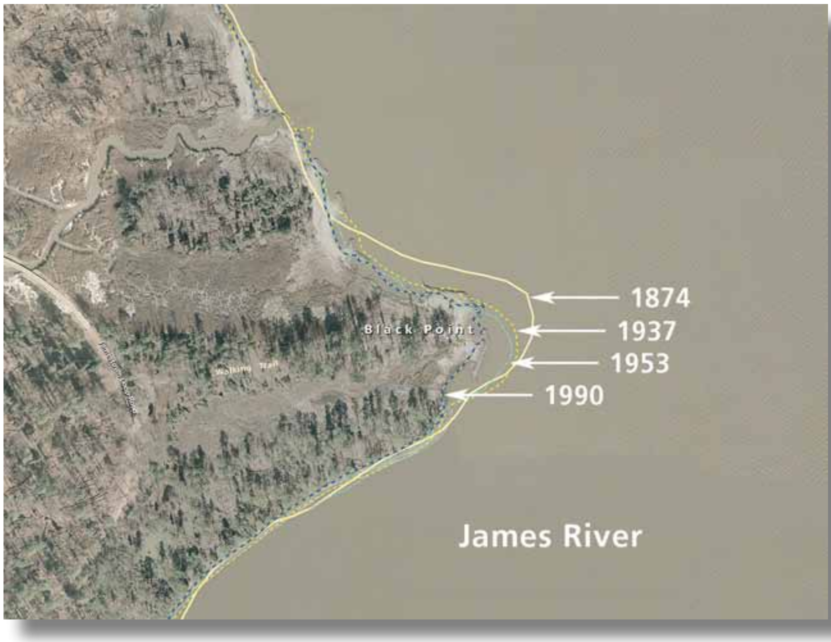
Scientific name	Common name	Status
Trees		
Ailanthus altissima	Tree of heaven	non-native invasive
Gymnocladus dioicus	Kentucky coffeetree	non-native
Paulownia tomentosa	Princesstree	non-native invasive
Populus alba	White poplar	non-native invasive
Vines		
Hedera helix	English ivy	non-native invasive
Wisteria sinensis	Chinese wisteria	non-native invasive

Increased impervious surface cover from upstream areas causes pulses of high energy stormwater to flow through streams, eroding and undercutting stream banks while increasing sedimentation. The adjacent I-64 corridor further contributes excessive stormwater runoff from impervious surface cover. Along Colonial Parkway, aging culvert infrastructure is often inadequate to direct large volumes of water resulting from stormwater events (Thornberry-Ehrlich 2005). The 2006 damage to Colonial Parkway at Papermill Creek provides a recent example of the dangers of inadequate off site stormwater control.

Hydrological alterations in the watershed threaten wetlands, vernal ponds, and ephemeral sinkholes used by rare skipper populations and by Mabee's salamander as breeding sites (NatureServe 2009). Tidal freshwater marsh habitat is relatively uncommon along its range from Virginia to Maine, and is especially impacted by dams and pollution. Hydrological alterations (e.g., through ditching, dredging) and associated effects of water contamination, bank erosion, and invasive species encroachment also threaten available habitat and contribute to the decline of sensitive joint vetch (*Aeschynomene virginica*) populations in the Park.

Shoreline erosion and sea level rise

Many cultural features of historic Jamestown, Colonial Parkway, and Yorktown are located in close proximity to the James and York Rivers (Thornberry-Ehrlich 2005). Within the Park, tidal fluctuations are on average about 0.75 m (2.5 ft), compounded by local sea level rise of 2.1 mm (0.1 in) per year. In the 400 years since the establishment of the original Jamestown colony, records indicate that the shoreline has likely eroded at least 120 m (400 ft). In 1985, a nor'easter destroyed the Yorktown waterfront pier and docks, and required the addition of beach fill and a breakwater to stabilize the shoreline. In 2003, Hurricane Isabel created a storm surge with 2 m (6 ft) waves that damaged shoreline stabilization structures and eroded beaches at Blacks Point in Jamestown, and severely damaged the Jamestown Visitor Center and several bridges. Threats to archeological and cultural sites are numerous. Blacks Point was the site of Native American artifacts that



Shoreline loss of 61 m (200 ft) at Black Point from 1874 to 2007. Aerial image taken March 2007.

Photo: Colonial NHP

White-tailed deer densities are believed to exceed environmental carrying capacities throughout Virginia.

required salvaging before the site eroded entirely. Several sites are threatened by erosion, including the site of a Confederate fort near Jamestown, and earthworks such as Fusiliers Redoubt and Redoubt 9 in Yorktown. Storm events continue to threaten the various shoreline stabilization efforts (e.g., breakwaters, riprap, stonewalls, beach replenishment, vegetation plantings) employed by Colonial NHP. While some sections of Colonial NHP's 64 km (40 mi) shoreline have structures (e.g., seawalls, riprap) to stabilize erosion, success is varied. Findings indicate that erosion along the James River and York River shorelines ranges from 0–0.58 m (0–1.9 ft) per year (NPS 1999). Shoreline erosion threatens the Glasshouse site at Jamestown, which is already damaged by long-term chemical weathering. While the shoreline near the Glasshouse is stabilized with revetments, big storm events could cause further erosion and damage.

Deer overbrowse

White-tailed deer (*Odocoileus virginianus*) densities have not been estimated directly for Colonial NHP, but are believed to exceed environmental carrying capacities throughout Virginia and especially on the Virginia Peninsula (West and Parkhurst 2002; VDGIF 2007). Populations may be labeled as overabundant if any of the following four requirements are fulfilled: 1) if the population threatens human life/livelihoods; 2) if the species is too numerous for its "own good"; 3) if the population depresses the densities of other economically or aesthetically important species; and 4) if the population contributes to ecosystem dysfunction (Côté et al. 2004). Negative impacts of overabundant deer populations include reducing species richness and abundance of herbs and shrubs, reducing sensitive songbird populations, inhibiting the regeneration of understory trees, and changing competitive balances to favor non-native plants (DeCalesta 1997; McShea and Rappole 1997; Côté et al. 2004).

Oaks are an especially palatable species that deer selectively browse upon throughout the eastern United States. Deer feed selectively on the acorns and saplings of oak trees, often resulting in direct impacts on forest composition. In several case studies, deer browsing has interrupted oak stand development by preventing understory growth and directing succession away from oak forests towards sparser conditions (Healy 1997). Similarly, land managers in the eastern United States have observed a significant reduction in Eastern hemlock (*Tsuga canadensis*) regeneration that may be partially attributable to overabundant deer herds. Deer browsing negatively affects the height and growth of native Eastern hemlock seeds as well as increases the mortality of hemlock saplings (Alverson and Waller 1997; McShea and Rappole 1997).

Watershed threats

Soil and water contamination

As of 1991, 30 underground storage tanks (UST) were known within Park boundaries holding both fuel oil and gasoline. These tanks are being removed and replaced with natural gas systems. In 1992, a leak was detected from the UST at Yorktown Visitor Center, but soil and groundwater testing yielded no contamination. Surface and groundwater contamination from surrounding lands continues to be a major stressor for the Park. Park water has been contaminated by several fuel spills on adjacent properties. For example, 17,000 L (4500 gal) of heating fuel spilled into Papermill Creek from the National Center for State Courts in 1991. Sewage spills also have occurred in recent years from Colonial Williamsburg into Papermill Creek and from Hampton Roads Sanitation Authority into the James River, resulting in the Virginia Department of Health temporarily suspending commercial shellfishing in the vicinity.

Hazardous waste sites are also located adjacent to Park land on Commonwealth of Virginia and U.S. Navy property. The Yorktown Naval Weapons Station, located upstream from Colonial Parkway and adjacent to Yorktown, contains 16 sites that have been used for hazardous waste disposal since 1925 (NPS 1999). These 16 sites have been listed on the National Priorities List for Uncontrolled Hazardous Waste Sites (Superfund) since 1992 based on contamination of groundwater, sediment, soil, and surface water from inorganics, metals, nitroaromatics, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), persistent organic pollutants, pesticides, and volatile organic compounds (VOCs) (US EPA 2011a; US EPA 2011b). The Naval Weapons Station at Cheatham Annex is also listed as a Superfund site; it was added to the National Priorities List in 2000 (US EPA 2011c). The groundwater, sediment, and soil at Cheatham Annex is contaminated with metals, PAHs, PCBs, persistent organic pollutants, and pesticides (US EPA 2011d). The Yorktown Naval Fuel Depot, located adjacent to Wormley Pond, has tested the sludge farm and recorded slightly elevated levels of petroleum hydrocarbons in the soil, surface water, and groundwater. An oil plume from an UST at this same site was also detected in the early 1990s. The Commonwealth of Virginia Emergency Fuel Storage Facility near Colonial Parkway and within the King's Creek drainage contains 23 eight-million liter (two-million gallon) capacity USTs that formerly held petroleum products and have PCBs present in the soil and water. Despite this contamination, the location is not listed as a Superfund site.

While groundwater flow paths into the Park are not well understood, groundwater can become contaminated with pollutants from sources such as septic-system effluent, fertilizer application, pesticide use, old hazardous waste disposal sites, fuel depots and leaking USTs, saltwater intrusion, and road salting. The Quaternary Aquifer, from which James City County draws water, is shallow (9 m [30 ft]) and therefore susceptible to pollution from septic systems and fertilizer and pesticide runoff.

Coliform levels are high in surface water around Jamestown Island, likely due to geese populations. Arsenic is also naturally high in the region and is a potential concern if groundwater is overpumped. The marl, calcareous clay-based soil, is atypical of the Coastal Plain and results in high pH levels for the Park. However, the James River can become highly acidic after rainstorms, due to the high clay content of upriver source areas. The James River basin has a slightly lower pH than the York.

Land use pressures

The U.S. Navy, U.S. Coast Guard, City of Newport, Colonial Williamsburg, College of William and Mary, and various private landowners all own property adjacent to Colonial. Development within the local vicinity of Jamestown Island include Jamestown Settlement, the Jamestown-Scotland Ferry landing, the Jamestown Marina, private residential developments, and Gospel Spreading Farm. Colonial Williamsburg is located approximately 10 km (6 mi) northeast of Jamestown. The

A fuel spill in Papermill Creek in 1991 contaminated park water.

Photo: Colonial NHP

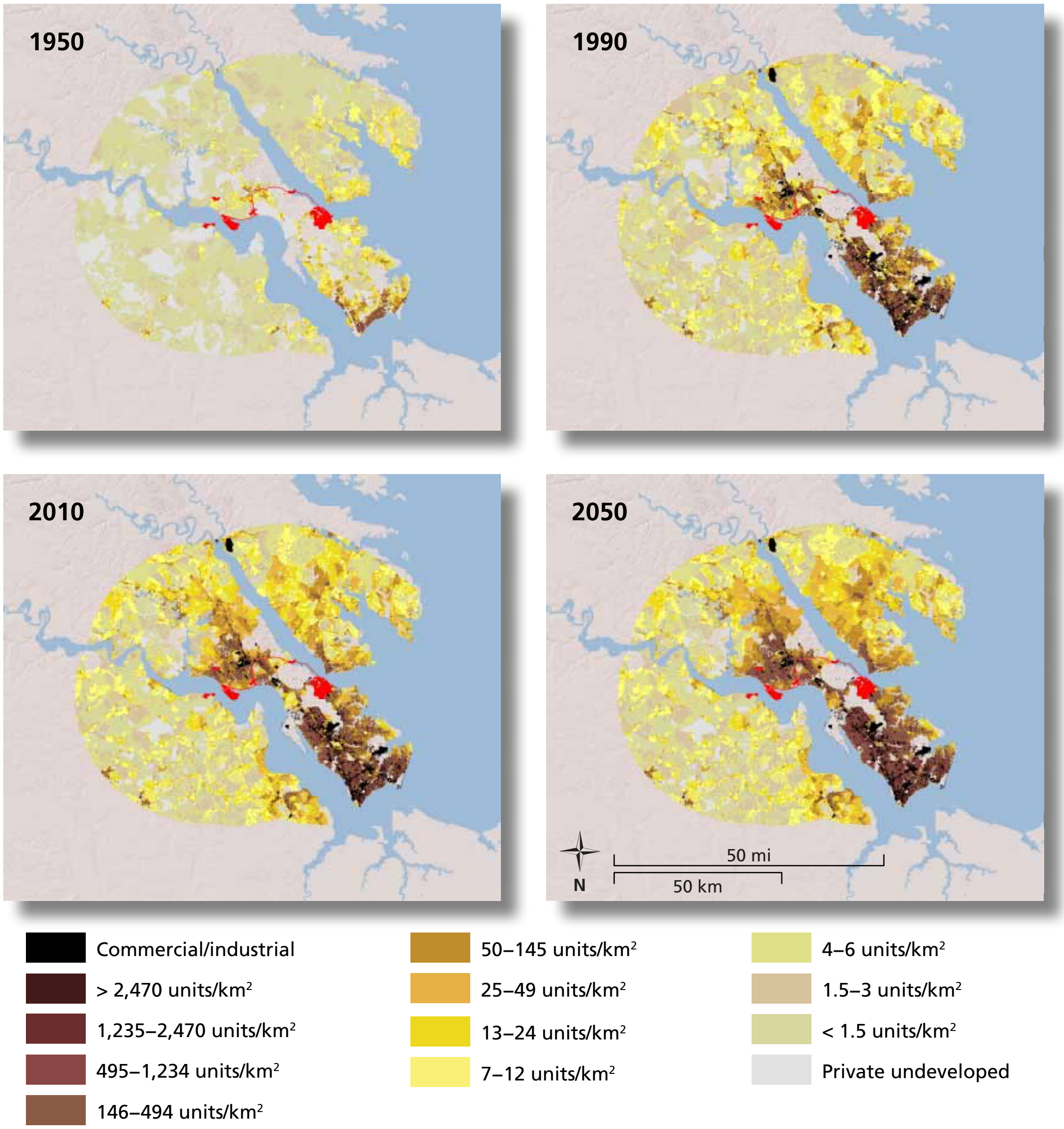


Figure 2.10. Housing density from 1950 and projected to 2050 showing a 30 km (19 mi) buffer around Colonial NHP. Adapted from NPScape products (Budde et al. 2009).

Yorktown unit is intertwined with the village of Yorktown. Ownership of these lands is of critical importance to the Park as changes in ownership can lead to an increasingly urbanized landscape. Williamsburg and James City County in general are experiencing steadily increasing sprawl. For example, impervious cover within the Powhatan Creek watershed has increased from approximately 3% in 1970 to 9.8% in 1998 (Beavers et al. 2009).

At regional scales, the Park is located 72 km (45 mi) southeast of the City of Richmond. Approximately 2.6 million people live in the James River watershed, and approximately 372,500 people lived in the York River watershed as of 2000. Population within 30 km (19 mi) of the Park has increased from 472,686 to 536,589 in the 10 years from 1990 to 2000 (Budde et al. 2009). These rates of rapid population expansion are leading to increasing urban land uses and decreasing agricultural and silvicultural land uses throughout the James River watershed (Figure 2.10; NPS 1994).

In addition to the impacts on water quality, hydrology, air quality, and wildlife, an increasing population on adjacent land can lead to increasing Park usage including illegal activities. Recreational activities such as camping, canoeing and kayaking, swimming, and hunting are not permitted in the Park, and yet occur in forested areas and along beaches and shoreline. These activities

Figure 2.11. Trail system of Colonial NHP.

trample vegetation and soils, and contribute to shoreline erosion. Trash disposal, vandalism, alcohol use, and drug trafficking occur in association with these activities. Development on lands adjacent to Colonial NHP also creates increased pressure on Park resources through dumping of refuse, boundary encroachment, illegal burning, illegal camping and fires, and illegal hunting.

All areas of the Park also report both current and potential impacts to dune vegetation communities as a consequence of day and overnight use. Trampling is primarily caused by foot traffic, in areas where visitors travel off established trails and boardwalks (Figure 2.11). Off-road mountain biking and illegal off-road vehicle (ORV) use are also sources of disturbance to vegetation and soils throughout the Park. Recreational activities, such as walking, biking, or horseback riding that originate in adjacent land often result in the creation of unplanned trails, leading to trampling and erosion of natural resources. Sheet erosion and gully erosion are both caused by these adverse user impacts.

Eutrophication

The Chesapeake Bay is listed by the U.S. Environmental Protection Agency as an impaired water body based on excessive nutrient inputs (nitrogen and phosphorus) and sediment loading (US EPA 2003). Inputs of nitrogen and phosphorus come from non-point and point sources, including power plants (through atmospheric deposition), agricultural runoff, septic systems, sewer overflows, and wastewater treatment plants (EcoCheck 2011). Phytoplankton respond favorably to nutrient inputs, forming large blooms when excessive nutrients are present. Phytoplankton growth reduces water clarity by lowering light attenuation into the water column; light is a necessary component for growth of submerged aquatic vegetation. When algae decompose, they are consumed by bacteria, a process by which high quantities of oxygen are removed from the water column. Sufficiently high algal decomposition therefore leads to hypoxic conditions in deep Bay waters (US EPA 2003).

Over the past 50 years, eutrophication has increased in the Chesapeake Bay. From the 1950s through 1980s, nitrogen and phosphorus contributions to the Bay increased, stimulating high phytoplankton chlorophyll *a* growth (Kemp et al. 2005). Over this same period, populations of phytoplankton grazers and filter feeders, such as Atlantic menhaden, American oysters, mesozooplankton, and likely benthic macroinvertebrates declined in the Chesapeake Bay (Lacouture et al. 2006). This spurred significant increases both in the volume of hypoxic water in the Bay, and in the areal extent of hypoxia further southward and into high salinity waters (Hagy et al. 2004). Concurrent with these trends, population of the Bay watershed nearly doubled, and inorganic fertilizer use nearly tripled (Boesch et al. 2001).

Regional threats

Regional threats to eastern Virginia that influence Colonial NHP natural resources include poor air quality, sea level rise, changes in climate, and increasing light and sound pollution. Sea level rise and an increased frequency of hurricanes and other large storms associated with climate change, have potential to damage Park structures, the Parkway itself, and natural resources such as Park wetlands and tidal freshwater swamps, almost exclusively found in the eastern United States. Climate change could also affect groundwater levels and subsequently flow paths.

Air quality

The East Coast has some of the worst air pollution in the U.S., with poor visibility, elevated ozone concentrations, and elevated rates of nitrogen and sulfur deposition. Air quality affects the health of humans and terrestrial and aquatic ecosystems and is largely influenced by fossil fuel combustion (e.g., cars, coal power generation), but also by other factors such as smelters and forest fires. Elevated ozone concentrations are known to cause premature defoliation of plants and nitrogen deposition can acidify and fertilize waters and soils affecting nutrient cycling, vegetation structure, stream biodiversity, and the eutrophication of streams and coastal waters. Air pollutants can be transported long distances (e.g., sulfate can be transported more than 500 km [300 mi]) making management of these threats difficult at the local scale.

Climate, sea level rise, and increased storm activity

As warming accelerates sea level rise and the severity and frequency of storms along the U.S. East Coast, it will directly affect Colonial NHP due to its close proximity to the James and York Rivers. Sea level rise results in greater storm surge heights, leading to shoreline erosion and loss of habitat, infrastructure, and archaeological and cultural sites. Combined with increased erosion, elevated sea levels can lead to greater saltwater intrusion affecting groundwater salinity, thereby affecting vegetation and organisms that depend on low salinity for habitat or reproduction. Increased storm activity can directly alter habitat structure and the succession of plant communities.

Light and sound pollution

The lower 48 states of the U.S. have some of the highest levels of artificial lighting in the world. The lack of dark night skies has ecological impacts on wildlife habitat quality, species interactions, and migration patterns. Park soundscapes have also been highly degraded in parks throughout the U.S. due to development at distances that can be far from park boundaries. Properly functioning soundscapes are important for intraspecies communication, territory establishment, courting and mating, nurturing and protecting young, predation and predator avoidance, and effective use of habitat. Both light and noise pollution can also distract visitors from their appreciation of the park's natural resources and the purpose of its cultural areas—the tranquility of historic settings and the solemnity of memorials, battlefields, prehistoric ruins, and sacred sites.

2.3 RESOURCE STEWARDSHIP

2.3.1 Management directives and planning guidance

Fundamental resources

Fundamental resources and values are the features, systems, processes, experiences, scenes, sounds, or other resources that collectively capture the essence of the park and warrant primary consideration by managers because they are critical to achieving the park's purpose (Carruthers et al. 2011).

Cultural, historical, and archeological resources serve as Colonial National Historical Park's fundamental resources (NPS 1993). Many of the land parcels within the Park commemorate events significant to United States history including the original landing site at Cape Henry Memorial, first settlement at Jamestown Island, and the end of the Revolutionary War at Yorktown Battlefield. Archeological artifacts from prehistoric, Native American, and 18th–20th century United States history exist throughout the Park. The only remaining building from the 17th century—the church tower at Jamestown Island—is managed by APVA. Several units within the Park, including Green Spring, are listed on the National Register of Historic Places. The Park contains many historic structures, among them the Nelson, Smith, Ballard, Somerwell, Dudley Digges, and Archer houses. The Nelson house was home to Thomas Nelson, a signer of the Declaration of Independence. The Moore house, located on the Yorktown Battlefield, was the site of surrender negotiations.

Fundamental values

Visitor experience of the historical landscape within the Park is critical (NPS 1993). Yorktown Battlefield and other areas are managed as warm-season grasslands, some with earthwork formations, to evoke a sense of the scale of the siege and encampment that occurred during the Revolutionary War. Jamestown Island, with minimal development, is intended to suggest the isolation and wilderness experienced by the first colonists who settled in this land in 1607. Colonial Parkway is also managed to provide visitors a way of experiencing otherwise disparate parts of the Park while maintaining historical character. Scenic vistas interspersed with interpretive pull-off areas describe the local history of the area. Views over the James and York Rivers are present along much of the Parkway.

Other important resources

Four categories of earthworks exist within the Park: Revolutionary War, Civil War, Civil War built on top of Revolutionary War, and reconstructed Revolutionary War (NPS 1999). There are about 58 km (36 mi) of earthworks: 21 km (13 mi) from the Revolutionary War, and 37 km (23 mi) from the Civil War. These earthworks are located primarily around Yorktown, with some along Colonial Parkway and on Jamestown Island.

Desired conditions

Parkwide desired conditions are resource conditions that the National Park Service aspires to achieve and maintain over time, and the conditions necessary for visitors to understand, enjoy, and appreciate those resources.

Desired conditions of natural resources for Colonial NHP as outlined in previous planning documents are provided on the following pages.

The reconstructed earthworks at Yorktown.

Photo: Blake Patterson

Entire Park (NPS 1993)

- Interpret for visitors the significance and relationships of the sites and events at Jamestown, Yorktown, and Colonial Parkway.
- Provide an integrated and high-quality visitor experience, incorporating historically relevant Park sites.
- Preserve colonial-period resources and make them accessible in a manner that is safe and enjoyable for visitors.
- Maximize the visual and historical integrity of the visitor experience.
- Protect, enhance, and interpret natural resources in a manner consistent with applicable policies and regulations while supporting cultural resource objectives.
- Actively promote conservation of the landscapes adjacent to Colonial NHP to enhance historic and scenic views and to protect Park resources and values.
- Cooperate with organizations, individuals, and other agencies to further Park objectives and encourage compatible land uses.
- Provide for compatible recreational uses such as walking, jogging, and bicycling when those uses do not conflict with the primary goals of resource protection and interpretation of historical themes.
- Interpret history of the Park as a continuum, highlighting other important events such as the Civil War, Colonial NHP as an early example of the American historic preservation movement, and the history of the Park as a focus for commemorative events. Emphasize past celebrations or commemorations that have taken place on the site.
- Develop and implement a comprehensive program to inventory, research, and monitor cultural and natural resources.
- Provide friendly, courteous service and accurate information for visitors.

Jamestown (NPS 1993)

- Interpret the 17th century history of Jamestown, with emphasis on the first settlement, the beginnings of representative government, the people who played various roles in the development of Jamestown, and the historical and archeological resources that remain.
- Keep human habitation sites clear of vegetation to the extent necessary for visitors to see cultural resources.
- In areas without evidence of habitation, maintain the natural environment in ways that suggest the conditions of the 1607 forest environments.
- Promote a sense of the primitive isolation Europeans experienced in 1607.

By the middle of the 18th century, Yorktown was the busiest seaport in the Chesapeake Bay region, whose wharves, docks, and warehouses would attract the attention of the British army when they needed supplies in the summer of 1781.

Artist: Sidney E. King

Yorktown (NPS 1993)

- Preserve, restore, and research historic structures and archeological sites of the colonial and revolutionary periods and the Victory Monument.
- Plan interpretation of Yorktown around the primary interpretive theme of the siege of Yorktown; interpret this from strategic points in the town. As a secondary theme, interpret colonial commerce on the waterfront and other aspects of colonial life on Main Street.
- Manage NPS properties to suggest the character and flavor of colonial times within the limits of safety and practicality.
- Impart a sense of Yorktown history while encouraging social and economic vitality in keeping with preservation and interpretation goals; support a balanced mix of homes, businesses, government functions, churches, waterfront activities, visitor services, roads, trails, and recreational uses that reflect the community's size, scale, traditions, and spirit.

Yorktown Battlefield (NPS 1993)

- Interpret the winning of American independence at Yorktown in its historical context. Emphasize the significance of the battle of Yorktown, discuss people who played important roles in the battle, and describe the cultural resources that remain.
- Establish conditions on the battlefield and the York River that reflect the visual scene of 1781.
- Promote a sense of the surrounding rural agricultural setting.

Colonial Parkway (NPS 1993)

- Maintain Colonial Parkway for safety while retaining the integrity of its design as a scenic roadway. Protect the historic sites, the landscapes, and the undeveloped vistas of the James and York rivers along the Parkway.
- The primary visitor experience along the Parkway involves enjoyment of the Parkway and its surroundings. It is best enjoyed as a limited access road with low to moderate traffic levels and little or no congestion.

Resource Management (NPS 1999)

- Preserve, protect and interpret cultural resources, museum collection and natural processes/resources in their environment.
- Rare, threatened, or endangered species, as identified through the process established by the Endangered Species Act, will be protected as a part of the naturally evolving ecosystem.
- Restore, protect and preserve natural watershed(s) conditions and processes, and native plant and animal communities that are characteristics of the Coastal Plain.
- Achieve better understanding of cultural and natural processes through research and monitoring to guide management activities and interpretation including ecological sound decision making; gather and evaluate information through research and monitoring in natural science, visitor use, archaeology, history, and land uses to guide decision making and management actions.
- Provide through interpretation, environmental education and outreach programs for public understanding, appreciation, involvement and support.
- Develop and maintain cooperative protection strategies with federal, state and local government agencies, community groups, corporations, and individuals to protect the integrity of the natural and cultural environments within and surrounding the Park.
- Park facilities will be developed, operated and maintained in a sustainable manner to avoid adverse impacts to Park resources.
- Park operations will be conducted to minimize impacts to natural and cultural resources.
- In 1998, an amendment to the Park's GMP was initiated for the Green Spring unit, which was authorized in 1936 but not acquired until 1966. The draft GMP is scheduled for completion in 1999. Development of this unit will require the support of outside groups, such as the Friends of the National Park Service for Green Spring, Inc.

Water Resources Management (NPS 1994)

- To develop an up-to-date water resources inventory and data base compatible with the Park's GIS and database management systems.
- To manage floodplain and wetland resources in a manner that will protect their beneficial attributes and uses.
- To protect rare, threatened, and endangered (RTE) species and their water-dependent habitats.
- To maintain and enhance surface and groundwater quality through both in-Park resource management initiatives and cooperative water quality protection activities involving local, state, and federal regulatory and planning agencies.
- To enhance regional water quality protection through full compliance with the Chesapeake Bay Preservation Act regulations.
- To develop an appropriate water resources monitoring program.
- To contribute to the scientific base for water resources management and support and/or coordinate water resources research.
- To promote water conservation through direct NPS action and through cooperation with local communities.
- To promote public awareness of the water resources and water-dependent environments of the Park and an understanding of current and potential human impacts upon these resources.

Table 2.4. Status of National Park Service inventory reports for Colonial NHP.

Inventory report	Status
Air quality	Complete
Air quality monitoring locations	Complete
Birds	Complete
Contaminant sources	Complete
Geology	Complete
Herps	Complete
Invertebrates	Complete
Mammals	Complete
Soil	Complete
Vascular plants	Certified
Vegetation mapping	Complete
Water body locations	NHD Complete
Water quality	Horizon Report
Weather and cllimate	Complete

Source: http://science.nature.nps.gov/im/units/ncbn/inv_reports.aspx accessed October 2011.

Table 2.5. Status of National Park Service Inventory and Monitoring Vital Signs monitoring for Colonial NHP.

Vital sign	Protocol status	Data
Coastal geomorphology	Complete	Historical
Estuarine nutrient enrichment: seagrass	Complete	
Estuarine nutrient enrichment: water quality	Complete	2003–2006
Estuarine nutrient loading	Complete	
Forest health	Complete	
Landscape change	Complete	
Marsh birds	In Development	
Salt marsh elevation	Complete	
Salt marsh nekton	Complete	2008
Salt marsh vegetation	Complete	2008–2009
Visitor use and impact	Complete	2003

Source: http://science.nature.nps.gov/im/units/ncbn/monitoring_products.aspx accessed October 2011.

Table 2.6. Status of Colonial NHP data sets.

Data set	Status	Data
Invasive exotic plants	Complete	1999–2000
Park fields	Complete	2000
Inventory of seasonal ponds	Complete	2005
Forest vegetation classification	Complete	2008

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Photo: Gary P. Fleming, Virginia Natural Heritage Program

Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Preliminary scoping for the Colonial National Historical Park Natural Resource Condition Assessment (NRCA) began in March 2010 with a mini-symposium of scientists with expertise on the Park's resources (Appendix A.1). Archived data for park resources were organized into an electronic library comprised of management reports, hard data files, and geospatial data (GIS), which provided the primary sources for the assessment. Planning and exchange of data occurred through a series of meetings with staff from Colonial NHP, the National Park Service (NPS) Northeast and Coastal Barrier Network (NCBN) Inventory and Monitoring (I&M) Program, the University of Richmond (UR), and the University of Maryland Center for Environmental Science Integration and Application Network (UMCES-IAN) (Appendix A.1). Outcomes of these meetings helped define habitat types and identify key metrics to assess the natural resource condition in each habitat. These meetings also provided the context of current conditions and background information not necessarily available in published form.

Additional data sets were obtained from the U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program (CBP), Virginia Institute of Marine Science (VIMS), EcoCheck (UMCES-NOAA), NPS GIS Division, and NPS Air Resources Division (NPS ARD). In conjunction with ongoing monitoring and research, efforts were made to integrate metrics from the NPS I&M vital signs program and the NPS ARD into this assessment.

Strong collaboration with Park natural resource staff was essential to the success of this assessment, and key Park staff invested significant time to assist in the development of reference conditions, calculation of metrics, and interpretation of calculated results. This discourse resulted in several attempts to develop metrics based on limited or fragmented data sets that were ultimately not used, mostly because it was eventually decided that confidence in the data was not high enough to warrant inclusion. Several iterations of habitat typing also were made before habitat maps were finalized.

Photo: Jane Thomas

Participants at the mini-symposium of scientists with expertise on Colonial NHP's resources.

3.2 STUDY DESIGN

3.2.1 Reporting areas

The focus of the reporting area for the NRCA was the Colonial NHP legislative boundary. The legislative boundary includes all lands contained in the fee boundary together with those lands within the Park's legislative jurisdiction that have not been acquired by the NPS (Figure 2.2). Lands within 30 km (19 mi) of the Park boundary were examined for context (Budde et al. 2009), but not included in the formal assessment. The assessment also did not report on Cape Henry Memorial (0.1 ha [0.23 ac]) or Tyndall's Point (0.4 ha [1 ac]), as these small units are disjunct from the other units of the Park and contain limited natural resources.

Data were compiled from all other units of Colonial NHP and combined to calculate overall Park-level scores. When possible, condition scores also were calculated for three main subunits of the Park: 1) Jamestown including Jamestown Island, Green Spring and Swann's Point; 2) Colonial Parkway including Ringfield; and 3) Yorktown (Figure 3.1). Jamestown was separated from the Parkway at Powhatan Creek. Similarly, Ballard Creek separated Yorktown from the Parkway. Green Spring and Swann's Point were included in the Jamestown subunit due to geographic proximity to Jamestown Island, which results in a coordination of management activities among these parcels.

3.2.2 Assessment framework

Metrics form the basis of this condition assessment. The NPS Inventory and Monitoring (I&M) program has previously developed a number of ecological monitoring metrics grouped as 'vital signs'. Fancy et al. (2009) defines vital signs as a "subset of physical, chemical, 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". The I&M vital signs are:

1. Air and climate
2. Water
3. Biological integrity
4. Landscapes (ecosystem pattern and processes)
5. Human use
6. Geology and soil

For the purposes of calculating natural resource condition in Colonial NHP, only the first four vital signs were used, though general features of 'human use' and 'geology and soil' are discussed throughout the report. Vital sign metrics were chosen by the Park in collaboration with UMCES-IAN and UR, and are outlined in Figure 3.2.

Detailed information of relevance, methods, reference condition, and attainment are provided for each indicator in Chapter 4. Each indicator also contains a section describing data gaps and level of confidence, which is given as a qualitative rating (i.e., very limited, limited, fair, high, very high) based on best professional judgment. Confidence in assessment did not influence the calculation of attainment or assessment scores.

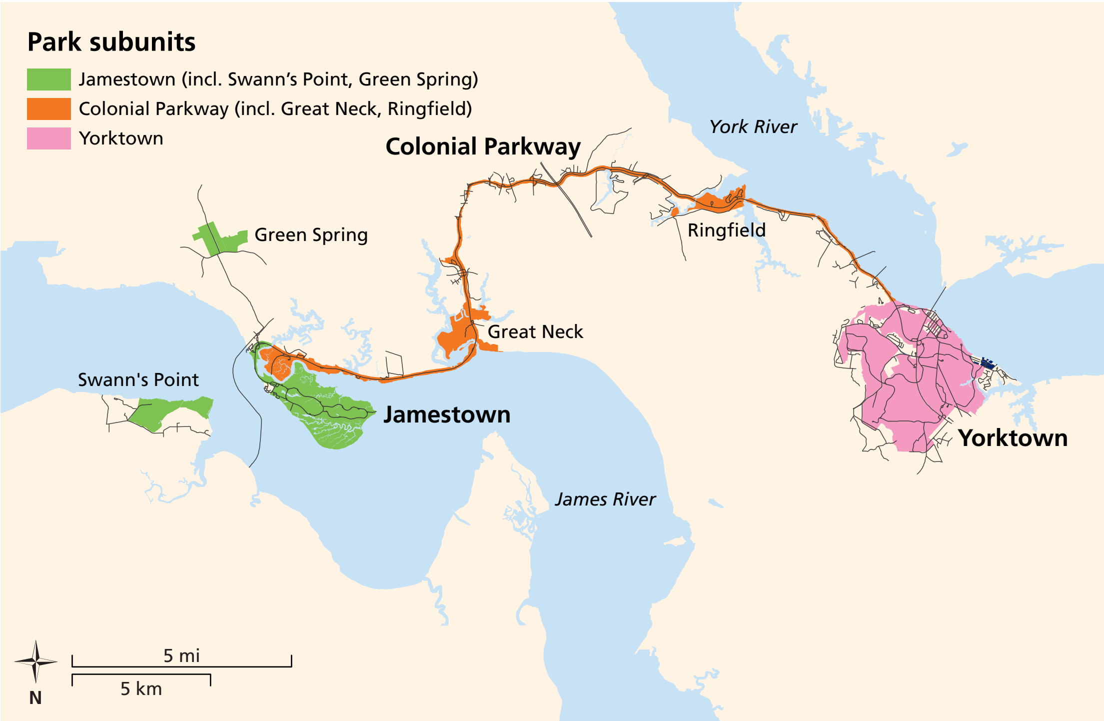


Figure 3.1. Three main subunits of the Park used in this assessment: 1) Jamestown including Green Spring and Swann's Point, 2) Colonial Parkway including Ringfield, and 3) Yorktown.

