National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Manassas National Battlefield Park Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/414

ON THE COVER

Manassas National Battlefield Park has been selected as an Audubon Important Bird Area.
Jane Thomas, IAN.

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

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Executive Summary

The lands within Manassas National Battlefield Park are much as they were on the day of the battle and the park is charged with maintaining them in historical land use to preserve the view of the battle. The first step in framing this Natural Resource Condition Assessment was to define the key habitats within the park. Three high-level habitats were identified: forests, wetlands and waterways, and grasslands. The ecological value of these habitats was assessed using vital sign metrics from the National Park Service (NPS) Inventory and Monitoring (I&M) Program in the National Capital Region Network (NCRN).

Patches of forest within Manassas National Battlefield Park are well connected with moderate forest interior area, maximizing the habitat potential for native fauna, including forest interior dwelling bird species. It is recommended to preserve this forest structure by limiting future fragmentation and minimizing stresses to forest areas. Very high deer populations are present within forest areas, resulting in limited regeneration capacity, as well as trampling, overgrazing, and reduction of habitat value for wildlife. It is recommended to implement deer reduction strategies. The abundant presence of exotic plant species displaces native species and reduces habitat value. Continued early detection of exotic species is recommended with subsequent active control measures. Assessment of exotic species cover would be better assessed with park-wide mapping as the current small number of plots is not ideal for assessing exotic species cover on a park scale.

Wetland and waterway habitats show no sign of acidification, low oxygen, high temperatures, salinity, or dissolved nitrate; however, high dissolved phosphate indicates reduced wetland habitat value, which is reflected in the very degraded benthic index of biotic integrity and physical habitat index. It is recommended to identify and work with partners to reduce non-point source nutrient inputs from the watershed, as well as continue to implement (and begin to monitor) best management practices in agricultural lands. Additionally, efforts should continue to establish riparian buffers where appropriate, in consideration of cultural resources and historic vistas.

It is recommended to carry out baseline grassland plant inventories and optimize fire management to assist a transition to a greater proportion of native warm-season grasses. Grassland areas are currently contiguous with moderate grassland interior area, providing habitat value to wildlife. It is recommended to remove tree lines and expand areas of native grasses where historically appropriate. Future assessments of natural resource condition would be improved by developing inventories and monitoring of bird, small mammal, and insect communities within native grassland habitats. Direct measures of the species and habitat diversity (i.e., range of successional stages) would also be beneficial in managing to maximize habitat value of warm-season grassland habitat.

An additional framework—the National Capital Region Network Inventory and Monitoring 'vital signs' framework—was used to assess the current condition of park-wide natural resources for Manassas National Battlefield Park; therefore, key data gaps and research needs were summarized using that framework.

Air quality is poor within the park and while it is well monitored, the specific implications to the flora and fauna in the park are less well known. Gaining a better understanding of how reduced air quality is impacting wetland and grassland habitats in particular would help prioritize management efforts such as nutrient reductions in park lands, by showing what gains may be expected from these efforts.

Water quality has signs of degradation. Stream channels are highly variable in condition and a comprehensive assessment of stream physical habitat would allow for targeted management efforts and also allow for targeted engineering efforts to reduce water energy and erosion in the most susceptible areas. A detailed wetland delineation, including groundwater, would

Three high-level habitats were identified: forests, wetlands and waterways, and grasslands. The ecological value of these habitats was assessed using vital sign metrics from the National Park Service Inventory and Monitoring Program in the National Capital Region Network.

also provide a greater understanding of current features and potential threats to park resources. Monitoring and enforcing implementation of Nutrient Management Plans would also help to identify nutrient sources within the park. Phosphates are consistently high throughout the region and as this nutrient often comes from non-point sources, challenges exist for identification and mitigation of these sources.

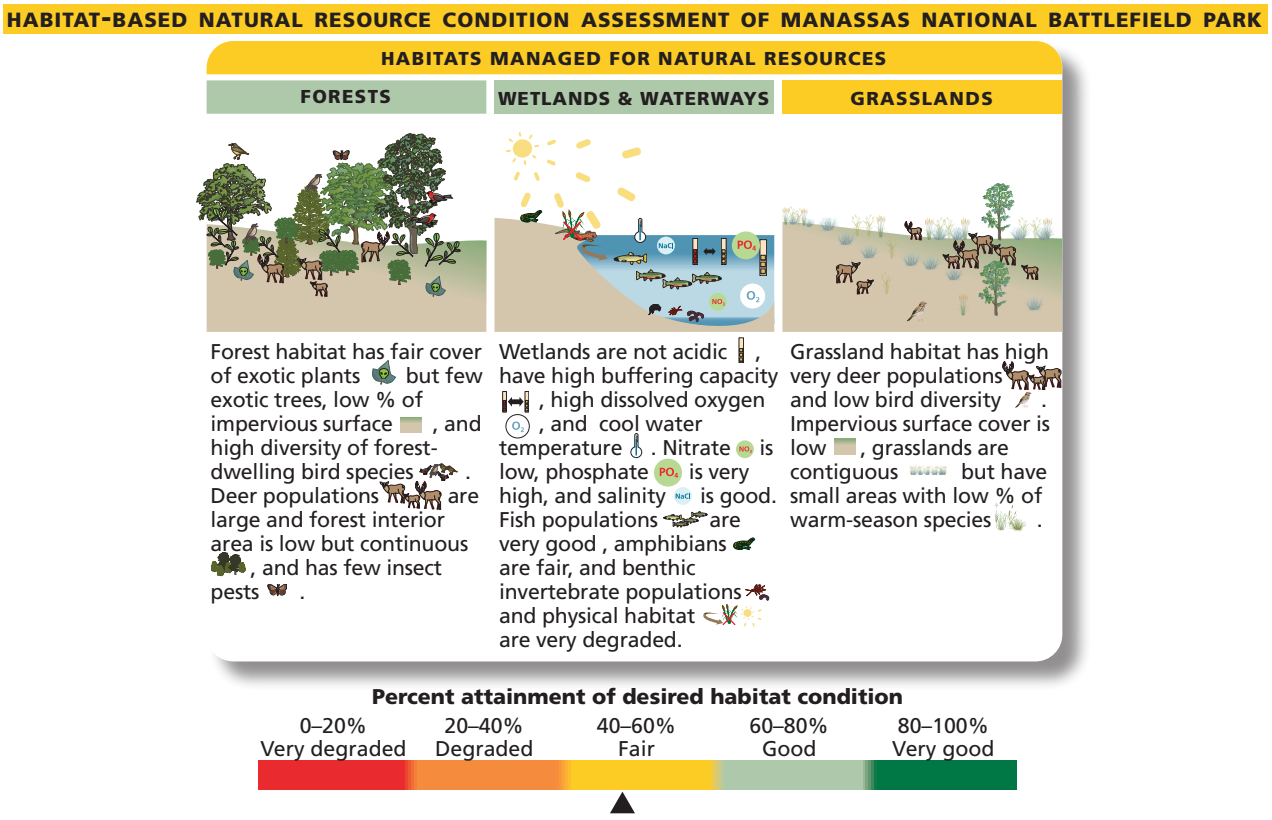
Some valuable biological communities occur within the park, with natural park habitats such as native warm-season grasslands becoming more significant as development continues throughout the region. Understanding the significance of these habitats to native grassland birds would require inventory and monitoring of these communities, including some specific studies on the potential impacts of traffic and vibrations to the success of these communities. The ecological community structure and succession of warm-season grassland communities themselves is poorly characterized in terms of habitat value to wildlife. Research into warm-season grassland communities would support the development of key indicators to monitor resource value of these habitats in the maintenance of a range of native biological communities. A better understanding of the dynamics of forest and grassland habitats in the presence of high deer populations and their ability to recover after deer reduction would assist in clarifying sustainable deer populations for future management.

Many of the faunal communities that constitute features of the park are migratory or have home ranges much greater than the park. For these reasons, assessing the connectivity and ownership of habitats and lands not just within but also outside of the park will allow a better understanding of the resilience of these communities and their susceptibility to change in the future. This is true for forest, grassland, and wetland and waterway habitats within the park. As a battlefield park, vegetating streamsides to reduce nutrient runoff into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies are needed to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters.

Manassas National Battlefield Park
Natural Resource Condition Assessment Resource Brief

A relatively new approach to assessing and reporting on park resource conditions, Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national parks. Over the next several years, the National Park Service (NPS) plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Division.

Habitats in Manassas National Battlefield Park are in fair condition overall. Forests were in good condition, with low forest interior area and large deer populations balanced by good bird diversity and continuous forest cover. Wetlands and waterways were also in good condition, with good pH, buffering capacity, and dissolved oxygen but high phosphate and degraded stream biological diversity. Grasslands were in fair condition, with large contiguous areas but large deer populations and low bird diversity.

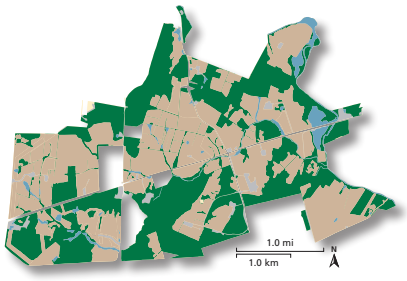


The habitat-based natural resource condition assessment is area-weighted. Areas of each habitat are given below:

Forests: 806 ha
Wetlands & waterways: 62 ha
Warm-season grasslands: 871 ha

Habitat framework

Habitats within the park were defined as being managed for natural resource values. A habitat map was created and desired/degraded conditions were defined for each of the three defined habitats. Metrics were then assigned to these habitat types, compared to established thresholds, leading to the condition assessment of each habitat.



Habitats

Managed for natural resource values
- Forests (*806 ha*)
- Grasslands (*871 ha*)
- Wetlands & waterways (*62 ha*)

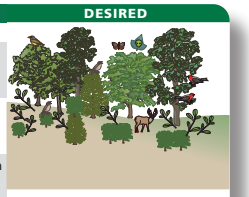
Other
- Developed lands

Manassas National Battlefield Park

FORESTS

DEGRADED | **INDICATORS** | **DESIRED**

	INDICATORS	
high	Cover of exotic plants	low
high	Presence of insect pests	low
low	Native tree seedling regeneration	high
low	Forest dwelling bird diversity	high
high	Deer density	low
low	Forest connectivity	high
high	Impervious surface	low
low	Forest interior area	high

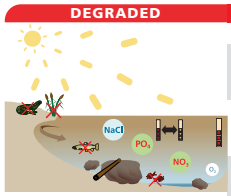


Degraded forest has high cover of exotic plants, large deer populations, and high % of impervious surface. Native seedling regeneration and diversity of forest-dwelling bird species are low in patchy forest with high occurrence of insect pests.

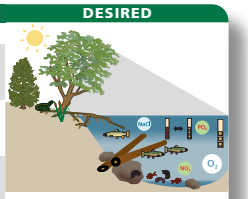
Desired forest has low cover of exotic plants, small deer populations, and low % of impervious surface. Native seedling regeneration and diversity of forest-dwelling bird species are high in contiguous forest with low occurrence of insect pests.

WETLANDS & WATERWAYS

DEGRADED | **INDICATORS** | **DESIRED**



	INDICATORS	
low	pH	high
low	Dissolved oxygen	high
high	Water temperature	low
low	Acid neutralizing capacity	high
high	Salinity	low
high	Nitrate	low
high	Phosphate	low
low	Benthos	high
low	Fish	high
low	Physical habitat	high
low	Amphibians	high



Degraded wetlands have eroded streambanks with no shade, little sheltering debris, and high nutrients and salinity, and acidic water with low buffering capacity, resulting in turbid water, low oxygen levels, and low populations of fish, amphibians, benthic invertebrates.

Desired wetlands have intact streambanks with shade and sheltering roots and debris, low nutrients and salinity, not acidic and with high buffering capacity, resulting in high oxygen, clear water, and high populations of fish, amphibians, benthic invertebrates.

GRASSLANDS

DEGRADED | **INDICATORS** | **DESIRED**

	INDICATORS	
high	Deer density	low
high	Impervious surface	low
low	Grassland bird diversity	high
low	Grassland interior area	high
low	Contiguous grassland area	high
low	Warm-season species	high

Degraded grasslands have high deer populations, high % of impervious surface, and low % of warm-season species. Grassland bird diversity is low in grasslands that are patchy and small in area.

Desired grassland habitat has small deer populations and low % of impervious surface, and high % of warm-season species. Grassland bird diversity is high in grasslands that have a lot of interior area and are large in total size.

For more information, please visit the Park's Visitor Center or call 703-361-1339.

Manassas National Battlefield Park
National Park Service
www.nps.gov/mana

Developed in collaboration with:

National Capital Region Network
Inventory & Monitoring Program
National Park Service

science.nature.nps.gov/im/units/nrcn/

Integration & Application Network (IAN)
University of Maryland Center for Environmental Science
www.ian.umces.edu

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Chapter 1: NRCA background information

1.1 NCRA 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 signs" monitoring indicators. They can also

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 subjective 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.

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.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA[9] 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.
9. Acronyms are defined in Table B-3 in Appendix B.

Chapter 2: Park resource setting/ resource stewardship context

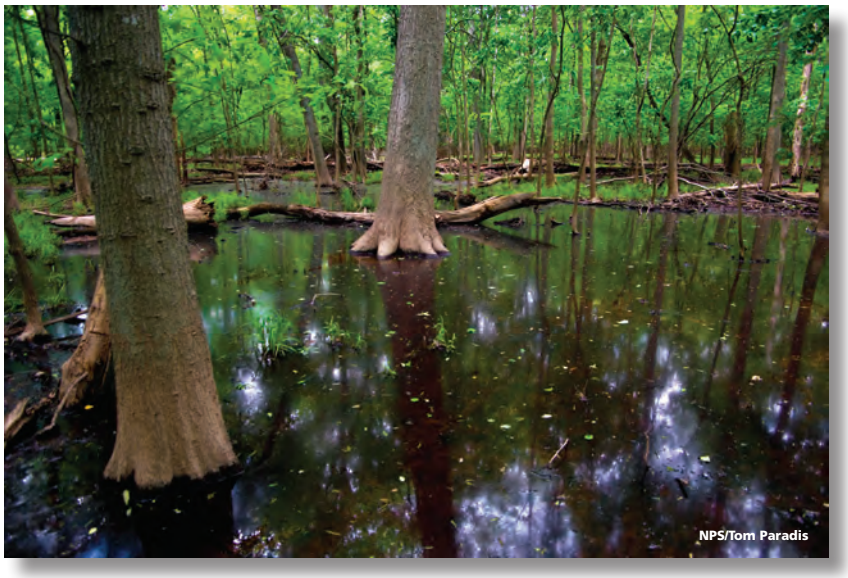
2.1 PARK RESOURCE SETTING

Manassas National Battlefield park was established in 1940 to preserve the scene of two major Civil War battles, the Battle of First Manassas (First Bull Run) and the Battle of Second Manassas (Second Bull Run). Located a few miles north of the prized railroad junction of Manassas, Virginia, the peaceful countryside there bore witness to clashes between the armies of the north and south in 1861 and 1862.

On May 10, 1940, almost a century later, Secretary of the Interior Harold L. Ickes designated Manassas National Battlefield Park. Subsequent legislation in 1954, 1980, and 1988 established the present park boundary to preserve the most historically important lands relating to the two battles of Manassas. Of the park's authorized 2,052 ha (5,071 acres), the federal government owns approximately 87% (1,809 ha [4,417 acres]) and private owners hold the remaining 13% (Figure 2.1).

During the Civil War, Manassas was a patchwork of open fields and woodlots scattered across gently rolling hills. While the areas to the north of the park retain some rural character, most of the surrounding areas of the park now bustle with residential and commercial development. The park is surrounded by lands under both public and private ownership—used for agricultural, business and commercial, residential, park and open space, and transportation purposes. The park's proximity to the greater Washington, DC metropolitan area and to growing areas of northern Virginia has led to increasing nearby development. The park remains an island of open space of historical, cultural, natural, and recreational value within a part of northern Virginia that is becoming more and more suburban and urban in character.

The park is divided by Lee Highway (U.S. Route 29, also known by its historic name, the Warrenton Turnpike) and Sudley Road (VA Route 234). These two roads follow the basic historic road alignments used by Civil War troops. Today, they provide the main visitor access to the battlefields. The roads also receive heavy use by commuters, residents, and trucks from nearby quarries and construction operations.



Vernal pool in Manassas National Battlefield Park.

Presently, Manassas has about 870 ha (2,150 acres) of managed grasslands and fields, more than 240 ha (600 acres) of which have been restored to native warm-season grasses (NCRN I&M and UERLA undated).[10] Woodlands and forests (approximately 800 ha (2,000 acres) consist of eight different forest types, primarily mature basic oak–hickory forest and Virginia pine–eastern red cedar successional forest.

Since its establishment as a park in 1940, Manassas has been both vehemently defended and intensively scrutinized in connection with land acquisitions, various park management actions, and private development plans for properties near or adjacent to the park. The proximity of the park to Washington, DC may be part of the reason Manassas is so often found under the magnifying glass.[11]

10. Throughout this document, the term "warm-season" is used interchangeably with "native" when referring to grasses and grasslands. "Cool-season" is used interchangeably with "non-native" in the same contexts.
11. The book, *Battling for Manassas: The Fifty-Year Preservation Struggle at Manassas National Battlefield Park* by Joan M. Zenzen, is an excellent resource for details on many of these controversies.

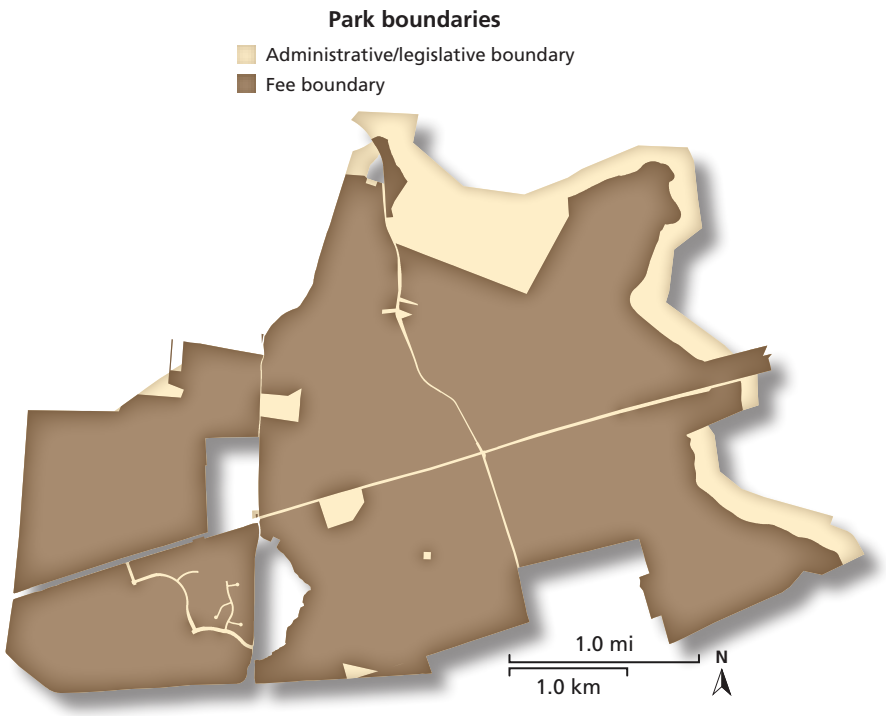


Figure 2.1. GIS data layer[12] showing the administrative/legislative and fee boundaries of Manassas National Battlefield Park, which encompass 2,052 ha (5,071acres)and1,809ha (4,417 acres), respectively.

A few of the events that created the greatest public outcry include plans in 1988 to build a mall next to the battlefield on Stuart's Hill tract (with the result that the federal government took approximately 226 ha (558 acres) of land [Gorsira 2004]); plans in 1993 by Walt Disney Co. to build a $650 million historical theme park on part of a 1,200-ha (3,000-acre) site in nearby Haymarket (Zenzen 1998); and a management action in 2007 that clear-cut 60 ha (140 acres) of forest in an area known as Deep Cut in order to re-establish the vista of the last Union assault at the Battle of Second Manassas (NPS 2005). The forest removal at Deep Cut has been a focal point for discussion of the concept of historic 'viewsheds' and the perceived conflict of cultural versus natural resources. Although the park's importance and designation as an NPS unit comes from the cultural history, Manassas National Battlefield Park's natural resources make a significant contribution to local and regional biodiversity, with grasslands, forests, and streams comprising important habitats for birds, amphibians, and other wildlife.

In summary, Manassas National Battlefield Park tells the story of two important battles of the Civil War. Situated in the growing Washington, DC metropolitan area, it faces challenges from nearby development that threatens both natural and cultural resources. Yet, the park's wartime character is still largely preserved and the park continues to be a valuable player in telling the story of pivotal events in the nation's history, as well as providing precious natural space in an increasingly urban area. A heavily used park, visitation to Manassas has declined over the past decade, from 815,000 in 1999 to 595,000 in 2008 (NPS Public Use Statistics Office).[13]

2.1.1 Park resources

In the face of encroaching development and with its diverse landscape including forests, wetlands, waterways, and grasslands, the park represents a sanctuary for many plant and animal species. A wide range of mammals, birds, amphibians, reptiles, and threatened plant species make their home in the park.

Resource setting

Manassas National Battlefield Park covers 2,052 ha (5,071 acres), and is located in Fairfax and Prince William Counties in northern Virginia (Figure 2.2). The park is in the Bull Run watershed, which forms part of the Occoquan River and ultimately the Potomac River and Chesapeake Bay watershed. (Fig-

12. MANA.
13. *http://www.nature.nps.gov/stats*

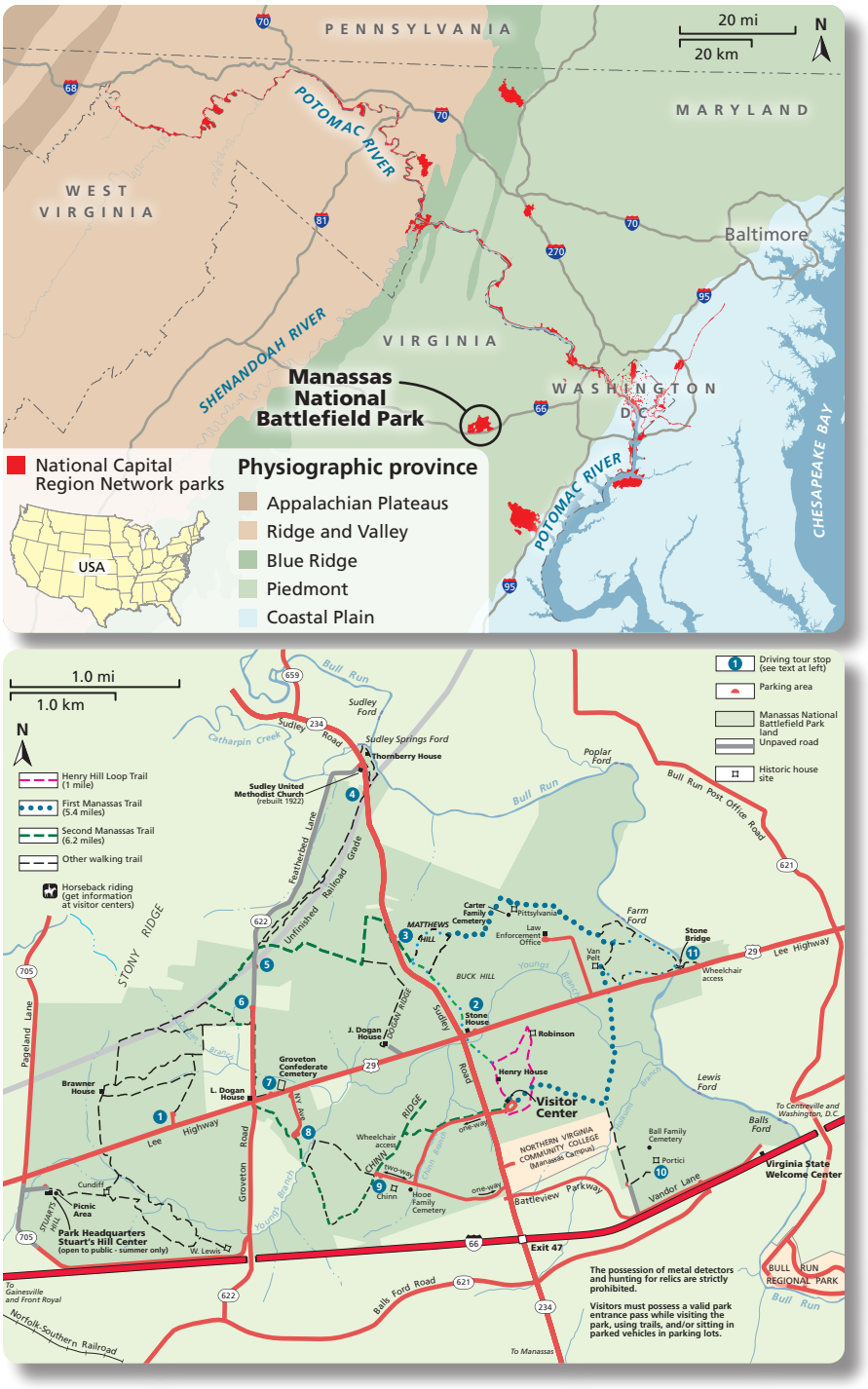


Figure 2.2. Location of Manassas National Battlefield Park in northern Virginia.[14]

ure 2.3). Bull Run forms much of the eastern border of the park and Youngs Branch—a tributary of Bull Run—is entirely contained within the park (Figure 2.4).

Geology

Manassas National Battlefield Park is located in the Piedmont physiographic province within the Culpeper Basin, a large Mesozoic trough that stretches across the central Piedmont, a landscape characterized by relatively low relief and gently rolling to nearly level topography (Fenneman 1938, Lee 1979). The park ranges from 45–100 m (150–340 ft) above sea level (Figure 2.5). The geology in Manassas National Battlefield Park influenced the two battles that occurred here and has resulted in the park's diverse forest and grassland ecosystems (Thorneberry–Ehrlich 2008).

14. NPS.

The geology favored soldiers who knew the terrain, using to their advantage their knowledge of the river crossings and fords, wetlands and forests, gulleys, cover, and topographic differences. The diverse ecosystems and habitats of the park are also a direct result of the geology, with wetlands, meadows, hill slopes, and ridge tops.

The primary bedrock underlying the majority of the park is the Chatham Group, Groveton Member of the Bull Run Formation, which is made up of gray–brown and red siltstone and sandy shale in thin beds with some lacustrine clays (Figure 2.6). This siltstone forms the parent material for 79% of park soils, which are generally strongly acidic, well-drained loams. In the western half of the park, the sedimentary rocks have been intruded by igneous dikes and sills of diabase. Soils derived from diabase (19% of park soils) are typically loamy, very rich in clay minerals, and have limited permeability (Figure 2.7). These diabase-derived soils support many rare grassland species, and the other soils in the park support eight different types of forest in Manassas National Battlefield Park (Thorneberry–Ehrlich 2008).

Forests

The diverse forests of Manassas National Battlefield Park make up 47% of its area (Fleming and Weber 2003). Eight different forest types have been identified within the park, ranging from early-successional Virginia pine (*Pinus virginiana*) stands to relatively mature oak–hickory and bottomland hardwood forests (Figures 2.8, 2.9; Fleming and Weber 2003). Most of these forest communities are in mid- to late-successional stages of recovery from some form of human disturbance, such as agriculture or logging, and the underlying geology of the park has influenced the distribution of these forest types. These eight types are discussed in more detail below.

Piedmont/mountain swamp forest. This forest type occurs in seasonally flooded sloughs and backswamps in the Bull Run floodplain, both north and south of U.S. Highway 29. Characteristic species of this community include pin oak (*Quercus palustris*), swamp white oak (*Quercus bicolor*), green ash (*Fraxinus pennsylvanica*), lizard's tail (*Saururus cernuus*), wood reed grass (*Cinna arundinacea*), and blunt broom sedge (*Carex tribuloides*). This forest type covers <1% of the park and is ranked as rare to uncommon state-wide.

Upland depression swamp. This community type occurs in shallow, seasonally flooded upland basins and wet, elongate bottoms along small streams. Characteristic species include swamp white oak, pin oak, black haw (*Viburnum prunifolium*), and dark-green bulrush (*Scirpus atrovirens*). This forest type covers <1% of the park and is ranked as imperiled to critically imperiled globally, and very rare generally state-wide.

Piedmont/mountain bottomland forest. This forest type occurs on elevated floodplain levees and terraces bordering Bull Run, Youngs Run, and a few other secondary streams. Characteristic species include American elm (*Ulmus americana*), box-elder (*Acer negundo*), American sycamore (*Platanus occidentalis*), paw-paw (*Asimina triloba*), spicebush (*Lindera benzoin*), wood nettle (*Laportea canadensis*), and wild ginger (*Asarum canadense*). This forest type covers 5% of the park and is ranked as widespread globally and common state-wide.

Basic mesic forest. This community type is confined in the park to a short, steep east-facing bluff bordering the inner edge of the Bull Run floodplain. Characteristic species include white ash (*Fraxinus americana*), bitternut hickory (*Carya cordiformis*), chinkapin oak (*Quercus muhlenbergii*), bladdernut (*Staphylea trifolia*), Virginia waterleaf (*Hydrophyllum virginianum*), and Nebraska sedge (*Carex jamesii*). This forest type covers <1% of the park.

Basic oak–hickory forest. This forest type is widespread in Manassas National Battlefield Park, primarily on diabase-derived soils but also locally on soils weathered from siltstone. Stands occupy low ridges and rolling to flat uplands. Characteristic species include white oak (*Quercus alba*), pignut hickory (*Carya glabra*), white ash, Eastern redbud (*Cercis canadensis*), cliff

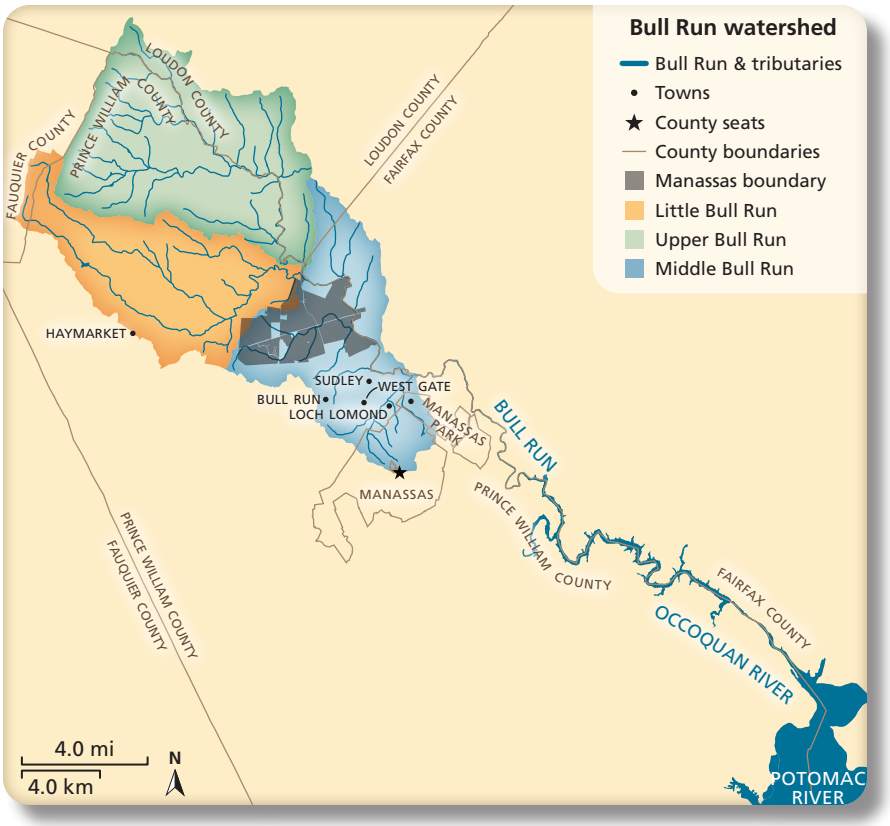


Figure 2.3. Bull Run and its watershed.[15]

muhly (*Muhlenbergia sobolifera*), and Bosc's panic grass (*Dichanthelium boscii*). This community type covers 13% of the park and is ranked as rare to uncommon state-wide.

Acidic oak–hickory forest. This community type is widespread in the park on acidic soils weathered from siltstone. Stands occur on low ridges and rolling to flat uplands. Characteristic species include white oak, black oak (*Quercus velutina*), mockernut hickory (*Carya alba*), flowering dogwood (*Cornus florida*), and early lowbush blueberry (*Vaccinium pallidum*). This forest type covers 6% of the park and is ranked as widespread globally and common to very common state-wide.

Eastern white pine–hardwood forest. This forest type is known only from a small area on the west side of Bull Run, where it occupies both sub-level uplands and relatively steep slopes of a ravine system and bluff-top along the stream, on acidic soils derived from siltstone. Characteristic species include Eastern white pine (*Pinus strobus*), chestnut oak (*Quercus prinus*), and mountain-laurel (*Kalmia latifolia*). This community type covers <1% of the park and is ranked as widespread globally and common state-wide.

Virginia pine–Eastern red cedar successional forest. This community type is widespread in Manassas National Battlefield Park on former fields and clearings that were abandoned within the past century. It occupies low ridges and rolling to flat uplands. The characteristic species are Virginia pine (*Pinus virginiana*) and Eastern red cedar (*Juniperus virginiana*). This forest type covers 19% of the park and is ranked both globally and state-wide as ruderal, meaning disturbed or early successional.

Wetlands and waterways

The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) database have identified several different types of wetlands within Manassas National Battlefield Park (Figure 2.9). These areas are mostly comprised of 'freshwater forested/shrub wetland' (i.e., floodplain and riparian areas along Bull Run and its tributaries)

15. USGS EDNA watersheds, ESRI, MANA.

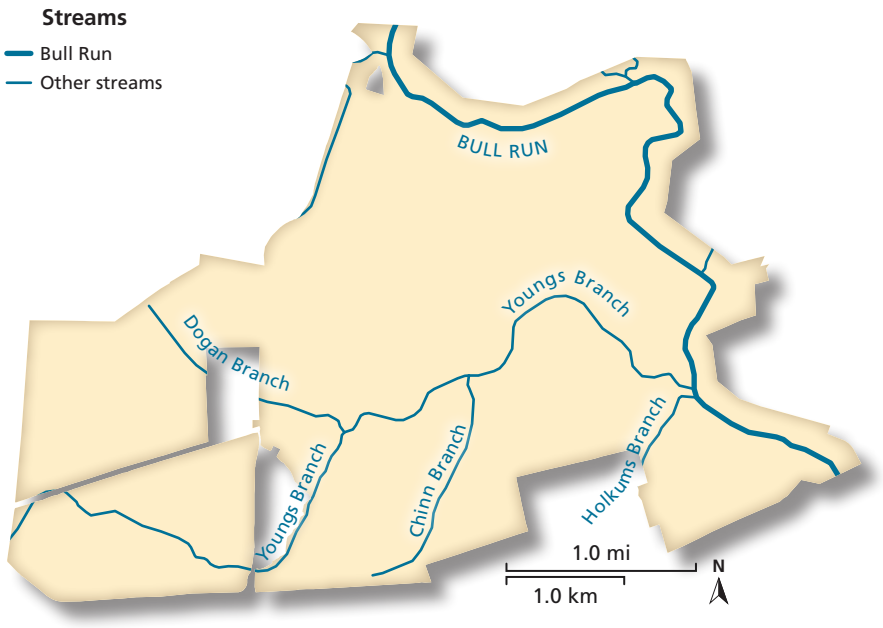


Figure 2.4. GIS data layer[16] depicting the stream network for Manassas National Battlefield Park.

and the waterways themselves, as well as small areas of freshwater emergent wetland and freshwater ponds.

All of the NWI-classified areas are considered 'wetlands' for legal and policy purposes. However, the floodplain and riparian areas can be considered as 'forest' for the ecological and habitat purposes of this assessment (Section *3.5.2—Habitat framework* will explain this methodology in more detail).

A project by Loomis and Heffernan (2003) classified and mapped wetlands on the Brawner Farm and Matthews Hill tracts of Manassas National Battlefield Park. Five wetland types were identified in these areas and are described in more detail below.

Emergent marsh. Wetlands typically supporting standing water from which the vegetation emerges; emergent marsh will not necessarily always have standing water throughout the year.

Scrub-shrub. Wetlands in succesional transition from herbaceous to woody; usually dominated by shrubs and sapling trees.

Wet meadow. Herbaceous wetlands that are maintained through regular mowing. These areas are part of the headwater drainages of Bull Run and Young's Branch which receive and hold water long enough during the growing season to promote growth of wetland vegetation.

Vernal pond. Temporary water bodies that usually fill during the winter and dry out as the growing season progresses.

Forested wetlands. Forested wetlands of Manassas were classified by natural community type as defined and mapped in Fleming and Weber (2003).

Upland depression swamp – typically occupies shallow, seasonally flooded upland basins and wet elongate bottoms along small streams.

Piedmont/mountain bottomland forest – occurs on elevated floodplain levees and terraces bordering rivers and streams.

Piedmont/mountain swamp forest – found in seasonally flooded sloughs and backswamps. They typically have shallow, standing water for much of the winter and spring.

Grasslands

Managed to maintain historic scenes and land use patterns that existed at the time of the battles, Manassas National Battlefield Park contains about 870 ha

16. ESRI, MANA.

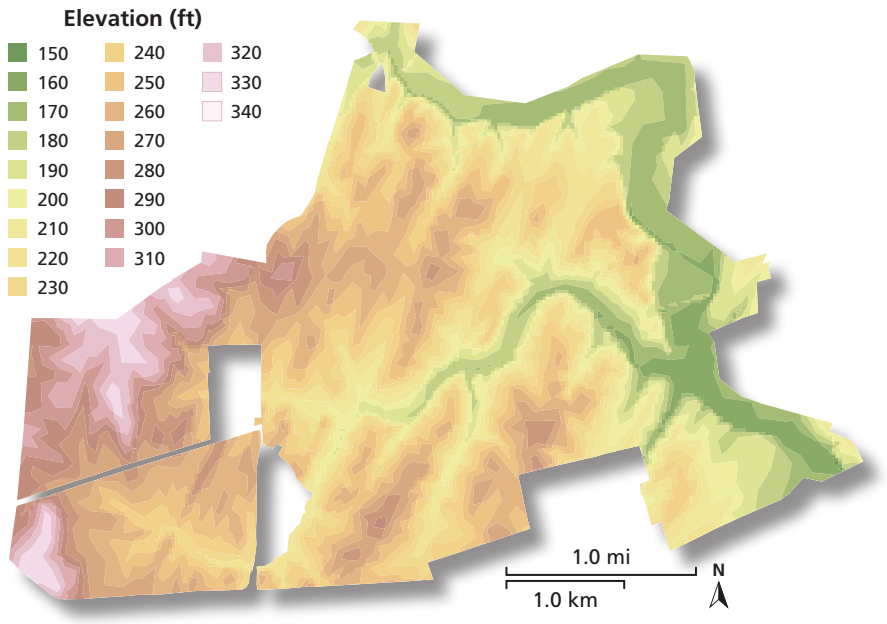


Figure 2.5. GIS data layer[17] of topographic elevation for Manassas National Battlefield Park.

(2,150 acres) of managed grasslands and fields (managed by the park or through agricultural leases), approximately 240 ha (600 acres) of which have recently been restored to native warm-season grasses (Figure 2.9). One of the park's goals is to promote better quality grassland habitat, for birds and other species that utilize grasslands, while still maintaining the agricultural heritage of the park. This is primarily achieved through the conversion of cool-season grasslands to warm-season grasslands. Cool-season grasslands are mown in late May or early June, and cutting may continue throughout the summer (Peterjohn 2006). Warm-season grasslands are harvested only once each summer, beginning in mid-July. Mowing ceases before early September to allow regrowth before winter (Peterjohn 2006).

