



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.

Manassas National Battlefield Park Natural Resource Condition Assessment

National Capital Region

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

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics 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

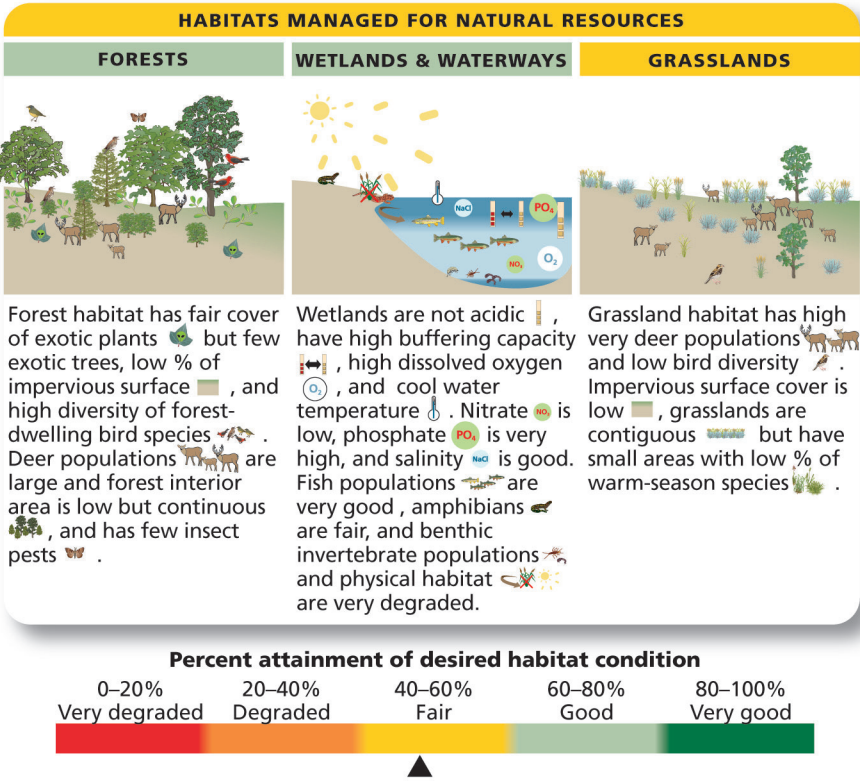
species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters.



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.

HABITAT-BASED NATURAL RESOURCE CONDITION ASSESSMENT OF MANASSAS NATIONAL BATTLEFIELD PARK

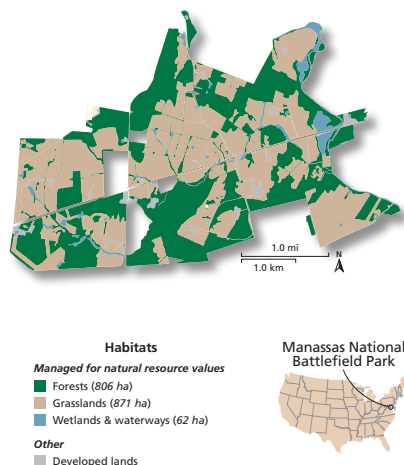


The habitat-based natural resource condition assessment is area-weighted. Areas of each habitat are given below:

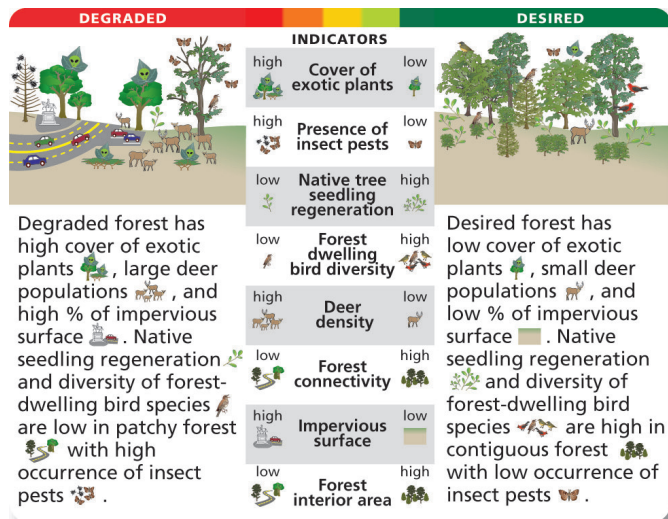
- Forests: 806 ha
Wetlands & waterways: 62 ha
Warm-season grasslands: 871 ha

Habitat framework

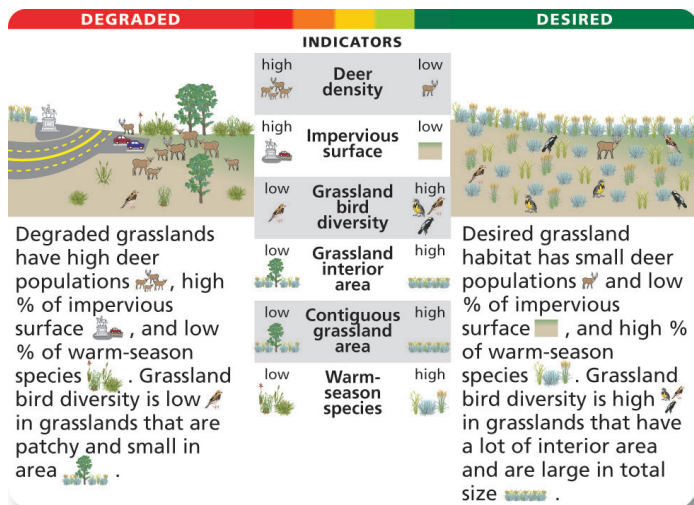
Habitats within the park were defined as being managed for natural resource values. A habitat map was created and desired/degraded conditions were defined for each of the three defined habitats. Metrics were then assigned to these habitat types, compared to established thresholds, leading to the condition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



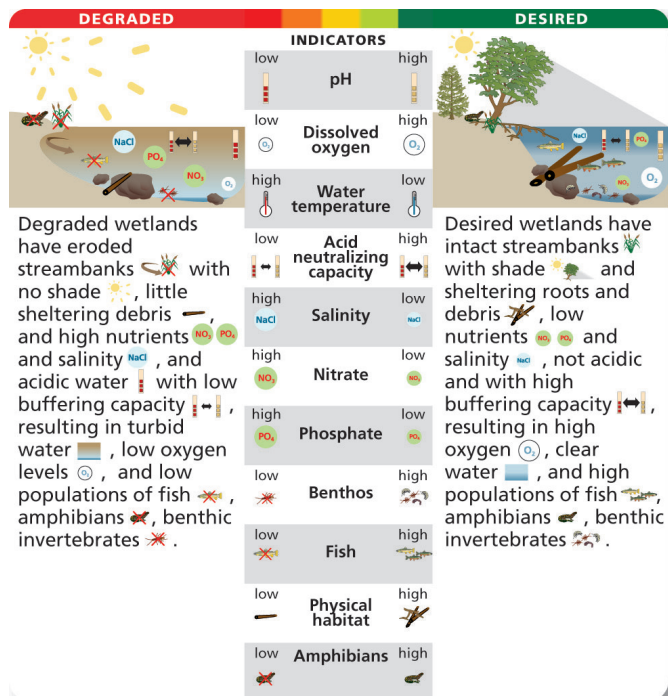
FORESTS



GRASSLANDS



WETLANDS & WATERWAYS



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/



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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 planning⁷ 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 cur-

rent 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 NRCA⁹ 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,



NPS/Tom Paradis

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.

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.

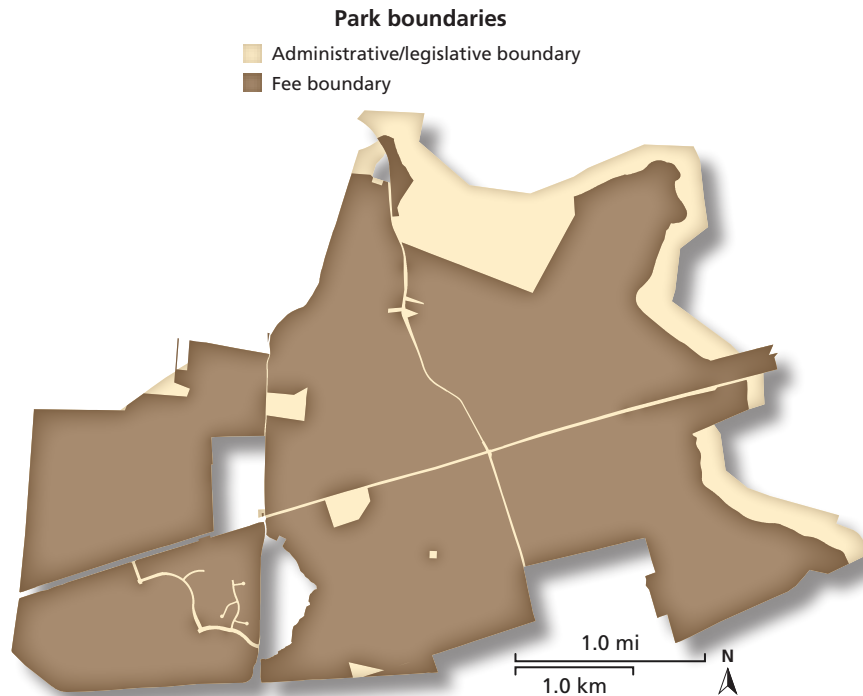
Since its establishment as a park in 1940, Manassas has been both vehemently defended and intensively scrutinized in connection with land acquisitions, various park management actions, and private development plans for properties near or adjacent to the park. The proximity of the park to Washington,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

Vernal pool in Manassas National Battlefield Park.

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 layer¹² showing the administrative/legislative and fee boundaries of Manassas National Battlefield Park, which encompass 2,052 ha (5,071 acres) and 1,809 ha (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*), boxelder (*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

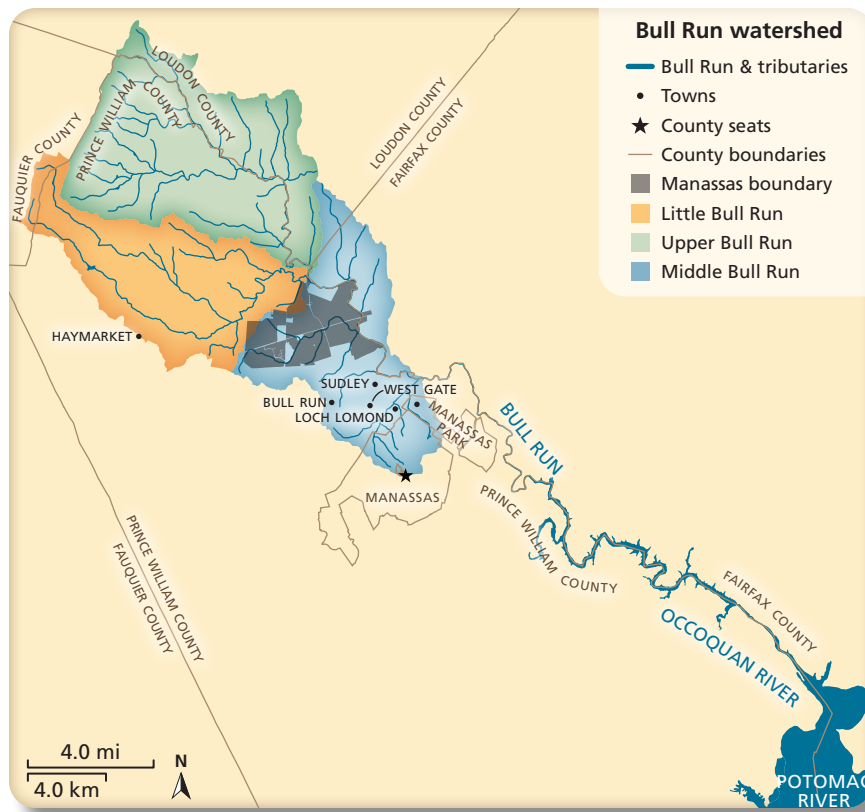


Figure 2.3. Bull Run and its watershed.¹⁵

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.

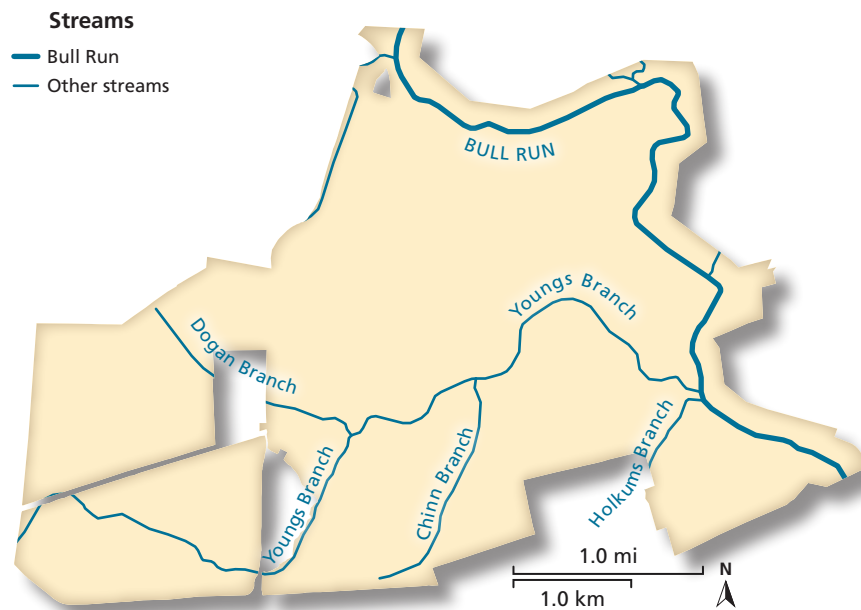
Virginia pine–Eastern red cedar successional forest. This community type is widespread in Manassas National Battlefield Park on former fields and clearings that were abandoned within the past century. It occupies low ridges and rolling to flat uplands. The characteristic species are Virginia pine (*Pinus 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 layer¹⁶ 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 successional 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.

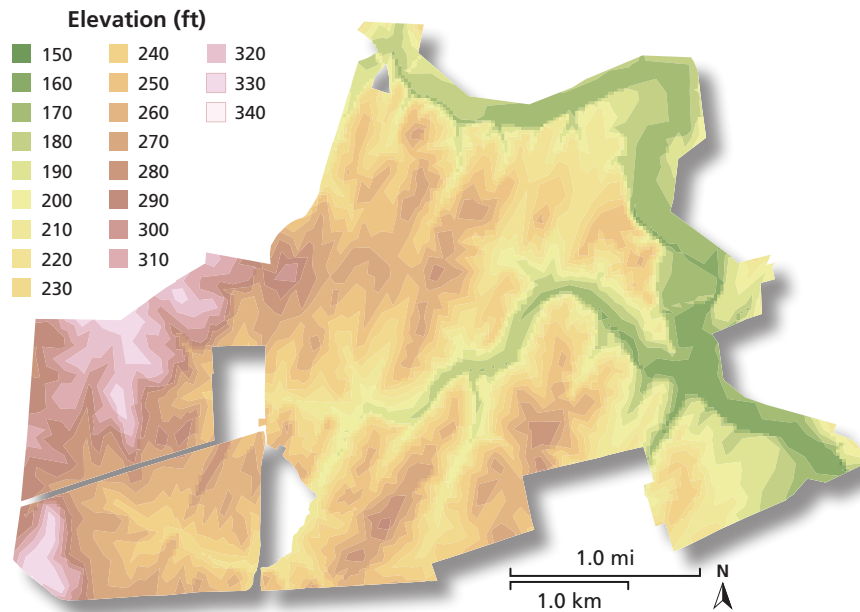


Figure 2.5. GIS data layer¹⁷ of topographic elevation for Manassas National Battlefield Park.

(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).

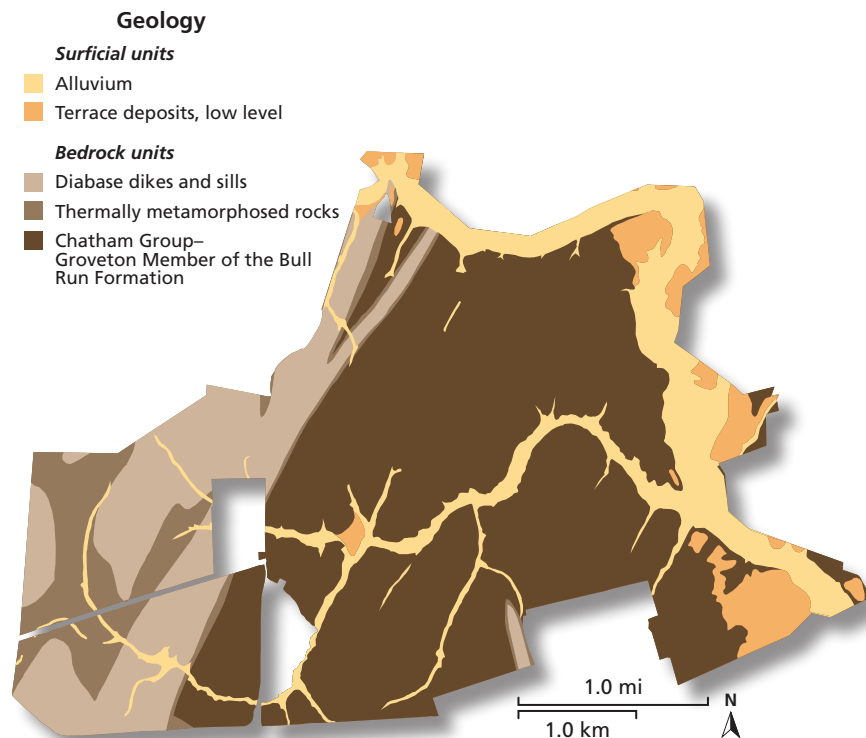
Warm-season grassland species are those that initiate growth in late spring and reach their peak during the warm summer months (Peterjohn 2006). Warm-season species are generally native to the Mid-Atlantic region, are deep-rooted and so are better at stabilizing soils, and are more drought resistant. 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 layer¹⁸ 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 [*Ver-*

mivora 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 ($>1.5 \text{ km km}^{-2}$) 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.