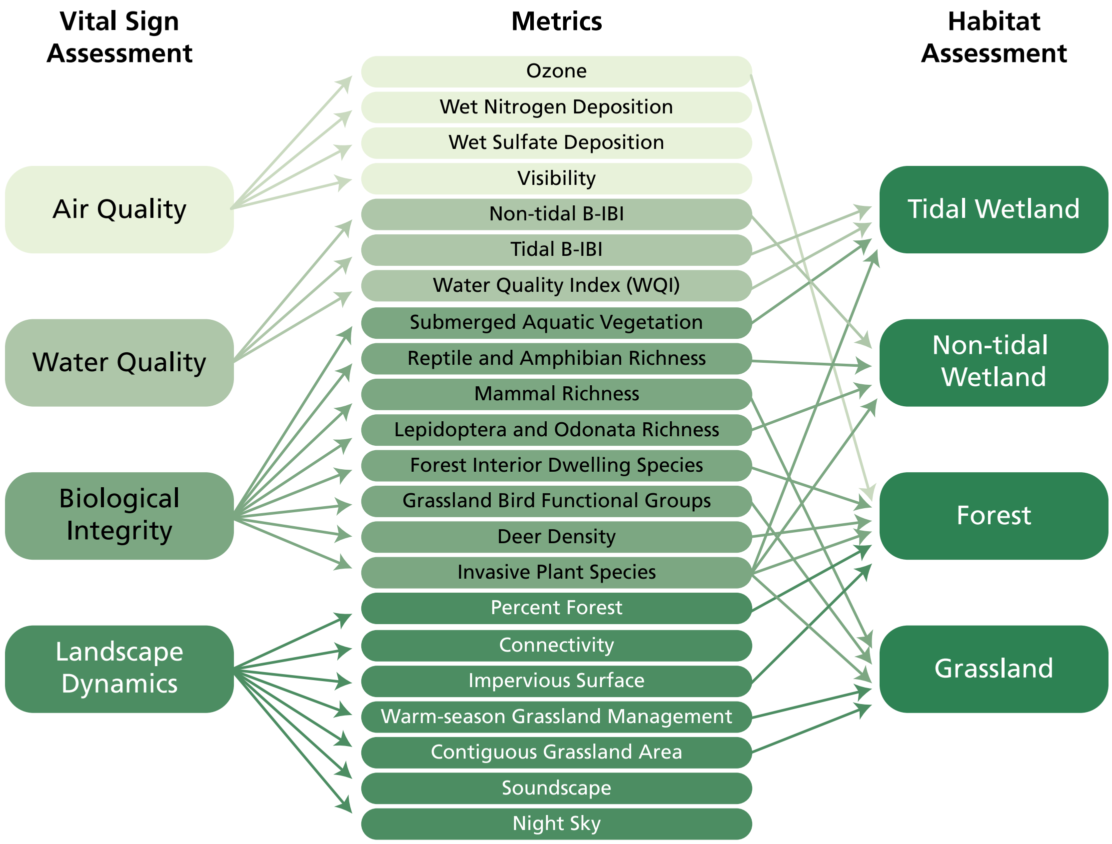


Figure 3.2. Vital signs, metrics, and habitat assessment framework for Colonial NHP.

3.2.3 Habitat classification

The report concludes with a habitat-based assessment of natural resource condition (Chapter 5). Many ecological classification systems exist in the literature, several of which are based on vegetation communities (Grossman 1998; Anderson et al. 1999) or land cover (Anderson et al. 1976). This approach was used to classify habitats for Colonial NHP using the Virginia Natural Heritage Program, which classified 40 vegetation assemblages (Patterson 2008). Based on management priorities, abundance of ecological cover types, and the availability of sufficient data to make an assessment, the 40 vegetation assemblages were grouped into four habitat types for this assessment of Colonial NHP (Appendix A.2):

1. Forest
2. Grassland
3. Non-tidal wetland
4. Tidal wetland

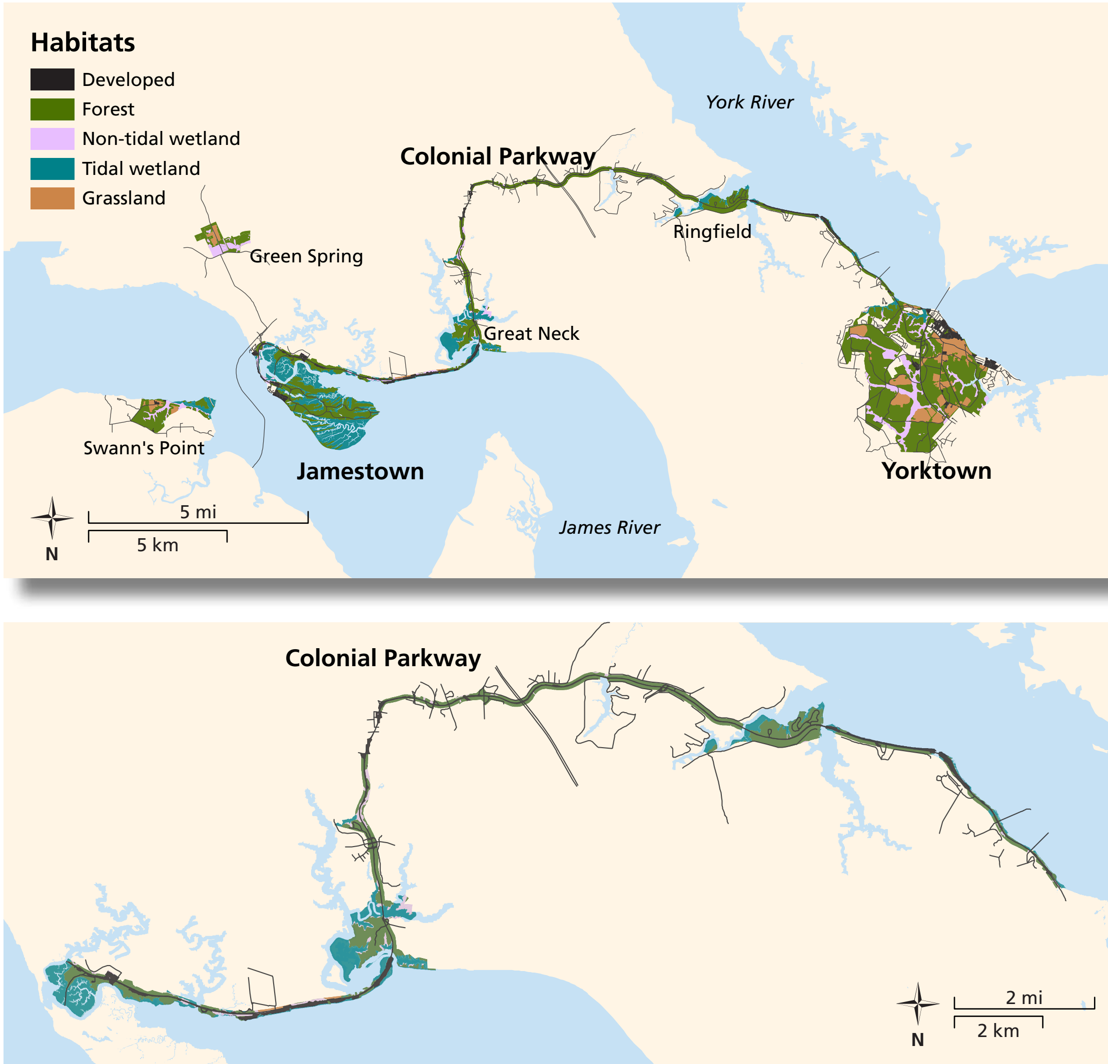
Only lands falling into one of these four categories were assessed. After an initial GIS mapping of the landscape using this modified classification scheme, several iterations of comments were solicited with park staff to identify potential misclassifications in the Park, and maps were edited accordingly (Figure 3.3).

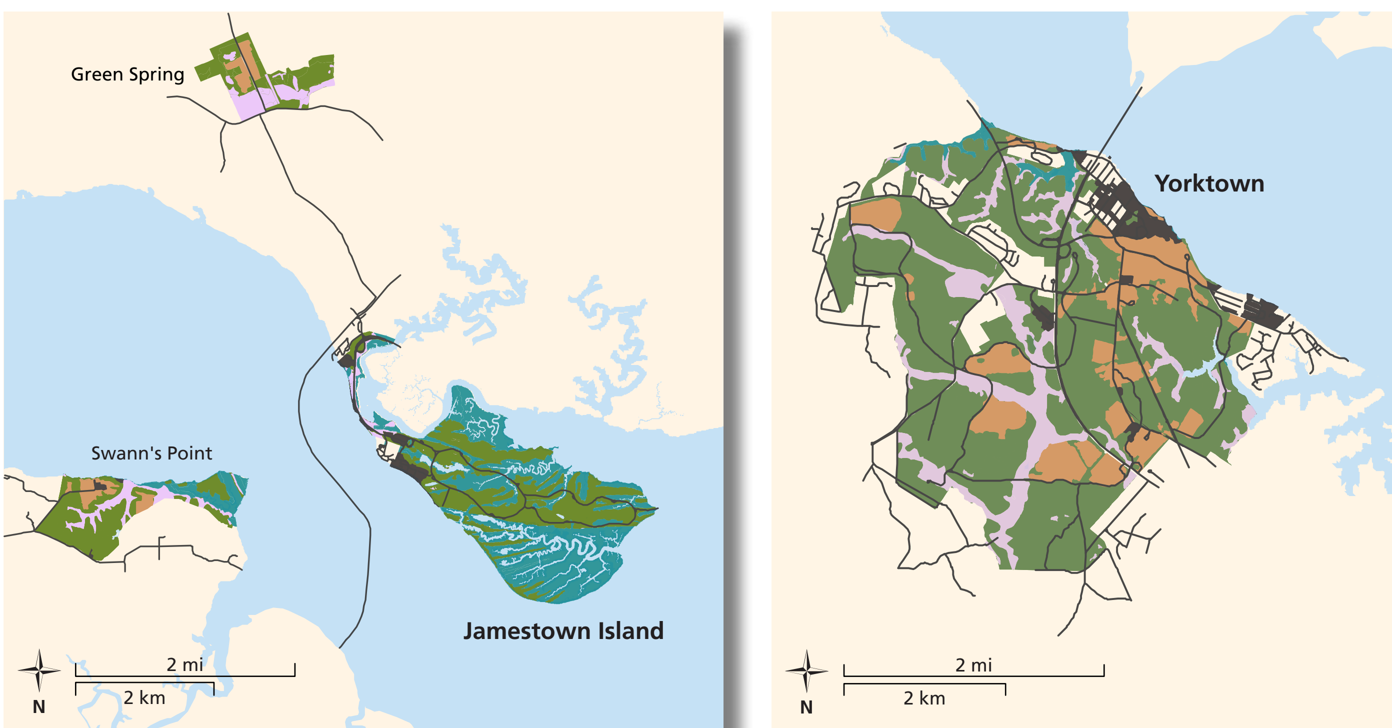
A subset of the 22 metrics were selected to represent each of the four habitat types. Not all metrics were used in the habitat assessment. Instead, metrics were selected to represent the natural resource values and stressors identified for each habitat type in a balanced manner (Figure 3.2). For example, because many of the measures of air quality were highly correlated, only one air quality metric (ozone) was included in the assessment of forest condition. Metric selection was also balanced in terms of the scale of influence on the Park, from regional (e.g., ozone) to local (e.g., invasive plants) factors.

3.2.4 Condition assessment calculations

A total of 22 vital sign metrics were reviewed in this assessment, with 16 indicators used to determine habitat condition. The approach

Figure 3.3. General location and types of habitats in Colonial NHP (top), showing the three analysis areas: Colonial Parkway (center), Jamestown, Green Spring, and Swann's Point (bottom left), and Yorktown (bottom right).





for assessing resource condition within Colonial NHP (as separate units and the park as a whole) 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-based thresholds were used. Instances when best professional judgment was used in consultation with park staff to define thresholds were clearly identified in the "Data gaps and level of confidence" subsections of Chapter 4.

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 and habitat. Attainment scores were categorized on a scale from very good to very degraded. Attainment scores for each metric are presented in Chapter 4 and synthesized further into habitat scores (forest, grassland, non-tidal wetland, and tidal wetland) in Chapter 5.

In order to visualize the continuum of habitat quality, a conceptual diagram of theoretical degraded and desired conditions for each habitat type was developed, based on the series of metrics identified for that habitat. Metrics and habitats were assigned a qualitative rating corresponding to the quantitative score: very degraded (0–20%), degraded (20–40%), fair (40–60%), good (60–80%), and very good (80–100%). These scores were reflected in a park-specific conceptual diagram of current condition for each habitat. Key findings and recommendations were also given for each habitat. The four habitat scores were then averaged to produce a single assessment score for the entire park.

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Photo: Gary P. Fleming, Virginia Natural Heritage Program

4.1 AIR QUALITY

4.1.1 Ozone

Relevance and context

Ozone, a secondary atmospheric pollutant, is not directly emitted, but is formed by a sunlight-driven chemical reaction on nitrous 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. Ozone concentrations of 120 parts per billion (ppb) can be harmful with only short exposure during heavy exertion such as jogging, while similar symptoms can occur from prolonged exposure to concentrations of 80 ppb ozone (McKee et al. 1996). One study in which 28 plant species were exposed to ozone for between three and six weeks showed foliar impacts, including premature defoliation in all species at ozone concentrations between 60–90 ppb (Kline et al. 2008). Ozone can also negatively affect pollination by destroying the scent-bearing molecules released by flowers to attract pollinators. As a consequence, a wide variety of eastern U.S. vegetation may be vulnerable on NPS lands (Lovett et al. 2009). Ozone pollution may also be playing a role in the recent collapse of honeybee and bumblebee colonies in the U.S. (McFrederick et al. 2008).

Data and methods

Ozone is not measured within the park boundary but is interpolated from nearby stations by kriging, a statistical interpolation process. Data used for the assessment was evaluated as the 5-year, 8-hour average of the 4th highest daily maximum eight-hour average ozone concentration measured between 2005 and 2009 and supplied by NPS Air Resources Division (Figure 4.1; NPS ARD 2010). Currently, there is only one interpolated assessment point for the park. This value was assessed against the threshold (ozone standard) for the quantification of current condition. For assessment of trends, NPS ARD estimates of the 5-year average values were considered dating back to the 1999 to 2003 analysis window (NPS ARD 2011).

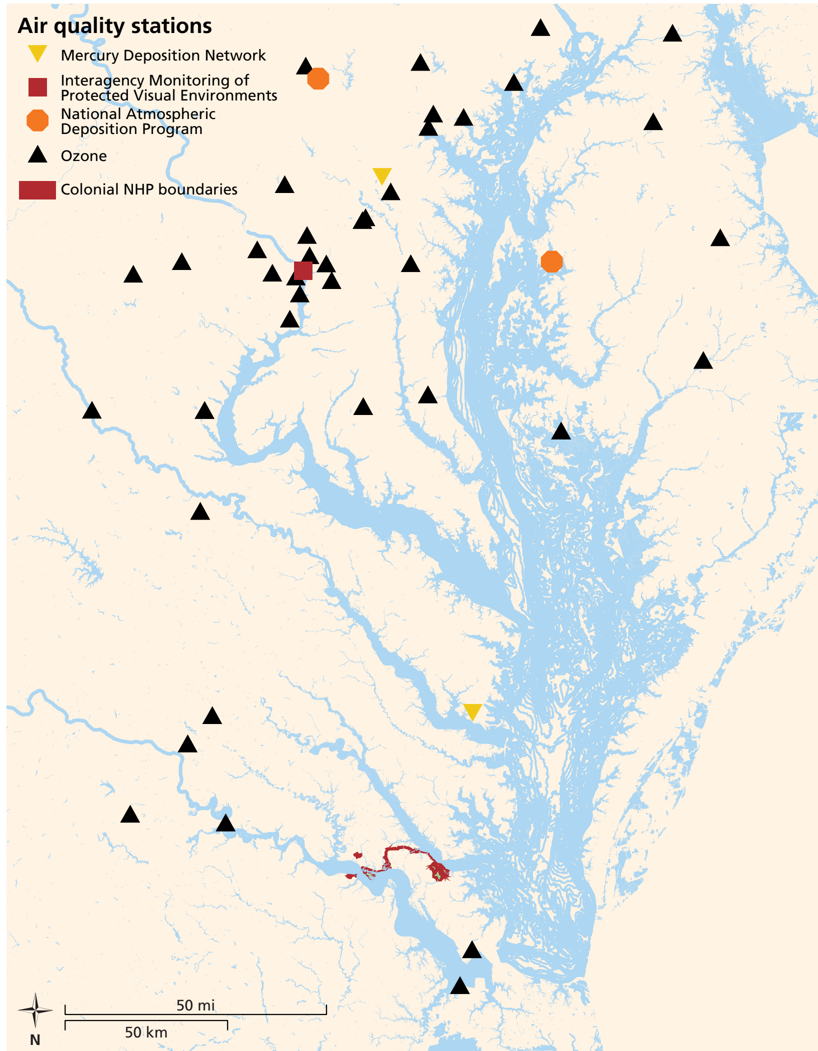

Figure 4.1. Air quality monitoring within the Chesapeake Bay region.

Threshold

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (US EPA 2004). In 1997, the ozone standard was set by the National Ambient Air Quality Standards (NAAQS) as 80 ppb for the 5-year average annual 4th highest daily maximum 8-hour ozone concentrations (US EPA 2006). This standard has subsequently been lowered to 75 ppb (NAAQS 2008), with a current proposal for further reduction to an acceptable range of 60–70 ppb (Federal

Register 2010). For this assessment, multiple threshold concentrations were used: ≥76 ppb were considered as of significant concern (score of 0%) and concentrations ≤60 ppb (set as 80% of the standard concentration limit) as in good condition (assigned a score of 100%). Concentrations between 61–75 ppb were considered in moderate condition (NPS ARD 2010), and condition scores were scaled linearly from 0–100 between these two reference points. The 10-year trend (1999–2008) was also considered for the park using the separate analysis of 159 national park units conducted in accordance with the Government Performance and Results Act (Table 4.22; NPS ARD 2010).

Current condition and trend

The 2005–2009 value of 77.0 ppb indicates a significant concern based on comparison to the threshold of 75.0 ppb. This represents a current condition of 0% for the park. The NPS Ozone Injury Risk Assessment (NPS 2004) listed 21 species at risk of foliar injury from ozone in Colonial NHP (Table 4.1).

Ozone has been improving over the past decade of monitoring. From the NPS Air Quality estimates (5-year averages), the interpolated 4th highest daily maximum 8-hour ozone concentration for the park has decreased for successive 5-year periods from 88.5 ppb in 1999–2003 to 77.0 ppb in 2005–2009 (Figure 4.2). This reported trend is consistent with the 10-year trend reported in the 2009 Annual Performance and Progress report (NPS ARD 2010), which found that no park units in the eastern U.S. show a degrading trend, with many parks showing no trend but a majority showing significant or possible improvement in atmospheric ozone concentration (Figure 4.3; Table 4.22; Table 4.23; NPS ARD 2010).

Table 4.1. Plant species found within Colonial NHP that are sensitive to ozone (NPS 2004).

Latin Name	Common Name	Family
Ailanthus altissima	Tree-of-heaven	Simaroubaceae
Asclepias syriaca	Common milkweed	Asclepiadaceae
Cercis canadensis	Redbud	Fabaceae
Fraxinus americana	White ash	Oleaceae
Fraxinus pennsylvanica	Green ash	Oleaceae
Liquidambar styraciflua	Sweetgum	Hamamelidaceae
Liriodendron tulipifera	Yellow-poplar	Magnoliaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Pinus taeda	Loblolly pine	Pinaceae
Pinus virginiana	Virginia pine	Pinaceae
Platanus occidentalis	American sycamore	Platanaceae
Prunus serotina	Black cherry	Rosaceae
Rhus copallina	Flameleaf sumac	Anacardiaceae
Robinia pseudoacacia	Black locust	Fabaceae
Rubus allegheniensis	Allegheny blackberry	Rosaceae
Sambucus canadensis	American elder	Caprifoliaceae
Sassafras albidum	Sassafras	Lauraceae
Spartina alterniflora	Smooth cordgrass	Poaceae
Verbesina occidentalis	Crownbeard	Asteraceae
Vitis labrusca	Northern fox grape	Vitaceae

Data gaps and level of confidence

Currently, there is a need for translating regional air data to park levels. All park units included in the NCBN are listed as Class II* and these network parks have no on-site ambient air quality monitoring; however, in most cases, there are nearby monitors. Ozone is the air pollutant with the most widespread sampling locations in the northeast U.S. Confidence in the current assessment is high.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

Ellen Porter, Air Resources Division, National Park Service

Holly Salazar, Environmental Protection Specialist, Air Resources Division, National Park Service

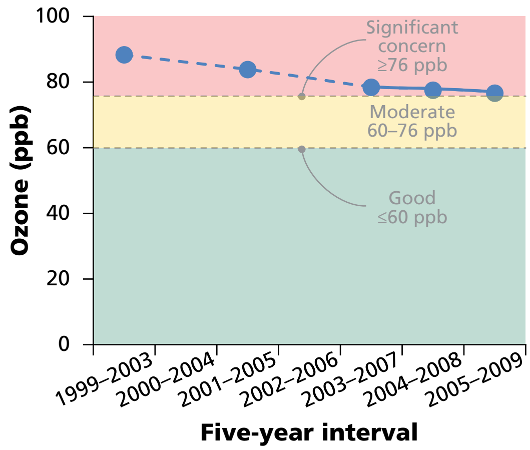

Figure 4.2. Five-year trends in annual 4th-highest 8-hour ozone concentration for Colonial NHP (NPS ARD 2011).

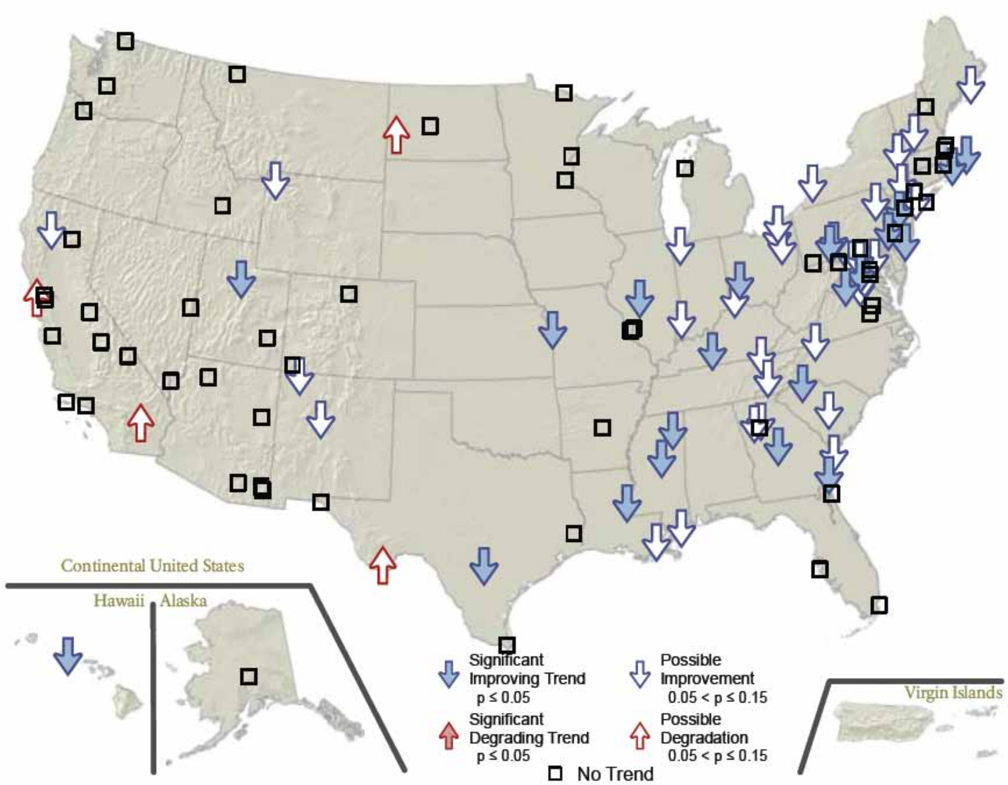

Figure 4.3. National 10-year trends in annual 4th-highest 8-hour ozone concentration, 1999–2008 (NPS ARD 2010).

* Class I areas are defined as national parks over 2400 ha (6000 ac), national wilderness areas and national memorial parks over 2000 ha (5000 ac), and international parks. Generally, parks that do not meet these criteria are designated Class II areas.

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4.1.2 Wet nitrogen deposition

Relevance and context

Atmospheric deposition is the depositing of airborne particles and gases on the Earth's surface. This process can occur either through precipitation (wet deposition) or as a result of atmospheric settling, impaction, and adsorption (dry deposition). For this assessment, we considered only wet deposition of total nitrogen. Deposited material includes a wide variety of natural and anthropogenic pollutants, including inorganic elements and compounds (e.g., nitrogen, sulfur, basic cations, mercury, other metals) and organic compounds (e.g., pesticides, herbicides). Once deposited, pollutants can have a variety of ecosystem effects (Porter and Morris 2007).

Nitrogen compounds comprise a group of atmospheric pollutants of significant concern to both terrestrial and aquatic ecosystems. During the 1940s and 1950s, the United States and Britain recognized that coal burning emissions from large-scale industry such as power plants and steel mills were causing severely degraded air quality in major cities, resulting in severe human health impacts. By the early 1970s, the U.S. EPA had established the National Ambient Air Quality Standards (NAAQS) (Porter and Johnson 2007). In addition to human health effects, significant ecosystem impacts of atmospheric nitrate deposition have become increasingly recognized (NPS ARD 2010). These impacts result largely from the acidification and nutrient fertilization of waters and soils, and include 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).

Data and methods

Data used for the assessment were deposition concentrations multiplied by normalized precipitation (PRISM 1971–2000 30-year average; Daly et al. 2002) to interpolate total nitrogen deposited between 2005–2009 for the central point within Colonial NHP. These data were supplied by NPS Air Resources Division (NPS ARD 2011a). There is currently only one assessment point for the park so this value was assessed against the reference condition, either attaining or failing to attain this threshold value. For assessment of trends, NPS ARD estimates of the 5-year average values were considered dating back to the 1999–2003 analysis window (NPS ARD 2011a).

Threshold

The total natural background 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 2011b). While there is no evidence of ecosystem harm at deposition rates less than 1 kg/ha/yr, sensitive ecosystems, such as upland coastal and estuarine waters areas, show responses to wet nitrogen deposition rates of 1.5 kg/ha/yr (Fenn et al. 2003). NPS Air Resources Division has established wet nitrogen deposition guidelines as <1 kg/ha/yr indicating good condition, 1–3 kg/ha/yr indicating moderate, and >3 kg/ha/yr indicating significant concern (NPS ARD 2011b) For the current assessment, the most conservative category of <1 kg/ha/yr was used as the threshold based on the established natural background wet nitrogen deposition of 0.25 kg/ha/yr (NPS ARD 2011b; Table 4.22).

Current condition and trend

The 2005–2009 value of 4.22 kg/ha/yr indicates a significant concern based on comparison to the reference standard of 1 kg/ha/yr. This represents a current condition of 0%. Total nitrogen wet deposition has been decreasing from a value of 4.50 kg/ha/yr for 2001–2005 to 4.22 kg/ha/yr for 2005–2009 (Figure 4.4; NPS ARD 2011a). This change reflects an improving trend consistent with nationwide reductions in emissions over the past decades (Driscoll et al. 2001), and is consistent with reducing trends in most parks in the eastern U.S. (NPS ARD 2010). However, large reductions in nitrogen wet deposition are still required to reduce negative impacts on natural resource condition (Table 4.22; Table 4.23; Porter and Johnson 2007).

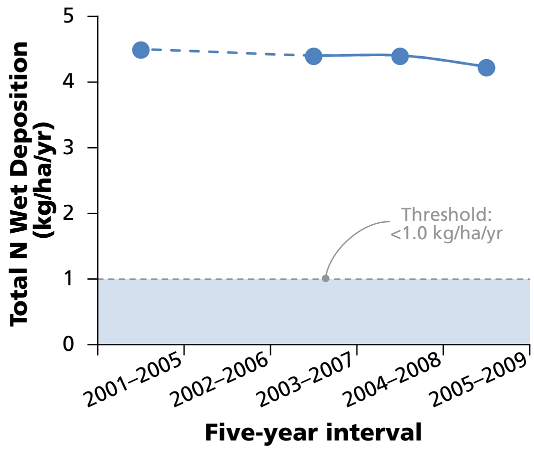

Figure 4.4. Five-year trends in total wet nitrogen deposition (kg/ha/yr) for Colonial NHP (NPS ARD 2011a).

Data gaps and level of confidence

Many of the closest National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitoring stations within the NCBN are inland of the parks, up to a distance of 137 km (85 mi). The distance to, and location of these sites is problematic, because in coastal areas there are substantial differences in wind patterns and localized meteorology may significantly affect pollutant deposition. The closest monitoring site to Colonial NHP was installed in Prince Edward County, Virginia (site #VA24) in 1999. A clear set of ecosystem thresholds is also required (Porter and Johnson, 2007). Confidence in the current assessment is high.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/planning/index.cfm

Ellen Porter, Air Resources Division, National Park Service

Holly Salazar, Environmental Protection Specialist, Air Resources Division, National Park Service

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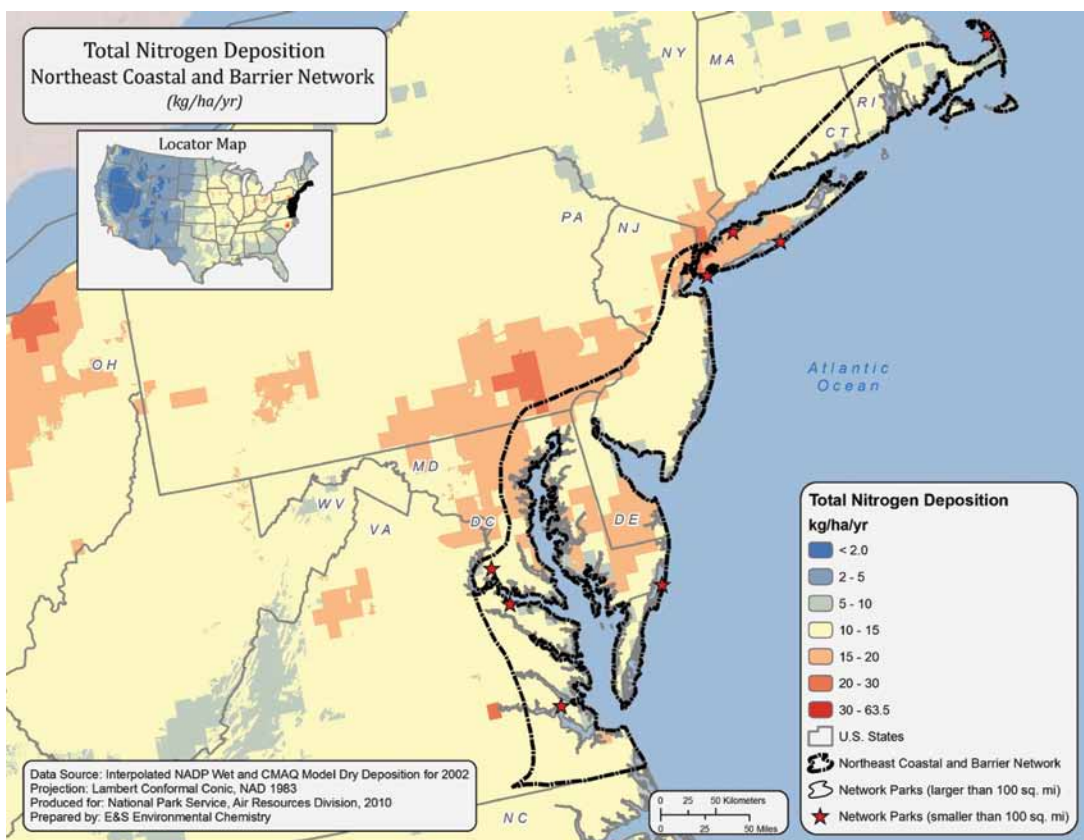

Figure 4.5. Total wet nitrogen deposition estimates for the Northeast Coastal and Barrier Network (Sullivan et al. 2011).

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4.1.3 Wet sulfur deposition

Relevance and context

Emissions of sulfate (SO_2) in the U.S. increased from 9 million metric tons in 1900 up to 28.8 million metric tons by 1973, with some 60% of these emissions coming from electric utilities and 41% coming from the seven Midwest states centered on the Ohio Valley (US EPA 2000; Driscoll et al. 2001). As a result of the establishment of the Clean Air Act (1990) regulations, emissions of SO_2 were reduced to 17.8 million metric tons by 1996. 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 mi) (Driscoll et al. 2001).

Data and methods

Data used for the assessment were statistically interpolated by NPS Air Resources Division from the closest National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitoring stations for the central point within Colonial NHP (NPS ARD 2011a). The closest monitoring site to Colonial NHP is in Prince Edward County, Virginia (site #VA24). Because there is only one assessment point for the park, this value was assessed against the reference condition, either attaining or failing to attain this threshold value. For current condition, the average annual total wet sulfur deposition for the 5-year period from 2005–2009 was used. For assessment of trends, data from 2001–2005 also were analyzed (NPS ARD 2011a).

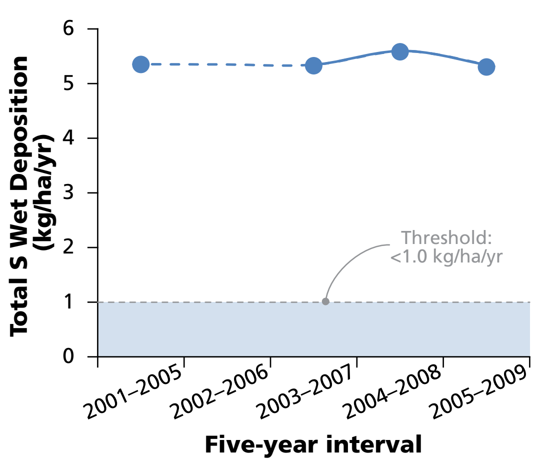

Figure 4.6. Five-year trends in total wet sulfur deposition (kg/ha/yr) for Colonial (NPS ARD 2011a).

Threshold

Natural background sulfur 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 2010). NPS Air Resources Division has established wet sulfur deposition guidelines as <1 kg/ha/yr indicating good condition, 1–3 kg/ha/yr indicating moderate, and >3 kg/ha/yr indicating significant concern. For the current assessment, the most conservative category of <1 kg/ha/yr was used as the threshold based on the established natural background wet sulfur deposition of 0.25 kg/ha/yr (NPS ARD 2011b; Table 4.22).

Current condition and trend

The 2005–2009 value of 5.32 kg/ha/yr indicates a significant concern based on comparison to the threshold of <1 kg/ha/yr. This represents a current condition of 0% attainment.

Total wet sulfur deposition has decreased slightly from a value of 5.36 kg/ha/yr for 2001–2005 (NPS ARD 2011a). Phase I of the sulfate reduction provision of the Clean Air Act ran from 1995–1999 and affected roughly 440 of the larger, higher emitting utility units, primarily in the eastern U.S. Phase II began in 2000, extending to all affected sources throughout the country (Table 4.22; Table 4.23; Driscoll et al. 2001).

Data gaps and level of confidence

Many of the closest NADP/NTN monitoring stations within the NCBN network are inland of the parks, up to a distance of 137 km (85 mi). The distance to, and location of these sites is problematic, because in coastal areas there are substantial differences in wind patterns and localized meteorology may significantly affect pollutant deposition. The closest monitoring site to Colonial NHP was installed in Prince Edward County, Virginia (site #VA24) in 1999. A clear set of ecosystem thresholds is also required (Porter and Johnson 2007). Nevertheless, confidence in the current assessment is high.

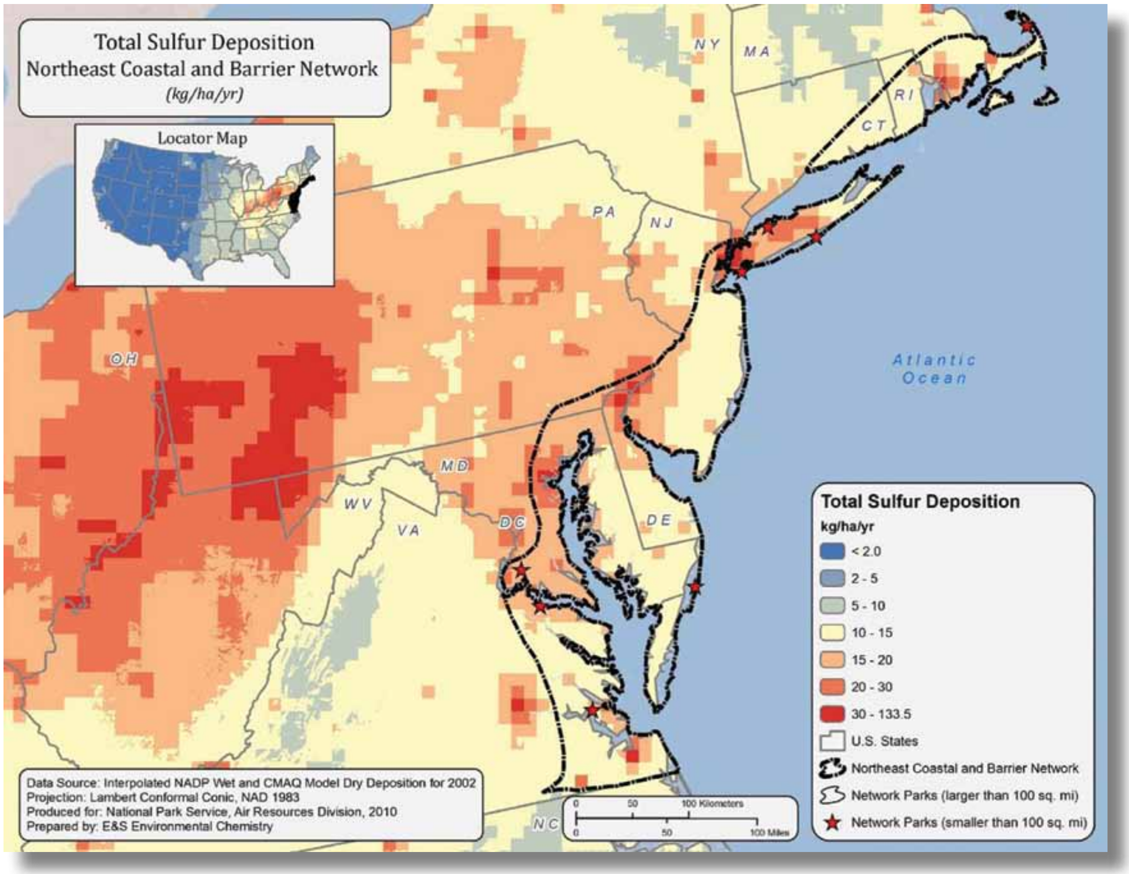

Figure 4.7. Total sulfur deposition estimates for the Northeast Coastal and Barrier Network (Sullivan et al. 2011).