Warm-season grassland species are those that initiate growth in late spring and reach their peak during the warm summer months (Peterjohn 2006). Warm-season species are generally native to the Mid-Atlantic region, are deep-rooted and so are better at stabilizing soils, and are more drought resistant. Species include such grasses as big bluestem (*Andropogon gerardii*), panic grasses (*Panicum* spp.), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), and purpletop (*Tridens flava*). 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). Cool-season grassland species start growing in early spring (April) and flower in June. Storage in rhizomes controls winter hardiness. Most cool-season grasses are non-native to the Mid-Atlantic region, including bluegrass (*Poa* spp.), brome (*Bromus* spp.), fescue (*Festuca* spp.), timothy (*Phleum pratense*), and orchard grass (*Dactylis glomerata*; Peterjohn 2006).

The Culpeper Basin (the physiographic region where Manassas National Battlefield Park is located), with its low relief and distinctive soils, historically had extensive natural savannas and grasslands (Allard and Leonard 1962, Brown 2000). These grasslands probably remained open because of frequent fires, both natural and deliberately set by Native Americans (Van Lear and Waldrop 1989, Maxwell 1910). After European settlement, these grasslands were mostly destroyed by extensive clearing and agriculture, widespread fire suppression, and repeated cutting, resulting in the mosaic of land uses that was present at the time of the Battles of First and Second Manassas.

17. National Elevation Database: Gesch et al 2002, Gesch 2007, MANA.

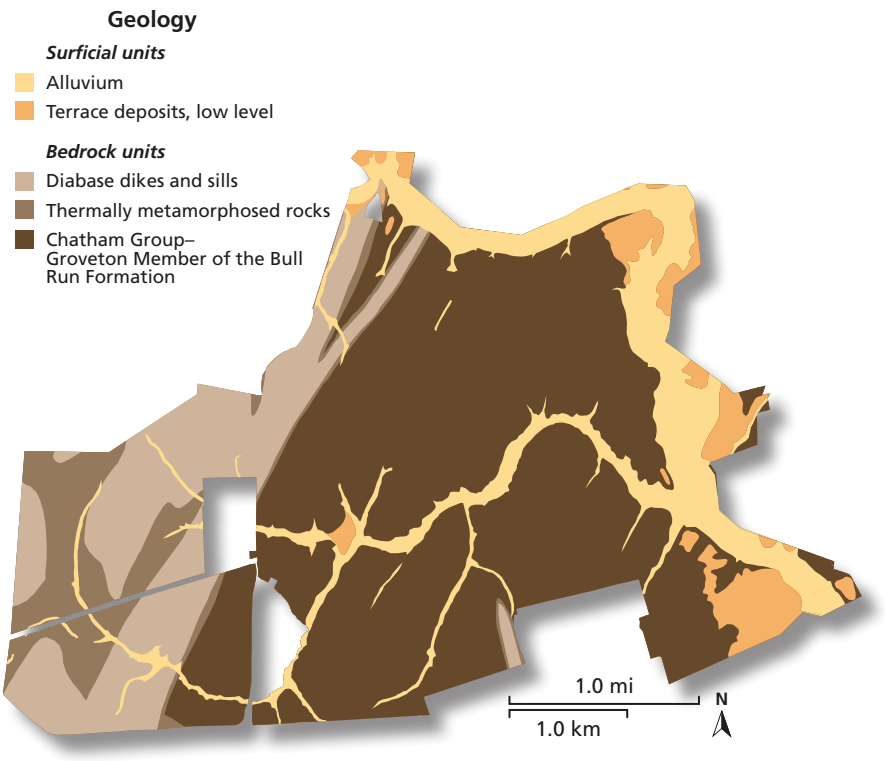


Figure 2.6. GIS data layer[18] of surficial and bedrock geology in Manassas National Battlefield Park.

Rare, threatened, and endangered species

Manassas National Battlefield Park provides habitat for several state-listed plant species. These are purple milkweed (*Asclepias purpurascens*), blue heart (*Buchnera americana*), Mead's sedge (*Carex meadii*), Appalachian quillwort (*Isoetes appalachiana*), hoary puccoon (*Lithospermum canescens*), hairy beardtongue (*Penstemon hirsutus*), marsh hedgenettle (*Stachys pilosa* var. *arenicola*), and buffalo clover (*Trifolium reflexum*). Many of these species are associated with the diabase or metasiltstone substrates in the park (MANA 2006).

As well as these bird species, there are several state-listed species of birds (great egret [*Ardea alba egretta*], long-eared owl [*Asio otus*], purple finch [*Carpodacus purpureus*], hermit thrush [*Catharus guttatus*], brown creeper [*Certhia americana*], northern harrier [*Circus cyaneus*], cerulean warbler [*Dendroica cerulea*], magnolia warbler [*Dendroica magnolia*], alder flycatcher [*Empidonax alnorum*], golden-crowned kinglet [*Regulus satrapa*], red-breasted nuthatch [*Sitta canadensis*], winter wren [*Troglodytes troglodytes*], golden-winged warbler [*Vermivora chrysoptera*]) and mammals (river otter [*Lontra canadensis lataxina*]) found in the park.

2.1.2 Resource management issues overview

Manassas National Battlefield Park faces a number of resource management issues, many of which are related to the surrounding land use (NCRN 2006; Figure 2.10). Encroaching development reduces the habitat available for native flora and fauna. Between 1990 and 2000, population density in the vicinity of the park increased, as the sprawl of Washington, DC's south-western suburbs continued to expand westward towards the park (Figure 2.11). Not surprisingly, housing density also increased between 2000 and 2010, with increases occurring to the north, west, and south of the park (Figure 2.12). Road density is highest to the east of the park (Figure 2.13). High road density (>1.5 km km^{-2}) can impact turtle populations (Gibbs and Shriver 2002, Steen and Gibbs 2004). The area surrounding Manassas National Battlefield Park also has a very low proportion of protected areas (Figure 2.14). Protection

18. Thorneberry–Ehrlich 2008, MANA.

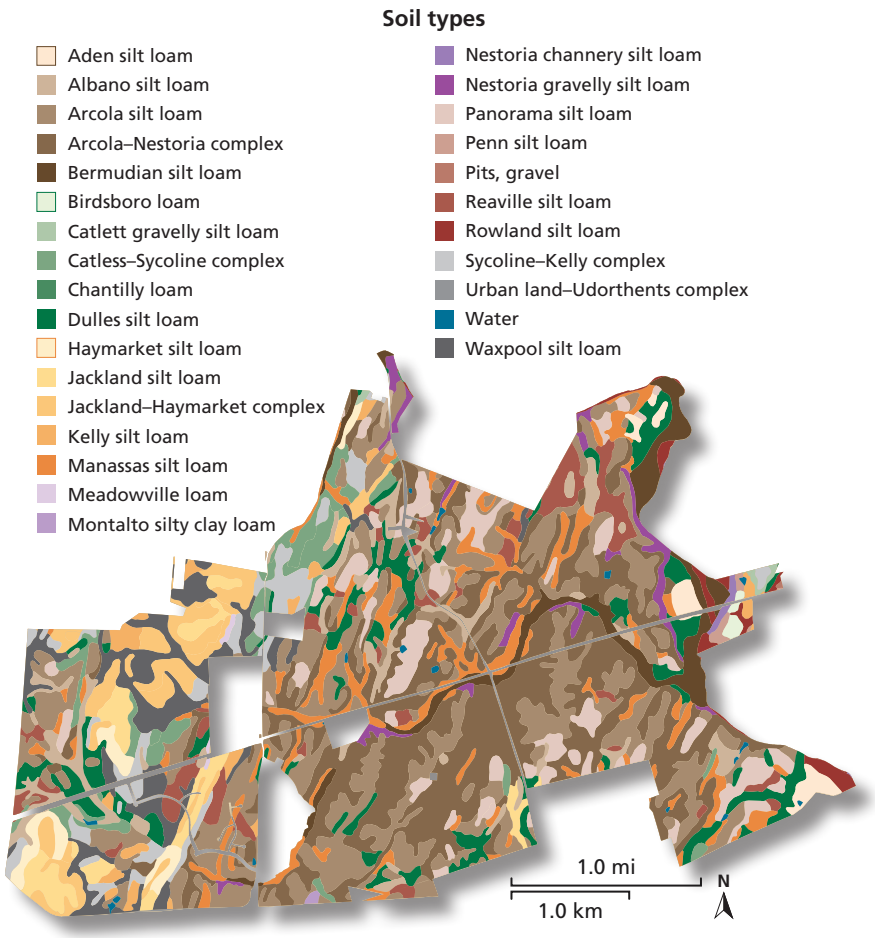


Figure 2.7. GIS data layer[19] of soil types found in Manassas National Battlefield Park.

of 10–60% of suitable habitat is necessary to sustain long-term populations of area-sensitive and rare species (Andrén 1994, Environmental Law Institute 2003). The overpopulation of deer in the park has greatly reduced woodland understory vegetation with potentially negative consequences on the park's woodland bird populations. The park provides the opportunity for visitors to explore the historic terrain in the increasingly urbanized landscape of northern Virginia (Figures 2.12, 2.15). However, two busy commuter corridors, Routes 29 and 234, bisect the park and can diminish the visitor experience. Exotic and invasive plants outcompete native species, while insect and other pests cause damage to forest trees. On a regional scale, degraded air quality associated with vehicular traffic also affects aquatic habitats and sensitive species, and continued road development increases stormwater runoff of sediments and pollutants into the rivers.

Water

In 2006, a Total Maximum Daily Load (TMDL) was approved for Bull Run for benthic and bacteriological impairments (U.S. EPA 2006a, b). A TMDL is a pollution limit ideally set for every identified problem pollutant in each waterbody on the 303(d) list. The cap defines the maximum amount of each pollutant that the waterbody can theoretically receive and still meet water quality standards for all its designated uses. All state waters in Virginia are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish; VAC 2008).

Grasslands

With grasslands (both warm- and cool-season) making up a significant portion of

19. SSURGO, MANA.

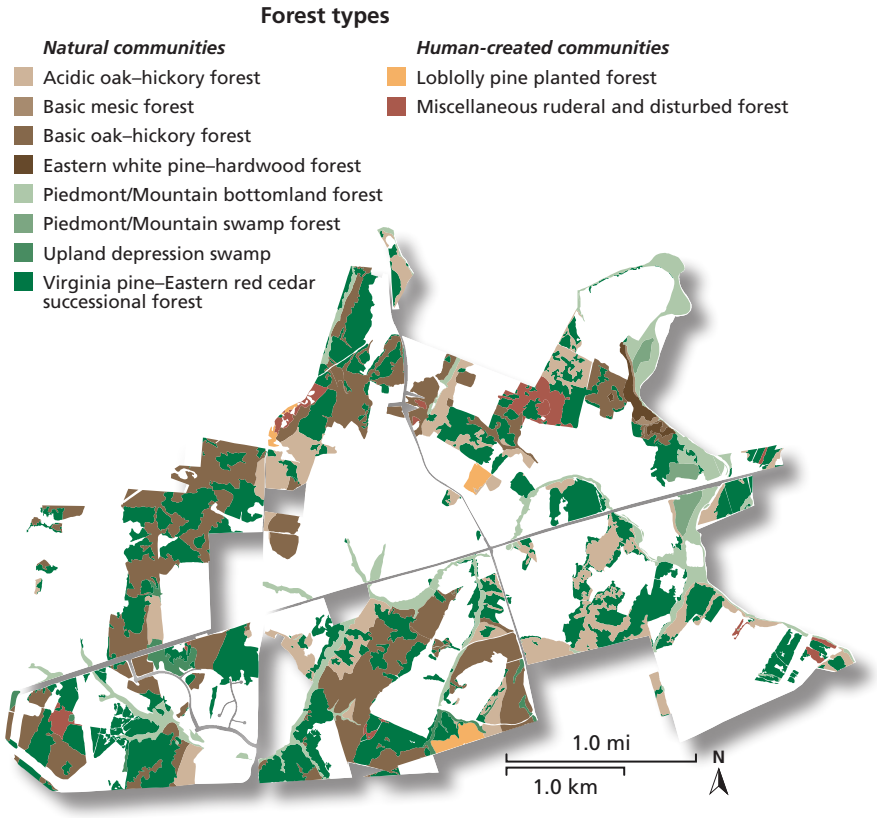


Figure 2.8. GIS data layer[20] of forest types found in Manassas National Battlefield Park. Note that the forest type data were only available within the park's fee boundary, not the larger administrative boundary shown on previous maps.

Manassas National Battlefield Park's historic and current viewsheds, management of these grasslands is high on the list of the Park's natural resource issues. Widespread declines have occurred in grassland bird communities of North America, with the primary cause in the eastern United States being afforestation (as land once cleared for agriculture reverts back to forest) that replaces of early successional and old-field habitats preferred by these species (Askins 2000, Brennan and Kuvlesky 2005). Grasslands naturally change to early successional forest if left undisturbed, so active management is required to maintain grassland areas. Native warm-season grasslands were historically maintained by a combination of soil moisture levels and fire (Askins 1999), and current management options include mowing and prescribed burns (Peterjohn 2006). The quality of the grasslands at Manassas National Battlefield Park is evidenced by its designation as an Important Bird Area by the National Audubon Society.

Forests

The mosaic of forest and grassland at Manassas National Battlefield Park is ideal habitat for white-tailed deer (*Odocoileus virginianus*), with deer densities within the park (61 deer km^{-2} [158 deer mi^{-2}]) well exceeding the recommended carrying capacity for the Piedmont region of Virginia (15 deer km^{-2} [39 deer mi^{-2}]) as well as the general recommended forest threshold of 8 deer km^{-2} (21 deer mi^{-2}; Bates 2005, 2009). There is widespread indirect evidence of overbrowsing by deer in the park (Fleming and Weber 2003). Indirect effects of overbrowsing observed in Manassas National Battlefield Park include: open understories with lack of structural diversity and sparse representation of tree saplings; complete absence of tree seedlings on some sites; sparse herb layers, even on some fertile, mesic sites; widespread populations of herbaceous species that show below-average size and vigor and consisting of vegetative individuals that do not flower; and areas of extensive, visible browse damage to plants, i.e., topped-off stems and leaves (Fleming and Weber 2003). Besides directly impacting vegetative communities, deer overbrowsing can contribute to declines in breeding bird abundances by decreasing the struc-

20. MANA.

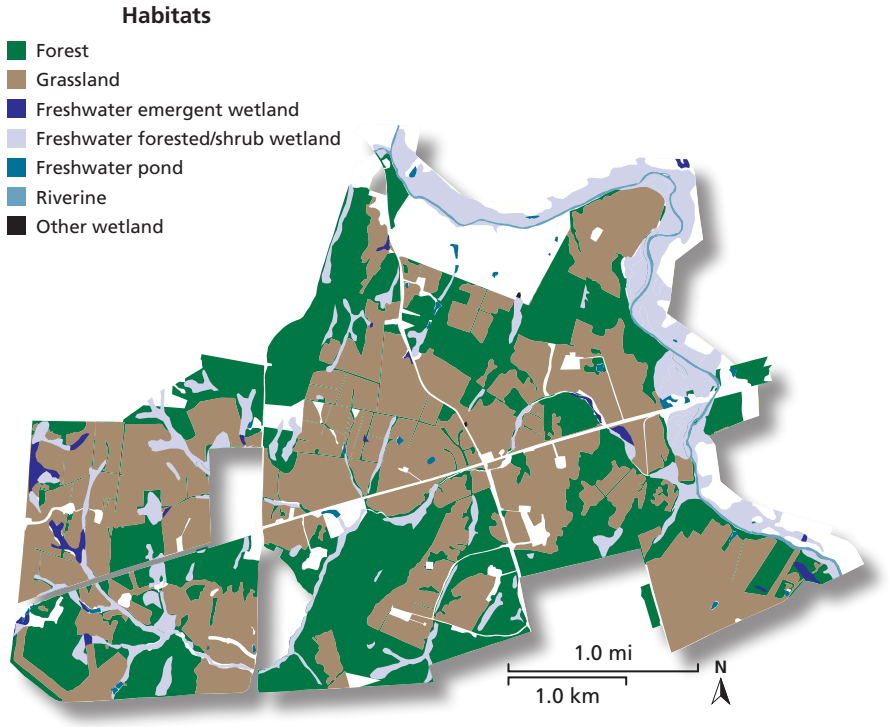


Figure 2.9. GIS data layer[21] showing general location and types of habitats in Manassas National Battlefield Park.

tural diversity and density in the forest understory (McShea and Rappole 1997).

A deer exclosure study by Rossell et al. (2005) performed within Manassas National Battlefield Park has provided experimental evidence supporting the observed indirect effects of deer over-browing. Control plots and deer exclosure plots were placed in oak–hickory, Virginia pine–Eastern red cedar successional, and Piedmont/mountain bottomland forest types (described above). Deer herbivory severely impacted forb cover and vertical plant cover in all three forest types. By the fourth year of the study, boxelder, hickory, and red maple (*Acer rubrum*) seedlings were completely eliminated from control plots, while red (*Quercus rubra*) and white oak seedlings were severely reduced. The study concluded that deer browsing in the park is directing succession of forests toward stands with fewer species and a greater dominance of ash, black cherry, and hackberry.

Another forest resource issue is that of exotic and/or invasive plants. Invasive exotic plants may compete with native plants and therefore lead to a reduction in biodiversity of the native flora (Mack et al. 2000). The past 50 years have seen an increase in the number of exotic plants documented in the northern Virginia Piedmont (Fleming and Weber 2003). In 1943, the only exotic plant documented as a serious threat to native vegetation in the Bull Run Mountains was Japanese honeysuckle (*Lonicera japonica*). In their 2003 inventory of the forests of Manassas National Battlefield Park, Fleming and Weber recorded up to seven exotic species in a single plot. Although there are more than 70 non-native plant species documented in the park, the most abundant exotic species in the park by forest type are:

Piedmont/mountain swamp forest: garlic mustard (*Alliaria petiolata*), rough-stalk bluegrass (*Poa trivialis*).

Upland depression swamp forest: meadow fescue (*Festuca pratensis*), Canada bluegrass (*Poa compressa*).

Piedmont/mountain bottomland forest: garlic mustard, Japanese stiltgrass (*Microstegium vimineum*), rough-stalk bluegrass.

Basic mesic forest: garlic mustard, Japanese honeysuckle (*Lonicera japonica*), Japanese stiltgrass.

21. National Wetlands Inventory, MANA.

Basic oak–hickory forest: Japanese honeysuckle, coralberry (*Symphoricarpos orbiculatus*).

Acidic oak–hickory forest: coralberry.

Virginia pine–Eastern red cedar successional forest: Japanese honeysuckle.

Insect and fungal pathogens have emerged as major stressors to forests in the Mid-Atlantic region in recent decades, and the 2003 forest inventory at Manassas National Battlefield Park documented most of these pathogens within the park (Fleming and Weber 2003). The principal pathogens of interest at the park are the exotic gypsy moth (*Lymantria dispar*), exotic hemlock woolly adelgid (*Adelges tsugae*), exotic emerald ash borer (*Agrilus planipennis*), Southern pine beetle (*Dendroctonus frontalis*), the fungal agent dogwood anthracnose (*Discula destructiva*), and the fungal agent Dutch elm disease (*Ceratocycstis ulmi*).

The origin of dogwood anthracnose fungus is unknown but it has become a significant pathogen of flowering dogwood (*Cornus florida*) in the Eastern United States (Anderson et al. 1993). In Manassas National Battlefield Park, more than half the vegetation plots samples in the forest inventory study contained dead or dying flowering dogwoods, and sites where this tree was formerly dominant (e.g., in oak–hickory forests) are typically littered with snags and downed wood from anthracnose-killed trees (Fleming and Weber 2003).

2.2 RESOURCE STEWARDSHIP CONTEXT

2.2.1 Park enabling legislation

The documents guiding natural resource management at Manassas are: the National Park Service Organic Act of 1916 ("Organic Act", Ch. 1, 39 Stat 535), the 1940 Order Designating the Manassas National Battlefield Park (Ickes 1940),[22] the Manassas National Battlefield General Management Plan (GMP; NPS 2008, 2009), and the NPS Management Policies (U.S. Dept of Interior 2006).

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

> *"the Service thus established shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."*

Consequently, like all parks in the National Park system, one of Manassas National Battlefield Park's chief environmental mandates is to preserve the viewshed as well as the natural resources of the park. Any visitor activities associated with enjoyment can occur only to the extent that they do not impair the scenery and the natural resources for future generations.

As a battlefield park, natural resource management at Manassas is set within a cultural and historic context. Both the park's 1940 founding legislation and the 2008 General Management Plan state the significance of the park's historic landscapes and views. The founding legislation states,

> *"The purpose of Manassas National Battlefield Park is to preserve the historic landscape containing historic sites, buildings, objects, and views which contribute to the national significance of the First and Second Battles of Manassas, for the use, inspiration, and benefit of the public."*

Thus, as a battlefield park, natural resource management at Manassas is set within a cultural and historic context. Section 5.3.5.2 (Cultural Landscapes) of NPS Management Policies (U.S. Dept of Interior

22. Subsequent legislation in 1954, 1980, and 1988 established the present park boundary to preserve the most historically important lands relating to the two battles of Manassas.

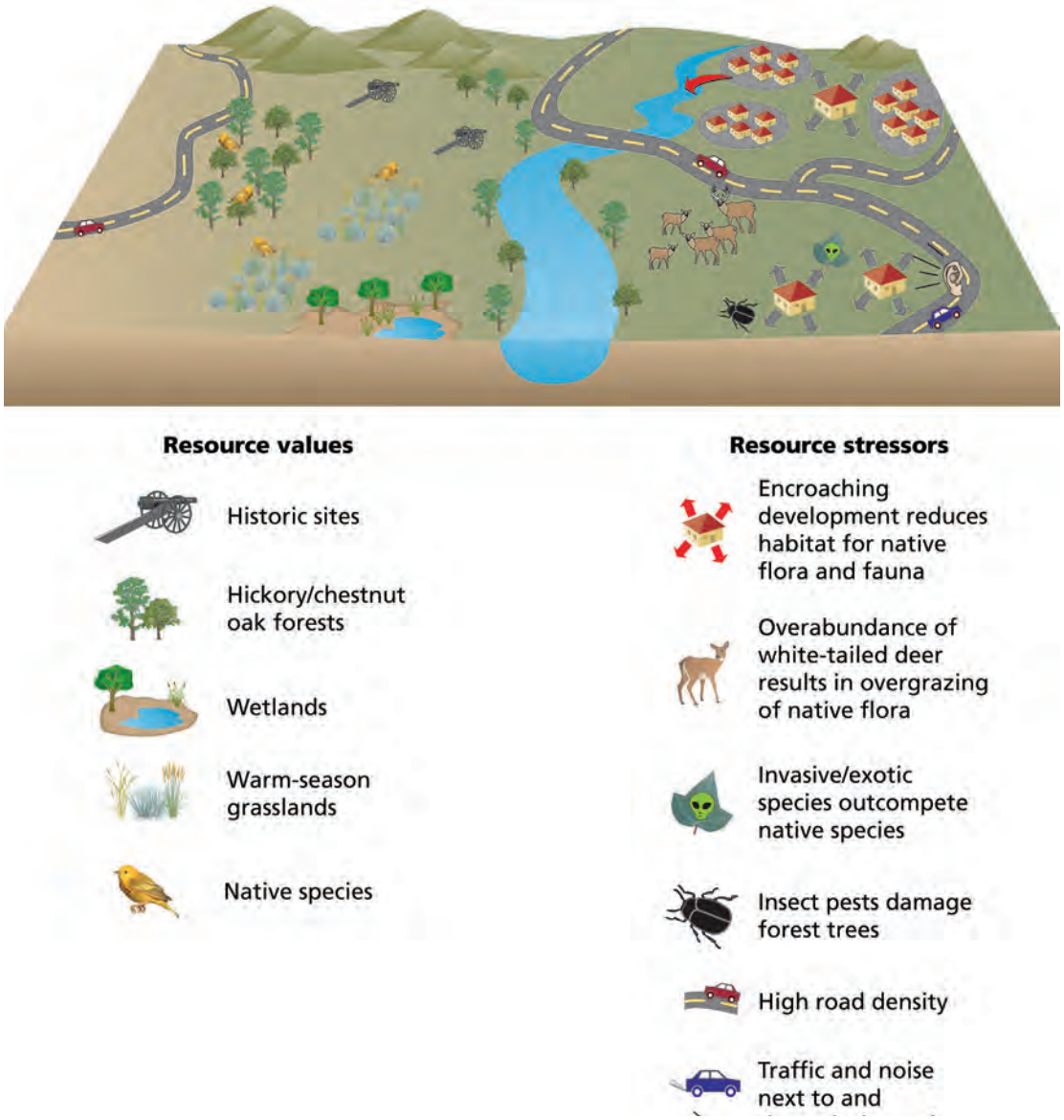


Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Manassas National Battlefield Park.

2006) clarifies the boundary between management for cultural and natural resources, stating that,

> *"The treatment of a cultural landscape will preserve significant physical attributes, biotic systems, and uses when those uses contribute to historical significance. Treatment decisions will be based on a cultural landscape's historical significance over time, existing conditions, and use. Treatment decisions will consider both the natural and built characteristics and features of a landscape, the dynamics inherent in natural processes and continued use, and the concerns of traditionally associated peoples."*

Manassas National Battlefield Park is therefore a park established to preserve and maintain a Civil War-era cultural landscape that is managed as much as possible to preserve physical attributes and biotic systems wherever historic considerations do not indicate otherwise.

2.2.2 Resource stewardship planning

While no official record of decision has been made for the GMP for Manassas National Battlefield Park (NPS 2008), it states,

> *" The park contains cultural landscapes from the period of the battles (1861–1862) that contain historic features of the battles, as well as woodlands, fields,*

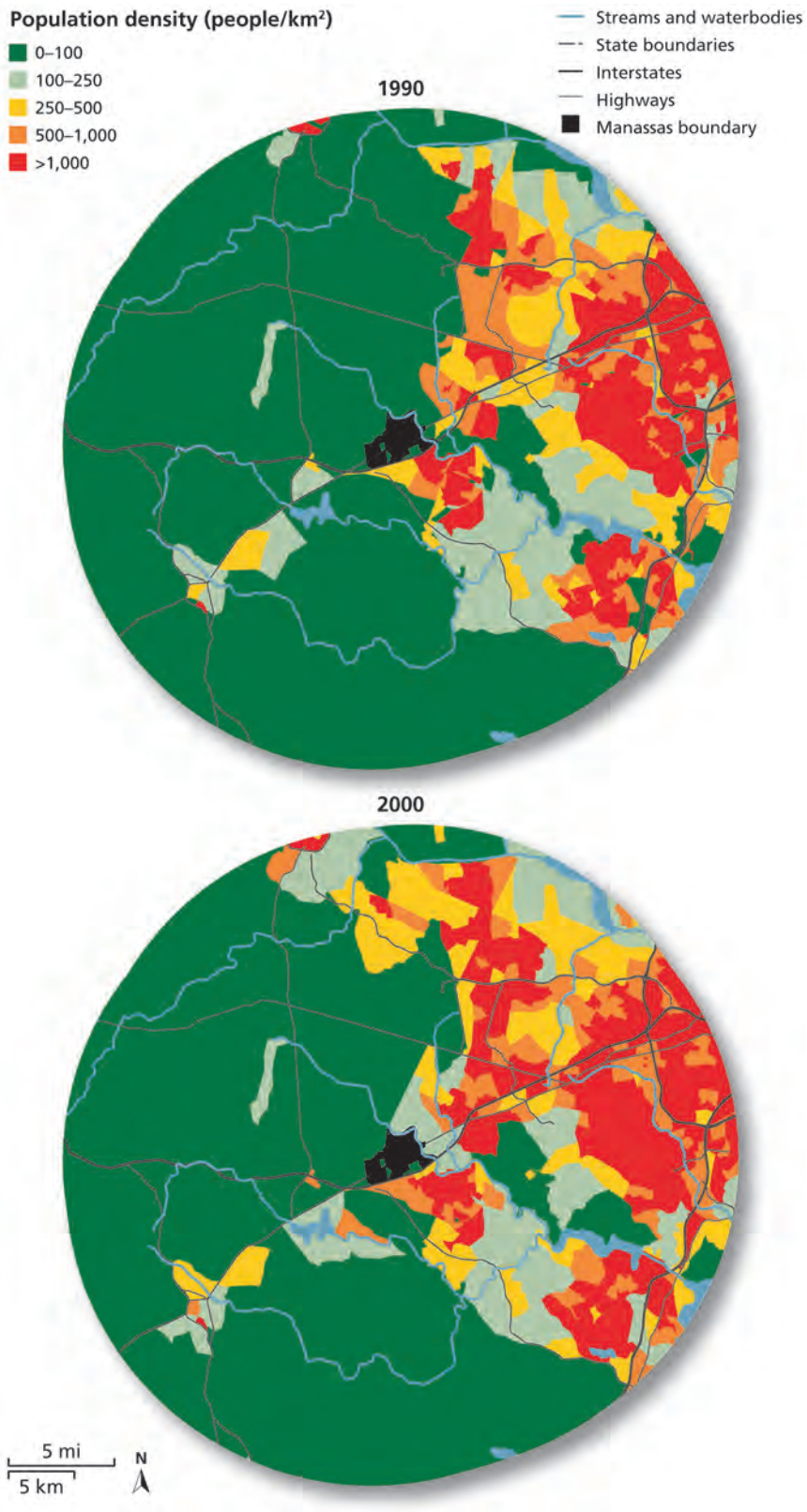


Figure 2.11. GIS data layer[23] showing population density surrounding the park in 1990 and 2000.

23. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

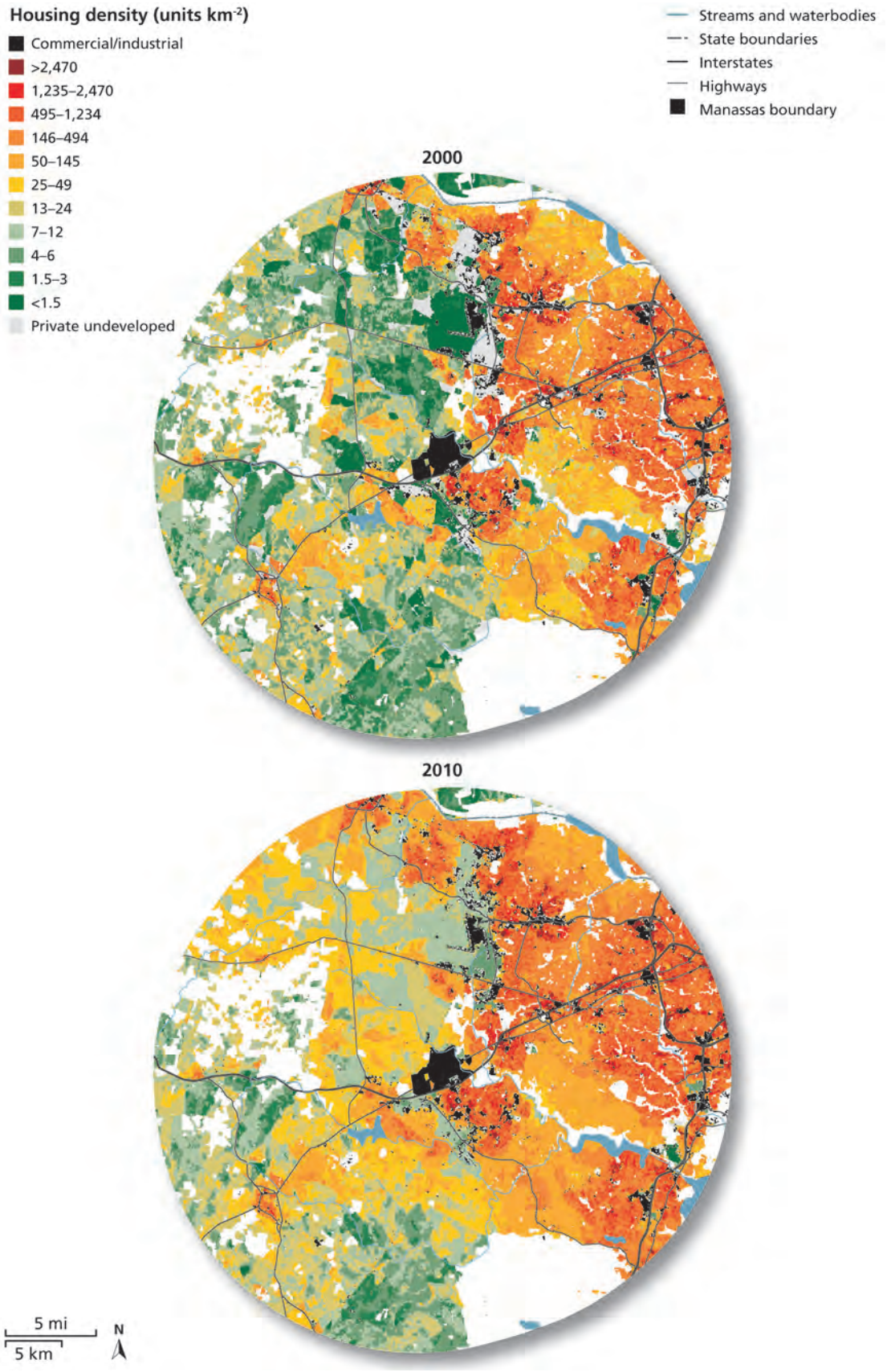


Figure 2.12 GIS data layer[24] showing housing density surrounding the park in 2000 and 2010.

24. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

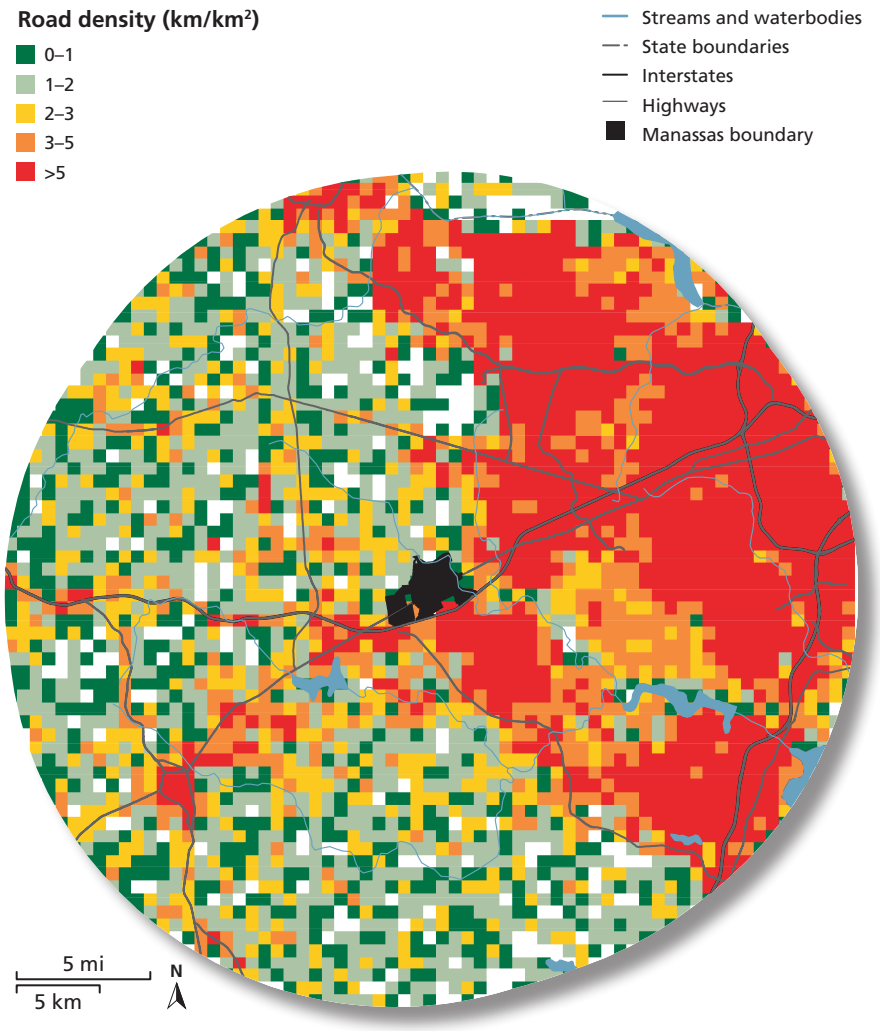


Figure 2.13. GIS data layer[25] showing road density surrounding the park in 2003.

streams, rolling hills, and certain views or vistas that are representative of the physical setting that existed at the time of the battles."

The GMP outlines the mandates and policies pertaining to the natural resources of the park, as follows:

1. Air quality

- The National Park Service has the responsibility to protect air quality under both the 1916 Organic Act and the Clean Air Act. Accordingly, the National Park Service will seek to perpetuate the best possible air quality in parks to preserve natural resources and systems, preserve cultural resources, and sustain visitor enjoyment, human health, and scenic vistas.

2. Natural soundscape

- The National Park Service will preserve, to the greatest extent possible, the natural soundscapes of parks. Using appropriate management planning, superintendents will identify what levels of human-caused sound can be accepted within the management purposes of the park.

3. Vegetation and wildlife

- The National Park Service will maintain as parts of the natural ecosystem all native plants and animals in the park. The National Park Service will achieve this maintenance by (1) preserving and restoring natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and

25. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

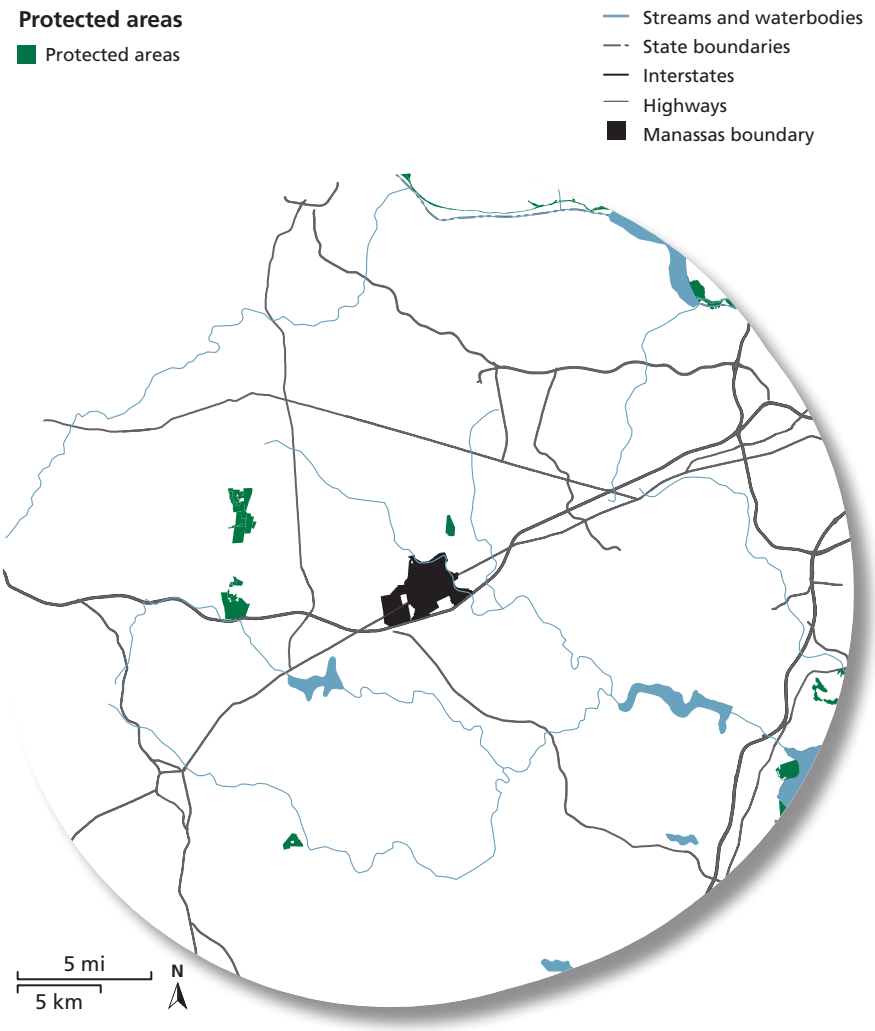


Figure 2.14. GIS data layer[26] showing protected areas surrounding the park in 2000.

the communities and ecosystems in which they occur; (2) restoring native plant and animal populations and the communities in parks when they have been extirpated by past human actions; and (3) minimizing human impact on native plants, animals, populations, communities, and ecosystems and the processes that sustain them.