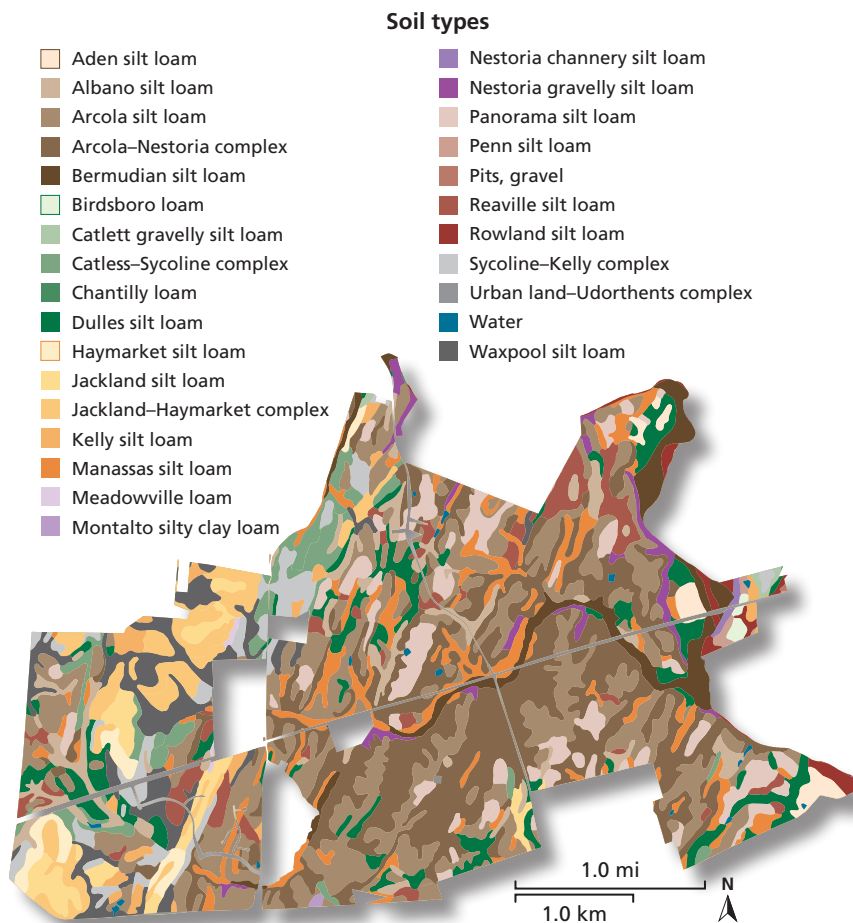


Figure 2.7. GIS data layer¹⁹ of soil types found in Manassas National Battlefield Park.

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

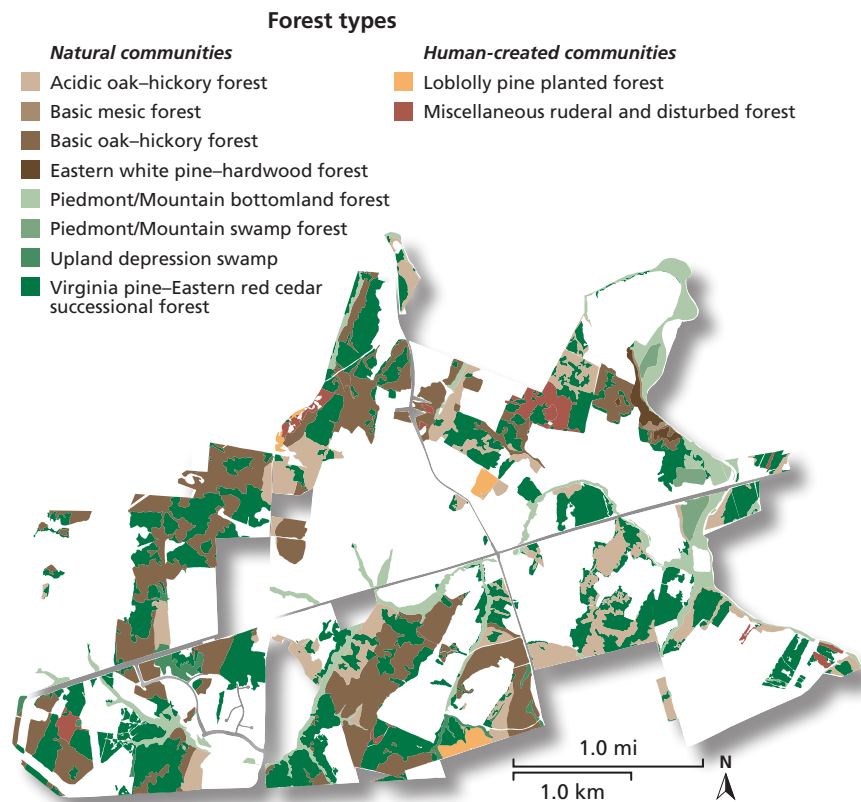
In 2006, a Total Maximum Daily Load (TMDL) was approved for Bull Run for benthic and bacteriological impairments (U.S. EPA 2006a, b). A TMDL is a pollution limit ideally set for every identified problem pollutant in each waterbody on the 303(d) list. The cap defines the maximum amount of each pollutant 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 layer²⁰ 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 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.

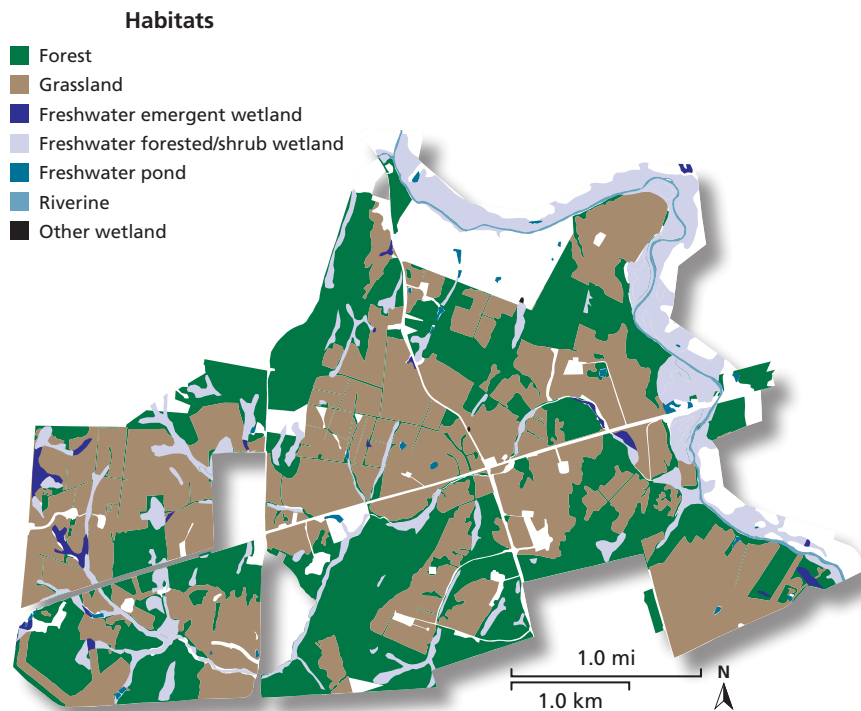


Figure 2.9. GIS data layer²¹ showing general location and types of habitats in Manassas National Battlefield Park.

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

A deer enclosure study by Rossell et al. (2005) performed within Manassas National Battlefield Park has provided experimental evidence supporting the observed indirect effects of deer overbrowsing. Control plots and deer enclosure 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 (*Ceratocystis 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.

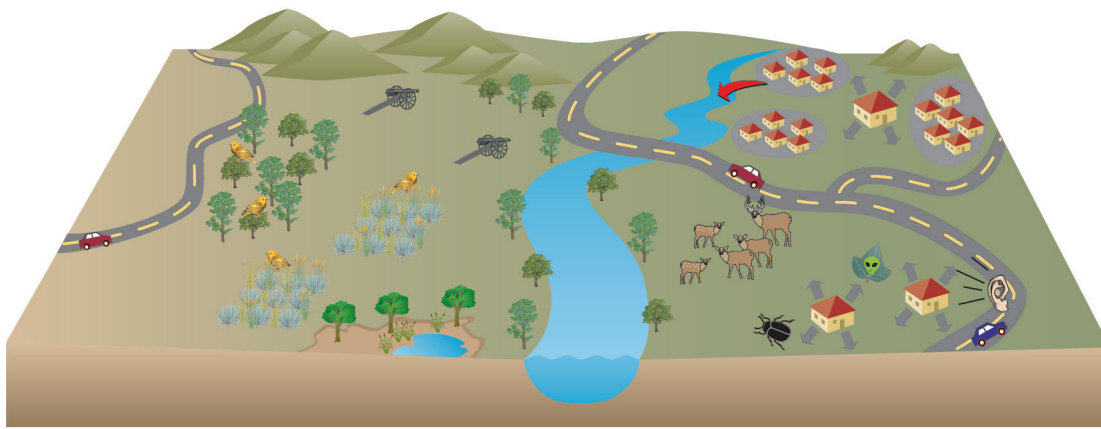
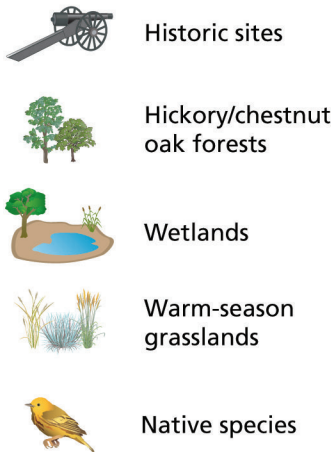
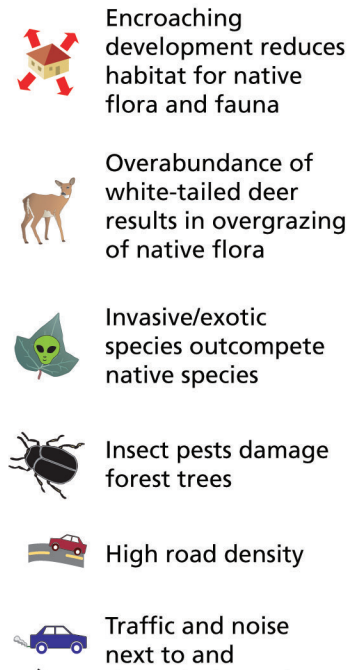


Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Manassas National Battlefield Park.

Resource values



Resource stressors



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."

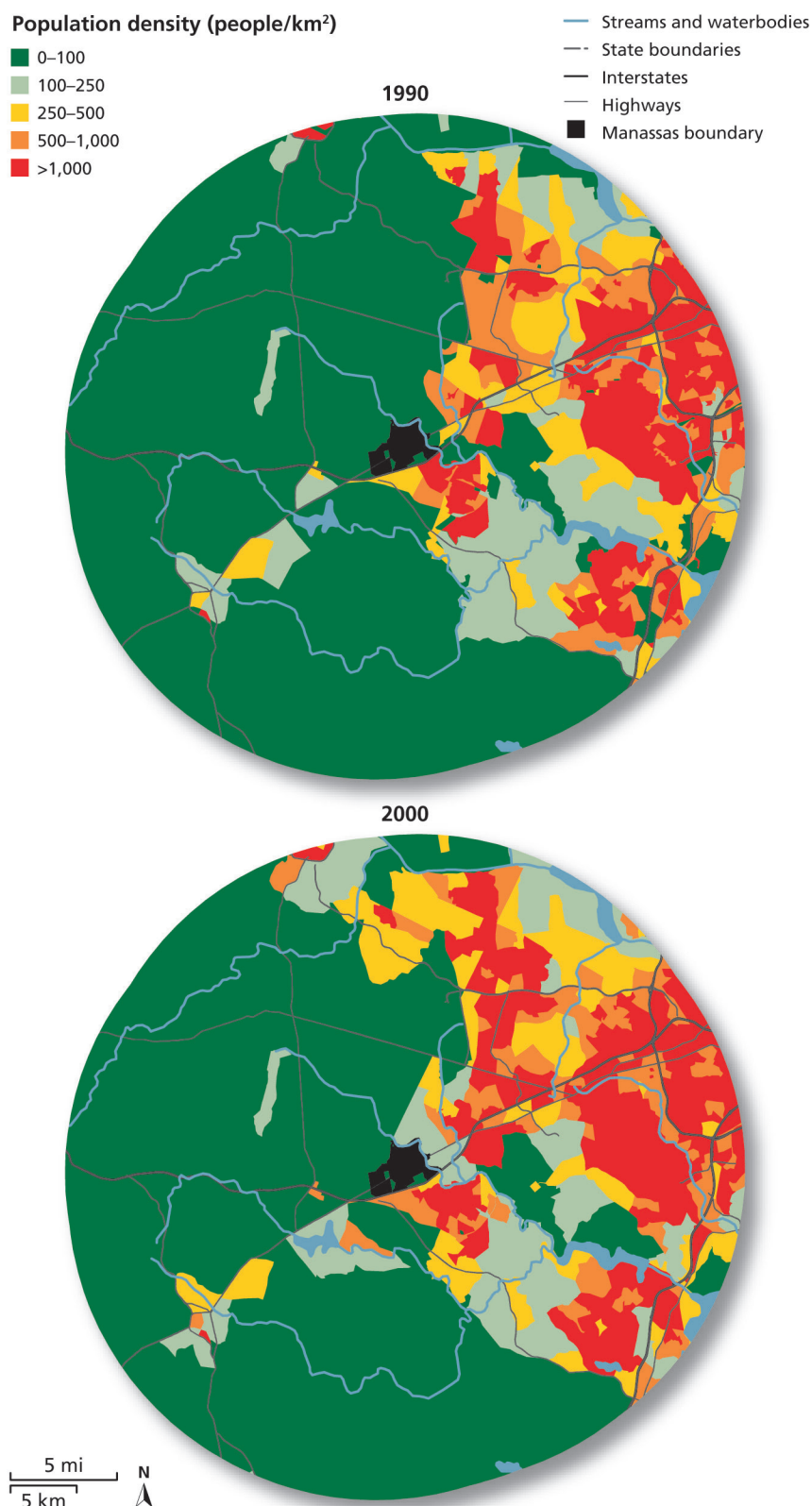
Manassas National Battlefield Park is therefore a park established to preserve and maintain a Civil War-era cultural landscape that is managed as much as possible to preserve physical attributes and biotic systems wherever historic considerations do not indicate otherwise.

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 layer²³ showing population density surrounding the park in 1990 and 2000.