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/

Ellen Porter, Air Resources Division, National Park Service

Holly Salazar, Environmental Protection Specialist, Air Resources Division, National Park Service

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4.1.4 Visibility

Relevance and context

Although the presence of sulfates (SO_2), organic matter, soot, nitrates, and soil dust all impair visibility, the major cause of reduced visibility in the eastern U.S. is sulfate particles formed from the SO_2 of coal combustion (National Research Council 1993). The Clean Air Act includes visibility as one of its national goals as an indicator of emissions related to broader air quality degradation linked to human health impacts (U.S. EPA 2004). Improving visibility in national parks and wilderness areas has been of special concern to protect the scenic vistas expected by visitors.

Data and methods

Data used for the assessment was a statistical spatial interpolation of nearby haze monitoring stations to the central point within Colonial NHP, as supplied by NPS Air Resources Division (NPS ARD 2011a). The haze index in deciviews (dv) indicates the difference between current group 50 visibility (mean of the 40th–60th percentile data) and the natural group 50 visibility (estimated visibility in the absence of human caused visibility impairment) (U.S. EPA 2003; NPS ARD 2011b). Current condition was assessed using the average haze index value for the 5-year period from 2005–2009. This value was assessed against the threshold, either attaining or failing to attain this threshold value.

Threshold

A calculated haze index where the visibility is ≥8 dv above a natural visibility condition was considered of significant concern, concentrations between 2–8 dv above a natural visibility condition as in moderate condition and concentrations ≤ 2 dv above a natural visibility condition as in good condition (NPS ARD 2010). The good condition, ≤ 2 dv, was used as the threshold in this assessment (Table 4.22).

Current condition and trend

The 2005–2009 value of 11.7 dv indicates a significant concern based on comparison to the reference standard of 2 dv. This represents a current condition of 0% attainment (Figure 4.8).

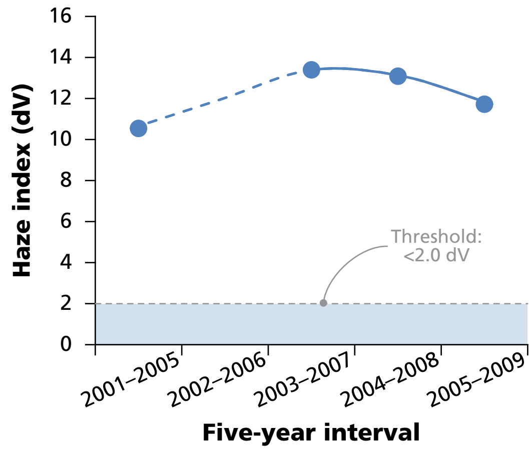

Figure 4.8. Five-year trends in haze index (dv) for Colonial (NPS ARD 2011a).

A national assessment of 10-year trends in visibility within 163 national park units found that, throughout the country, 12 park units showed significant improvement, five significant decline and the remaining 146 showed no trend (NPS ARD 2010). Considering data from the haziest days in the eastern U.S., several of the parks in Virginia and Maryland showed possible or significant improvement from 1999–2008 (Figure 4.9; Table 4.22; Table 4.23).

Data gaps and level of confidence

Data are collected from nearby stations rather than in the park, which contributes to the uncertainty of the assessment. Up to five Interagency Monitoring of Protected Visual Environments (IMPROVE) sites have been recommended in or near parks in the Northeast and Coastal Barrier Network. It is unlikely that any of these would be in Colonial NHP; however, all parks in the NCBN will have an IMPROVE monitoring station within 185 km (115 mi). This will be sufficient to provide a network-range assessment of visibility. Confidence in the current assessment is high.

Sources of expertise

Air Resources Division, National Park Service; http://www.nature.nps.gov/air/planning/index.cfm

Ellen Porter, Air Resources Division, National Park Service

Holly Salazar, Environmental Protection Specialist, Air Resources Division, National Park Service

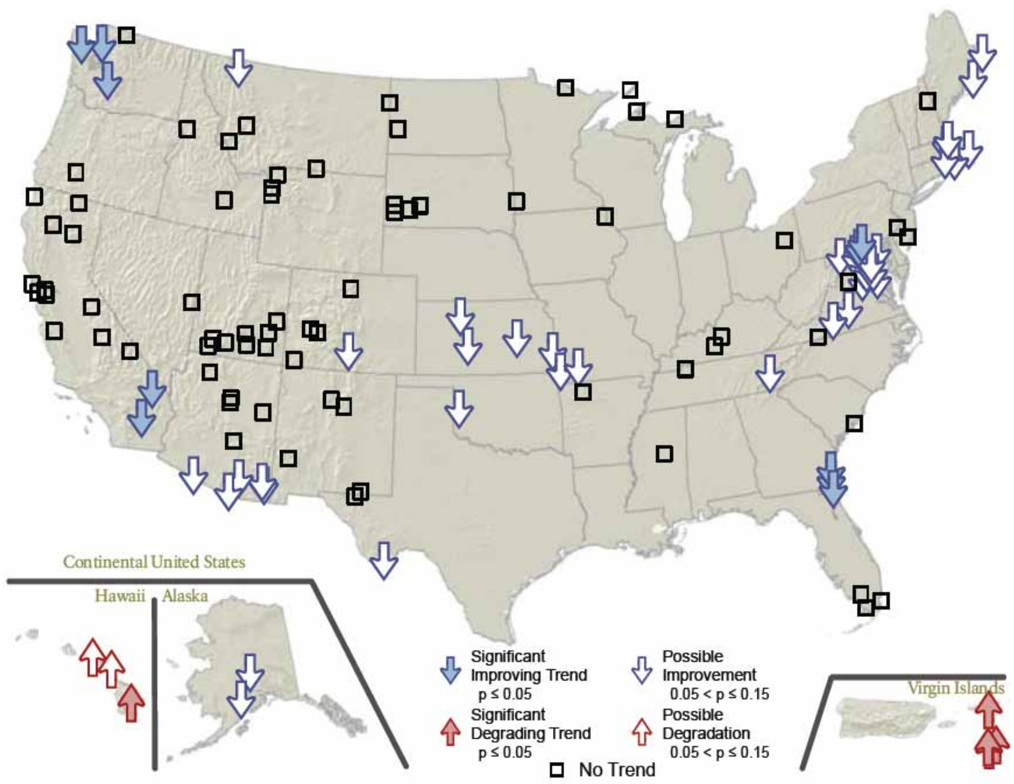

Figure 4.9. Trends in haze index (deciviews) on haziest days, 1999–2008 (NPS ARD 2010).

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4.2 WATER QUALITY

4.2.1 Non-tidal benthic index of biotic integrity (B-IBI)

Relevance and context

The benthic index of biotic integrity (B-IBI) measures the condition of macroinvertebrate communities large enough to be seen with the naked eye (e.g., crustaceans, snails, mussels, worms) living in or on the bottom of waterways as a proxy for evaluating water and sediment quality (VA DEQ 2006). The assessment compares the community of benthic macroinvertebrates collected from a waterway where there are no significant disturbances (reference waterway), to the community of benthic macroinvertebrates under investigation. Macroinvertebrate community structure and composition are affected by changes in water quality, with some families and functional groups more sensitive and some more tolerant to degraded conditions.

Data and methods

Thirteen sampling points at 12 sites within non-tidal sections of Colonial NHP and the surrounding watershed were surveyed for macroinvertebrates to assess the B-IBI (Figure 4.10). Two sites were located within Park boundaries (one in Yorktown and one along Colonial Parkway near Ringfield) and 10 sites were located outside the Park within the watershed for the James and York Rivers. The site within Yorktown was sampled twice, during two separate sampling events. Sampling occurred from 2000–2008, with the majority of sites sampled in 2000 and 2003. Data were collected by the Virginia Department of Environmental Quality and compiled by the Chesapeake Bay Program as part of the Non-Tidal Tributary Work Group.

The Mid-Atlantic Coastal Streams (MACS) protocol (US EPA 1997) was used to sample these Coastal Plain streams. MACS protocols apply to the southern Coastal Plain EcoRegion 63S, of which Colonial NHP is a part. The assessment area consists of a 100 m (328 ft) section of stream channel, for which three types of measurements are taken (US EPA 1997; VA DEQ 2006): i) macroinvertebrates, ii) habitat, and iii) water quality. Macroinvertebrate, habitat,

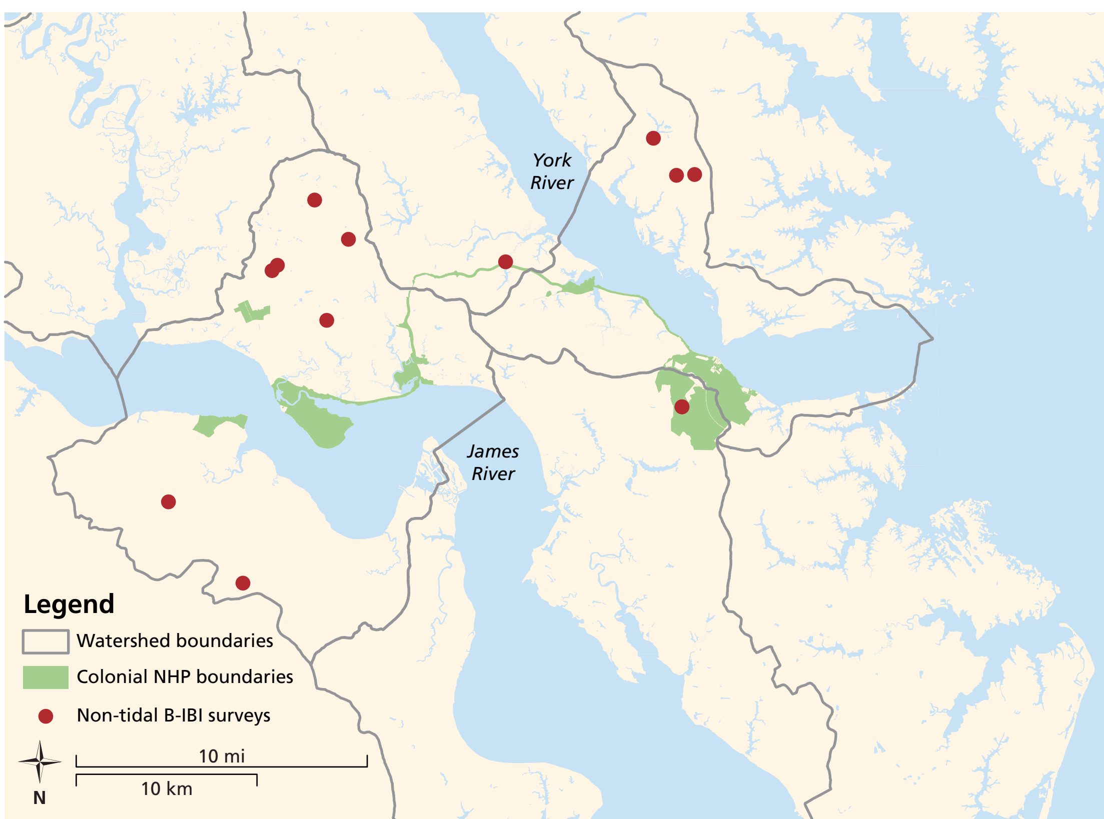

Figure 4.10. Non-tidal benthic index of biotic integrity (B-IBI) sample sites within Jamestown and Yorktown HUC 12 watersheds.

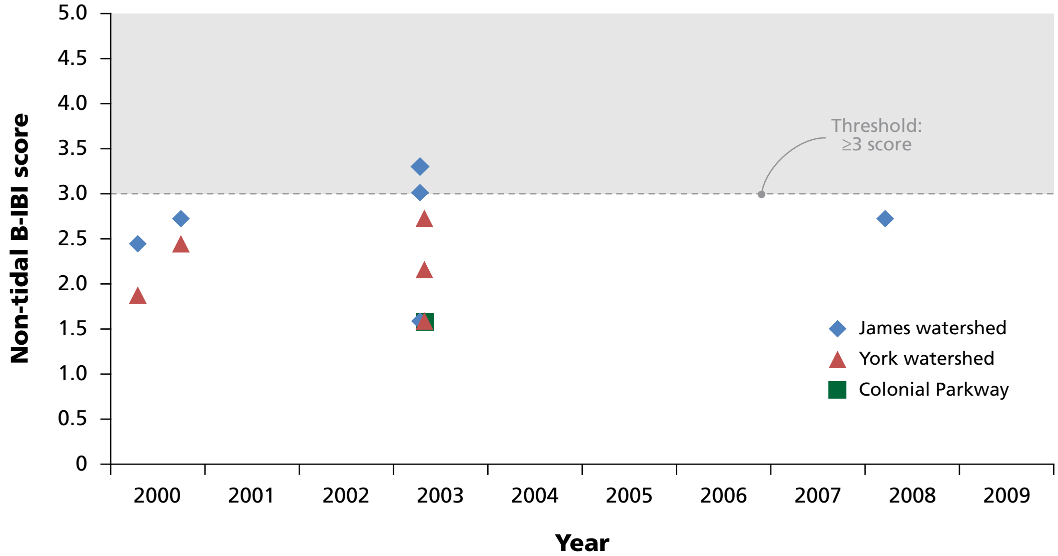

Figure 4.11. Benthic index of biotic integrity (B-IBI) scores over time for sites sampled in the James River watershed, York River watershed, and Colonial Parkway. Dotted line represents the threshold B-IBI score of ≥3.

and water quality metrics are averaged to produce a score on a 1–5 scale (Foreman et al. 2008).

Threshold

An B-IBI score = 3 indicates a site is considered to be comparable (not significantly different) to reference sites. A B-IBI score > 3 indicates that a site is in better condition than the reference sites. Any sites with a B-IBI score < 3 are in worse condition than reference sites (Stribling et al. 1998; Maxted et al. 2000). Therefore, the threshold for aquatic macroinvertebrates is a B-IBI score ≥ 3, indicating that a site is in, at least, reference condition (Table 4.22; Stribling et al. 1998; Maxted et al. 2000).

Current condition

The percent attainment of sites that met the B-IBI threshold of ≥ 3 was: 42.9% for the James River watershed; 0% for combined York River and Yorktown; and 0% for Colonial Parkway (Table 4.2). This represents 14.3% overall attainment of the B-IBI threshold for Colonial NHP as a whole.

Figure 4.11 shows benthic index of biotic integrity (B-IBI) scores over time for sites sampled in the James River watershed, York River watershed, and Colonial Parkway. Only sites in the James watershed had data spanning multiple years for any interpretation of trend, which shows that the B-IBI scores in the watershed are relatively stable over time at or near the threshold and in better condition than the other sites when they were assessed (Table 4.22; Table 4.23).

Data gaps and level of confidence

Available monitoring data and sampling sites were minimal for calculation of non-tidal B-IBIs for Colonial NHP. Sites that were available were mostly located within the James and York watersheds and not within the park boundary. Only three sampling sites were located within the park. Unless continual data sets are collected within each

Table 4.2. Benthic index of biotic integrity (B-IBI) scores and percent attainment of threshold value for each park unit and the park as a whole.

River	Samples with B-IBI scores ≥ 3	Samples with B-IBI scores < 3	Total number of sites sampled	Percent attainment of B-IBI threshold
Jamestown and watershed	3	4	7	42.9%
Yorktown and watershed	0	5	5	0%
Colonial Parkway	0	1	1	0%
			Park average	**14.3%**

park unit and catchment, no trend analysis on this indicator will be possible in the future. Confidence in current assessment is very limited.

Sources of expertise

Katie Foreman, Water Quality Analyst, EPA Chesapeake Bay Program, University of Maryland Center for Environmental Science

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4.2.2 Tidal benthic index of biotic integrity (B-IBI)

Relevance and context

Similar to non-tidal benthic macroinvertebrates, tidal benthic macroinvertebrates (e.g., clams, worms) are commonly used as proxies of environmental condition due to their various physiological tolerances, feeding modes, trophic interactions, and life history strategies that manifest in different responses to natural and anthropogenic stress (Weisberg et al. 1997; Dauer et al. 2008).

Benthic macroinvertebrate communities have deteriorated in the Chesapeake Bay over the past 50 years due to degraded water quality conditions resulting from nutrient enrichment and sediment pollution (Kemp et al. 2005). While low levels of eutrophication can, in some cases, increase benthic productivity, high nutrient levels detrimentally affect benthic diversity and function (Dauer et al. 2000). Low benthic dissolved oxygen concentrations associated with eutrophication further negatively affect benthic communities (Llansó et al. 2003; Dauer et al. 2008), as do toxic substances that become particle-bound and concentrated in the sediments (Dauer and Alden 1995). During the period 1996–2003, the majority of benthic sampling sites in the James River were classified as degraded, with the majority of York River sites severely degraded (Dauer and Lane 2005).

Data and methods

Benthic macroinvertebrate data and B-IBI scores used in this assessment were collected and derived by the Chesapeake Bay Program. Samples were collected from 98 sites in subtidal unvegetated soft substrates (i.e., sand or mud). As the B-IBI is season dependent, data used for the assessment were from summer months (July 15–September 30) of the sampling duration 2000–2009. Sampling sites within the HUC 12 watersheds—State HUC 316 in the James River and State HUC 303 in the York River—adjacent to the park were used for habitat condition assessment (Figure 4.12). The tidal B-IBI compares each sample with established reference values expected at a non-degraded site of similar habitat with no chemical contamination or significant low dissolved oxygen events. Samples were classified by salinity regime, with different criteria chosen based on salinity, as this plays an important role in

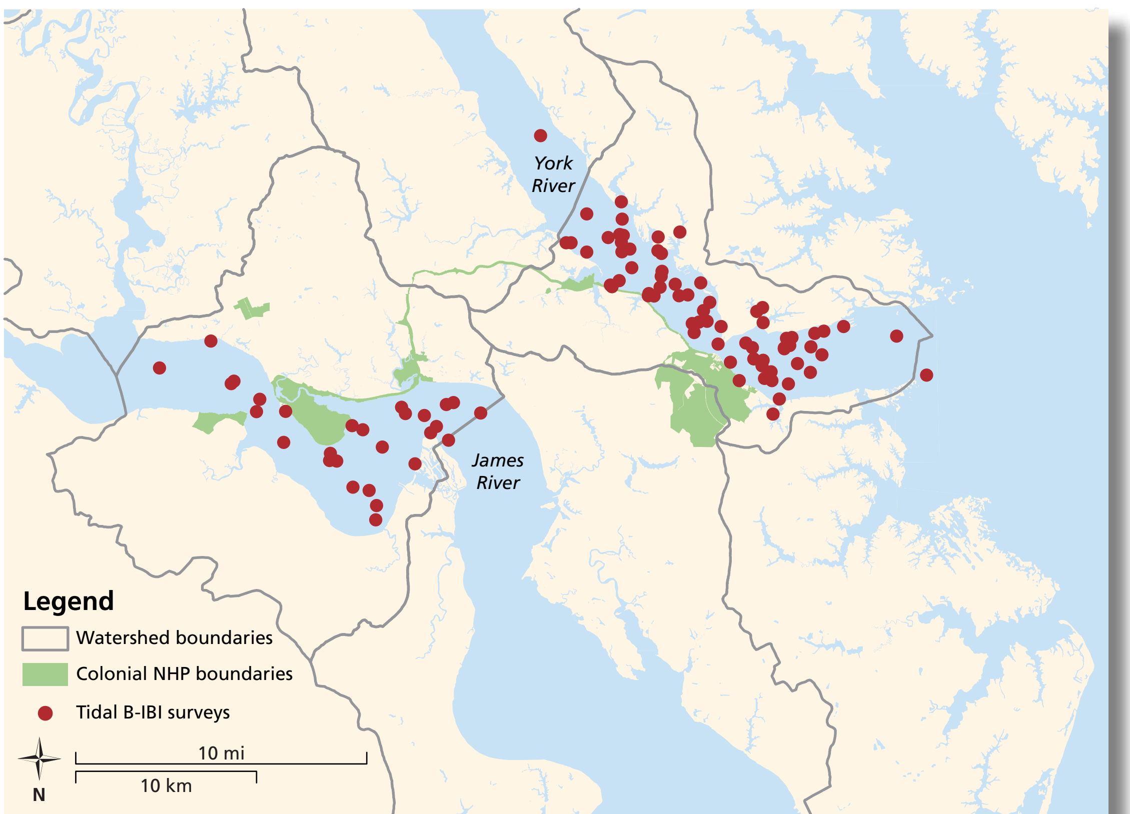

Figure 4.12. Tidal benthic index of biotic integrity (B-IBI) sample sites within Jamestown and Yorktown HUC 12 watersheds.

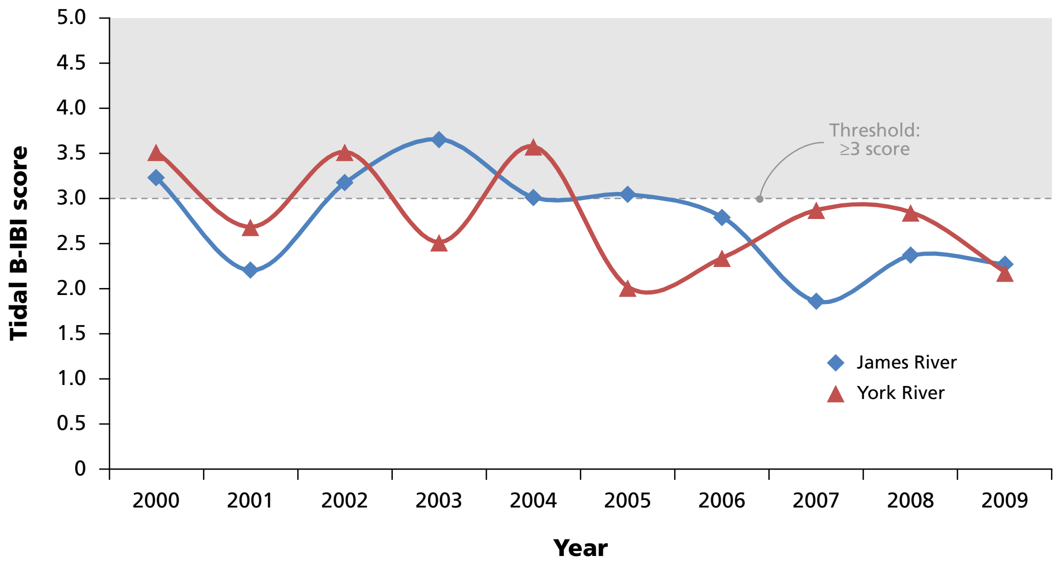

Figure 4.13. Median tidal benthic index of biotic integrity (B-IBI) values as measured in the James and York Rivers during the sampling period of January-December, 2000–2009. Dotted line represents the threshold B-IBI score of ≥3.

determining benthic assemblages. The James River in proximity to the park boundary is oligohaline (low salinity 0.5–5 ppt; Cowardin et al. 1979) and the York River in proximity to Colonial NHP is polyhaline (high salinity 18–30 ppt; Cowardin et al. 1979).

Threshold

As with the non-tidal B-IBI, tidal B-IBI is also ranked on a scale between 1–5 with values above ≥ 3 considered to meet desired habitat conditions and used as the threshold. This approach is also used as the criteria for meeting Chesapeake Bay benthic community restoration goals (Table 4.22; Ranasinghe et al. 1994).

Current condition and trend

The percent attainment of sites that met the B-IBI threshold of ≥ 3 was 41.3% for James River and 41.2% within the York River during the sampling period 2000–2009. This represents 41.3% overall attainment of the B-IBI threshold for Colonial NHP as a whole (Table 4.3; Table 4.22; Table 4.23).

Both the James and York Rivers exhibit wide interannual variability for tidal benthic index of biotic integrity samples. Overall, scores have decreased (indicating degrading condition) in both rivers over the past decade of monitoring (Figure 4.13).

Data gaps and level of confidence

Data were collected and analyzed consistently throughout the 10-year sampling duration. High quantities of data points were available, allowing condition assessment. While 10 years provides sufficient duration for trend analysis, long-term trends cannot be adequately determined without a longer data set. Confidence in assessment is high.

Sources of expertise

Jacqueline Johnson, Living Resource Data Manager/Analyst, Interstate Commission on the Potomac River Basin, Chesapeake Bay Program

Roberto Llansó, Senior Scientist, Versar

Table 4.3. Benthic index of biotic integrity (B-IBI) scores and percent attainment of threshold value for each park unit and the park as a whole.

River	Samples with B-IBI scores ≥ 3	Samples with B-IBI scores < 3	Total number of sites sampled	Percent attainment of B-IBI threshold
James	19	27	46	41.3%
York	40	57	97	41.2%
			Park average	**41.3%**

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Weisberg SB, JA Ranasinghe, DM Dauer, LC Schaffner, RJ Diaz, and JB Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20(1): 149–158.

4.2.3 Water quality index

Relevance and context

Water quality indicators are commonly used to evaluate aquatic ecosystems (Koop et al. 2001; Hoover and Gold 2005; Meng et al. 2008). Five water quality indicators were used to evaluate the condition of the James and York Rivers, including: total nitrogen, total phosphorus, chlorophyll *a*, dissolved oxygen, and secchi depth. Nutrients drive the growth of phytoplankton (measured as chlorophyll *a*), which consume large quantities of oxygen at night and when decomposed by bacteria (Valiela 1995). Dissolved oxygen concentrations above 5 mg/L are required for growth, development, and reproduction of fish, shellfish, and other aquatic organisms. Low dissolved oxygen concentrations have been shown to increase mortality, hamper growth rates, and alter the distribution and behavior of aquatic species in Chesapeake Bay (Breitburg 2002; US EPA 2003). As oxygen becomes depleted, the oxidation-reduction potential decreases, thereby affecting nutrient cycling and sediment biogeochemistry, such as the release of toxic hydrogen sulfide (Hagy et al. 2004). Additional features of anoxic conditions in the water column include elevated phosphate release from bottom sediments; dissolution of iron oxides and/or conversion to iron sulfides; and a decrease in denitrifying bacteria (Kemp et al. 2005). Phytoplankton growth also reduces water clarity (as measured by secchi depth) by lowering light attenuation into the water column (Valiela 1995), and thereby reducing the light climate for submerged aquatic vegetation.

Over the past 50 years, eutrophication has increased in the Chesapeake Bay. From the 1950s–1980s, nitrogen contributions to the Bay increased, stimulating high phytoplankton chlorophyll *a* growth (Kemp et al. 2005). During this period, the population of the Bay watershed nearly doubled, and inorganic fertilizer use nearly tripled (Boesch et al. 2001). In the 1980s and 1990s, several measures were taken to reduce phosphorus loads, including updates to wastewater treatment plants and a ban on phosphates from detergents. Chlorophyll *a* concentrations have increased overall during the past half century due to increased nutrient enrichment, regardless of freshwater inflow, salinity, or temperature (Harding and Perry 1997). Dissolved oxygen conditions,

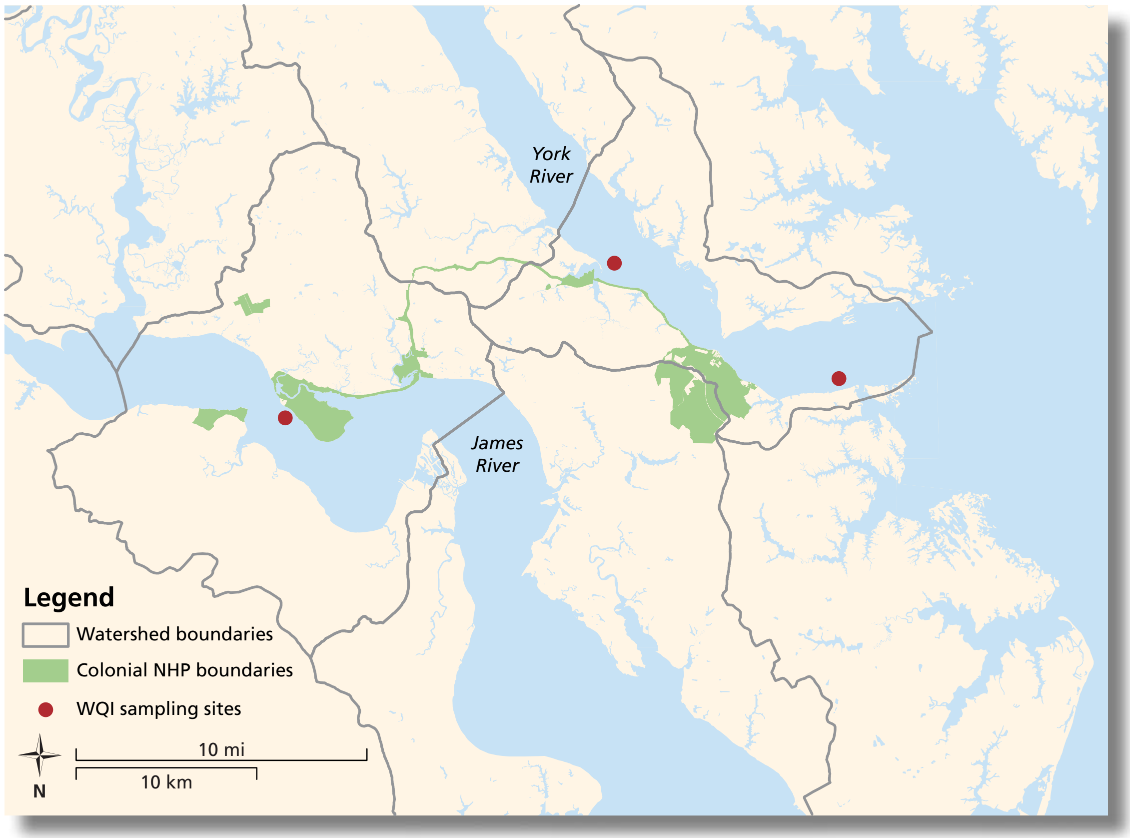


Figure 4.14. Sampling sites from the Chesapeake Bay Program (CBP) Chesapeake Information Management System (CIMS) for total nitrogen, total phosphorus, chlorophyll *a*, dissolved oxygen, and secchi depth.

with increasingly longer and more frequent hypoxic events, reflect this phytoplankton trend (Hagy et al. 2004). Over this same time period, populations of phytoplankton grazers and filter feeders, such as Atlantic menhaden, American oysters, mesozooplankton, and likely benthic macroinvertebrates declined in the Chesapeake Bay (Lacouture et al. 2006).

The Chesapeake Bay is listed by the U.S. Environmental Protection Agency (EPA) as an impaired water body based on excessive nutrient inputs (nitrogen and phosphorus) and sediment loading (US EPA 2003). U.S. EPA 1998 Section 303(d), lists nutrients as the second leading cause of impairments, after sediment, to the Chesapeake Bay and tidal tributaries from Maryland and Virginia (US EPA 2003). Lowering nutrient and sediment concentrations will likely help achieve Bay rehabilitation goals for habitat quality and living resources, as outlined in the Chesapeake 2000 Agreement.

Data and methods

Data for five water quality parameters were sourced from the Chesapeake Bay Program's Chesapeake Information and Management System (CIMS), which collects water quality data through the DataFlow Monitoring Project. Data was obtained for one sampling station (RET5.2) monitored in the James River offshore of Jamestown Island and Swann's Point, and two stations (LE4.2 and LE4.3) monitored in the York River offshore of Yorktown (Figure 4.14). These three sites were monitored monthly for the sampling duration of 2000–2009. The five water quality parameters included: total nitrogen (TN mg/L), total phosphorus (TP mg/L), dissolved oxygen (DO mg/L), chlorophyll *a* (µg/L), and secchi depth (m).

Data from each metric were analyzed with the EcoCheck protocol developed for the Mid-Atlantic Tributary Assessment Coalition (EcoCheck 2011). The EcoCheck multiple threshold scale (scores 1–5) was converted

Table 4.4. Summary of available data, threshold values, median values, and attainment scores for indicators used in calculating the water quality index at Colonial NHP from 2000–2009.

Indicator	Park unit	Source	Threshold	Sites	Samples passed	Samples failed	Total samples	Percent attainment
Total Nitrogen (mg/L)	James River	EcoCheck 2011	≤ 0.9 mg/L	3	67	6	73	91.8%
	York River	EcoCheck 2011	≤ 0.5 mg/L	3	80	66	146	54.8%
Total Phosphorus (mg/L)	James River	EcoCheck 2011	≤ 0.07 mg/L	3	39	36	75	52.0%
	York River	EcoCheck 2011	≤ 0.05 mg/L	3	94	56	150	62.7%
Chlorophyll *a* (ug/L)	James R. Spring	Lacouture et al. 2006	≤ 20.9 µg/L	3	19	7	26	64.2%
	James R. Summer	Lacouture et al. 2006	≤ 9.5 µg/L	3	15	12	27	
	York R. Spring	Lacouture et al. 2006	≤ 2.8 µg/L	3	1	56	57	3.5%
	York R. Summer	Lacouture et al. 2006	≤ 4.5 µg/L	3	3	55	58	
Dissolved Oxygen (mg/L)	James River	US EPA 2003	≥ 5 mg/L	3	68	0	68	100.0%
	York River	US EPA 2003	≥ 5 mg/L	3	120	9	129	93.0%
Secchi Depth (m)	James River	Buchanan et al. 2005	≥ 0.7 m	3	13	74	87	14.9%
	York River	Buchanan et al. 2005	≥ 2.0 m	3	4	171	175	2.3%
							Water quality index	**53.9%**

to a pass/fail threshold at the 75th percentile: scores 1–3 failed, while scores 4–5 passed. Sampling data for each metric was compared to the corresponding threshold for each river. Percent attainment was calculated using a restricted subset of sampling months (TN March–October, TP March–October, Chl *a* March–October, DO April–October, Secchi James April–October, Secchi York March–November), determined by the growing season for phytoplankton and seagrass, during which time the values for each metric have the greatest ecological consequence (EcoCheck 2011). Data for five water quality parameters were combined into an equally-weighted water quality index for this assessment (Table 4.4).

Threshold

Thresholds for each metric varied based on salinity regime. The James River at Jamestown Island and Swann's Point is classified as oligohaline (low salinity 0.5–5 ppt), while the York River at Yorktown is classified as polyhaline (high salinity 18–30ppt; Cowardin et al. 1979). Thresholds were derived from long-term data sets and established scientific literature for ecological relevance (US EPA 2003; Buchanan et al. 2005; Lacouture et al. 2006; EcoCheck 2011). Thresholds took into account seasonally restricted data sets. In the case of chlorophyll *a*, different thresholds were derived for spring and summer, based on the seasonal transition of phytoplankton communities (Table 4.22; Lacouture et al. 2006).

Current condition and trend

Water quality in the James and York Rivers adjacent Colonial NHP was in fair condition, with an overall percent attainment of 53.9% (Table 4.4). Water quality was generally in better condition in the James River compared to the York River based on the indicators assessed. The James River displayed excellent threshold attainment scores (> 90%) for total nitrogen and dissolved oxygen, whereas water clarity (as measured by secchi disk) scored poorly (14.9%) in comparison the threshold set. The York River displayed very low threshold attainment scores (< 5%) for chlorophyll *a* and secchi depth, whereas it scored well for dissolved oxygen concentrations (93.0% attainment) and better than the James River for total phosphorus (62.7% attainment in the York River compared to 52.0% attainment in the James River).

Trends in water quality between 2000–2009 for the James and York Rivers show relatively stable conditions for nutrients (with the exception of a spike in TN in 2003 in the York River of unknown cause), dissolved oxygen, and secchi depth. Chlorophyll *a* concentrations, however, showed a marked interannual variability (particularly between 2000–2005) and an overall decline in concentration between 2000–2009 in both spring and summer seasons over the sampling period. The James River generally exhibited higher annual variability than the York River in both seasons (Figure 4.15; Table 4.22; Table 4.23).

Data gaps and level of confidence

There was a distinct lack of data for non-tidal wetlands and streams in the park. However, the water quality data set included many sampling events in each river (more in the York than the James River) that allowed for assessment with a high level of confidence. The data set duration was 10 years, sufficient for assessing trend, although a longer data set is preferable to determine long-term trends.