4. Threatened and endangered species

- The National Park Service will survey for, protect, and strive to recover all species native to national park system units that are listed under the Endangered Species Act. The National Park Service will determine all management actions for the protection and perpetuation of federally, state-, or locally listed species through the park management planning process, and will include consultation with lead federal and state agencies as appropriate.

5. Lightscape management/night sky

- The National Park Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light. Current policy desires a condition whereby excellent opportunities to see the night sky are available. It is desired that artificial light sources both within and outside the park do not affect opportunities to see the night sky unacceptably and adversely, and that artificial light sources should be shielded when possible. Current policy requires that artificial light sources be restricted to those areas where security, basic human safety, and special cultural resource requirements must be met.

26. NPScape Landscape Monitoring Project *http://science.nature.nps.gov/im/monitor/npscape/index.cfm*

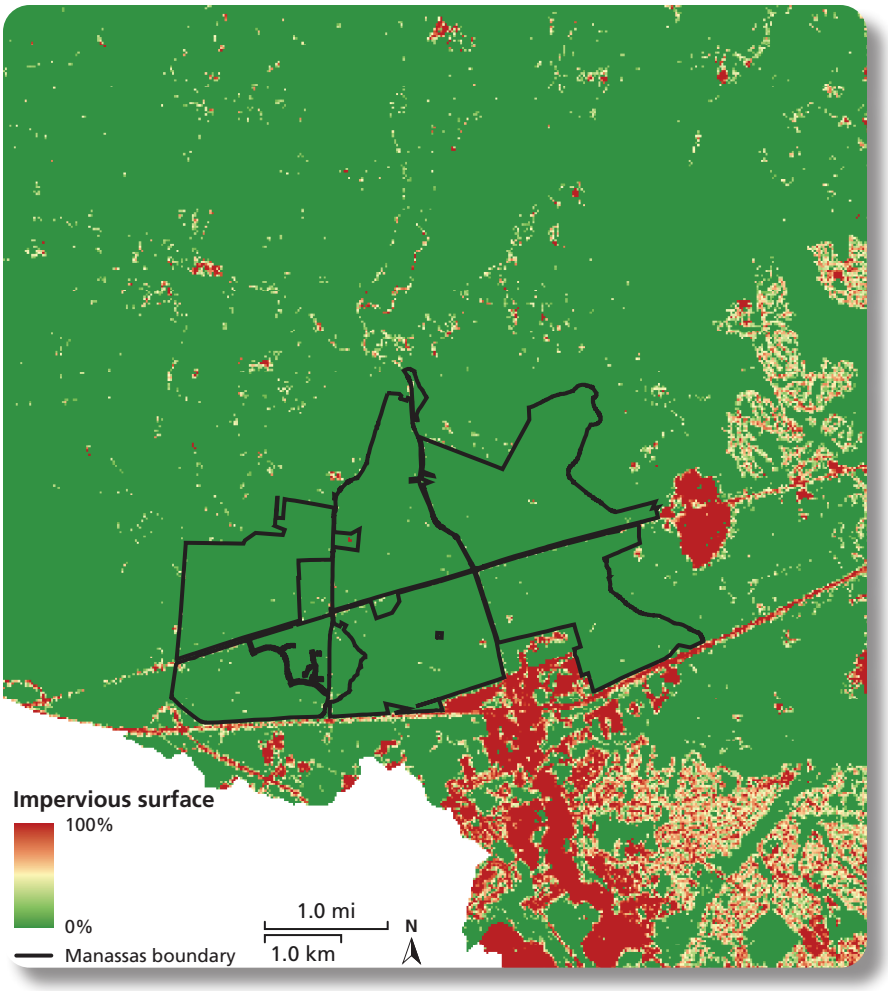


Figure 2.15. GIS data layer[27] showing percent impervious surface in and around Manassas National Battlefield Park in 2000.

6. Habitat manipulation

- In historic zones, habitat manipulation may be used to recreate a scene that is mandated by the enabling legislation of the area or the park's general management plan, or is deemed essential to the original intent for which the park was designated. For historic zones in parks where a historical perspective is not essential to the management goals or original purposes for the area, or to the intent of the enabling legislation, the area should be managed as a natural area to the largest extent possible, consistent with Sections 106 and 110 of the National Historic Preservation Act.

7. Soils

- The National Park Service actively seeks to understand and preserve the soil resources of the park, and to prevent, to the extent possible, the unnatural erosion, physical removal, or contamination of the soil, or its contamination of other resources. Natural soil resources and processes function in as natural a condition as possible, except where special considerations are allowable under policy.

8. Topography and geology

- The park's geologic resources are preserved and protected as integral components of the park's natural systems.

9. Water resources/water quality

- Surface water and groundwater are protected, and water quality meets or exceeds all applicable water quality standards. NPS and NPS-permitted programs and facilities are maintained and operated to avoid pollution of surface water and groundwater.

27. RESAC Impervious Surface Area Time Series, MONO.

10. Floodplains

- Natural floodplain values are preserved or restored. Long- and short-term environmental effects associated with the occupancy and modification of floodplains are avoided. When it is not practicable to locate or relocate development or inappropriate human activities to a site outside the floodplain or where the floodplain will be affected, the Director's Order #77-2 guides National Park Service procedures, including:
  - Preparing and approving a statement of findings;
  - Using non-structural measures as much as practicable to reduce hazards to human life and property while minimizing impacts on the natural resources of floodplains;
  - Ensuring that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program (44 Code of Federal Regulations 60).

11. Wetlands

- The natural and beneficial values of wetlands are preserved and enhanced. The National Park Service implements a 'no net loss of wetlands' policy and strives to achieve a longer-term goal of net gain of wetlands across the national park system through the restoration of previously degraded wetlands. The National Park Service avoids to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and avoids direct or indirect support of new construction in wetlands wherever there is a practicable alternative. The National Park Service compensates for remaining unavoidable adverse impacts on wetlands by restoring wetlands that have been previously degraded.

Manassas National Battlefield Park also has a draft Natural Resources Management Plan (MANA 2006) which is specific to the resource management aspect of the park and follows the guidelines for natural resource management laid out in the General Management Plan.

2.2.3 Resource stewardship science

The GMP (NPS 2008) describes and analyzes three alternatives for managing Manassas National Battlefield Park. The approved plan will help managers make decisions about managing natural and cultural resources, visitation, and development for the next 15–20 years. Alternative A, the no-action alternative, describes the existing conditions and current directions of park management. It serves as the basis for comparing the other alternatives and for understanding why certain changes have been proposed. This alternative proposes limited, if any, changes in interpretation and management of the park.

The two 'action' alternatives describe various approaches to managing the park's resources and visitation. Both call for the removal of commuter and truck traffic from U.S. Route 29 and VA Route 234. Alternative B (NPS preferred alternative)—*The Two Battles of Manassas—A Comprehensive Understanding of Each Battle* proposes a future condition at the park that focuses on interpreting the two battles of Manassas as distinct military events. The visitor center at Henry Hill would orient visitors to the park as a whole and focus on the Battle of First Manassas. A separate visitor contact station would focus on the events of the Battle of Second Manassas.

While the GMP guides the management of the park, an interim document outlines plans needed while the GMP is being implemented. While not yet approved, the Park Operations Plan (MANA 2009) lists the work that is needed in the park for the next three years and who is responsible for leading that work. These goals are shown within priority categories as follows:

1. Immediate attention needed

- Expand interpretive programs in accordance with park purposes and significance:

  - Update and upgrade interpretation of the First Battle of Manassas
  - Include interpretation of the Second Battle of Manassas
  - Tell the reunification story as an inspiration for the world community
  - Develop outreach for a wider audience, including users of emerging technologies and diverse populations
- Develop facilities and media for interpretation of the Second Battle of Manassas.
- Successfully observe the 150th anniversary of the Civil War and the battles at Manassas.
- Compete for special funding to enhance the park's ability to accomplish its goals.
- Identify and submit those projects that meet the criteria for NPS Centennial funding; implement the projects funded.

2. Ongoing/operational

- Promote and ensure a safe environment for visitors and employees.
- Landscapes within the park are rehabilitated, as needed, protected and maintained; viewsheds outside the park are protected and maintained.
- Restore, as needed, protect, and maintain historic structures and objects, including the museum collection.
- Promote stewardship of the park with local communities, local stewardship organizations, partners, groups with similar interests and other stakeholders.
- The park law enforcement staff provides the full range of resource protection and visitor services.
- Diversify the workforce and maintain the competencies needed to meet goals through robust staffing, training and retention activities.
- Improve the park's ability to manage and protect natural resources compatible with cultural landscape planning and needed facilities.
- Promote the park as a venue for developing a greater understanding of cultural and natural resources.
- Maintain and protect the non-historic park facilities and infrastructure.
- Conduct all activities in compliance with the environmental management system.

3. Intermediate/as opportunities arise

- Develop interim alternatives for safe visitor transportation/circulation in the park.
- Promote recreational uses that are compatible with the purposes of the park and lead to discovery of the significance of the area.
- Acquire land crucial for the preservation of the battlefield.

4. Long-range

- Relocate non-park traffic to routes outside the park.

This natural resource condition assessment builds on these management plans by synthesizing monitoring data into a habitat-assessed framework, putting management goals in a landscape context and identifying data gaps.

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Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Manassas park staff, including natural resource manager Bryan Gorsira, initially met in May 2009, along with National Capital Region Network Inventory & Monitoring (NCRN I&M) staff Mark Lehman, Patrick Campbell, and Megan Nortrup, and University of Maryland Integration and Application Network staff Tim Carruthers and Jane Thomas. Topics discussed included which park boundaries to use in the assessment, identification of assessment metrics and data sources, habitat identification, and framework definition.

Additional conference calls were held in August and November 2009 to further progress the project. Also participating in these calls were natural resource staff from Antietam National Battlefield and Monocacy National Battlefield, to facilitate the concurrent natural resource assessments occurring at these three parks. Topics discussed during these calls included furthering the habitat identification and delineation and how to best assess the agricultural lands in the park, ultimately culminating in the creation of the 'habitats managed for natural resource values' and 'habitats managed for agricultural values' groupings.

A meeting was held at Monocacy National Battlefield in January 2010. Natural resource staff from Antietam National Battlefield and Monocacy National Battlefield were also present at this meeting. The purpose of this meeting was to draft the key findings and identify data gaps and management recommendations which are presented in Chapter 5.

3.1.2 Other NPS involvement

The NCRN I&M was the primary coordinator and leader for the production of this NRCA for Manassas National Battlefield Park. NCRN staff established a cooperative agreement with University of Maryland Center for Environmental Science Integration and Application Network (IAN) to work on this document, supplied the majority of the data used in the assessment, and provided knowledge of the larger context of the region's battlefield parks.

Traffic in Manassas National Battlefield Park.

Prior to the first meeting with park staff in April 2009, NCRN staff compiled an extensive collection of data and literature about the park, combining data gathered and analyzed by the NCRN with government reports, scientific literature, and park-generated data to provide a comprehensive picture of the available natural resource knowledge about the park. Following the April meeting, the NCRN produced map products for the assessment based on NCRN and other data, supplied introduc-

tory text on the park's background, and provided substantial editing and feedback during multiple stages in the document's production. NCRN staff also participated in several conference calls on topics including classification of agricultural lands and park boundaries.

In June 2010, following the completion of a working draft document, NCRN held a briefing with regional science staff from the Center for Urban Ecology to familiarize them with the status and content of the NRCAs for Manassas National Battlefield Park, Antietam National Battlefield, and Monocacy National Battlefield. NCRN staff contributed extensive comments on the initial draft report incorporating several suggestions made by Acting Regional Chief of Natural Resources, Dan Sealy. Comments were compiled and submitted by NCRN Science Communicator Megan Nortrup who also fielded follow-up questions from IAN staff.

3.2 REPORTING AREAS

3.2.1 Ecological reporting units

Two reporting frameworks were used in this assessment—the Inventory and Monitoring Vital Signs framework (Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics) and a habitat-based framework. For the habitat-based framework, the park fee boundary was used, which differs from the administrative/legislative boundary shown in the figures in Chapter 2 in that the fee boundary encompasses only the lands that are currently owned by NPS (Figure 2.1). NPS jurisdiction limitations generally prohibit the park from managing resources outside of the fee boundary, so the habitat assessment is limited to those lands. The administrative/legislative boundary equals 2,052 ha (5,071 acres), while the fee boundary is 1,809 ha (4,417 acres). Four predominant ecological habitat types were identified within Manassas National Battlefield Park. Three of these (forests, wetlands and waterways, grasslands) were classified as habitats managed for natural resource values. The remaining area (developed lands) were identified but not assessed in this document (Figure 3.1). Many ecological classification systems are based on vegetation communities (Anderson et al. 1998, Grossman et al. 1998) or land cover (Anderson et al. 1976). However, this habitat classification system was agreed upon in consultation with park staff and is at a sufficient level of classification to permit comparisons to other systems (i.e., formation class or Anderson level one) while also being coarse enough to contain sufficient monitoring data within each habitat to allow a meaningful assessment of resource condition. More detail on this methodology is presented in Section *3.5—Study methods*.

3.3 STUDY RESOURCES AND INDICATORS

3.3.1 Assessment frameworks used in this study

Introduction

For the assessment of resource condition within Manassas National Battlefield Park, two synthetic frameworks were applied that addressed key structural and functional aspects of the ecosystem (U.S. EPA 2002). Recognizing the large amount of data included in this assessment from the NPS I&M, the first framework utilized was the ecological monitoring framework or 'vital signs' categorization developed by NPS I&M (Fancy et al. 2008). Fancy identified a key challenge of such large-scale monitoring programs as the development of information products which integrate and translate large amounts of complex scientific data into highly aggregated metrics for communication to policy-makers and non-scientists. Aggregated indices were developed and are presented within this document. More specific indices and raw data (Appendix A) are also presented to facilitate communication of key conclusions to scientists and field practitioners and to ensure that all approaches and calculations are explicit. The second framework (the habitat framework) calculates aggregated condition indices based upon the three main ecological habitats present within Manassas National Battlefield Park—forests, wetlands and waterways, grasslands. Developed areas, although de-

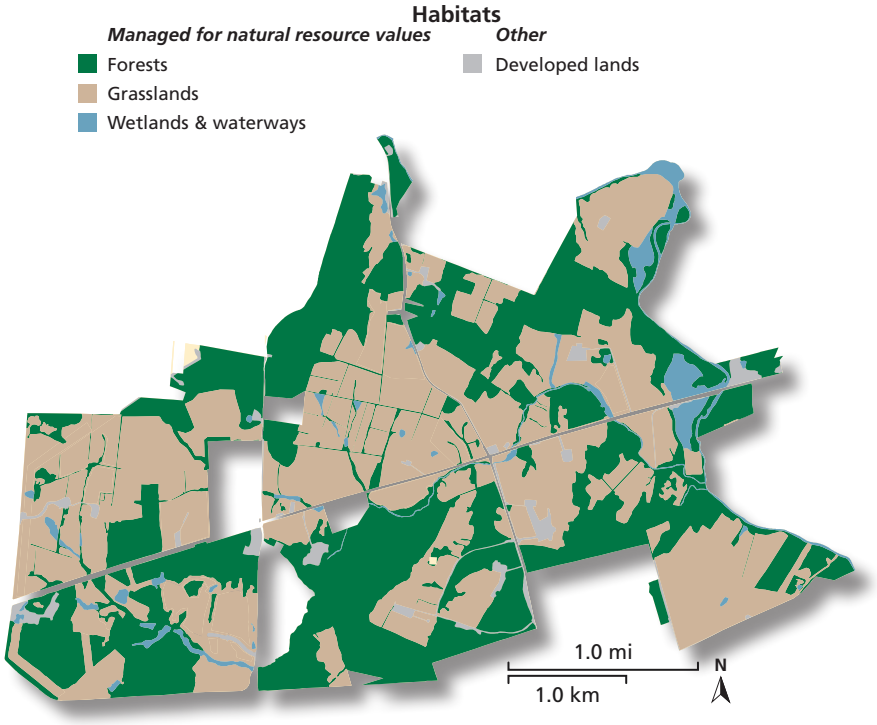

Figure 3.1. GIS data layer[28] of major habitat types in Manassas National Battlefield Park, as defined by aggregation of other GIS data layers.

fined as a fourth habitat, were not assessed for natural resource condition.

Utility of thresholds

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

Definition and types of thresholds

A threshold indicates a point or zone where current knowledge predicts a change in state or some aspects of ecosystem condition. More specifically, however, it represents an accepted value or range indicating that an ecosystem is moving away from a desired state and towards an undesirable ecosystem endpoint (Biggs 2004, Bennetts et al. 2007). Recognizing that many managed systems have multiple and broad-scale stressors, another perspective is to define a threshold as measuring the level of impairment that an environment can sustain before resulting in significant—and perhaps irreversible—damage (Hendricks and Little 2003). Three types of thresholds are used for different aspects of natural resources management and all can provide useful information for the assessment of natural resource condition. These thresholds are management, ecological, or regulatory and while in some cases they overlap (or are the same), these thresholds often provide different information as a result of being established for very different purposes (Figure 3.2; Bennetts et al. 2007).

Management thresholds are intended to instigate changes in management activity

28. NCRN I&M, MANA.

so as to maintain the natural resources of an ecosystem in a desired state. Therefore, these are likely to be the most conservative thresholds as it is necessary for management responses to occur before an ecological threshold is passed (Figure 3.2).

Ecological thresholds are based on best current scientific understanding and indicate a value where large changes in an ecosystem (and therefore natural resource values) are predicted (Figure 3.2). This definition includes the concept of 'critical loads,' as both ecological thresholds and critical loads estimate a metric value expected to be associated with change in the ecosystem. The difference is that an ecological threshold is based upon a response metric while a critical load relates to a known amount of some input to the system. Both ecological thresholds and critical loads are often determined by large modeling studies across multiple sites in varying ecosystem condition, e.g., the ecological threshold for Benthic Index of Biologic Integrity (Southerland et al. 2005) and critical loads for atmospheric nitrogen oxide and sulfur dioxide deposition (Dupont et al. 2005). If changes in an ecosystem begin and there is no early warning resulting in a management response (e.g., no management threshold) and the change continues past the ecological threshold (so that the ecosystem changes and natural resource values become impacted) then regulatory thresholds become relevant.

Regulatory thresholds are likely to be the least conservative threshold as they are frequently based on an aspect of the ecosystem posing a threat to human health (e.g., mercury concentration in fish; Meili et al. 2003), in which case the ecosystem may well have already undergone change to a degraded condition.

Process of threshold determination within ecological monitoring and habitat frameworks

Within this report, a range of management, ecological, and regulatory thresholds were used, although ecological thresholds were used preferentially. One helpful resource was the report by Hendricks and Little (2003) to the U.S. Environmental Protection Agency (U.S. EPA) specifically working towards the establishment of environmental thresholds for multiple metrics. U.S. EPA documentation also provided a basis for Air & Climate (National Ambient Air Quality Standards) and Water Resources (Freshwater Recreational Standards) thresholds, which were supplemented by scientific literature to clarify whether thresholds could be considered as ecologically relevant (rather than simply regulatory) (Tables 3.1, 3.2). Thresholds for Biological Integrity metrics were largely based on National Park Service (NPS) management thresholds and so the scientific literature was further investigated for experimental or correlative justification of these thresholds (Table 3.3). Finally, the thresholds established for Landscape Dynamics metrics were based on research studies, some of which are ongoing within the NCRN (Townsend et al. 2009; Table 3.4).

To conduct an assessment of the natural resource condition of the entire park, it was necessary to develop a framework incorporating all major habitats within the park (Figures 3.1, 3.3). In this habitat assessment, ecosystem or vital sign metrics were used as indicators of ecosystem function within the three habitats (forests, wetlands and waterways, grasslands; Figure 3.3).

3.3.2 Candidate study resources and indicators

If time and resources for data gathering were unlimited, this assessment would include many more data sets and consider many additional components. The Inventory and Monitoring program in the National Capital Region provided a solid range of data types for this evaluation of natural resource conditions, but due to funding and technical constraints could not address the following possible components of the natural resources of Manassas: bird monitoring (grassland, wetland, forest, birds of prey, etc.), macrofungi, regular small mammal monitoring, grasses, groundwater levels, insects, toxics/drugs/hormones in water, plankton, and other components.

3.3.3 Priority study resources and indicators

Two frameworks were employed in this assessment: the ecological monitoring framework (based on Inventory & Monitoring Vital Signs) and the habitat framework (Figure 3.4). Measures of priority study resources and indicators are presented within these frameworks. More information on the ecological monitoring and habitat frameworks is presented in Section *3.5.1—Ecological monitoring framework* and Section *3.5.2—Habitat framework*.

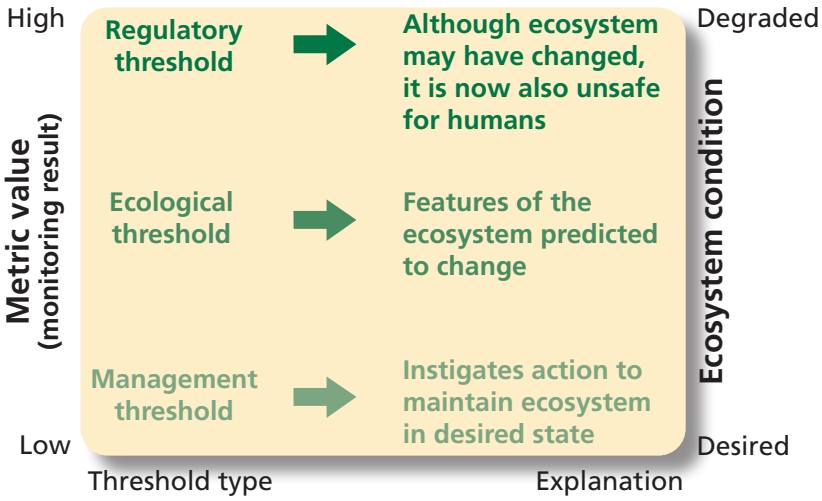

Figure 3.2. Conceptual relationship between ecosystem condition and the different types of thresholds. In all cases, it is presumed that the metric is well-studied with a reliable measurement protocol and well-understood responses (e.g., available large spatio-temporal data sets).

3.4 FORMS OF REFERENCE CONDITIONS/REFERENCE VALUES USED IN THE STUDY

3.4.1 Air & Climate

Ozone—regulatory

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004). In 1997, a human health ozone threshold was set by the National Ambient Air Quality Standards (NAAQS) at 0.08 ppm (U.S. EPA 2006), but has recently been revised and lowered to 0.075 ppm (NAAQS 2008), where the threshold concentration is the three-year average of the fourth-highest daily maximum eight-hour average ozone concentration measured at each monitoring station. In humans, and potentially other mammals, ozone can cause a number of health-related issues such as lung inflammation and reduced lung function, which can result in hospitalization. Concentrations of 0.12 ppm can be harmful with only short exposure during heavy exertion such as jogging, while similar symptoms can occur from prolonged exposure to concentrations of 0.08 ppm ozone (McKee et al. 1996). One study on 28 plant species, where plants were exposed for between three and six weeks, showed foliar impacts including premature defoliation in all species at ozone concentrations between 0.06 and 0.09 ppm (Kline et al. 2008).

Table 3.1. Thresholds for Air & Climate metrics.

Metric	Threshold	Justification	Threshold source
Ozone	0.06 ppm for the 3-yr average of 4th-highest daily maximum 8-hr average ozone concentration, averaged over five years.	The ozone threshold was based on human health but is also appropriate for plant health. Ozone was sampled on an hourly basis. An hourly value was calculated (mean of 4 hours before and after), recording the maximum 8-hr average value per day. For each year the 4th-highest daily value was recorded and then a 3-yr average was calculated.	NPS 2009
Wet nitrogen (N) deposition	1 kg N ha^{-1} yr^{-1} (annual total per site)	The nitrogen threshold was based on maintaining ecosystem structure and function. Annual wet deposition was used—NH_4 and NO_3 results were summed to obtain total wet nitrogen deposition.	NPS 2009
Wet sulfur (S) deposition	1 kg S ha^{-1} yr^{-1} (annual total per site)	The sulfur threshold was based on maintaining ecosystem structure and function.	NPS 2009
Visibility	2 dv (annual per site)	The visibility threshold was based upon how well and how far park visitors can see.	NPS 2009
Mercury (Hg) deposition	2 ng Hg L^{-1} (annual mean)	This modeled value corresponds to an inland fish tissue concentration of 0.5 mg methylmercury kg^{-1} wet weight.	Meili et al. 2003 Hammerschmidt and Fitzgerald 2006

Table 3.2. Thresholds for Water Resources metrics.

Metric	Threshold	Justification	Threshold source
pH	$6.0 \leq pH \leq 9.0$ (monthly instantaneous measurements)	Extreme pH values limit suitability of habitat for biota, e.g., salamander larvae abundance are reduced at extreme pH, by direct effects and reducing available food.	State Water Control Board 2009
Dissolved oxygen (DO)	≥ 4.0 mg DO L^{-1} (monthly instantaneous measurements)	Low concentrations of dissolved oxygen cause limitation and ultimately death of fish, benthic invertebrates and aquatic plants.	State Water Control Board 2009
Temperature	< 32.0°C (monthly instantaneous measurements)	Increased stream water temperature is unsuitable for many biota such as brook trout.	State Water Control Board 2009
Acid neutralizing capacity (ANC)	> 200 µeq L^{-1} (monthly instantaneous measurements)	Threshold based on U.S. EPA "sensitive to acidification" standard of 200 µeq L^{-1} (1 mg L^{-1} $CaCO_3$ = 20 µeq L^{-1}). Also justified by relationship to stream Benthic IBI.	Southerland et al. 2007
Salinity	< 0.25 (monthly instantaneous measurements)	Threshold based on U.S. EPA human drinking water standards of maximum 250 mg L^{-1} chloride ions (equivalent to a salinity of 0.25). Salinity was measured at each sample location for all sampling dates (2005–2006).	U.S. EPA 2009 EPA Standards for Drinking
Nitrate (NO_3)	< 2 mg NO_3 L^{-1} (monthly instantaneous measurements)	Threshold based on relationship to benthic invertebrate index.	Southerland et al. 2007
Phosphate (PO_4)	0.1133 mg PO_4 L^{-1} (monthly instantaneous measurements)	Threshold based on U.S. EPA nutrient ecoregional criteria, to maintain baseline conditions with minimal impact from anthropogenic eutrophication.	U.S. EPA 2000 U.S. EPA nutrient criteria inland waters
Benthic index of biotic integrity (IBI)	Benthic IBI > 3 (one sample per site)	Threshold based on statewide assessment of benthic communities; resulting in the scale: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007 Norris and Sanders 2009
Physical habitat index (PHI)	PHI > 81 (one sample per site)	Threshold based on Maryland Biological Stream Survey data on the condition of MD streams: 0–50 (severely degraded), 51–65 (partially degraded), 66–80 (degraded), and 81–100 (minimally degraded).	Paul et al. 2003 Southerland et al. 2005

Table 3.3. Thresholds for Biological Integrity metrics.

Metric	Threshold	Justification	Threshold source
Cover of herbaceous species, woody vines, and target exotic trees and shrubs	< 5% cover. Measured as area of ground covered by herbs and vines, and percent of total basal area for shrubs and trees (one sample per site)	This threshold is more than a simple presence of these species, but an indication that they have the potential to increase in abundance, displacing native species.	This threshold is a guideline to commence active management of an area by removal of these species.
Presence of pest species	>1% of trees infested (one sample per site)	The emerald ash borer threshold is based upon any observed presence of this pest species being unacceptable. The gypsy moth threshold is based on documented forest response.	Montgomery 1990 Liebhold et al. 1994
Native tree seedling regeneration	35,000 seedlings ha^{-1} (one sample per site)	Based on natural densities of native tree seedlings in a healthy and self-sustaining forest. This threshold may vary depending on deer population.	McWilliams et al. 1995 Carter and Fredericksen 2007 Marquis et al. 1992
Fish index of biotic integrity (IBI)	Fish IBI > 3 (one sample per site)	Based on 1994–1997 data from a total of 1,098 sites. Sites were classified based on physical and chemical data and compared to a range of stream fish related metrics: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007
Proportion of area occupied (PAO) by adult amphibians	20% < PAO < 80% (one sample per site)	The threshold is based on preserving a diverse and abundant population of amphibians. Calculated on a species-by-species basis, at < 20% PAO, a species risks becoming locally extinct and > 80% PAO indicates local disturbance favoring one species at the expense of others.	Although the technique is well established (Mackenzie et al. 2005), the threshold is a guideline currently used for management of these areas.
Presence of forest interior dwelling species (FIDS) of birds	> 4 sensitive FIDS or >1 highly sensitive FIDS (one park-wide assessment)	Threshold is based on bird sensitivity to forest fragmentation and disturbance both within and surrounding a forest patch, particularly during the breeding season. One highly sensitive species indicates high-quality FIDS habitat, > 6 highly sensitive species indicates exceptional quality habitat, and < 4 sensitive species indicates severe forest fragmentation and poor FIDS habitat.	MD DNR undated Jones et al. 2000
Grassland bird diversity	No threshold as such. Percentage of functional groups found in the park translates directly to the percent attainment.	Threshold is based on the percentage of four functional groups that is found in the park.	Peterjohn 2006
White-tailed deer density	Forest: < 8 deer km^{-2} Grassland: < 20 deer km^{-2} (one assessment per year)	The forest threshold for deer abundance is based on a 10-yr manipulative experiment. The grassland threshold is a guideline currently used for management of these areas.	Horsley et al. 2003

Table 3.4. Thresholds for Landscape Dynamics metrics.

Metric	Threshold	Justification	Threshold source
Impervious surface (within the park)	10% (one park-wide assessment)	Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact above this impervious surface threshold. Recent studies on stream macro-invertebrates continue to show shifts to tolerant species and reductions in biodiversity at around this threshold. Overall, <10% is protected, 10–30% is impacted and >30% is degraded.	Arnold and Gibbons 1996 Lussier et al. 2008
Impervious surface (within the park + 5 times buffer area)	10% (one park-wide assessment)	As above	As above
Forest interior area	No threshold as such. Percentage of forest interior area in the park translates directly to the percent attainment.	Interior forest area is essential for the breeding success of many birds. The indicator is expressed as the number of acres of interior forest in the park divided by the number of potential acres of interior forest.	Temple 1986 MD DNR 2008
Forest connectivity index (Dcrit; -within the park)	Dcrit < 360 m (one park-wide assessment)	Based on the distance that many small mammals and tree seeds can disperse, Dcrit is a measure of the distance where 75% of forest patches are connected (allowing dispersal).	Townsend et al. 2006, 2009 Bowman et al. 2002 He and Mladenoff 1999
Forest connectivity index (within the park + 5 times buffer area)	Dcrit < 360 m (one park-wide assessment)	As above	As above
Grassland interior area	No threshold as such. Percentage of grassland interior area in the park translates directly to the percent attainment.	Studies have shown that grassland bird nests located in grassland interior areas are more successful than those located near ecotone edges. The indicator is expressed as the number of acres of interior grassland in the park divided by the number of potential acres of interior grassland.	Burger et al. 1994
Contiguous grassland area	≥ 10 ha (one park-wide assessment)	Based on area needed to support grassland bird communities. Categories are as follows: 0–12 ac (very poor), 12–25 ac (poor), 25–50 ac (moderate), 50–100 ac (good), >100 ac (very good).	Peterjohn 2006
Cover of warm-season grassland	No threshold as such. Percentage of warm-season grassland area in the park translates directly to the percent attainment.	Based on warm-season species providing better habitat than cool-season species for birds and other animals. Indicator is expressed as acreage of warm-season grassland as a percentage of total grassland.	Peterjohn 2006

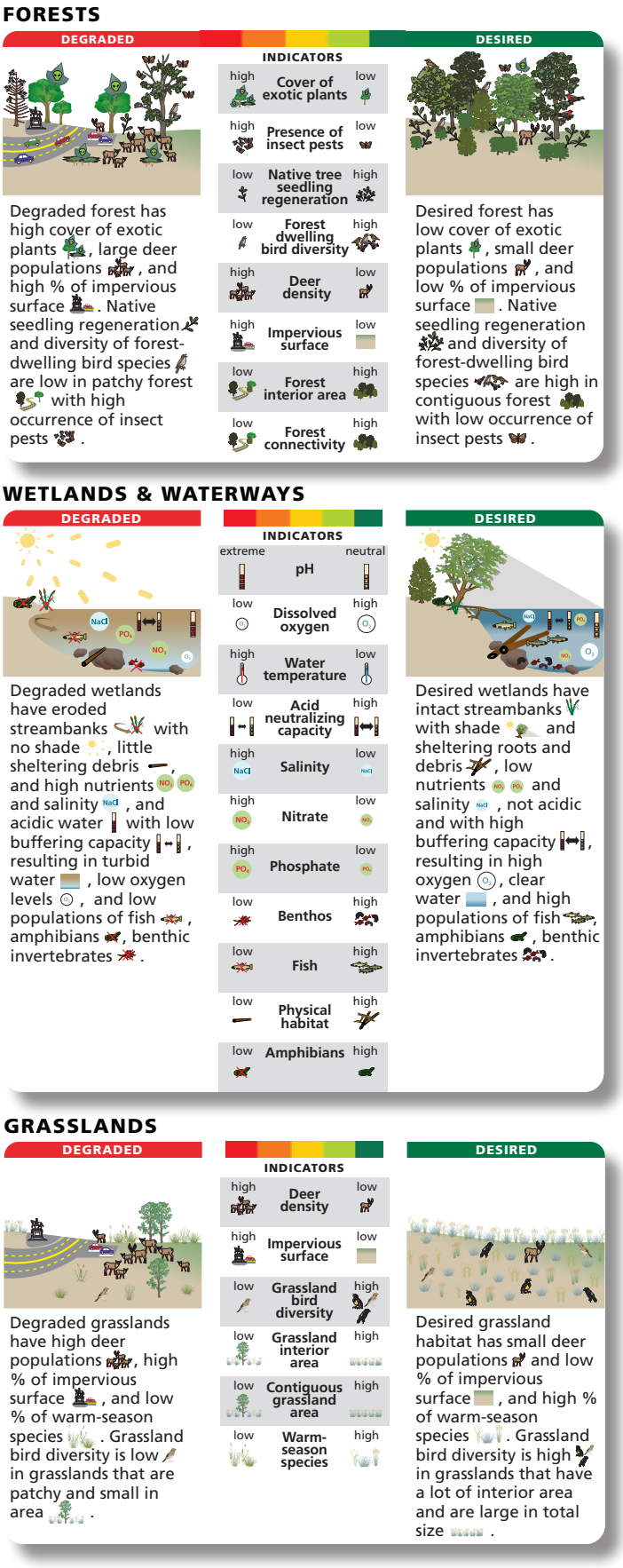

Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Manassas National Battlefield Park, indicating metrics to track status of condition.

To assess individual park condition, the NPS Air Resources Division has adopted a protocol of comparing the five-year mean (of the annual fourth-highest eight-hour rolling ozone concentration) against the established threshold (of 0.075 ppm; NPS 2009). A condition rating of Moderate ozone condition is defined as 0.061–0.075 ppm, and 80% of that threshold (≤0.06 ppm) is the upper limit for a condition rating of Good (NPS 2009). If the five-year mean is great than 0.076 ppm, ozone concentrations are considered to be of significant concern. Therefore, the 80% value (0.06 ppm) was used as the threshold in this assessment. The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Wet nitrogen and sulfur deposition—ecological

Deposition thresholds were based on maintaining ecosystem structure and function. Annual wet deposition (kg ha^{-1} y^{-1}) was used. Natural background deposition of nitrogen and sulfur in the eastern United States is approximately 0.5 kg ha^{-1} y^{-1} (0.4 lb $acre^{-1}$ y^{-1}; NPS 2005, 2009). Wet deposition makes up roughly half of this amount (~0.25 kg ha^{-1} y^{-1} [0.2 lb $acre^{-1}$ y^{-1}]; NPS 2009). Sensitive aquatic ecosystems as well as some organisms, such as lichens and freshwater diatom communities, can show deleterious effects of total nitrogen deposition at rates as low as 3.0–8.0 kg ha^{-1} y^{-1} (2.7–7.1 lb $acre^{-1}$ y^{-1}; wet deposition of 1.5–4.0 kg ha^{-1} y^{-1}[1.3–3.6 lb $acre^{-1}$ y^{-1}]; Fenn et al, 2003; Krupa 2002). The NPS Air Resources Division defines parks with less than 1 kg ha^{-1} y^{-1} (0.89 lb $acre^{-1}$ y^{-1}) wet deposition of N and S to be in good condition (NPS 2009), which was the threshold used in this assessment. The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Visibility condition—management

Regional haze regulations were developed by the U.S. EPA in 1999 to protect visual air quality in some 156 national parks and wilderness areas (U.S. EPA 2003) . The metric for visibility is expressed in terms of a Haze Index, in deciview units (dv). This index is a measure of visibility calculated from light extinction, measured in inverse megameters (Mm^{-1}), with high values of the index being associated with poor visibility (U.S. EPA 2003). Natural visibility was estimated using the IMPROVE model (U.S. EPA 2003), based upon a series of regional characteristics, and this baseline subtracted from currently observed visibility values, using the mean value from all measurements in the 40–60th percentiles (group 50) (NPS 2009). The NPS Air Resources Division threshold of 2 dv, above which parks are considered to have a moderate or significant concern for visibility, was used in the current assessment (NPS 2009). The data assessed are presented in the NPS Air Quality Estimates 2003–2007 (NPS 2010). The result for the park was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Mercury deposition—regulatory

The threshold value of 2 ng Hg L^{-1} (2 ppt; annual mean) in rain, used in this assessment, is an indirect modeled estimate of rainfall concentrations that result in tissue concentrations within inland fish species of 0.5 mg methylmercury kg^{-1} (0.5 ppm) wet weight (Meili et al. 2003, Hammerschmidt and Fitzgerald 2006). The authors do concede that this value is for low organic soils, as highly humic soils are known to potentially store large amounts of mercury which can slowly leach into inland waters, in some cases contributing much more to mercury concentrations than current atmospheric deposition (Meili et al. 2003). Currently, the U.S. EPA also has a lower recommended fish tissue regulatory maximum threshold of 0.3 mg methylmercury kg^{-1} (0.3 ppm) wet weight, which would result in reducing the modeled atmospheric deposition threshold (U.S. EPA 2001). Human and mammalian regulatory thresholds are based on the effects of exposure. In vitro exposure can cause mental retardation, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and adult exposure can cause motor dysfunction and

other neurological and mental impacts (U.S. EPA 2001). Avian species are particularly susceptible as mercury reduces reproductive potential (Wolfe et al. 1998). Measured atmospheric wet and dry mercury deposition trends from west to east across North America can also be measured in the common loon (*Gavia immer*) and throughout North America in mosquitoes (Evers et al. 1998, Hammerschmidt and Fitzgerald 2002). Mercury is also recognized to have a toxic effect on soil microflora, although no ecological depositional threshold is currently available (Meili et al. 2003). Mercury deposition data from 2004–2008 from the two sites closest to the park were obtained from the Maryland Deposition Network website (*http://nadp.sws.uiuc.edu/mdn*). The annual mean was calculated and compared to the threshold.