23. NPScape Landscape Monitoring Project <http://science.nature.nps.gov/lim/monitor/npscape/index.cfm>

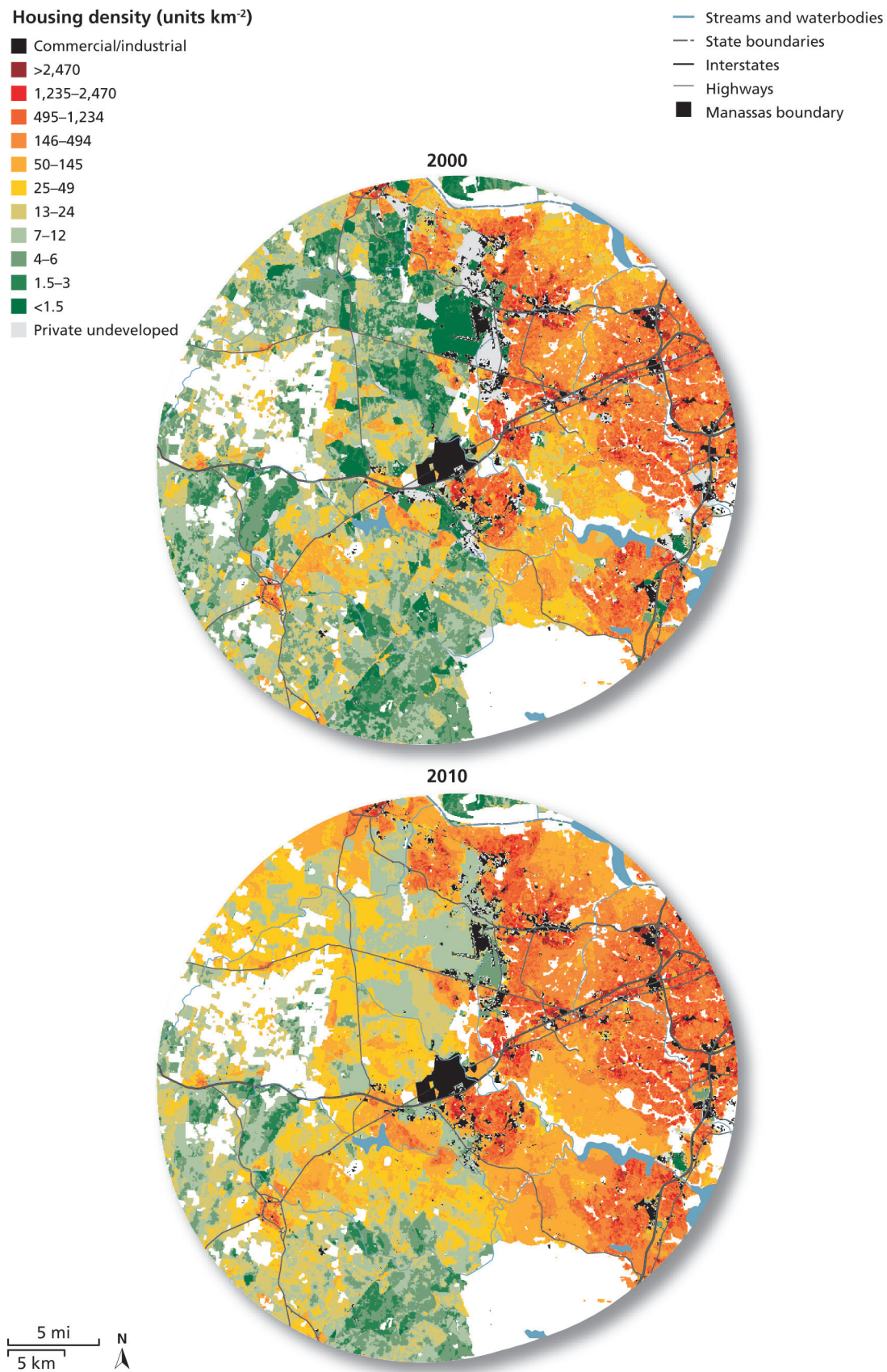
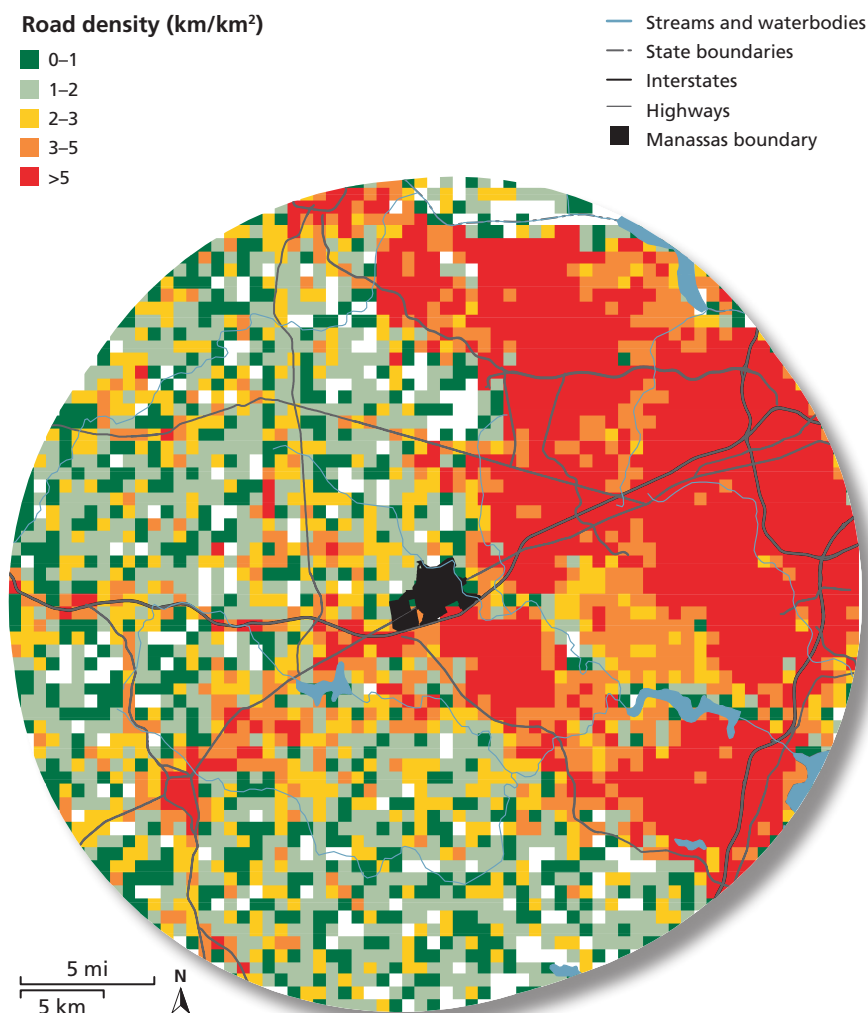


Figure 2.12 GIS data layer²⁴ showing housing density surrounding the park in 2000 and 2010.

24. NPSCAPE Landscape Monitoring Project <http://science.nature.nps.gov/im/monitor/npscape/index.cfm>

Figure 2.13. GIS data layer²⁵ 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>

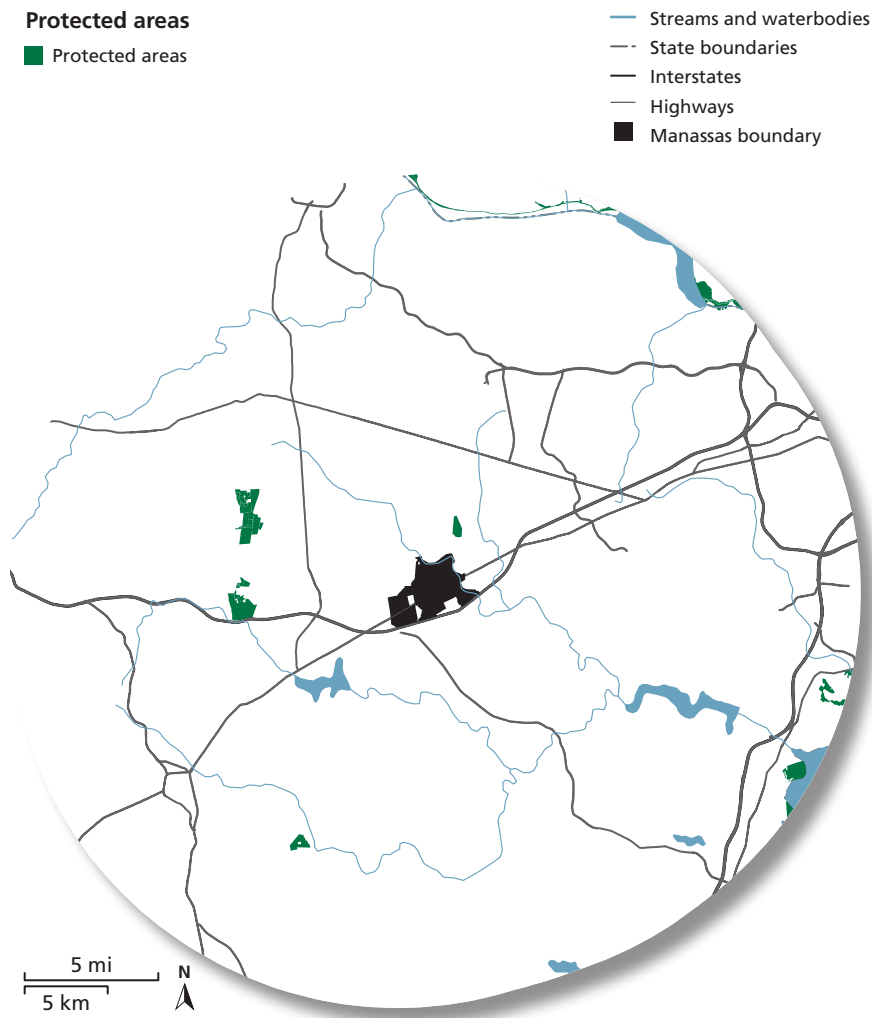


Figure 2.14. GIS data layer²⁶ showing protected areas surrounding the park in 2000.

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

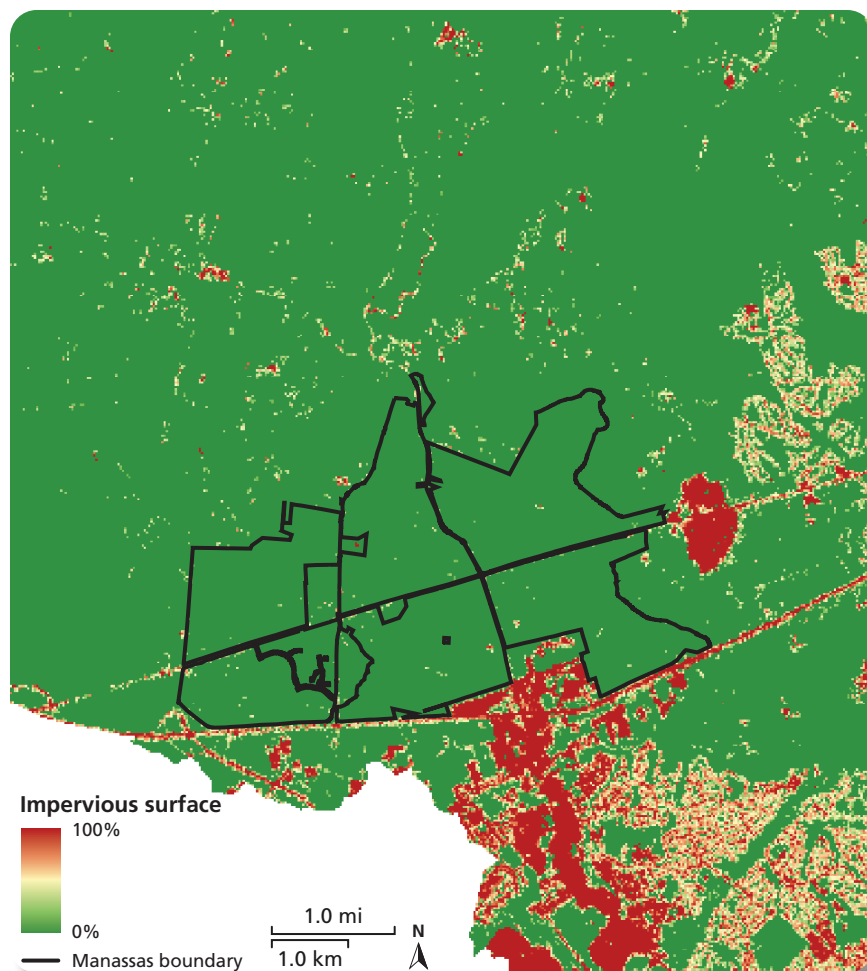
- The National Park Service will survey for, protect, and strive to recover all species native to national park system units that are listed under the Endangered Species Act. The National Park Service will determine all management actions for the protection and perpetuation of federally, state-, or locally 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 lightscares 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 layer²⁷ 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.

2.3 LITERATURE CITED (CHAPTER 2)

- Allard, H.A. and E.C. Leonard. 1962. List of vascular plants of the Northern Triassic area of Virginia. *Castanea* 27: 1–56.
- Anderson, R.L., J.L. Knighten, M. Windham, K. Langdon, F. Hedrix, and R. Roncardori. 1993. Dogwood anthracnose and its spread in the south. USDA Forest Service Southern Region, Forest Health Protection, Atlanta, GA.
- Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* 71: 355–366.
- Askins, R.A. 1999. History of grassland birds in eastern North America. *Studies in Avian Biology* 19: 60–71.
- Askins, R.A. 2000. Restoring North America's birds: Lessons from landscape ecology. Yale University Press, New Haven, CT.
- Bates, S. 2005. Deer survey report FY 2004. National Park Service, National Capital Region, Washington, DC.
- Bates, S. 2009. National Capital Region Network 2008 Deer monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR-2009/275. National Park Service, Fort Collins, CO.
- Brennan, L.A. and W.P. Kuvlesky Jr. North American grassland birds: an unfolding conservation crisis? *Journal of Wildlife Management* 69: 1–13.
- Brown, H. 2000. Wildland burning by American Indians in Virginia. *Fire Management Today* 60: 3. USDA Forest Service, Washington, DC.
- Environmental Law Institute. 2003. Conservation thresholds for land use planners. Environmental Law Institute. Washington, DC. 55 pp.
- Fenneman, N.M. 1938. Physiography of the eastern United States. McGraw-Hill Book Company, NY.
- Fleming, G.P. and J.T. Weber. 2003. Inventory, classification, and map of forested ecological communities at Manassas National Battlefield Park, Virginia. Natural Heritage Technical Report 03-7. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. Unpublished report submitted to the National Park Service.
- Gesch, D., M. Oimoen, S. Greenlee, C. Nelson, M. Steuck, and D. Tyler, D. 2002. The National Elevation Dataset: photogrammetric engineering and remote sensing, v. 68, no. 1.
- Gesch, D.B. 2007. The National Elevation Dataset. In: Maune, D. (ed.) *Digital Elevation Model Technologies and Applications: the DEM users manual*, 2nd edition. Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing.
- Gibbs, J.P. and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16: 1647–1652.
- Gorsira, B. 2004. Wetland and historic landscape restoration at Manassas National Battlefield Park. In: Soukup, M. (ed.). *NPS Natural Resource Year in Review 2004*.
- Ickes, H. Ch 5. National Battlefield Parks 1. Manassas National Battlefield Park. Order Designating the Manassas National Battlefield Park, Prince William County, Va. [May 10, 1940—5 F.R. 1824].
- Lee, K.Y. 1979. Triassic–Jurassic geology of the northern part of the Culpeper Basin, Virginia and Maryland. U.S. Geological Survey Open-File Report 79-1557.
- Loomis D.T. & K.E. Heffernan. 2003. Classification and mapping of wetlands at Manassas National Battlefield Park, Virginia: Brawner Farm and Matthews Hill tracts. Natural Heritage Technical Report 03-21. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. Unpublished report submitted to the National Park Service.
- Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10: 689–710.
- MANA. 2006. Manassas National Battlefield Park Natural Resources Management Plan.
- MANA. 2009. Park Operations Plan.
- Maxwell, H. 1910. The use and abuse of forests by the Virginia Indians. *William and Mary College Quarterly Historical Magazine* XIX: 73–103.
- May 10, 1940, Order Designating the Manassas National Battlefield Park, Prince William County, VA. [May 10, 1940—S F. R. 1824].

- McShea, W.J. and J.H. Rappole. 1997. Herbivores and the ecology of forest understory birds. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: deer ecology and population management. Smithsonian Institution Press, Washington, DC.
- NCRN. 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
- NCRN I&M and Urban Ecology Research Learning Alliance (UERLA). Undated. Grasslands conservation. http://science.nature.nps.gov/im/units/ncrn/products/grassland_fact_sheet.pdf
- NPS. 2005. Brawner Farm-Deep Cut Vista Enhancement Manassas National Battlefield Park Virginia.
- NPS. April 2008. Manassas National Battlefield Park, Final General Management Plan/Environmental Impact Statement.
- NPS. 2009. Manassas National Battlefield Park, Park Operations Plan.
- Peterjohn, B. 2006. Conceptual ecological model for management of breeding grassland birds in the Mid-Atlantic region. Technical Report NPS/NER/NRR—2006/005. National Park Service, Philadelphia, PA.
- RESAC Impervious Surface Area Time Series version 1.3. University of Maryland and the Woods Hole Research Center.
- Rossell Jr, C.R., B. Gorsira, and S. Patch. Effects of white-tailed deer on vegetation structure and woody seedling composition in three forest types on the Piedmont Plateau. Forest Ecology & Management 210: 415–424.
- SSURGO. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Prince William County, Virginia. Available online at <http://soildatamart.nrcs.usda.gov>
- Steen, D.A. and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143–1148.
- Thorneberry–Ehrlich, T. 2008. Manassas National Battlefield Park Geologic Resource Evaluation Report. Natural Resources Report NPS/NRPC/GRD/NRR—2008/050. National Park Service, Denver, CO.
- U.S. Congress. Ch. 1, 39 Stat 535. Act to establish a National Park Service (Organic Act), 1916. 16 USC 1, 2, 3, and 4. August 25, 1916.
- U.S. Congress. 68 Stat 56. 2. Manassas National Battlefield Park. Boundaries established Act of April 17, 1954.
- U.S. Congress. Ch 8, 94 Stat 1885. National Battlefields. 1. Manassas. Public Law 96-442, 96th Congress. October 13, 1980. [H.R. 5048].
- U.S. Congress. 102 Stat. 3810-3812.. 2. Manassas. Public Law 100-647-Nov. 10, 1988. Title X. Manassas National Battlefield Park Amendments of 1988. [H.R. 4333].
- U.S. Department of Interior. National Park Service. 2006. Management Policies 2006.
- U.S. EPA. 2006a. Decision rationale for the aquatic life use (benthic) impairment TMDLs for Bull Run and Popes Head Creek, Virginia. http://www.epa.gov/reg3wapd/tmdl/VA_TMDLs/BullRun/BullandPopes_DR.pdf
- US EPA. 2006b. Decision rationale: Total Maximum Daily Loads for the primary contact use (bacteriological) impairments on Broad Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds, Prince William and Fauquier Counties, Virginia http://www.epa.gov/reg3wapd/tmdl/VA_TMDLs/OccoquanRiver/OccoquanRiverDR.pdf
- VAC (Virginia Administrative Code). 2008. 9 VAC 25-260-10. Designation of uses. http://www.deq.state.va.us/wqs/documents/TR_WQS_proposed_language_17OCT2008.pdf
- Van Lear, D.H. and T.A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. USDA Forest Service General Technical Report SE-54. Southeastern Forest Experiment Station, Clemson, SC.
- Zenzen, Joan M. 1998. Battling for Manassas: the Fifty-Year Preservation Struggle at Manassas National Battlefield Park. Pennsylvania State University Press, University Park, PA.

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 Inte-



gration 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.

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-

Traffic in Manassas National Battlefield Park.