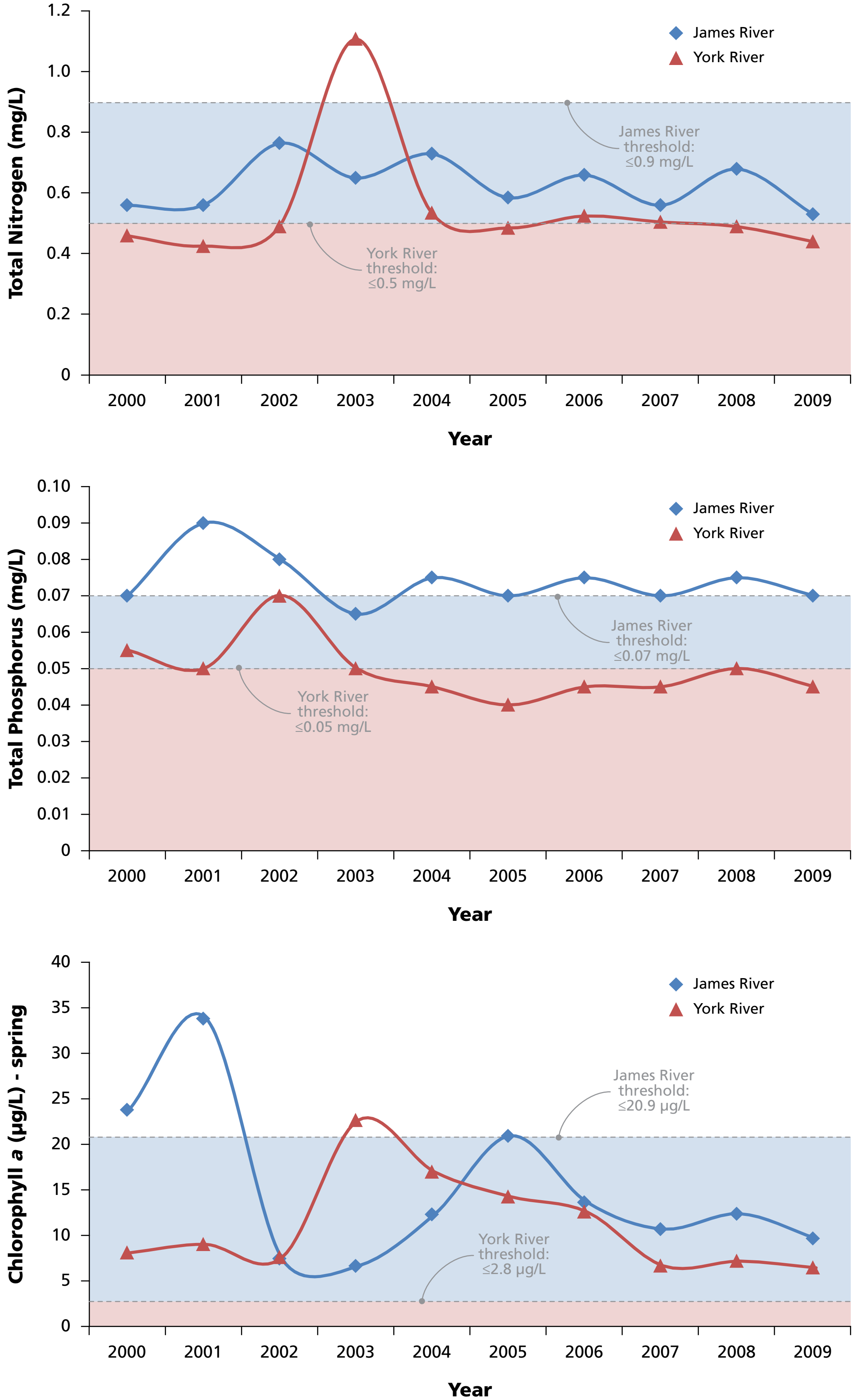
Sources of expertise

Mike Malonee, Water Quality Database Manager, Interstate Commission on the Potomac River Basin, Chesapeake Bay Program

Penelope Pooler, Quantitative Ecologist, National Coastal and Barrier Network, National Park Service

Michael Williams, Associate Research Scientist, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science

Figure 4.15. Annual median total nitrogen, total phosphorus, chlorophyll *a* (spring and summer), dissolved oxygen, and secchi depth values measured in the James and York Rivers during the sampling period 2000–2009. Dotted line represents the relevant threshold.



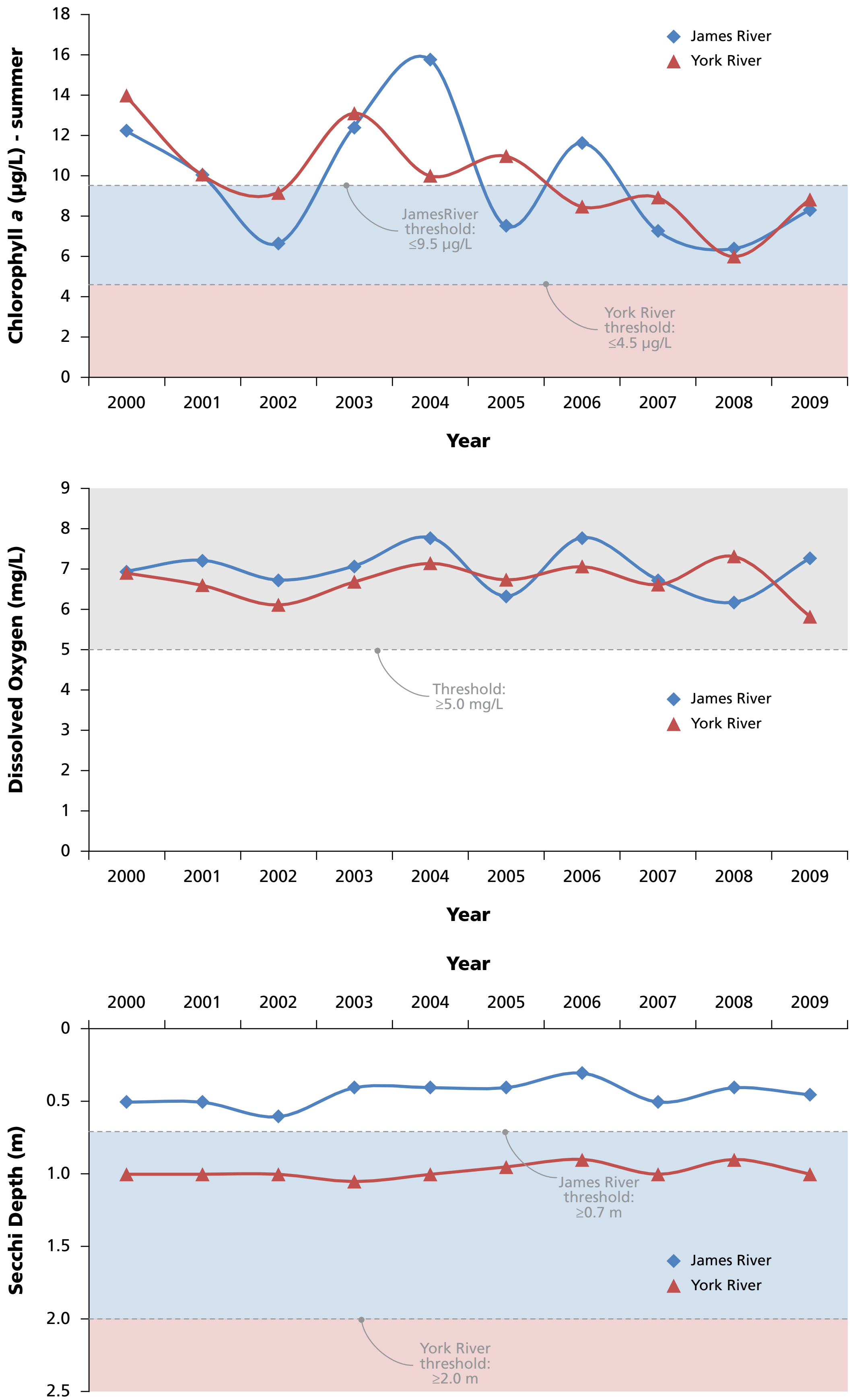


Figure 4.15. Annual median total nitrogen, total phosphorus, chlorophyll *a* (spring and summer), dissolved oxygen, and secchi depth values measured in the James and York Rivers during the sampling period 2000–2009. Dotted line represents the relevant threshold.

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4.3 BIOLOGICAL INTEGRITY

4.3.1 Submerged aquatic vegetation

Relevance and context

Submerged aquatic vegetation (SAV) collectively includes marine, estuarine, and freshwater vascular plants such as seagrasses. The principal seagrass species in Chesapeake Bay are eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). Seagrasses provide many ecological functions, including: carbon sequestration (Duarte et al. 2010), sediment stabilization and thereby water clarity improvement, nutrient absorption, oxygenation of the water column, attenuation of wave energy that would otherwise contribute to shoreline erosion (Koch 2001; Orth et al. 2006), nursery habitat for fish and shellfish, and food sources for herbivores.

SAV growth is dependent on light and is therefore sensitive to factors that attenuate light availability in the overlying water column such as phytoplankton, total suspended solids, and dissolved organic matter. Light availability is further attenuated by epiphytic growth of algae, bacteria, and detritus on SAV and smothering by sediments (US EPA 2003; Kemp et al. 2004). This sensitivity to changes in the surrounding environment makes SAV health and distribution a useful indicator of changes in water quality (Dennison et al. 1993).

Over the past 50 years, SAV density and distribution in Chesapeake Bay has shown an overall decline, particularly during the late 1960s and early 1970s, attributed to poor water quality caused by increased nutrient and sediment loading (Dennison et al. 1993; Kemp et al. 2005), climatic events, physical disturbance, and herbicide toxicity (US EPA 2003; Kemp et al. 2004).

Photo: Tim Carruthers, IAN Image Library

Widgeon grass (*Ruppia maritima*) is one of the two key seagrass species found in Chesapeake Bay.

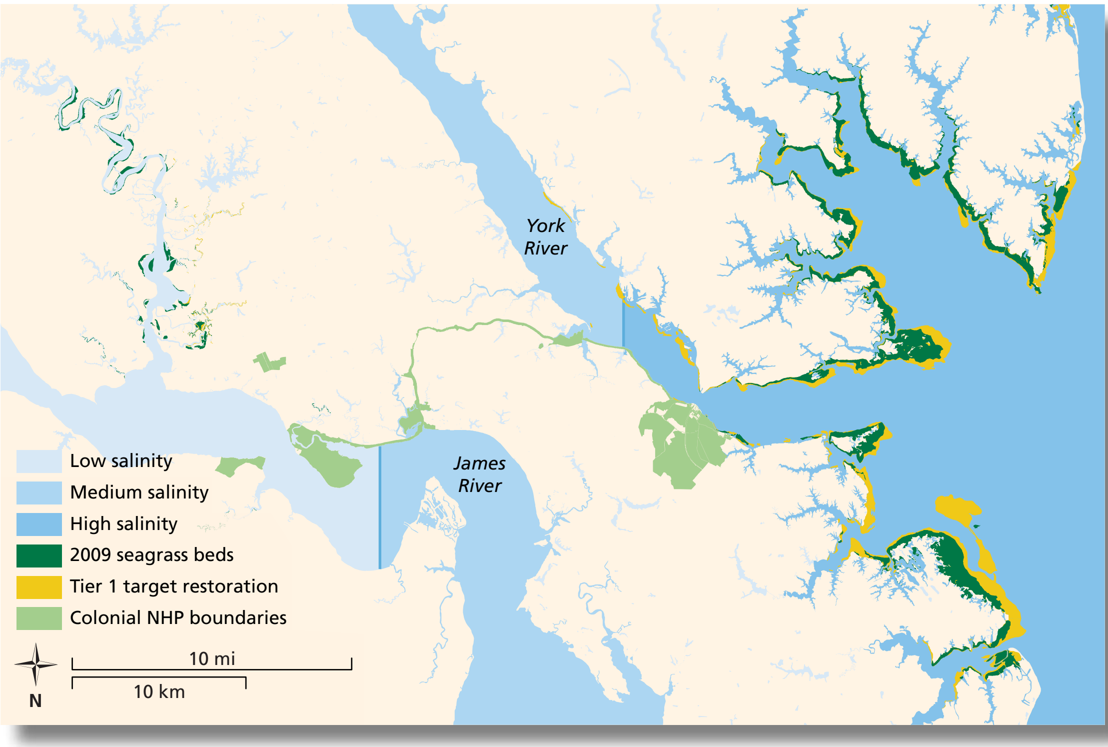

Figure 4.16. Map of submerged aquatic vegetation extent in the James and York Rivers in 2009. During 2009, 17.3 ha (42.3 ac) were mapped in the James oligohaline section and 228.3 ha (564.1 ac) were mapped in the York polyhaline section. This extent is overlaid with the Tier I goal extents, which were used to calculate percent attainment for each river (Orth et al. 2010).

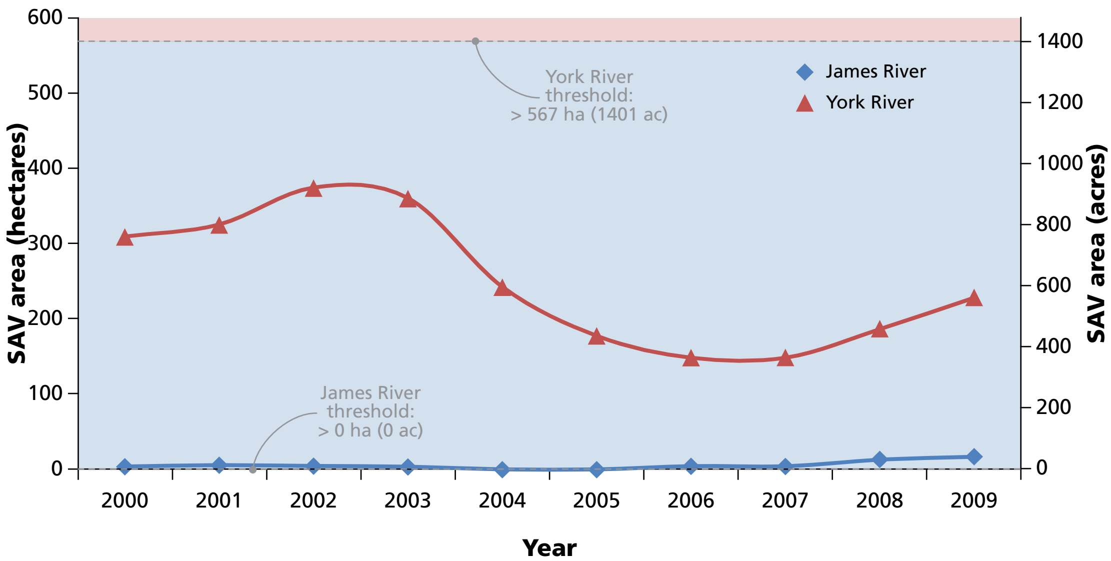

Figure 4.17. Submerged aquatic vegetation coverage in the James River oligohaline (low salinity) and York River polyhaline (high salinity) sections, 2000–2009 (Orth et al. 2010).

Data and methods

Data used in this assessment of SAV in the James and York Rivers were sourced from surveys performed by Orth et al. (2010), who used black and white aerial photography (1:24,000) to assess SAV cover and extent in Chesapeake Bay and its tributaries (Figure 4.16). Photographs from 173 flight lines in 2009 were orthorectified for use in Geographic Information Systems (GIS). Ground surveys augmented and verified existence of SAV beds mapped from aerial photography and provided species identification.

The Chesapeake Bay Program subdivides Chesapeake Bay and its tributaries into 93 segments, grouped into three zones of Upper, Middle, and Lower Bay. Watersheds for Colonial NHP fall within the Lower Bay zonation, with segments for the Middle James River near Jamestown Island and the Lower York River near Yorktown. The Middle James River is classified as oligohaline (low salinity 0.5–5 parts per thousand [ppt]), the Lower York River as polyhaline (high salinity 18–30 ppt).

Thresholds

SAV extent surveyed by Orth et al. (2010) was compared to the SAV restoration goals set by the Chesapeake Bay Program (Batiuk et al. 2000). The Tier I target is the acreage for SAV restoration to areas currently or previously inhabited by SAV, as evidenced by aerial surveys performed between 1971-1990. Tier II and Tier III restoration targets reflect the SAV acreage for restoration to existing and potential SAV habitat down to 1 m and 2 m depth contours, respectively, excluding those areas unlikely to support SAV based on historical observations, recent survey information, and exclusion zones (e.g., areas with high wave action) (Batiuk et al. 2000). Percent attainment for SAV in this condition assessment was calculated as the number of years that met or exceeded Tier I goals set for the James and York Rivers (0 ha [0 ac]; and 567 ha [1401 ac]), respectively (Table 4.22).

Current condition and trend

As the SAV threshold for the James River is 0 ha (0 ac), the presence of any SAV in a given year passes the threshold. This occurred in 8 of the 10 years of the sampling period, thus an 80% attainment was obtained for SAV in the James River. The York River did not meet the Tier I threshold of 567 ha (1401 ac) in any year, and thus had a 0% attainment score. The Park average was 40% attainment.

Despite the James River receiving a greater threshold attainment score, the York River has a greater extent of SAV (mean area of 249.6 ha since 2000) than the James River (mean area of 5.8 ha since 2000). Trends in the extent of SAV in the James and York Rivers have shown variability since 2000 with an overall decline in SAV cover in the York River and an overall increase in the James River (Figure 4.17; Table 4.22; Table 4.23).

Data gaps and level of confidence

Data were collected consistently from year to year as part of a long-term data set at the Virginia Institute of Marine Science. Level of confidence in assessment is very high, given the confidence in both data collection and thresholds established for SAV restoration targets by the Chesapeake Bay Program. Although a longer duration of data is preferable, 10 years still provides sufficient data for trend analysis.

Sources of expertise

Robert J Orth, Professor of Marine Science, Virginia Institute of Marine Science

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4.3.2 Reptile and amphibian richness

Relevance and context

Reptiles and especially amphibians (collectively termed herpetofauna) have been used as indicators of environmental change (Pechmann et al. 1991; Blaustein et al. 1994; Fontenot et al. 1996). Their reliance on moist areas, limited home range, long life span of some species, and unique physiology (e.g., cutaneous respiration in frogs and salamanders) make them sensitive to climate change, pollution, and habitat destruction and fragmentation (Blaustein et al. 1994; Phelps and Lancia 1995; Gibbons et al. 1997). As such, herpetofauna have been shown to be in decline worldwide (Blaustein et al. 1994). Colonial NHP supports multiple herpetofauna species with many species requiring both aquatic and terrestrial habitat types (Mitchell 2004). Habitats that are known to support relatively unique assemblages at Colonial NHP include hardwood forests, tidal marshes, seasonal ponds, springs and seepages, and freshwater sources. Only two species are known to be habitat-specific, the two-toed amphiuma (*Amphiuma means*) found in ponds, and the Northern diamond-backed terrapin (*Malaclemys terrapin*) in estuarine marshes (Mitchell 2004). Streamside salamanders (*Desmognathus, Eurycea spp.*) constitute another relatively unique assemblage that inhabit springs and associated wet areas with one state-threatened species recorded, Mabee's salamander (*Ambystoma mabeei*) (Mitchell 2004).

Table 4.5. Habitat reclassification.

Mitchell 2004 survey	Current NRCA Assessment
Mixed hardwoods and pine	
Mixed hardwoods	Forest
Mixed pine	
Grassland	Grassland
Impoundments	
Swamp	Non-tidal wetland
Stream	
Beach	Tidal wetland
Marsh	

Data and methods

Herpetofauna were surveyed from 2001-2003 in Colonial NHP and surrounding counties (Mitchell 2004) (Figure 4.18). Based on known herpetofauna distributions, 30 species of amphibians (frogs and salamanders) and 37 species of reptiles (turtles, lizards, and snakes) were expected for the park area (Mitchell 2004). A variety of techniques were employed to sample

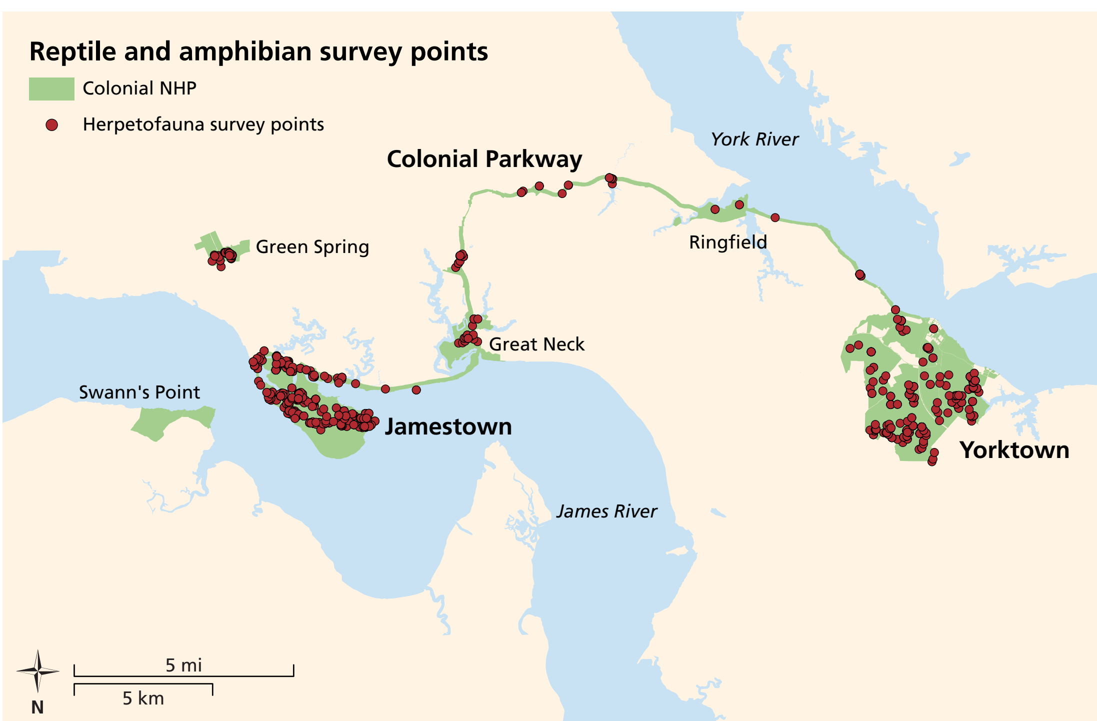


Figure 4.18. Herpetofauna sample locations from 2001–2003 inventory (Mitchell 2004).

different habitat types and enhance detection of certain herpetofauna groups. Techniques included visual encounter, audio, nighttime road, dip-net, minnow trap, and turtle trap surveys. In May 2008, the Virginia Herpetological Society surveyed four park parcels—Jamestown Island, Green Spring, Ringfield Plantation, and Yorktown Battlefield—to update information from the prior survey and to evaluate herpetofauna on units for which little to no prior data existed (Christensen 2009). Herpetofauna were sampled by hoop traps, visual encounter, inspection of microhabitat material (e.g., logs, bark, leaf litter), dip nets, and crayfish traps. Habitats where herpetofauna were found were noted in both surveys. In the Mitchell (2004) survey, nine habitat classifications were used, which were reclassified to fit the four habitats used in this report (Table 4.5).

Photo: Colonial NHP

The pickerel frog (*Rana palustris*) is common within Colonial NHP.

Thresholds

The total number of species observed was divided by the total number of species expected. This proportion constituted the percent attainment, rather than using a threshold number for species (Table 4.22).

Current condition and trend

Combined survey success from the Mitchell (2004) and Christensen (2009) surveys 2001–2003 sampling period was 87% of expected amphibians and 82% of expected reptiles. Overall herpetofauna attainment was 84%, representing observations for 57 of 68 expected species. On a per park unit basis, Jamestown had 54% of expected herpetofauna species, the Parkway had 12% of expected herpetofauna species, and Yorktown had 60% of expected herpetofauna species (Table 4.6). On a per park habitat basis, forest habitat had 70% of expected herpetofauna species, grassland had 52% of expected herpetofauna species, non-tidal wetland had 60% of expected herpetofauna species, and tidal wetland had 63% of expected herpetofauna species (Table 4.7; Table 4.22; Table 4.23). Grassland and tidal wetland habitat observed 7 and 5 species, respectively, that were not expected and not included in calculations.

The ratios of observed to expected species were as follows: 15/16 frogs (94% success rate), 11/14 salamanders (79%), 10/10 turtles (100%), 6/7 lizards (86%), and 15/21 snakes (71%).

More species of frogs, salamanders, and turtles were observed at Yorktown, while more species of lizards and snakes were observed in Jamestown (Figure 4.19). Few species of any herpetofauna taxonomic group were observed along Colonial Parkway. Species diversity was greatest in forest and non-tidal wetland habitats; grassland and tidal wetlands were least frequently utilized by herpetofauna overall

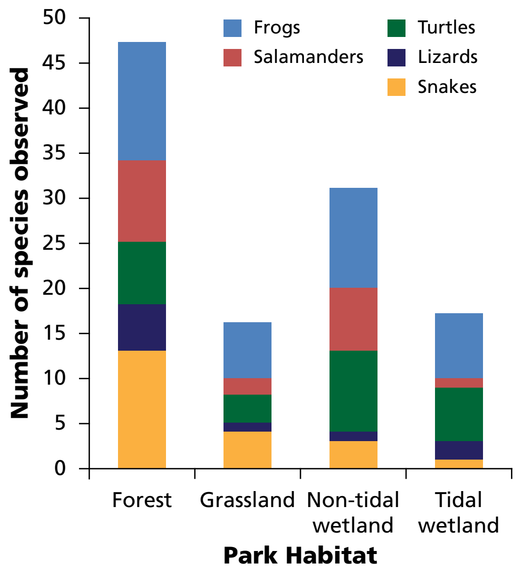
Table 4.6. Number of herpetofauna species observed/expected in each Park unit.

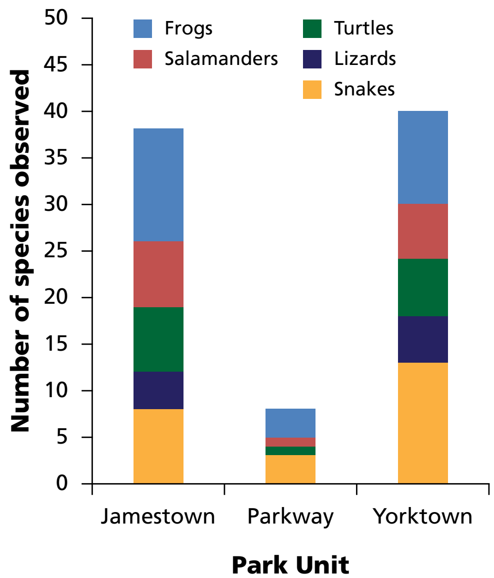
Herpetofauna	Jamestown	Parkway	Yorktown
Observed/Expected (%)	37/68 (54%)	8/68 (12%)	41/68 (60%)

Table 4.7. Number of herpetofauna species observed/expected in each habitat according to life histories accounts (VDGIF 2011).

Herpetofauna	Forest	Grassland	Non-tidal wetland	Tidal wetland
Observed/Expected (%)	47/67 (70%)	9/31 (29%)	31/52 (60%)	12/27 (44%)

Figure 4.19. Number of herpetofauna species observed in each Colonial NHP habitat (top) and within each park unit (bottom) (Mitchell 2004; Christensen 2009).





(Figure 4.19). Several rare herpetofauna were observed during surveys, including Mabee's salamander, which is state-listed as threatened due to rare and imperiled status, and Eastern black kingsnake (*Lampropeltis getula*), which is considered very rare and imperiled in Virginia (Roble 2010). Brimley's chorus frog and the two-toed amphiuma, both of which are considered uncommon, were observed. Two species are included on Virginia's watchlist: the Northern diamond-backed terrapin, which was observed, and the rainbow snake (*Farancia erytrogramma*), which was expected but not observed in either survey.

Temporal trends cannot be determined from the available data set.

Data gaps and level of confidence

Herpetofauna data for Colonial NHP were sparse. Only two inventory surveys were available, and no monitoring data was available. Surveys documented species presence, but absence cannot be determined as this might be an artifact of sampling effort and not local extirpation. Trend cannot be calculated for any herpetofauna population within the park. Confidence in assessment is limited.

Sources of expertise

Tim Christensen, Chairman of the Conservation Committee, Virginia Herpetological Society

Susan Watson, Biologist, Virginia Department of Game and Inland Fisheries

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4.3.3 Mammal richness

Relevance and context

Climatic and landscape change over prehistoric, historic, and modern time frames has altered and determined vegetation and animal species viable for the Mid-Atlantic region (Bellows et al. 2001). Disturbance from natural and anthropogenic sources interrupted forest succession, affecting interior forest dwelling species. Grassland habitats, typically ephemeral due to forest succession, were maintained through anthropogenic disturbances such as fire. Habitat generalist species adapted to thrive in a landscape fragmented by development, agriculture, logging, and other uses. Following European settlement, populations of mammals declined dramatically and many were extirpated from the region, including bison (1797; *Bison bison*), elk (1855; *Cervus elephus*), mountain lion (1882; *Puma concolor*), fisher (1890; *Martes pennanti*), Eastern shore fox squirrel (1895), gray wolf (1910; *Canis lupus*), beaver (1911; *Castor canadensis*), and white-tailed deer (*Odocoileus virginianus*) and river otter (*Lontra canadensis*) in the early 20th century (Handley 1992). Invasive mammals in the region include black rat (*Rattus rattus*) and Norway rats (*Rattus norvegicus*), the house mouse (*Mus musculus*), and nutria (*Myocastor coypus*). While many efforts to reintroduce species failed (e.g., elk, snowshoe hare (*Lepus americanus*), fisher, mountain lion), several were successful, including restoration of white-tailed deer and beaver populations (Handley 1992). Today, Colonial NHP supports a predictable assemblage of mammals given the diversity of habitats present. Adequate habitat exists to sustain populations of grassland specialists such as the Eastern harvest mouse (*Reithrodontomys humulis*) and meadow vole (*Microtus pennsylvanicus*). In addition, the hispid cotton rat (*Sigmodon hispidus*) persists in the park,

Table 4.8. Habitat reclassification for mammal richness calculations.

Mitchell 2004 survey	Current NRCA Assessment
Mixed coniferous-deciduous forest	Forest
Pine forest	Forest
Deciduous forest	Forest
Golden bamboo	Forest
Field/mixed forest edge	Forest
Marsh/mixed forest edge	Forest
Field	Grassland
Forested wetland	Non-tidal wetland
Wetland	Tidal wetland

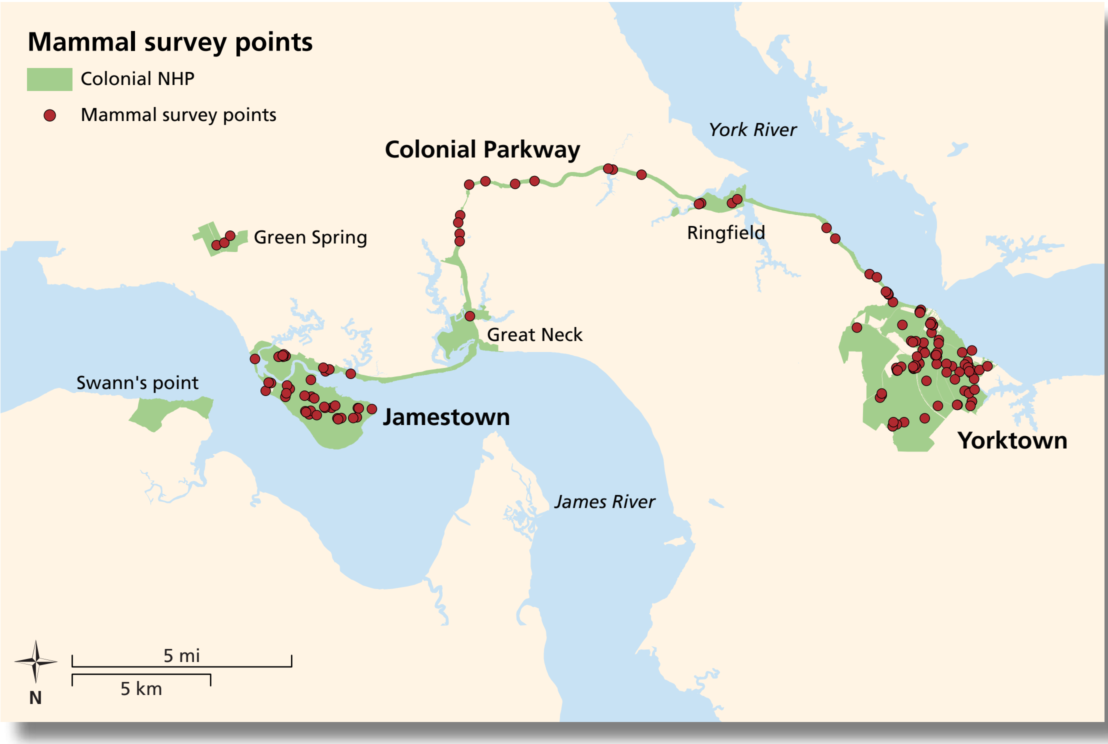


Figure 4.20. Mammal sample locations from 2003-2004 inventory (Barry et al. 2010)

albeit at low densities in isolated pockets of grassland habitat. Wetland and riverine/riparian habitats support healthy populations of the marsh oryzomys, muskrat (*Ondatra zibethicus*), American beaver (*Castor canadensis*), and American river otter (*Lontra canadensis*).

Mammals were chosen as an indicator for this assessment as they respond rapidly to change in habitat structure (Abramsky 1978; Kaufman et al. 1983; Kincaid et al. 1983) and plant composition (Kaufman et al. 1983), and occupy key positions in food webs (Kaufman et al. 1998). This makes them useful biological indicators of change (Dale and Beyeler 2001).

Data and methods

Mammal surveys were undertaken within the park over 2003–2004 by Barry et al. (2010; Figure 4.20). Survey techniques included live trapping with Sherman, Tomahawk, and pitfall traps; direct observation of individuals, tracks and scat sign; road kill assessments; and remote photography.

Nine habitat types were identified during these surveys that were reclassified into the four categories for this report as outlined in Table 4.8.

Reference lists for mammals in Colonial NHP were compiled from the NPSpecies database, which yielded historical records for 50 mammal species, including 9 species of bats. Due to a lack of data on bats, apart from a scoping study conducted to assess the suitability of bat habitat (Gates and Johnson 2007), bats were not included in this assessment. The marsh rabbit (*Sylvilagus palustris*), had a historical record within the park, but was not predicted to presently occur within the park.


Photo: Colonail NHP

White footed mouse (*Peromyscus leucopus*).

Thresholds

The total number of species observed was divided by the total number of species expected. This proportion constituted the percent attainment, rather than using a threshold number for species (Table 4.22).

Current condition and trends

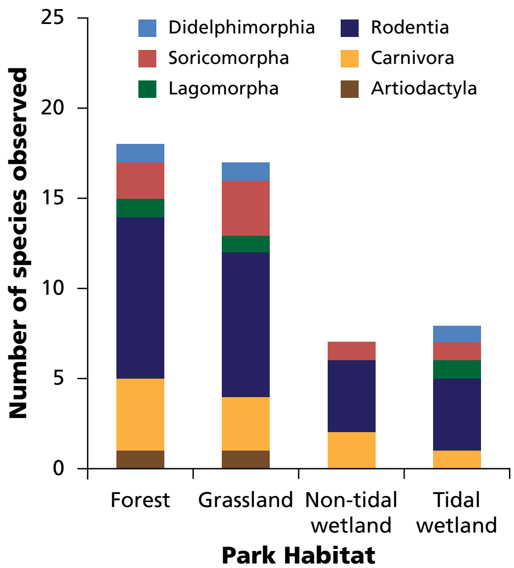
Surveys yielded 27 of the 40 (68%) mammal species (excluding bats) expected to occur within the park, and 27 of 41 (66%) of species for which there are historical records of occurrence. On a per park unit basis,

Table 4.9. Number of mammal species, excluding bats, observed/expected in each Park unit (Barry et al. 2010). All four habitat types are present in Jamestown and Yorktown, therefore all mammal species presumably occur in those Park units. Colonial Parkway contains three habitats, excluding grasslands, therefore two grassland specialists (Eastern harvest mouse and hispid cotton rat) were not expected to occur within this Park unit.

Mammals	Jamestown	Parkway	Yorktown
Observed/Expected (%)	14/40 (35%)	6/38 (16%)	21/40 (53%)

Table 4.10. Number of mammal species, excluding bats, observed/expected in each Park habitat (Barry et al. 2010) determined from species life history accounts (VDGIF 2011).

Mammals	Forest	Grassland	Non-tidal wetland	Tidal wetland
Observed/Expected (%)	16/36 (44%)	15/27 (56%)	6/21 (29%)	7/17 (41%)



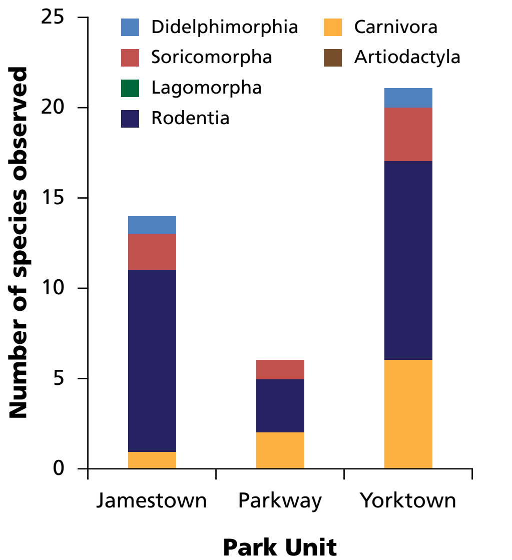


Figure 4.21. Total number of mammal species observed in each Colonial NHP habitat (top) and within each park unit (bottom). Habitats were not specified for three species of Carnivora. Location was not specified for one species of each Lagomorpha, Rodentia, Carnivora, and Artiodactyla Orders.