3.4.2 Water Resources

pH, dissolved oxygen, temperature—regulatory

The State of Virginia has classified its waterbodies on the basis of their designated uses. Minimum water quality critera have been established that will maintain these designated uses. The thresholds for dissolved oxygen concentration, pH, and water temperature were determined from the water quality criteria for Class III: Nontidal Waters (Coastal and Piedmont Zones) (State Water Control Board 2009). The pH may not be less than 6.0 or higher than 9.0 (State Water Control Board 2009). The dissolved oxygen concentration is regulated to be equal to or greater than 4 mg DO L^{-1} (4 ppm) at all times (State Water Control Board 2009). In all cases, water temperature is regulated to be less than 32.0°C (89.6°F; State Water Control Board 2009). Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Acid neutralizing capacity—ecological

The acid neutralizing capacity (ANC) threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling (1995–1997). The MBSS data were used to detect stream degradation so as to identify streams in need of restoration and to identify 'impaired waters' candidates (Southerland et al. 2007). A total of 539 streams that received a fish or benthic index of biotic integrity (FIBI or BIBI) rating of poor (2) or very poor (1) were pooled and field observations and site-specific water chemistry data were used to determine stressors likely causing degradation. The resulting ANC threshold linked to degraded streams was values less than 200 µeq L^{-1}, which was used as the threshold in this assessment (Southerland et al. 2007, Norris and Sanders 2009; where 1 mg L^{-1} (1 ppm) $CaCO_3$ = 20 µeq L^{-1}). A less conservative threshold of 50 µeq L^{-1} has also been suggested by some authors (Hendricks and Little 2003, Schindler 1988). ANC is reported monthly as an instantaneous measure. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Salinity—regulatory

Salinity in drinking water is regulated by U.S. EPA under the National Secondary Drinking Water Standards (NSDWS) regulations. These regulations control contaminants in drinking water and are non-enforceable. The Secondary Maximum Contaminant Level (advisory only) for salinity is 250 mg L^{-1} (250 ppm; NSDWS 1997), which is equivalent to a salinity of 0.25. Therefore, the salinity threshold for this assessment was <0.25. Measurements were instantaneous and taken monthly. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Nitrate—ecological

The nitrate concentration threshold was developed by the MBSS program after their first round of sampling as described for the ANC threshold. The MBSS determined that a nitrate concentration of 2 mg NO_3 L^{-1} (2 ppm) indicated stream degradation (Southerland et al. 2007, Norris and Sanders 2009). Instantaneous measurements

Figure 3.4. Summary of the two frameworks used in this assessment, including metrics.

Ecological monitoring framework

Air & Climate
Ozone (ppm)
Wet nitrogen deposition (kg N ha^{-1} yr^{-1})
Wet sulfate deposition (kg S ha^{-1} yr^{-1})
Visibility condition (dv)
Mercury deposition (ng Hg L^{-1})

Water Resources
pH
Dissolved oxygen (mg DO L^{-1})
Water temperature (°C)
Acid neutralizing capacity (µeq L^{-1})
Salinity
Nitrate (mg NO_3 L^{-1})
Phosphate (mg PO_4 L^{-1})
Benthic index of biological integrity
Physical habitat index

Biological Integrity
Exotic herbaceous species (% cover)
Exotic tree/shrub density (% cover)
Presence of forest pests (trees infested)
Native seedling regeneration (seedlings ha^{-1})
Fish index of biotic integrity
Presence of forest interior dwelling bird species
Grassland bird diversity
Deer density (deer km^{-2})

Landscape Dynamics
Impervious surface (% cover)
Forest interior area
Forest connectivity (m)
Grassland interior area
Contiguous grassland area

Habitat framework

—Habitats managed for natural resource values—

Forests
Exotic herbaceous species (% cover)
Exotic tree/shrub density (% cover)
Presence of forest pest species (trees infested)
Native seedling regeneration (seedlings ha^{-1})
Area occupied by amphibians (%)
Presence of forest interior dwelling bird species
Deer density (deer km^{-2})
Impervious surface (% cover)
Forest interior area
Forest connectivity (m)

Wetlands & waterways
pH
Dissolved oxygen (mg DO L^{-1})
Water temperature (°C)
Acid neutralizing capacity (µeq L^{-1})
Salinity
Nitrate (mg NO_3 L^{-1})
Phosphate (mg PO_4 L^{-1})
Benthic index of biological integrity
Fish index of biological integrity
Physical habitat index

Grasslands
Deer density (deer km^{-2})
Impervious surface (% cover)
Grassland bird diversity
Grassland interior area (ha)
Contiguous grassland area (ha)

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

Phosphate—ecological

The phosphate threshold is based on the U.S. EPA Ecoregional Nutrient Criteria. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria are developed as baselines for specific geographic regions. Manassas National Battlefield Park is located in Ecoregion IX or the Southeastern Temperate Forested Plains and Hills region (U.S. EPA 2000). The ecoregional reference condition value for total phosphorus is 0.03656 mg P L^{-1} (36.56 ppb), which equates to a phosphate threshold of 0.1133 mg PO_4 L^{-1} (0.1133 ppm; U.S. EPA 2000). Measurements were taken monthly as instantaneous measurements. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for phosphate is lower than the assessment threshold (M. Norris, pers. comm.).

Benthic IBI—ecological

The aquatic macroinvertebrates threshold is based on the MBSS interpretation of the benthic index of biotic integrity (IBI). The IBI scores range from 1 to 5 and are calculated by comparing the site's benthic assemblage to the assemblage found at minimally impacted sites (Norris and Sanders 2009). An IBI score of 3 indicates that a site is considered to be comparable to (i.e., not significantly different from) reference sites. A score greater than 3 indicates that a site is in better condition than the reference sites. Any sites with IBIs less than 3 are in worse condition than reference sites (Southerland et al. 2007, Norris and Sanders 2009), and the entire scale is 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good; Southerland et al. 2007). Therefore, the threshold used in this assessment for aquatic macroinvertebrates was >3, which indicates that a site is in fair or good condition (Southerland et al. 2007). Reported data are for one IBI assessment per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Physical habitat index—ecological

For the physical habitat index (PHI), in-stream and near-stream habitat measures of first- through third-order streams were recorded between June and September at the same time as the fish were being sampled (Norris and Sanders 2009). This sampling period was chosen because the low flow conditions are typically limiting to the abundance of lotic (living in moving water) fish. Habitat assessments are determined based on data from numerous metrics such as stream width, riparian zone vegetation type and width, surrounding land use, extent of stream channelization, degree of stream erosion, and many more. Sites are given scores for each of the applicable categories and then those scores are adjusted to a percentile scale (Norris and Sanders 2009). The PHI threshold was developed by the MBSS program after initial sampling as described for the ANC threshold. The MBSS determined the scale for PHI values to be 0–50 (severely degraded), 51–65 (partially degraded), 66–80 (degraded), and 81–100 (minimally degraded), so the threshold used in this assessment was >81, indicating minimally degraded condition (Paul et al. 2002, Southerland et al. 2005). Data reported represent one sample per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

3.4.3 Biological Integrity

Percent cover of herbaceous species, woody vines, and target exotic trees and shrubs—management

Invasive exotic plants may compete with native plants and therefore lead to a reduction in biodiversity of the native flora

(Mack et al. 2000). The threshold used for this assessment was that the abundance of these invasive exotic plants should not exceed 5% cover, measured as area of ground covered by herbs and vines, and percent of total basal area for shrubs and trees. Because 100% eradication is not a realistic goal, the threshold is intended to suggest more than just simple presence of these exotic species but that the observed abundance has the potential to establish and spread, i.e., 5% cover may be considered as the point where the exotic plants are becoming established rather than just present. The Organic Act that established the National Park Service in 1916 mandate the conservation of both natural and cultural resources (see Section *2.2.1—Park enabling legislation*). This threshold is a guide to commence active management of an area by removal of these species. Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. The cover of exotic herbaceous species in a plot was calculated from the percent cover of the single exotic species with the greatest cover. The cover of exotic trees and shrubs in a plot was calculated as the percentage of total tree or shrub basal area. Tree saplings and seedlings were not included in this calculation. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Presence of pest species—management, ecological

The gypsy moth (*Lymantria dispar*) was accidentally introduced to North America in the late 1860s and has spread widely, resulting in an estimated 160,000 km^2 (62,500 mi^2) of forest defoliation during the 1980s alone (Liebhold et al. 1994, Montgomery 1990). The gypsy moth larvae feed on the foliage of hundreds of species of plants in North America, but its most common hosts are oak and aspen (*Populus* spp.) trees (USDA Forest Service 2009a). Hemlock woolly adelgid (*Adelges tsugae*) is another insect pest first reported in the eastern United States in 1951 near Richmond, Virginia (USDA Forest Service 2009b). This aphid-like insect is originally from Asia and feeds on Eastern hemlock trees (*Tsuga canadensis*), which are often damaged and killed within a few years of becoming infested. Due to the destructive nature and potential for forest damage from these pests, the threshold used was established as any observation of these pests (i.e., >1% of trees infested) being considered degraded. Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. The percentage of trees infested was calculated by dividing the number of trees afflicted by pests in each plot by the total number of trees in each plot. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. Data reported for each plot were for hemlock woolly adelgid, gypsy moth, and "other insect damage."

Native tree seedling regeneration—ecological

The ecological native tree seedling regeneration threshold used in this assessment of 35,000 seedlings ha^{-1} (14,000 seedlings $acre^{-1}$) is based upon seedling numbers in a mature, non-industrial private forestland in south-central Virginia (Carter and Fredericksen 2007). However, some estimates of required desirable native species regeneration to maintain a sustainable forest under different deer grazing scenarios are much higher—15 million tree seedlings per hectare (6,100,000 seedlings $acre^{-1}$; all desirable species) under very low, and as many as 21 million tree seedlings per hectare (8,500,000 seedlings $acre^{-1}$; all desirable species) under very high deer grazing pressure (Marquis et al. 1992). Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Fish Index of Biotic Integrity—ecological

A threshold value of 3 was used as an ecological threshold indicating attainment of overall reference ecosystem condition. The fish index of biotic integrity (IBI) was pro-

posed as a way of providing an informative measure of anthropogenic influence on fish communities and ecological integrity than measurements of physiochemical metrics alone (Karr 1981). The metric was then adapted and validated for streams of Maryland using a reference condition approach, based on 1994–1997 data from a total of 1,098 sites. Sites were classified based on physical and chemical data and compared to a range of stream fish-related metrics: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), and 4.0–5.0 (good), finding that 29% of stream sites sampled in Maryland were in poor or very poor condition (Southerland et al. 2007). The threshold used for this assessment was a fish IBI >3, indicating that a site is considered to be in fair or good condition (Southerland et al. 2007). Data used represent one sample per site. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Proportion of area occupied by adult amphibians—management

The threshold of between 20 and 80% area occupied (PAO) is currently used as a management threshold, intended to maintain abundant and diverse amphibian communities. The percent area occupied is calculated according to whether amphibians are: 1) present and detected, 2) present and not detected, or 3) not present, with a probabilistic function to determine differences between not present versus present but not detected (Bailey et al. 2007). The probabilistic function has been developed for diverse faunal species (Mackenzie et al. 2003).

Presence of forest interior dwelling species of birds—ecological

Presence of bird species can effectively provide a bio-indicator of subtle or unexpected changes in environmental condition (Koskimies 1989). Although data is scarce for Virginia, there was a documented 63% decline in individual birds of neotropical origin (including forest interior dwelling species [FIDS]) between 1980 and 1989 in Maryland (Jones et al. 2000). This represented a continuation of documented declines at some sites between 1940 and 1980 (Terborgh 1992). The presence of FIDS is used as an indicator of high-quality forest interior habitat. Maryland Department of Natural Resources lists 39 FIDS that currently or historically nested in Maryland (MD DNR undated). Fifteen of those 39 species are either obligate riparian breeding species that are strongly associated with riparian forests during the breeding season, or for which riparian forests represent optimal breeding habitats for these species. For the purposes of this assessment, those 15 species were classified as 'highly area-sensitive' FIDS. Presence of at least four FIDS or at least one highly area-sensitive FIDS was assessed as high-quality forest interior habitat (Jones et al. 2000). Using this information, the ecological threshold was based on the presence of appropriate habitat for FIDS and defined as observation of at least four FIDS or one highly area-sensitive FIDS. In both cases, these birds ideally would have been observed in probable or confirmed breeding status (Jones et al. 2000), however, breeding status was not recorded for the available data within the park, which was collected at 23 sites in 2007 and 24 sites in 2008 (Goodwin and Shriver 2009). These data were compared against the list of FIDS (MD DNR undated) and the number of FIDS was compared to the threshold. The park was given a rating of either 100% or 0% attainment .

Grassland bird diversity—ecological

Percent attainment for grassland birds is derived directly from the percentage of all four functional groups present. The four functional groups are defined as: disturbance-tolerant, preference for young grasslands, preference for mature grasslands, and "other" (rarely encountered in the Mid-Atlantic; Peterjohn 2006). The percent attainment is equivalent to the percentage of these functional groups that were present in the park, based on the species observations from the 2007 and 2008 avian monitoring in the National Capital Region parks (Goodwin and Shriver 2009). Thus, the park was given a rating of 0%, 25%, 50%, 75%, or 100% attainment.

White-tailed deer density: forest—management, ecological; grassland—management

The forest threshold for white-tailed deer density (8.0 deer km^{-2} [21 deer mi^{-2}]) is a well-established ecological threshold (Horsley et al. 2003), and this threshold is also used as the management threshold (Horsley et al. 2003). Species richness and abundance of herbs and shrubs are consistently reduced as deer densities approach 8.0 km^{-2} (21 deer mi^{-2}), although shown in some studies to change at densities as low as 3.7 deer km^{-2} (9.6 deer mi^{-2}; Decalesta 1997). One large manipulation study in central Massachusetts found deer densities of 10–17 km^{-2} (26–44 deer mi^{-2}) inhibited the regeneration of understory species, while densities of 3–6 deer km^{-2} (8–16 deer mi^{-2}) supported a diverse and abundant forest understory (Healy 1997). There are multiple sensitive species of songbirds that cannot be found in areas where deer grazing has removed the understory vegetation needed for nesting, foraging and protection. Even though songbird species vary in how sensitive they are to increases in deer populations, these changes generally occur at deer densities greater than 8 deer km^{-2} (21 deer mi^{-2}; Decalesta 1997). In contrast, the grassland (or agricultural land) management threshold for deer abundance is less well-studied or justified and is used as a guiding management threshold, but is currently 20 deer km^{-2} (52 deer mi^{-2}). A deer exclosure study in Manassas National Battlefield Park (Rossell et al. 2005) showed that overbrowsing by deer in the park is having negative effects on the park's forested areas. Data used represents annual assessments at a park scale. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

3.4.4 Landscape Dynamics

Impervious surface—ecological

Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact above 10% impervious surface, used as the threshold in this assessment (Arnold and Gibbons, 1996) and recent studies on stream macro-invertebrates continue to show shifts to more tolerant species and reductions in biodiversity at around this same threshold (Lussier et al. 2008). A study of nine metropolitan areas in the United States demonstrated measurable effects of impervious surface on stream invertebrate assemblages at impervious surface cover below 5% (Cuffney et al. 2010). Percent urban land is highly correlated to impervious surface and can provide a good approximation of watershed degradation due to increases of impervious surface. An impervious surface threshold of 10% was used in this assessment and data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.5). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Forest interior area

Interior forest area is essential for the breeding success of many birds. Interior forest was defined as mature forested land cover ≥100 m (330 ft) from non-forest land cover or from primary, secondary, or county roads (i.e., roads considered large enough to break the canopy; Temple 1986). The threshold attainment was expressed as the number of acres of interior forest in the park as a percentage of the total potential acres of interior forest within the park (if the total forest area was one large circular patch). The data used were a one-off, park-wide assessment.

Forest connectivity index—ecological

The connectivity of forest resources is an important control on species biodiversity (Franklin 1993). The critical dispersal threshold (Dcrit) is a measure of the distance at which 75% of forest patches are connected, therefore allowing landscape-level dispersal (Townsend et al. 2009). From 13 tree species, an effective dispersal

distance of 65 ± 15 m (210 ± 50 ft; mean ± standard error) has been calculated, indicating on average a 95% probability of effective dispersal over that distance. The maximum dispersal distance for these same species was 997 ± 442 m (3,271 ± 1,450 ft), indicating almost zero probability (<0.1%) of a seed dispersing that distance (He and Mladenoff 1999). Other studies have shown similar dispersal ranges for small mammals (Bowman et al. 2002). For this assessment, Dcrit was calculated and compared to a threshold of <360 m (1,180 ft) based on the distance that many small mammals and tree seeds can disperse (He and Mladenoff 1999, Bowman et al. 2002).

Data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.6). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Grassland interior area

Studies have shown that grassland bird nests located in grassland interior areas are more successful than those located near ecotone edges (Burger et al. 1994). Interior grassland was defined as grassland ≥60 m (200 ft) from other land uses (Burger et al. 1994). The threshold attainment was expressed as the number of acres of interior grassland in the park as a percentage of the total potential acres of interior grassland within the park (if the total grassland area was one large circular patch). The data used were a one-off, park-wide assessment.

Contiguous grassland area

Peterjohn (2006) developed criteria to define area needed to support grassland bird communities. Contiguous grassland areas <5 ha (<12 acres) in size are generally avoided by grassland birds. Areas 5–10 ha (12–25 acres) are occupied by some species, areas 10–20 ha (25–50 acres) are consistently occupied by some species, and areas 40–100 ha (100–250 acres) can support entire grassland bird communities. Categories are as follows: 0–5 ha (very poor), 5–10 ha (poor), 10–20 ha (moderate), 20–40 ha (good), >40 ha (very good). This metric is based on the largest single contiguous patch of grassland within the park. The threshold used in this assessment was ≥10 ha, representing moderate to very good potential habitat. Data was a one-off park-wide assessment. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Warm-season grassland cover

Warm-season grass species are generally native to the Mid-Atlantic region, are deep-rooted and so 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). This metric was selected for use in Manassas because this park has a management goal of restoring grasslands back to primarily native, warm-season species and this metric will allow the park to track progress towards this management goal. The threshold attainment was expressed as the cover of warm-season grassland as a percentage of all grassland acres in the park. The data used were a one-off, park-wide assessment.

3.5 STUDY METHODS

3.5.1 Ecological monitoring framework

An ecological monitoring framework has been established by the National Park Service (NPS) Inventory and Monitoring program (I&M; Fancy et al. 2008), based on multiple efforts, such as the U.S. EPA scientific advisory board assessment on reporting ecological condition (U.S. EPA 2002). The NPS ecological monitoring framework has six high-level data categories: Air & Climate; Geology & Soils; Water Resources; Biological Integrity; Human

Use; and Landscape Dynamics (Fancy et al. 2008). In the assessment of natural resource condition of Manassas National Battlefield Park, data were available for four of these six data categories: Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics.

Data used

A total of 31 metrics across the four ecological monitoring framework categories were included from multiple data sources (Table 3.5), each with an established ecological, management, or regulatory threshold and based on a categorical scoring of threshold attainment (Table 3.6). While some metrics were measured at the park scale and therefore only have one value for the entire park (e.g., deer density and Landscape Dynamics metrics), there were up to 17 sampling sites for some Biological Integrity metrics within Manassas National Battlefield Park. Temporal intensity of measurement also varied between metrics, with only single assessments of Landscape Dynamics metrics, while Water Resources metrics were measured monthly during the available data range (Table 3.6). All data used in the assessment was collected between 2000 and 2008 (Table 3.6). Data used in the assessment was obtained from multiple sources, with the Air & Climate data coming from national air monitoring programs and the NPS Air Resources Division, Water Resources and Biological Integrity data from the NCRN I&M monitoring program, and Landscape Dynamics data from a collaborative project between NCRN I&M and the University of Maryland Center for Environmental Science (Table 3.5).

Air & Climate results for ozone, wet nitrate and sulfur deposition, and visibility (2003–2007) were taken from interpolated results from an NPS (2009) report, while mercury deposition data (2004–2008) came from two nearby monitoring sites (Figure 3.5). A total of four sites were monitored for water quality (pH, dissolved oxygen, temperature, ANC, salinity, nitrate [all 2005–2008], and phosphate [2007–2008]) in Manassas National Battlefield Park (Figure 3.6). Two sites were monitored in 2004 by NCRN I&M for the Benthic Index of Biotic Integrity, Physical Habitat Index (both Water Resources metrics), and the Fish Index of Biotic Integrity (a Biological Integrity metric; Figure 3.7).

Forest data (exotic species cover and density, presence of pest species, and native tree seedling regeneration) were collected at 17 sites from 2006–2008, and a route for counting deer density was travelled each year from 2000–2008 (Figure 3.8). Data for the remaining two Biological Integrity metrics—presence of forest interior dwelling species of birds and grassland bird diversity—were obtained from an initial assessment in 2007–2008, currently presented in draft format (Goodwin and Shriver 2009).

Two Landscape Dynamics metrics (impervious surface [2000] and critical connectivity [2001]) were calculated at two scales: 1) within the park boundary, and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary. The purpose of this analysis was to assess land use immediately surrounding the park. It should be noted that 10.6% of the 5x buffer area was not covered by the impervious surface data map for Manassas National Battlefield Park, so this area was omitted from the impervious surface area calculations.

The remaining Landscape Dynamics metrics (forest interior area, grassland interior area, contiguous grassland area, and cover of warm-season grassland) were calculated from land use data from 2008.

Due to the number of sampling sites (or spatial scale of measurement) and sampling frequency (monthly to annual), the amount of information used to characterize park resources (data density) varied from one (e.g., assessment of deer population in the park) to 120 measurements (dissolved oxygen, water temperature, and ANC) during the nine-year period (Table 3.6; Appendix A). These data were compared to threshold values (Tables 3.1, 3.2, 3.3, 3.4), as a percentage of measurements attaining the threshold value for each metric, where a value of 100% indicated that all sites and times met the threshold to maintain natural resources, and

Table 3.5. Sources of data used in Manassas National Battlefield Park resource condition assessment.

Metric	Agency	Reference/source
Air & Climate		
Ozone	NPS	NPS 2009
Wet nitrogen deposition	NPS	NPS 2009
Wet sulfur deposition	NPS	NPS 2009
Visibility condition	NPS	NPS 2009
Hg deposition	MDN-NADP	*http://nadp.sws.uiuc.edu/mdn*
Water Resources		
pH	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Dissolved oxygen	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Water temperature	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Acid neutralizing capacity	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Salinity	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Nitrate	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Phosphate	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Benthic index biological integrity (BIBI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Physical habitat index (PHI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Biological Integrity		
Cover of exotic herbaceous species	NCRN I&M	Schmit and Campbell 2007, 2008
Cover of exotic trees and shrubs	NCRN I&M	Schmit and Campbell 2007, 2008
Presence of forest pest species	NCRN I&M	Schmit and Campbell 2007, 2008
Native tree seedling regeneration	NCRN I&M	Schmit and Campbell 2007, 2008
Fish index biological integrity (FIBI)	NCRN I&M, MBSS	Norris and Sanders 2009
Proportion of area occupied by amphibians	NCRN I&M	Mattfeldt et al. 2008
Presence of forest interior dwelling species (FIDS) of birds	NCRN I&M	Goodwin and Shriver 2009
Grassland bird diversity	NCRN I&M	Goodwin and Shriver 2009
Deer density	NCRN I&M	Bates 2007
Landscape Dynamics		
Impervious surface (within park)	UMCES, NCRN I&M	Townsend et al. 2006
Impervious surface (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Forest interior area	UMCES, NCRN I&M	NCRN I&M
Forest connectivity (Dcrit; within park)	UMCES, NCRN I&M	Townsend et al. 2006
Forest connectivity (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Grassland interior area	UMCES, NCRN I&M	NCRN I&M
Contiguous grassland area	UMCES, NCRN I&M	NCRN I&M
Cover of warm-season grassland	UMCES, NCRN I&M	NCRN I&M

Table 3.6. Summary of data used in Manassas National Battlefield Park resource condition assessment.

Metric	Threshold	Sites	Samples	Period
Air & Climate				
Ozone	< 0.06 ppm	Park	1	2003–2007
Wet nitrogen (N) deposition	< 1 kg N ha^{-1} yr^{1}	Park	1	2003–2007
Wet sulfur (S) deposition	< 1 kg S ha^{-1} yr^{1}	Park	1	2003–2007
Visibility condition	< 2 dv	Park	1	2003–2007
Mercury (Hg) deposition	< 2 ng Hg L^{-1}	2	405	2004–2008
Water Resources				
pH	6.0 ≥ pH ≥ 9.0	4	109	2005–2008
Dissolved oxygen (DO)	≥ 4.0 mg DO L^{-1}	4	120	2005–2008
Water temperature	≤ 32.0°C	4	120	2005–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	4	120	2005–2008
Salinity	< 0.25	4	108	2005–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	4	116	2005–2008
Phosphate (PO_4)	< 0.1133 mg PO_4 L^{-1}	4	62	2007–2008
Benthic index biological integrity (BIBI)	> 3	2	2	2004
Physical habitat index (PHI)	> 81	2	2	2004
Biological Integrity				
Cover of exotic herbaceous species	< 5% (of area)	17	17	2006–2008
Cover of exotic trees and shrubs	< 5% (of total basal area)	16	24	2006–2008
Presence of forest pest species	< 1% of trees infested	16	16	2006–2008
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	17	17	2006–2008
Fish index biological integrity (FIBI)	> 3	2	2	2004
Proportion area occupied (PAO) by amphibians	20% < PAO < 80%	Park	2	2007–2009
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	24	25	2007–2008
Grassland bird diversity	% functional groups found translates directly to % attainment	24	2	2007–2008
Deer density	< 8 deer km^{-2} (forest) < 20 deer km^{-2} (grassland)	Park	9	2000–2008
Landscape Dynamics				
Impervious surface (within park)	10%	Park	1	2000
Impervious surface (within park) + 5X buffer	10%	Park	1	2000
Forest interior area	% of total forest area translates to % attainment	Park	1	2008
Forest connectivity (Dcrit; within park)	< 360 m	Park	1	2001
Forest connectivity (within park) + 5X buffer	< 360 m	Park	1	2001
Grassland interior area	% of total grassland area translates to % attainment	Park	1	2008
Contiguous grassland area	≥ 10 ha	Park	1	2008
Cover of warm-season grassland	% of total grassland area translates to % attainment	Park	1	2008

Figure 3.5. Map of sampling stations MD99/BEL116 and VA28/SHN418[29] used for measuring mercury concentrations near Manassas National Battlefield Park.

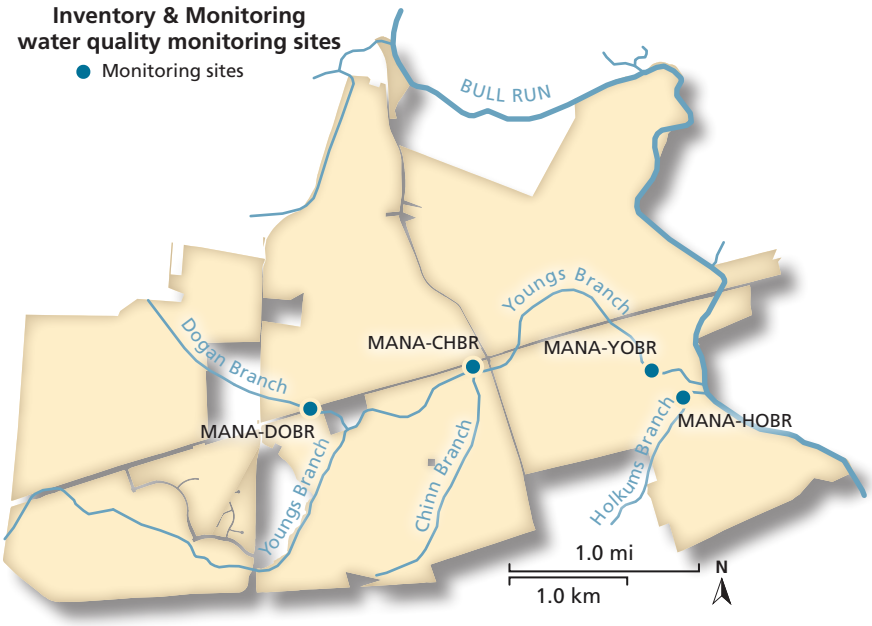

Figure 3.6. Stream sampling locations[30] used for long-term water quality monitoring at Manassas National Battlefield Park.

29. National Atmospheric Deposition Program: *http://nadp.sws.uiuc.edu;* Mercury Deposition Network: *http://nadp.sws.uiuc.edu/mdn*
30. Norris et al. 2007.

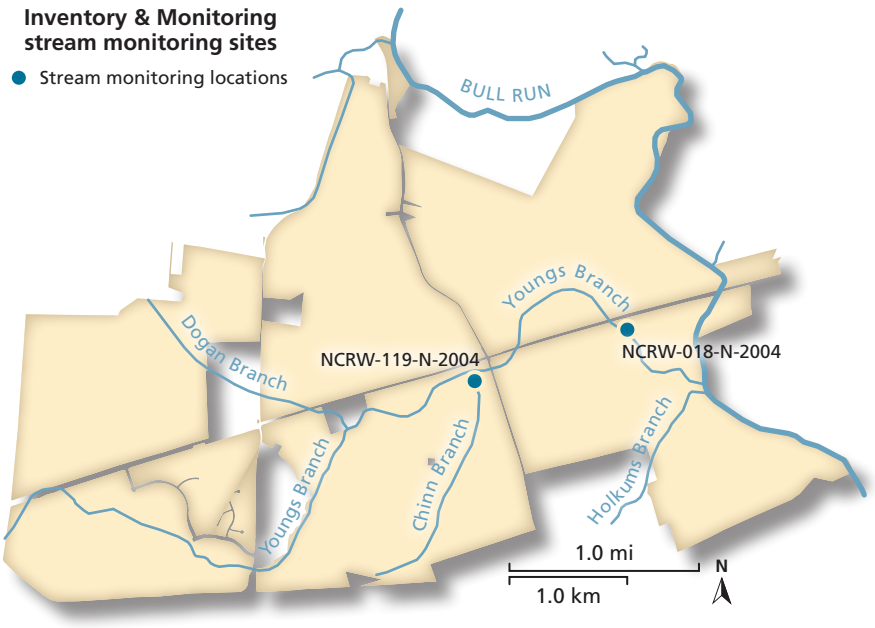

Figure 3.7. Stream sampling locations[31] monitored for BIBI, FIBI, and PHI.

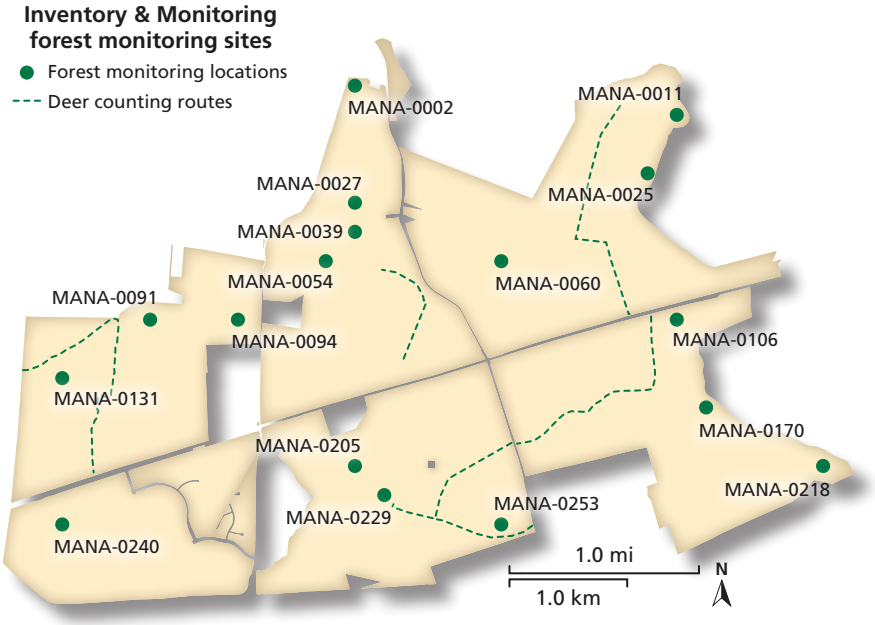

Figure 3.8. Forest monitoring sites and deer counting routes[32] in Manassas National Battlefield Park.

31. NCRN I&M, ANTI.
32. NCRN I&M, ANTI.

a value of 0% indicated that no sites at any sampling time met the threshold value. For all four categories (Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics), an un-weighted mean was calculated for all metrics within that category to produce a category percentage attainment for all four categories of available data in Manassas National Battlefield Park. An assessment was made of the whole park by calculating an un-weighted mean of the four category percentage attainment values. For determination of status of metrics, vital sign categories, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.7).

Table 3.7. Categorical ranking of threshold attainment categories.

Measured attainment of thresholds	Natural resource condition
80–100%	Very good
60–<80%	Good
40–<60%	Fair
20–<40%	Degraded
0–<20%	Very degraded

3.5.2 Habitat framework

The habitat list defined by the International Union for the Conservation of Nature (IUCN) was chosen as the basis from which park-specific habitats were determined (IUCN 2007). The IUCN habitat classification includes 16 habitat types at the highest level, which are further divided into sub-habitats (Table 3.8). A total of four general habitat types were identified for Manassas National Battlefield and these were defined as being either managed for natural resource values (forests, wetlands and waterways, grasslands) or managed for other values (developed lands) (Figures 3.1, 3.3).

A habitat map was created for the park by starting with the draft Inventory & Monitoring (I&M) vegetation map which is based on color infrared aerial photography captured in March and April of 2004. Next, a table was created to crosswalk the I&M vegetation map classes to the IUCN vegetation classes. This vegetation layer was then unioned with the National Wetlands Inventory in an effort to capture small wetland areas not represented on the vegetation map and a park-provided agricultural lease layer which contained

Table 3.8. Summary of IUCN major habitat classifications.

	IUCN general habitat description	# sub-habitats
1	Forest	9
2	Savanna	2
3	Shrubland	8
4	Grassland	7
5	Wetland (inland)	18
6	Rocky areas (inland cliffs and mountain peaks)	0
7	Caves and non aquatic subterranean	2
8	Desert	3
9	Marine neritic (submerged nearshore, oceanic islands)	10
10	Marine oceanic	4
11	Marine deep benthic	6
12	Marine intertidal	7
13	Marine coastal/supratidal	5
14	Artificial terrestrial	6
15	Artificial aquatic	13
16	Other	

the most current information on the usage of leased areas. This resulted in a new vector layer that could be symbolized to highlight polygons where these three layers were in disagreement. These disagreements were resolved through consultation with the park natural resource staff and site visits where required. Lastly, where the park natural resource staff had more current or detailed information for an area—for example, grassland maintenance regimes, or current restoration projects—this information was integrated into the final habitat map.

To provide a basis for condition assessment for each habitat, the desired versus degraded extremes were conceptually described (Figure 3.3) based on a series of 24 metrics which can be used to track the relative condition of the habitat between these two states. Metrics were assigned to these habitat types based on being of a relevant spatial scale, responsive to change, and with an established ecological threshold, such that an explicit measurement of condition was calculated relative to the conceptual range of a desired through to degraded state.

Much of the data set was a subset of that used for the ecological monitoring framework, so the the threshold justifications are presented in Tables 3.1, 3.2, 3.3, and 3.4 and the sources of all data are presented in Table 3.5. Justification for the inclusion of metrics as relevant to a particular habitat assessment is provided below.

Calculating habitat scores

For each individual metric, the percent attainment of the threshold value was calculated as described for ecological monitoring categories. The attainment of threshold condition for each of the habitat types present within Manassas National Battlefield Park was calculated as an un-weighted mean of the attainment scores for the metrics used to assess the condition of that particular habitat (Table 3.9). Calculation of the park condition status was calculated as an area-weighted mean, based upon the relative area of each habitat type within the park (Table 3.10). For determination of status of metrics, habitats, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.7).

Of the 1,787 ha (4,417 acres) within the fee boundary of Manassas National Battlefield Park, 1,739 ha (4,298 acres) were designated as habitats that are managed for natural resource values (forests: 806 ha [1,992 acres]; wetlands and waterways: 62 ha [154 acres]; and grasslands: 871 ha [2,152 acres]; Table 3.10). The remaining 48 ha (118 acres) were developed lands were not assessed, making the total area assessed 1,739 ha (4,299 acres).

Table 3.9. Summary of data used in Manassas National Battlefield Park habitat-based condition assessment of habitats managed for natural resource values.

Metric	Threshold	Sites	Samples	Period
Forests				
Cover of exotic herbaceous species	< 5% (of area)	17	17	2006–2008
Cover of exotic trees and shrubs	< 5% (of total basal area)	16	24	2006–2008
Presence of forest pest species	< 1% of trees infested	16	16	2006–2008
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	17	17	2006–2008
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	24	25	2007–2008
Deer density (forest)	< 8 deer km^{-2} (forest)	Park	9	2000–2008
Impervious surface (within park)	10%	Park	1	2000
Forest interior area	% of total forest area translates to % attainment	Park	1	2008
Forest connectivity (Dcrit; within park)	< 360 m	Park	1	2001
Wetlands & waterways				
pH	6.5 ≥ pH ≥ 8.5	4	109	2005–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1}	4	120	2005–2008
Water temperature	≤ 32.0ºC	4	120	2005–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	4	120	2005–2008
Salinity	< 0.25	4	108	2005–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	4	116	2005–2008
Phosphate (PO_4)	< 0.1133 mg PO_4 L^{-1}	4	62	2007–2008
Benthic index biological integrity (BIBI)	> 3	2	2	2004
Fish index biological integrity (FIBI)	> 3	2	2	2004
Physical habitat index (PHI)	> 81	2	2	2004
Proportion area occupied (PAO) by amphibians	20% < PAO < 80%	Park	2	2007–2009
Grasslands				
Deer density (grassland)	< 20 deer km^{-2} (grassland)	Park	9	2001–2008
Impervious surface (within park)	10%	Park	1	2000
Grassland bird diversity	% functional groups found translates directly to % attainment	24	2	2007–2008
Grassland interior area	% of total grassland area translates to % attainment	Park	1	2008
Contiguous grassland area	≥ 10 ha	Park	1	2008
Cover of warm-season grassland	% of total grassland area translates to % attainment	Park	1	2008

Table 3.10. Area of each habitat type in Manassas National Battlefield Park. Developed lands make up another 48 ha (118 acres) but were not assessed.

Habitat	Area (hectares)	Area (acres)	% of area assessed
Habitats managed for natural resource values			
Forests	806	1,992	46%
Wetlands and waterways	62	154	4%
Grasslands	871	2,152	50%
Habitats managed for natural resource values	***1,739***	***4,299***	
TOTAL AREA ASSESSED	**1,739**	**4,299**	

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Chapter 4: Natural resource conditions

4.1 REGIONAL/LANDSCAPE CONTEXT

As detailed in Section *2.1.2—Resource management issues overview*, Manassas National Battlefield Park faces a number of resource management issues, many of which are related to the surrounding land use (NCRN 2006; Figure 2.10). These issues include encroaching development, increasing population density (Figure 2.11) and housing density (Figure 2.12), high road density (Figure 2.13), low proportion of protected areas (Figure 2.14), excessive numbers of white-tailed deer, and exotic and invasive plants.