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 docu-

ment (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-

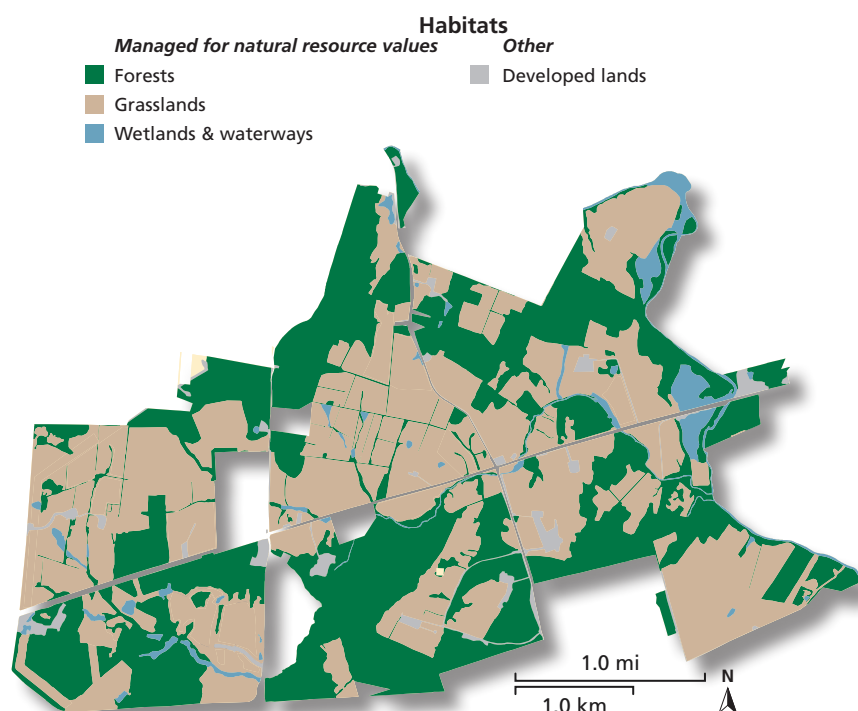


Figure 3.1. GIS data layer²⁸ of major habitat types in Manassas National Battlefield Park, as defined by aggregation of other GIS data layers.

defined 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

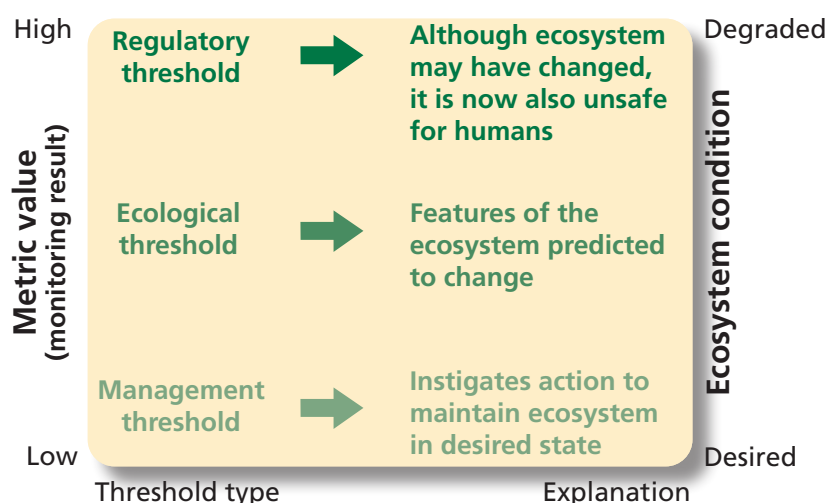
Two frameworks were employed in this assessment: the ecological monitoring framework (based on Inventory & Monitoring Vital Signs) and the habitat framework (Figure 3.4). Measures of priority study resources and indicators are presented within these frameworks. More information on the ecological monitoring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

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).

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).

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	$6.0 \leq \text{pH} \leq 9.0$ (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)	$\geq 4.0 \text{ mg DO L}^{-1}$ (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	$< 32.0^{\circ}\text{C}$ (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)	$> 200 \text{ } \mu\text{eq L}^{-1}$ (monthly instantaneous measurements)	Threshold based on U.S. EPA "sensitive to acidification" standard of $200 \text{ } \mu\text{eq L}^{-1}$ ($1 \text{ mg L}^{-1} \text{ CaCO}_3 = 20 \text{ } \mu\text{eq L}^{-1}$). 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)	$< 2 \text{ mg NO}_3 \text{ L}^{-1}$ (monthly instantaneous measurements)	Threshold based on relationship to benthic invertebrate index.	Southerland et al. 2007
Phosphate (PO_4)	$0.1133 \text{ mg PO}_4 \text{ L}^{-1}$ (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

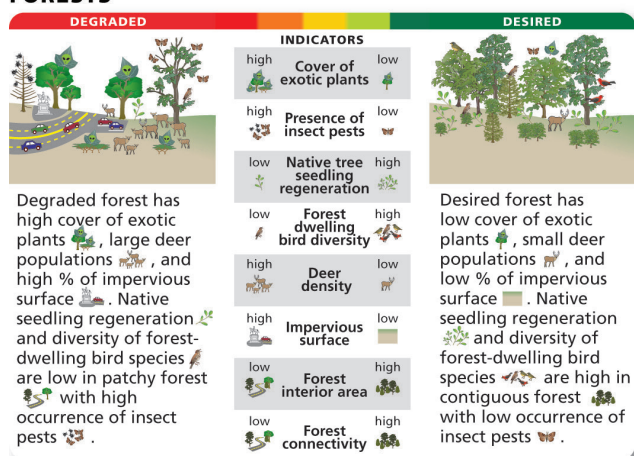
Table 3.3. Thresholds for Biological Integrity metrics.

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

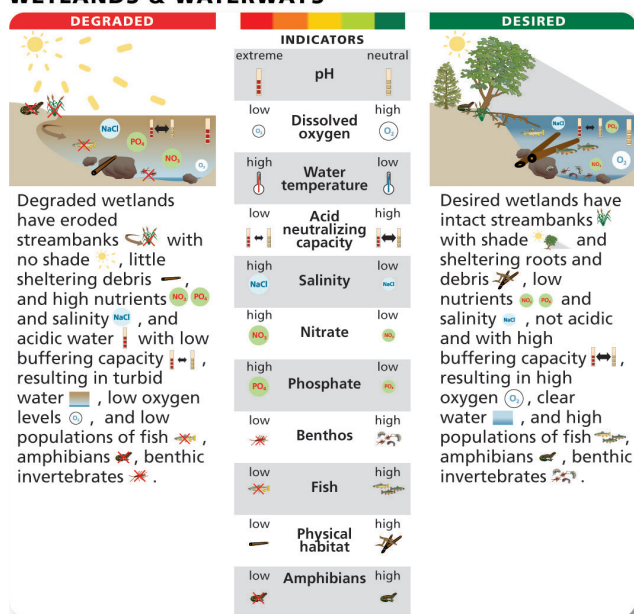
Table 3.4. Thresholds for Landscape Dynamics metrics.

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

FORESTS



WETLANDS & WATERWAYS



GRASSLANDS

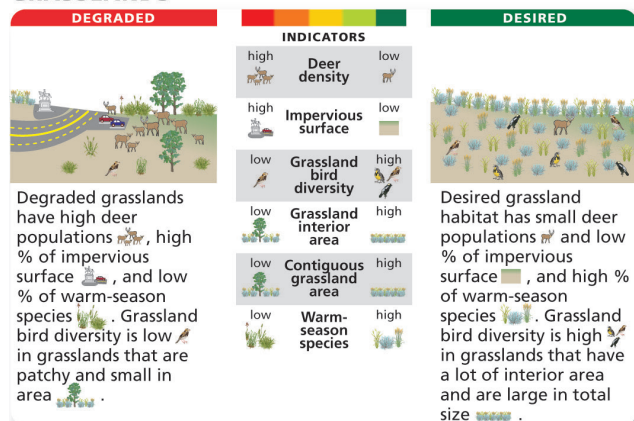


Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Manassas National Battlefield Park, indicating metrics to track status of condition.

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 ($\text{kg ha}^{-1} \text{y}^{-1}$) was used. Natural background deposition of nitrogen and sulfur in the eastern United States is approximately $0.5 \text{ kg ha}^{-1} \text{y}^{-1}$ ($0.4 \text{ lb acre}^{-1} \text{y}^{-1}$; NPS 2005, 2009). Wet deposition makes up roughly half of this amount ($\sim 0.25 \text{ kg ha}^{-1} \text{y}^{-1}$ [$0.2 \text{ lb acre}^{-1} \text{y}^{-1}$]; 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 $3.0\text{--}8.0 \text{ kg ha}^{-1} \text{y}^{-1}$ ($2.7\text{--}7.1 \text{ lb acre}^{-1} \text{y}^{-1}$; wet deposition of $1.5\text{--}4.0 \text{ kg ha}^{-1} \text{y}^{-1}$ [$1.3\text{--}3.6 \text{ lb acre}^{-1} \text{y}^{-1}$]; Fenn et al, 2003; Krupa 2002). The NPS Air Resources Division defines parks with less than $1 \text{ kg ha}^{-1} \text{y}^{-1}$ ($0.89 \text{ lb acre}^{-1} \text{y}^{-1}$) 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 $0.5 \text{ mg methylmercury kg}^{-1}$ (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 $0.3 \text{ mg methylmercury kg}^{-1}$ (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.svs.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 criteria 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: Non-tidal 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) CaCO₃ = 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 NO₃ 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)
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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 $0.03656 \text{ mg P L}^{-1}$ (36.56 ppb), which equates to a phosphate threshold of $0.1133 \text{ mg PO}_4 \text{ L}^{-1}$ (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 km² (62,500 mi²) 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 $10\text{--}17 \text{ km}^{-2}$ ($26\text{--}44 \text{ deer mi}^{-2}$) inhibited the regeneration of understory species, while densities of $3\text{--}6 \text{ deer km}^{-2}$ ($8\text{--}16 \text{ deer mi}^{-2}$) 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 $\geq 100 \text{ m}$ (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 (D_{crit}) 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 $\pm$ 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 ($3,271 \pm 1,450$ 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, D_{crit} 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 In-

tegrity, 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

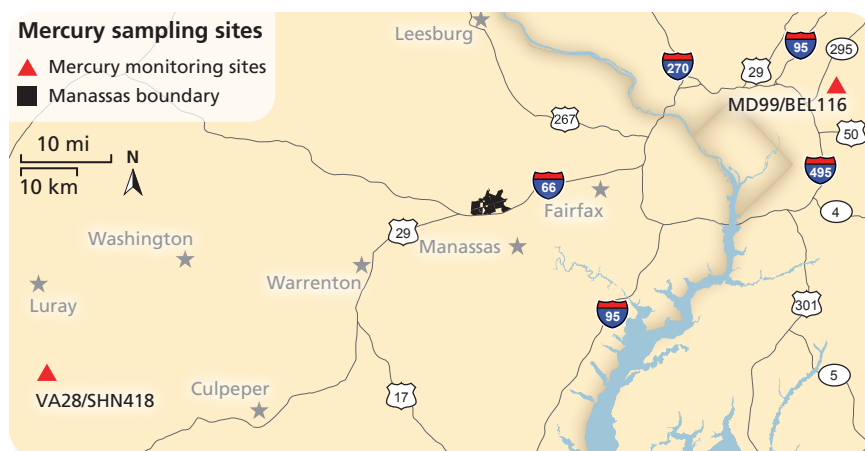


Figure 3.5. Map of sampling stations MD99/BEL116 and VA28/SHN418²⁹ used for measuring mercury concentrations near Manassas National Battlefield Park.

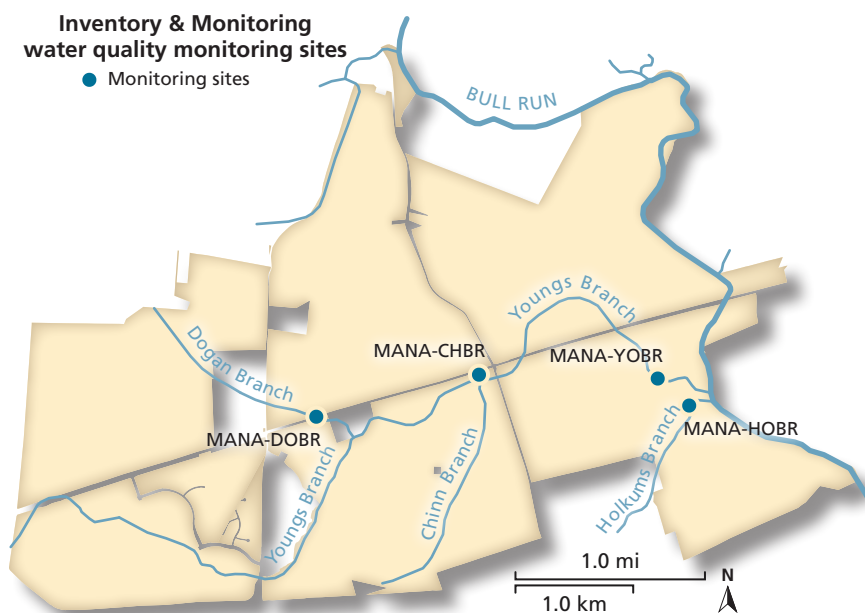


Figure 3.6. Stream sampling locations³⁰ used for long-term water quality monitoring at Manassas National Battlefield Park.

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 locations³¹ monitored for BIBI, FIBI, and PHI.

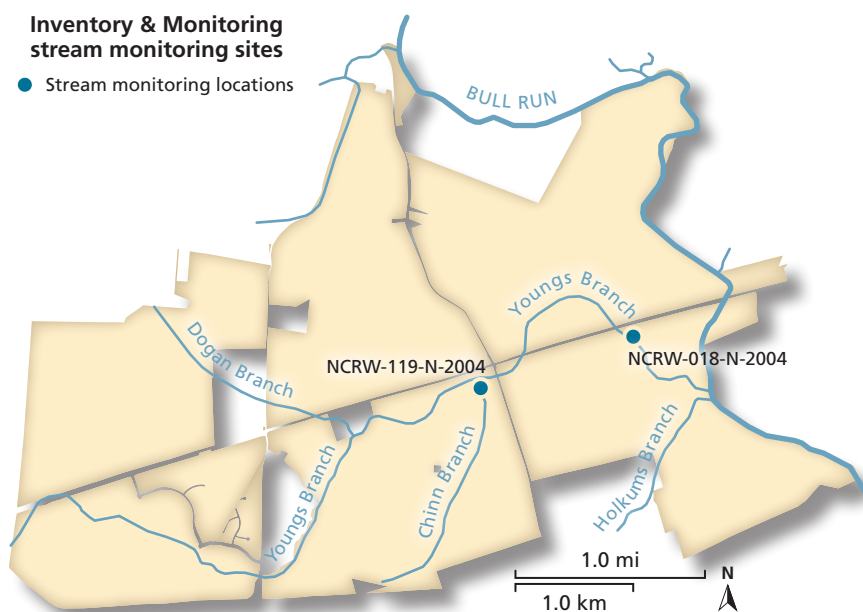
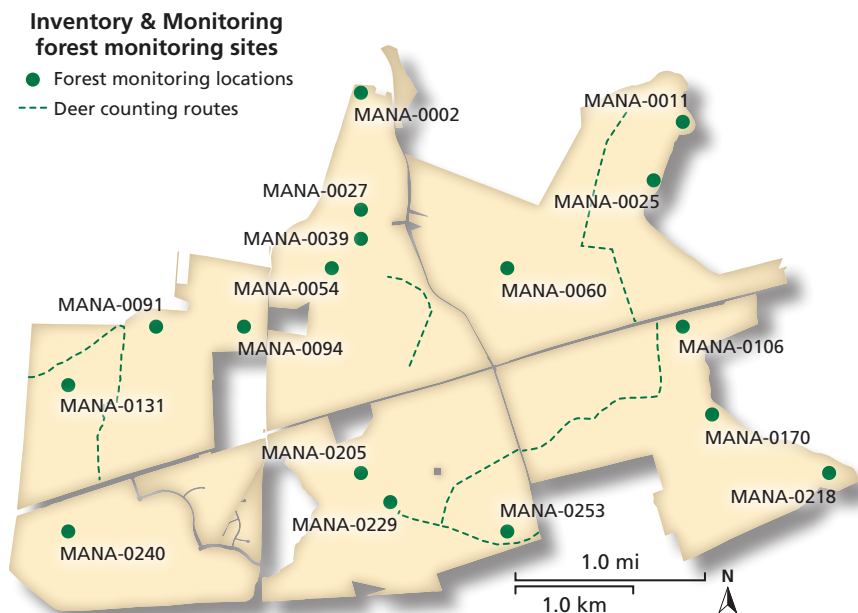


Figure 3.8. Forest monitoring sites and deer counting routes³² in Manassas National Battlefield Park.



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	≤ 32.0°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
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%
<i>Habitats managed for natural resource values</i>	1,739	4,299	
TOTAL AREA ASSESSED	1,739	4,299	

3.6 LITERATURE CITED (CHAPTER 3)

- Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964, U.S. Geological Survey, Reston, VA.
- Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A.S. Weakley. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume II. The National Vegetation Classification System: List of types. The Nature Conservancy, Arlington, VA.
- Arnold Jr, C.L. and C.J. Gibbons. 1996. Impervious surface coverage. *Journal of the American Planning Association* 62: 243–269.
- Bailey, L.L., E.H. Campbell Grant, and P. Mattfeldt. 2007. National Capital Region Network Amphibian Monitoring Protocol. <http://science.nature.nps.gov/im/monitor/VitalSigns/BrowseProtocol.aspx>
- Bates, S. 2007. National Capital Region Network 2006 deer monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2007/033. National Park Service, Fort Collins, CO.
- Bennetts, R.E., J.E. Gross, K. Cahill, C. McIntyre, B.B. Bingham, A. Hubbard, L. Cameron, and S.L. Carter. 2007. Linking monitoring to management and planning: assessment points as a generalized approach. *The George Wright Forum* 24: 59–79.
- Biggs, H.C. 2004. Promoting ecological research in national parks – a South African perspective. *Ecological Applications* 14: 21–24.
- Bowman, J., A. Jochen, G. Jaeger, and L. Fahrig. 2002. Dispersal distance of mammals in proportion to home range size. *Ecology* 83: 2049–2055.
- Burger, L.D., L.W. Burger, Jr., & J.R. Faaborg. 1994. Effects of prairie fragmentation on predation on artificial nests. *Journal of Wildlife Management*. 58: 249–254.
- Carter, W.K. and T.S. Fredericksen. 2007. Tree seedling and sapling density and deer browsing incidence on recently logged and mature non-industrial private forestlands in Virginia, USA. *Forest Ecology and Management* 242: 671–677.
- Cuffney, T.F., R.A. Brightbill, J.T. May, and I.R. Waite. 2010. Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. *Ecological Applications* 20: 1134–1401.
- Decalesta, D.S. 1997. Deer ecosystem management. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). *The science of overabundance: deer ecology and population management*. Springer, Netherlands.
- Dupont, J., T.A. Clair, C. Gagnon, D.S. Jeffries, J.S. Kahl, S.J. Nelson, and J.M. Peckenhams. 2005. Estimation of critical loads of acidity for lakes in northeastern United States and eastern Canada. *Environmental Monitoring and Assessment*. 109: 275–291.
- Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, W.E. Braselton, A. Major, N. Burgess, and A.M. Scheuhammer. 1998. Geographic trend in mercury measured in common loon feathers and blood. *Environmental Toxicology and Chemistry* 17: 173–183.
- Fancy, S.G., J.E. Gross, and S.L. Carter. 2008. Monitoring the condition of natural resources in U.S. national parks. *Environmental Monitoring and Assessment: Electronically published May 29, 2008*.
- Fenn, M.E., J.S. Baron, E.B. Allen, H.M. Rueth, K.R. Nydick, L. Geiser, W.D. Bowman, J.O. Sickman, T. Meixner, D.W. Johnson, and P. Neitlich. 2003. Ecological effects of nitrogen deposition in the western United States. *BioScience* 53: 404–420.
- Goodwin, S. and G. Shriver. 2009. Avian monitoring in the National Capital Region: 2007 and 2008 Annual Report. Draft. U.S. Department of the Interior.
- Groffman, P.M. J.S. Baron, T. Blett, A.J. Gold, I. Goodman, L.H. Gunderson, B.M. Levinson, M.A. Palmer, H.W. Paerl, G.D. Peterson, N. L. Poff, D.W. Rejeski, J.F. Reynolds, M.G. Turner, K.C. Weathers and J. Wiens. 2006. Ecological thresholds: the key to successful environmental management or an important concept with no practical application? *Ecosystems* 9: 1–13.
- Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, VA.