Jamestown had 35% of expected mammal species, the Parkway had 16% of expected mammal species, and Yorktown had 53% of expected mammal species (Figure 4.21; Table 4.9; Table 4.22; Table 4.23). On a per park habitat basis, forest habitat had 50% of expected mammal species, grassland had 63% of expected mammal species, non-tidal wetland had 33% of expected mammal species, and tidal wetland had 47% of expected mammal species (Figure 4.21; Table 4.10). Forest, grassland, non-tidal wetland and tidal wetland habitat had 2, 2, 1, and 1 species, respectively, that were not expected and not included in calculations.

The most abundant and widespread mammal was the white-footed deermouse (*Peromyscus leucopus*), found in all habitat types. Small mammal diversity was highest in grassy fields and lowest in deciduous forests. Habitat generalists, such as the white-footed deermouse, northern short-tailed shrew (*Blarina brevicauda*), Virginia opossum (*Didielphis virginiana*), raccoon (*Procyon lotor*), and white-tailed deer faired best in surveys throughout the park. Healthy populations of several habitat specialists for grasslands (e.g., Eastern harvest mouse [*Reithrodontomys humulis*] and meadow vole [*Microtus pennsylvanicus*]) and wetlands (e.g., marsh rice rat [*Oryzomys palustris*], muskrat [*Ondatra zibethicus*], American beaver [*Castor canadensis*], and American river otter [*Lontra canadensis*]) were also found within Colonial NHP.

The American river otter, a Virginia watchlist species, was observed in the park. The Rafinesque's big-eared bat (*Corynorhinus rafinesquii macrotis*), which likely occurs in the park, is state-listed as endangered, but its presence could not be confirmed due to the lack of bat survey data. Two other bats species likely within Colonial NHP—the silver-haired bat (*Lasionycteris noctivagans*) and hoary bat (*Lasiurus cinereus*)—are Virginia watchlist species, but their presence could not be confirmed either.

As data are only available from a single survey, it is not possible to assess temporal trends for this metric.

Data gaps and level of confidence

Minimal mammal data was available for Colonial NHP. Only one survey was conducted in the park, and location (park unit and habitat) information is not provided for all species observations. A bat scoping survey took place, but the survey was not conducted, so no information is known about bats present in Colonial NHP. Trend could not be calculated since monitoring data were not available. Confidence in assessment is very limited.

Sources of expertise

Ronald Barry, Lecturer, Bates College

Edward Gates, Professor, University of Maryland Center for Environmental Science Appalachian Laboratory

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4.3.4 Lepidoptera and Odonata richness

Relevance and context

Insects belonging to the order Lepidoptera (i.e., butterflies and skippers) and Odonata (i.e., dragonflies and damselflies) are some of the most widespread and widely recognizable insect orders in the world. Lepidopteran insects are often dependent on larval host plants, adult nectar sources, climate, distance to colonizing source, and predator and parasite interactions. Lepidopteran insects have been used as indicators of revegetation success in grasslands (Erhardt 1985), riparian zones (Nelson and Anderson 1994) and, in the case of butterflies, have been correlated with bird and mammal species richness (Murphy and Wilcox 1986).

Odonate insects require a variety of habitats over their life history, spending larval stages in aquatic habitats and adult stages in terrestrial habitats. During their aquatic larval stage, Odonates are sensitive to changes in water quality and habitat structure, such as substrate. Adult Odonates are also sensitive to vegetation structure, including light availability and/or shading. Despite this sensitivity, many Odonates are able to live in degraded or patchy habitats and rapidly colonize restored habitat (Clausnitzer et al. 2009). Complex life histories make Odonates, particularly damselflies that lay eggs in macrophytes, valuable as indicators. In the United States, an estimated 11–18% of the total 456 estimated Odonata species are considered vulnerable to extirpation or extinction (Butler and deMaynadier 2008).

Gray hairstreak (*Strymon melinus*).

Photo: Anne C. Chazal, Virginia Natural Heritage Program

Table 4.11. Habitat reclassification for Lepidoptera and Odonata species richness calculations.

Chazal 2006 survey	Current NRCA Assessment
Loblolly pine-oak forest alliance	Forest
Mesic mixed hardwood forest	
Successional tuliptree-loblolly pine forest	
Coastal Plain/Piedmont floodplain forest	
Coastal Plain/Piedmont swamp forest	
Planted/cultivated/cultural herbaceous vegetation	Grassland
Coastal Plain/Piedmont basic seepage swamp	Non-tidal wetland
Coastal Plain depression wetland	
Sweetgum-red maple seasonally flooded forest	
Beaver meadow	
Freshwater pond	
Tidal bald cypress forest/woodland	Tidal wetland
Tidal freshwater marsh	
Tidal oligohaline marsh	

The diversity of terrestrial and aquatic habitats within Colonial NHP results in a rich assemblage of insects, of which Lepidopteran and Odonates are used as indicators in this condition assessment.

Data and methods

Sampling for Lepidoptera and Odonata species took place during May–July 2003 and April–October 2004 (Chazal 2006) based on county boundaries rather than park unit. James City County and Surry County correspond to Jamestown and the western Colonial Parkway, and York County corresponds to Yorktown and the eastern part of the Parkway (Figure 4.22). Fourteen habitat types were identified by Chazal (2006) and were reclassified into the four categories for this report as outlined in Table 4.11.

Developed areas (mowed right-of-way, open

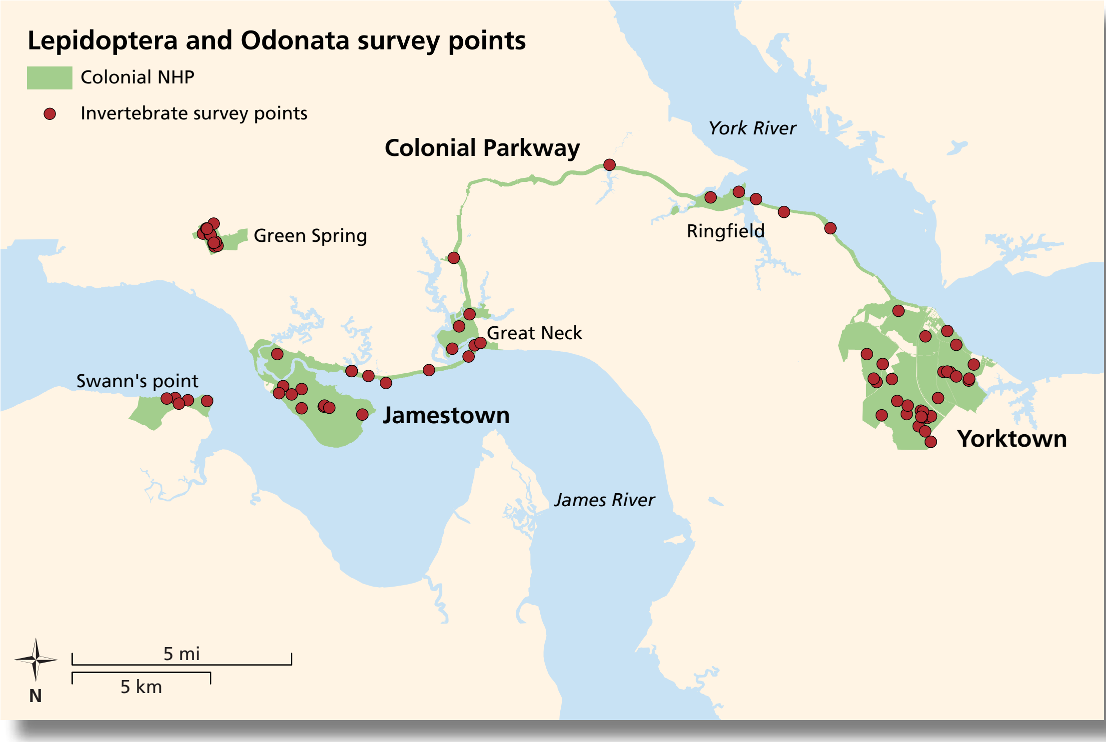


Figure 4.22. Lepidoptera and Odonata sampling locations from 2003–2004 inventory (Chazal 2006).

developed, and pipeline/powerline right-of-way) were not included. Surveys were conducted during daylight hours, by walking through habitats and noting the species observed. Some surveys were done with particular attention to rare skipper (*Problema bulenta*) by targeting marsh habitat and important nectar species for observation of the butterfly. Reference lists were compiled by searching the available literature for species likely to occur within the park, based on their known range and availability of suitable habitat. A total of 68 Lepidoptera and 58 Odonata species were determined known or likely to occur at Colonial NHP.

Thresholds

The proportion of total species observed in comparison to the total number of species expected was used as the percent attainment score for this metric (Table 4.22).

Current condition and trend

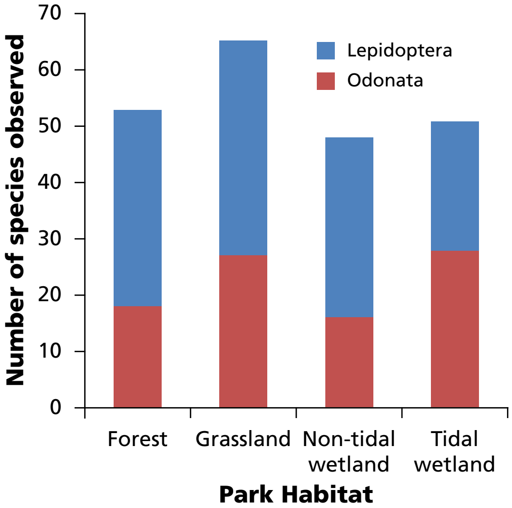
Surveys yielded 57 Lepidoptera species and 42 Odonata species. This represents an 84% attainment (57 of 68 species) of observed to expected Lepidoptera species, and a 72% attainment (42 of 58 species) for Odonata taxa. Overall, attainment was 78.6% (99 of 126 expected species). On a per park unit basis, Jamestown and Parkway had 47% of expected species, and Yorktown and Parkway had 37% of expected species (Table 4.12). On a per park habitat basis, forest habitat had 27% of expected species, grassland had 42% of expected species, non-tidal wetland had 31% of expected species, and tidal wetland had 34% of expected species (Table 4.13; Table 4.22; Table 4.23). Forest, grassland, non-tidal wetland and tidal wetland habitat had 11, 34, 9 and 15 species, respectively, that were not expected and not included in calculations.

Table 4.12. Number of Lepidoptera and Odonata species observed/expected in each Park unit.

Lepidoptera and Odonata species	Jamestown & Parkway	Yorktown & Parkway
Observed/Expected (%)	99/209 (47%)	77/209 (37%)

Table 4.13. Number of Lepidoptera and Odonata species observed/expected in each Park habitat according to life history accounts (Butterflies and Moths 2011; Odonata Central 2011).

Lepidoptera and Odonata species	Forest	Grassland	Non-tidal wetland	Tidal wetland
Observed/Expected (%)	42/158 (27%)	31/74 (42%)	42/136 (31%)	33/96 (34%)



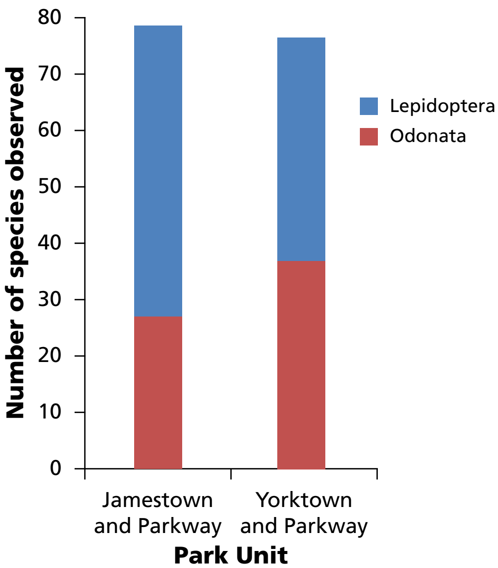


Figure 4.23. Total number of Lepidoptera and Odonata species observed in each Colonial NHP habitat (a) and within each park unit (b).

Several species were documented as new county records: 27 species of Lepidoptera and 26 records for Odonata. Lepidopterans had the greatest species diversity in the grassland, with the fewest species present in non-tidal wetland habitat, while Odonates were most diverse in non-tidal wetlands and least diverse in developed and tidal wetland areas (Figure 4.23). Grassland habitats hosted the greatest species diversity overall. More species of Lepidoptera were observed in James City and Surry Counties (Jamestown and Parkway), while more species of Odonata were observed in York County (Yorktown and Parkway) (Figure 4.23). The rare skipper, a butterfly listed as critically imperiled in the state of Virginia, was observed, in addition to five Virginia watchlist species (Aaron's skipper [*Poanes aaroni*], comet darner [*Anax longipes*], blue-faced meadowhawk [*Sympetrum ambiguum*], furtive forktail [*Ischnura prognata*], and duckweed firetail [*Telebasis byersi*]).

The inventory data represent one point in time; therefore, no temporal trend could be calculated.

Data gaps and level of confidence

Lepidoptera and Odonata survey data was minimal, allowing for calculation of species presence but not absence, and not population trends. Confidence in assessment is very limited.

Sources of expertise

Anne Chazal, Field Zoologist, Virginia Natural Heritage Program, Virginia Department of Conservation and Recreation

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4.3.5 Forest interior dwelling species

Relevance and context

The presence of bird species can effectively provide a bioindicator of subtle or unexpected changes in environmental condition (Koskimies 1989). In nearby Maryland, there has been a 63% decline in individual birds of neotropical origin (including forest interior dwelling species [FIDS]) between 1980–1989 (Jones et al. 2000). This represents a continuation of documented declines at some sites between 1940–1980 (Terborgh 1992). The presence of FIDS is used as an indicator of high-quality forest interior habitat. Twenty-five species of FIDS breed in the Chesapeake Bay Critical Area, of which 13 species are obligate riparian breeding species or are strongly associated with riparian forests during the breeding season (Jones et al. 2000). For the purposes of this assessment, those 13 species were classified as "highly area-sensitive" FIDS.

Photo: Chris Koontz

The barred owl (*Strix varia*) is listed as a highly area-sensitive forest interior dwelling species.

Method

Data for the assessment were comprised of 14 years of Breeding Bird Survey (BBS) data along the Parkway and a 2003 inventory for the park (Bradshaw unpublished data). Current condition was surmised primarily from the 2003 inventory of the entire park commissioned by the National Park Service. Trend was derived from the BBS data, which were compiled for the years 1992–2007, excluding 1993 and 2002, when surveys were

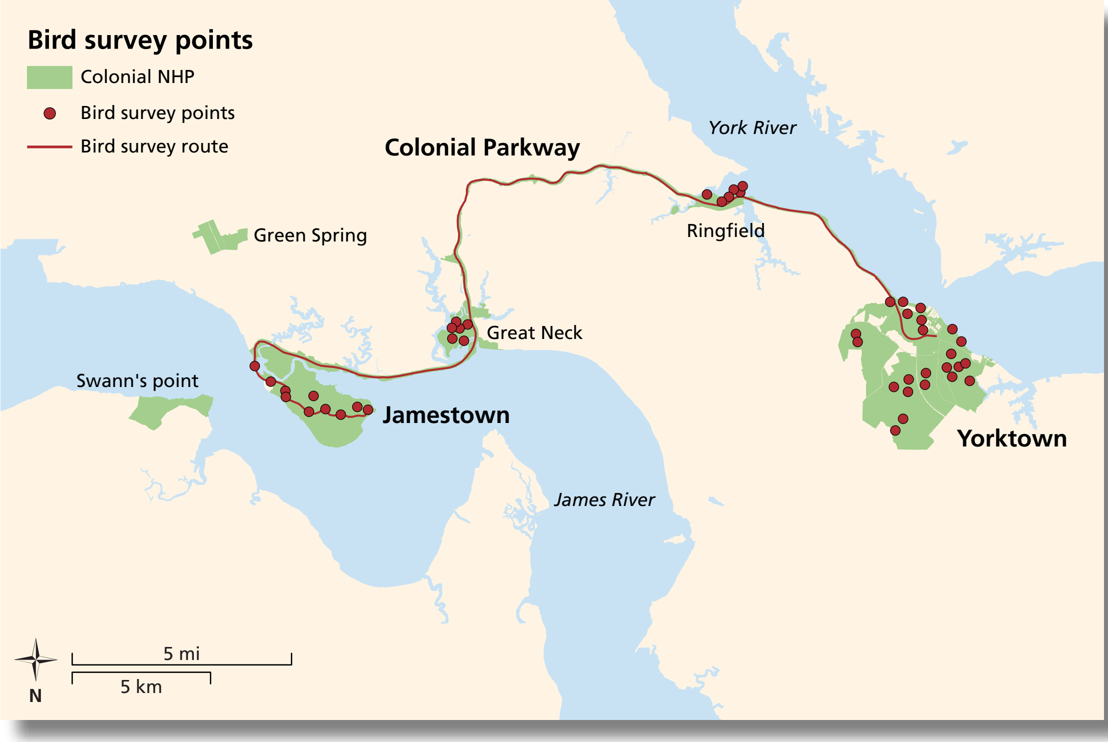
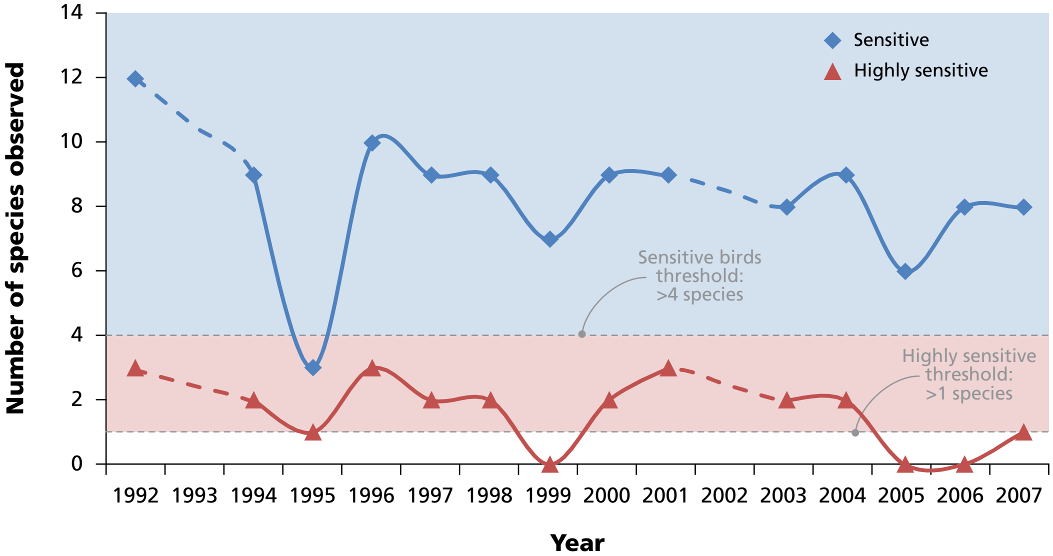


Figure 4.24. Bird sample locations from 2003 inventory and Breeding Bird Survey Route Number 88913.

Figure 4.25. Number of sensitive and highly sensitive bird species observed over 15 years.



not conducted. The 40.9 km (25.4 mi) BBS Route Number 8893 is oriented mostly along the Parkway (Figure 4.24).

Threshold

The reference condition for FIDS is ecological. Presence of at least four sensitive FIDS, or at least one highly area-sensitive FIDS, indicates high-quality forest interior habitat (Jones et al. 2000). Using this information, the ecological threshold was based on the presence of an appropriate habitat for FIDS and defined as the observation of at least four FIDS, or one highly area-sensitive FIDS. In both cases, these birds must be observed in probable or confirmed breeding status (Jones et al. 2000). However, breeding status was not recorded with the data used—presence was only recorded and is what was used for this analysis. The park was given a rating of either 100% or 0% attainment for each year based on whether or not the observation met this minimum FIDS threshold (Table 4.22).

Current condition and trend

A total of 6882 birds were observed as part of the 2003 inventory (Bradshaw unpublished data). These observations included 10 species classified as sensitive and four classified as highly sensitive (Kentucky warbler [*Oporornis formosus*], barred owl [*Strix varia*], brown creeper [*Certhia americana*], and red-shouldered

Photo: Kelly Colgan Azar

The scarlet tanager *(Piranga olivacea)* is listed as an area-sensitive forest interior dwelling species.

hawk [*Buteo lineatus*]). These observations exceeded the ecological threshold and the forest birds were considered in good condition for the park (100% attainment). Taken separately, Jamestown, Colonial Parkway, and Yorktown also each had at least four sensitive species observed for attainment scores of 100% (Table 4.14; Table 4.22; Table 4.23).

The FIDS threshold of either four sensitive species or one highly sensitive species was also exceeded in every year recorded in the BBS data (Figure 4.25). From 1992–2007, a total of eight of the potential 13 highly sensitive FIDS were observed at least one time, all except the broad-winged hawk (*Buteo platypterus*), black-throated green warbler (*Setophaga virens*), cerulean warbler (*Dendroica cerulea*), worm-eating warbler (*Helmitheros vermivorum*), and Swainson's warbler (*Limnothlypis swainsonii*). The whip-poor-will (*Caprimulgus vociferus*)and veery (*Catharus fuscescens*) were the only two sensitive species never observed in the time series. There is a negative slope to the regression line of sensitive species for the period of record, but it is not statistically significant. Therefore, no trend is reported.

Data gaps and level of confidence

Current monitoring of FIDS is appropriate to assess this resource. However, it should be noted that this assessment is highly dependent on BBS data. The park is not conducting its own monitoring of this resource and only one year of inventory data has been collected in 2003. Confidence in the assessment of current condition was high and confidence in assessment of trend was also high. An estimation of detection probabilities could be conducted to further improve confidence in the data.

Sources of expertise

Dana Bradshaw, Senior Biologist, Center for Conservation Biology, College of William and Mary

Literature cited

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Table 4.14. Sensitive and highly sensitive Forest Interior Dwelling Species (FIDS) found in 2003 inventory.

Unit	Highly sensitive	Sensitive
Jamestown		Acadian Flycatcher
		Hairy Woodpecker
		Pileated Woodpecker
		Red-eyed Vireo
		Wood Thrush
Jamestown total	*0*	*5*
College Creek	Barred Owl	Acadian Flycatcher
		Hairy Woodpecker
		Pileated Woodpecker
		Red-eyed Vireo
		Scarlet Tanager
		Wood Thrush
Ringfield	Kentucky Warbler	Acadian Flycatcher
		Hairy Woodpecker
		Northern Parula
		Ovenbird
		Pileated Woodpecker
		Red-eyed Vireo
		Wood Thrush
		Yellow-throated Vireo
Colonial Parkway total	*2*	*9*
Yorktown	Barred Owl	Acadian Flycatcher
	Brown Creeper	Hairy Woodpecker
	Red-shouldered Hawk	Northern Parula
		Ovenbird
		Pileated Woodpecker
		Prothonotary Warbler
		Red-eyed Vireo
		Scarlet Tanager
		Wood Thrush
		Yellow-throated Vireo
Yorktown total	*3*	*10*
Colonial NHP overall	**4**	**10**

4.3.6 Grassland bird functional groups

Relevance and context

Grassland bird populations have generally been in decline since the 1970s at rates that outpace other North American species (Peterjohn 2006). This decline has been caused by factors including the conversion of grassland to other land cover types, habitat fragmentation, and mowing regimes. In 2005, NPS formally recognized this decline and began taking actions to combat the loss of grassland birds (Peterjohn 2006). These guidelines recommend a species-specific approach to park management of this critical resource that focuses on obligate grassland species. An obligate grassland bird is defined as "any species that has become adapted to and reliant on some variety of grassland habitats for part or all of its life" (Vickery et al. 1999).

Data and methods

Data for the assessment (Figure 4.24) were comprised of a 2003 inventory for the park commissioned by the National Park Service (Bradshaw unpublished data) and 14 years of Breeding Bird Survey data (1992–2007, excluding 1993 and 2002). All sample points were recorded in Yorktown, where the preponderance of grassland habitat is located.

Grasshopper sparrow (*Ammodramus savannarum*).

Photo: Ken Schneider

Threshold

Percent attainment for grassland birds was derived directly from the percentage of four functional groups present. The four functional groups were defined as: disturbance-tolerant, preference for young grasslands, preference for mature grasslands, and rarely encountered in the Mid-Atlantic (Peterjohn 2006). The percent attainment was equivalent to the percentage of these four functional groups that were present in the park, based on the species observations from the 2003 avian inventory in the park and the 1992–2007 BBS data. The park was given a rating of 0%, 25%, 50%, 75%, or 100% attainment for each of these 15 data points (Table 4.22).

Current condition and trend

Only one obligate species of bird, the Eastern meadowlark (*Sturnella magna*), was found in the 2003 avian inventory. This species represents the young grasslands functional group. The park scored a 25% attainment level for 13 of the 14 years of the BBS data and a 0% attainment level for one year. The overall attainment score for all 15 points was 23% (Table 4.22; Table 4.23). No trend was observed in the 14 years of BBS data. Thirteen out of the 14 years met a 25% attainment level (1 out of 4 function groups represented) and one out of the 14 years met a 0% attainment level. The main functional group represented was the species preferring young grasslands group, which was represented by the Eastern meadowlark (*Sturnella magna*) and the grasshopper sparrow (*Ammodramus savannarum*).

Data gaps and level of confidence

Current monitoring of grassland birds is appropriate to assess this resource. However, it should be noted that this assessment is highly dependent on BBS data. The park is not conducting its own monitoring of this resource and only year of inventory data has been collected in 2003. Data was collected only for the Yorktown unit, where the vast majority of grasslands are located. Confidence in the assessment of current condition was high and confidence in assessment of trend was also high. An estimation of detection probabilities could be conducted to further improve confidence in the data.

Sources of expertise

Dana Bradshaw, Senior Biologist, Center for Conservation Biology, College of William and Mary

Literature cited

Peterjohn B. 2006. Conceptual ecological model for management of breeding grass-land birds in the Mid-Atlantic region. Natural Resources Report NPS/NER/NRR–2006/005. National Park Service, Philadelphia, PA.

Vickery PD, PL Tubaro, JM Cardoso da Silva, PG Peterjohn, JR Herkert, and RB Cavalcanti. 1999. Conservation of grassland birds in the Western Hemisphere. *Studies in Avian Biology* 19: 2–26.

4.3.7 Deer density

Relevance and context

White-tailed deer (*Odocoileus virginianus*) are the smallest members of the North American deer family, Cervidae, and are the most abundant species of ungulate on the North American continent (Russell et al. 2001). This species commonly occurs throughout the eastern United States at densities ranging between 5–20 deer/km^2 (Bowers 1997). Due to their generalized diet, broad habitat ranges, and high densities, white-tailed deer can drastically affect the forest ecosystems in which they live (Bowers 1997). Browsing reduces height growth of tree species. Deer directly affect the growth, reproduction, and survival of plant species by browsing, often with specific preferences, on the leaves, stems, flowers, and seeds of various plant species (Côté et al. 2004). Browsing contributes to shifts in the understory composition of forest ecosystems with the potential to change the succession patterns of these forests, especially to non-native species (Knight et al. 2009). Miller et al. (1992) found that deer can disturb populations of threatened or endangered plants. In addition, changes in undergrowth due to deer herbivory can account for a decrease in the sensitive species of birds that depend on those areas needed for nesting, foraging, and protection (McShea and Rappole 1997).

Estimates of pre-colonial deer populations in Virginia range from 313,000–433,000 (3.1–4.2 deer/km^2), with populations highest for the Tidewater region of the state (Knox 1997). Subsequently, a decline in deer during colonial times (A in Figure 4.26) is widely attributed to overharvesting for food and hides by settlers (Knox 1997). The early 1900s marked the lowest white-tailed deer densities; the deer in the Piedmont and highland physiographic provinces of Virginia were almost completely overexploited (Knox 1997; Horsley et al. 2003; Côté et al. 2004). Management strategies in the early and mid-1900s emphasized encouraging growth of white-tailed deer populations throughout Virginia and the southeastern United States. Strict hunting regulations and changes in land use contributed to the rise of deer populations (Russell et al. 2001). A deer restoration program, initiated by the Virginia Department of Game and Inland Fisheries (VDGIF) in 1926 (B in Figure 4.26), focused on repopulating Virginia's deer by importing and stocking forests with deer from other regions and states (VGDIF 2007). Although most restocking was conducted west of the Blue Ridge Mountains, James City County also received deer during this period. These management techniques proved effective as Virginia's population of deer grew from approximately 25,000 in 1931 to approximately 215,000 in 1970 according to VDGIF estimates (C in Figure 4.26).

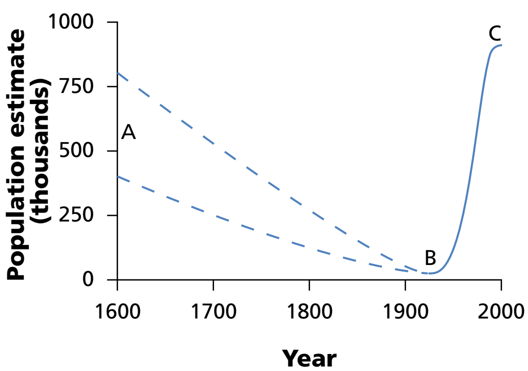

Figure 4.26. Hypothetical population curve for Virginia's deer herd, 1600–present (VDGIF 2007). The dotted lines indicate the estimated range of deer densities from 1600 to early 1900.

A variety of factors have contributed to the success of white-tailed deer in the eastern United States. The most significant contributing factors are increased forage and habitat availability. Increased range expansion can be attributed to land use changes from dense forest to agricultural area and fragmented forest areas (Côté et al. 2004). White-tailed deer thrive in transitional habitats like wooded areas with openings for foraging. Forests transitioning to developed areas and agricultural areas provide deer their preferred habitat. In addition, natural predators are no longer available for deer population control (Côté et al. 2004). Parks and other privately owned areas that prohibit hunting also contribute to high densities of deer throughout the southeastern United States (Porter and Underwood 1999). Protected from hunting, and without natural predators, deer in parks have exhibited explosive population growth (McCullough 1997). In 1970, populations of deer exhibiting high densities corresponded directly to federal and state properties (Knox 1997).

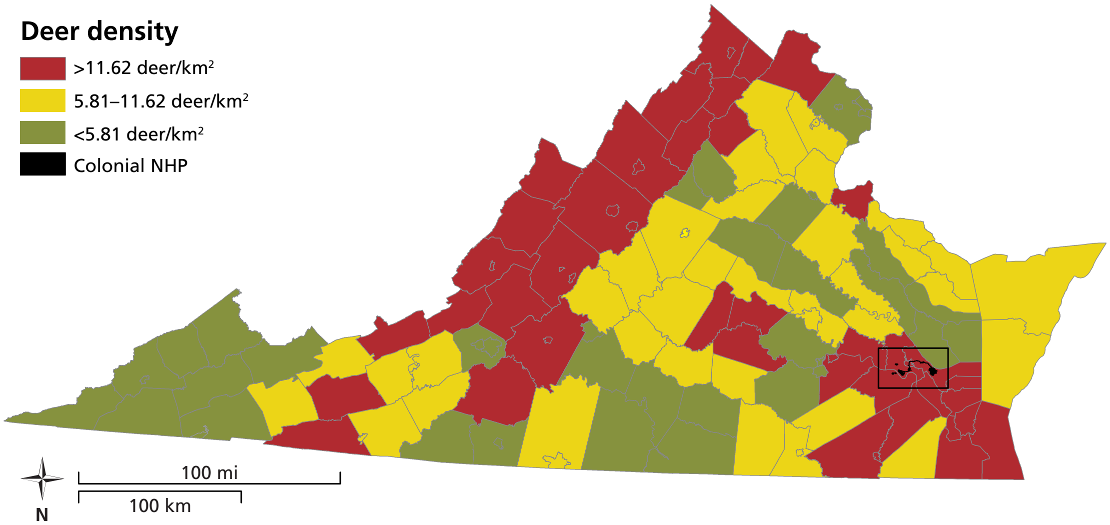

Figure 4.27. Most recent year of data on statewide deer density estimates for Virginia (adapted from VDGIF 2007). Estimates produced by the Southeastern Cooperative Wildlife Disease Study.

Data and methods

White-tailed deer densities have not been estimated directly for Colonial NHP. To derive a best estimate of densities in the park, data were used from the Commonwealth of Virginia (West and Parkhurst 2002; VDGIF 2007) and nearby national parks. Estimates for 2010 were available for Richmond National Battlefield (Prowatzke 2010) and Petersburg National Battlefield (Blumenschine 2010). Data from 2001–2009 from ten parks in the National Capital Region (Bates 2010) were used to assess the trend. Historical estimates of the trend were also taken from the Virginia Department of Game and Inland Fisheries (VGDIF 2007) as part of their efforts to control deer populations throughout the Commonwealth.

Threshold

According to Knox (1997), the environmental carrying capacity for deer in Virginia is 1.9–9.7 deer/km^2. Any densities exceeding this threshold are considered an overly abundant population and can significantly affect the structure and composition of forest ecosystems (Rossell et al. 2005). As densities approach 8.0 deer/km^2, plant species are continuously reduced and songbird populations may be affected (DeCalesta 1997). Experimental studies in northwestern Pennsylvania indicate a threshold for white-tailed deer of 8.0 deer/km^2 past which forest ecosystems begin to exhibit negative effects due to overbrowsing (Horsley et al. 2003). An ecosystem manipulation study in central Massachusetts found that deer densities of 10–17 deer/km^2 inhibited the regeneration of understory species, and densities of 3–6 deer/km^2 were optimal for supporting a diverse and abundant forest understory (Healy 1997). Table 4.15 summarizes these potential threshold values.

For this assessment, an ecological and management threshold of 8.0 deer/km^2 was used for the forest habitat (Table 4.22).

Current condition and trend

White-tailed deer populations in the state of Virginia are estimated between 7.7–14.8 deer/km^2 (West and Parkhurst 2002), with the highest concentrations observed in Northern Virginia and the Virginia Peninsula where Colonial NHP is located (Figure 4.27).

Table 4.15. Potential deer density thresholds for Colonial NHP.

Type	Threshold (deer/km^2)	Source
Pre-colonial historical baseline for Virginia	3.1–4.2	Knox 1997
Environmental carrying capacity for Virginia	1.9–9.7	Knox 1997
Ecosystem manipulation study	3–6	Healy 1997
Enclosure studies within forest ecosystem	8.0	Horsley et al. 2003

White-tailed deer populations are highest in Northern Virginia and the Virginia Peninsula, where Colonial NHP is located.

Photo: Copyright © 2011 Richard Schuerger

The National Parks of the National Capital Region in northern Virginia, Maryland, West Virginia, and the District of Columbia have densities that greatly exceed the ecological threshold level of 8.0 deer/km^2 (Table 4.16). The most recent estimates of density for Petersburg National Battlefield are 48.6 deer/km^2 (Blumenschine 2010) and for Richmond National Battlefield are 14.5–25.7 deer/km^2 (Prowatzke 2010). Given the range of current estimates from 14.3–53.8 deer/km^2 at our comparison parks (Table 4.16), it seems likely that the park is above the 8 deer/km^2 threshold and deer management should be a significant concern.

More recently, the white-tailed deer populations have increased drastically. After reaching pre-colonial densities around 1980, white-tailed deer populations in Virginia grew from 575,000 deer in 1987 to nearly 1,000,000 deer at the turn of the century (VDGIF 2007). Since the 20th century, white-tailed deer populations have been relatively stable. Within the National Capital Region Network, deer densities have also remained relatively stable in the last decade (Table 4.16).

Data gaps and confidence in assessment

No direct measurements of deer densities in Colonial NHP are available. This represents a significant data gap to the assessment. Based on statewide data and data from parks with similar forest/field ratios and surrounding land use patterns, it seems highly likely that deer density in the park exceeds reasonable carrying capacity. However, we do not provide a score for the deer metric at this time, based on lack of data specifically for the park, and the confidence placed on any speculations of density is low. It is recommended that future assessments quantify and emphasize the

Table 4.16. Deer densities per square kilometer in nearby parks over time (Bates 2009; Bates 2010; Blumenshine 2010).

National Capital Region Network Park Unit	Deer/km^2 2001	Deer/km^2 2008	Deer/km^2 2009
Antietam National Battlefield	35.1	52.71	50.21
Monocacy National Battlefield	58.8	77.26	53.8
Piscataway Park	42.93	58.2	27.28
Greenbelt Park	33.45	39.14	32.97
Manassas National Battlefield	66.31	62.81	38.14
Catoctin Mountain Park	71.75	44.13	47.66
George Washington Memorial Parkway	33.9	25.62	47.49
Chesapeake and Ohio Canal NHP	47.26	45.17	49.23
Petersburg National Battlefield	120.7	112.3	123.6
Prince William Forest Park	15.47	11.7	14.3
Rock Creek Park	24.24	25.94	25.68

effects of deer herbivory on the park's plant community health (Table 4.22; Table 4.23).