On a regional scale, atmospheric deposition of nitrate (Figure 4.1) and mercury (Figure 4.2, 4.3) are persistent problems. As in the case of upstream pollution in park waters, this suite of atmospheric stressors acts to potentially degrade the resources in Manassas National Battlefield Park, yet stressor abatement outside the park poses significant challenges.

Grassland road.

4.2 CONDITION SUMMARIES BY REPORTING AREAS

4.2.1 Habitat framework

Using the habitat framework to synthesize 24 metrics measuring the condition of forest, wetland and waterway, and grassland habitats, these habitats were assessed to be in fair condition (55% attainment of threshold condition; Tables 3.9, 4.1, 4.2). Forests and wetlands and waterways were in good condition, while grasslands were in fair condition. These results are synthesized in Figure 4.4.

Forests

Forest habitat within Manassas National Battlefield Park was assessed as being in good condition, attaining desired condition in 62% of the 111 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.9, 4.1). Presence of forest interior dwelling bird species scored as very good, as did percent impervious surface (Figure 4.5), forest connectivity within the park (all 100% attainment; Figure 4.6), cover of exotic trees and shrubs (92% attainment), and presence of forest pest species (81% attainment). Cover of exotic herbaceous species scored as good (65% attainment). The remaining metrics (interior area [Figure 4.7], native tree seedling regeneration, and deer density) were very degraded, with 21%, 0%, and 0% attainment, respectively.

Wetlands and waterways

Wetland and waterway habitat within Manassas National Battlefield Park was assessed as being in good condition, attaining desired condition in 64% of 763 measurements across all 11 metrics, collected between 2004 and 2008 (Tables 3.9, 4.1). Water temperature, acid neutralizing capacity, stream fish (all 100% attainment; Figures 4.8, 4.9), pH (98% attainment; Figure 4.10), nitrate (97% attainment; Figure 4.11), and dissolved oxygen (86% attainment; Figure 4.12) were all in very good (desired) condition, while salinity was in good condition (67% attainment; Figure 4.13). Amphibians (50% attainment) were in fair condition, while phosphate (10% attainment; Figure 4.14), stream benthos and Physical Habitat Index (both 0% attainment) were in very degraded condition.

While wetlands and waterways were in good condition, the relatively small area

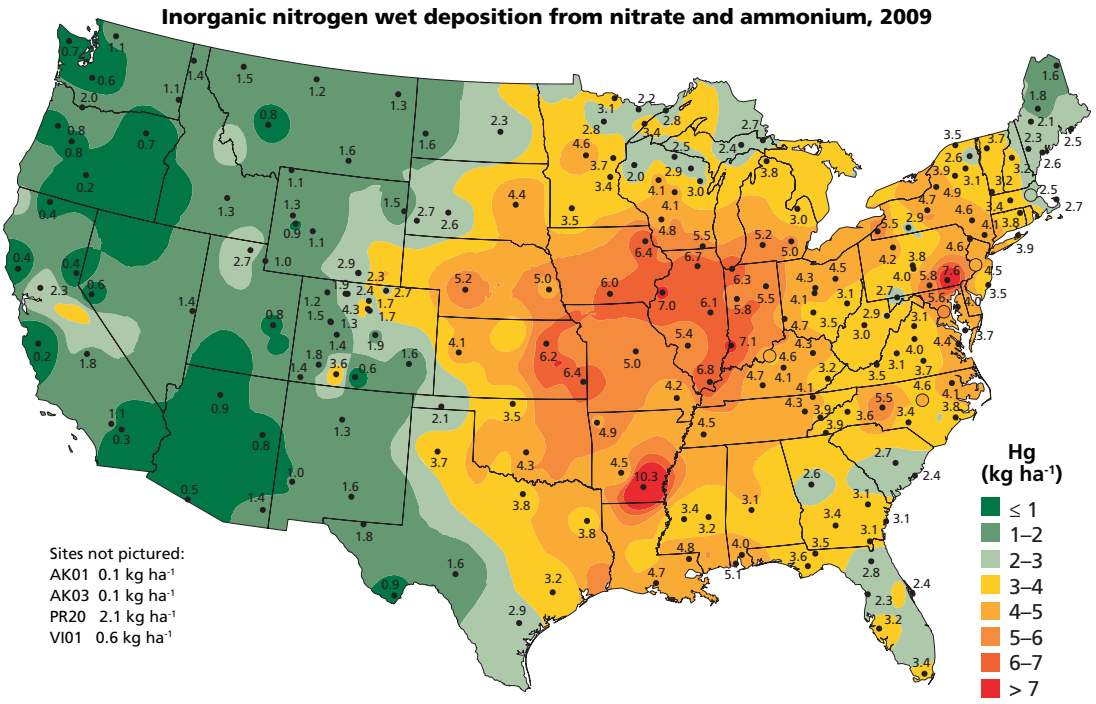

Figure 4.1. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg ha^{-1}) for the continental United States in 2009.[33]

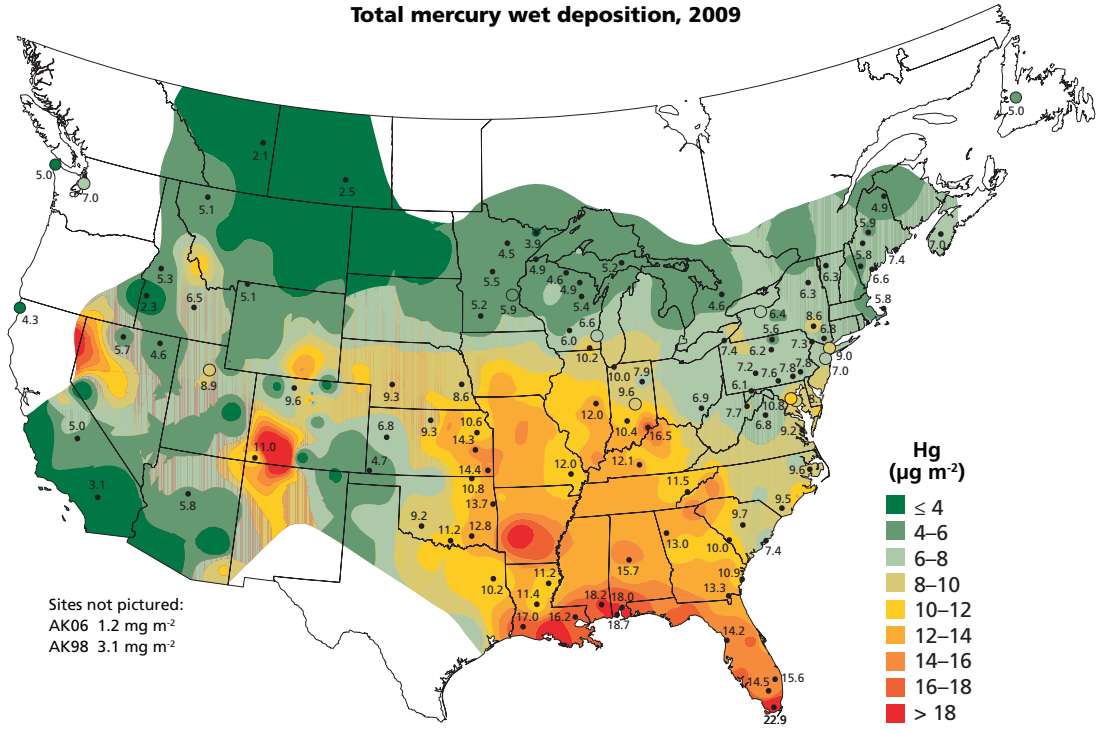

Figure 4.2. Total wet mercury (Hg) deposition (µg m^{-2}) for the continental United States in 2009.[34]

33. National Atmospheric Deposition Program/National Trends Network *http://nadp.sws.uiuc.edu*
34. National Atmospheric Deposition Program/Mercury Deposition Network *http://nadp.sws.uiuc.edu*

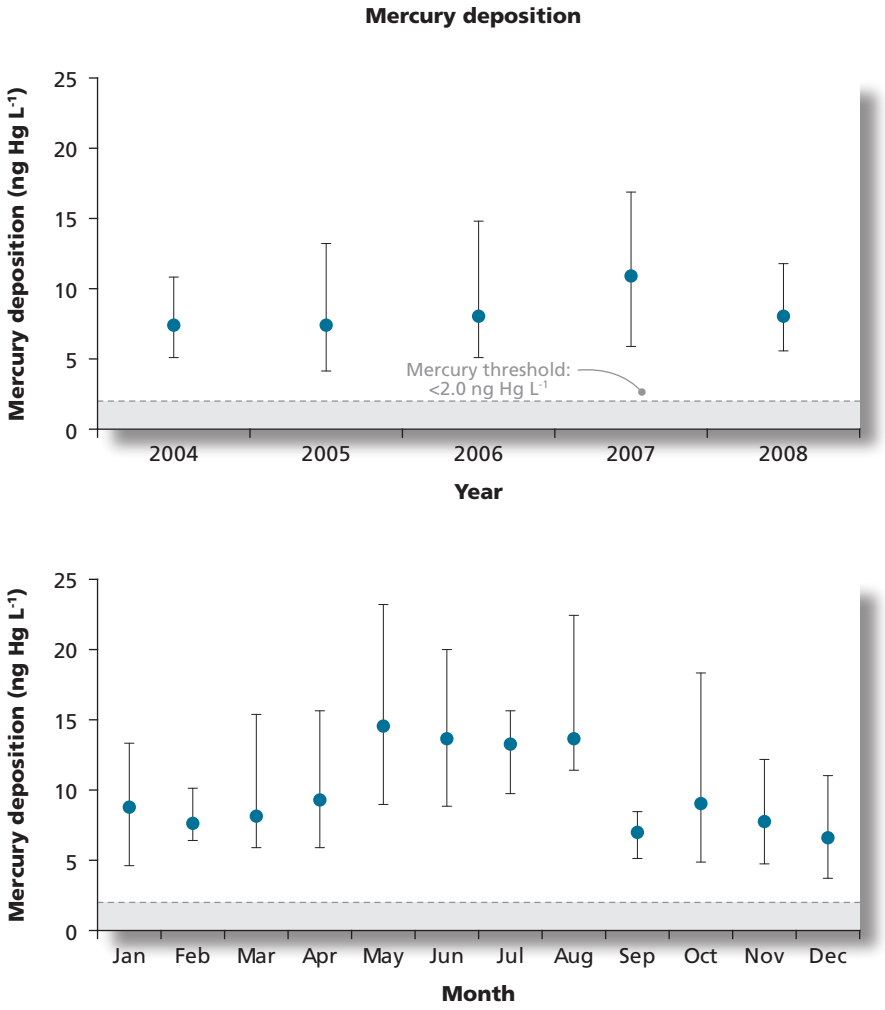

Figure 4.3. Mean monthly mercury deposition (ng Hg L^{-1}) from 2004 to 2007 at sites VA28 and MD99 (see Figure 3.4).[35] Acceptable range (Hg ≤ 2 ng L^{-1}) is shown in gray.

35. Mercury Deposition Network, *http://nadp.sws.uiuc.edu/mdn*

Table 4.1. Summary of habitat-based resource condition assessment of Manassas National Battlefield Park for habitats that are managed for natural resource values. Park score is area-weighted average, based on the area of each habitat (see Table 3.10).

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Forests				
Cover of exotic herbaceous species	11.2%	65		
Cover of exotic trees and shrubs	8.4%	92		
Presence of forest pest species	0.9%	81		
Native tree seedling regeneration	6,421 seedlings ha^{-1}	0		
Presence of forest interior dwelling species (FIDS) of birds	7 highly sensitive 5.5 sensitive	100	62	
Deer density (forest)	60.6 deer km^{-2}	0		
Impervious surface (within park)	0.4%	100		
Forest interior area	19%	21		
Forest connectivity (Dcrit; within park)	90 m	100		
Wetlands & waterways				
pH	7.5	98		
Dissolved oxygen (DO)	8.0 mg DO L^{-1}	86		
Water temperature	12.2 °C	100		
Acid neutralizing capacity	1,615 µeq L^{-1}	100		
Salinity	0.2	67		
Nitrate (NO_3)	0.7 mg NO_3 L^{-1}	97		
Phosphate (PO_4)	0.26 mg PO_4 L^{-1}	10	64	
Benthic index biological integrity (BIBI)	1.6	0		
Fish index biological integrity (FIBI)	3.7	100		
Physical habitat index (PHI)	56.1	0		
Proportion area occupied by amphibians	68.8	50		
Grasslands				
Deer density	60.6 deer km^{-2}	0		
Impervious surface (within park)	0.4%	100		
Grassland bird diversity	25%	25		
Grassland interior area	28%	31	48	
Contiguous grassland area	83 ha	100		
Cover of warm-season grassland	33%	33		

55

Table 4.2. Area-weighted results of habitat-based resource condition assessment of Manassas National Battlefield Park.

Habitat	Area (ha)	Score (%)	Area-weighted score (%)
Forests	806	62	55
Wetlands and waterways	62	64	
Grasslands	871	48	

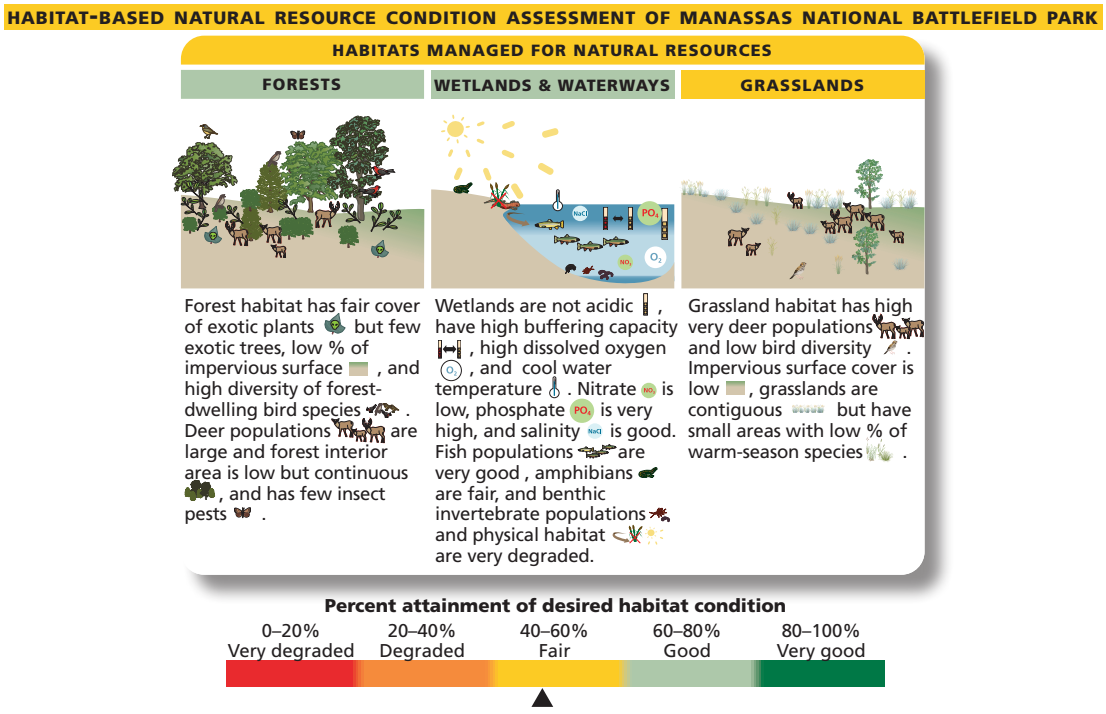

Figure 4.4. Summary results of habitat-based resource condition assessment of Manassas National Battlefield Park.

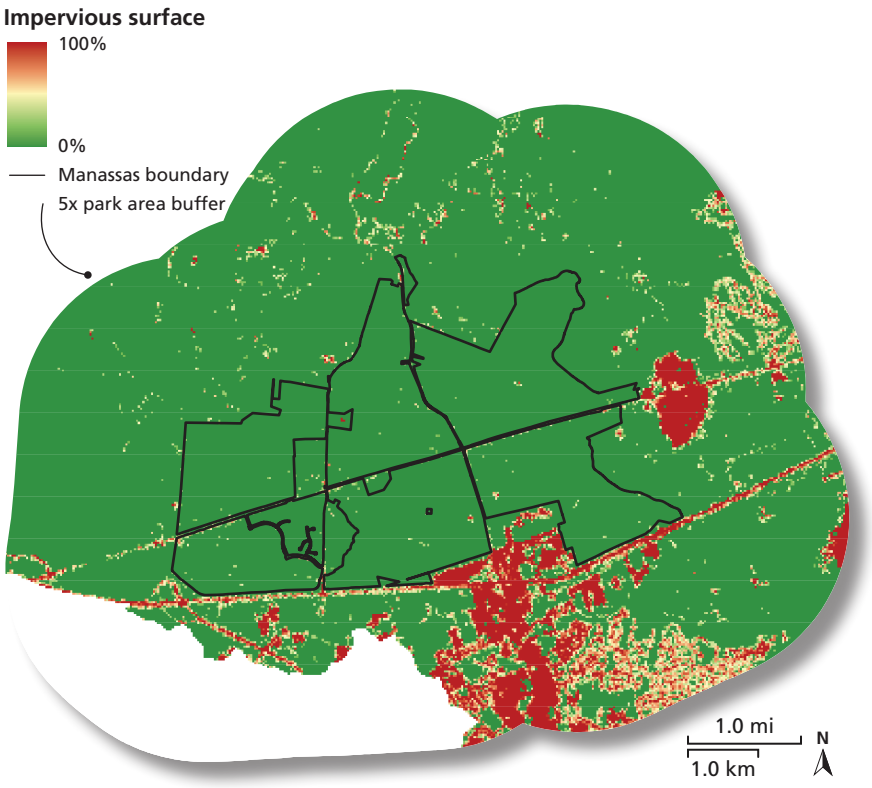

Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Manassas National Battlefield Park.[36] The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

Figure 4.6. Extent of forest and non-forest landcover (Landsat 30-m) within and around Manassas National Battlefield Park in 2000.[37] The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

36. NCRN I&M.
37. Townsend et al. 2006.

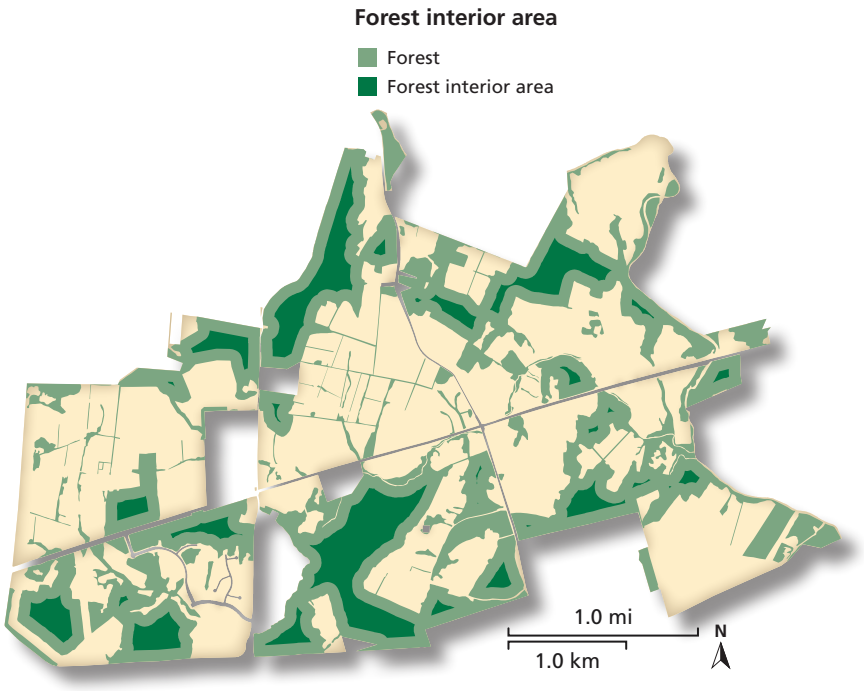

Figure 4.7. Forest area and forest interior area in Manassas National Battlefield Park.[38] Forest interior area is defined as forested land cover ≥ 100 m from non-forest land cover or from primary, secondary, or county roads.

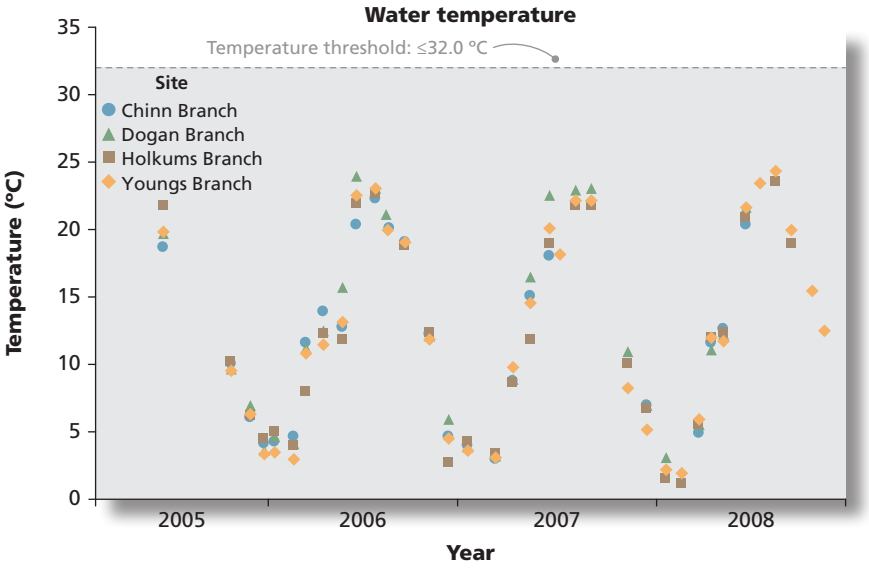

Figure 4.8. Water temperature (°C) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.[39] Acceptable range (temp. ≤ 32.0°C) is shown in gray.

38. NCRN I&M.
39. Norris et al. 2007.

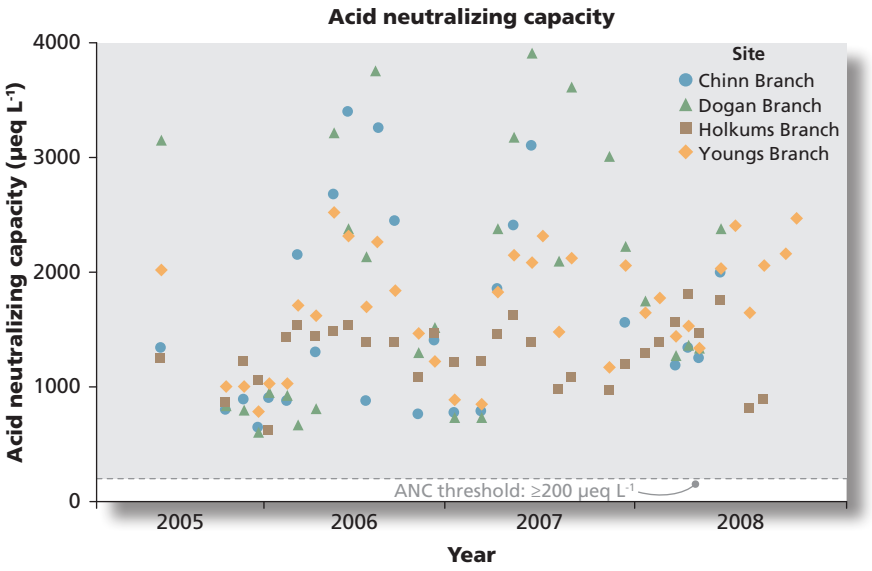

Figure 4.9. Acid neutralizing capacity (ANC; µeq L^{-1}) from 2005 to 2008 for three stream sampling location (see Figure 3.5) in Manassas National Battlefield Park.[40] Acceptable range (ANC ≥ 200 µeq L^{-1}) is shown in gray.

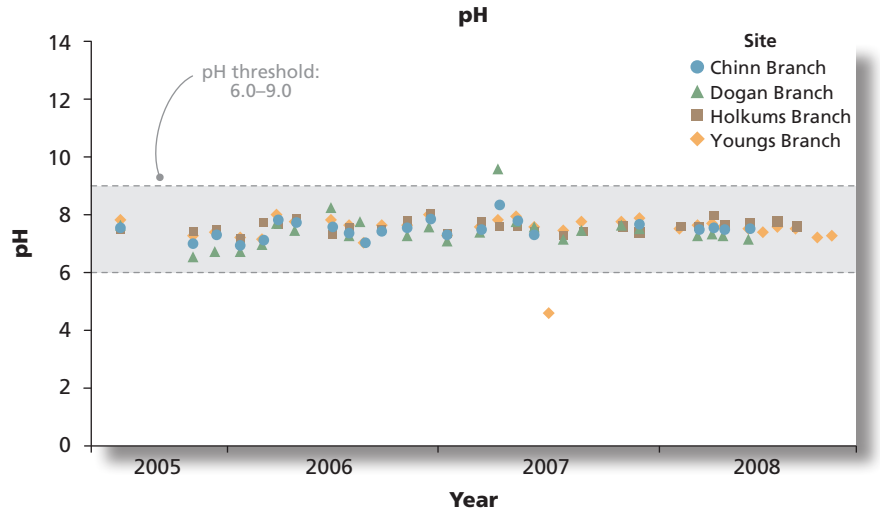

Figure 4.10. pH values from 2005 to 2008 for four stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.[41] Acceptable ranges (6.0 ≤ pH ≤ 9.0) are shown in gray.

40. Norris et al. 2007.
41. Norris et al. 2007.

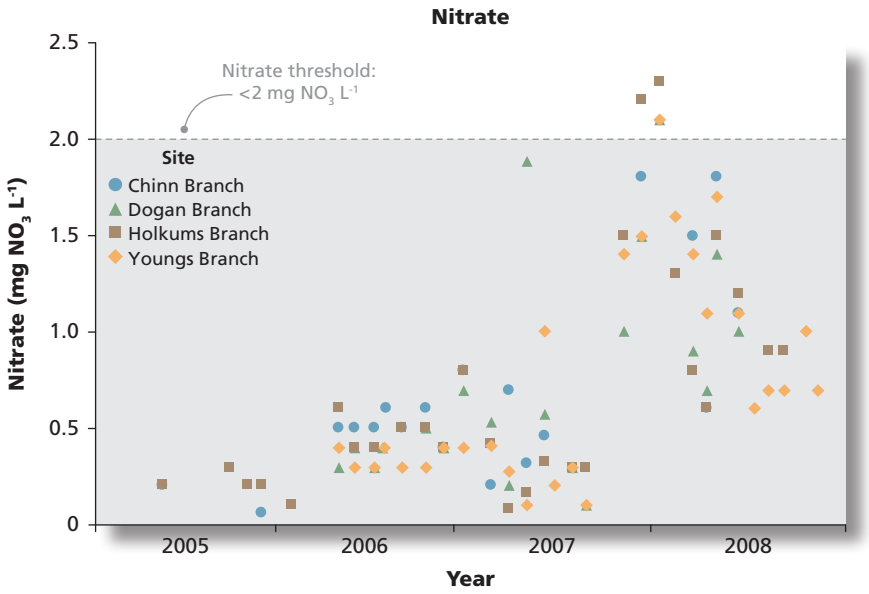

Figure 4.11. Nitrate concentration (mg NO_3 L^{-1}) from 2005 to 2008 for 16 stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.[42] Acceptable range ($NO_3 \leq 2.0$ mg L^{-1}) is shown in gray.

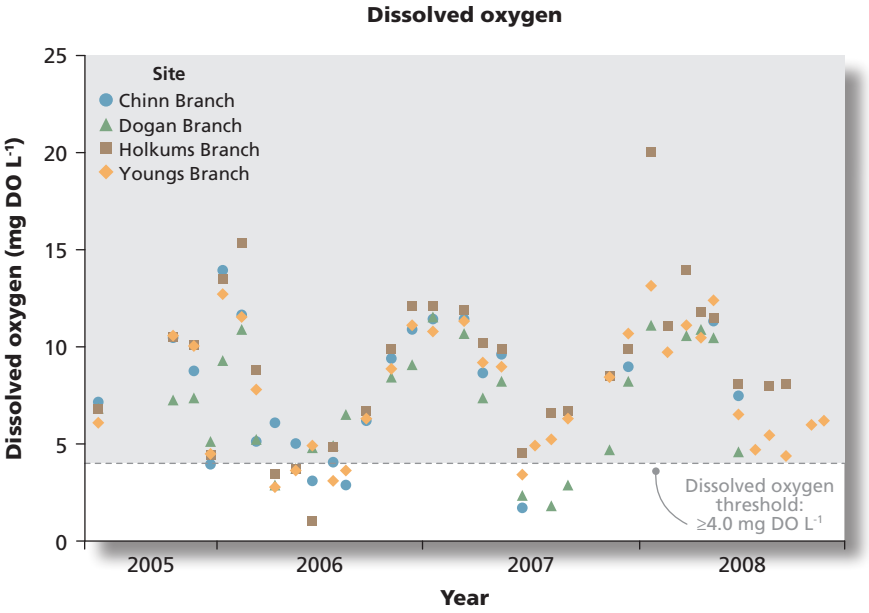

Figure 4.12. Dissolved oxygen concentration (mg DO L^{-1}) from 2005 to 2008 for four stream sampling locations in Manassas National Battlefield Park (see Figure 3.5).[43] Acceptable range (DO $\geq$ 4.0 mg L^{-1}) is shown in gray.

42. Norris et al. 2007.
43. Norris et al. 2007.

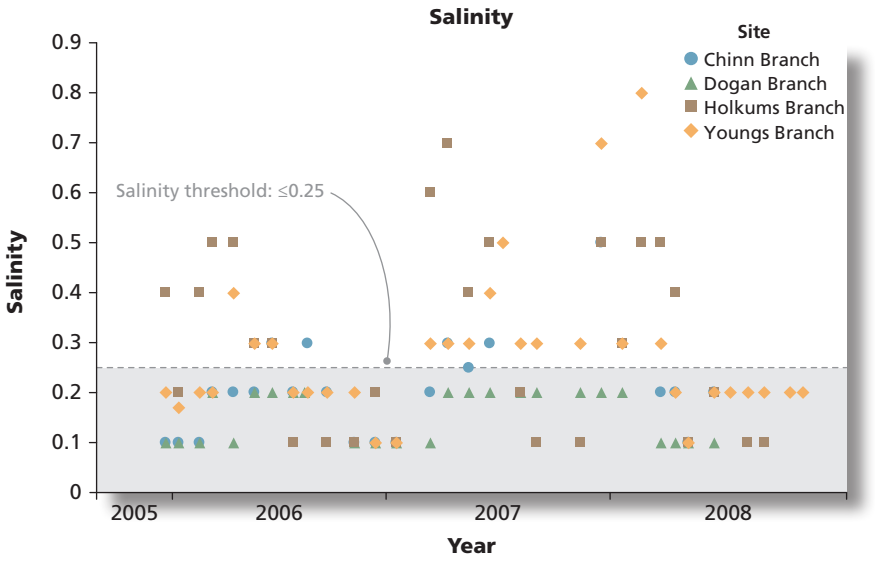

Figure 4.13. Monthly salinity concentration from 2005 to 2008 for four stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.[44] Acceptable range (salinity ≤ 0.25) is shown in gray.

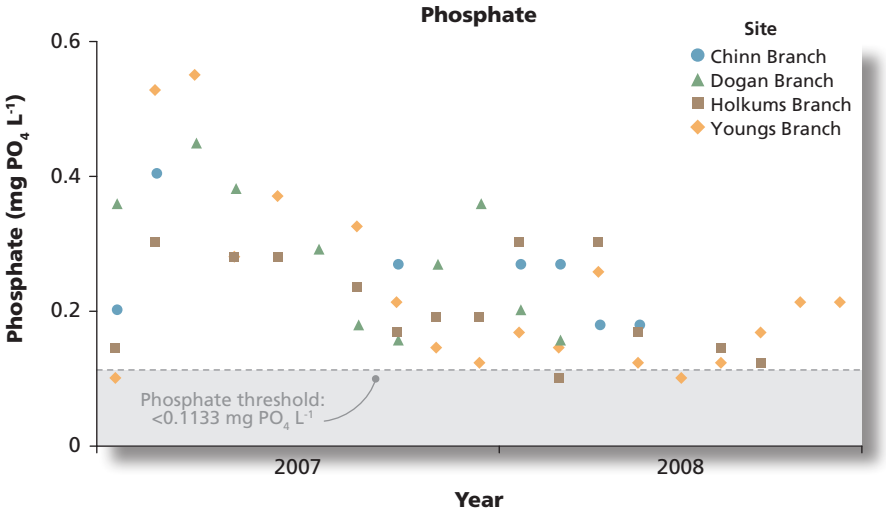

Figure 4.14. Phosphate concentrations (mg PO_4 L^{-1}) from 2007 to 2008 for four stream sampling locations (see Figure 3.5) for Manassas National Battlefield Park.[45] Acceptable range (PO_4 < 0.1133 mg L^{-1}) is also shown in gray.

44. Norris et al. 2007.
45. Norris et al. 2007.

of this habitat in the park (62 ha out of the 1,739 ha assessed) meant that this habitat had a proportionally small contribution to the area-weighted park score.

Grasslands

Grasslands in Manassas National Battlefield Park were assessed as being in fair condition overall, attaining desired condition in 48% of 15 measurements across six metrics, collected between 2000 and 2008 (Tables 3.9, 4.1). Impervious surface cover within the park was <1%, well below the desired threshold of 10% (Figure 4.5). Contiguous grassland area was also assessed as very good (100% attainment), while cover of warm-season grassland, grassland interior area (Figure 4.15), and grassland bird diversity were degraded (33%, 31%, and 25% attainment, respectively), and deer density was very degraded (0% attainment).

4.3 PARK-WIDE CONDITIONS

4.3.1 Ecological monitoring framework

Using an ecological monitoring framework to synthesize 31 metrics measuring the condition of Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics, natural resources within Manassas National Battlefield Park were assessed to be in a fair condition (48% attainment of threshold condition; Tables 3.6, 4.3). Water Resources and Landscape Dynamics were assessed as being in good condition, while Biological Integrity was fair and Air & Climate were in a very degraded condition.

Air & Climate

Using the interpolated results from NPS Air Resources Division and mercury monitoring data, Air & Climate in Manassas National Battlefield Park were measured to be in a very degraded condition (0% attainment of threshold condition; Table 4.3). Ozone concentration and wet nitrogen and sulfur deposition were within an order of magnitude of the threshold; however, visibility and mercury deposition were all an order of magnitude higher than threshold concentrations (Figure 4.3, Table 3.6).

Water Resources

Water Resources within Manassas National Battlefield Park were assessed as being in good condition, attaining desired condition in 62% of the 759 measurements across all nine metrics, collected between 2004 and 2008 (Tables 3.6, 4.3). Most Water Resources metrics were in desired (very good) condition, including water temperature, acid neutralizing capacity (both 100% attainment of threshold condition; Figures 4.8, 4.9), pH (98% attainment; Figure 4.10), nitrate (97% attainment; Figure 4.11) and dissolved oxygen (86% attainment; Figure 4.12). Salinity was assessed as being in good condition (67% attainment; Figure 4.13), while phosphate (10% attainment; Figure 4.14), the Benthic Index of Biotic Integrity, and Physical Habitat Index (both 0% attainment) were very degraded.

Biological Integrity

Biological Integrity within Manassas National Battlefield Park attained desired threshold condition in 57% of 114 measures over nine metrics, resulting in an assessment of fair condition (Tables 3.6, 4.3). Presence of forest interior dwelling bird species and stream fish were very good (both 100% attainment) and exotic tree and shrub density as well as presence of forest pest species were low (92% and 81% attainment, respectively), resulting in very good status for all four metrics. Percent cover of herbaceous species was moderate, resulting in a good assessment (65% attainment), while the area occupied by amphibians was fair (50% attainment). Grassland bird diversity was degraded (25% attainment), and native tree seedling regeneration and deer density were both very degraded (both 0% attainment).

Landscape Dynamics

Landscape Dynamics were assessed both within and just surrounding Manassas National Battlefield Park, and overall were in good condition, attaining desired threshold condition in 73% of eight measurements over eight metrics (Tables 3.6, 4.3). Forest patches were well connected and so attained desired condition for forest connectivity (Figure 4.6), as did contiguous grassland area; however, the proportion of

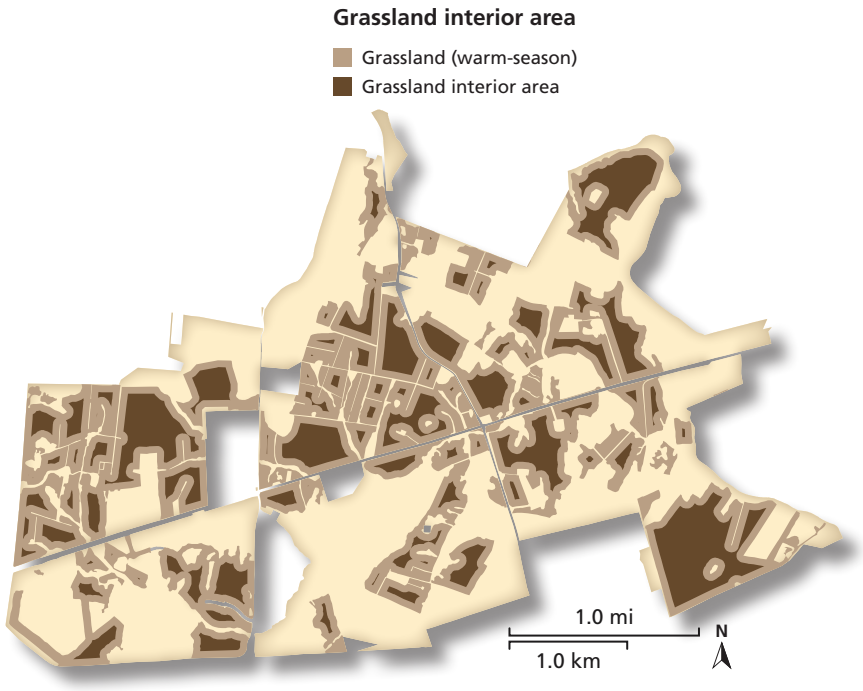

Figure 4.15. Grassland area and grassland interior area in Manassas National Battlefield Park.[46] Grassland interior area is defined as grassland ≥60 m from other land uses.

forest interior area was low (21% of potential forest interior area; Figure 4.7), as was grassland interior area (31% of potential grassland interior area; Figure 4.15). Cover of warm-season grassland was 33%—a poor result, but this is expected to change as park management continues to convert cool-season grasslands to warm-season species. Percentage of impervious surface both within and surrounding the park was acceptably low and well below the threshold of 10% impervious cover; however, the impervious surface data did not completely cover the 5x buffer area surrounding the park. Percentage of impervious surface was 6.9% in the area of the 5x buffer that was covered by the impervious surface data map (10.6% of the 5x buffer was not covered by the impervious surface data map; Figure 4.5). In addition, the impervious surface data used in this analysis was from 2000, and significant development has occurred to the west and south of the park since then.

46. NCRN I&M.

Table 4.3. Summary resource condition assessment for Manassas National Battlefield Park by metric categories.