- Hammerschmidt, C.R. and W.F. Fitzgerald. 2002. Methylmercury in mosquitoes related to atmospheric mercury. *Environmental Science and Technology* 39: 3034–3039.
- Hammerschmidt, C.R. and W.F. Fitzgerald. 2006. Methylmercury in freshwater fish linked to atmospheric mercury deposition. *Environmental Science and Technology* 40: 7764–7770.
- He, H.S. and D.J. Mladenoff. 1999. The effects of seed dispersal on the simulation of long-term forest landscape change. *Ecosystems* 2: 308–319.
- Healy, W.M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). *The science of overabundance: deer ecology and population management*. Springer, Netherlands.
- Hendricks, J. and J. Little 2003. Thresholds for regional vulnerability analysis. Regional vulnerability assessment program. National exposure research laboratory. U.S. EPA (E243-05). http://www.nrac.wvu.edu/classes/resm493Q/files/final_stressor_threshold_table.pdf
- Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 13: 98–118.
- Huggett A. 2005. The concept and utility of "ecological thresholds" in biodiversity conservation. *Biological Conservation* 124: 301–310.
- IUCN. 2007. Habitats classification scheme (version 3.0). International Union for the Conservation of Nature. http://www.iucnredlist.org/info/major_habitats
- Jensen, M.E., K. Reynolds, J. Andreasen, and L.A. Goodman. 2000. A knowledge based approach to the assessment of watershed condition. *Environmental Monitoring and Assessment* 64: 271–283.
- Jones, C., J. McCann, and S. McConville. 2000. A guide to the conservation of forest interior dwelling birds in the Chesapeake Bay Critical Area. Report to the Critical Area Commission for the Chesapeake and Atlantic Coastal Bays http://www.dnr.state.md.us/criticalarea/tweetyjune_2000.pdf
- Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 6: 21–27.
- Kline, L.J., D.D. Davis, J.M. Skelly, J.E. Savage, and J. Ferdinand. 2008. Ozone sensitivity of 28 plants selections exposed to ozone under controlled conditions. *Northeastern Naturalist* 15: 57–66.
- Koskimies, P. 1989. Birds as a tool in environmental monitoring. *Annales Zoologici Fennici* 26: 153–166.
- Krupa, S.V. 2003. Effects of atmospheric ammonia (NH₃) on terrestrial vegetation: A review. *Environmental Pollution* 124: 179–221.
- Liebhold, A., K. Thorpe, J. Ghent, and D.B. Lyons. 1994. Gypsy moth egg mass sampling for decision-making: a user's guide. USDA-Forest Service. NA-TP-04-94. http://www.sandyliebhold.com/pubs/Liebhold_etal_1994_guide_color.pdf
- Lussier, S.M., S.N. da Silva, M. Charpentier, J.F. Heltshe, S.M. Cormier, D.J. Klemm, M. Chintala, and S. Jayaraman. 2008. The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams. *Environmental Monitoring and Assessment* 139: 119–136.
- Mack, R.N, D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10: 689–710.
- MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2005. *Occupancy estimation and modelling: inferring patterns and dynamics of species occurrence*. Academic Press, New York.
- Marquis, D.A., R.L. Ernst, and S.L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). United States Department of Agriculture: Forest Service. General Technical Report NE-96.
- Mattfeldt, S.D., E.H. Grant, and L.L. Bailey. 2008. Amphibian monitoring in the National Capital Region: a focus on lentic and lotic habitats. Natural Resources Technical Report NPS/NRTR/NCRN—2008/088. National Park Service.
- McKee, D.J., V.V. Atwell, H.M. Richmond, W.P. Freas, and R.M. Rodriguez. 1996. Review of national ambient air quality standards for ozone, assessment of scientific and technical information. OAQPS Staff Paper. EPA-452/R-96-007.

- McWilliams, W.H., T.W. Bowersox, D.A. Gansner, L.H. McCormick, and S.L. Stout 1995. Landscape-level regeneration adequacy for native hardwood forests of Pennsylvania. Proceedings, 10th Central Hardwood Forest Conference. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 196-203.
- MD DNR, Forest Service. 2008. Interior Forest. http://www.dnr.maryland.gov/forests/planning/sflalindicators/interior_forest.htm
- MD DNR. Undated. A list of forest interior dwelling birds that currently or historically nested in Maryland. Maryland Department of Natural Resources, Natural Heritage Program.
- Meili, M., K. Bishop, L. Bringmark, K. Johansson, J. Muthe, H. Sverdrup, and W. de Vries. 2003. Critical levels of atmospheric pollution: criteria and concepts for operational modelling of mercury in forest and lake ecosystems. *The Science of the Total Environment* 304: 83–106.
- Montgomery, M.E. 1990. Predicting defoliation by the gypsy moth using egg mass counts and a helper variable. Proceedings U.S. Department of Agriculture Interagency Gypsy Moth Research Review. USDA Forest Service. General Technical Report NE-146.
- NAAQS. 2008. National Ambient Air Quality Standards. <http://www.epa.gov/air/criteria.html#6>
- Norris, M., J.P. Schmit, and J. Pieper. 2007. National Capital Region Network 2005–2006 water resources monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2007/066. Natural Resources Program Center, Fort Collins, CO.
- Norris, M., and Pieper, J. 2010. National Capital Region Network 2009 water resources monitoring report. Natural Resources Data Series NPS/NCR/NCRN/NRDS—2010/095. Natural Resources Program Center, Fort Collins, CO.
- Norris M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report. NPS/NCRN/NRR—2009/116. National Park Service, Fort Collins, CO.
- NPS. 2005. Wet Deposition Monitoring Protocol. U.S. Department of the Interior. D-1655. <http://www.nature.nps.gov/air/Monitoring/docs/200508FinalWetDepProtocol.pdf>
- NPS. 2009. Assessment of Current Air Quality Conditions. U.S. Department of the Interior. http://www.nature.nps.gov/air/Maps/AirAtlas/docs/2009_Assessment_of_Current_Air_Quality_Conditions.pdf
- NPS. 2010. Air quality estimates for the Inventory and Monitoring Program. http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm
- NSDWS. 1997. National Secondary Drinking Water Standards. <http://www.sciencefaircenter.com/nsdws.tpl>
- Pantus, F.J. and W.C. Dennison. 2005. Quantifying and evaluating ecosystem health: A case study from Moreton Bay, Australia. *Environmental Management* 36: 757–771.
- Paul, M.J., J.B. Stribling, R. Klauda, P. Kazyak, M. Southerland, and N. Roth. 2003. A Physical Habitat Index for freshwater Wadeable streams in Maryland. Report to the Maryland Department of Natural Resources, Annapolis, MD.
- Peterjohn, B. 2006. Conceptual ecological model for management of breeding grassland birds in the Mid-Atlantic region. Technical Report NPS/NER/NRR—2006/005. National Park Service, Philadelphia, PA.
- Rossell Jr, C.R., B. Gorsira, and S. Patch. Effects of white-tailed deer on vegetation structure and woody seedling composition in three forest types on the Piedmont Plateau. *Forest Ecology & Management* 210: 415–424.
- Schindler, D.W. 1988. Effects of acid rain on fresh water ecosystems. *Science* 239: 149–157.
- Schmit, J.P. and J.P. Campbell. 2007. National Capital Region Network 2006 forest vegetation monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2007/046. Natural Resource Program Center, Fort Collins, CO.
- Schmit, J.P. and J.P. Campbell. 2008. National Capital Region Network 2007 forest vegetation monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2008/125. Natural Resource Program Center, Fort Collins, CO.
- Southerland, M.T., L.A. Erb, G.M. Rogers, and P.F. Kazyak. 2005. Maryland Biological Stream Survey 2000–2004. Volume 7: statewide and tributary basin results. Prepared for Maryland Department of Natural Resources.

- Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. *Ecological Indicators* 7: 751–767.
- State Water Control Board. 2009. 9 VAC 25-260 Virginia Water Quality Standards. Statutory Authority: § 62.1-44.15 3a of the Code of Virginia. With amendments effective August 20, 2009.
- Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: A comparison of two models. In: Verner, J., M.L. Morrison, and C.J. Ralph (eds). *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*.
- Terborgh, J. 1992. Why American songbirds are vanishing. *Scientific American* 266: 98–104.
- Townsend, P.A., R.H. Gardner, T.R. Lookingbill, and C.C. Kingdom. 2006. National Capital Region Network—remote sensing and landscape pattern protocol for long-term monitoring of parks. University of Maryland Center for Environmental Science, Appalachian Laboratory, Frostburg, MD.
- Townsend, P.A., T.R. Lookingbill, C.C. Kingdom, and R.H. Gardner. 2009. Spatial pattern analysis for monitoring protected areas. *Remote Sensing of Environment* 113: 1410–1420.
- USDA (United States Department of Agriculture) Forest Service. 2009a. Gypsy moth in North America. <http://www.fs.fed.us/ne/morgantown/4557/gmoth/>
- USDA (United States Department of Agriculture) Forest Service. 2009b. Hemlock woolly adelgid, Forest Health Protection, USDA Forest Service. <http://na.fs.fed.us/fhpl/hwal/>
- U.S. EPA. 2000. Ambient water quality criteria recommendations – rivers and streams in Nutrient Ecoregion IX. EPA 822-B-00-019.
- U.S. EPA. 2001. Water quality criterion for the protection of human health: methylmercury. United States Environmental Protection Agency, Washington DC. EPA-823-R-01-001.
- U.S. EPA. 2002. A Framework for Assessing and Reporting on Ecological Condition: an SAB Report. Environmental Protection Agency. Science Advisory Board. Washington, DC. EPA-SAB-EPEC-02-009.
- U.S. EPA. 2003. Guidance for estimating natural visibility conditions under the regional haze rule. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Contract No. 68-D-02-0261, Work Order No. 1-06.
- U.S. EPA. 2004. The Clean Air Act. Washington United States Environmental Protection Agency, Washington DC. <http://epw.senate.gov/envlaws/cleanair.pdf>
- U.S. EPA. 2006. Air quality criteria for ozone and related photochemical oxidants. Volume I of III. EPA 600/R-05/004aF.
- U.S. EPA. 2009. National recommended water quality criteria. <http://www.epa.gov/waterscience/criteria/wqctable/>
- Wolfe, M.F., S. Schwarzbach, and R.A. Sulaiman. 1998. Effects of mercury on wildlife: a comprehensive review. *Environmental Toxicology and Chemistry* 17: 146–160.

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.

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



Grassland road.

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

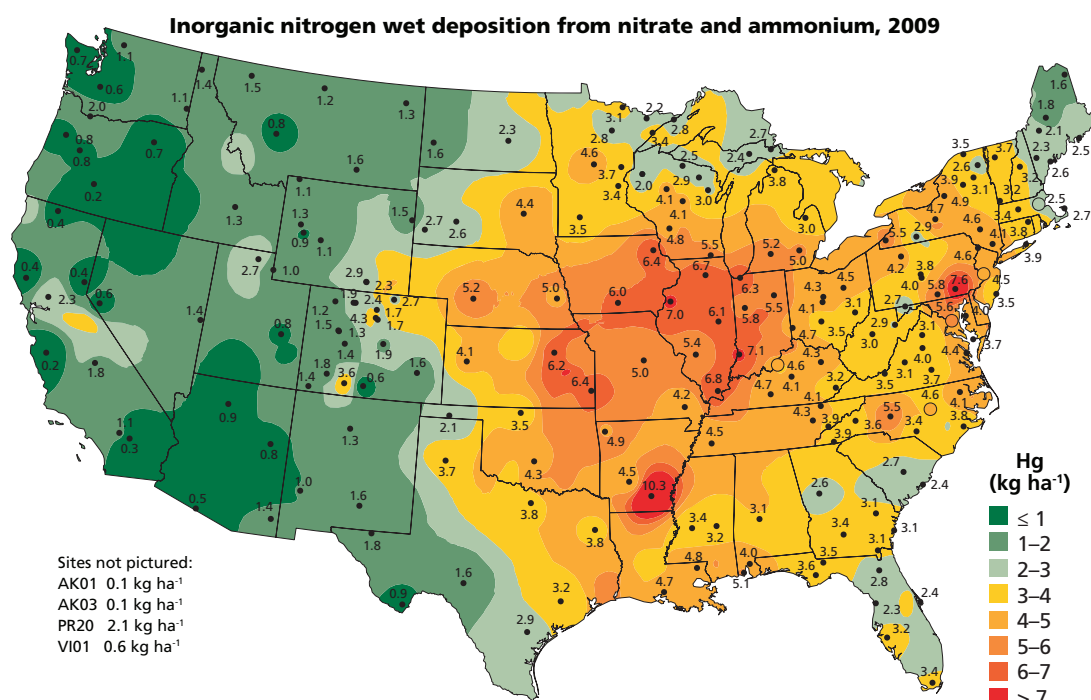
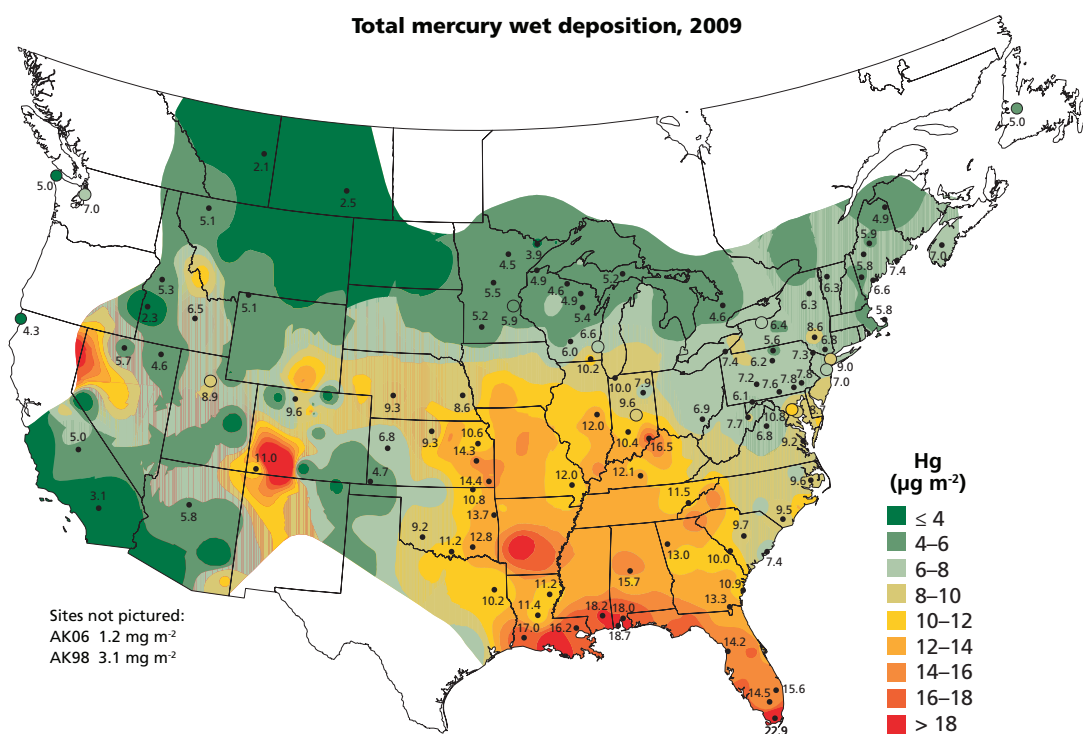


Figure 4.2. Total wet mercury (Hg) deposition ($\mu\text{g m}^{-2}$) for the continental United States in 2009.³⁴



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>

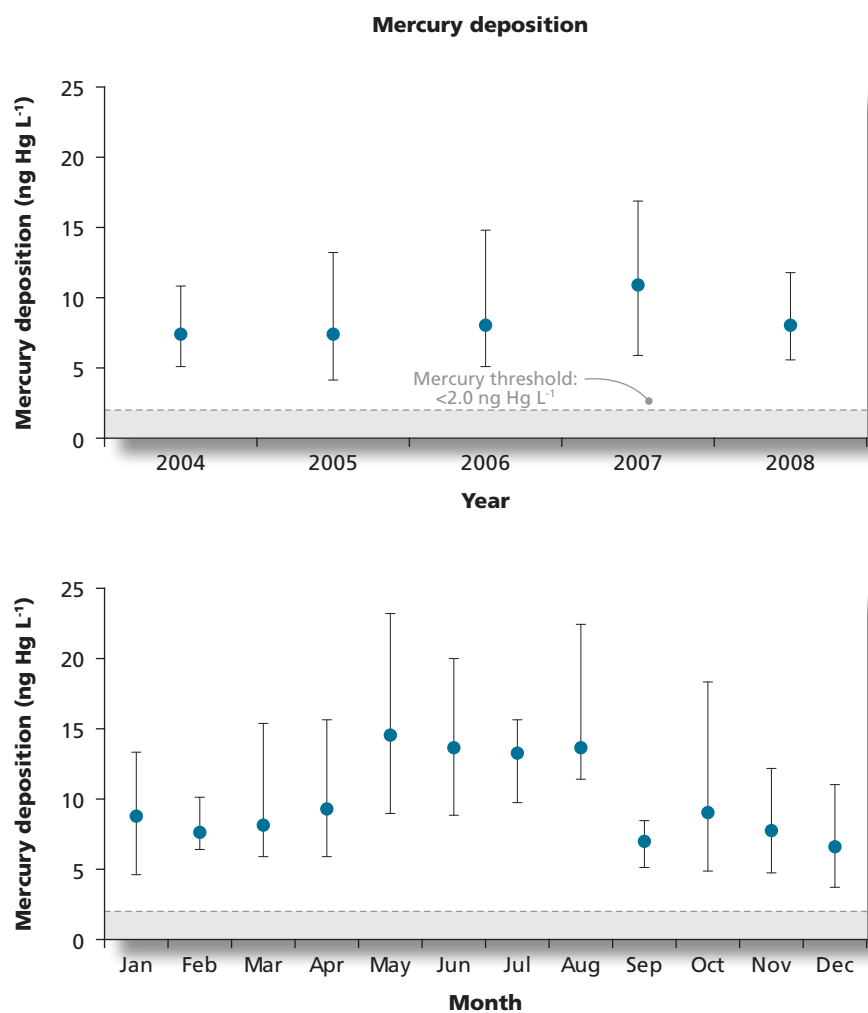


Figure 4.3. Mean monthly mercury deposition (ng Hg L⁻¹) from 2004 to 2007 at sites VA28 and MD99 (see Figure 3.4).³⁵ Acceptable range (Hg ≤ 2 ng L⁻¹) is shown in gray.