Sources of expertise

Scott Bates, Wildlife Biologist, National Capital Region, National Park Service

Tim Blumenschine, Biologist, Petersburg National Battlefield, National Park Service

Michael Prowatzke, Biological Science Technician, Richmond National Battlefield, National Park Service

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4.3.8 Invasive plant species

Relevance and context

Invasive exotic plants can compete with native plants and therefore lead to a reduction in biodiversity of the native flora (Mack et al. 2000). In fragmented forest landscapes, invasive plants can exacerbate the effects of habitat destruction by displacing native species through their overwhelming production of new propagules (i.e., mass effects; Rouget and Richardson 2003) and direct competition for resources (Levine et al. 2003). In 2008, more than 1 million ha (2.6 million ac; 5% of park lands) were estimated to be dominated by non-native, invasive plant species in national parks (NPS 2008). Invasive plants within Colonial NHP pose a serious risk to native plants and animals, infrastructure, and the historical and cultural setting. At least two species of invasive exotic plants, Japanese stiltgrass (*Microstegium viminium*) and Japanese honeysuckle (*Lonicera japonica*), have become so widespread in the park that even an estimation of their abundance is unrealistic, much less any expectation of their eradication (Gounaris and Grubbs 2000).

Data and methods

Data used to assess condition for the assessment were from the 1999–2000 invasive exotic plants inventory of the park (Gounaris and Grubbs 2000). All forested, field, and wetland areas were divided into mapping units for which the percent cover for each invasive species (except the widely abundant Japanese stiltgrass and Japanese honeysuckle) and the total percent groundcover of all invasive species were estimated. The inventory data were summarized in 2009 for the Exotic Plant Management Team (EPMT) Mid-Atlantic Workplan 2010–2014 to get an estimate of total infested area for all invasive species combined, which is the metric used to estimate current condition for this NRCA (Akerson 2009).

Because the comprehensive invasive species inventory data represent a one-time sample, they could be used to estimate condition in the park only. Invasive exotic plant invasion trends were estimated for the park for two species characterized by moderate invasiveness, while covering a relatively low percentage of the park. These species are a focus of park management due to their impacts not only on the native flora and fauna within the park but also on the cultural landscape due to their tall growth forms. Golden bamboo (*Phyllostachys aurea*) cover was estimated using aerial photographs, digitized by the park GIS staff, of infested stands from 1999, 2007, 2010 (Figure 4.28). In 2011, the 2010 estimate was assessed with field measurements, as an informal ground check of the aerial photography digitization. Annual geographic distribution of treatment actions have also been mapped by park staff

Golden bamboo (*Phyllostachys aurea*) cover at the pumphouse in Jamestown before (left), during (center), and after (right) treatment.

Photos: Dorothy Geyer, Colonial NHP

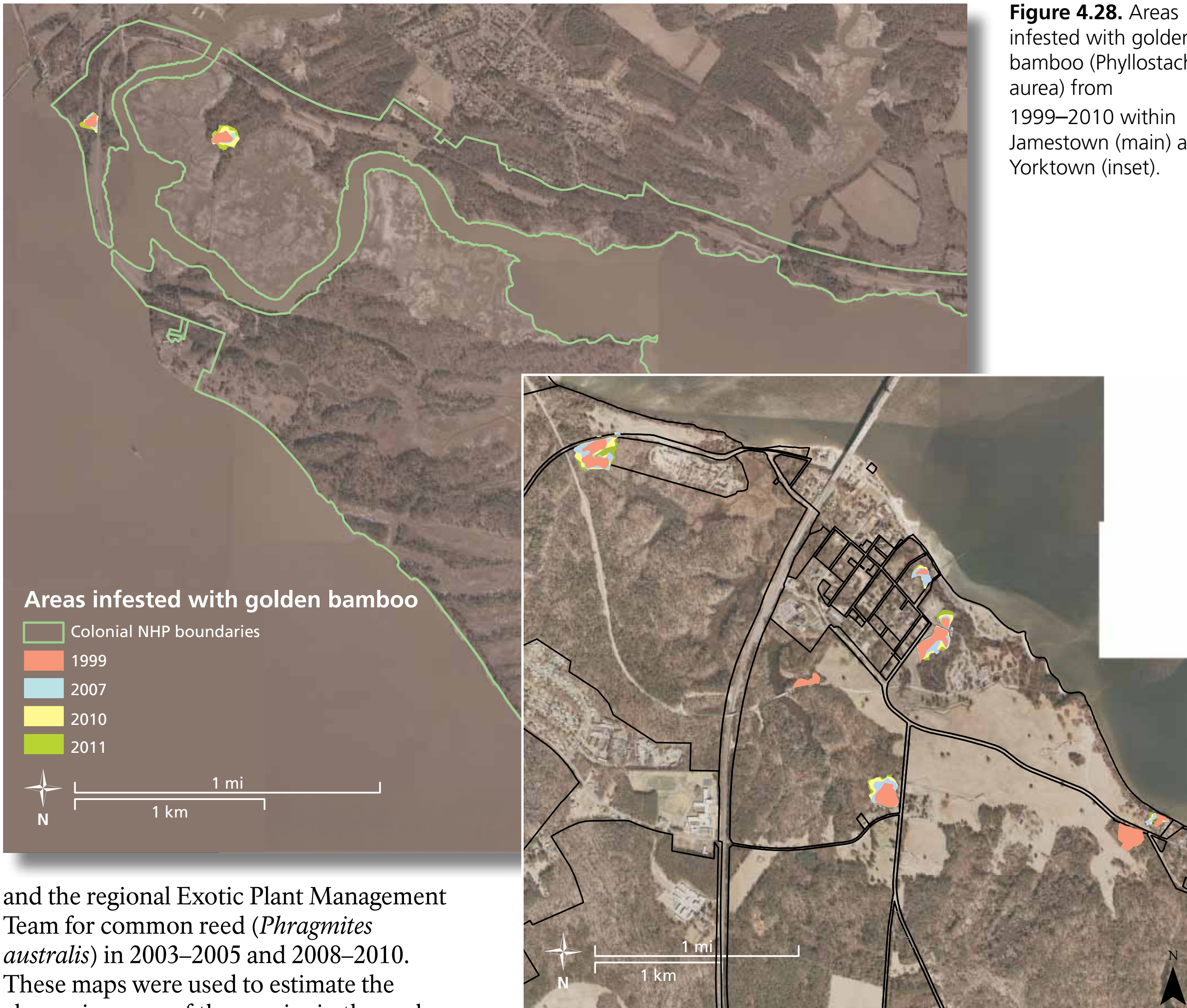

Figure 4.28. Areas infested with golden bamboo (Phyllostachys aurea) from 1999–2010 within Jamestown (main) and Yorktown (inset).

and the regional Exotic Plant Management Team for common reed (*Phragmites australis*) in 2003–2005 and 2008–2010. These maps were used to estimate the change in cover of the species in the park.

Thresholds

The threshold used to assess condition was that the total percent groundcover of all invasive exotic plants should not exceed 25% of the total park land. Because 100% eradication is not a realistic goal (at least in the short term), this management objective was determined to be a reasonable management goal. This threshold also serves as a guide to evaluate the effectiveness of active plant controls implemented within a treatment area (i.e., treatment actions are deemed successful by the park if no more than 25% of a treatment area is infested with invasive exotic plants). The park inventory data were assessed against the threshold and assigned a 0% or 100% attainment score based on the 25% cover criterion.

For assessment of trends, the first year of data available for the two focal species was used as a baseline for comparison (1999 for golden bamboo and 2003 for common reed). Based on conversation with park staff, a decrease of 20% below these baseline levels was set as a threshold to assign a decrease in cover for the species for any given year (Table 4.22).

Current condition and trend

The 2000 inventory identified 1500 ha (3700 ac) infested with invasive species, representing 43% of the total Park area. This represents 0% overall attainment of the invasive plant species threshold for Colonial NHP as a whole. All of the parks' special status areas, including Natural Heritage areas

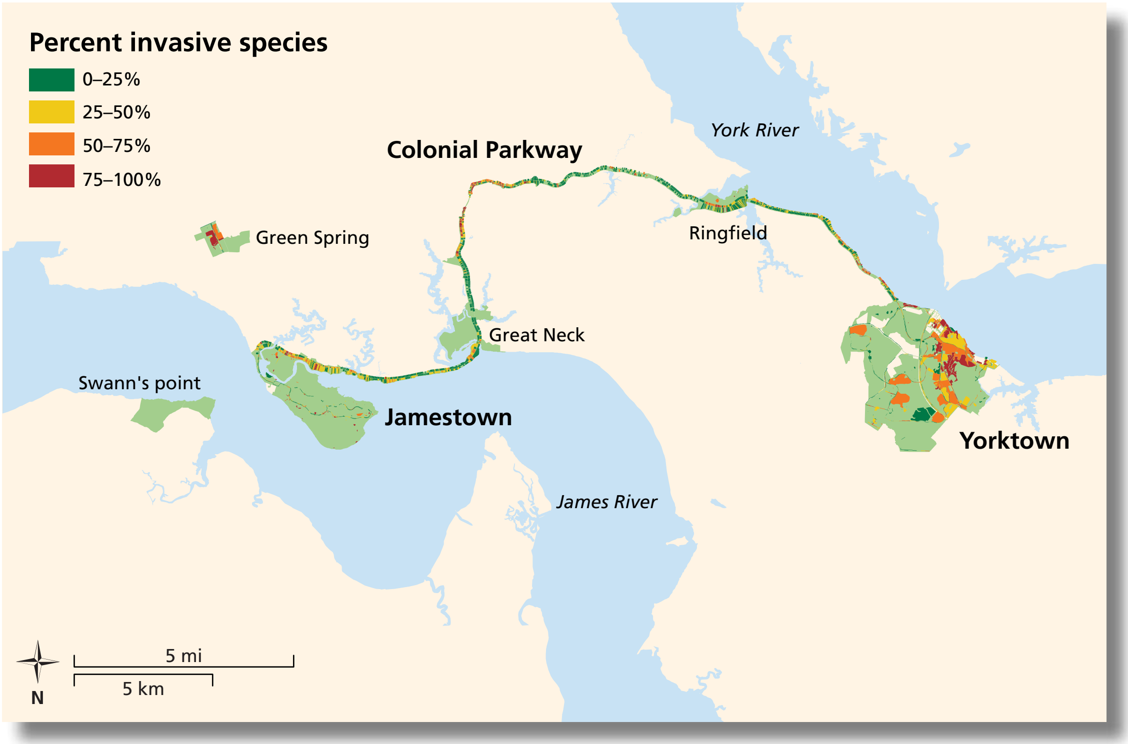

Figure 4.29. Percent of invasive species found within survey units of Colonial NHP.

and Yorktown's earthworks, were infested with at least small populations of invasive plants (Figure 4.29).

In the assessment of trend, golden bamboo did not meet the 20% reduction threshold criterion in any year and is generally increasing in the park, although two small patches were effectively eradicated prior to the 2011 field survey (Figure 4.30). By 2010, golden bamboo cover had reached 7.8 ha (19.3 ac) in the Park: 1.4 ha (3.4 ac) in Jamestown and 6.4 ha (15.9 ac) in Yorktown (Figure 4.28).

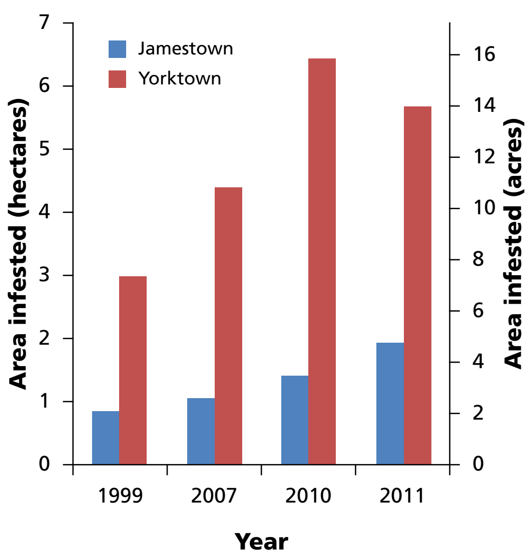

Figure 4.30. Area infested with golden bamboo (*Phyllostachys aurea*) derived from aerial photography (1999-2010) and field survey (2011).

The total amount of common reed treated within the park also did not meet the assessment threshold of 20% of 2003 levels for four out of the five years assessed (Figure 4.31). An average of 11 ha (27 ac) of common reed were treated per year. Treatment occurred primarily in Jamestown and along Colonial Parkway (Figure 4.32). Unlike golden bamboo, which the data suggest is increasing in the park, common reed treatment levels did not have a discernable trend. Because the golden bamboo data indicate a deteriorating trend and the observations of common reed were above the threshold level for four out of five year, the overall trend for invasive species is assessed as declining (Table 4.22; Table 4.23).

Data gaps and level of confidence

Although the 2000 inventory was a high quality data source, it has now been more than a decade since the last comprehensive inventory of the park. That time span can result in substantial changes for invasive species populations. Nevertheless, it is highly unlikely that invasive exotic plant cover has decreased from 43% of total park area in 2000 to less than 25% today, and confidence that the current condition still exceeds threshold is high.

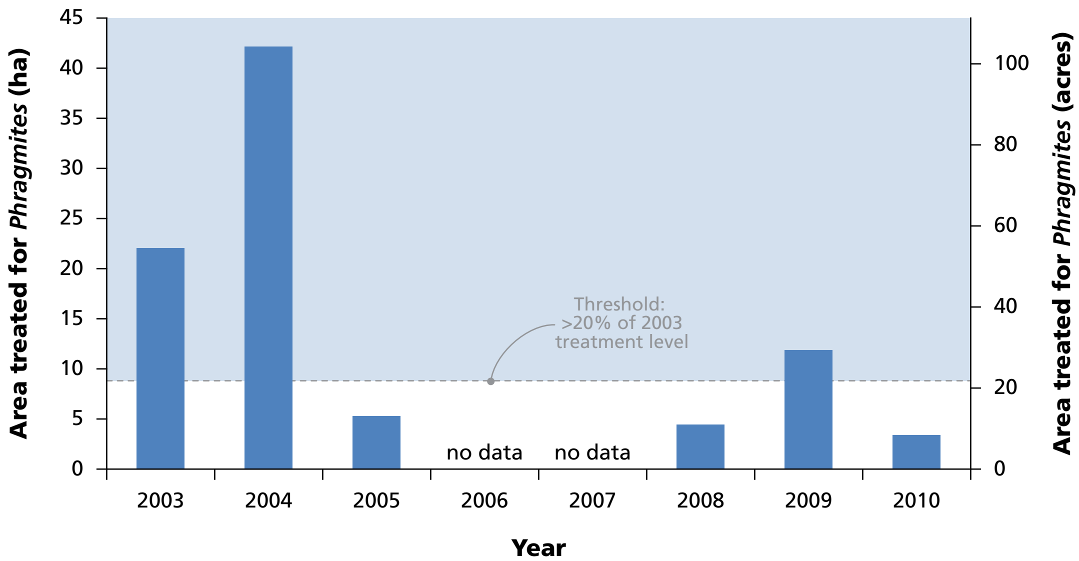

Figure 4.31. Total area treated for common reed (*Phragmites australis*) within Colonial NHP.

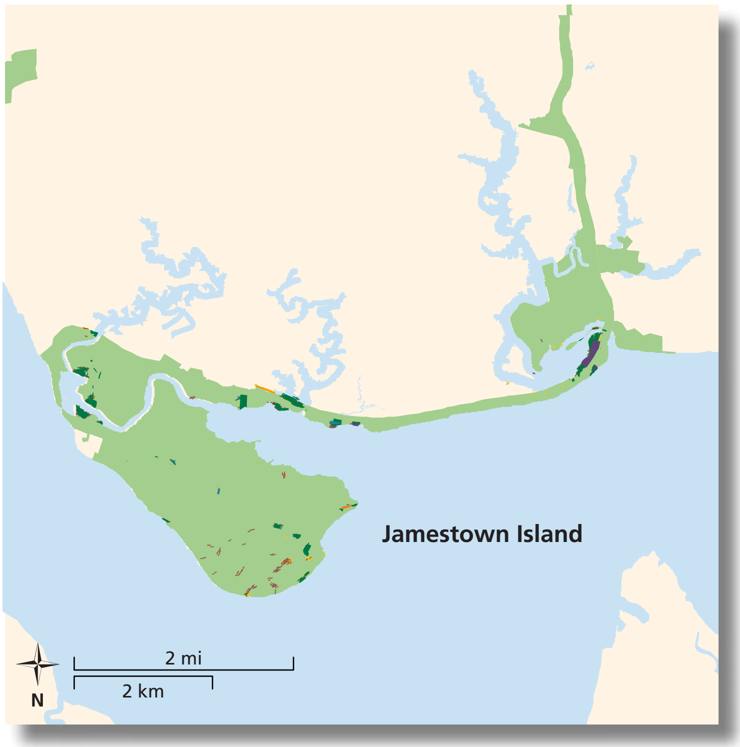

Figure 4.32. Locations treated for common reed (*Phragmites australis*) within Colonial NHP (left) with greater detail for Jamestown (bottom left) and Yorktown (bottom right).

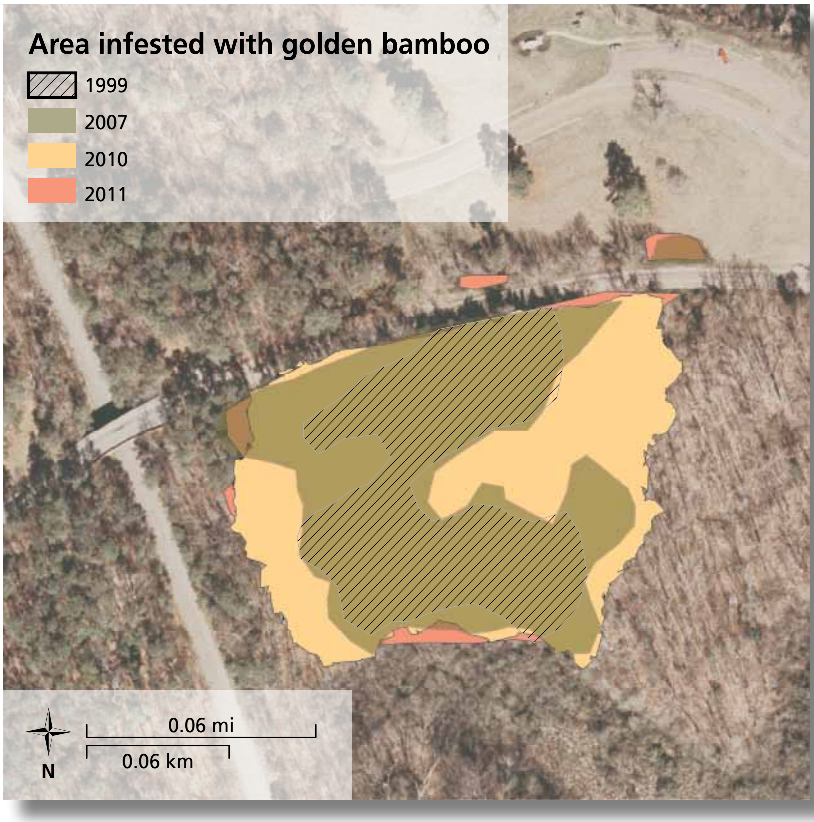

Figure 4.33. Example change in golden bamboo (*Phyllostachys aurea*) area from 1999–2011 for a patch in Yorktown as derived from aerial imagery analysis (1999–2010) and field survey (2011).

In assessing trend, the estimates derived from the aerial photography (Figure 4.28) were substantially lower than the estimate from the 2000 field-based inventory, in which ground cover of golden bamboo was estimated at 22.5 ha (55.7 ac; Gounaris and Grubbs 2000). These differences may be explained by the differences in the survey methods, but warranted additional fieldwork to help resolve. As part of this assessment, field visits were conducted in 2011 of sites mapped using 2010 aerial photography. These field visits confirmed good correspondence between the remotely sensed and ground-based observations (Figure 4.33). At least part of the discrepancy with the 2000 inventory data is likely explained by an intermingling of golden bamboo with native bamboo (i.e., giant cane *Agarundinaria gigantea*) and large, pure stands of giant cane that are included in the 2000 inventory.

Sources of expertise

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4.4 LANDSCAPE DYNAMICS

4.4.1 Percent forest

Relevance and context

Habitat loss is the primary cause of species extinctions in the United States (Czech et al. 2000). Land conversion from forest can occur for a variety of purposes, including agriculture, timber harvesting, and mining (Dale et al. 2000), but in the Coastal Plain of Virginia this conversion is primarily from forest to urban lands (Loveland et al. 1999). From 1963–1997, total forest area has not undergone significant changes at the national scale (Noss et al. 2002), though recent decades have seen a forest decline in the eastern U.S. of several percent (Drummond and Loveland 2010). This regional trend can be observed in the 30 km (19 mi) neighborhood around the Colonial NHP (Figure 4.34), for which the percentage of forest cover fell from 43% in 1992 to 39% in 2001 (Budde et al. 2009). A variety of studies have documented the ecological linkages between protected and surrounding land uses (Pringle 2000; Defries et al. 2007; Hansen and Defries 2007). In addition to its effects on species extinctions, loss of forest cover can lead to increased exotic species invasions (Vitousek et al. 1997), degraded and diminished water flows (Meyer and Turner 1992), and spread of new diseases (Langlois et al. 2001).

Data and methods

Data from the Virginia Natural Heritage (Patterson 2008) classification was aggregated by habitat type. Field sampling for the Natural Heritage mapping was conducted in 2003–2005. For this NRCA, the 40 vegetation assemblages were modified from the Natural Heritage classification into 6 broad classes, including forest land cover. Additional modifications to the land cover classification were made based on consultation with NPS staff, National Wetland Inventory data (US FWS 2012), and the 1990 vegetation survey (see Chapter 3; http://www.fws.gov/wetlands/data/).

Thresholds

Theoretical studies of simulated forest loss have demonstrated that once the total amount of forest cover drops below a threshold value of 59% of the landscape area, the pattern of remaining forest begins to lose the characteristic qualities of intact forest required of organisms such as forest interior birds and forest dwelling mammals (Gardner

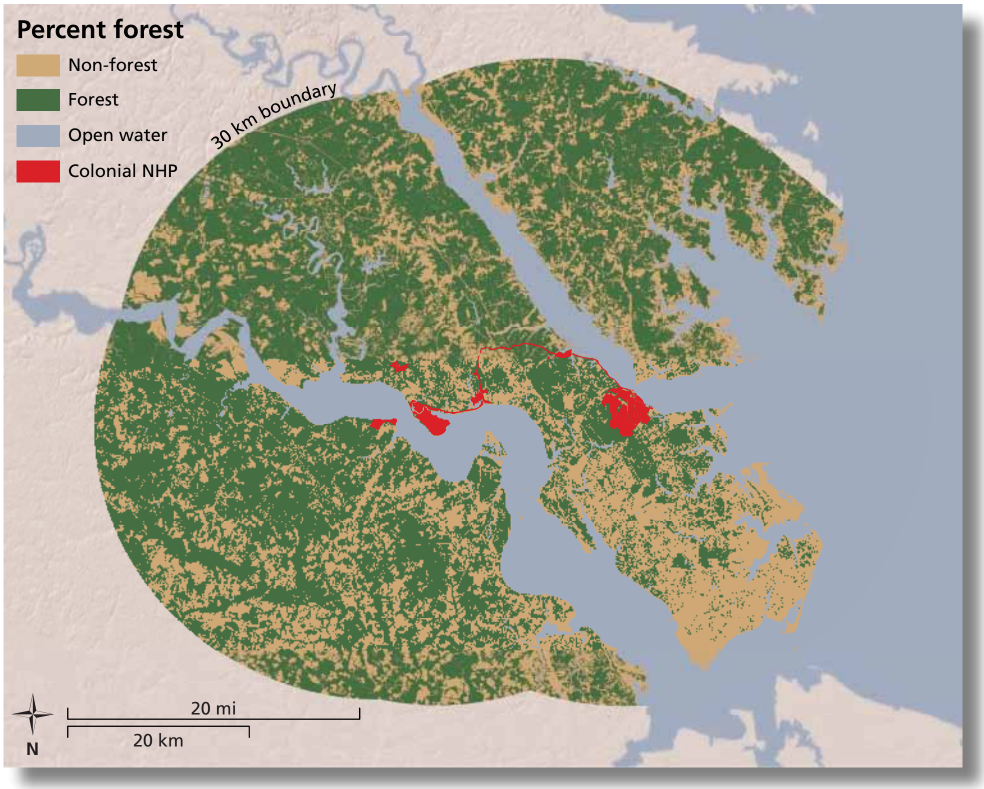

Figure 4.34. Forest land cover (2001) for a 30 km (19 mi) buffer surrounding the Colonial NHP (shown in red). Data from NPScape project (Budde et al. 2009).

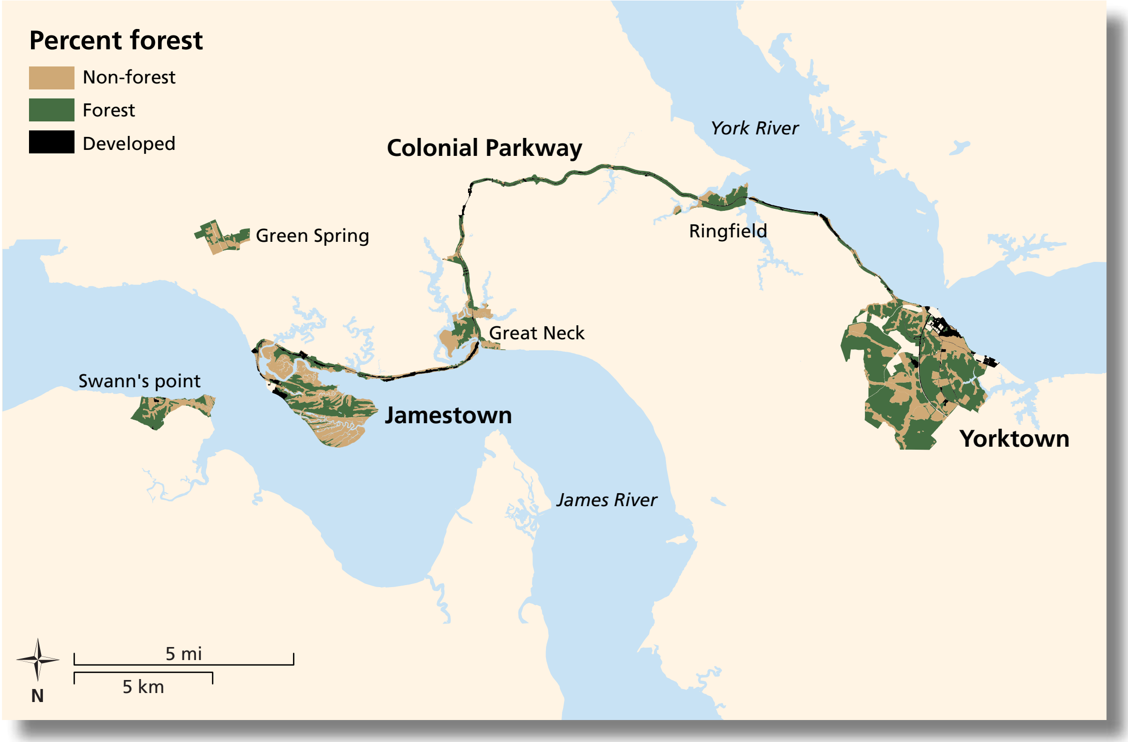

Figure 4.35. Percent forest landcover within Colonial NHP as derived for this assessment (see Chapter 3 for details).

et al. 1987; Turner et al. 2001). For example, the number of patches tends to increase from one to many at this threshold level of fragmentation, average patch size decreases markedly, the amount of interior forest decreases, and the amount of edge increases. These same studies identified a second threshold value of 30%, below which concerns related to forest fragmentation are replaced by concerns related to complete forest disappearance. For example, the number of forest patches starts to decrease with additional forest loss because patches are no longer being divided by fragmentation, but removed entirely from the landscape. For this assessment, land cover percentages above 59% were assigned an attainment score of 100%; land cover percentages below 30% were assigned an attainment score of 0%; and land cover percentages between 30–59% were scaled linearly from 0–100% attainment (Table 4.22).

Current condition and trend

Using our modification of the Natural Heritage land cover map (see Chapter 3), the park has a total forest area of 56.0%, which represents a 90% attainment relative to the baseline threshold values. Jamestown (46%) has the lowest amount of forest of the park units and an attainment value of 55% (Figure 4.35; Table 4.22; Table 4.23). Yorktown is in the best condition with 64% of the unit in forest land cover. The Virginia Natural Heritage vegetation mapping used as the foundation for the forest mapping in this assessment was only available for one point in time. Therefore, trend in forest cover was not assessed within the park.

Data gaps and level of confidence

Unlike other parks with extensive forest habitats in the region, Colonial NHP did not have any long-term forest vegetation monitoring plots established as part of its initial Inventory and Monitoring plan. The NPS has recognized this deficiency and as of the summer of 2011, began establishing and monitoring forest vegetation in the Park.

It should also be noted that this forest cover metric treats all non-forest cover the same, whether it be a road or field or wetland or something else. Therefore, the non-forest habitats such as the extensive marsh lands at Jamestown, which are highly productive and valuable natural resource assets (but are unforested), will cause that study unit to have a lower score (Table 4.17). However, different types of non-forest land could have drastically different effects on the forest. Future research may want to take into account the variety of

Table 4.17. Percent of forest land cover and percent attainment scores for each park unit of Colonial NHP.

Park unit	Forested land cover (%)	Condition score (%)
Jamestown	46%	55%
Colonial Parkway	50%	69%
Yorktown	64%	100%
Colonial National Historical Park	**56%**	**90%**

consequences non-forested land can have on neighboring forest patches (The Heintz Center 2002). The overall level of confidence in this metric is fair.

Sources of expertise

Chris Ludwig, Chief Biologist, Virginia Department of Conservation and Recreation

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4.4.2 Connectivity

Relevance and context

Landscape connectivity, or the degree to which the landscape facilitates or impedes movement among resource patches (Taylor et al. 1993), has implications for many ecological processes, including spread of invasive species and conservation of native ones. While it is clear that habitat loss has detrimental effects, habitat fragmentation independent of habitat loss can also have important effects on juvenile dispersal, recolonization of disturbed sites, species migration, and genetic diversity (Clergeau and Burel 1997; Opdam and Wascher 2004; Dixo et al. 2009). A recent review of corridor studies emphasizes the effectiveness of linked habitat networks for species conservation (Gilbert-Norton et al. 2010). Habitat connectivity is especially important when habitat is degraded, rare, fragmented, or otherwise sparsely distributed (Flather and Bevers 2002; King and With 2002).

Landscape connectivity can be quantified in many ways (Calabrese and Fagan 2004); measurements of potential connectivity use general information on species mobility to estimate how well habitat patches are linked on the landscape. These measures are thought to be the most cost-effective for addressing questions of basic ecology and applied natural resource management (Calabrese and Fagan 2004).

Photo: Dorothy Geyer, Colonial NHP

Landscape connectivity has implications for the spread of invasive species and conservation of native species. Here, Japanese stiltgrass (*Microstegium viminium*) has become so prevalent within the Park it is difficult to estimate its abundance.

Data and methods

The forest map derived from the Virginia Natural Heritage (Patterson 2008) classification was used to assess this metric (Figure 4.35). Connectivity was measured as the percent of the forest area that would be connected for an organism capable of moving 360 m (1181 ft) across non-forest to get from one forest patch to another (Townsend et al. 2009). The distance of 360 m (1181 ft) was based on the distance that many small mammals and tree seeds can disperse (He and Mladenoff 1999; Bowman et al. 2002).

Thresholds

The threshold used was at least 75% of the forest area being connected for a species with a gap-crossing ability of 360 m (1181 ft; Townsend et al. 2009). A landscape with less than 75% of the forest area connected would be considered highly fragmented and degraded. The park was given a rating of either 0% or 100% attainment based on whether the one forest habitat map available for the park was above or below the threshold (Table 4.22).

Current condition and trend

The park as a whole is considered degraded by this metric (0% attainment) with only 59% of its forest connected (Table 4.18; Table 4.22; Table 4.23). However, the forests within the Yorktown unit are highly connected with 99% of forest habitat accessible to an organism that can cross 360 m (1181 ft) of non-habitat. Data are not available to assess trend in forest connectivity within the park.

Data gaps and level of confidence

This metric considers only the connectivity of forest patches. However, other types of landcover provide habitat for species in the park (e.g., wetlands, grasslands). Future assessments should consider the connectivity of these additional resources. Similarly, it was assumed that all "matrix" lands between

Table 4.18. Potential connectivity of forest fragments in Colonial NHP. Potential connectivity is 100% if all fragments are connected for a species that can move 360 m (1181 ft) across non-forest lands between patches. Condition score is 100% if the potential connectivity measure is at least 75%.

Park unit	Potential connectivity (%)	Condition score (%)
Jamestown	54%	0%
Colonial Parkway	48%	0%
Yorktown	99%	100%
Colonial National Historical Park	**59%**	**0%**

forest patches were equivalent in terms of movement. However, it is likely that a species would be more likely to cross a grassland than a road, for example, to move among forest patches. With a more sophisticated modeling approach, these differences in matrix quality could be incorporated into future assessments. Different species also have different movement abilities. A single, generic value of 360 m (1181 ft) was used to represent the gap-crossing ability of all organisms in the assessment. This assumption could be refined and individual species of interest could be considered. The overall level of confidence in this metric is fair.

Sources of expertise

Todd Lookingbill, Assistant Professor of Geography and the Environment, University of Richmond

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4.4.3 Impervious surface

Relevance and context

Impervious surface is a representation of human impact on the landscape and directly correlates to land development (Conway 2007). It includes rooftops and transport systems that decrease infiltration, water quality, and habitat, while increasing runoff (Center for Watershed Protection 2003). Percent impervious surface can provide a good approximation of watershed and habitat degradation, even within areas of little development (Booth and Reinelt 1993). Ecosystem components such as floral and faunal communities show considerable impact when impervious surface comprises 10% or more of habitat area (Arnold and Gibbons 1996; Lussier et al. 2008). For context, approximately 20% of a 30 km (19 mi) buffer around the park is impervious surface cover (Budde et al. 2009), but most of this development is downstream from the park (Figure 4.36).

Data and methods

Impervious surface data were taken from the 2001 National Land Cover Database (NLCD) in which all 30 m (98 ft) pixels were classified into 101 possible values (0–100%) (Homer et al. 2007). Mean impervious surface values were then calculated for all pixels in the park.

Thresholds

Many studies have documented threshold type effects on different ecosystem resources at relatively low impervious surface cover. A study in coastal New Jersey revealed that impervious surface as low as 2% may have effects on pH and specific conductance, and recommended a threshold between 2.4–5.1% (Conway 2007). In a Maryland study, impervious surface cover from 0.5–2% resulted in the decline of the majority (80%) of the stream taxa, while 2–25% cover showed a decline in 100% of the taxa (King et al. 2011). Watersheds with 3–5% cover have shown significant changes in stream flow, and Coastal Plain watersheds with 4–23% cover have shown a loss of sensitive aquatic invertebrate taxa (Utz et al. 2009; Yang et al. 2010). This assessment used a threshold value based on the idea that impervious surface totaling less than 10% of total area represented a good ecological condition (Table 4.22; Arnold and Gibbons 1996; Lussier et al. 2008).

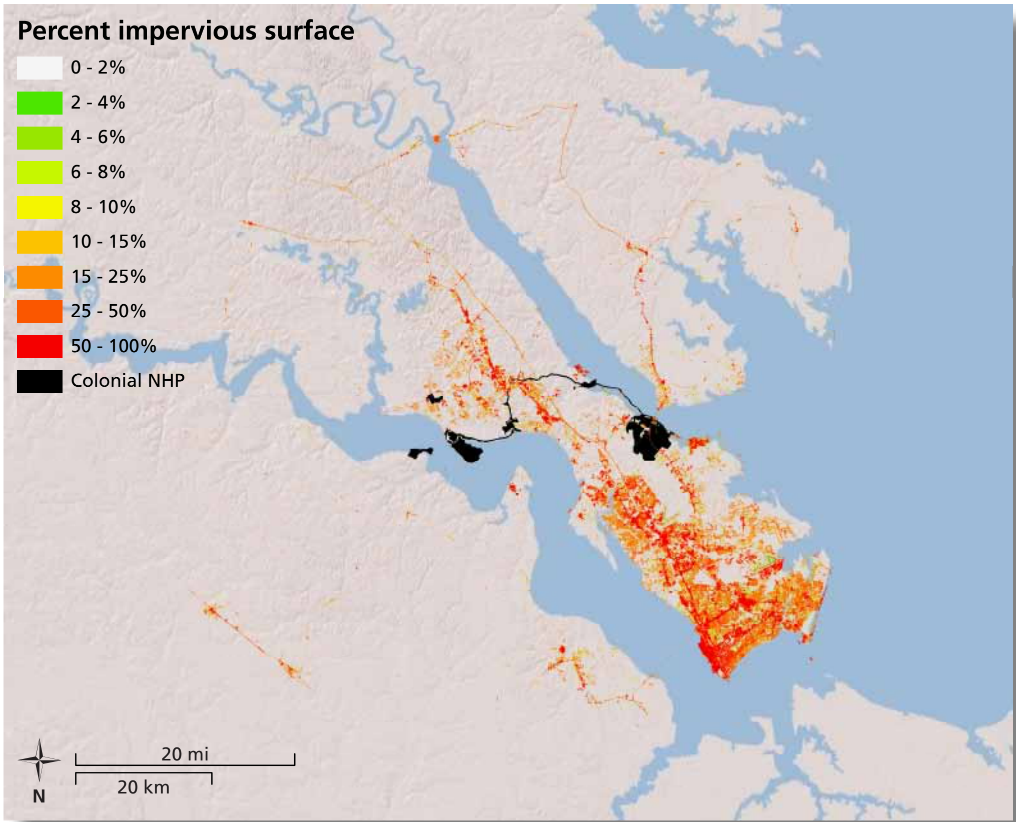

Figure 4.36. Impervious surface cover (2001) for a 30 km (19 mi) buffer surrounding Colonial NHP. Data from NPScape project (Budde et al. 2009). Red represents 30 m (98 ft) pixels with greater than 50% impervious surface cover.