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Air & Climate				
Ozone	0.081 ppm	0		
Wet nitrogen (N) deposition	4.2 kg N ha^{-1} yr^{-1}	0		
Wet sulfur (S) deposition	5.1 kg S ha^{-1} yr^{-1}	0	0	
Visibility	13.93 dv	0		
Mercury (Hg) deposition	11.5 ng Hg L^{-1}	0		
Water Resources				
pH	7.5	98		
Dissolved oxygen (DO)	8.0 mg DO L^{-1}	86		
Water temperature	12.2 °C	100		
Acid neutralizing capacity	1,615 µeq L^{-1}	100		
Salinity	0.2	67	62	
Nitrate (NO_3)	0.7 mg NO_3 L^{-1}	97		
Phosphate (PO_4)	0.26 mg PO_4 L^{-1}	10		
Benthic index biological integrity (BIBI)	1.6	0		
Physical habitat index (PHI)	56.1	0		
Biological Integrity				
Cover of exotic herbaceous species	11.2%	65		
Cover of exotic trees and shrubs	8.4%	92		**48**
Presence of forest pest species	0.9%	81		
Native tree seedling regeneration	6,421 seedlings ha^{-1}	0		
Fish index biological integrity (FIBI)	3.7	100		
Proportion area occupied by amphibians	68.8	50	57	
Presence of forest interior dwelling species (FIDS) of birds	7 highly sensitive 5.5 sensitive	100		
Grassland bird diversity	25%	25		
Deer density (forest)	60.6 deer km^{-2}	0		
Deer density (grassland)	60.6 deer km^{-2}			
Landscape Dynamics				
Impervious surface (within park)	0.4%	100		
Impervious surface (within park) + 5X buffer	6.9%	100		
Forest interior area	19%	21		
Forest connectivity (Dcrit; within park)	90 m	100	73	
Forest connectivity (within park) + 5X buffer	90 m	100		
Grassland interior area	28%	31		
Contiguous grassland area	83 ha	100		
Cover of warm-season grassland	33%	33		

4.4 LITERATURE CITED (CHAPTER 4)

National Capital Region Network. 2006. A conceptual basis for natural resource monitoring. Department of the Interior, National Park Service, Washington, DC. *http://ian.umces.edu/ncr/pdfs/nrm_booklet.pdf*

Chapter 5: Discussion

5.1 ASSESSING NATURAL RESOURCE CONDITION IN A BATTLEFIELD PARK

Enabling legislation for many parks was established for reasons other than to specifically protect the ecological benefits of natural areas within the park. Therefore a landscape may be maintained for a particular historic view or to maintain other cultural features of significance, raising the question of how to assess the natural resource condition of these landscapes. The lands within the park are much as they were on the day of the battle and the park is charged with maintaining them in historical land use to preserve the view of the battle. The first step in framing this Natural Resource Condition Assessment was to define the key habitats within the park, considering ecology as well as how these different areas are managed and what data may be available to assess habitats. Three high-level habitats were identified: forests, wetlands and waterways, and grasslands. The ecological value of these habitats was assessed using vital sign metrics from the National Park Service (NPS) Inventory & Monitoring (I&M) Program in the National Capital Region Network (NCRN).

An assessment framework must allow for change (e.g., improvement) and metrics must be measurable and show variation, so it was deemed ultimately unhelpful to assess working landscapes as 'degraded' natural habitats. This approach works at recognizing the park's management goals by synthesizing an assessment of whether these cultural or working lands are in their best condition for that landscape. In this way, it was possible to assess all lands within the park, recognizing management goals and cultural resource values but providing an integrated framework that supports an assessment of the natural resource value of the whole park.

5.2 KEY FINDINGS AND MANAGEMENT IMPLICATIONS

To synthesize multiple diverse data sets, a habitat framework was used to assess current condition of natural resources for Manassas National Battlefield Park (Chapters 3, 4), therefore key findings and management implications are summarized using the same framework (Tables 5.1, 5.2, 5.3).

Eastern tiger swallowtail (*Papilio glaucus*).

5.2.1 Forests

Patches of forest within Manassas National Battlefield Park are well connected, although there is poor forest interior area, limiting the habitat potential for native fauna including forest interior dwelling bird species (FIDS; Table 5.1). It is recommended to preserve this forest connectivity by limiting future fragmentation (such as roads, trails, and structures) of these forest patches, as well as minimizing stresses (such as invasive species) on these forest areas. Very high deer populations are present within these forest areas resulting in limited regeneration capacity of these forests, as well as trampling, overgrazing, and reduction of habitat value for wildlife. It is recommended to implement deer reduction strategies to attain a population closer to the sustainable 8 deer km^{-2} (21 deer mi^{-2}), down from the current population of over 60 deer km^{-2} (155 deer mi^{-2}). The abundant presence of exotic herbaceous and woody species displaces native species and reduces habitat value. Continued

Table 5.1. Key findings, management implications, and recommended next steps for forest habitat in Manassas National Battlefield Park.

Key findings	Management implications	Recommended next steps
Forests		
• Deer overpopulation reducing forest regeneration capacity	• Increased herbivory reducing desired plant and bird species • More road collisions	• Implement deer population control measures
• Presence of exotic plants	• Displacement of native species, reducing biodiversity	• Early detection • Exotic control measures (spraying and mechanical) • Prioritize control strategies
• Well-connected forest but with small patch sizes/limited interior area	• Acts as a refuge for some forest species, but limited habitat value for interior dwelling species of birds	• Minimize stressors • Minimize fragmentation (roads, structures, trails) • Maintain size, especially of larger patches

Table 5.2. Key findings, management implications, and recommended next steps for wetland and waterway habitat in Manassas National Battlefield Park.

Key findings	Management implications	Recommended next steps
Wetlands and waterways		
• Bull Run and tributaries have degraded water quality (phosphate)	• Affects stream flora and fauna • Reduces quality of visitor experience	• Reduce non-point source nutrient inputs from watershed (partnership with agencies) • Continue riparian buffer establishment (woody or herbaceous, depending upon cultural resources/viewshed present)
• Stream benthos (IBI) very poor	• Reduced biodiversity • Reduced support of higher trophic levels	• Improve water quality
• Stream physical habitats vary from good to poor	• Affects riparian habitat and in-stream fauna (fish) • Affects park infrastructure via erosion	• Comprehensive assessment of stream Physical Habitat Condition

Table 5.3. Key findings, management implications, and recommended next steps for grassland habitat in Manassas National Battlefield Park.

Key findings	Management implications	Recommended next steps
Grasslands		
• General lack of comprehensive data for grasslands	• Difficulties in assessing the health of grasslands	• Implement grassland monitoring, particularly diversity, invasive species, birds, mammals, and insects • Carry out a baseline grassland plant inventory
• Grassland areas are contiguous with poor interior area	• High potential habitat value for avian fauna and mammals (by decreasing potential predation)	• Remove tree lines where historically appropriate • Maintain size, especially of larger patches
• Poor cover of warm-season species	• Warm-season grasslands have higher habitat potential than cool-season species	• Increase proportion of warm-season grassland

early detection of exotic species is recommended with subsequent active control measures (spraying and physical removal). Assessment of exotic species cover would be better assessed with park-wide mapping as the current small number of plots is not ideal for assessing exotic species cover on a park scale.

5.2.2 Wetlands and waterways

Wetland and waterway habitats show no sign of acidification, low oxygen, high temperatures, salinity, or dissolved nitrate; however, high dissolved phosphate indicates reduced wetland habitat value, which is reflected in the very degraded benthic index of biotic integrity and physical habitat index (Table 5.2). It is recommended to identify and work with partners to reduce non-point source nutrient inputs from the watershed as well as continue to implement best management practices in agricultural lands. Additionally, efforts should continue to establish riparian buffers (ideally to 50 m [160 ft]; Mayer et al. 2006) where appropriate, in consideration of cultural resources and historic vistas (using shrubs and grasses instead of trees may be appropriate in these cases).

5.2.3 Grasslands

It is recommended to carry out baseline grassland plant inventories and optimize fire management to assist a transition to a greater abundance of native warm-season grasses, monitoring the effectiveness of different burning cycles (Table 5.3). Grassland areas are contiguous but with poor grassland interior area and warm-season species cover, providing some habitat value for birds, mammals, and insects. It is recommended to remove tree lines and expand areas of native warm-season grasses where historically appropriate and to develop inventories and monitor these key faunal communities. Future assessments of natural resource condition would be improved by inclusion of measures of monitoring of bird, small mammal, and insect communities within native grassland habitats. Direct measures of the species and habitat diversity (i.e., range of successional stages) would also be beneficial in managing to maximize habitat value of warm-season grassland habitat.

More grassland bird species were documented by Sinclair et al (2004) than were found by Goodwin and Shriver (2009). Additional species documented were: northern harrier (*Circus cyaneus*), savannah sparrow (*Passerculus sandwichensis*), and vesper sparrow (*Pooecetes gramineus*). Henslow's sparrow (*Ammodramus henslowii*) was also documented by Peterjohn (2006), which represents one of very few recent breeding records for this state-listed for the Piedmont region of northern Virginia.

5.3 DATA GAPS AND SUBSEQUENT RESEARCH NEEDS

The NPS NCRN I&M 'vital signs' framework was used to assess the current condition of park-wide natural resources for Manassas National Battlefield Park (Chapters 3, 4), therefore key data gaps and research needs were summarized using the same framework (Tables 5.4, 5.5, 5.6, 5.7).

5.3.1 Air & Climate

Air quality is poor within the park and while it is well monitored, the specific implications to the flora and fauna in the park are less well known (Table 5.4). Gaining a better understanding of how reduced air quality is impacting wetland and grassland habitats (particularly) would help prioritize management efforts such as nutrient reductions in park lands, by showing what gains may be expected from these efforts. Currently available air quality data is regional, it would be beneficial to translate this data down to a park scale with modeling efforts as well as some strategic calibration, especially on major roadways within the park.

5.3.2 Water Resources

Water quality has signs of degradation, and is essential to the preservation of biotic integrity within all major habitats in the park (Table 5.5). Stream channels are highly variable in condition and a comprehensive assessment of stream physical habitat would allow for targeted management efforts and also allow for targeted engineering efforts

Table 5.4. Data gaps, justification, and research needs for Air & Climate in Manassas National Battlefield Park.

Data gaps	Justification	Research needs
Air & Climate		
• Ecological thresholds (for atmospheric effects on water and grasslands—deposition of nitrogen, sulfur, and mercury)	• Ecosystem impacts from deposition and human influence (acid rain and fertilization) unknown	• Investigating habitat-specific effects • Deposition impacts to wetlands and grasslands • Prevailing wind patterns within the park
• Park-scale air quality data	• Need to implement park-specific management actions	• Using transport and deposition models • Calibrating with roadside data within the park

Table 5.5. Data gaps, justification, and research needs for Water Resources in Manassas National Battlefield Park.

Data gaps	Justification	Research needs
Water Resources		
• Stream channel morphology, and changes due to erosion	• Biodiversity relies on maintenance of stable wetland morphology	• Research engineering solutions to reduce water energy and erosion
• Water quality, including groundwater	• Degraded water quality reduces habitat value of wetlands for native flora and fauna	• Identify nutrient sources, especially phosphate, as this nutrient is consistently high throughout the region and sources are non-point
• Detailed wetland delineation	• In this pervious karst landscape, all habitats are connected by water flows	• Fine-scale mapping including surface and sub-surface flows • 'Groundwatershed' maps of flow throughout park
• Nutrient and salt sources are poorly defined both within and outside the park	• Need to know where to prioritize management actions	• Tracers, models and budgets needed (inside and outside the park) • Identify inputs (point and diffuse)
• Comprehensive assessment of stream physical habitat condition	• High spatial variability of condition	• Mapping and assessing streambank condition
• Watershed condition	• Strong connectivity in water resources within the park to external stressors throughout the watershed	• Work with watershed partners and agencies to assess watershed and stream condition

Table 5.6. Data gaps, justification, and research needs for Biological Integrity in Manassas National Battlefield Park.

Data gaps	Justification	Research needs
Biological Integrity		
• Bird community thresholds and management goals	• The park contains increasingly rare habitat for neotropical and grassland birds	• Inventory and monitor types of birds, particularly grassland birds, within the park
• Acoustic and vibration monitoring	• Traffic vibrations and noise can impact bird populations	• Monitor noise and vibrations and assess impacts to bird communities
• Understanding grazing impacts on multiple habitats (grassland, cropland, pasture)	• Intense herbivory impacts habitat structure and function	• Impacts of different deer densities on different habitats, including establishing deer density thresholds
• Importance of maintaining late successional warm-season grasslands	• Grassland diversity can enhance diversity of birds, mammals and insect pollinators	• Actively monitor effects of different grassland management actions, including burn strategy
• Small mammal dynamics and populations in grasslands	• Park contains increasingly rare grassland habitat important to declining populations of mammals dependent on early successional habitats	• Inventory and monitor small mammals specific to grasslands
• Grassland insect and pollinator populations and roles	• Park contains increasingly rare grassland habitat	• Inventory and monitor insects, particularly those that are important food sources for grassland birds
• Sustainability of raptor populations and affects on grassland birds	• Park contains increasingly rare grassland habitat	• Inventory and monitor raptors that prey on neotropical and grassland birds • Establish baseline for sound levels and types of sounds within park

Table 5.7. Data gaps, justification, and research needs for Landscape Dynamics in Manassas National Battlefield Park.

Data gaps	Justification	Research needs
Landscape Dynamics		
• Implications of external land use changes on park resources	• Connectivity of ecological processes from park to watershed	• Landscape analysis at multiple scales
• Wetland corridor function	• Needed for migration and movement of fauna	• Assessment of current and potential use by fauna
• Cultural requirements for tree heights	• Vegetating streamsides needs to be carried out in a way that maintains cultural viewscapes	• Assess maximum acceptable plant height and species

45. Litvaitis, J. 2001. Importance of early successional habitat to mammals in eastern forests. Wildlife Society Bulletin 29: 466–473.

to reduce water energy and erosion in the most susceptible areas. A detailed wetland delineation, including groundwater, would also provide a greater understanding of current features and potential threats to park resources. Phosphates are consistently high throughout the region and as this nutrient often comes from non-point sources, challenges exist for identification and mitigation of these sources.

5.3.3 Biological Integrity

Some valuable biological communities occur within the park, with the natural park habitats such as native warm-season grasslands becoming more significant as development continues throughout the region (Table 5.6). Understanding the significance of these habitats to native grassland birds would require inventory and monitoring of these communities, including some specific studies on the potential impacts of traffic and vibrations to the success of these communities. The ecological community structure and succession of warm-season grassland communities themselves is poorly characterized in terms of habitat value to birds, small mammals, and insect pollinators. Research into warm-season grassland communities would support the development of key indicators to monitor resource value of these habitats in the maintenance of a range of native biological communities. Very high deer populations in the park have contributed to very low native tree seedling regeneration. A better understanding of the dynamics of these forest habitats in the presence of high deer populations and their ability to recover after deer reduction would assist in clarifying sustainable deer populations for future management.

The data used for the assessment of forest interior dwelling species of birds and grassland birds (Goodwin and Shriver 2009) was focused on forested sites within the park. Therefore, grassland bird species were likely under-represented.

5.3.4 Landscape Dynamics

Many of the faunal communities that constitute features of the park are migratory or have home ranges much greater than the park. For these reasons, assessing the connectivity and ownership of habitats and lands not just within but also outside of the park will allow a better understanding of the resilience of these communities and their susceptibility to change in the future (Table 5.7). This is true for forest, wetland and waterway, and grassland habitats within the park. As a battlefield park, vegetating streamsides to reduce nutrient runoff into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies are needed to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters.

5.4 LITERATURE CITED (CHAPTER 5)

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Sinclair, J.A., M. Koenen, S. Hood, M. Milton, and C. Wright. 2004. Avian inventory at six National Capital Region National Parks. Final report (revised). National Park Service, Inventory & Monitoring Program, National Capital Region Network, Washington, DC.

Appendix A: Raw data used in Manassas National Battlefield Park Natural Resource Condition Assessment

Table A-1. Annual mean mercury wet deposition (ng Hg L^{-1}). Values that fail threshold (>2.0 ng Hg L^{-1}) are in bold.

Year	Count	Mean
2004	72	**10.24**
2005	82	**10.69**
2006	75	**11.81**
2007	88	**13.80**
2008	88	**10.65**
Overall	405	11.48
Std error		0.52

Table A-2. Water quality data. Values that do not meet the thresholds are in bold. Site locations are shown in Figure 3.5 and thresholds are shown in Table 3.2.

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
NCRN_MANA_CHBR	6/22/2005	7.60	7.15	18.65	1344		0.2	
NCRN_MANA_CHBR	10/27/2005	7.04	10.42	10.10	800		*Non-detect	
NCRN_MANA_CHBR	12/1/2005	7.35	8.76	6.10	888		*Non-detect	
NCRN_MANA_CHBR	12/27/2005		**3.92**	4.10	648	0.1	0.06	
NCRN_MANA_CHBR	1/17/2006	7.00	13.91	4.30	904	0.1	*Non-detect	
NCRN_MANA_CHBR	2/21/2006	7.18	11.67	4.65	880	0.1	*Non-detect	
NCRN_MANA_CHBR	3/15/2006	7.81	5.13	11.60	2144	0.2		
NCRN_MANA_CHBR	4/18/2006	7.80	6.04	13.95	1296	0.2	*Non-detect	
NCRN_MANA_CHBR	5/22/2006		5.04	12.70	2672	0.2	0.5	
NCRN_MANA_CHBR	6/19/2006	7.57	**3.10**	20.40	3396	**0.3**	0.5	
NCRN_MANA_CHBR	7/25/2006	7.44	4.11	22.30	880	0.2	0.5	
NCRN_MANA_CHBR	8/17/2006	7.03	**2.85**	20.05	3256	**0.3**	0.6	
NCRN_MANA_CHBR	9/18/2006	7.47	6.24	19.00	2448	0.2	0.5	
NCRN_MANA_CHBR	11/2/2006	7.60	9.40	12.20	760	0.1	0.6	
NCRN_MANA_CHBR	12/5/2006	7.92	10.91	4.65	1400	0.1	0.4	
NCRN_MANA_CHBR	1/10/2007	7.37	11.42	4.03	768	0.1	0.8	**1.25**
NCRN_MANA_CHBR	3/5/2007	7.53	11.43	3.00	784	0.2	0.2	**0.12**
NCRN_MANA_CHBR	4/5/2007	8.40	8.69	8.75	1848	**0.3**	0.7	0.11
NCRN_MANA_CHBR	5/8/2007	7.84	9.62	15.05	2408	**0.25**	0.32	**0.2**
NCRN_MANA_CHBR	6/11/2007	7.35	**1.70**	18.00	3104	**0.3**	0.46	**0.41**
NCRN_MANA_CHBR	12/10/2007	7.74	8.96	6.90	1560	**0.5**	1.8	**0.26**
NCRN_MANA_CHBR	3/17/2008	7.54	11.67	4.90	1184	0.2	1.5	**0.26**
NCRN_MANA_CHBR	4/10/2008	7.60	10.71	11.60	1344	0.2	0.6	**0.28**
NCRN_MANA_CHBR	5/1/2008	7.55	11.36	12.65	1248	0.1	1.8	**0.17**
NCRN_MANA_CHBR	6/12/2008	7.51	7.47	20.30	2000	0.2	1.1	**0.17**
NCRN_MANA_DOBR	6/22/2005	7.64	6.86	19.65	3152		*Non-detect	
NCRN_MANA_DOBR	10/27/2005	6.56	7.23	9.68	840		*Non-detect	
NCRN_MANA_DOBR	12/1/2005	6.74	7.38	7.00	800		*Non-detect	
NCRN_MANA_DOBR	12/27/2005		5.17	3.65	600	0.1	*Non-detect	
NCRN_MANA_DOBR	1/17/2006	6.76	9.25	4.60	952	0.1	*Non-detect	
NCRN_MANA_DOBR	2/21/2006	7.01	10.93	4.10	920	0.1	*Non-detect	
NCRN_MANA_DOBR	3/15/2006	7.74	5.23	11.20	672	0.2		
NCRN_MANA_DOBR	4/18/2006	7.48	**2.92**	12.45	816	0.1	*Non-detect	
NCRN_MANA_DOBR	5/22/2006		**3.75**	15.70	3216	0.2	0.3	

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
NCRN_MANA_DOBR	6/19/2006	8.28	4.86	24.00	2376	0.2	0.4	
NCRN_MANA_DOBR	7/25/2006	7.28	4.93	23.00	2136	0.2	0.3	
NCRN_MANA_DOBR	8/11/2006	7.80	6.51	21.10	3752	0.2	0.4	
NCRN_MANA_DOBR	11/2/2006	7.31	8.43	12.10	1300	0.1	0.5	
NCRN_MANA_DOBR	12/5/2006	7.62	9.04	5.95	1520	0.1	0.4	
NCRN_MANA_DOBR	1/10/2007	7.12	11.59	3.90	736	0.1	0.7	**1.02**
NCRN_MANA_DOBR	3/5/2007	7.43	10.68	3.20	736	0.1	0.53	**0.45**
NCRN_MANA_DOBR	4/5/2007	**9.61**	7.41	8.90	2376	0.2	0.2	**0.13**
NCRN_MANA_DOBR	5/8/2007	7.78	8.20	16.45	3176	0.2	1.89	**0.21**
NCRN_MANA_DOBR	6/11/2007	7.57	**2.36**	22.50	3912	0.2	0.57	**0.35**
NCRN_MANA_DOBR	8/1/2007	7.16	**1.81**	22.90	2096	0.2	0.3	**0.45**
NCRN_MANA_DOBR	8/28/2007	7.47	**2.88**	23.00	3616	0.2	0.1	**0.38**
NCRN_MANA_DOBR	10/9/2007							
NCRN_MANA_DOBR	11/6/2007	7.66	4.65	11.00	3016	0.2	1	**0.29**
NCRN_MANA_DOBR	12/10/2007	7.51	8.23	6.90	2224	0.2	1.5	**0.17**
NCRN_MANA_DOBR	1/15/2008		11.13	3.10	1752	0.2	**2.1**	**0.15**
NCRN_MANA_DOBR	3/17/2008	7.30	10.59	5.55	1272	0.1	0.9	**0.28**
NCRN_MANA_DOBR	4/10/2008	7.37	10.95	11.05	1368	0.1	0.7	**0.36**
NCRN_MANA_DOBR	5/1/2008	7.29	10.46	12.20	1336	0.1	1.4	**0.2**
NCRN_MANA_DOBR	6/12/2008	7.16	4.56	21.60	2384	0.1	1	**0.15**
NCRN_MANA_HOBR	6/22/2005	7.53	6.70	21.75	1248		0.2	
NCRN_MANA_HOBR	10/27/2005	7.48	10.44	10.20	864		0.3	
NCRN_MANA_HOBR	12/1/2005	7.55	10.00	6.20	1216		0.2	
NCRN_MANA_HOBR	12/27/2005		4.34	4.50	1056	**0.4**	0.2	
NCRN_MANA_HOBR	1/17/2006	7.22	13.45	5.00	616	0.2	*Non-detect	
NCRN_MANA_HOBR	2/21/2006	7.80	15.25	4.00	1432	**0.4**	0.1	
NCRN_MANA_HOBR	3/15/2006	7.73	8.75	8.00	1536	**0.5**		
NCRN_MANA_HOBR	4/18/2006	7.89	**3.38**	12.25	1440	**0.5**	*Non-detect	
NCRN_MANA_HOBR	5/22/2006		**3.59**	11.80	1480	**0.3**	0.6	
NCRN_MANA_HOBR	6/19/2006	7.36	**0.98**	21.90	1528	**0.3**	0.4	
NCRN_MANA_HOBR	7/25/2006	7.59	4.78	22.70	1392	0.1	0.4	
NCRN_MANA_HOBR	9/18/2006	7.56	6.67	18.85	1392	0.1	0.5	
NCRN_MANA_HOBR	11/2/2006	7.86	9.86	12.30	1080	0.1	0.5	
NCRN_MANA_HOBR	12/5/2006	8.10	12.08	2.70	1460	0.2	0.4	
NCRN_MANA_HOBR	1/10/2007	7.42	12.12	4.30	1208	0.1	0.8	**0.62**
NCRN_MANA_HOBR	3/5/2007	7.76	11.87	3.40	1224	**0.6**	0.42	**0.2**
NCRN_MANA_HOBR	4/5/2007	7.68	10.10	8.60	1456	**0.7**	0.08	0.11
NCRN_MANA_HOBR	5/8/2007	7.65	9.87	11.88	1624	**0.4**	0.16	**0.13**
NCRN_MANA_HOBR	6/11/2007	7.49	4.51	18.90	1384	**0.5**	0.33	**0.29**
NCRN_MANA_HOBR	8/1/2007	7.27	6.49	21.70	976	0.2	0.3	**0.28**
NCRN_MANA_HOBR	8/28/2007	7.50	6.60	21.80	1080	0.1	0.3	**0.26**
NCRN_MANA_HOBR	11/6/2007	7.58	8.41	10.00	960	0.1	1.5	**0.22**
NCRN_MANA_HOBR	12/10/2007	7.40	9.88	6.70	1200	**0.5**	**2.2**	**0.15**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
NCRN_MANA_HOBR	1/15/2008		20.00	1.50	1280	**0.3**	**2.3**	**0.18**
NCRN_MANA_HOBR	2/14/2008	7.66	11.02	1.15	1384	**0.5**	1.3	**0.18**
NCRN_MANA_HOBR	3/17/2008	7.67	13.89	5.50	1552	**0.5**	0.8	**0.29**
NCRN_MANA_HOBR	4/10/2008	8.03	11.79	11.95	1800	**0.4**	0.6	0.1
NCRN_MANA_HOBR	5/1/2008	7.64	11.48	12.40	1472	0.1	1.5	**0.29**
NCRN_MANA_HOBR	6/12/2008	7.70	7.96	20.80	1752	0.2	1.2	**0.15**
NCRN_MANA_HOBR	8/6/2008	7.75	7.90	23.50	806	0.1	0.9	**0.14**
NCRN_MANA_HOBR	9/3/2008	7.58	8.02	18.90	888	0.1	0.9	**0.12**
NCRN_MANA_YOBR	6/22/2005	7.82	6.08	19.80	2024		*Non-detect	**0.18**
NCRN_MANA_YOBR	10/27/2005	7.26	10.58	9.52	1008		*Non-detect	*Non-detect
NCRN_MANA_YOBR	12/1/2005	7.44	10.05	6.35	1008		*Non-detect	*Present <QL
NCRN_MANA_YOBR	12/27/2005		4.51	3.35	784	0.2	*Non-detect	**1.25**
NCRN_MANA_YOBR	1/17/2006	7.25	12.76	3.50	1032	0.17	*Non-detect	**0.38**
NCRN_MANA_YOBR	2/21/2006	7.19	11.59	2.90	1032	0.2	*Non-detect	*Non-detect
NCRN_MANA_YOBR	3/15/2006	7.99	7.80	10.77	1712	0.2		**0.34**
NCRN_MANA_YOBR	4/18/2006	7.78	**2.78**	11.40	1616	**0.4**	*Non-detect	*Non-detect
NCRN_MANA_YOBR	5/22/2006		**3.67**	13.10	2520	**0.3**	0.4	**1.46**
NCRN_MANA_YOBR	6/19/2006	7.83	4.93	22.50	2320	**0.3**	0.3	**0.21**
NCRN_MANA_YOBR	7/25/2006	7.66	**3.06**	23.10	1696	0.2	0.3	**0.4**
NCRN_MANA_YOBR	8/16/2006	7.05	**3.64**	19.90	2264	0.2	0.4	**1.01**
NCRN_MANA_YOBR	9/18/2006	7.64	6.33	19.10	1840	0.2	0.3	**0.76**
NCRN_MANA_YOBR	11/2/2006	7.63	8.83	11.90	1460	0.2	0.3	**0.12**
NCRN_MANA_YOBR	12/5/2006	8.05	11.06	4.53	1220	0.1	0.4	0.11
NCRN_MANA_YOBR	1/10/2007	7.31	10.81	3.57	888	0.1	0.4	**0.69**
NCRN_MANA_YOBR	3/5/2007	7.61	11.33	3.08	848	**0.3**	0.41	**0.12**
NCRN_MANA_YOBR	4/5/2007	7.84	9.22	9.73	1824	**0.3**	0.28	0.07
NCRN_MANA_YOBR	5/8/2007	7.93	8.95	14.57	2144	**0.3**	0.1	0.08
NCRN_MANA_YOBR	6/11/2007	7.57	**3.45**	20.10	2080	**0.4**	1	**0.51**
NCRN_MANA_YOBR	7/2/2007	**4.64**	4.87	18.20	2312	**0.5**	0.2	**0.53**
Mean		7.53	7.99	12.18	1615	0.24	0.72	0.26
Std error		0.04	0.31	0.65	67.46	0.01	0.06	0.03

Table A-3. Benthic Index of Biotic Integrity. Values that do not meet the threshold (<3.0) are in bold. Site locations are shown in Figure 3.7.

Site name	BIBI
NCRW-018-N-2004	**1.25**
NCRW-119-N-2004	**2.00**
Mean	1.63
Std error	0.38

Table A-4. Physical Habitat Index. Values that do not meet the threshold (<81) are in bold. Site locations are shown in Figure 3.7.

Site name	PHI
NCRW-018-N-2004	**62.52**
NCRW-119-N-2004	**49.69**
Mean	56.10
Std error	6.41

Table A-5. Percent cover of exotic herbaceous plants. Values that do not meet the threshold (>5%) are in bold. Site locations are shown in Figure 3.8.

Site	Year	Mean cover (%)
MANA-0002	2006	1
MANA-0011	2008	**15**
MANA-0025	2006	4
MANA-0027	2006	0
MANA-0039	2007	3
MANA-0054	2006	0
MANA-0060	2006	2
MANA-0091	2007	**9**
MANA-0094	2007	**11**
MANA-0106	2007	0
MANA-0131	2008	4
MANA-0170	2007	**39**
MANA-0205	2008	0
MANA-0218	2008	**14**
MANA-0229	2007	1
MANA-0240	2008	**87**
MANA-0253	2006	0
Mean		11.2
Std error		5.30

Table A-6. Percent cover of exotic shrubs and trees. Values that do not meet the threshold (>5%) are in bold. Site locations are shown in Figure 3.8.

Site	Year	Invasive basal area	Total basal area	% invasive by basal area
		Shrubs		
MANA-0002	2006	0	7.6	0
MANA-0011	2008	0	305.1	0
MANA-0025	2006	0	0	
MANA-0027	2006	0	1.5	0
MANA-0039	2007	0	0	
MANA-0054	2006	0	0	
MANA-0060	2006	0	21.2	0
MANA-0091	2007	0	34.2	0
MANA-0094	2007	23.8	23.8	**100**
MANA-0106	2007	0	0	
MANA-0131	2008	0	0	
MANA-0170	2007	0	0	
MANA-0205	2008	0	0	
MANA-0218	2008	67.6	67.6	**100**
MANA-0229	2007	0	0	
MANA-0240	2008	0	352.2	0
MANA-0253	2006	0	0	
		Trees		
MANA-0002	2006	0	20442.4	0
MANA-0011	2008	0	11615.2	0
MANA-0025	2006	0	17609.7	0
MANA-0027	2006	78.5	14335.1	0.5
MANA-0039	2007	0	17373.4	0
MANA-0054	2006	0	21882.8	0
MANA-0060	2006	0	11146.2	0
MANA-0091	2007	0	13147.3	0
MANA-0094	2007	0	7563.2	0
MANA-0106	2007	0	14034.5	0
MANA-0131	2008	0	0	
MANA-0170	2007	0	26350.4	0
MANA-0205	2008	0	16695.2	0
MANA-0218	2008	0	16589.8	0
MANA-0229	2007	0	38260.6	0
MANA-0240	2008	0	15737.9	0
MANA-0253	2006	0	8814.7	**0**
Mean				8.4
Std error				5.76

Table A-7. Presence of forest pest species. Values that do not meet the threshold (>1%) are in bold. Site locations are shown in Figure 3.8.

Site	Year	Mean cover (%)
MANA-0002	2006	0
MANA-0011	2008	0
MANA-0025	2006	0
MANA-0027	2006	0
MANA-0039	2007	0
MANA-0054	2006	**2**
MANA-0060	2006	0
MANA-0091	2007	0
MANA-0094	2007	0
MANA-0106	2007	0
MANA-0170	2007	0
MANA-0205	2008	**6**
MANA-0218	2008	0
MANA-0229	2007	0
MANA-0240	2008	0
MANA-0253	2006	**7**
Mean		0.9
Std error		0.56

Table A-8. Native seedling regeneration (seedlings ha^{-1}). Values that do not meet the threshold (35,000 seedlings ha^{-1}) are in bold. Site locations are shown in Figure 3.8.

Site	Year	All seedlings	Native seedlings
MANA-0002	2006	15000	**15000**
MANA-0011	2008	4166	**4166**
MANA-0025	2006	5000	**5000**
MANA-0027	2006	26666	**26666**
MANA-0039	2007	0	**0**
MANA-0054	2006	5833	**5833**
MANA-0060	2006	10833	**10833**
MANA-0091	2007	19166	**19166**
MANA-0094	2007	8333	**7500**
MANA-0106	2007	0	**0**
MANA-0131	2008	4166	**4166**
MANA-0170	2007	0	**0**
MANA-0205	2008	0	**0**
MANA-0218	2008	833	**833**
MANA-0229	2007	0	**0**
MANA-0240	2008	4166	**4166**
MANA-0253	2006	5833	**5833**
Mean			6421
Std error			1841

Table A-9. Fish Index of Biotic Integrity. Values that do not meet the threshold (<3.0) are in bold. Site locations are shown in Figure 3.7.

Site	Date	Fish IBI
NCRW-018-N-2004	2004	4.00
NCRW-119-N-2004	2004	3.33
Mean		3.67
Std error		0.34

Table A-10. Presence of forest interior dwelling species of birds. Values that do not meet the threshold (>1 highly sensitive species; >4 sensitive species) are in bold. ✓ indicates presence; — indicates absence.

Species	Common name	2007	2008	
	Highly sensitive			
Buteo lineatus	Red-shouldered hawk	✓	✓	
Dendroica caerulescens	Black-throated blue warbler	✓	—	
Dendroica virens waynei	Black-throated green warbler	✓	—	
Dryocopus pileatus	Pileated woodpecker	✓	—	
Empidonax virescens	Acadian flycatcher	✓	✓	
Parula americana	Northern parula	✓	✓	
Setophaga ruticilla	American redstart	✓	—	
Strix varia	Barred owl	✓	—	
Number of species		8	3	
Mean				5.5
Std error				2.5
	Sensitive			
Bureo platypterus	Broad-winged hawk	—	✓	
Catharus fuscenscens	Veery	✓	—	
Catharus guttatus	Hermit thrush	✓	—	
Catharus ustulatus	Swainson's thrush	—	✓	
Helmitheros vermivorus	Worm-eating warbler	✓	—	
Hylocichla mustelina	Wood thrush	✓	✓	
Picoides villosus	Hairy woodpecker	—	✓	
Piranga olivacea	Scarlet tanager	✓	✓	
Seiurus aurocapillus	Ovenbird	✓	—	
Vireo olivaceus	Red-eyed vireo	✓	✓	
Wilsonia citrina	Hooded warbler	✓	—	
Number of species		8	6	
Mean				7.0
Std error				1.0

Table A-11. Presence and functional diversity of grassland birds.

Species	Common name	Functional group			
		1	2	3	4
Ammodramus savannarum	Grasshopper sparrow		✓		
Sturnella magna	Eastern meadowlark		✓		

Functional group 1: Disturbance-tolerant species
Functional group 2: Prefers young grasslands
Functional group 3: Prefers mature grasslands
Functional group 4: Other (rarely encountered)

Table A-12. Deer density (deer km^{-2}). Values that exceed the threshold (forest: 8 deer km^{-2}; grassland: 20 deer km^{-2}) are in bold. Deer-counting routes are shown in Figure 3.8.