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	62	55		
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				
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	64	55		
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				
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	48	55		
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				
Contiguous grassland area	83 ha	100				
Cover of warm-season grassland	33%	33				

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	

HABITAT-BASED NATURAL RESOURCE CONDITION ASSESSMENT OF MANASSAS NATIONAL BATTLEFIELD PARK

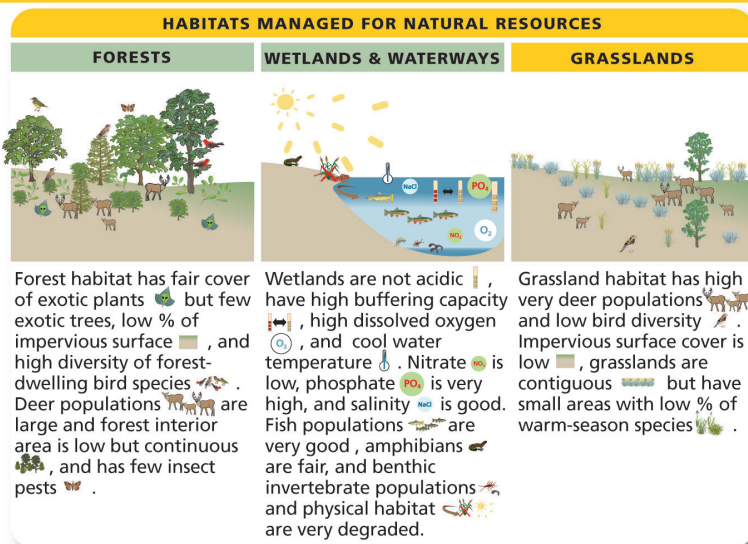


Figure 4.4. Summary results of habitat-based resource condition assessment of Manassas National Battlefield Park.

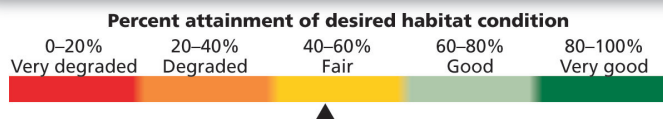


Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Manassas National Battlefield Park.³⁶ The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

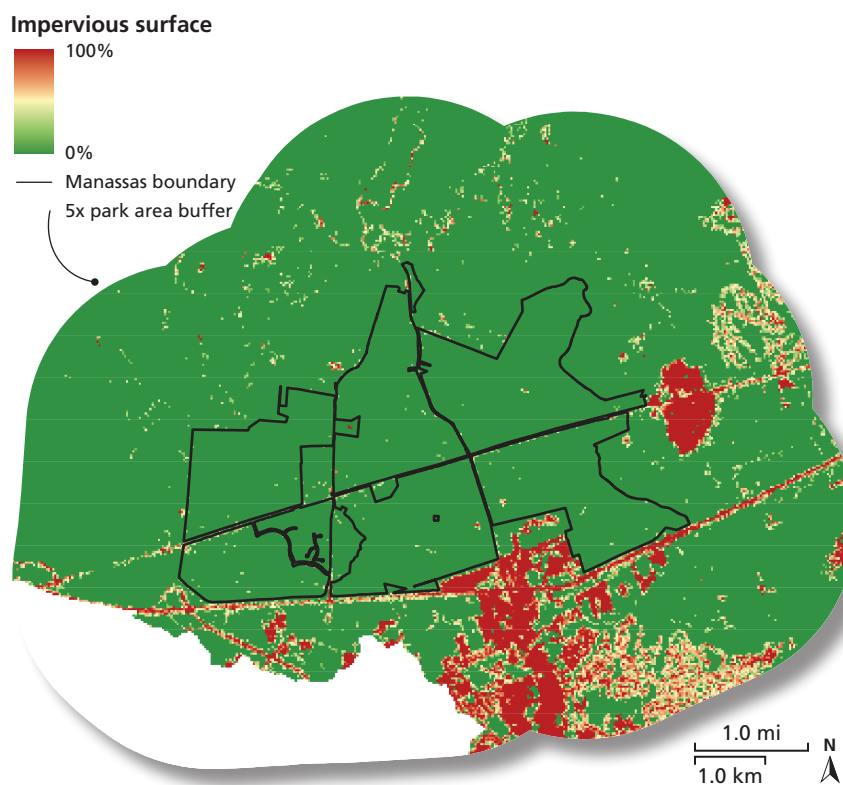


Figure 4.6. Extent of forest and non-forest landcover (Landsat 30-m) within and around Manassas National Battlefield Park in 2000.³⁷ The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.



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.

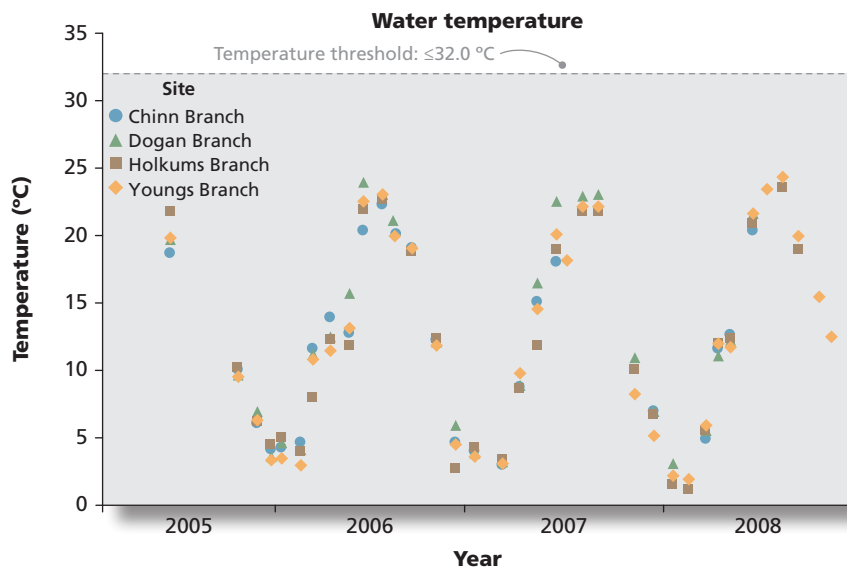


Figure 4.8. Water temperature (°C) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.³⁹ Acceptable range (temp. ≤ 32.0 °C) is shown in gray.

38. NCRN I&M.

39. Norris et al. 2007.

Figure 4.9. Acid neutralizing capacity (ANC; $\mu\text{eq L}^{-1}$) from 2005 to 2008 for three stream sampling location (see Figure 3.5) in Manassas National Battlefield Park.⁴⁰ Acceptable range (ANC $\geq 200 \mu\text{eq L}^{-1}$) is shown in gray.

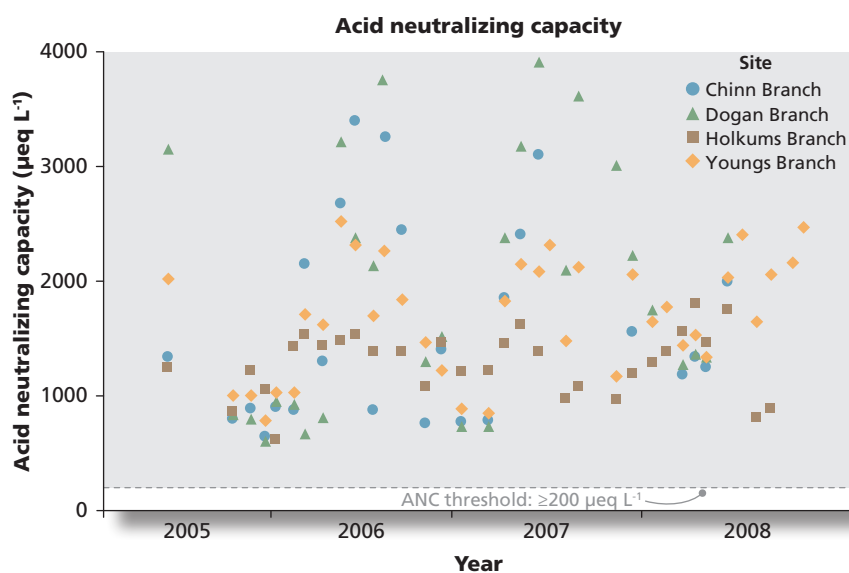
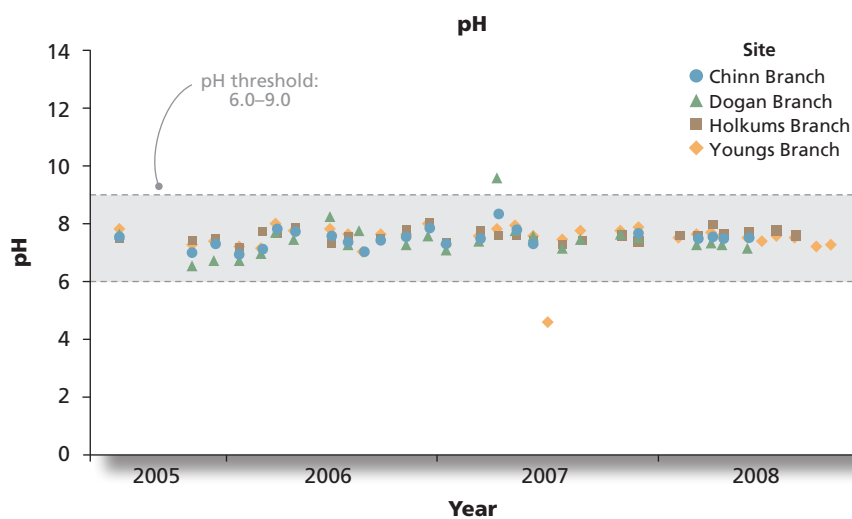


Figure 4.10. pH values from 2005 to 2008 for four stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.⁴¹ Acceptable ranges ($6.0 \leq \text{pH} \leq 9.0$) are shown in gray.



40. Norris et al. 2007.

41. Norris et al. 2007.

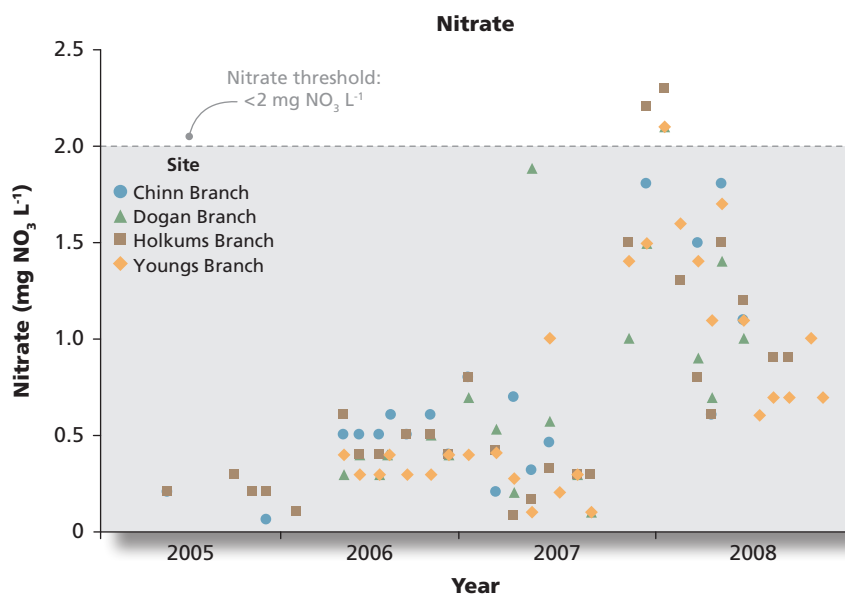


Figure 4.11. Nitrate concentration ($\text{mg NO}_3 \text{ L}^{-1}$) from 2005 to 2008 for 16 stream sampling locations (see Figure 3.5) in Manassas National Battlefield Park.⁴² Acceptable range ($\text{NO}_3 \leq 2.0 \text{ mg L}^{-1}$) is shown in gray.

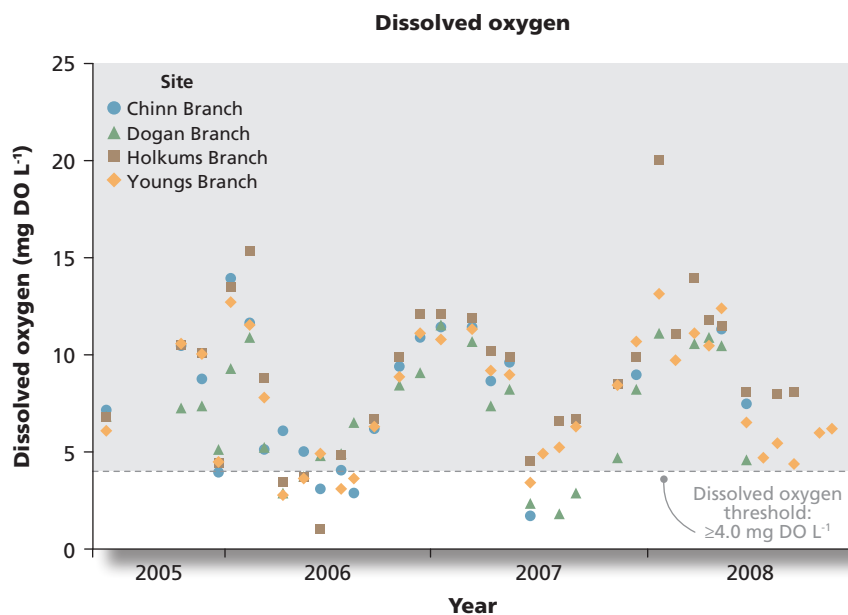


Figure 4.12. Dissolved oxygen concentration (mg DO L^{-1}) from 2005 to 2008 for four stream sampling locations in Manassas National Battlefield Park (see Figure 3.5).⁴³ Acceptable range ($\text{DO} \geq 4.0 \text{ mg L}^{-1}$) is shown in gray.

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.

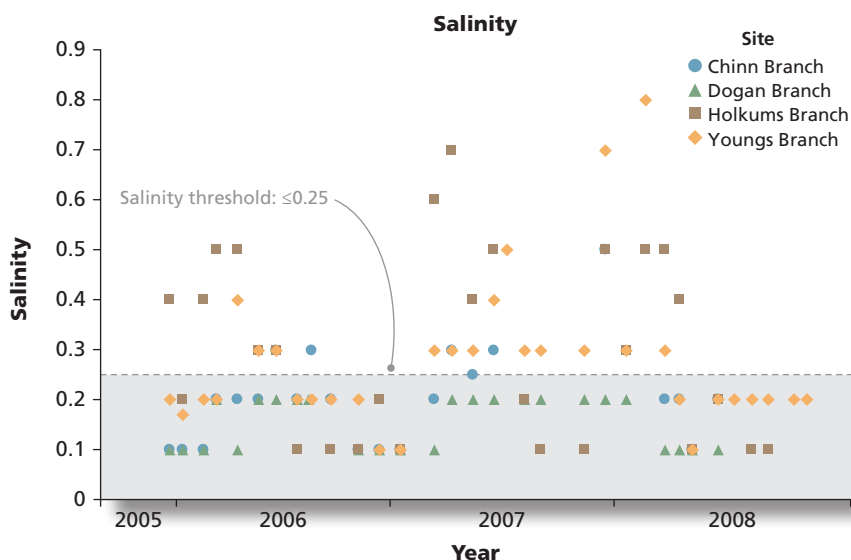
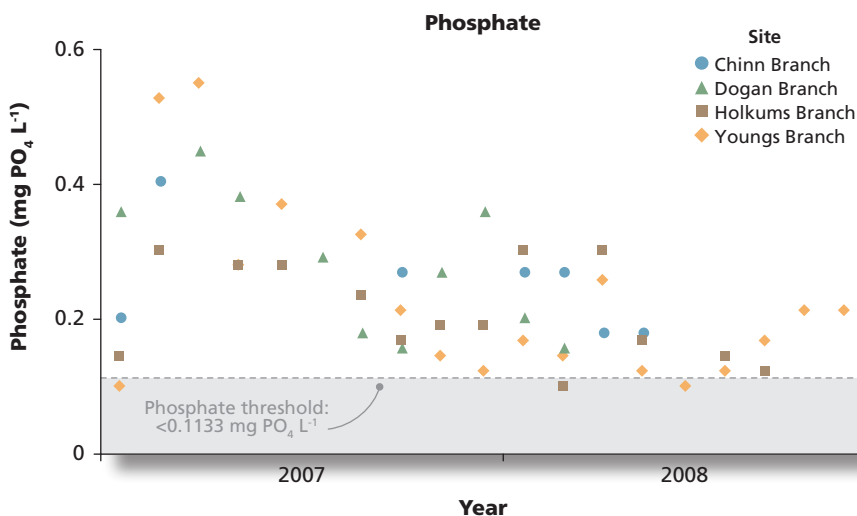


Figure 4.14. Phosphate concentrations ($\text{mg PO}_4 \text{ L}^{-1}$) from 2007 to 2008 for four stream sampling locations (see Figure 3.5) for Manassas National Battlefield Park.⁴⁵ Acceptable range ($\text{PO}_4 < 0.1133 \text{ mg L}^{-1}$) is also shown in gray.