Current condition and trend

Using the impervious surface estimate from the 2001 NLCD, all units of Colonial NHP except the Parkway met the ecological threshold (100% attainment; Table 4.22; Table 4.23). After the Parkway, the next highest value of impervious surface was found in Yorktown (Figure 4.37). The impervious surface analysis results for Yorktown were not unexpected as much of this area of the park is actively managed and maintained as an urban cultural landscape to concentrate visitor impacts and provide a focal point for park interpretation efforts. No data are available to assess trend directly for this metric.

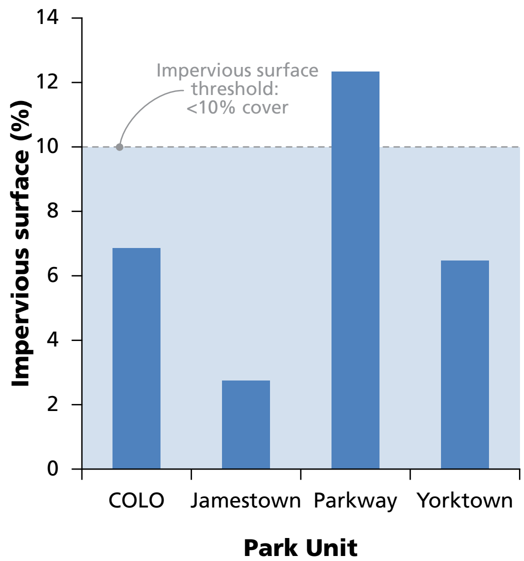

Figure 4.37. Impervious surface (mean percent cover per 30 m (98 ft) gridcell) estimates for park units within Colonial NHP.

Data gaps and level of confidence

Future determination of impervious surface would be beneficial to allow for updated assessment of this metric, as roads and facilities change within the park. A more local data source than the National Land Cover Database used would also allow for improved classification accuracy of impervious surfaces. Confidence in assessment of condition is fair. No assessment of trend was possible.

Sources of expertise

Matt Baker, Associate Professor of Geography, University of Maryland Baltimore County

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4.4.4 Warm-season grassland management

Relevance and context

Warm-season grass species are generally native to the Mid-Atlantic region, are deep-rooted and thus are better at stabilizing soils, and are more drought resistant. These bunch grasses provide habitat for birds and other animals by providing a complex three-dimensional structure with high species richness and varying extent of bare ground resulting from grazing, fires, and other disturbances (Peterjohn 2006). Conversely, most cool-season grasses are non-native to the Mid-Atlantic region and do not provide the habitat complexity of warm-season grasses (Peterjohn 2006). Most of the significant grassland habitat remaining in the Mid-Atlantic Coastal Plain is located on public lands (Watts 2000). In his assessment of the fields of Colonial NHP, Watts (2000) identified 177 patches of open habitat covering 379 ha (936 ac; 10.6% of the total area of the park). Although many of these patches were too small to be managed for wildlife, a significant portion of the total area had the potential to support species of conservation concern given appropriate management to restore native warm-season grasses (Figure 4.38). This management regime (schedule D in Figure 4.38) includes low frequency mowing (one mowing per year recommended), haying to prevent the buildup of plant biomass every year between early March and mid-May, or burning on a three-year rotation.

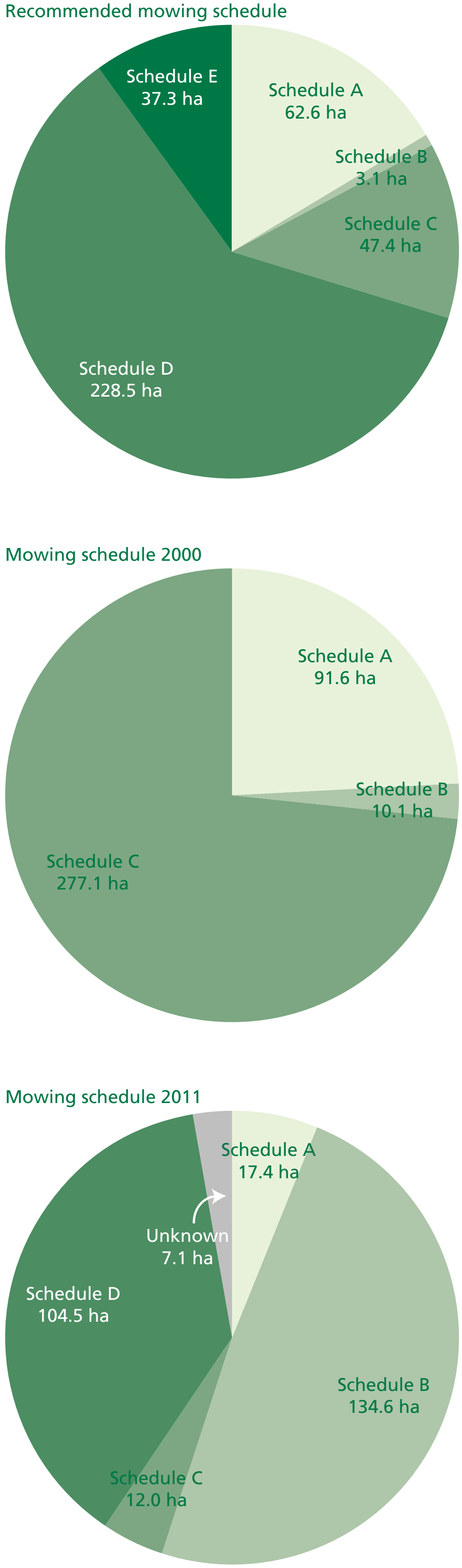

Figure 4.38. Watts' (2000) recommendation for area in various grassland management regimes (top). Hectares of open land area under different management schedules in 2000 (middle) and 2010 (bottom). Schedule D is the recommended regime to maintain native warm-season grasses.

Data and methods

Watts' 2000 description of grassland management was updated to 2010 status for this assessment. Park data were compiled on the current management regime of all grassland patches in the park. The 2010 data were compared to the threshold value to calculate current condition. Changes from 2000–2010 were used to assess trend.

Thresholds

The threshold was based on a management objective of 228.5 ha (564.6 ac; 60%) managed for warm-season grasses. Threshold attainment was expressed as the percentage of these 228.5 ha of grassland that are being

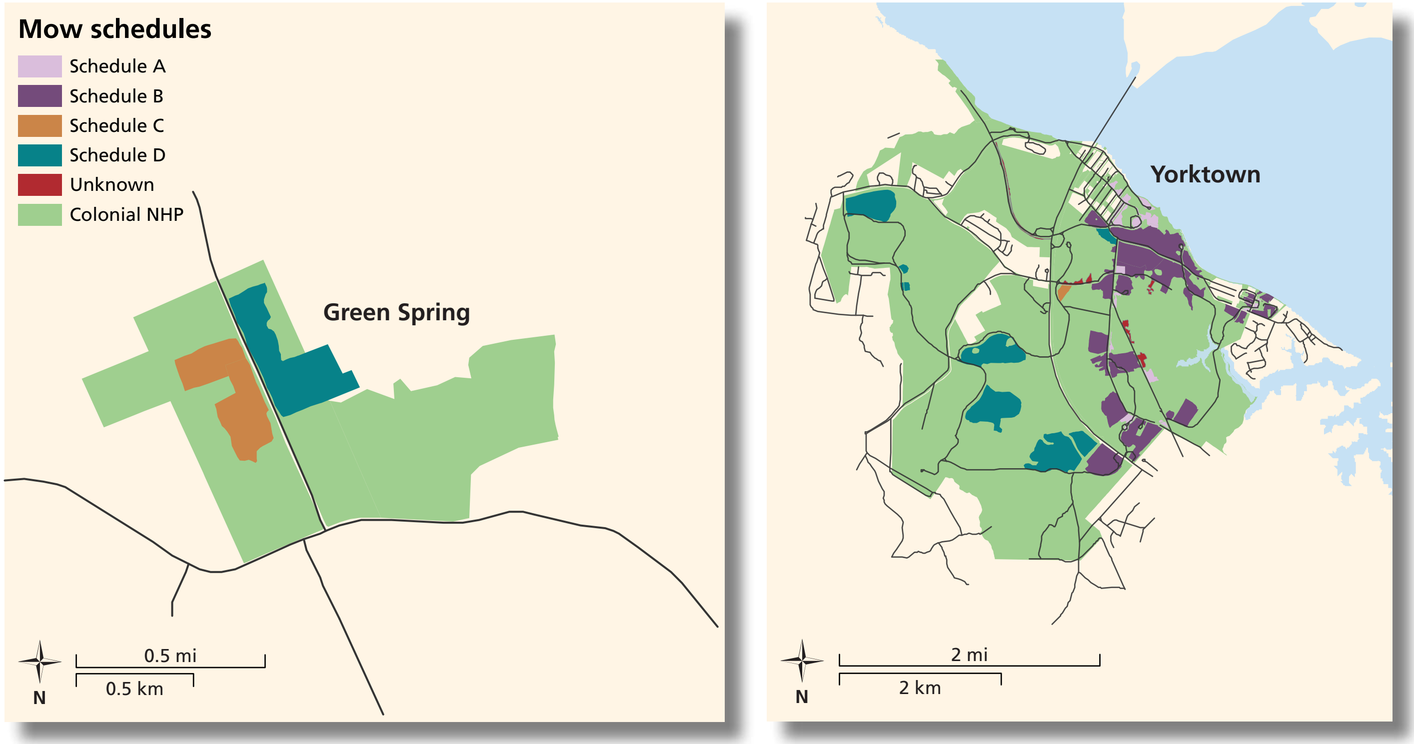

Figure 4.39. Current mowing schedules in Green Spring and Yorktown.

mowed in a regime supporting a warm-season grassland (i.e., schedule D of Watts 2000; Table 4.22).

Current condition and trend

Grassland area is almost entirely in Yorktown, with grassland comprising 15% of that subunit. In contrast, grassland area in Jamestown and Yorktown is less than 4% of the total landcover for each unit, with only Green Spring in the Jamestown unit having sizable fields. Eighty-five fields are delineated in Yorktown (Figure 4.39). Under current management, 38% of all grassland fields are being managed under the recommended Schedule D (63% attainment; Figure 4.38). Yorktown has 36.6% of its grassland fields managed in Schedule D (61% attainment). Green Spring in the Jamestown unit has 53.7% of its grassland fields managed in Schedule D (90% attainment; Table 4.22; Table 4.23).

In 2000, Watts could find no lands in the parks being managed according to his recommended mowing schedule D. This has changed in the past decade and there are now 11 fields managed explicitly for warm-season grasses over a total of 104 ha (257 ac; Figure 4.38). There has also been a shift towards increasing acreage in Schedule B Management, which represents an increasing mowing frequency rather than the recommended decreased mowing frequency. The overall trend is assessed as improving.

Data gaps and level of confidence

Confidence in this metric is assessed as limited based on incomplete knowledge about whether fields are successfully being converted to warm-season grasses. Changes in frequency of mowing is but one of the practices recommended by Watts (2000) to effectively realize this conversion, but it is the only recommendation for which data were available to assess. Additional data on the timing of mowing and the species of vegetation present would increase the confidence in this metric.

Sources of expertise

Bryan Watts, Directors, Center for Conservation Biology, College of William and Mary/Virginia Commonwealth University

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4.4.5 Contiguous grassland area

Relevance and context

The decline of grassland birds in the Mid-Atlantic can be attributed to a combination of factors, but one of the most important is the fragmentation of open space in the region (Watts 2000; Peterjohn et al. 2007). The combination of increasing urban development and aggrading forests has generally resulted in fewer and smaller grassland patches. In Virginia, the amount of open grassland has been reduced by 55% since 1945 and currently comprises less then 2% of the landscape (Watts 2000). Up to 95% of these grassland patches are < 10 ha (25 ac) in size. Most grassland bird species are highly sensitive to patch size, and grassland birds are experiencing one of the highest rates of decline of any group of birds in North America (Peterjohn and Sauer 1999). Historical and cultural parks may be critical refuges for grassland birds in the Northeast (Peterjohn et al. 2007). In a recent inventory of four battlefield parks (Antietam, Monocacy, Manassas, and Gettysburg), compositions of grassland communities were highly variable among sites, but a consistent finding was that breeding grassland birds avoided fields < 10 ha (25 ac) in size.

Data and methods

Data used for this assessment were Watts' 2000 description of the field sizes in Colonial NHP and a 2010 update of field status provided by park staff. All fields were characterized by size in both of these data sets. This metric is based on the largest single contiguous patch of grassland within the park.

Mowed and landscaped grassland within Colonial NHP.

Photo: Allison Dungan, IAN Image Library

Table 4.19. Largest grassland patch size by park unit in Colonial NHP.

Park unit	Largest patch size (ha)
Jamestown	18.2
Colonial Parkway	2.2
Yorktown	77.5
Colonial National Historical Park	**77.5**

Thresholds

Watts (2000) provides a minimum patch size requirement of <10 ha (25 ac). Peterjohn (2006) also developed criteria to define the area needed to support grassland bird communities. According to his assessment, contiguous grassland areas <4.9 ha (12 ac) in size are generally avoided by grassland birds. Areas 4.9–10 ha (12–25 ac) are occupied by some species, areas 10–20 ha (25–50 ac) are consistently occupied by some species, and areas 40–100 ha (100–250 ac) can support entire grassland bird communities. The threshold used in this assessment was having at least one patch ≥ 10 ha, representing moderate to very good potential habitat. The assessment was conducted at the park scale for 2010 and repeated for the 2000 data set. The park was given a rating of 0, 50, or 100% attainment based on the number of years in which the park met the threshold criterion (Table 4.22).

Current condition and trend

The park met the ecological threshold of having at least one patch ≥ 10 ha (25 ac) in size both years for an attainment score of 100% (Table 4.19; Table 4.22; Table 4.23). Four patches were > 20 ha (50 ac) in size. All individual park units also met the threshold, with the exception of Colonial Parkway. However, the majority of patches (>75%) were < 2 ha (5 ac) in size. The park met the threshold patch size using both the 2000 and 2010 data, for an assessment of no discernable trend.

Data gaps and level of confidence

Confidence in this metric is assessed as good. The size of grassland patches can be quantified with a high level of accuracy using relatively simple mapping techniques, and little variation was observed between the two sample years. The level of confidence would be increased by additional research to refine the threshold, (e.g., the influence of patch quality on minimum patch size, species-specific minimum area requirements).

Sources of expertise

Bryan Watts, Directors, Center for Conservation Biology, College of William and Mary/Virginia Commonwealth University

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4.4.6 Soundscapes

Relevance and context

A soundscape is defined by the total ambient acoustic environment, including the total ambient sound level of a given area (Wrightson 2000). The importance of soundscapes has become an increasingly important component of landscape ecology (Truax and Barrett 2011). In a park setting, the soundscape is comprised of both natural ambient sounds and human-made sounds within the park. Natural soundscapes are valuable resources that influence and are a part of the ecological communities that parks seek to preserve (Miller 2008). Examples of acoustic resources include sound sources such as wildlife, waterfalls, wind, rain, and historical and cultural sounds (Pijanowski et al. 2011). Properly functioning soundscapes are important for intraspecies communication, territory establishment, courting and mating, nurturing and protecting young, predation and predator avoidance, and effective use of habitat. Furthermore, natural sounds are thought to provide valuable indicators of the health of various ecosystems. Specific species may be sensitive to sound, and changes in sound regime can displace animals, as well as make them accustomed to noise and eventually not react to noise disturbances (Barber et al. 2009).

Visitors also appreciate natural sounds throughout the parks, which offer a source of relaxation and pleasant experiences. As was reported to the U.S. Congress, a system-wide survey of park visitors revealed that nearly as many visitors come to national parks to enjoy the natural soundscape (91%) as come to view the scenery (93%; NPS 1995). Established in 2000, The Natural Sounds Program is a unit of the NPS Natural Resource Stewardship and works to help parks manage the acoustic environment in a way that addresses the protection of park resources to ensure educational and inspirational visitor experiences. As a result, the Natural Sounds Program aims to discern the difference between the physical sound sources and human perceptions of those sounds. The program also works closely with the Federal Aviation Administration (FAA) to develop Air Tour Management Plans (ATMP) in national parks to address noise effects from overflights and commercial air tours. Additional management efforts in the preservation of natural soundscapes associated with national park units are through compliance with Director's Order 47: Sound Preservation and Noise Management (NPS 2000).

Recent studies in national parks have demonstrated that noise pollution is not a threat restricted to developed areas and that many protected natural areas experience significant noise loads (Miller 2008; Barber et al. 2011). In 2010, the NPS established a Soundscape Management Plan (SMP) for Zion National Park which outlines an approach to manage and protect the acoustic environment for visitor enjoyment and for wildlife needs (NPS 2011). Other acoustic work in Sequoia National Park was used to identify 25 vegetation regimes in the park with unique management goals (Krause et al. 2011).

Data and methods

Unwanted noise is a growing concern within all park units (Jamestown, Colonial Parkway, and Yorktown) of Colonial NHP because it can interfere with communications and the visitor experience, bother surrounding neighborhoods, and potentially disrupt wildlife activities. Colonial NHP has been recently considered one of the few parks in the Northeast as a potential prototype park to implement a streamlined Air Tour Management Plan (ATMP), which would allow for air tour operations over the park area. In 2005, another proposal considered the addition of an alternative transportation system (ATS) that would add a fixed-route transit service within Colonial NHP. Implementing this proposal would potentially impact soundscapes, air quality, and visitor use and experience (NPS 2005). As part of this proposal, a noise analysis was conducted at 12 different locations in and around the project area (Table 4.20). This noise analysis followed the Federal Highway Administration (FHWA) noise impact assessment procedures and criteria because the predominant project-related noise sources are motor vehicles. In the

Table 4.20. Noise monitoring data for Colonial NHP (NPS 2005). L_{eq} = equivalent sound level measured. FHWA = Federal Highway Administration.

Receptor number	Receptor location	L_{eq} measured	FHWA criterion
Jamestown			
1	Jamestown Island Loop Drive	51	57
2	Jamestown Island Parking Area	53	67
3	Jamestown Settlement-Route 31 at Route 359	65	67
4	Residents at Back River Lane	51	67
5	Colonial Parkway near attempted settlement sign	64	67
6	Colonial Parkway at the Isthmus pullout	65*	67
7	Williamsburg Visitor Center—Route 132Y	69	67
8	Route 31 at Old Colony Lane	62t	67
Colonial Parkway			
9	Residences at Jefferson Street	64**	67
10	Residences at Lakeshead Drive	50**	67
11	Colonial Parkway at Jones Mill Pond parking area	67	67
12	Residences at Mason Row	51**	67

*wind noise was a substantial noise source at this location. **Extrapolated from measurements at nearby location.

Table 4.21. Noise abatement criteria (NAC) one hour, A-weighted sound levels in decibels dB(A). *L_{eq} (h) is an energy-averaged, one hour, A-weighted sound level in decibels. Source: 23 CFR Part 772 Procedures for abatement of highway traffic noise and construction noise.

Activity Category	L_{eq} (h)*	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purposes.
B	67 (Exterior)	Picnic areas, recreation areas, playgrounds, parks, residences, schools, hospitals.
C	72 (Exterior)	Developed lands and properties (activities not included in Categories A or B above)
D	--	Undeveloped lands
E	52 (Interior)	Residences, hotels, public meeting rooms, etc.

analysis, sound and noise were defined by loudness, frequency, and duration. Loudness is the sound pressure level measured on a logarithmic scale in units of decibels (dB). An A-weighted dB(A) frequency filter is used for a community noise impact assessment. This filter is necessary because it best approximates the way humans hear sounds.

Thresholds

The FHWA has established Noise Abatement Criteria (NAC) according to land use, to help protect the public health and welfare from excessive traffic noise (Table 4.21; 4.22).

Current condition and trend

The only data available concerning soundscapes in the park is the noise monitoring data gathered for the ATS Plan from 2005 and this only addresses motor vehicles as a noise source. Therefore, current condition and trend cannot be assessed at this time (Table 4.22; Table 4.23).

Data gaps and level of confidence

Currently no data are available to assess this metric. Research is also needed to identify the types of sounds within Colonial NHP, to establish a baseline for sound levels. A comprehensive soundscape management plan (SMP) is recommended for the park.

Sources of expertise

National Park Service, Natural Sounds Program, www.nature.nps.gov/naturalsounds

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4.4.7 Natural lightscapes/night sky

Relevance and context

The lower 48 states of the U.S. have some of the highest levels of artificial lighting in the world, with 60% of the population having insufficient night time darkness to fully transition over from cone to rod vision (Longcore and Rich 2004). Natural lightscapes, including dark night skies, are an important component of visitors' park experiences (NPS 2007). Two recognized aspects of light pollution are astronomical (the ability to view stars and other celestial bodies) and ecological (the effects on wildlife and wildlife behavior) pollution (Longcore and Rich 2004). Ecological impacts on wildlife can include changes to biodiversity, migration patterns, and habitat quality for birds, trees, marine mammals, fish, and sea turtles, as well as changing animal interactions such as prey species losing the protective cover of darkness (Rich and Longcore 2006). Regulations that limit the intensity of light and maintain longer wavelengths minimize the negative effects of artificial lighting, as already implemented, for example, in most counties in Florida for the protection of sea turtles (Salmon 2003).

Data and methods

Night sky brightness is measured in units of "V magnitudes" per arcsecond^{-2} using charged coupled device (CCD) digital cameras with a "V" (green) filter. These measurements can then be compared to a reference value representing natural sky conditions. At present, no measurements of night sky brightness have been collected in Colonial NHP.

Thresholds

A reference condition of >21.5 magnitudes arcsecond^{-2} represents a value half a magnitude brighter than the observed and modeled value for natural sky brightness and has been recommended by the NPS Night Sky Team as a threshold value (Garstang 1989a; Skiff 2001). During a full moon or in suburbs of a large city, V magnitudes of approximately 18.0 magnitudes arcsecond^{-2} have been previously measured, with one study recording a value of 18.7 magnitudes arcsecond^{-2} for urban centers from Rhode Island down to Connecticut, representing approximately 21 times natural background level (Table 4.22; Garstang 1989a; Skiff 2001).

Current condition and trend

The condition of natural lightscapes in Colonial NHP is unknown. No data are available to assess current condition or trend directly for this metric. However, even with improvements in lighting technology, a very high correlation between increasing human population and light pollution throughout the U.S. suggests that night sky brightness is at risk of increasing (Table 4.22; Table 4.23; Garstung 1989b).

Data gaps and level of confidence

Data are not currently available for an assessment of this metric. Night sky resource inventories are needed in the park area and will contribute to Air Quality Related Value Assessments being completed servicewide. Colonial NHP should be considered for inclusion in the national assessment of park units by Air Resources Division for night sky brightness to fill this important data need.

Sources of expertise

National Park Service Air Resources Division, Night Sky Team http://www.nature.nps.gov/air/lightscapes/monitorData/index.cfm

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Table 4.22. Thresholds and summary of data used in the Colonial NHP condition assessment.

Metric	Indicator	Source	Park unit	Samples	Years	Threshold	Result	Current condition	Trend	% Attainment Park unit	% Attainment Overall
Air Quality											
Ozone	5-year interpolated 4th highest daily maximum 8-hour ozone concentration	NPS ARD 2011	Jamestown Parkway Yorktown	1	1999–2009	≥76ppb = 0; 76-60 scaled 0-100; ≤60 ppb =100	77	Very degraded	Improving	0%	**0%**
Total wet nitrogen deposition	5-year average interpolated total nitrogen wet deposition	NPS ARD 2011	Jamestown Parkway Yorktown	1	2001–2009	<1 kg/ha/yr	4.22	Very degraded	Improving	0%	**0%**
Total wet sulfur deposition	5-year average interpolated total sulfur wet deposition	NPS ARD 2011	Jamestown Parkway Yorktown	1	2001–2009	<1 kg/ha/yr	5.32	Very degraded	Stable	0%	**0%**
Visibility	5-year average interpolated haze index in deciviews	NPS ARD 2011	Jamestown Parkway Yorktown	1	2001–2009	≤2 dv	11.7	Very degraded	Stable	0%	**0%**
										Air quality overall	**0%**
Water Quality											
Non-tidal B-IBI	Average of macroinvertebate, habitat, and water quality scores	EPA CBP; Foreman et al. 2008	Jamestown	7	2000, 2003, 2008	≥3	3 of 7 samples	Fair	No trend	42.9%	**14.3%**
			Parkway	1	2003		0 of 1 sample	Very degraded	No trend	0.0%	
			Yorktown	5	2000, 2003		0 of 5 samples	Very degraded	No trend	0.0%	
Tidal B-IBI	Macroinvertebrate assemblage	EPA CBP; Versar	James River	46	2000–2009	≥3	19 of 46 samples	Fair	Degrading	41.3%	**41.3%**
			York River	97	2000–2009		40 of 97 samples	Fair	Degrading	41.2%	
Water Quality Index	Total Nitrogen (mg/L)	CBP CIMS; EcoCheck 2011	James River	73	2000–2009	≤0.9 mg/L	67 of 73 samples	Very good	Stable	91.8%	**53.9%**
			York River	146	2000–2009	≤0.5 mg/L	80 of 146 samples	Fair	Stable	54.8%	
	Total Phosphorus (mg/L)	CBP CIMS; EcoCheck 2011	James River	75	2000–2009	≤0.07 mg/L	39 of 75 samples	Fair	Stable	52.0%	
			York River	150	2000–2009	≤0.05 mg/L	94 of 150 samples	Good	Stable	62.7%	
	Chlorophyll *a* (µg/L)	CBP CIMS; Lacouture et al. 2006	James River spring	26	2000–2009	≤20.9 µg/L	19 of 26 samples	Good	Degrading	64.2%	
			James River summer	27	2000–2009	≤9.5 µg/L	15 of 27 samples	Good	Degrading		
			York River spring	57	2000–2009	≤2.8 µg/L	1 of 57 samples	Very degraded	Degrading	3.5%	
			York River summer	58	2000–2009	≤4.5 µg/L	3 of 58 samples	Very degraded	Degrading		

Table 4.22. Thresholds and summary of data used in the Colonial NHP condition assessment.

Metric	Indicator	Source	Park unit	Samples	Years	Threshold	Result	Current condition	Trend	% Attainment	
										Park unit	Overall
Water Quality Index cont.	Dissolved Oxygen concentration	CBP CIMS; US EPA 2003	James River	68	2000–2009	≥5 mg/L	68 of 68 samples	Very good	Stable	100.0%	53.9%
			York River	129	2000–2009	≥5 mg/L	120 of 129 samples	Very good	Stable	93.0%	
	Secchi depth	CBP CIMS; Buchanan et al. 2005	James River	87	2000–2009	≥0.7 m	13 of 87 samples	Very degraded	Stable	14.9%	
			York River	175	2000–2009	≥2.0 m	4 of 175 samples	Very degraded	Stable	2.3%	
										Water quality overall	**36%**
Biological Integrity											
Submerged aquatic vegetation (SAV)	Seagrass area	VIMS; Orth et al. 2010	James River	10	2000–2009	0 ha	8 of 10 sampling years	Good to very good	Improving	80.0%	**40.0%**
			York River	10	2000–2009	567 ha	0 of 10 sampling years	Very degraded	Degrading	0.0%	
Reptile and amphibian richness	Detection	Mitchell 2004; Christensen 2009	Jamestown	268	2001–2003, 2008	N/A	37 of 68 expected species	Fair	N/A	54.4%	**83.8%**
			Parkway	65	2001–2003, 2008	N/A	8 of 68 expected species	Very degraded	N/A	11.8%	
			Yorktown	127	2001–2003, 2008	N/A	41 of 68 expected species	Good	N/A	60.3%	
Mammal richness	Detection	Barry et al. 2010	Jamestown	46	2003–2004	N/A	14 of 40 expected species	Degraded	N/A	35.0%	**67.5%**
			Parkway	26	2003–2004	N/A	6 of 38 expected species	Very degraded	N/A	15.8%	
			Yorktown	83	2003–2004	N/A	21 of 40 expected species	Fair	N/A	52.5%	
Lepidoptera and Odonata richness	Detection	Chazal 2006	Jamestown & Parkway	36	2003–2004	N/A	99 of 126 expected species	Good	N/A	78.6%	**78.6%**
			Yorktown & Parkway	23							
Forest interior dwelling species (FIDS)	Detection	USGS Breeding Bird Survey; Bradshaw 2003	Jamestown	>7000	1992–2007, except 1993 and 2002	>4 sensitive FIDS or >1 highly sensitive FIDS	5 & 0, respectively	Very good	No trend	100.0%	**100.0%**
			Parkway				9 & 2, respectively	Very good	No trend	100.0%	
			Yorktown				10 & 3, respectively	Very good	No trend	100.0%	
Grassland bird functional groups	Number of functional groups	USGS Breeding Bird Survey; Bradshaw 2003	Jamestown, Parkway, & Yorktown	>1000	1992–2007, except 1993 and 2002	0 functional groups = 0; 1 functional group = 25; 2 functional groups = 50; 3 functional groups = 75; 4 functional groups = 100	14 of 15 samples had 1 functional group; 1 sample had 0 functional groups	Degraded	No trend	21.7%	**21.7%**
Deer density	Number of deer	Not available	Jamestown, Parkway, & Yorktown	N/A	N/A	8.0 deer/km^2	N/A	N/A	N/A	N/A	N/A

Table 4.22. Thresholds and summary of data used in the Colonial NHP condition assessment.

Metric	Indicator	Source	Park unit	Samples	Years	Threshold	Result	Current condition	Trend	% Attainment	
										Park unit	Overall
Invasive plant species	Percent invasive species cover	Gounaris and Grubbs 2000	Jamestown, Parkway, & Yorktown	1 all invasives inventory; 3 bamboo; 6 common reed	1999–2000 all invasives; 1999-2010 bamboo; 2003-2010 common reed	≤25% cover of park land	43% (1500 ha [3700 ac] infested)	Very degraded	Degrading	0.0%	0.0%
										Biological integrity overall	**56%**
Landscape Dynamics											
Percent forest	Percent cover	Patterson 2008	Jamestown	1	2005	<30% = 0; 30-59 scaled 0-100; >59% =100	46.0%	Fair	N/A	55.0%	**90.0%**
			Parkway				50.0%	Good	N/A	69.0%	
			Yorktown				64.0%	Very good	N/A	100.0%	
Connectivity	360 m (1181 ft) between forest patches	Patterson 2008	Jamestown	1	2005	≥75%	54%	Very degraded	N/A	0.0%	**0.0%**
			Parkway				48%	Very degraded	N/A	0.0%	
			Yorktown				99%	Very good	N/A	100.0%	
Impervious surfaces	Mean impervious surface for all 30 m (98 ft) pixels of park	National Land Cover Database; Homer et al. 2007	Jamestown	1	2001	≤10%	2.8%	Very good	N/A	100.0%	**100.0%**
			Parkway				12.3%	Very degraded	N/A	0.0%	
			Yorktown				6.5%	Very good	N/A	100.0%	
Warm-season grassland management	Grassland area mowed	NPS; Watts 2000	Jamestown	2	2000, 2010	228.5 ha (565.6 ac) (60%)	53.7%	Very Good	Improving	90.0%	**63.0%**
			Parkway				N/A	N/A	N/A	N/A	
			Yorktown				36.6%	Good	Improving	61.0%	
Contiguous grassland area	Grassland patch size	NPS; Watts 2000	Jamestown	2	2000, 2010	At least one patch ≥10 ha (25 ac)	18.2 ha	Very good	No trend	100.0%	100.0%
			Parkway				2.2 ha	Very degraded	No trend	0.0%	
			Yorktown				77.5 ha	Very good	No trend	100.0%	
Soundscape	Equivalent sound level	Not available	All	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Night sky	Night sky brightness	Not available	All	N/A	N/A	>21.5 magnitudes arcsecond^{-2}	N/A	N/A	N/A	N/A	N/A
										Landscape dynamics overall	**71%**

Table 4.23. Percent attainment for each indicator and each habitat within Colonial NHP.

Indicators	Reference condition attainment	Current condition	Trend in condition
Non-tidal benthic index of biotic integrity (B-IBI)	14%	Very degraded	No trend
Reptile & amphibian richness	60%	Fair/Good	NA
Lepidoptera and Odonata richness	31%	Degraded	NA
Invasive plant species	0%	Very degraded	Degrading
Non-tidal wetland habitat	**26%**	**Degraded**	**-**
Mammal richness	29%	Degraded	NA
Grassland bird functional groups	23%	Degraded	No trend
Invasive plant species	0%	Very Degraded	Declining
Warm-season grassland management	63%	Good	Improving
Contiguous grassland area	100%	Very Good	No trend
Grassland habitat	**43%**	**Fair**	-
Ozone	0%	Very Degraded	Improving
Forest interior dwelling species (FIDS)	100%	Very Good	No trend
Invasive plant species	0%	Very Degraded	Degrading
Percent forest	90%	Very Good	N/A
Impervious surface	100%	Very Good	N/A
Forest habitat	**58%**	**Fair**	**-**
Tidal benthic index of biotic integrity (B-IBI)	41%	Fair	Declining
Water quality index	54%	Fair	Stable
Submerged aquatic vegetation (SAV)	40%	Degraded/Fair	Improving
Invasive plant species	0%	Very Degraded	Declining
Tidal wetland habitat	**34%**	**Degraded**	**-**
OVERALL COLONIAL NHP	**40%**	**Degraded/Fair**	**-**

Photo: Jean Dickey, NPS

Chapter 5: Discussion

5.1 COLONIAL NATIONAL HISTORICAL PARK CONTEXT FOR ASSESSMENT

The resources of Colonial National Historical Park possess historical, aesthetic, cultural, economic, and scientific values. The condition of natural resources in Colonial NHP must be considered in context of its geography, legislative mission, and history. Founding documents for the park require management to certain historical conditions that include the preservation of the original Jamestown Colony site, the landscape and buildings associated with the Revolutionary War, and the scenic Parkway that connects Jamestown Island to Yorktown Battlefield.

The natural condition of these resources have been assessed systematically through describing the park resource setting; consulting with relevant stakeholders on the assessment approach; compiling available data for resources and stressors; identifying suitable metric indicators of resource condition; using available literature and expert opinion to develop thresholds for these metrics; and deriving a percentage score for each habitat and the park as a whole. Based on this information, this final chapter summarizes the key conditions and stressors and threats to resources within the park, and provides recommendations for maintaining or improving these park resources and, in turn, the park as a whole.

5.2 PARK NATURAL RESOURCE CONDITION

Acknowledging different park management objectives required for each habitat type within Colonial NHP, the overall natural condition of the park has been assessed based on the following four habitat types: non-tidal wetland, grassland, forest, and tidal wetland as outlined in Chapter 3. For each habitat, a subset of metrics outlined in Chapter 4 was used to provide a score for habitat condition. Not all metrics from Chapter 4 were applicable in calculating habitat condition scores due to correlation of metrics that would result in unbalanced weighting (e.g., although all four air quality metrics could reasonably be applied to assess forest habitat, only ozone was included in order to preserve a balance with other metrics).

Painting: Sidney E. King

Portrayal of settlers coming ashore in 1607.

Photo: Gary P. Fleming, Virginia Natural Heritage Program

Non-tidal wetland.

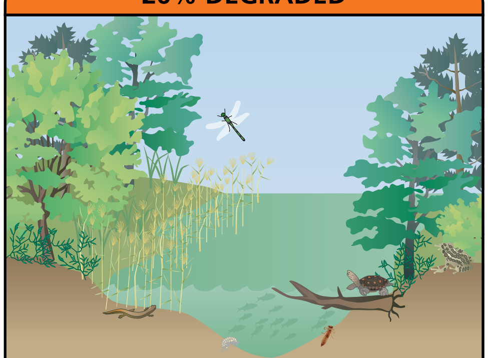
Non-tidal wetland habitat

Non-tidal wetlands were assessed as being in "degraded" condition, based on attaining 26% of desired threshold scores. Confidence in the assessment for this habitat is very limited, based on minimal data availability. Several of the metrics available did not yield information specific to non-tidal wetlands. For example the non-tidal benthic index of biotic integrity (B-IBI) assessed macroinvertebrate populations within streams; while streams and wetlands share a hydrologic connection, biotic communities within each habitat are not synonymous. Invasive species cover data specific to this habitat is missing. For two metrics, herpetofauna and Lepidoptera/Odonata richness, data was divided by expected species in each habitat, though many species are mobile and exist across multiple habitats over the course of their life history. Observation of species, or lack thereof, within the non-tidal wetland habitat only reveals a snapshot of species presence, but not absence or population trends within the Park. Additionally, all four metrics used to assess non-tidal wetlands were biotic; water quality and landscape metrics would be useful additions to this assessment.