Year	Deer density (deer km^{-2})	95% confidence interval	95% confidence interval
2000	**57.0**	51.0	63.8
2001	**66.31**	52.27	84.12
2002	**67.2**	58.40	77.32
2003	**73.55**	45.53	118.83
2004	**55.63**	40.94	75.59
2005	**47.99**	33.51	68.71
2006	**65.59**	52.31	82.24
2007	**50.09**	39.04	64.25
2008	**62.18**	28.18	139.98
Mean	60.62		
Std error	2.83		

Table A-13. List of plant species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Vascular plants	
Acalypha virginica	mercuryweed, threeseeded mercury, Virginia copperleaf, Virginia three-seed mercury, wax balls	Native
Acer negundo	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder	Native
Acer platanoides	Norway maple	Non-Native
Acer rubrum	red maple	Native
Acer saccharinum	silver maple	Native
Achillea millefolium	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)	Non-Native
Adiantum pedatum	maidenfern, maidenhair, maidenhair fern, northern maidenhair	Native
Agalinis purpurea	purple false foxglove	Native
Agalinis tenuifolia		Native
Ageratina altissima	white snakeroot	Native
Agrimonia parviflora	harvestlice, manyflowered groovebur	Native
Agrimonia pubescens	groovebur, roadside agrimony, soft agrimony, soft groovebur	Native
Agrimonia rostellata	beaked agrimony, woodland groovebur	Native
Agrostis elliottiana	Elliot bentgrass, elliott bentgrass, Elliott's bentgrass	Native
Agrostis gigantea	black bent, redtop, water bentgrass	Non-Native
Agrostis hyemalis		Native
Agrostis hyemalis var. scabra	ticklegrass	Native
Agrostis perennans	autumm bentgrass, upland bent, upland bentgrass	Native
Agrostis perennans var. perennans	autumn bent grass, upland bent grass, upland bentgrass	Native
Ailanthus altissima	ailanthus, copal tree, tree of heaven, tree-of-heaven	Non-Native
Albizia julibrissin	mimosa, mimosa tree, powderpuff tree, silk tree, silktree	Non-Native
Alisma subcordatum	American water plantain, waterplaintain	Native
Alliaria petiolata	garlic mustard, garlic-mustard	Non-Native
Allium canadense	Canada garlic, meadow garlic, meadow onion, wild onion	Native
Allium vineale	wild garlic	Non-Native
Ambrosia artemisiifolia		Native
Ambrosia trifida	blood ragweed, giant ragweed, great ragweed, horseweed, perennial ragweed (great), tall ragweed	Non-Native
Amelanchier arborea		Native
Amelanchier laevis	Allegheny serviceberry	Native
Amelanchier stolonifera	running service-berry, running serviceberry	Native
Amphicarpa bracteata		Native
Amphicarpaea bracteata	American hogpeanut, hog-peanut	Native
Andropogon gerardii	big bluestem, bluejoint, turkeyfoot	Native
Andropogon virginicus	broomsedge, broomsedge bluestem, yellow bluestem	Native
Anemone quinquefolia	nightcaps	Native
Anemone virginiana	tall thimbleweed, Virginia anemone	Native
Anemonella thalictroides		Native
Angelica venenosa	hairy angelica, venous angelica	Native
Antennaria neglecta	field pussytoes	Native

Scientific name	Common name/s	Status
	Vascular plants	
Antennaria parlinii ssp. fallax	Parlin's pussytoes	Native
Antennaria parlinii ssp. parlinii	Parlin's pussytoes	Native
Antennaria plantaginifolia	plantainleaf pussytoes, woman's tobacco	Native
Antennaria plantaginifolia var. parlinii	Parlin's pussy-toes	Native
Anthemis arvensis	corn chamomile, mayweed, scentless chamomile	Non-Native
Anthoxanthum odoratum	sweet vernalgrass	Non-Native
Apocynum androsaemifolium	bitterroot, flytrap dogbane, spreading dogbane	Native
Apocynum cannabinum	common dogbane, dogbane, hemp dogbane, Indian hemp, Indian-hemp, Indianhemp, prairie dogbane	Native
Aquilegia canadensis	American columbine, Colorado columbine, red columbine	Native
Arabis lyrata	lyrate rockcress	Native
Arctium minus	bardane, beggar's button, burdock, common burdock, lesser burdock, lesser burrdock, small burdock, smaller burdock, wild burdock, wild rhubarb	Non-Native
Arisaema dracontium	green dragon, greendragon	Native
Arisaema triphyllum	Indian jack in the pulpit, Jack in the pulpit, Jack-in-the-pulpit	Native
Aristida longispica	slimspike threeawn	Native
Aristida oligantha	Oldfield (Prairie) 3-awn, oldfield threeawn, prairie threeawn	Native
Aristolochia serpentaria	Virginia dutchmanspipe, Virginia snakeroot	Native
Artemisia annua	annual wormwood, sweet sagewort	Non-Native
Artemisia vulgaris	common wormwood, mugwort	Non-Native
Arthraxon hispidus	hairy jointgrass, small carpgrass	Non-Native
Asarum canadense	Canadian wild ginger, Canadian wildginger	Native
Asclepias incarnata	rose milkweed, swamp milkweed	Native
Asclepias purpurascens	purple milkweed	Native
Asclepias quadrifolia	fourleaf milkweed	Native
Asclepias syriaca	broadleaf milkweed, common milkweed	Native
Asclepias verticillata	eastern whorled milkweed, whorled milkweed	Native
Asclepias viridiflora	green antelopehorn milkweed, green comet milkweed, green milkweed	Native
Asimina triloba	pawpaw	Native
Asparagus officinalis	asparagus, garden asparagus, garden-asparagus	Non-Native
Asplenium platyneuron	ebony spleenwort	Native
Asplenium rhizophyllum	walking fern	Native
Asplenium trichomanes	maidenhair spleenwort	Native
Aster cordifolius	common blue wood aster	Native
Aster divaricatus		Native
Aster dumosus	rice button aster	Native
Aster infirmus		Native
Aster lanceolatus	white panicle aster	Native
Aster lateriflorus	calico aster	Native
Aster pilosus	white heath aster, white oldfield aster	Native
Aster prenanthoides	crookedstem aster	Native
Aster schreberi	Schreber's aster	Native
Aster undulatus	waxyleaf aster	Native

Scientific name	Common name/s	Status
	Vascular plants	
Aureolaria pedicularia var. intercedens	fernleaf yellow false foxglove	Native
Aureolaria virginica	downy yellow false foxglove	Native
Baptisia tinctoria	horseflyweed, yellow wildindigo	Native
Barbarea verna	early yellowrocket	Non-Native
Barbarea vulgaris	garden yellow rocket, garden yellow-rocket, garden yellowrocket, winter cress, yellow rocket	Non-Native
Berberis thunbergii	Japanese barberry	Non-Native
Betula lenta	sweet birch	Native
Betula nigra	river birch	Native
Bidens aristosa	bearded beggarticks, bearded beggerticks, long-bracted beggar-ticks, tickseed sunflower	Native
Bidens frondosa	bur marigold, devil's beggartick, devil's beggarticks, devil's bootjack, devil's-pitchfork, devils beggartick, pitchfork weed, sticktight, sticktights, tickseed sunflower	Native
Bidens tripartita	three-lobe beggarticks, threelobe beggarticks	Native
Boehmeria cylindrica	small-spike false nettle, smallspike false nettle, smallspike falsenettle	Native
Botrychium dissectum	cut-leaf grape fern, cutleaf grapefern	Native
Botrychium virginianum	rattlesnake fern	Native
Brachyelytrum erectum	bearded shorthusk	Native
Bromus commutatus	hairy brome, hairy chess, meadow brome	Non-Native
Bromus inermis	awnless brome, smooth brome	Non-Native
Bromus japonicus	Japanese brome, Japanese bromegrass, Japanese chess	Non-Native
Bromus pubescens	hairy wood brome grass, hairy woodland brome	Native
Bromus racemosus	bald brome	Non-Native
Bromus sterilis	barren bromegrass, poverty brome, sterile brome	Non-Native
Buchnera americana	American bluehearts, bupleurum	Native
Buglossoides arvensis	corn gromwell, corn-gromwell, field gromwell	Non-Native
Callitriche heterophylla	differentleaf waterstarwort, greater water starwort, larger waterstarwort, twoheaded water-starwort, variedleaf waterstarwort	Native
Calystegia spithamaea	low false bindweed	Native
Capsella bursa-pastoris	shepardspurse, shepherd's purse, shepherd's-purse, shepherdspurse	Native
Cardamine concatenata	cutleaf toothwort	Native
Cardamine hirsuta	hairy bittercress	Non-Native
Cardamine pensylvanica	Pennsylvania bittercress, Quaker bittercress	Native
Carduus nutans	chardon penche, musk thistle, nodding plumeless thistle, nodding plumeless-thistle, nodding thistle, plumeless thistle	Non-Native
Carex aggregata	glomerate sedge	Native
Carex albicans var. albicans	whitetinge sedge	Native
Carex albicans var. australis	stellate sedge	Native
Carex albolutescens	greenwhite sedge	Native
Carex amphibola	amphibious sedge, eastern narrowleaf sedge	Native
Carex amphibola var. amphibola	eastern narrowleaf sedge	Native
Carex amphibola var. turgida	eastern narrowleaf sedge	Native
Carex annectens	yellowfruit sedge	Native
Carex blanda	bland sedge, eastern woodland sedge, woodland sedge	Native

Scientific name	Common name/s	Status
	Vascular plants	
Carex brevior	brevior sedge, fescue sedge, shortbeak sedge	Native
Carex bushii	Bush's sedge	Native
Carex caroliniana	Carolina sedge	Native
Carex cephalophora	oval-leaf sedge, oval-leaved sedge, ovalleaf sedge	Native
Carex communis	fibrousroot sedge	Native
Carex complanata var. hirsuta		Native
Carex conjuncta	soft fox sedge	Native
Carex digitalis	slender wood sedge, slender woodland sedge	Native
Carex festucacea	fescue sedge	Native
Carex flaccosperma var. glaucodea		Native
Carex frankii	Frank's sedge	Native
Carex glaucodea	blue sedge	Native
Carex gracilescens	slender looseflower sedge	Native
Carex granularis	limestone meadow sedge, limestone-meadow sedge	Native
Carex grayi	Gray's sedge	Native
Carex grisea		Native
Carex intumescens	greater bladder sedge	Native
Carex jamesii	James' sedge	Native
Carex laevivaginata	smoothsheath sedge, wooly sedge	Native
Carex laxiflora var. laxiflora	broad looseflower sedge	Native
Carex louisianica	Louisiana sedge	Native
Carex lupulina	hop sedge	Native
Carex lurida	shallow sedge	Native
Carex meadii	Mead sedge, Mead's sedge	Native
Carex mesochorea	midland sedge	Native
Carex muehlenbergii	Muhlenberg's sedge, muhlenberg's sedge	Native
Carex nigromarginata	black edge sedge	Native
Carex normalis	greater straw sedge	Native
Carex oligocarpa	eastern few-fruit sedge, richwoods sedge	Native
Carex pellita	woolly sedge	Native
Carex pensylvanica	Penn sedge, Pennsylvania sedge	Native
Carex platyphylla	broad-leaved sedge, broadleaf sedge	Native
Carex radiata	eastern star sedge	Native
Carex retroflexa	reflexed sedge	Native
Carex rosea	rosy sedge	Native
Carex scoparia	broom sedge, pointed broom sedge	Native
Carex spicata	prickly sedge	Native
Carex squarrosa	squarrose sedge	Native
Carex stipata	owlfruit sedge, sawbeak sedge, stalk-grain sedge	Native
Carex stipata var. maxima	stalkgrain sedge	Native
Carex straminea	eastern straw sedge	Native
Carex stricta	upright sedge, uptight sedge	Native
Carex styloflexa	bent sedge	Native
Carex swanii	swan sedge, Swan's sedge	Native

Scientific name	Common name/s	Status
	Vascular plants	
Carex tonsa	shaved sedge	Native
Carex tribuloides	blunt broom sedge	Native
Carex typhina	cat-tail sedge, cattail sedge	Native
Carex umbellata	parasol sedge	Native
Carex vulpinoidea	common fox sedge, fox sedge	Native
Carex willdenowii	Willdenow's sedge	Native
Carpinus caroliniana	American hornbeam, american hornbean	Native
Carya alba	mockernut hickory	Native
Carya cordiformis	bitternut hickory	Native
Carya glabra	pignut hickory	Native
Carya ovalis	pignut hickory, red hickory	Native
Castanea mollissima	Chinese chestnut	Non-Native
Caulophyllum thalictroides	blue cohosh	Native
Ceanothus americanus	Jersey tea, jerseytea, New Jersey tea, new jersey tea	Native
Celastrus orbiculatus	Asian bittersweet, Asiatic bittersweet, oriental bittersweet	Non-Native
Celtis laevigata	sugar berry, sugar hackberry, sugarberry	Native
Celtis occidentalis	common hackberry, hackberry, western hackberry	Native
Celtis tenuifolia	dwarf hackberry, georgia hackberry	Native
Centaurea biebersteinii	spotted knapweed	Non-Native
Cephalanthus occidentalis	buttonbush, common buttonbush	Native
Cercis canadensis	eastern redbud, Redbud	Native
Chaerophyllum procumbens	spreading chervil	Native
Chamaecrista fasciculata	partridge pea, Showy partridgepea, sleepingplant	Native
Chamaecrista nictitans	partridge pea, partridge-pea	Native
Chamaesyce maculata	large spurge, spotted sandmat, spotted spurge	Native
Chamaesyce nutans	eyebane, nodding spurge, spotted sandmat, spotted spurge	Native
Chelone glabra	white turtlehead	Native
Chenopodium album	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot	Non-Native
Chimaphila maculata	striped prince's pine, striped prince's-pine	Native
Chimaphila umbellata	common pipsissewa, pipsissewa	Native
Chionanthus virginicus	fringetree, white fringetree	Native
Cichorium intybus	blue sailors, chicory, coffeeweed, Common chicory, succory	Non-Native
Cicuta maculata	common water hemlock, poison parsnip, spotted cowbane, spotted parsley, spotted water hemlock, spotted water-hemlock, spotted waterhemlock, water hemlock	Native
Cimicifuga racemosa	black bugbane	Native
Cinna arundinacea	stout wood reed-grass, stout woodreed, sweet wood-reed, sweet woodreed	Native
Circaea lutetiana	broad-leaf enchanter's-nightshade, broadleaf enchanter's nightshade	Native
Circaea lutetiana ssp. canadensis	broad-leaf enchanter's-nightshade, broadleaf enchanter's nightshade	Native
Cirsium discolor	field thistle	Native
Cirsium muticum	swamp thistle	Native
Cirsium pumilum	pasture thistle	Native
Cirsium vulgare	bull thistle, common thistle, spear thistle	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Claytonia virginica	narrow-leaved spring beauty, Spring beauty, Virginia springbeauty	Native
Clematis ochroleuca	curlyheads	Native
Clematis terniflora	leatherleaf clematis, sweet autumn virginsbower, yam-leaved clematis	Non-Native
Clinopodium vulgare	wild basil	Native
Clitoria mariana	Atlantic pigeonwings, pidgeonwings	Native
Comandra umbellata	bastard toadflax	Native
Commelina communis	Asiatic dayflower, common dayflower	Non-Native
Commelina virginica	Virginia dayflower	Native
Conopholis americana	American squawroot, squaw-root	Native
Conyza canadensis	Canada horseweed, Canadian horseweed, horseweed, horseweed flea-bane, mares tail, marestail	Native
Corallorrhiza odontorhiza	autumn coralroot	Native
Coreopsis tripteris	atlantic coreopsis, tall tickseed	Native
Coreopsis verticillata	whorled tickseed	Native
Cornus amomum	silky dogwood	Native
Cornus florida	flowering dogwood	Native
Coronilla varia	crownvetch, purple crown-vetch, purple crownvetch, Varia crownvetch	Non-Native
Corydalis flavula	pale corydalis, yellow fumewort	Native
Corylus americana	American hazelnut, american hazelnut, hazel, hazelnut	Native
Crataegus flabellata	fanleaf hawthorn, fanleaf hawthorne	Native
Crataegus intricata	biltmore hawthorn, Copenhagen hawthorn	Native
Crataegus punctata	dotted hawthorn	Native
Cruciata pedemontana	piedmont bedstraw	Non-Native
Cryptotaenia canadensis	Canadian honewort, honewort	Native
Cunila origanoides	common dittany	Native
Cuphea viscosissima	blue waxweed	Native
Cynodon dactylon	Bermudagrass, chiendent pied-de-poule, common bermudagrass, devil-grass, grama-seda, manienie, motie molulu	Non-Native
Cynoglossum virginianum	blue houndstongue, wild comfrey	Native
Cyperus echinatus	globe flatsedge	Native
Cyperus lancastriensis	manyflower flatsedge	Native
Cyperus odoratus	fragrant flatsedge, rusty flat sedge	Native
Cyperus strigosus	stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass, straw-colored flatsedge, strawcolored nutgrass	Native
Cypripedium acaule	lady's-slipper orchid, moccasin flower, pink lady's slipper, pink lady's-slip-per, pink lady's-slipper orchid, pink ladyslipper, pink moccasin flower	Native
Cystopteris protrusa	lowland bladderfern	Native
Dactylis glomerata	cocksfoot, orchard grass, orchardgrass	Non-Native
Danthonia spicata	poverty danthonia, poverty oatgrass, poverty wild oat grass	Native
Datura stramonium	Jamestown weed, jimsonweed, mad apple, moonflower, stinkwort, thorn apple	Non-Native
Daucus carota	bird's nest, Queen Anne's lace, wild carrot	Non-Native
Deschampsia flexuosa	wavy hairgrass	Native
Desmodium canescens	hoary tickclover, hoary ticktrefoil	Native
Desmodium ciliare	hairy small-leaf ticktrefoil, littleleaf tickclover	Native

Scientific name	Common name/s	Status
	Vascular plants	
Desmodium glabellum	Dillenius' ticktrefoil	Native
Desmodium laevigatum	smooth tickclover, smooth ticktrefoil	Native
Desmodium marilandicum	maryland tickclover, smooth small-leaf ticktrefoil	Native
Desmodium nudiflorum	bare-stemmed tick-treefoil, barestem tickclover, nakedflower ticktrefoil	Native
Desmodium paniculatum	narrow-leaf tick-trefoil, panicled tickclover, panicledleaf ticktrefoil	Native
Desmodium perplexum	perplexed ticktrefoil	Native
Desmodium rotundifolium	prostrate ticktrefoil, roundhead tickclover	Native
Desmodium viridiflorum	velvetleaf tickclover, velvetleaf ticktrefoil	Native
Dianthus armeria	Deptford pink, Deptford's pink	Non-Native
Dicentra cucullaria	dutchman's breeches, Dutchman's-breeches, Dutchmans breeches, dutchmans britches	Native
Dichanthelium acuminatum	hotsprings panicum, hotsprings rosette grass, tapered rosette grass	Native
Dichanthelium acuminatum var. acuminatum	tapered rosette grass	Native
Dichanthelium acuminatum var. lindheimeri	Lindheimer panicgrass	Native
Dichanthelium boscii	Bosc's panicgrass	Native
Dichanthelium clandestinum	deertongue	Native
Dichanthelium commutatum	variable panicgrass	Native
Dichanthelium depauperatum	starved panicgrass	Native
Dichanthelium dichotomum	cypress panicgrass	Native
Dichanthelium latifolium	broadleaf rosette grass	Native
Dichanthelium laxiflorum	openflower rosette grass	Native
Dichanthelium linearifolium	slim-leaf rosette grass, slimleaf panicgrass, slimleaf panicum	Native
Dichanthelium scoparium	velvet panicum	Native
Dichanthelium sphaerocarpon	roundseed panicgrass, roundseed panicum	Native
Dichanthelium sphaerocarpon var. isophyllum	roundseed panicgrass, roundseed panicum	Native
Dichanthelium sphaerocarpon var. sphaerocarpon	roundseed panicgrass, roundseed panicum	Native
Dichanthelium villosissimum	white-hair rosette grass, whitehair rosette grass	Native
Digitaria ischaemum	small crabgrass, smooth crab grass, smooth crabgrass	Non-Native
Digitaria sanguinalis	Crabgrass, hairy crab grass, hairy crabgrass, large crabgrass, purple crab-grass, redhair crabgrass	Non-Native
Diodia teres	poor joe, poorjoe, rough buttonweed	Native
Dioscorea quaternata	fourleaf yam	Native
Diospyros virginiana	common persimmon, eastern persimmon, Persimmon	Native
Dipsacus fullonum	common teasel, Fuller's teasel, teasel, venuscup teasle	Non-Native
Dipsacus sylvestris	common teasel, Fuller's teasel	Non-Native
Dryopteris intermedia	intermediate woodfern	Native
Dryopteris marginalis	marginal woodfern, woodfern	Native
Duchesnea indica	India mockstrawberry, Indian strawberry	Non-Native
Echinochloa crus-galli	barnyard grass, barnyardgrass, cockspur, Japanese millet, large barnyard grass, watergrass	Non-Native
Echinochloa muricata	rough barnyard grass, rough barnyardgrass	Native
Echium vulgare	blueweed, common echium, common vipersbugloss	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Eclipta prostrata	eclipta, false daisy, yerba de tago, yerba de tajo	Native
Elaeagnus umbellata var. parvifolia	autumn olive, oleaster	Non-Native
Eleocharis obtusa	blunt spikerush, blunt spikesedge	Native
Eleocharis tenuis	slender spikerush	Native
Eleocharis tenuis var. tenuis	slender spikerush	Native
Elephantopus carolinianus	Carolina elephantsfoot, leafy elephantfoot	Native
Eleusine indica	crowsfoot grass, goose grass, goosegrass, Indian goose grass, Indian goosegrass, manienie ali'I, silver crabgrass, wiregrass	Non-Native
Elodea nuttallii	nuttall waterweed, western waterweed	Native
Elymus hystrix	eastern bottle-brush grass, eastern bottlebrush grass	Native
Elymus repens	quackgrass	Non-Native
Elymus riparius	river wild-rye, riverbank wildrye	Native
Elymus virginicus	Virginia wild rye, Virginia wildrye	Native
Eragrostis cilianensis	candy grass, lovegrass, stink grass, stinkgrass, strongscented lovegrass	Non-Native
Eragrostis curvula	weeping lovegrass	Non-Native
Eragrostis pilosa	India lovegrass, Indian love grass, Indian lovegrass	Non-Native
Eragrostis spectabilis	petticoat-climber, purple lovegrass	Native
Erechtites hieraciifolia	American burnweed	Native
Erigenia bulbosa	harbinger of spring	Native
Erigeron annuus	annual fleabane, eastern daisy fleabane	Native
Erigeron strigosus	Daisy Fleabane, prairie fleabane, rough fleabane	Native
Erythronium americanum	dogtooth violet	Native
Euonymus alata	burning bush, winged burning bush, winged euonymus	Non-Native
Euonymus americana	strawberry bush, strawberrybush	Native
Euonymus americanus		Native
Euonymus atropurpureus	eastern burningbush	Native
Eupatorium coelestinum	blue mistflower	Native
Eupatorium fistulosum	Joe Pye weed, trumpetweed	Native
Eupatorium hyssopifolium	hyssopleaf thoroughwort	Native
Eupatorium perfoliatum	bonset, common boneset	Native
Eupatorium serotinum	late eupatorium, lateflowering thoroughwort	Native
Euphorbia corollata	flowering spurge, floweringspurge euphorbia	Native
Euthamia graminifolia	flat-top goldentop, flattop goldentop	Native
Fagus grandifolia	American beech	Native
Festuca elatior		Non-Native
Festuca pratensis		Native
Festuca rubra	ravine fescue, red fescue	Unknown
Festuca subverticillata	nodding fescue	Native
Floerkea proserpinacoides	false mermaid-weed, false mermaidweed, falsemermaid	Native
Fragaria virginiana	thickleaved wild strawberry, Virginia strawberry, wild strawberry	Native
Fraxinus americana	white ash	Native
Fraxinus pennsylvanica	green ash	Native
Galactia volubilis	downy milkpea	Native

Scientific name	Common name/s	Status
	Vascular plants	
Galium aparine	bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, stickywilly, white hedge	Native
Galium circaezans	licorice bedstraw, wild licorice, woods bedstraw	Native
Galium concinnum	shining bedstraw	Native
Galium obtusum var. filifolium		Native
Galium obtusum var. obtusum	large marsh bedstraw	Native
Galium pilosum	hairy bedstraw	Native
Galium tinctorium	dye bedstraw, stiff marsh bedstraw	Native
Galium triflorum	fragrant bedstraw, sweet bedstraw, sweetscented bedstraw	Native
Gamochaeta purpurea	spoon-leaf purple everlasting, spoonleaf purple everlasting	Native
Gaura biennis	biennial beeblossom	Native
Gaylussacia baccata	black huckleberry	Native
Gentiana clausa	bottle gentian	Native
Geranium maculatum	spotted crane's-bill, spotted geranium, wild crane's-bill	Native
Geum canadense	white avens	Native
Geum virginianum	cream avens	Native
Glechoma hederacea	creeping charlie, gill-over-the-ground, ground ivy, groundivy, haymaids	Non-Native
Gleditsia triacanthos	common honeylocust, Honey locust, honey-locust, honeylocust, honey-locusts	Native
Glyceria septentrionalis	floating mannagrass	Native
Glyceria striata	fowl manna grass, fowl mannagrass	Native
Gnaphalium obtusifolium		Native
Goodyera pubescens	downy rattlesnake plantain, downy rattlesnake-plantain	Native
Gratiola neglecta	clammy hedge-hyssop, clammy hedgehyssop, drug hedgehyssop, hedge hyssop, neglected hedgehyssop	Native
Hackelia virginiana	beggar's-lice, beggarslice, sticktight, virginia stickseed	Native
Hamamelis virginiana	American witchhazel, witch-hazel, witchhazel	Native
Hedeoma pulegioides	American false pennyroyal	Native
Helenium autumnale	bitterweed, common sneezeweed, fall sneezeweed, false sunflower	Native
Helenium flexuosum	purplehead sneezeweed	Native
Helianthus decapetalus	thinleaf sunflower	Native
Helianthus divaricatus	woodland sunflower	Native
Heliopsis helianthoides	heliopsis sunflower, oxeye, smooth oxeye, sunflower heliopsis	Native
Hepatica americana		Native
Heuchera americana	alumroot, American alumroot	Native
Hieracium caespitosum	meadow hawkweed, yellow hawkweed	Non-Native
Hieracium gronovii	Gronovis hawkweed, queendevil	Native
Hieracium scabrum	rough hawkweed	Native
Hieracium venosum	rattlesnakeweed	Native
Holcus lanatus	common velvetgrass, velvetgrass, Yorkshire fog	Non-Native
Hordeum pusillum	little barley, little wildbarley	Native
Houstonia caerulea	azure bluet	Native
Houstonia purpurea	purple bluets, Venus' pride	Native
Hybanthus concolor	eastern greenviolet, nodding violet	Native
Hydrangea arborescens	smooth hydrangea, wild hydrangea	Native

Scientific name	Common name/s	Status
	Vascular plants	
Hydrophyllum virginianum	Shawnee salad, Shawnee-salad	Native
Hypericum canadense	lesser Canadian St. Johnswort	Native
Hypericum gentianoides	orangegrass, pinweed st. johnswort	Native
Hypericum gymnanthum	claspingleaf St. Johnswort	Native
Hypericum hypericoides ssp. multicaule	St. Andrew's cross	Native
Hypericum mutilum	dwarf St. Johnswort	Native
Hypericum perforatum	common St Johnswort, common St. John's wort, common St. Johnswort, Klamath weed, Klamathweed, St. John's wort, St. Johnswort	Non-Native
Hypericum prolificum	shrubby st johnswort, shrubby St. Johnswort	Native
Hypericum punctatum	spotted St. Johnswort	Native
Hypericum stragulum		Native
Hypoxis hirsuta	common goldstar, eastern yellow star-grass	Native
Hystrix patula		Native
Ilex opaca	American holly	Native
Ilex verticillata	common winterberry	Native
Impatiens capensis	jewelweed, spotted touch-me-not	Native
Impatiens pallida	pale snapweed, pale touch-me-not	Native
Ipomoea hederacea		Non-Native
Ipomoea pandurata	bigroot morningglory, bigroot morninglory, man of the earth, man-of-the-earth	Native
Ipomoea purpurea	common morning-glory, common morningglory, common morninglory, tall morning-glory, tall morningglory	Non-Native
Iris versicolor	harlequin blueflag	Native
Isanthus brachiatus	false pennyroyal, fluxweed	Native
Isoetes appalachiana	Appalachian quillwort	Native
Iva annua	annual marsh-elder, annual marshelder, seacoast sumpweed	Native
Juglans cinerea	butternut	Native
Juglans nigra	black walnut	Native
Juncus acuminatus	sharp-fruit rush, tapertip rush	Native
Juncus biflorus	bog rush	Native
Juncus brachycarpus	whiteroot rush	Native
Juncus canadensis	Canadian rush	Native
Juncus dichotomus	forked rush	Native
Juncus dudleyi	Dudley rush, Dudley's rush	Native
Juncus effusus	common rush, lamp rush	Native
Juncus tenuis	field rush, path rush, poverty rush, slender rush, slender yard rush, wire-grass	Native
Juniperus virginiana	eastern red-cedar, eastern redcedar, red cedar juniper	Native
Justicia americana	American water-willow, common water-willow, spike justica	Native
Kalmia latifolia	mountain laurel	Native
Krigia dandelion	potato dwarfdandelion, tuber dandelion, tuber dwarfdandelion	Native
Krigia virginica	Virginia dwarfdandelion	Native
Kummerowia stipulacea	Korean clover, korean lespedeza	Non-Native
Kummerowia striata	common lespedeza, Japanese clover	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Kyllinga pumila	low spikesedge	Native
Lactuca canadensis	Canada lettuce, Florida blue lettuce, wild lettuce	Native
Lactuca floridana	Florida lettuce, woodland lettuce	Native
Lamium purpureum	purple deadnettle, red deadnettle	Non-Native
Laportea canadensis	Canada lettuce, Canada woodnettle, Canadian wood-nettle, Canadian woodnettle	Native
Lechea racemulosa	Illinois pinweed	Native
Leersia oryzoides	rice cut grass, rice cutgrass	Native
Leersia virginica	white grass, whitegrass	Native
Lemna minor	common duckweed, least duckweed, lesser duckweed	Native
Leonurus marrubiastrum	lion's tail	Non-Native
Lepidium campestre	cream-anther field pepperwort, field pepperweed	Non-Native
Lepidium virginicum	peppergrass, poorman pepperweed, poorman's pepper, poorman's-pep-perwort, Virginia pepperweed, Virginian peppercress	Native
Lespedeza capitata	roundhead lespedeza	Native
Lespedeza cuneata	Chinese lespedeza, sericea lespedeza	Non-Native
Lespedeza hirta	hairy lespedeza	Native
Lespedeza intermedia	intermediate lespedeza	Native
Lespedeza procumbens	trailing lespedeza	Native
Lespedeza repens	creeping lespedeza	Native
Lespedeza virginica	slender lespedeza	Native
Leucanthemum vulgare	ox-eye daisy, oxeye daisy, oxeye-daisy, oxeyedaisy	Non-Native
Liatris squarrosa	scaly blazing star, scaly gayfeather	Native
Ligustrum obtusifolium	border privet	Non-Native
Lindera benzoin	northern spicebush, spicebush	Native
Lindernia dubia var. anagallidea	false pimpernel, falsepimpernel, yellow-seed false pimpernel, yellowseed false pimpernel	Native
Lindernia dubia var. dubia	yellow-seed false pimpernel, yellowseed false pimpernel	Native
Linum medium var. texanum	stiff yellow flax, sucker flas	Native
Liparis liliifolia	brown widelip orchid	Native
Liriodendron tulipifera	tulip poplar, tuliptree, yellow poplar, yellow-poplar	Native
Lithospermum canescens	hoary gromwell, hoary puccoon	Native
Lobelia cardinalis	Cardinal flower, cardinalflower	Native
Lobelia inflata	Indian tobacco, Indian-tobacco	Native
Lobelia puberula	downy lobelia	Native
Lobelia siphilitica	great blue lobelia	Native
Lobelia spicata	pale-spike lobelia, pale-spiked lobelia, palespike lobelia	Native
Lobelia spicata var. scaposa	palespike lobelia	Native
Lolium arundinaceum	Lolium arundinaceum, tall fescue	Non-Native
Lolium perenne	italian ryegrass, perennial rye grass, perennial ryegrass	Non-Native
Lolium pratense	meadow fescue, meadow ryegrass	Non-Native
Lonicera japonica	Chinese honeysuckle, Japanese honeysuckle	Non-Native
Lonicera maackii	Amur honeysuckle, Amur honeysuckle bush	Non-Native
Lonicera morrowii	Morrow's honeysuckle	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Lotus corniculatus	birdfoot deervetch, Birdsfoot trefoil, bloomfell, cat's clover, crowtoes, garden bird's-foot-trefoil, garden birdsfoot trefoil, ground honeysuckle	Non-Native
Ludwigia alternifolia	bushy seedbox, seedbox	Native
Ludwigia palustris	marsh primrose-willow, marsh seedbox	Native
Luzula bulbosa	bulbous woodrush	Native
Luzula echinata	hedgehog woodrush	Native
Luzula multiflora	common wood-rush, common woodrush	Native
Lycopodium digitatum	fan clubmoss	Native
Lycopus americanus	American bugleweed, American water horehound, American waterhore-hound, cut-leaf water-horehound, water horehound, waterhorehound	Native
Lycopus uniflorus	bugleweed, northern bugleweed, northern water-horehound, oneflower bugleweed	Native
Lycopus virginicus	Virginia bugleweed, virginia bugleweed, Virginia water horehound	Native
Lysimachia ciliata	fringed loosestrife, fringed yellow-loosestrife	Native
Lysimachia quadriflora	four-flower yellow-loosestrife, fourflower yellow loosestrife	Native
Lysimachia quadrifolia	whorled loosestrife, whorled yellow loosestrife	Native
Maianthemum racemosum	false Solomon's-seal, feathery false lily of the vally, feathery false Solo-mon's seal, feathery false Solomon's-seal	Native
Malus angustifolia	southern crabapple	Native
Malus pumila	paradise apple	Non-Native
Malva neglecta	buttonweed, cheeseplant, cheeseweed, common mallow, dwarf mallow, roundleaf mallow	Non-Native
Melica mutica	oniongrass, twoflower melic, twoflower melicgrass	Native
Melilotus officinalis	yellow sweet-clover, yellow sweetclover	Non-Native
Menispermum canadense	Canadian moonseed, common moonseed	Native
Mentha arvensis	field mint, wild mint	Unknown
Mentha X piperita	peppermint	Non-Native
Mertensia virginica	Virginia bluebells	Native
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	Non-Native
Microthlaspi perfoliatum	claspleaf pennycress	Non-Native
Mikania scandens	climbing hempvine, climbing hempweed	Native
Mimulus alatus	sharpwing monkeyflower	Native
Mimulus ringens	Allegheny monkey-flower, Allegheny monkeyflower, ringen monkey-flower	Native
Miscanthus sinensis	Chinese silvergrass, eulalia	Non-Native
Mitchella repens	partridgeberry	Native
Mollugo verticillata	carpetweed, green carpetweed	Non-Native
Monotropa uniflora	Indianpipe, one-flower Indian-pipe	Native
Morus alba	mulberry, white mulberry	Non-Native
Morus rubra	red mulberry	Native
Muhlenbergia frondosa	wire-stem muhly, wirestem muhly	Native
Muhlenbergia schreberi	nimblewill, nimblewill muhly	Native
Muhlenbergia sobolifera	rock muhly	Native
Murdannia keisak	aneilima, Asian spiderwort, wartremoving herb	Non-Native
Myosotis discolor	changing forget-me-not, yellowandblue forget-me-not	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Myosotis macrosperma	largeseed forget-me-not, southern forget me not	Native
Myosotis verna	spring forget me not, spring forget-me-not	Native
Myriophyllum sibiricum	American watermilfoil, milfoil, shortspike watermilfoil, Siberian water-milfoil	Unknown
Nepeta cataria	catmint, catnip, catwort, field balm	Non-Native
Nyssa sylvatica	black gum, black tupelo, blackgum	Native
Oenothera fruticosa	narrowleaf evening-primrose	Native
Oenothera perennis	little evening-primrose	Native
Onoclea sensibilis	sensitive fern	Native
Ophioglossum vulgatum	adder's tongue, southern adderstongue	Native
Orobanche uniflora	naked broom-rape, naked broomrape, oneflowered broomrape	Native
Osmorhiza longistylis	aniseroot, longstyle sweetroot	Native
Ostrya virginiana	eastern hophornbeam, hophornbeam	Native
Oxalis dillenii	Dillen's oxalis	Native
Oxalis stricta	common yellow oxalis, erect woodsorrel, sheep sorrel, sourgrass, toad sorrel, upright yellow wood-sorrel, upright yellow woodsorrel, yellow woodsorrel	Native
Oxalis violacea	purple woodsorrel, violet wood-sorrel, violet woodsorrel	Native
Panicum anceps	beaked panicgrass, beaked panicum	Native
Panicum capillare	annual witchgrass, common panic grass, common witchgrass, panicgrass, ticklegrass, tumble panic, tumbleweed grass, witches hair, witchgrass	Native
Panicum dichotomiflorum	fall panic, fall panicgrass, fall panicum, western witchgrass	Native
Panicum lanuginosum		Native
Panicum philadelphicum	philadelphia panic grass, Philadelphia panicgrass	Native
Panicum rigidulum	redtop panicgrass, redtop panicum	Native
Panicum rigidulum var. elongatum	redtop panicgrass	Native
Panicum virgatum	old switch panic grass, switchgrass	Native
Parietaria pensylvanica	Pennsylvania pellitory	Native
Paronychia canadensis	smooth forked nailwort	Native
Paronychia fastigiata	clusterstem nailwort, hairy forked nailwort	Native
Parthenocissus quinquefolia	American ivy, fiveleaved ivy, Virginia creeper, woodbine	Native
Paspalum laeve	field paspalum	Native
Paspalum setaceum	fringeleaf paspalum, sand paspalum, slender crown grass, thin paspalum	Native
Peltandra virginica	green arrow arum, Virginia peltandra	Native
Penstemon canescens	eastern gray beardtongue	Native
Penstemon digitalis	talus slope penstemon	Native
Penstemon hirsutus	hairy beardtongue	Native
Penstemon laevigatus	eastern smooth beardtongue	Native
Penthorum sedoides	ditch stonecrop, ditch-stonecrop, Virginia penthorum	Native
Perilla frutescens	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Non-Native
Phalaris arundinacea	reed canary grass, reed canarygrass	Native
Phleum pratense	common timothy, timothy	Non-Native
Phryma leptostachya	American lopseed, lopseed	Native
Physalis longifolia var. subglabrata	longleaf groundcherry	Native

Scientific name	Common name/s	Status
	Vascular plants	
Physalis virginiana	ground cherry (Virginia), lanceleaf groundcherry, Virginia ground-cherry, Virginia groundcherry	Native
Physocarpus opulifolius	Atlantic ninebark, common ninebark	Native
Pilea pumila	Canada clearweed, Canadian clearweed	Native
Pinus strobus	easter white pine, eastern white pine, northern white pine, soft pine, weymouth pine, white pine	Native
Pinus taeda	loblolly pine	Native
Pinus virginiana	jersey pine, scrub pine, Virginia pine	Native
Plantago aristata	bottlebrush Indianwheat, largebracted plantain	Native
Plantago lanceolata	buckhorn plantain, English plantain, lanceleaf Indianwheat, lanceleaf plantain, narrowleaf plantain, ribgrass, ribwort	Non-Native
Plantago major	broadleaf plantain, buckhorn plantain, common plantain, great plantain, rippleseed plantain	Non-Native
Plantago rugelii	black-seed plantain, blackseed plantain, Rugel's plantain	Non-Native
Plantago virginica	paleseed Indianwheat, Virginia plantain	Native
Platanthera lacera	green fringed orchid	Native
Platanus occidentalis	American sycamore, sycamore	Native
Poa annua	annual blue grass, annual bluegrass, walkgrass	Non-Native
Poa autumnalis	autumn bluegrass	Native
Poa compressa	Canada bluegrass, flat-stem blue grass	Non-Native
Poa cuspidata	early bluegrass	Native
Poa pratensis	Kentucky bluegrass	Non-Native
Poa sylvestris	woodland bluegrass	Native
Poa trivialis	rough bluegrass	Non-Native
Podophyllum peltatum	may apple, mayapple	Native
Polygala sanguinea	blood milkwort, purple milkwort	Native
Polygala verticillata	whorled milkwort	Native
Polygonatum biflorum	king Solomon's seal, King Solomon's-seal, smooth Solomon's seal, Solomon's seal	Native
Polygonum arenastrum	common knotweed, doorweed, matweed, oval-leaf knotweed, ovalleaf knotweed, prostrate knotweed	Non-Native
Polygonum cespitosum var. longisetum	oriental ladysthumb	Non-Native
Polygonum hydropiperoides	swamp smartweed	Native
Polygonum pensylvanicum	Pennsylvania knotweed, Pennsylvania smartweed, pinkweed, pinweed	Native
Polygonum perfoliatum	Asiatic tearthumb, mile-a-minute weed	Non-Native
Polygonum persicaria	lady's-thumb, ladysthumb, ladysthumb smartweed, smartweed, spotted knotweed, spotted ladysthumb, spotted smartweed	Non-Native
Polygonum punctatum	dotted smartweed	Native
Polygonum sagittatum	arrow-leaf tearthumb, arrowleaf knotweed, arrowleaf tearthumb, arrowvine	Native
Polygonum scandens var. cristatum	climbing false buckwheat, false buckwheat	Native
Polygonum tenue	pleatleaf knotweed	Native
Polygonum virginianum	jumpseed, Virginia smartweed	Native
Polypodium virginianum	rock polypody	Native
Polystichum acrostichoides	Christmas fern	Native

Scientific name	Common name/s	Status
	Vascular plants	
Pontederia cordata	pickerelweed	Native
Portulaca oleracea	akulikuli-kula, common purslane, duckweed, garden purslane, little hog-weed, little-hogweed, purslane, pursley, pusley, wild portulaca	Non-Native
Potamogeton diversifolius	waterthread, waterthread pondweed	Native
Potentilla canadensis	dwarf cinquefoil	Native
Potentilla recta	roughfruit cinquefoil, sulfur (or erect) cinquefoil, sulfur cinquefoil, sulphur cinquefoil	Non-Native
Potentilla simplex	common cinquefoil, oldfield cinquefoil, oldfield fivefingers, spreading cinquefoil	Native
Prenanthes serpentaria	cankerweed	Native
Proserpinaca palustris	marsh mermaid-weed, marsh mermaidweed	Native
Prunella vulgaris ssp. lanceolata	lance selfheal	Native
Prunus americana	American plum	Native
Prunus angustifolia	Chickasaw plum	Native
Prunus avium	sweet cherry	Non-Native
Prunus domestica	European plum	Non-Native
Prunus serotina	black cherry, black chokecherry	Native
Prunus virginiana	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry	Native
Pteridium aquilinum var. latiuscu-lum	bracken, bracken fern, northern bracken fern, western brackenfern	Native
Pycnanthemum incanum	hoary mountainmint	Native
Pycnanthemum tenuifolium	narrowleaf mountainmint, narrowleaf mountianmint	Native
Pyrus communis	common pear, pear	Native
Quercus alba	white oak	Native
Quercus bicolor	swamp white oak	Native
Quercus coccinea	scarlet oak	Native
Quercus falcata	southern red oak	Native
Quercus falcata var. pagodifolia		Native
Quercus imbricaria	shingle oak	Native
Quercus michauxii	swamp chestnut oak	Native
Quercus muehlenbergii	chinkapin oak	Native
Quercus palustris	pin oak	Native
Quercus phellos	willow oak	Native
Quercus prinoides	dwarf chinkapin oak, dwarf chinquapin oak	Native
Quercus prinus	chestnut oak	Native
Quercus rubra	northern red oak	Native
Quercus shumardii	shumard oak, Shumard's oak	Native
Quercus stellata	post oak	Native
Quercus velutina	black oak	Native
Ranunculus abortivus	early woodbuttercup, kidney-leaf buttercup, littleleaf buttercup, small-flower buttercup, smallflower crowfoot	Native
Ranunculus bulbosus	blister flower, bulbous buttercup, bulbous crowfoot, gowan, St. Antho-ny's turnip, yellow weed	Non-Native
Ranunculus caricetorum		Native
Ranunculus hispidus	bristly buttercup	Native