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.

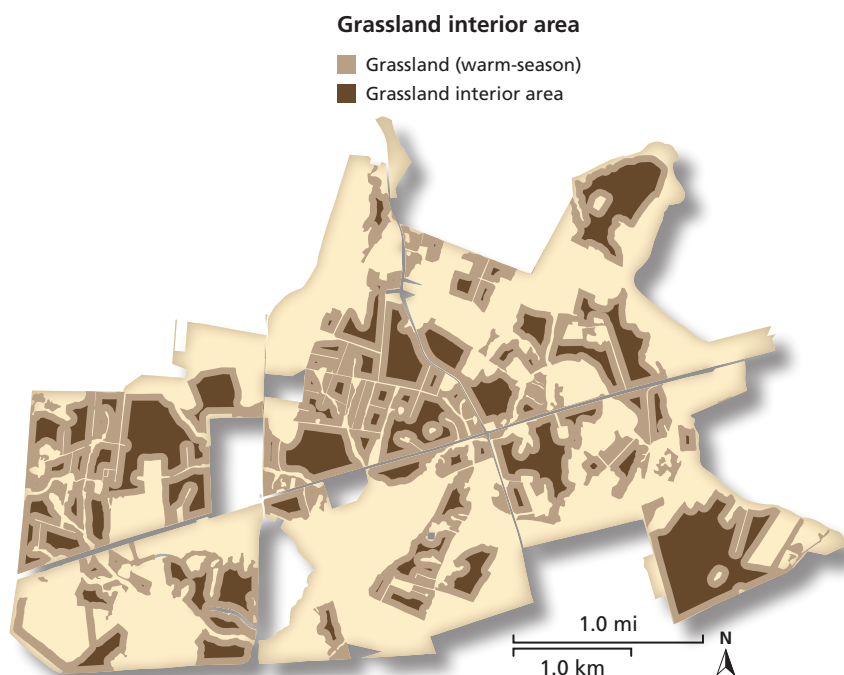
Biological Integrity

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				48
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		
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		
Forest connectivity (within park) + 5X buffer	90 m	100	73	
Grassland interior area	28%	31		
Contiguous grassland area	83 ha	100		
Cover of warm-season grassland	33%	33		

48

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



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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 effects 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)

- Goodwin, S. and G. Shriver. 2009. Avian monitoring in the National Capital Region: 2007 and 2008 annual report. Draft. U.S. Department of the Interior.
- Mayer, P.M., S.K. Reynolds, M.D. McCutchen, and T.J. Canfield. 2006. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations. EPA/600/R-05/118. Cincinnati, OH, U.S. Environmental Protection Agency.
- Peterjohn, B. 2006. Grassland and shrubland birds on Manassas National Battlefield Park: current status and management recommendations. Draft report. USGS Patuxent Wildlife Research Center, Laurel, MD.
- 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

Manassas National Battlefield Park Natural Resource Condition Assessment

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

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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			
<i>Buteo lineatus</i>	Red-shouldered hawk	✓	✓
<i>Dendroica caerulescens</i>	Black-throated blue warbler	✓	—
<i>Dendroica virens waynei</i>	Black-throated green warbler	✓	—
<i>Dryocopus pileatus</i>	Pileated woodpecker	✓	—
<i>Empidonax vireescens</i>	Acadian flycatcher	✓	✓
<i>Parula americana</i>	Northern parula	✓	✓
<i>Setophaga ruticilla</i>	American redstart	✓	—
<i>Strix varia</i>	Barred owl	✓	—
Number of species		8	3
Mean			5.5
Std error			2.5
Sensitive			
<i>Bureo platypterus</i>	Broad-winged hawk	—	✓
<i>Catharus fuscenscens</i>	Veery	✓	—
<i>Catharus guttatus</i>	Hermit thrush	✓	—
<i>Catharus ustulatus</i>	Swainson's thrush	—	✓
<i>Helmitheros vermivorus</i>	Worm-eating warbler	✓	—
<i>Hylocichla mustelina</i>	Wood thrush	✓	✓
<i>Picoides villosus</i>	Hairy woodpecker	—	✓
<i>Piranga olivacea</i>	Scarlet tanager	✓	✓
<i>Seiurus aurocapillus</i>	Ovenbird	✓	—
<i>Vireo olivaceus</i>	Red-eyed vireo	✓	✓
<i>Wilsonia citrina</i>	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
<i>Ammodramus savannarum</i>	Grasshopper sparrow		✓		
<i>Sturnella magna</i>	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		
<i>Acalypha virginica</i>	mercuryweed, threeseeded mercury, Virginia copperleaf, Virginia three-seed mercury, wax balls	Native
<i>Acer negundo</i>	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder	Native
<i>Acer platanoides</i>	Norway maple	Non-Native
<i>Acer rubrum</i>	red maple	Native
<i>Acer saccharinum</i>	silver maple	Native
<i>Achillea millefolium</i>	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)	Non-Native
<i>Adiantum pedatum</i>	maidenfern, maidenhair, maidenhair fern, northern maidenhair	Native
<i>Agalinis purpurea</i>	purple false foxglove	Native
<i>Agalinis tenuifolia</i>		Native
<i>Ageratina altissima</i>	white snakeroot	Native
<i>Agrimonia parviflora</i>	harvestlice, manyflowered groovebur	Native
<i>Agrimonia pubescens</i>	groovebur, roadside agrimony, soft agrimony, soft groovebur	Native
<i>Agrimonia rostellata</i>	beaked agrimony, woodland groovebur	Native
<i>Agrostis eliottiana</i>	Elliot bentgrass, eliott bentgrass, Elliott's bentgrass	Native
<i>Agrostis gigantea</i>	black bent, redtop, water bentgrass	Non-Native
<i>Agrostis hyemalis</i>		Native
<i>Agrostis hyemalis var. scabra</i>	ticklegass	Native
<i>Agrostis perennans</i>	autumm bentgrass, upland bent, upland bentgrass	Native
<i>Agrostis perennans var. perennans</i>	autumn bent grass, upland bent grass, upland bentgrass	Native
<i>Ailanthus altissima</i>	ailanthus, copal tree, tree of heaven, tree-of-heaven	Non-Native
<i>Albizia julibrissin</i>	mimosa, mimosa tree, powderpuff tree, silk tree, silktree	Non-Native
<i>Alisma subcordatum</i>	American water plantain, waterplaintain	Native
<i>Alliaria petiolata</i>	garlic mustard, garlic-mustard	Non-Native
<i>Allium canadense</i>	Canada garlic, meadow garlic, meadow onion, wild onion	Native
<i>Allium vineale</i>	wild garlic	Non-Native
<i>Ambrosia artemisiifolia</i>		Native
<i>Ambrosia trifida</i>	blood ragweed, giant ragweed, great ragweed, horseweed, perennial ragweed (great), tall ragweed	Non-Native
<i>Amelanchier arborea</i>		Native
<i>Amelanchier laevis</i>	Allegheny serviceberry	Native
<i>Amelanchier stolonifera</i>	running service-berry, running serviceberry	Native
<i>Amphicarpa bracteata</i>		Native
<i>Amphicarpaea bracteata</i>	American hogpeanut, hog-peanut	Native
<i>Andropogon gerardii</i>	big bluestem, bluejoint, turkeyfoot	Native
<i>Andropogon virginicus</i>	broomsedge, broomsedge bluestem, yellow bluestem	Native
<i>Anemone quinquefolia</i>	nightcaps	Native
<i>Anemone virginiana</i>	tall thimbleweed, Virginia anemone	Native
<i>Anemonella thalictroides</i>		Native
<i>Angelica venenosa</i>	hairy angelica, venous angelica	Native
<i>Antennaria neglecta</i>	field pussytoes	Native

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Scientific name	Common name/s	Status
Vascular plants		
<i>Viola cucullata</i>	marsh blue violet	Native
<i>Viola hastata</i>	halberdleaf yellow violet	Native
<i>Viola palmata</i> var. <i>triloba</i>		Native
<i>Viola pubescens</i> var. <i>leiocarpon</i>		Native
<i>Viola pubescens</i> var. <i>pubescens</i>	downy yellow violet, smooth yellow violet	Native
<i>Viola sagittata</i>	arrow-leaved violet, arrowleaf violet	Native
<i>Viola sororia</i>	common blue violet, hooded blue violet	Native
<i>Viola striata</i>	striped cream violet	Native
<i>Vitis aestivalis</i> var. <i>aestivalis</i>	summer grape	Native
<i>Vitis aestivalis</i> var. <i>bicolor</i>	summer grape	Native
<i>Vitis vulpina</i>	fox grape, frost grape, wild grape	Native
<i>Vulpia myuros</i>	foxtail fescue, rat-tail fescue, rat-tailed fescue, rattail fescue	Non-Native
<i>Vulpia octoflora</i>	eight-flower six-weeks grass, pullout grass, sixweeks fescue, sixweeks grass	Native
<i>Xanthium strumarium</i>	cocklebur, cockleburr, common cocklebur, rough cocklebur, rough cocklebur	Native
<i>Yucca filamentosa</i>	Adam's needle	Native
<i>Zanthoxylum americanum</i>	common pricklyash, Common prickly-ash, toothachetree	Native
<i>Zizia aptera</i>	heart-leaf alexanders, heartleaf alexanders, meadow zizia, meadowparsnip, zizia	Native
<i>Zizia aurea</i>	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		
<i>Ameiurus natalis</i>	yellow bullhead	Native
<i>Ameiurus nebulosus</i>	brown bullhead	Native
<i>Anguilla rostrata</i>	American eel	Native
<i>Catostomus commersoni</i>	white sucker	Native
<i>Chaenobryttus gulosus</i>	warmouth	Non-Native
<i>Clinostomus funduloides</i>	rosyside dace	Native
<i>Cyprinella analostana</i>	satinfin shiner	Native
<i>Cyprinella galactura</i>	whitetail shiner	Native
<i>Cyprinella spiloptera</i>	spotfin shiner	Native
<i>Enneacanthus gloriosus</i>	bluespotted sunfish	Native
<i>Erimyzon oblongus</i>	creek chubsucker	Native
<i>Esox americanus</i>	redfin pickerel	Native
<i>Etheostoma flabellare</i>	fantail darter	Native
<i>Etheostoma olmstedii</i>	tessellated darter	Native
<i>Exoglossum maxillingua</i>	cutlips minnow	Native
<i>Hybognathus regius</i>	eastern silvery minnow	Native
<i>Hypentelium nigricans</i>	northern hogsucker	Native
<i>Ictalurus punctatus</i>		Non-Native
<i>Lepomis auritus</i>	redbreast sunfish	Native
<i>Lepomis cyanellus</i>	green sunfish	Non-Native
<i>Lepomis gibbosus</i>	pumpkinseed	Native
<i>Lepomis macrochirus</i>		Non-Native
<i>Luxilus cornutus</i>	common shiner	Native
<i>Micropterus dolomieu</i>	smallmouth bass	Non-Native
<i>Micropterus salmoides</i>	largemouth bass	Non-Native
<i>Nocomis micropogon</i>	river chub	Native
<i>Notemigonus crysoleucas</i>	golden shiner	Native
<i>Notropis amoenus</i>	comely shiner	Native
<i>Notropis hudsonius</i>	spottail shiner	Native
<i>Notropis procne</i>	swallowtail shiner	Native
<i>Notropis rubellus</i>	rosyface shiner	Native
<i>Noturus insignis</i>	marginated madtom	Native
<i>Percina peltata</i>	shield darter	Native
<i>Pimephales notatus</i>	bluntnose minnow	Non-Native
<i>Pomoxis nigromaculatus</i>	black crappie	Non-Native
<i>Rhinichthys atratulus</i>	blacknose dace	Native
<i>Rhinichthys cataractae</i>	longnose dace	Native
<i>Semotilus atromaculatus</i>	creek chub	Native
<i>Semotilus corporalis</i>	fallfish	Native
<i>Rhinichthys atratulus</i>	blacknose dace, eastern blacknose dace	Native
<i>Rhinichthys cataractae</i>	longnose dace	Native
<i>Semotilus atromaculatus</i>	creek chub	Native
<i>Semotilus corporalis</i>	fallfish	Native

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

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

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

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

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

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

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

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

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

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

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

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

Bailey, L.L., E.H. Campbell Grant, and S.D. Matfeldt. 2007. Amphibian monitoring protocol, revision 1.3. Northeast Amphibian and Research Monitoring Initiative, USGS Patuxent Wildlife Research Center, Laurel, MD.

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 National 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.

Norris, M. and J. Pieper. 2010. National Capital Region Network 2009 Water resources monitoring report. Natural Resource Data Series NPS/NCR/NCRN/NRDS—2010/095. Natural Resource Program Center, Fort Collins, CO.

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.

Schmit, J.P., G. Sanders, M. Lehman, and T. Paradis. 2009. National Capital region Network long-term forest vegetation monitoring protocol, version 2.0. Natural Resource Report NPS/NCRN/NRR—2009/113. Natural Resource Program Center, Fort Collins, CO.

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.

Anderson, R.R., D.M. McFaden, M.C. Jeck, and S. Daniels. 1976. Resources basic inventory, Manassas National Battlefield Park. Department of Biology, American University, Washington, DC.	Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 10. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 1. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Cundiff dam, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 2. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Dunn dam, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 3. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Wheeler 2 dam. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 4. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Pageland dam 1, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 5. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Pageland dam 2, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 6. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: White Oak dam, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 7. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Arthur Beard Engineers. 1989. Informal dam inspection report, National Dam Safety Program: Williams Center dam, Manassas National Battlefield Park. Arthur Beard Engineers, for the National Park Service, Vienna, VA.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 8. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Bates, S. 2006. National Capital Region deer survey report—fall 2005.
Arthur Beard Engineers. 1982. Informal dam inspection report, National Dam Safety Program: Manassas National Battlefield Park, Manassas dam 9. Arthur Beard Engineers, for the National Park Service, Vienna, VA.	Bates, S. 2009. National Capital Region Network 2007 deer monitoring report. NPS/NCRN/NRTR—2009/183 National Park Service, Fort Collins, CO.
	Belden, A., G.P. Flemming, and N.E. Van Alstine. 1998. A National Heritage Inventory of Manassas National Battlefield Park.,

74. Richmond, VA: Virginia Department of Conservation and Recreation, Division of Natural Heritage. Abstract: This report contains results from an inventory designed to document the presence/absence, distribution, and population status of rare, threatened or endangered species. Includes global ranking data and important management recommendations in addition.
- Biaisolli, T. 2000. Letter.
- Bulmer, W. 2000. Manassas checklist: mammals, amphibians and reptiles. 3. Abstract: Checklist of mammals, amphibians and reptiles, based on Walt Bulmer's work with students at Northern Virginia Community College.
- Bulmer, W. 2001. Manassas National Battlefield park survey. 8. Abstract: Results of 16 visits to Manassas National Battlefield Park to survey for amphibians, reptiles and mammals occurring between February and October 2000. Species lists and the habitats in which the species were recorded are provided.
- C & C Analytical Services. 1993. Stream water quality in Manassas National Battlefield Park, Manassas, VA. C & C Analytical Services, Woodbridge, VA.
- Calio, A.W. 1990. Beaver population dynamics in Manassas National Battlefield Park.
- Causey, M.F. 1985. Untitled: Kestrel monitoring. Manassas, VA.
- Chazal, A.C. 2000. Surveys for rare insects and crustaceans in Manassas National Battlefield Park. 46. Richmond, VA: Virginia Department of Conservation and Recreation, Division of Natural Heritage. Abstract: Results from a 1998 cooperative agreement between the Virginia Department of Conservation and Recreation, Division of Natural Heritage and the US Department of the Interior, National Park Service to conduct an inventory for selected rare insect and c...Notes: Survey performed under Cooperative Agreement CA3840-9-8001.
- Crist, A.L. 1979. Untitled: Soil and water conservation plan, Manassas National Battlefield Park. US Department of Agriculture, Soil Conservation Service, Manassas, VA.
- Dames & Moore. 1979. Selected inventory, analysis, and mapping of resource variables, phase II - Manassas National Battlefield, Virginia. Dames and Moore, for the National Park Service, Washington, DC. Contract No. Cx 3000-8-0017.
- Davis, J.A. and R. Michaelson. 1988. Bills on indoor air pollution, Manassas battlefield advance (includes various energy and environment legislative activity). Congressional Quarterly Weekly Report. 46:1990 (1).
- Dent, J. 2000. Data for Manassas National Battlefield Subsection. In Author unknown. Christmas Bird Count 12/23/2000.
- Dent, J. 2001. Data for Manassas National Battlefield Park Subsection, Christmas Bird Count, December 22, 2001.
- Dibble, A.C. and C.A. Rees. 2003. Fire management options for controlling woody invasive plants in the northeastern and mid-Atlantic US: Progress Report II. 10. USDA Forest Service. Abstract: In a study to quantify the difference in fuel beds between forest stands that are invaded with non-native invasive plants and those that are not, Carter and Brawner Woods, in Manassas National Battlefield, were surveyed. Brawner Woods was classified Notes: Study funded by the U.S. Congress through the Joint Fire Science Program, National Interagency Fire.
- Engelhardt, K.A., S. Tessel, and S. Adams. 2008. A sedge, grass and rush inventory of seven parks in the National Capital Region. NPS/NCRN/NRTR—2008/090. National Park Service, National Capital Region.
- Ernst, C.H. and T.R. Brophy. 1998. Wildlife management: baseline data: beaver re-introduction survey and management recommendations.
- Fairfax Audubon Society. 1996. Fairfax Audubon Society: results of birdathon 1996.
- Fairfax County Office of Comprehensive Planning. 1991. 1991 annual report on the environment. Fairfax County Office of Comprehensive Planning, Communications Division, Fairfax, VA. 95-37692
- Fleming, G. 1993. Manassas National Battlefield Park, VA Stuarts Hill and Brawner Farm Tracts inventory for threatened & endangered plants and animals final report.
- Fleming, G.P. 1993. An inventory for threatened & endangered species at Manassas Battlefield Park, Virginia. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. Natural Heritage Technical Report 93-25.
- Fleming, G.P. and A. Belden Jr. 2008. The flora of Manassas National Battlefield Park, Prince William and Fairfax Counties, Virginia.