While non-tidal wetlands provide valuable habitat for animals and rare vegetation communities, they face numerous threats. Hydrology is crucial to maintaining these wetland habitats, but groundwater levels and contamination are poorly understood. As development increases within the watershed, water table levels can be expected to change as groundwater is withdrawn for consumptive commercial and residential uses. Several instances of pollutant contamination have been documented from properties adjacent to Colonial NHP, such as sewage spills from Colonial Williamsburg and hazardous waste at Commonwealth of Virginia and U.S. Navy sites, but the effects of such contamination on non-tidal wetlands in the Park are poorly known.

NON-TIDAL WETLAND HABITAT

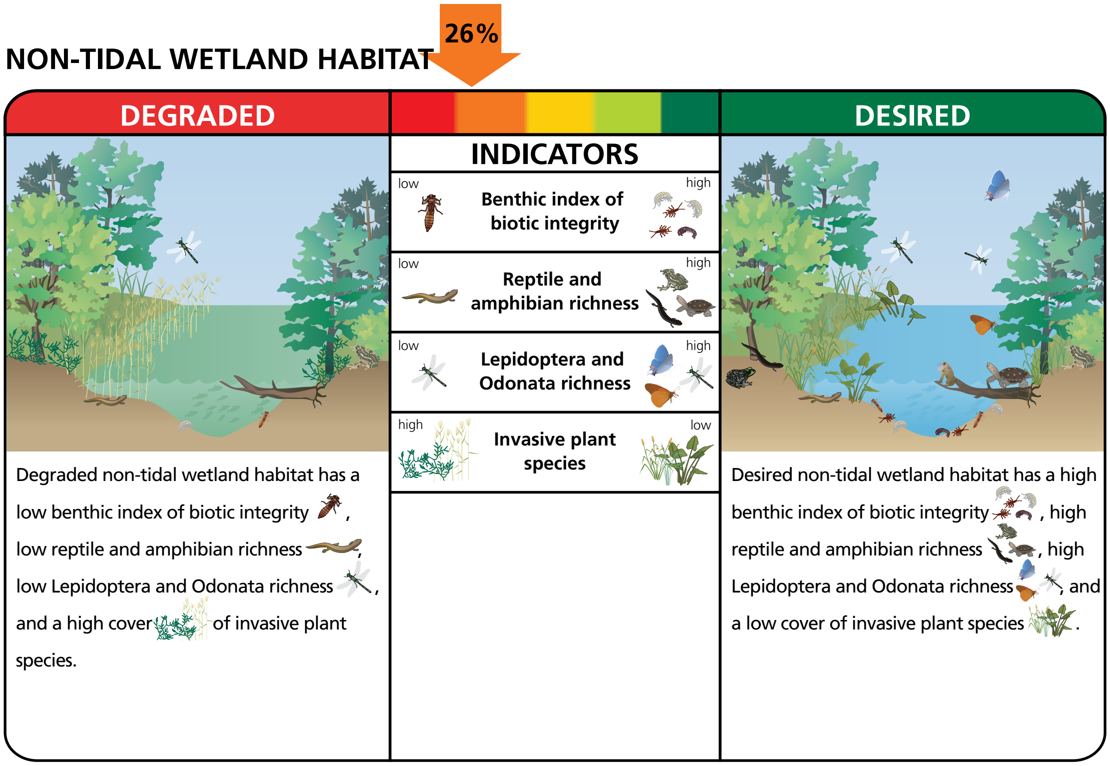
26% DEGRADED



Assessed non-tidal wetland habitat had a low benthic index of biotic integrity, fair/good reptile and amphibian richness, low Lepidoptera and Odonata richness, and a very high cover of invasive plant species.

Indicators	Reference condition attainment	Current condition	Trend in condition
Non-tidal benthic index of biotic integrity (B-IBI)	14%	Very degraded	No trend
Reptile & amphibian richness	60%	Fair/Good	NA
Lepidoptera and Odonata richness	31%	Degraded	NA
Invasive plant species	0%	Very degraded	Degrading
Non-tidal wetland habitat	**26%**	**Degraded**	-

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good



Conceptual range of habitat condition from degraded to desired for non-tidal wetland habitat with metrics selected for evaluation of park habitat.

Key findings	Recommendations
Non-tidal wetland habitat	
• High herpetofauna diversity, including several imperiled amphibians	• Continue to perform annual surveys of key herpetofauna species to analyze trends.
• Several rare or endemic vegetation assemblages threatened by invasive plants	• Conduct more comprehensive wetland mapping and monitoring. • Continue to treat invasive plant species. • Re-plant native species.
• Threats from water quality, groundwater withdrawals, and pollutant contamination	• Use targeted monitoring to identify specific stressor-response relationships. • Work collaboratively with federal, state, and local partners to identify and reduce pollutant sources.

Key findings and recommendations for non-tidal wetland habitat in Colonial NHP.

Photo: Colonial NHP

Cultural grassland at Yorktown Battllefield.

Grassland habitat

Warm-season grassland was assessed as fair in condition based on 43% attainment of desired grassland bird, mammal, land cover, and management thresholds. Confidence in this assessment score, however, is limited based on minimal data availability. Grasslands are the least abundant of the four habitat types assessed, comprising only 9% of Colonial NHP. Nearly all grassland area is located in Yorktown with a few fields in the Green Spring section of the Jamestown subunit (after reclassifying mowed roadside, utility corridors, and other built-up lands as non-habitat).

Due to the cultural mandate of the Park, mowing of grasslands has been a necessity for maintenance of cultural and aesthetic values. Subsequently, management of the natural resource objectives of the grasslands has proven difficult. Nevertheless, the Park has made substantial progress since 2000 in decreasing the frequency of mowing on many of its fields. Alternate management actions currently employed in comparative parks in the region (e.g., Fredericksburg and Spotsylvania National Military Park, Richmond National Battlefield Park) include prescribed burning and deer exclosures that the Park may want to consider for restoring native grassland ecosystems. At present, Colonial NHP has not replanted any of its fields in native warm-season grasses. If this type of active restoration is desirable in the future, other parks in the region could be consulted as model programs (e.g., Monocacy National Battlefield).

Direct measures of the grassland vegetation community would be beneficial to future condition assessments. These include measures of successional stage as well as measures of abundance and richness of native grassland/meadow specialist and non-native vascular plants. Relevant metrics for assessing the condition of these resources would include

GRASSLAND HABITAT

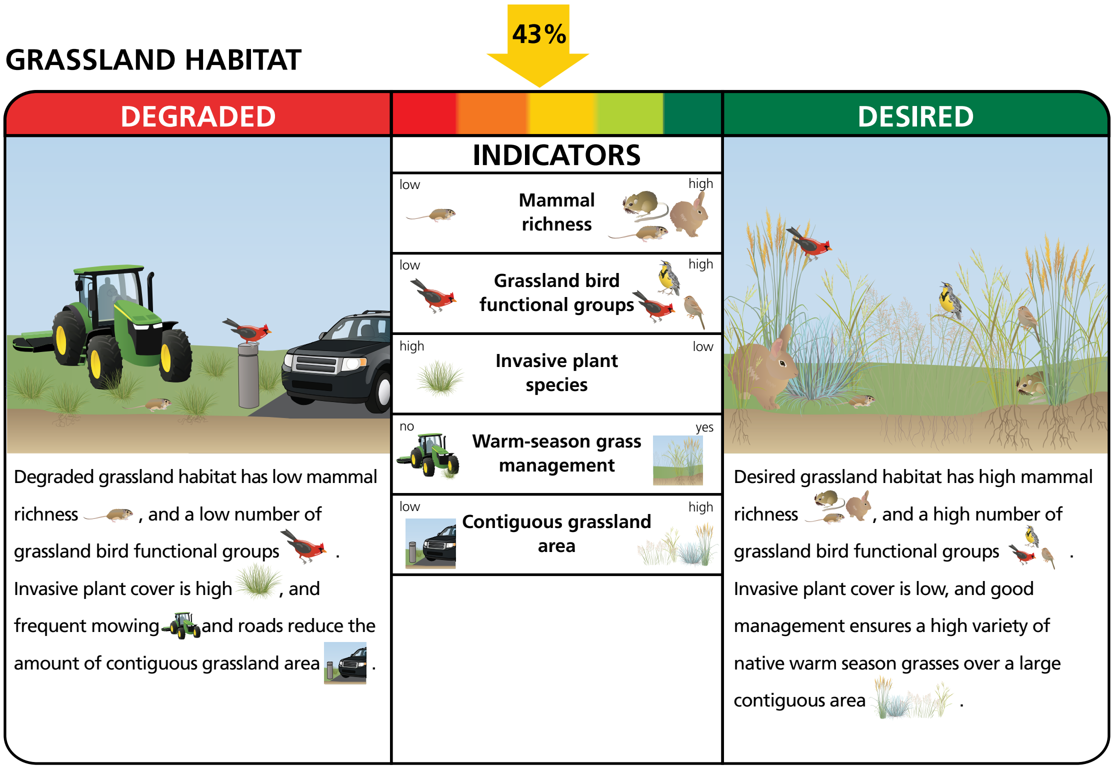
43% FAIR

Assessed grassland habitat had degraded mammal richness, a low number of grassland bird functional groups, and invasive plant cover is very high. Warm-season grassland management is good, with a reduction in mowing frequency on many fields. Contiguous grassland area is high.

Indicators	Reference condition attainment	Current condition	Trend in condition
Mammal richness	29%	Degraded	NA
Grassland bird functional groups	23%	Degraded	No trend
Invasive plant species	0%	Very Degraded	Declining
Warm-season grassland management	63%	Good	Improving
Contiguous grassland area	100%	Very Good	No trend
Grassland habitat	**43%**	**Fair**	-

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

i) proportion of plot cover; ii) species counts; and iii) proportion of total species (Latham 2009). Direct measures of invasive species in grassland habitat would also assist future assessments. Improved monitoring of small mammals and birds within native grassland habitats is recommended including grassland bird abundance and density (Goodwin and Wakamiya 2010). Deer monitoring also would be beneficial for this habitat type. Deer have the potential to impact grassland vegetation though trampling, preferential grazing, and general overgrazing, though the carrying capacity of grasslands is thought to be higher than for forest ecosystems (Horsely et al. 2003).



Conceptual range of habitat condition from degraded to desired for grassland habitat showing indicators appropriate to assess condition.

Key findings	Recommendations
Grassland habitat	
• Low grassland bird diversity based on limited data	• Augment data sources by incorporating volunteer birding activities. • Provide a more detailed analysis of Breeding Bird Survey data. • Develop density estimates including effects of detection probabilities in sample efforts.
• Unknown vegetation composition	• Initiate monitoring of relevant vegetation metrics, including diversity and invasive species.
• Too few fields being managed for warm-season grasses	• Decrease mowing frequency on additional fields. • Consider the timing of mowing based on best available advice and potentially restoration planting of warm-season grasses.

Key findings and recommendations for grassland habitat in Colonial NHP.

Literature cited

Goodwin SE and SW Wakamiya. 2010. Breeding bird monitoring: Mid-Atlantic Network 2009 annual report. Natural Resource Data Series NPS/MIDN/NRDS–2010/XXX. National Park Service, Fort Collins, Colorado.

Horsley SB, SL Stout, and DS DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 13: 98–118.

Latham R. 2009. Desired future condition of grasslands and meadows in Valley Forge National Historical Park. National Park Service. Northeast Region, Philadelphia; 223 pp.

Photo: Gary P. Fleming, Virginia Natural Heritage Program

Non-riverine saturated forest in Colonial NHP.

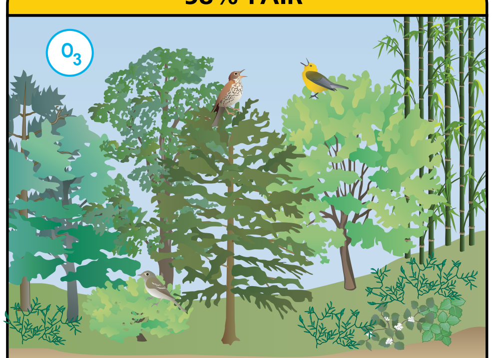
Forest habitat

Forest habitats of Colonial NHP were assessed as being in "fair" condition based on meeting 58% of desired thresholds. Confidence in the assessment of this habitat was fair due to abundant data quantity for appropriate indicators. Of the three major subunits, Yorktown was deemed to be in the best condition for forest resources. This result was driven largely by the higher amount of forest found in Yorktown relative to the other units, rather than any notable differences in the quality of forest among the units. In general, forests are present at fairly high levels in the Park; and the fauna, as represented by forest interior dwelling species (i.e., birds), are in good condition with no noticeable trend of degradation. Although there are high levels of impervious surfaces in the region, much of the developed lands are located downriver from the Park. Air quality continues to be in poor condition, but this is not a metric that the Park has much control over and the general trend in air quality is improving.

One of the most pressing issues currently facing parks throughout the region is the overpopulation of white-tailed deer and associated effects on park vegetation. Given that county-level estimates of deer populations far exceed carrying capacity and the estimates from nearby comparative parks, it seems likely that the Park is above the 8 deer/km^2 threshold and deer management should be a significant concern. As a first step, an initial inventory of deer densities would allow this metric to be better assessed. Such actions are currently being taken or considered at other NPS parks in the region. The soon to be implemented vegetation monitoring I&M protocol will be a valuable source of data to assess general impacts such as the lack of forest regeneration due to deer overgrazing. The installation and monitoring of deer exclosures would help the Park to assess the potential impact of deer browsing on the Park's vegetation.

FOREST HABITAT

58% FAIR



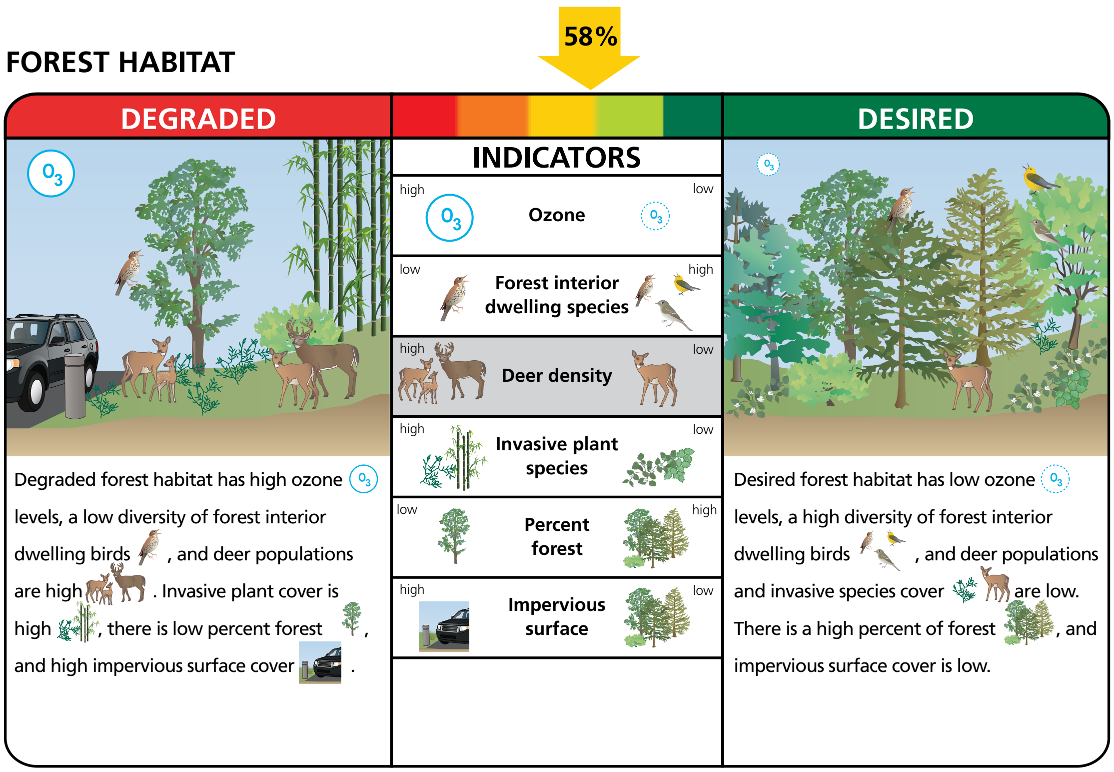
Assessed forest habitat had high ozone (O_3) levels, a high diversity of forest interior dwelling birds, and invasive plant cover was high. There is a high percent of forest, and impervious surface cover is low.

Indicators	Reference condition attainment	Current condition	Trend in condition
Ozone	0%	Very Degraded	Improving
Forest interior dwelling species (FIDS)	100%	Very Good	No trend
Invasive plant species	0%	Very Degraded	Degrading
Percent forest	90%	Very Good	N/A
Impervious surface	100%	Very Good	N/A
Forest habitat	**58%**	**Fair**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good

Changes in climate are also of concern as the Park's significant shoreline along two large tidal rivers is especially sensitive to changes in sea level. Jamestown, the subunit with the lowest total forest amount, is especially vulnerable to loss of forest due to sea level rise. More subtle responses to changing climate may include changes in phenology and competitive dynamics of forest species. Future vegetation monitoring could track the potential consequences of sea level rise to forest resources through simple efforts such as groundwater monitoring of saltwater intrusion.

Confidence in the forest habitat assessment would be improved with better data on invasive species cover in the Park. The invasive plant condition score is based on the 1999–2000 inventory of invasive exotic plants conducted over 10 years ago. Trends indicate the invasive species are increasing (e.g., golden bamboo); and a new assessment including effectiveness of previous and current treatment actions would be useful at the park scale. These efforts could be better targeted by species and area of the Park through improved effectiveness monitoring and an updated inventory of invasive plant cover.



Conceptual range of habitat condition from degraded to desired for forest habitat showing indicators appropriate to assess condition. No data was available in the current assessment for grayed out indicators.

Key findings	Recommendations
Forest habitat	
• Deer population potentially at unsustainable level	• Implement monitoring of deer density. • Increase studies of deer impacts to forest structure and composition.
• High invasive plant cover	• Continue to monitor, track, and eradicate invasive plant species. • Prioritize control strategies based on effectiveness monitoring.
• Forest loss to sea level rise	• Proactively manage, intervene, and closely monitor sea level markers and groundwater salinity. • Educate the public about the potential consequences of changes in sea level to park resources.
• Degraded air quality	• Work collaboratively with federal, state, and local partners to identify and reduce sources. • Educate the public about the potential consequences of degraded air quality to park resources.

Key findings and recommendations for forest habitat in Colonial NHP.

Photo: Allison Dungan, IAN Image Library

Tidal wetland habitat at Yorktown Creek.

Tidal wetland habitat

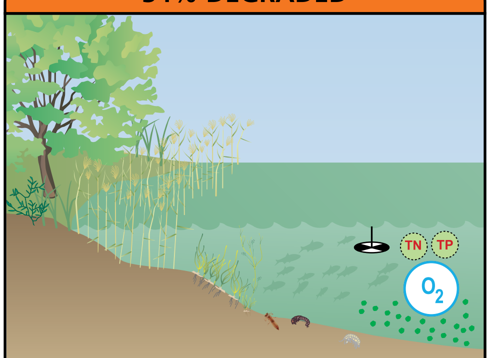
Tidal wetland habitat was in "degraded" condition, representing 34% of threshold attainment. Despite some metrics having high data availability (i.e., water quality index, submerged aquatic vegetation), confidence in this assessment is limited as other metrics (i.e., tidal benthic index of biotic integrity, invasive plants) had only a few sample points. The globally rare Tidal Bald Cypress Forest/ Woodland assemblage is included within this habitat, although little is known about the condition of this habitat type. Several rare or imperiled species utilize tidal wetland habitats, including the sensitive joint vetch and rare skipper.

A potential limitation of the water quality and submerged aquatic vegetation metrics used was that they were only available for open water sites of the James and York Rivers. While water is tidally exchanged within wetland habitats, the degree to which this water quality influences tidal wetlands is not evident.

Climate change, particularly with sea level rise, threatens the tidal wetland habitats found at Colonial NHP. Sea level rise contributes to shoreline erosion and saltwater intrusion. Due to the critical influence that salinity plays in tidal wetland communities, vegetation communities will shift in relation to saltwater intrusion. Sediment elevation also influences marsh accretion: if sea level rise outpaces sediment accretion, marsh habitat will be lost. Increased storm intensity due to climate change could also pose a threat to tidal wetlands and contribute to shoreline erosion. Other threats to tidal wetland habitat include ditching, dredging, and restricting tidal inundation. Pesticide use from watershed sources degrades tidal wetland water quality and threatens food sources for species like the rare skipper.

TIDAL WETLAND HABITAT

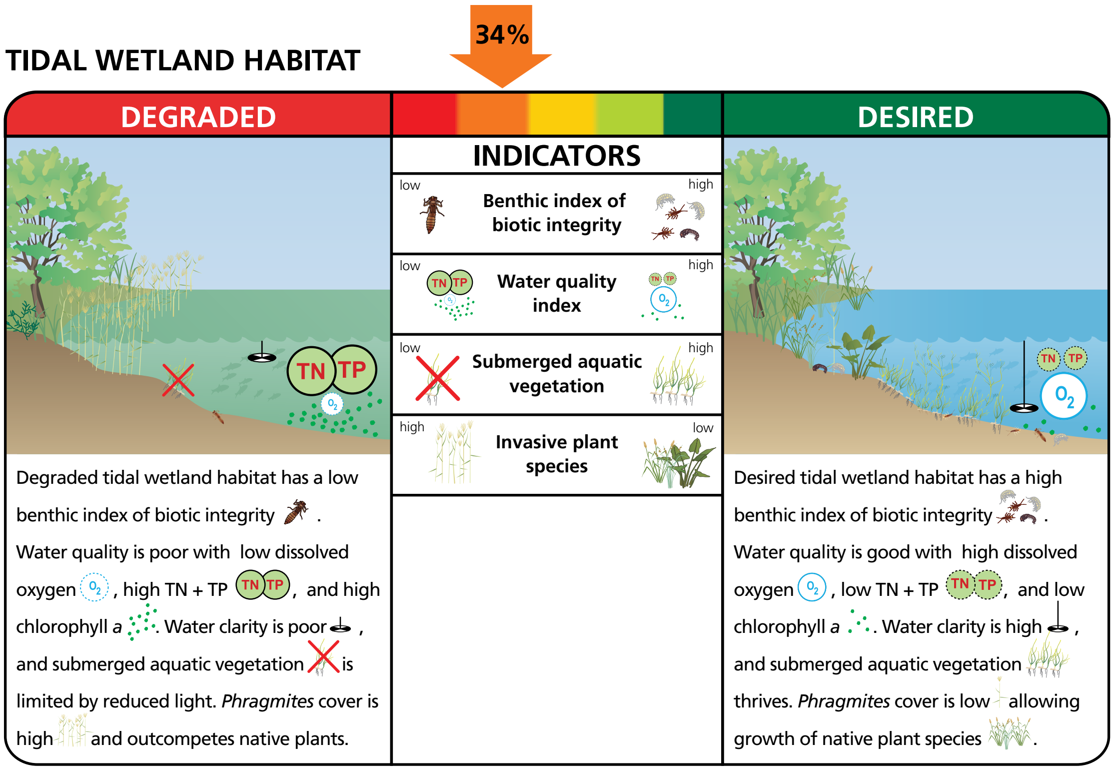
34% DEGRADED



Assessed tidal wetland habitat had a fair but declining benthic index of biotic integrity. Water quality is fair with high dissolved oxygen, low TN + TP, high chlorophyll *a*, and poor water clarity. Submerged aquatic vegetation is fair, and *Phragmites* cover is very high.

Indicators	Reference condition attainment	Current condition	Trend in condition
Tidal benthic index of biotic integrity (B-IBI)	41%	Fair	Declining
Water quality index	54%	Fair	Stable
Submerged aquatic vegetation (SAV)	40%	Degraded/Fair	Improving
Invasive plant species	0%	Very Degraded	Declining
Tidal wetlands habitat	**34%**	**Degraded**	**-**

0-20 %	20-40 %	40-60 %	60-80 %	80-100%
Very Degraded	Degraded	Fair	Good	Very Good



Conceptual range of habitat condition from degraded to desired for tidal wetland habitat showing indicators appropriate to assess condition.

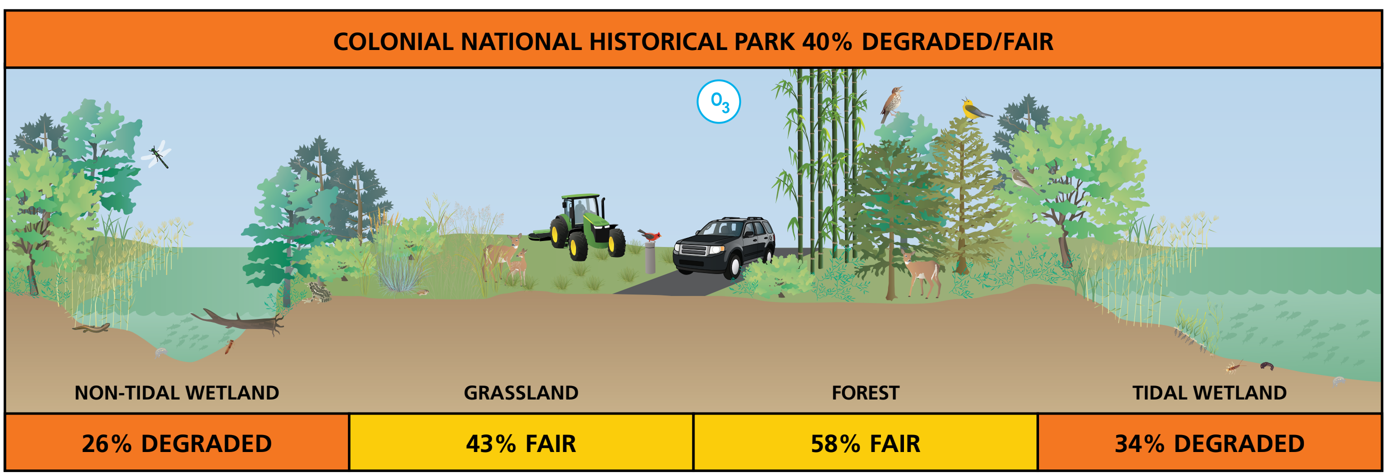
Key findings	Recommendations
Tidal wetlands habitat	
• Several rare vegetation assemblages and species.	• Track potential conversion of vegetation to brackish community types. • Coordinate with Inventory and Monitoring to establish monitoring plots within the globally rare Tidal Bald Cypress forest/woodland.
• Water quality is mostly assessed in open water sites, not directly within tidal wetlands.	• Initiate water quality monitoring within park boundaries. • Work with neighbors to identify and reduce point and non-point source pollution.
• Sea level rise and saline intrusion will adversely affect wetland habitat.	• Implement inundation and salinity monitoring. • Educate the public about the potential consequences of sea level rise and saline intrusion to park resources.

Key findings and recommendations for tidal wetlands habitat in Colonial NHP.

5.3 OVERALL PARK CONDITION

Overall, the combined natural resources of Colonial NHP were assessed to be on the border of "degraded" and "fair" condition, attaining 40% of desired threshold scores (Table 5.5). However, the confidence in that assessment is limited by the minimal data available for some key indicators. Specifically, new data collection protocols are strongly recommended to establish Park estimates of deer density, noise, and light pollution. The data on several other key indicators, notably invasive species, are also dated and in need of updating. Some of this information will come as Colonial NHP begins to implement the NPS Inventory and Monitoring protocol for forest health monitoring in the Park. It is also noteworthy to point to the improving trends for air quality, submerged aquatic vegetation, and warm-season grassland management in the Park. Coupled with the continued presence of uncommon, rare, and endangered species (e.g., the sensitive joint vetch and Mabee's salamander) and communities (e.g., Coastal Plain Dry Calcareous Forest), and the return of such charismatic megafauna as coyotes and bobcats to the Park, these trends are an encouraging sign for the Colonial NHP's natural resources and should be carefully tracked in future assessments.

Habitat	Reference condition attainment	Current condition	Confidence in assessment
Non-tidal wetland	26%	Degraded	Very limited
Grassland	43%	Fair	Limited
Forest	58%	Fair	Fair
Tidal wetland	34%	Degraded	Limited
Colonial National Historical Park	**40%**	**Degraded/Fair**	**Limited**



APPENDIX TABLES

Table A.1. Timeline of significant benchmarks and project meetings in the assessment of Colonial NHP.

Date	Meeting type	Topics Discussed	Attendees
03/10/2010	In person	Overview of assessment process, examples from previous NRCAs, field survey of habitats	NPS-COLO: Dorothy Geyer, Dave Frederick, Skip Brooks, Karen Rehm, Jonathan Connolly, Tim McLean, Daniel Smith; NPS-Other: Charles Roman, Dennis Skidds; UMCES-IAN: Bill Dennison, Tim Carruthers, Jane Thomas, Kate Bentsen; UR: Todd Lookingbill, Ericka Poppell
03/11/2010	In person	Review of available data sets (stream, hydrology, marshes, herps, vegetation, invertebrates, birds)	NPS-COLO: Dorothy Geyer, Skip Brooks, Karen Rehm, Jonathan Connolly, Tim McLean, Daniel Smith; NPS-Other: Charles Roman, Dennis Skidds; UMCES-IAN: Bill Dennison, Tim Carruthers, Jane Thomas, Kate Bentsen; UR: Todd Lookingbill, Ericka Poppell; Rick Berquist, Dana Bradshaw, Tim Christensen, Greg Garman, Chris Ludwig, Ken Moore, Jim Perry, Gary Speiran, Susan Watson
07/29/2010	In person	Discussion of habitat maps and metrics	NPS-COLO: Dorothy Geyer, Dave Frederick; NPS-Other: Peter Sharpe; UMCES-IAN: Tim Carruthers, Allison Dungan; UR: Todd Lookingbill
08/26/2010	Conference call	Discussion of deer survey, vegetation classifications	NPS-COLO: Dorothy Geyer, Dave Frederick; NPS-Other: Peter Sharpe; UMCES-IAN: Tim Carruthers, Allison Dungan; UR: Todd Lookingbill, Carolyn Doherty
09/13-09/14/2010	In person	Meeting about data inventory and conceptual modeling	UMCES-IAN: Tim Carruthers, Allison Dungan; UR: Todd Lookingbill
09/28/2010	Conference call	Discussion of bamboo metric, habitat maps, deer, and rare habitats and species	UR: Todd Lookingbill; UMCES-IAN: Tim Carruthers, Allison Dungan; NPS-COLO: Dorothy Geyer, Dave Frederick; NPS-Other: Peter Sharpe
10/20/2010	Conference call	Discussion of salt marsh vegetation and nekton data set	NPS-Other: Penelope Pooler; UMCES-IAN: Tim Carruthers, Allison Dungan
10/24/2010	Field survey	Photographed park units and habitats	UMCES-IAN: Allison Dungan
10/26/2010	Conference call	Discussion of birds, park boundary revision, warm-season grasses and water	UR: Todd Lookingbill, Ericka Poppell; UMCES-IAN: Tim Carruthers, Allison Dungan, Jane Thomas; NPS-COLO: Dorothy Geyer, Dave Frederick
10/26/2010	In person	Site visit to Jamestown Glasshouse and wetland habitats	UR: Todd Lookingbill; NPS-COLO: Dorothy Geyer
11/2/2010	In person	Discussion and observation of Richmond Battlefield's deer monitoring	NPS-RICH: Michael Prowatzke; UR: Todd Lookingbill
12/09/2010	Conference call	Discussion of preliminary results for wetland and landscape metrics, biotic inventories, and habitat maps	NPS-COLO: Dorothy Geyer; NPS-Other: Peter Sharpe, Sara Stevens; UMCES-IAN: Tim Carruthers, Allison Dungan; UR: Todd Lookingbill; Other: Dana Bradshaw
12/16/2010	Conference call	Discussion of fields, invasives, and mammals	UMCES-IAN: Tim Carruthers, Allison Dungan; UR: Todd Lookingbill; NPS-COLO: Dorothy Geyer; NPS-Other: Peter Sharpe
12/21/2010	Conference call	Discussion of fields, bamboo, phragmites, and habitat map revision	UR: Todd Lookingbill; NPS-COLO: Dorothy Geyer, Dave Frederick
02/01/2011	Conference call	Review of report format, data gaps, visitation statistics, air quality, soundscapes	NPS-COLO: Dorothy Geyer, Dave Frederick; NPS-Other: Peter Sharpe, Dennis Skidds; UMCES-IAN: Tim Carruthers, Kate Bentsen; UR: Todd Lookingbill
03/08/2011	In person & conference call	Discussion of Chapters 2&4 progress, Chapter 5 management recommendations	NPS-COLO: Dorothy Geyer, Dave Frederick; NPS-Other: Peter Sharpe, Dennis Skidds; UMCES-IAN: Kate Bentsen; UR: Todd Lookingbill

NPS National Park Service; NPS COLO Colonial National Historical Park; UR University of Richmond; MCBP Maryland Coastal Bays Program; UMCES-IAN Integration & Application Network, University of Maryland Center for Environmental Science; USGS United States Geological Survey; VIMS Virginia Institute of Marine Science.

Table A.1. Timeline of significant benchmarks and project meetings in the assessment of Colonial NHP.

Date	Meeting type	Topics Discussed	Attendees
05/16/2011	Email	Submission of first draft to NPS	UMCES-IAN: Kate Bentsen; UR: Todd Lookingbill
07/26/2011	Email	Receive NPS Peer Review Comments	
09/16/2011	Conference call	Discussion of Peer Review Comments	UR: Todd Lookingbill; NPS-COLO: Dorothy Geyer; NPS-Other: Peter Sharpe
10/18/2011	In person	Discussion of Chapter 5, conceptual diagrams, comments from first draft	UMCES-IAN: Bill Dennison, Kate Bentsen; UR: Todd Lookingbill, Ericka Poppell
01/26/2012	Email	Submission of second draft to NPS	UMCES-IAN: Kate Bentsen, Simon Costanzo, Tracey Saxby; UR: Todd Lookingbill, Ericka Poppell
03/15/2012	Email	Receive second round of NPS Peer Review Comments	NPS-COLO: Dan Smith, Dorothy Geyer; NPS-Other: Peter Sharpe, Jim Comiskey, Sheila Colwell, Marian Norris
05/16/2012	Email	Submission of final draft to NPS	UMCES-IAN: Kate Bentsen, Simon Costanzo, Tracey Saxby; UR: Todd Lookingbill, Ericka Poppell

Table A.2. Habitat reclassification of Patterson 2008 classification for Colonial NHP.

Assemblage Name	Classification for this report	Classification in Patterson 2008
Successional Tuliptree - Loblolly Pine Forest	Forest	Transitional
Mesic Mixed Hardwood Forest	Forest	Upland forest
Coastal Plain Loblolly Pine - Oak Forest	Forest	Upland forest
Coastal Plain / Piedmont Small-Stream Floodplain Forest	Forest	Non-tidal wetland
Loblolly Pine Plantation	Forest	Cultural
Coastal Plain / Piedmont Floodplain Swamp Forest (Green Ash - Red Maple Type)	Forest	Non-tidal wetland
Coastal Plain Mesic Calcareous Ravine Forest	Forest	Upland forest
Acidic Oak - Hickory Forest	Forest	Upland forest
Successional Mixed Scrub	Forest	Transitional
Dense Hardwood Regeneration	Forest	Cultural
Disturbed Calcareous Forest	Forest	Transitional
Piedmont / Coastal Plain Oak - Beech / Heath Forest	Forest	Upland forest
Coastal Plain Dry Calcareous Forest	Forest	Upland forest
Successional Black Walnut Forest	Forest	Transitional
Successional Tree-of-Heaven Forest	Forest	Transitional
Successional Sweetgum Forest	Forest	Transitional
Golden Bamboo Shrubland	Forest	Cultural
Piedmont / Low Elevation Mixed Oak / Heath Forest	Forest	Upland forest
Cultural Meadow	Grassland (warm-season)	Cultural
Non-Riverine Saturated Forest	Non-tidal wetland	Non-tidal wetland
Coastal Plain Calcareous Seepage Swamp	Non-tidal wetland	Non-tidal wetland
Semipermanent Impoundment	Non-tidal wetland	Transitional
Disturbed Seepage Swamp	Non-tidal wetland	Transitional
Coastal Plain Depression Wetland (Red Maple - Sweetgum - WIllow Oak Type)	Non-tidal wetland	Non-tidal wetland
Disturbed Depressional Wetland	Non-tidal wetland	Transitional
Coastal Plain Depression Wetland (Swamp Tupelo Type)	Non-tidal wetland	Non-tidal wetland
Mixed Urban or Built-up Land	Not assessed	Cultural
Transportation, Communications, and Utilities	Not assessed	Cultural
Other Urban or Built-up Land	Not assessed	Cultural
Industrial and Commercial Complexes	Not assessed	Cultural
Residential	Not assessed	Cultural
Tidal Oligohaline Marsh	Tidal wetland	Tidal wetland
Tidal Freshwater Marsh	Tidal wetland	Tidal wetland
Tidal Mesohaline and Polyhaline Marsh	Tidal wetland	Tidal wetland
Tidal Bald Cypress Forest / Woodland	Tidal wetland	Tidal wetland
Beaches	Tidal wetland	Tidal wetland
Salt Scrub	Tidal wetland	Tidal wetland
Disturbed Tidal Hardwood Swamp	Tidal wetland	Transitional
Tidal Shrub Swamp (Wax Myrtle Type)	Tidal wetland	Tidal wetland
Water	Not assessed	Water

NPS 333/115250, June 2012

National Park Service
U.S. Department of the Interior

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