Scientific name	Common name/s	Status
	Vascular plants	
Ranunculus hispidus var. caricetorum	bristly buttercup	Native
Ranunculus micranthus	rock buttercup	Native
Ranunculus recurvatus	blisterwort, littleleaf buttercup	Native
Rhododendron periclymenoides	pink azalea	Native
Rhus aromatica	fragrant sumac	Native
Rhus copallinum	flameleaf sumac	Native
Rhus glabra	smooth sumac	Native
Rhus hirta	staghorn sumac	Native
Robinia pseudoacacia	black locust, false acacia, yellow locust	Native
Rorippa sylvestris	creeping yellow cress, creeping yellowcress, keek, yellow fieldcress	Non-Native
Rosa carolina	Carolina rose	Native
Rosa multiflora	multiflora rose	Non-Native
Rubus allegheniensis	Allegheny blackberry	Native
Rubus argutus	prickly Florida blackberry, sawtooth blackberry	Native
Rubus cuneifolius	sand blackberry	Native
Rubus flagellaris	northern dewberry, whiplash dewberry	Native
Rubus idaeus	American red raspberry, common red raspberry, western red raspberry	Native
Rubus occidentalis	black raspberry	Native
Rudbeckia fulgida	orange coneflower	Native
Rudbeckia hirta	blackeyed Susan, blackeyedsusan	Native
Rudbeckia laciniata	cutleaf coneflower, green-head coneflower	Native
Ruellia caroliniensis	Carolina wild petunia	Native
Rumex acetosella	common sheep sorrel, field sorrel, red (or sheep) sorrel, red sorrel, sheep sorrel	Non-Native
Rumex crispus	Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock	Non-Native
Rumex obtusifolius	bitter dock, bluntleaf dock	Non-Native
Rumex verticillatus	swamp dock	Native
Sabatia angularis	rosepink, squarestem rosegentian	Native
Salix nigra	black willow	Native
Salvia lyrata	lyreleaf sage	Native
Sambucus canadensis	american elder	Native
Samolus valerandi var. parviflorus		Native
Sanguinaria canadensis	bloodroot	Native
Sanicula canadensis	Canada sanicle, Canadian blacksnakeroot	Native
Sanicula gregaria		Native
Sanicula odorata	cluster sanicle, clustered blacksnakeroot	Native
Sassafras albidum	sassafras	Native
Saururus cernuus	lizard's tail, lizards tail	Native
Saxifraga virginiensis	early saxifrage	Native
Schizachyrium scoparium	little bluestem	Native
Schizachyrium scoparium var. scoparium	little bluestem	Native
Schoenoplectus tabernaemontani	great bulrush, soft-stem bulrush, softstem bulrush	Native
Scirpus atrovirens	dark-green bulrush, green bulrush	Native

Scientific name	Common name/s	Status
	Vascular plants	
Scirpus cyperinus	bulrush, woolgrass	Native
Scirpus georgianus	Georgia bulrush	Native
Scirpus pendulus	hanging bulrush, pendulous bulrush, rufous bulrush	Native
Scleria pauciflora	fewflower nutrush	Native
Scutellaria elliptica	hairy skullcap	Native
Scutellaria integrifolia	helmet flower	Native
Scutellaria lateriflora	blue skullcap, mad dog skullcap	Native
Scutellaria nervosa	veiny skullcap	Native
Scutellaria parvula var. leonardii	Leonard's skullcap	Native
Sedum ternatum	woodland stonecrop	Native
Senecio anonymus	Small's ragwort	Native
Senecio aureus	golden ragwort	Native
Senecio pauperculus	balsam groundsel	Native
Senna hebecarpa	American senna	Native
Sericocarpus asteroides	toothed whitetop aster	Native
Setaria faberi	Chinese foxtail, Chinese millet, giant bristlegrass, giant foxtail, Japanese bristlegrass, nodding foxtail, tall green bristlegrass	Non-Native
Setaria glauca	pearl millet, pigeongrass, wild millet, yellow bristlegrass, yellow foxtail	Non-Native
Setaria parviflora	knotroot bristlegrass, marsh bristle grass, marsh bristlegrass, yellow bristlegrass	Native
Setaria viridis	bottle grass, green bristle grass, green bristlegrass, green foxtail, pigeon-grass, wild millet	Native
Sida spinosa	prickly fanpetals, prickly sida	Non-Native
Silene caroliniana ssp. pensylva-nica	Pennsylvania catchfly	Native
Silene latifolia	bladder campion, bladder-campion	Non-Native
Silphium trifoliatum	whorled rosinweed	Native
Sisyrinchium mucronatum	needle-tip blue-eyed-grass, needletip blue-eyed grass	Native
Smilax glauca	cat greenbrier	Native
Smilax herbacea	herbaceous greenbriar, smooth carrionflower	Native
Smilax pulverulenta	downy carrionflower	Native
Smilax rotundifolia	bullbriar, common catbriar, common greenbrier, greenbrier, horsebriar, roundleaf greenbriar, roundleaf greenbrier	Native
Smilax tamnoides	bristly greenbrier	Native
Solanum carolinense	apple of Sodom, bull nettle, Carolina horsenettle, devil's tomato, horsen-ettle, sand briar	Native
Solanum dulcamara	bitter nightshade, bittersweet nightshade, blue nightshade, climbing nightshade, European bittersweet, fellenwort, woody nightshade	Non-Native
Solidago bicolor	white goldenrod	Native
Solidago caesia	wreath goldenrod	Native
Solidago canadensis	Canada goldenrod, Canadian goldenrod, common goldenrod	Native
Solidago juncea	early goldenrod	Native
Solidago nemoralis	dyersweed goldenrod, gray goldenrod	Native
Solidago ulmifolia	elmleaf goldenrod	Native
Sonchus asper	perennial sowthistle, prickly sowthistle, spiny sowthistle, spiny-leaf sow-thistle	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Sonchus oleraceus	annual sowthistle, common sow-thistle, common sowthistle, pualele, sow thistle, sow-thistle	Non-Native
Sorghastrum nutans	Indiangrass, yellow indian-grass	Native
Sphenopholis intermedia	slender wedgegrass, slender wedgescale	Native
Sphenopholis nitida	shiny wedgescale	Native
Sphenopholis obtusata	prairie wedgegrass, prairie wedgescale	Native
Sphenopholis pensylvanica	swamp wedgescale	Native
Spiraea latifolia		Native
Spiranthes lacera var. gracilis	northern slender ladies'-tresses, northern slender ladiestresses	Native
Spiranthes tuberosa	little ladies'-tresses, little ladiestresses	Native
Sporobolus vaginiflorus	poverty dropseed, poverty grass	Native
Stachys hispida		Native
Stachys pilosa var. arenicola	hairy hedgenettle	Native
Staphylea trifolia	American bladdernut, american bladdernut	Native
Stellaria longifolia	long-leaf starwort, longleaf chickweed, longleaf starwort	Native
Stellaria media	chickweed, common chickweed, nodding chickweed	Non-Native
Stellaria pubera	star chickweed	Native
Strophostyles umbellata	perennial wildbean, pink fuzzybean	Native
Stylosanthes biflora	endbeak pencilflower, sidebeak pencilflower	Native
Symphoricarpos orbiculatus	coralberry, coralberry (buck brush), Indiancurrant coralberry	Unknown
Taenidia integerrima	yellow pimperal, yellow pimpernel, yellow pimpernell	Native
Taraxacum officinale	blowball, common dandelion, dandelion, faceclock	Non-Native
Taxus canadensis	Canada yew	Native
Tephrosia virginiana	Virginia tephrosia	Native
Teucrium canadense	American germander, Canada germander, Candad germander, germander, hairy germander, wood sage	Native
Thalictrum dioicum	early meadow-rue	Native
Thalictrum revolutum	waxyleaf meadow-rue, waxyleaf meadowrue	Native
Thalictrum thalictroides	rue anemone	Native
Thaspium barbinode	hairyjoint meadowparsnip, hairyspine thaspium	Native
Thelypteris noveboracensis	New York fern	Native
Tipularia discolor	crippled cranefly	Native
Toxicodendron radicans	eastern poison ivy, poison ivy, poisonivy	Native
Toxicodendron rydbergii	poison ivy, W. Poison ivy, western poison ivy, western poison-ivy	Native
Tragopogon dubius	common salsify, goat's beard, goatsbeard, meadow goat's-beard, salsifis majeur, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify	Non-Native
Trichostema dichotomum	blue curls, forked bluecurls	Native
Tridens flavus	Purpletop, purpletop tridens	Native
Trifolium arvense	hairy clover, hare's foot clover, oldfield clover, rabbit-foot clover, rabbit-foot clover, stone clover	Non-Native
Trifolium campestre	Field (Big-hop) clover, field clover, large hop clover, lesser hop clover, low hop clover	Non-Native
Trifolium hybridum	alsike clover	Non-Native
Trifolium pratense	red clover	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Trifolium reflexum	buffalo clover	Native
Trifolium repens	Dutch clover, ladino clover, white clover	Non-Native
Triodanis perfoliata	clasping bellwort, clasping Venus' looking-glass, clasping Venus' looking-glass, clasping venuslookingglass, clasping-leaf venus'-looking-glass, common Venus' lookingglass, roundleaved triodanis, Venus lookingglass	Native
Triosteum perfoliatum	common horsegentian, feverwort	Native
Triplasis purpurea	purple sand grass, purple sandgrass	Native
Tripsacum dactyloides	eastern gamagrass	Native
Tsuga canadensis	canada hemlock, eastern hemlock, hemlock spruce	Native
Typha latifolia	broadleaf cattail, cattail, cattail (common), common cattail	Native
Ulmus americana	American elm	Native
Ulmus rubra	slippery elm	Native
Uvularia perfoliata	perfoliate bellwort	Native
Vaccinium corymbosum	highbush blueberry	Native
Vaccinium pallidum	Blue Ridge blueberry, blueridge blueberry	Native
Vaccinium stamineum	deerberry	Native
Valerianella radiata	beaked cornsalad	Native
Verbascum blattaria	moth mullein, white moth mullein	Non-Native
Verbascum thapsus	big taper, common mullein, flannel mullein, flannel plant, great mullein, mullein, velvet dock, velvet plant, woolly mullein	Non-Native
Verbena hastata	blue verbena, blue vervain, Simpler's-joy, swamp verbena	Native
Verbena simplex	narrow-leaved vervain, narrowleaf vervain, simple verbena	Native
Verbena urticifolia	white verbena, white vervain	Native
Verbesina alternifolia	wingstem	Native
Verbesina occidentalis	yellow crownbeard	Native
Vernonia glauca	broadleaf ironweed	Native
Vernonia noveboracensis	New York ironweed	Native
Veronica arvensis	common speedwell, corn speedwell, rock speedwell, wall speedwell	Non-Native
Veronica hederifolia	ivyleaf speedwell	Non-Native
Veronica officinalis	common gypsyweed	Non-Native
Veronica peregrina	neckweed, purslane speedwell	Non-Native
Veronica persica	bird-eye speedwell, birdeye speedwell, birdseye speedwell, Persian speedwell, winter speedwell	Non-Native
Veronica serpyllifolia	thyme-leaf speedwell, thymeleaf speedwell	Non-Native
Viburnum acerifolium	mapleleaf viburnum	Native
Viburnum dentatum	arrow-wood viburnum, arrowwood, southern arrowwood	Native
Viburnum dentatum var. lucidum	southern arrowwood	Native
Viburnum prunifolium	blackhaw	Native
Vicia caroliniana	Carolina vetch	Native
Vicia cracca	bird vetch, cow vetch	Non-Native
Vicia sativa	Common Vetch, garden vetch, narrowleaf vetch, sweetpea (garden vetch)	Non-Native
Vicia tetrasperma	lentil vetch, sparrow vetch	Non-Native
Vinca major	bigleaf periwinkle, greater periwinkle, periwinkle	Non-Native
Vinca minor	common periwinkle, lesser periwinkle, myrtle	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Viola cucullata	marsh blue violet	Native
Viola hastata	halberdleaf yellow violet	Native
Viola palmata var. triloba		Native
Viola pubescens var. leiocarpon		Native
Viola pubescens var. pubescens	downy yellow violet, smooth yellow violet	Native
Viola sagittata	arrow-leaved violet, arrowleaf violet	Native
Viola sororia	common blue violet, hooded blue violet	Native
Viola striata	striped cream violet	Native
Vitis aestivalis var. aestivalis	summer grape	Native
Vitis aestivalis var. bicolor	summer grape	Native
Vitis vulpina	fox grape, frost grape, wild grape	Native
Vulpia myuros	foxtail fescue, rat-tail fescue, rat-tailed fescue, rattail fescue	Non-Native
Vulpia octoflora	eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass	Native
Xanthium strumarium	cocklebur, cockleburr, common cocklebur, rough cocklebur, rough cockleburr	Native
Yucca filamentosa	Adam's needle	Native
Zanthoxylum americanum	common pricklyash, Common pricky-ash, toothachetree	Native
Zizia aptera	heart-leaf alexanders, heartleaf alexanders, meadow zizia, meadowparsnip, zizia	Native
Zizia aurea	golden alexanders, golden zizia	Native

Table A-14. List of fish species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Fish	
Ameiurus natalis	yellow bullhead	Native
Ameiurus nebulosus	brown bullhead	Native
Anguilla rostrata	American eel	Native
Catostomus commersoni	white sucker	Native
Chaenobryttus gulosus	warmouth	Non-Native
Clinostomus funduloides	rosyside dace	Native
Cyprinella analostana	satinfin shiner	Native
Cyprinella galactura	whitetail shiner	Native
Cyprinella spiloptera	spotfin shiner	Native
Enneacanthus gloriosus	bluespotted sunfish	Native
Erimyzon oblongus	creek chubsucker	Native
Esox americanus	redfin pickerel	Native
Etheostoma flabellare	fantail darter	Native
Etheostoma olmstedi	tessellated darter	Native
Exoglossum maxillingua	cutlips minnow	Native
Hybognathus regius	eastern silvery minnow	Native
Hypentelium nigricans	northern hogsucker	Native
Ictalurus punctatus		Non-Native
Lepomis auritus	redbreast sunfish	Native
Lepomis cyanellus	green sunfish	Non-Native
Lepomis gibbosus	pumpkinseed	Native
Lepomis macrochirus		Non-Native
Luxilus cornutus	common shiner	Native
Micropterus dolomieu	smallmouth bass	Non-Native
Micropterus salmoides	largemouth bass	Non-Native
Nocomis micropogon	river chub	Native
Notemigonus crysoleucas	golden shiner	Native
Notropis amoenus	comely shiner	Native
Notropis hudsonius	spottail shiner	Native
Notropis procne	swallowtail shiner	Native
Notropis rubellus	rosyface shiner	Native
Noturus insignis	margined madtom	Native
Percina peltata	shield darter	Native
Pimephales notatus	bluntnose minnow	Non-Native
Pomoxis nigromaculatus	black crappie	Non-Native
Rhinichthys atratulus	blacknose dace	Native
Rhinichthys cataractae	longnose dace	Native
Semotilus atromaculatus	creek chub	Native
Semotilus corporalis	fallfish	Native
Rhinichthys atratulus	blacknose dace, eastern blacknose dace	Native
Rhinichthys cataractae	longnose dace	Native
Semotilus atromaculatus	creek chub	Native
Semotilus corporalis	fallfish	Native

Table A-15. List of amphibian species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Amphibians	
Acris crepitans crepitans	Eastern Cricket Frog, Northern Cricket Frog	Native
Ambystoma jeffersonianum	Jefferson Salamander	Native
Ambystoma maculatum	Spotted Salamander	Native
Ambystoma opacum	Marbled Salamander	Native
Anaxyrus americanus americanus	Eastern American Toad	Native
Anaxyrus woodhousii fowleri	Fowler's Toad	Native
Anaxyrus woodhousii woodhousii	Rocky Mountain Toad, Woodhouse's Toad	Non-Native
Desmognathus fuscus fuscus	Northern Dusky Salamander	Native
Eurycea bislineata	Northern Two-lined Salamander, Two-lined Salamander	Native
Hemidactylium scutatum	Four-toed Salamander	Native
Hyla chrysoscelis	Cope's Gray Treefrog	Native
Hyla versicolor	Gray Treefrog	Native
Notophthalmus viridescens viridescens	red eft, red-spotted newt	Native
Plethodon cinereus	Eastern Red-backed Salamander, Redback Salamander, Red-backed Salamander	Native
Plethodon glutinosus	Northern Slimy Salamander, Slimy Salamander	Native
Pseudacris crucifer crucifer	Northern Spring Peeper	Native
Pseudacris feriarum feriarum	Upland Chorus Frog	Native
Pseudacris triseriata feriarum	upland chorus frog	Native
Pseudacris triseriata triseriata	Western Chorus Frog	Non-Native
Rana catesbeiana	American Bullfrog, Bullfrog	Non-Native
Rana clamitans melanota	Green Frog, Northern Green Frog	Native
Rana palustris	Pickerel Frog	Native
Rana sylvatica	Wood Frog	Native

Table A-16. List of reptile species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Reptiles	
Agkistrodon contortrix mokasen	Northern Copperhead	Native
Carphophis amoenus amoenus	Eastern Worm Snake	Native
Chelydra serpentina serpentina	common snapping turtle	Native
Chrysemys picta marginata	Midland Painted Turtle	Unknown
Chrysemys picta picta	Eastern Painted Turtle	Native
Clemmys guttata	Spotted Turtle	Native
Coluber constrictor constrictor	Northern Black Racer	Native
Diadophis punctatus edwardsii	Northern Ringneck Snake	Native
Elaphe obsoleta obsoleta	Black Rat Snake	Native
Eumeces fasciatus	Five-lined Skink	Native
Eumeces inexpectatus	Southeastern Five-lined Skink	Native
Eumeces laticeps	Broad-headed Skink	Native
Heterodon platirhinos	Eastern Hog-nosed Snake	Native
Kinosternon subrubrum	common mud turtle, Eastern Mud Turtle	Native
Lampropeltis calligaster rhombo-maculata	Mole Kingsnake	Native
Nerodia sipedon sipedon	Northern Water Snake	Native
Pseudemys rubriventris	American red-bellied turtle, Northern Red-bellied Cooter, Red-bellied Turtle	Native
Sternotherus odoratus	Common Musk Turtle	Native
Storeria dekayi dekayi	Northern Brown Snake	Native
Storeria occipitomaculata	Red-bellied Snake, Redbelly Snake	Native
Terrapene carolina carolina	Eastern Box Turtle	Native
Thamnophis sirtalis sirtalis	Common Garter Snake	Native
Trachemys scripta elegans	Red-eared Slider	Non-Native
Virginia valeriae valeriae	Eastern Earth Snake	Native

Table A-17. List of bird species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Birds	
Accipiter cooperii	Cooper's Hawk	Native
Accipiter striatus	Sharp-shinned Hawk	Native
Actitis macularia	Spotted Sandpiper	Native
Aegolius acadicus	Northern Saw-whet Owl	Native
Agelaius phoeniceus	Red-winged Blackbird	Native
Aix sponsa	Wood Duck	Native
Ammodramus savannarum	grasshopper sparrow	Native
Anas platyrhynchos	mallard	Native
Anas rubripes	American Black Duck	NA
Anthus rubescens	American Pipit	NA
Archilochus colubris	Ruby-throated Hummingbird	Native
Ardea alba	Great Egret	NA
Ardea herodias	Great Blue Heron	Native
Asio otus	Long-eared Owl	Native
Aythya affinis	Lesser Scaup	NA
Aythya collaris	Ring-necked Duck	NA
Bombycilla cedrorum	Cedar Waxwing	Native
Bonasa umbellus		NA
Branta canadensis	Canada Goose	Native
Bubo virginianus	Great-horned Owl	Native
Bubulcus ibis	Cattle Egret	NA
Bucephala albeola		NA
Bucephala clangula	Common Goldeneye	NA
Buteo jamaicensis	Red-tailed Hawk	Native
Buteo lagopus	Roughleg, Rough-legged Hawk	NA
Buteo lineatus	Red-shouldered Hawk	Native
Buteo platypterus	Broad-winged Hawk	Native
Butorides virescens	Green Heron	Native
Caprimulgus vociferus	Whip-poor-will	NA
Cardinalis cardinalis	Northern Cardinal	Native
Carduelis flammea	Common Redpoll	NA
Carduelis pinus	Pine Siskin	NA
Carduelis tristis	American Goldfinch	Native
Carpodacus mexicanus	House Finch	Non-Native
Carpodacus purpureus	Purple Finch	Native
Cathartes aura	Turkey Vulture	Native
Catharus fuscescens	Veery	Native
Catharus guttatus	Hermit Thrush	Native
Catharus ustulatus	Swainson's thrush	Native
Certhia americana	Brown Creeper	Native
Ceryle alcyon	Belted Kingfisher	Native
Chaetura pelagica	Chimney Swift	Native
Charadrius vociferus	killdeer	Native

Scientific name	Common name/s	Status
	Birds	
Chordeiles minor	Common Nighthawk	NA
Circus cyaneus	Northern Harrier	Native
Cistothorus palustris	Marsh Wren	Native
Coccothraustes vespertinus	Evening Grosbeak	NA
Coccyzus americanus	Yellow-billed Cuckoo	Native
Coccyzus erythropthalmus	Black-billed Cuckoo	Native
Colaptes auratus	Northern Flicker	Native
Colinus virginianus	Northern Bobwhite	Native
Columba livia	Rock Dove	Non-Native
Contopus virens	Eastern Wood Pewee, Eastern Wood-Pewee	Native
Coragyps atratus	Black Vulture	Native
Corvus brachyrhynchos	American Crow	Native
Corvus corax	Common Raven, Northern Raven	Native
Corvus ossifragus	Fish Crow	Native
Cyanocitta cristata	Blue Jay	Native
Dendroica caerulescens	Black-throated Blue Warbler	Native
Dendroica castanea	Bay-breasted Warbler	Native
Dendroica cerulea	Cerulean Warbler	Native
Dendroica coronata	Yellow-rumped Warbler	Native
Dendroica discolor	Prairie Warbler	Native
Dendroica dominica	Yellow-throated Warbler	Native
Dendroica fusca	Blackburnian Warbler	Native
Dendroica magnolia	Magnolia Warbler	Native
Dendroica palmarum	Palm Warbler	Native
Dendroica pensylvanica	Chestnut-sided Warbler	Native
Dendroica petechia	American Yellow Warbler, Yellow Warbler	Native
Dendroica pinus	Pine Warbler	Native
Dendroica striata	Blackpoll Warbler	Native
Dendroica tigrina	Cape May Warbler	NA
Dendroica virens	Black-throated Green Warbler	Native
Dolichonyx oryzivorus	Bobolink	NA
Dryocopus pileatus	Pileated Woodpecker	Native
Dumetella carolinensis	Gray Catbird, Grey Catbird	Native
Empidonax alnorum	Alder Flycatcher	Native
Empidonax traillii	Willow Flycatcher	Native
Empidonax virescens	Acadian Flycatcher	Native
Eremophila alpestris	Horned Lark	NA
Eudocimus albus	American White Ibis, White Ibis	Native
Euphagus carolinus	Rusty Blackbird	Native
Falco columbarius	Merlin	Native
Falco sparverius	American Kestrel	Native
Gallinago gallinago	common snipe	Native
Gavia immer	Common Loon, Great Northern Loon	Native
Geothlypis trichas	Common Yellowthroat	Native

Scientific name	Common name/s	Status
	Birds	
Guiraca caerulea	blue grosbeak	Native
Haliaeetus leucocephalus	Bald Eagle	Native
Helmitheros vermivorus	Worm-eating Warbler	Native
Hirundo rustica	Barn Swallow	Native
Hylocichla mustelina	Wood Thrush	Native
Icteria virens	Yellow-breasted Chat	Native
Icterus galbula	Baltimore oriole, northern oriole	Native
Icterus spurius	Orchard Oriole	Native
Junco hyemalis	Dark-eyed Junco	Native
Lanius ludovicianus	Loggerhead Shrike	NA
Larus argentatus	Herring Gull	NA
Larus delawarensis	Ring-billed Gull	Native
Lophodytes cucullatus	Hooded Merganser	Native
Melanerpes carolinus	Red-bellied Woodpecker	Native
Melanerpes erythrocephalus	Red-headed Woodpecker	Native
Meleagris gallopavo	Wild Turkey	Native
Melospiza georgiana	Swamp Sparrow	Native
Melospiza lincolnii	Lincoln's Sparrow	Native
Melospiza melodia	Song Sparrow	Native
Mergus serrator	Red-breasted Merganser	Native
Mimus polyglottos	Northern Mockingbird	Native
Mniotilta varia	Black-and-white Warbler	Native
Molothrus ater	Brown-headed Cowbird	Native
Myiarchus crinitus	Great Crested Flycatcher	Native
Nycticorax nycticorax	Black-crowned Night Heron, Black-crowned Night-Heron	Native
Oporornis formosus	Kentucky Warbler	Native
Otus asio	Eastern Screech-Owl	NA
Oxyura jamaicensis	ruddy duck	NA
Pandion haliaetus	Osprey	Native
Parula americana	Northern Parula	Native
Parus bicolor	Tufted Titmouse	Native
Parus carolinensis	Carolina Chickadee	Native
Passer domesticus	House Sparrow	Non-Native
Passerculus sandwichensis	Savannah Sparrow	Native
Passerella iliaca	Fox Sparrow	NA
Passerina cyanea	Indigo Bunting	Native
Phalacrocorax auritus	Double-crested Cormorant	Native
Phasianus colchicus	Common Pheasant, ring-necked pheasant	NA
Pheucticus ludovicianus	Rose-breasted Grosbeak	Native
Picoides pubescens	Downy Woodpecker	Native
Picoides villosus	Hairy Woodpecker	Native
Pipilo erythrophthalmus	Eastern Towhee	Native
Piranga olivacea	Scarlet Tanager	Native
Piranga rubra	Summer Tanager	Native

Scientific name	Common name/s	Status
	Birds	
Podilymbus podiceps	Pied-billed Grebe	Native
Polioptila caerulea	blue-gray gnatcatcher, Blue-grey Gnatcatcher	Native
Pooecetes gramineus	Vesper Sparrow	Native
Porphyrula martinica	purple gallinule	Native
Progne subis	Purple Martin	Native
Protonotaria citrea	Prothonotary Warbler	Native
Quiscalus quiscula	Common Grackle	Native
Regulus calendula	Ruby-crowned Kinglet	Native
Regulus satrapa	Golden-crowned Kinglet	Native
Riparia riparia	Bank Swallow, Sand Martin	Native
Sayornis phoebe	Eastern Phoebe	Native
Scolopax minor	American Woodcock	Native
Seiurus aurocapillus	Ovenbird	Native
Seiurus motacilla	Louisiana Waterthrush	Native
Setophaga ruticilla	American Redstart	Native
Sialia sialis	Eastern Bluebird	Native
Sitta canadensis	Red-breasted Nuthatch	Native
Sitta carolinensis	White-breasted Nuthatch	Native
Sphyrapicus varius	Yellow-bellied Sapsucker	Native
Spizella arborea	American Tree Sparrow	Native
Spizella pallida	Clay-colored Sparrow	Native
Spizella passerina	Chipping Sparrow	Native
Spizella pusilla	Field Sparrow	Native
Stelgidopteryx serripennis	Northern rough-winged swallow	Native
Strix varia	Barred Owl	Native
Sturnella magna	Eastern Meadowlark	Native
Sturnus vulgaris	European Starling	Non-Native
Tachycineta bicolor	Tree Swallow	Native
Thryothorus ludovicianus	Carolina Wren	Native
Toxostoma rufum	Brown Thrasher	Native
Tringa solitaria	Solitary Sandpiper	Native
Troglodytes aedon	House Wren	Native
Troglodytes troglodytes	Winter Wren	Native
Turdus migratorius	American Robin	Native
Tyrannus tyrannus	Eastern Kingbird	Native
Tyto alba	Barn Owl, Common Barn-Owl	Native
Vermivora chrysoptera	Golden-winged Warbler	Native
Vermivora peregrina	Tennessee Warbler	Native
Vermivora pinus	Blue-winged Warbler	Native
Vermivora ruficapilla	Nashville Warbler	Native
Vireo flavifrons	Yellow-throated Vireo	Native
Vireo gilvus	Warbling Vireo	Native
Vireo griseus	White-eyed Vireo	Native
Vireo olivaceus	red-eyed vireo	Native

Scientific name	Common name/s	Status
	Birds	
Vireo philadelphicus	Philadelphia Vireo	Native
Vireo solitarius	Blue-headed Vireo, Solitary Vireo	Native
Wilsonia canadensis	Canada Warbler	Native
Wilsonia citrina	Hooded Warbler	Native
Wilsonia pusilla	Wilson's Warbler	Native
Zenaida macroura	Mourning Dove	Native
Zonotrichia albicollis	White-throated Sparrow	Native
Zonotrichia leucophrys	White-crowned Sparrow	Native

Table A-18. List of mammal species recorded in Manassas National Battlefield Park.

Scientific name	Common name/s	Status
	Mammals	
Blarina brevicauda	mole shrew, northern short-tailed shrew, short-tailed shrew	Native
Canis latrans	Coyote	Non-Native
Castor canadensis	american beaver, beaver	Native
Didelphis virginiana	Virginia opossum	Native
Eptesicus fuscus	big brown bat	Native
Glaucomys volans	southern flying squirrel	Native
Lasiurus borealis	eastern red bat, red bat	Native
Lontra canadensis	North American River Otter, northern river otter, river otter	Native
Lynx rufus	bobcat	Native
Marmota monax	woodchuck	Native
Mephitis mephitis	striped skunk	Native
Microtus pennsylvanicus	meadow vole	Native
Mus musculus	house mouse	Non-Native
Mustela vison	American Mink, mink	Native
Odocoileus virginianus	white-tailed deer	Native
Ondatra zibethicus	muskbeaver, muskrat	Native
Peromyscus leucopus	white-footed mouse	Native
Pipistrellus subflavus	eastern pipistrelle	Native
Procyon lotor	common raccoon, northern raccoon, Raccoon	Native
Rattus norvegicus	Norway rat	Non-Native
Reithrodontomys humulis	eastern harvest mouse	Native
Scalopus aquaticus	Eastern Mole, topos	Native
Sciurus carolinensis	eastern gray squirrel, gray squirrel	Native
Sciurus niger	eastern fox squirrel, fox squirrel	Native
Sylvilagus floridanus	Eastern Cottontail	Native
Tamias striatus	eastern chipmunk	Native
Tamiasciurus hudsonicus	red squirrel	Native
Urocyon cinereoargenteus	common gray fox, Gray Fox	Native
Ursus americanus	American Black Bear, black bear	Native
Vulpes vulpes	Red Fox	Native
Sylvilagus floridanus	Eastern Cottontail	Native
Synaptomys cooperi	southern bog lemming	Native
Tamias striatus	eastern chipmunk	Native
Tamiasciurus hudsonicus	red squirrel	Native
Urocyon cinereoargenteus	common gray fox, Gray Fox	Native
Ursus americanus	American Black Bear, black bear	Native
Vulpes vulpes	Red Fox	Native

Appendix B: Information used in Manassas National Battlefield Park Natural Resource Condition Assessment

Table B-1. I&M reports used in the natural resource condition assessment.

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Bates, S. 2006. White-tailed deer density monitoring protocol version 1.1: distance and pellet-group surveys. National Capital Region Network Inventory and Monitoring Program, Washington, DC.

Dawson, D.K. and M.G. Efford. 2006. Protocol for monitoring forest-nesting birds in National Park Service parks. National Capital Region Network Inventory and Monitoring Program, Washington, DC.

National Park Service. 2005. Long-term monitoring plan for natural resources in the Natural Capital Region Network. Inventory and Monitoring Program, Center for Urban Ecology, Washington, DC.

Norris M.E. and G. Sanders. 2009. National Capital Region Network biological stream survey protocol version 2.0: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report NPS/NCRN/NRR—2009/116, Natural Resource Program Center, Fort Collins, CO.

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Schmit, J.P. and J.P. Campbell. 2009. National Capital Region Network 2009 forest vegetation monitoring report. Natural Resource Data Series NPS/NCRN/NRDS—2010/043. Natural Resource Program Center, Fort Collins, CO.

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Townsend, P.A., R.H. Gardner, T.R. Lookingbill, and C.C. Kingdom. 2006. Remote sensing and landscape pattern protocol for long-term monitoring of parks. National Capital Region Network Inventory and Monitoring Program, Washington, DC.

Table B-2. Listing of known literature pertaining to Manassas National Battlefield Park, based on a query of NPS NatureBib made on March 27, 2009. Brief abstract information is provided where available. Citations not having a date or author are not shown.

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Belden, A., G.P. Flemming, and N.E. Van Alstine. 1998. A National Heritage Inventory of Manassas National Battlefield Park.,

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Banisteria 23: 3–25. Abstract: Manassas National Battlefield Park (MNBP) is a 1,179 ha National Park Service Unit located 42 km west of Washington, DC. A total of 706 plant species and subspecific taxa are reported from the park for the 1993-2000 period. These include 53 new Prince William County, Virginia, records and six state-rare taxa. Ten habitat types are described for MNBP, and the habitats where each taxon was observed are listed.

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Kozur, H.W. and R.E. Weems. 2005. Conchostracan evidence for late Rhaetian to early Hettangian age for the CAMP volcanic event in the Newark Supergroup, and Sevatian (lage Norian) age for the immediately underlying beds. Hallesches Jahrb. Geowiss. B 27: 21-51. Abstract: The oldest and lowest lava flow in the Culpeper Basin (the Mount Zion Church basalt) accumulated no later than the late Rhaetian, because the immediately overlying Midland Formation has an abundant conchostracan fauna of late Rhaetian age that consists exclusively of *Euestheria brodieana* (Jones) as in the late Rhaetian of England. The highest part of the youngest unit in the Culpeper Basin (the Waterfall Formation) has an early Hettangian *Bulbilimnadia conchostracan* fauna. The lowermost Waterfall Formation, immediately above the Sander basalt, contains the oldest and most primitive representatives of *Bulbilimnadia* in co-occurrence with the youngest known *E. brodieana*. This fauna is very close to the Triassic–Jurassic boundary (TJB), which is placed on the basis of these data at the base of the Waterfall Formation. Thus, in the Newark Supergroup as in Morocco, extrusion of the plateau basalts of the CAMP began in the upper Rhaetian and continued past the TJB into the Early Jurassic (Hettangian). This relationship to a period boundary is very similar to that determined for the Siberian Trap, which straddles the Permian–Triassic boundary. Most probably the eruption of the CAMP plateau basalts caused both the sharp drop in biotic diversity across the TJB and the minima in ^{13}C observed around the TJB, the latter both directly (by huge volcanic production of CO_2) and indirectly (by suppression of bioproductivity). The beds immediately below a distinct sporomorph spike, documented a few meters below the oldest lava flow (Orange Mountain basalt) in the Newark Basin in Exeter, Pennsylvania and previously assigned to the TJB, instead belong to the Sevatian (late Norian) rather than the Rhaetian as previously assumed. This is indicated by the abundant occurrence of *Shipingia olseni nov.* sp., which is found throughout the entire Sevatian section of the Newark Supergroup and in the Sevatian Stubensandstein 3 of Baden-Württemberg in the Germanic Basin. No species belonging to the Norian conchostracan genus *Shipingia* is known to range as high as the Rhaetian anywhere in the world. The conchostracan genus *Redondestheria* nov. gen. occurs in undisputed Norian strata of the upper Groveton Member of the Bull Run Formation at Groveton Cemetery in the Culpeper Basin, Virginia. This occurrence confirms a late Norian age for the lower Redonda Formation (lower Apachean LVF) in New Mexico. Several new conchostracan taxa are here established: two new families (Bulbilimnadiidae KOZUR & WEEMS nov. fam. and Shipingiidae KOZUR & WEEMS nov. fam.), a new genus (*Redondestheria* KOZUR, WEEMS & LUCAS nov.

gen.), and 5 new species (*Redondestheria novomexicoensis* KOZUR, WEEMS & LUCAS nov. sp., *Redondestheria grovetonensis* KOZUR & WEEMS nov. sp., *Shipingia olseni* Kozur & Weems nov. sp., *Bulbilimnadia sheni* KOZUR & WEEMS nov. sp., and *Bulbilimnadia froelichi* KOZUR & WEEMS nov. sp.).

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Table B-3. List of acronyms used in this document.

Acronym	Description
ANC	Acid neutralizing capacity
ANTI	Antietam National Battlefield (NPS—NCRN)
BIBI	Benthic Index of Biotic Integrity
CATO	Catoctin Mountain Park (NPS—NCRN)
CHOH	Chesapeake & Ohio Canal National Historical Park (NPS—NCRN)
DC	District of Columbia
DO	Dissolved oxygen
FIBI	Fish Index of Biotic Integrity
FIDS	Forest Interior Dwelling Species of birds
GIS	Geographic Information Systems
GMP	General Management Plan
GWMP	George Washington Memorial Parkway (NPS—NCRN)
HAFE	Harpers Ferry National Historical Park (NPS—NCRN)
I&M	Inventory & Monitoring Program (NPS)
IAN	Integration & Application Network (UMCES)
IBI	Index of Biotic Integrity
IMPROVE	Interagency Monitoring of Protected Visual Environments
IUCN	International Union for Conservation of Nature
MANA	Manassas National Battlefield Park (NPS—NCRN)
MBSS	Maryland Biological Stream Survey
MD DNR	Maryland Department of Natural Resources
MDN	Mercury Deposition Network
MONO	Monocacy National Battlefield (NPS—NCRN)
NAAQS	National Ambient Air Quality Standards
NACE	National Capital Parks—East (NPS—NCRN)
NADP	National Atmospheric Deposition Program
NPS	National Park Service
NCRN	National Capital Region Network
NRCA	Natural Resource Condition Assessment
NSDWS	National Secondary Drinking Water Standards
NWI	National Wetlands Inventory
PAO	Proportion of Area Occupied (by amphibians)
PHI	Physical Habitat Index
PRWI	Prince William Forest Park (NPS—NCRN)
RESAC	Regional Earth Science Applications Center
ROCR	Rock Creek Park (NPS—NCRN)
RSS	Resource Stewardship Strategy
TMDL	Total Maximum Daily Load
UERLA	Urban Ecology Research Learning Alliance
UMCES	University of Maryland Center for Environmental Science
UNESCO	United Nations Educational, Scientific, and Cultural Organization
U.S. EPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WOTR	Wolf Trap National Park for the Performing Arts (NPS—NCRN)

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