- 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.
- Fleming, G.P. and J.T. Weber. 2003. Inventory, classification, and map of forested ecological communities at Manassas National Battlefield Park, Virginia., 101. Richmond, VA: Virginia Department of Conservation and Recreation, Division of Natural Heritage. Abstract: A study was undertaken to re-map the forest vegetation in Manassas National Battlefield Park using ecological community types supported by data analysis and classification consistent with the United States National Vegetation Classification.
- Fordney, C. 1994. Embattled ground. National Parks. 68:26-31.
- Gates, E. and J. Johnson. 2005. Bat inventories of the National Capital Region parks.
- Gore, P.J. 1986. Triassic notostracans in the Newark Supergroup, Culpeper Basin, Northern Virginia. Journal of Paleontology. 60:1086-1096.
- Gorsira, B. 2000. Bird list supplied by Bryan Gorsira, 6/13/2000, Data from Northern Virginia Breeding Bird Survey and other birders.
- Hayslett, M.S. 2007. Results of a preliminary field survey of vernal pools and other isolated wetlands at Manassas National Battlefield Park in Prince William County, Virginia. 16. Abstract: Results of a study to survey vernal pools and related isolated wetland resources within Manassas National Battlefield Park. Locations and descriptions, including species present, of vernal pools located are provided.
- Johnston, R.H. and J.D. Larson. 1979. Principal sources of ground water in Fairfax County, Virginia. Map. USGS.
- Kenworthy, J.P. and V.L. Santucci. 2004. Paleontological resource inventory and monitoring - National Capital Region Network.
- 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 (late Norian) age for the immediately underlying ing 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 *Shippingia 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 *Shippingia* 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 Shippingiidae 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 olsenii* Kozur & Weems nov. sp., *Bulbilimnadia sheni* KOZUR & WEEMS nov. sp., and *Bulbilimnadia froelichi* KOZUR & WEEMS nov. sp.).
- Lewis, T.A. 1989. Fighting for the past. Audubon. 91: 56–72.
- Lindholm, R.C. 1980. Guide to the TR-JR rocks in the Culpeper Basin, Virginia: 1980 field trip of AIPG. George Washington University, Washington, DC.
- Lindholm, R.C., P.J. Gore, and J.K. Crowley. 1982. A lacustrine sequence in the Upper Triassic Bull Run Formation (Culpeper Basin) in Northern Virginia. Abstracts with programs, 1982, Northeastern and Southeastern combined section meetings: Abstracts with Programs, Geological Society of America. Washington, DC., Geological Society of America, Washington, DC March 25-27, 1982:35.
- Lookingbill, T., S.L. Carter, B. Gorsira, and C.C. Kingdon. 2008. Using landscape analysis to evaluate ecological impacts of battlefield restoration. Park Science 25. Abstract: Restoration activities at landscape scales frequently must balance multiple objectives associated with both human and natural resources. Manassas National Battlefield Park was established to preserve the scene of two significant Civil War battles. Additionally, the park is an important regional source of wildlife habitat. Management practices must carefully balance the park's mandate to maintain a battlefield landscape with the need to preserve the ecological integrity of existing habitats. We examined whether a forest cut to restore battlefield conditions would result in isolation of forest patches containing sensitive amphibian populations. A landscape-level analysis of the park pre- and post-harvesting used remotely sensed imagery within a geographic information system (GIS) to model the potential effect of the cut on connectivity of forest habitat. The analysis indicated that landscape connectivity will likely remain high following the proposed timber harvesting, but at least one patch may become locally isolated. Efforts to mitigate the impacts of the cut on local resources have been taken, which include removal of a small swath of land from an active hay lease to allow a new dispersal corridor to potentially develop across the fragmented landscape.
- Mauler, B. 1982. Letter to D. Manski. Letter.
- Mauler, B.L., P.R. Dotson, and H.D. Thompson. 1987. Stream life survey in selected streams, Manassas National Battlefield Park, Virginia. National Park Service, Manassas, VA.
- Metzgar, A.J. 1990. A sampling of the water quality of rivers and streams in Manassas National Battlefield Park. National Park Service, Manassas, VA.
- Metzgar, A.J. 1990. Survey of beaver in Manassas National Battlefield Park. National Park Service, Manassas, VA.
- Morris, B., I.J. Firth, and S.P. Bratton. 1991. A cultural landscape restoration report for the Stuarts Hill tract, Manassas National Battlefield Park. University of Georgia, Athens, GA. Cooperative agreement CA-3040-1-9002.
- National Capital Region Lands, Resources, And Planning Natural Resource Services And Natural Resources Advisory Team In Cooperation With TNC. 1999. National Capital Region natural resource information status report. National Park Service.
- National Park Service and National Park Service. 1974. Land status and ownership. Map. National Park Service.
- National Park Service, Water Resources Division and Servicewide Inventory and Monitoring Program. 1997. Baseline water quality data inventory and analysis: Manassas National Battlefield Park. National Park Service.
- National Park Service, Water Resources Division. 1997. Baseline water quality data inventory and analysis: Manassas National Battlefield Park. NPS/NRWRD/NRTR-97/99. National Park Service, Fort Collins, CO.
- National Park Service. 1935. Approximate land ownership. Map. National Park Service.
- National Park Service. 1935. Boundary study. Map. National Park Service.
- National Park Service. 1935. Existing conditions-entire area. Map. National Park Service.
- National Park Service. 1935. General development. National Park Service.
- National Park Service. 1935. Growth conditions study. National Park Service.
- National Park Service. 1936. Hyw234 planting plan. National Park Service.
- National Park Service. 1936. Wooded areas treatment. National Park Service.

National Park Service. 1939. Erosion control plan. National Park Service.	National Park Service. 1972. Land status map 01. Map. National Park Service.
National Park Service. 1939. Planting plan. National Park Service.	National Park Service. 1977. Boundary map. Map. National Park Service.
National Park Service. 1940. Boundary map. Map. National Park Service.	National Park Service. 1979. Boundary map. Map. National Park Service.
National Park Service. 1940. General development plan. National Park Service.	National Park Service. 1980. Boundary map. Map. National Park Service.
National Park Service. 1940. Seeding and sodding plan. National Park Service.	National Park Service. 1981. Boundary map. Map. National Park Service.
National Park Service. 1941. Land status plan. Map. National Park Service.	National Park Service. 1981. Resource management plan, Manassas National Battlefield Park. National Park Service, Manassas, VA.
National Park Service. 1941. Location map. National Park Service.	National Park Service. 1982. 100 year floodplain. Map. National Park Service.
National Park Service. 1949. Hdqtrs planting plan. National Park Service.	National Park Service. 1982. Adjacent land use. Map. National Park Service.
National Park Service. 1950. Proposed land acquisition. Map. National Park Service.	National Park Service. 1982. Existing trail system. Map. National Park Service.
National Park Service. 1951. Soil and moisture conservation. Map. National Park Service.	National Park Service. 1982. Forest and field restoration plan. Map. National Park Service.
National Park Service. 1951. Topographic base map. Map. National Park Service.	National Park Service. 1982. General management plan. National Park Service.
National Park Service. 1958. Exist condits-central section. Map. National Park Service.	National Park Service. 1982. Historic landscape circa 1861–1862. National Park Service.
National Park Service. 1958. General development. National Park Service.	National Park Service. 1982. Land protection as authorized—1980. Map. National Park Service.
National Park Service. 1959. Boundary and land status. Map. National Park Service.	National Park Service. 1982. Land protection. Map. National Park Service.
National Park Service. 1963. Boundary and land status. Map. National Park Service.	National Park Service. 1983. Forest and field restoration plan. Map. National Park Service.
National Park Service. 1963. Viscntrplanting plan. National Park Service.	National Park Service. 1983. General management plan. National Park Service, Manassas, VA.
National Park Service. 1965. Boundary map. Map. National Park Service.	National Park Service. 1983. Historic landscape circa 1861-1862. National Park Service.
National Park Service. 1966. Basic info - the land. Map. National Park Service.	National Park Service. 1983. Land protection as authorized-1980. Map. National Park Service.
National Park Service. 1966. Land acquisition plan. Map. National Park Service.	National Park Service. 1983. Land protection plan. National Park Service.
National Park Service. 1966. Regional base map. Map. National Park Service.	National Park Service. 1983. Land protection. Map. National Park Service.
National Park Service. 1972. Development plan. National Park Service.	

- National Park Service. 1986. Distribution of all hornfels. Map. National Park Service.
- National Park Service. 1986. Distribution of all quartzite. Map. National Park Service.
- National Park Service. 1986. Distribution of all rhyolite. Map. National Park Service.
- National Park Service. 1986. Distrubution of all quartz. Map. National Park Service.
- National Park Service. 1986. Location map Manassas NBP. Map. National Park Service.
- National Park Service. 1986. Resources located. Map. National Park Service.
- National Park Service. 1986. Topographic map. Map. National Park Service.
- National Park Service. 1988. Brawner Farm soils. National Park Service.
- National Park Service. 1988. Existing and remove and restore vegetation, wayside-view points and viewsheds. National Park Service.
- National Park Service. 1989. Boundary map. Map. National Park Service.
- National Park Service. 1989. Existing conditions/ Brawner Farm. National Park Service.
- National Park Service. 1989. Statement for management, Manassas National Battlefield Park. National Park Service, Manassas, VA.
- National Park Service. 1994. Report to Congress: report on effects of aircraft overflights on the National Park System prepared pursuant to Public Law 100-91, the National Parks Overflights Act of 1987. U.S. Department of Interior, National Park Service, Denver Service Center, Denver.
- National Park Service. 1994. Vegetation. Map. National Park Service.
- National Park Service. 2008. NPSpecies data file that was submitted for upload on 9/17/2008. Dataset
- Norris, M., J.P. Schmit, and J. Pieper. 2007. National Capital Region Network 2005–2006 water resources monitoring report. NPS/NCRN/NRTR—2007/066. Natural Resource Program Center, Fort Collins, CO.
- North American Resource Management. 1987. Forest management plan, Manassas National Battlefield Park. North American Resource Management, Charlottesville, VA.
- North American Resource Management. 1990. Forest management plan for the Hazel–Peterson Tract, Manassas National Battlefield Park. North American Resource Management, Charlottesville, VA.
- O'Connor, J.V. 1988. Remote sensing of northern Virginia resources. *Virginia Journal of Science*. 39: 155.
- Olson, C.G. 1983. Soils and land use tour. American Society of Agronomy, Division S-5, Madison, WI.
- Pauley, T.K. and M.B. Watson. 2003. Annual amphibian and reptile inventory report reporting year: fiscal year 2003.
- Pauley, T.K. and M.B. Watson. 2003. Annual report for herpetological inventories of Capitol region parks for year 2002.
- Pauley, T.K., M.B. Watson, and J.C. Mitchell. 2005. Final report: reptile and amphibian inventories in eight parks in the National Capital Region.
- Pelej, L. 1993. Wetland inspection, National Battlefield Park, Manassas, Virginia, June 14, 15, and 16, 1993. 10. Atlanta: Environmental Protection Agency. Abstract: A detailed description of a wetlands survey conducted at Manassas National Battlefield Park in June of 1993, giving scientific and common names for plant species found, site characteristics, and historical, current, and recommended management practic Notes: Includes map of wetland areas.
- Perrier, G.K. 2007. Recovery of vegetation and small mammals at the Stewart Hill Restoration site - final report.
- Powell, J. 1988. Battling over Manassas: the outcome will decide the fate of Americas historic parks (Manassas Battlefield). *National Parks*. 62: 12–13.
- Rankin, B. and A. Snyder. 1989. The third battle of Manassas. *Preservation Forum* 3: 2.
- Rossell, C.R., B. Gorsira, and S. Patch. 2005. Effects of white-tailed deer on vegetation structure and woody seedling composition in three forest types on the Piedmont Plateau.
- Schmit, J.P. and J.P. Campbell. 2007. National Capital Region Network 2006 Forest Vegetation Monitoring Report. NPS/NCRN/NRTR—2007/046. National Park Service, Fort Collins, CO.
- Schmit, J.P. and J.P. Campbell. 2008. National

- Capital Region Network 2007 forest vegetation monitoring report. NPS/NCRN/NRTR—2008/125. National Park Service, Fort Collins, CO.
- Schmit, J.P., P. Campbell and J. Parrish. 2009. National Capital Region Network 2008 Forest Vegetation Monitoring Report. NPS/NCRN/NRTR—2009/181. National Park Service, Fort Collins, CO.
- Sherman, L. 1990. Civil War sites to expand. National Parks. 64: 11.
- Soule, P.L. 1977. Flood-plain delineation for Bull Run, Little Rocky Run, Johnny Moore Creek, and Popes Head Creek Basins/Fairfax County, Virginia. USGS.
- Southworth, S. and D. Denenny. 2006. Geologic map of the National Parks in the National Capital Region, Washington, DC., Virginia, Maryland, and West Virginia. Map. USGS, Reston, VA.
- Staunton, N. and D.A. Lindholm. 1992. Untitled: Effects of mowing at Stone Bridge on species diversity. Virginia Native Plant Society and Fairfax Audubon Society, Fairfax, VA.
- Swihart, G. 1982. Fish species composition in selected streams in Manassas National Battlefield Park. Notes: Unpublished report by Fishery Assistance, USFWS, Gloucester Point, VA.
- Texas Instruments. 1978. Aerial radiometric and magnetic reconnaissance survey of Baltimore, Washington, and Richmond quadrangles; final report. GJBX-79-28120.
- The Wyatt Group, Inc. 1993. Water quality report on selected streams and tributaries of Manassas National Battlefield Park Virginia. The Wyatt Group, Inc, Lancaster, PA.
- The Wyatt Group, Inc. 1995. Water quality report on selected streams and tributaries of Manassas National Battlefield Park, Virginia. The Wyatt Group, Inc, Lancaster, PA.
- Thornberry-Ehrlich, T. 2008. Manassas National Battlefield Park geologic resource evaluation report. NPS/NRPC/GRD/NRR—2008/050. Geologic Resources Division, Denver, CO. (http://www.nature.nps.gov/geology/inventory/publications/reports/mana_gre_rpt_view.pdf).
- Trew, L.D. 1993. Untitled: Results of preliminary rare species inventory of Stuarts Hill and Brawner Farm, Manassas National Battlefield Park. Commonwealth of Virginia, Department of Conservation and Recreation, Richmond, VA.
- Trew, L.D. 1996. Potential natural heritage resources, Manassas National Battlefield Park. Commonwealth of Virginia, Department of Conservation and Recreation, Richmond, VA.
- United States Congress Senate Committee On Energy And Natural Resources. Subcommittee On Parks, Recreation, And Renewable Resources. 1980. Manassas National Battlefield, Virginia & Hawaii Park Proposals: Subcommittee on Parks, Recreation, and Renewable Resources Committee on Energy and Natural Resources, US Senate, 96th Congress, 2nd session, S1857: S2844: HR7217: Sept 3, 1980. United States Government Printing Office, Washington, DC.
- VARGIS and NatureServe. 2005. NCRN vegetation mapping—ground control report.
- Virginia Natural Heritage. 2001. Plant inventory of Manassas National Battlefield: summary list.
- Williams, R.M. 1989. Save or pave? (preservation of Civil War battlefields). Americana. 17: 23.
- Williamsburg Environmental Group, Inc. 1994. Determination of waters of the U.S. including wetlands on the power line relocation at Manassas National Battlefield Park. Williamsburg Environmental Group, Inc, Williamsburg, VA.
- Wofsy, S.C., M.B. McElroy, and J.W. Elkins. 1981. Transformations of nitrogen in a polluted estuary; nonlinearities in the demand for oxygen at low flow. Science 213: 754–757.
- Wyatt Group I. 1995. Water quality report on selected streams and tributaries of Manassas National Battlefield Park, Virginia. 63. Lancaster, PA: The Wyatt Group, Inc. Abstract: Water quality report on selected streams and tributaries at Manassas National Battlefield Park. Includes information on purpose of the study; analysis of data; previous baseline studies (water quality, macrobenthos, fish); stream systems.

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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